Combined attachments #1-14 submitted with the Southern Environmental Law Center (SELC) comment letter for the DAQ methyl bromide AAL recommendation, 3/27/2019.

Attachment 1

Methyl Bromide (Bromomethane)

74-83-9

Hazard Summary

Methyl bromide is used as a fumigant and pesticide. Exposure may occur during fumigation activities. Methyl bromide is highly toxic. Studies in humans indicate that the lung may be severely injured by the acute (short-term) inhalation of methyl bromide. Acute and chronic (long-term) inhalation of methyl bromide can lead to neurological effects in humans. Neurological effects have also been reported in animals. Degenerative and proliferative lesions in the nasal cavity developed in rats chronically exposed to methyl bromide by inhalation. Chronic inhalation exposure of male animals has resulted in effects on the testes at high concentrations. EPA has classified methyl bromide as a Group D, not classifiable as to human carcinogenicity.

Please Note: The main sources of information for this fact sheet are EPA's Integrated Risk Information System (IRIS) (3), which contains information on inhalation chronic toxicity of methyl bromide and the RfC, oral chronic toxicity and the RfD, and the Agency for Toxic Substances and Disease Registry's (ATSDR's) Toxicological Profile for Bromomethane. (1) Other secondary sources include The Merck Index (7) and EPA's Health Effects Assessment for Bromomethane. (5)

Uses

- The primary use of methyl bromide is as a fumigant in soil to control fungi, nematodes, and weeds; in space fumigation of food commodities (e.g., grains); and in storage facilities (such as mills, warehouses, vaults, ships, and freight cars) to control insects and rodents. (2,7,10)

Sources and Potential Exposure

- In most places, levels of methyl bromide in the air are usually < 0.025 parts per billion (ppb). Industrial areas have higher levels (ranging up to 1.2 ppb) because of releases from chemical factories. (1) Workers
- who fumigate homes and fields may be exposed to high levels of methyl bromide if proper safety precautions are not followed. (1)
- Trace amounts of methyl bromide have been detected in drinking water. (2)
- Some methyl bromide is formed naturally by algae or kelp in the ocean. (1)

Assessing Personal Exposure

- The main breakdown product of methyl bromide (the bromide ion) can be measured in blood samples; this test is useful only if it is done within 1 to 2 days following exposure. (1)

Health Hazard Information

Acute Effects:

- Studies in humans indicate that the lung may be most severely injured by the acute inhalation exposure of methyl bromide. Breathing high concentrations of methyl bromide may cause pulmonary edema, impairing respiratory function. (1,3)

- Acute exposure by inhalation of methyl bromide frequently leads to neurological effects in humans. Symptoms of acute exposure in humans include headaches, dizziness, fainting, apathy, weakness, confusion, speech impairment, visual effects, numbness, twitching, and tremors; in severe cases paralysis and convulsions are possible. Acute exposure may produce delayed effects. Symptoms may improve without treatment in less serious cases. (1,3)
- Methyl bromide is irritating to the eyes, skin, and mucous membranes of the upper respiratory tract. Dermal exposure to methyl bromide can cause itching, redness, and blisters in humans. (1)
- Kidney damage has been observed in humans who have inhaled high levels of methyl bromide. (1)
- Inhalation of methyl bromide may cause the liver to become swollen and tender, but no significant injury to the liver has been observed in humans. (1)
- Injury to the heart has been observed in mice and rats exposed to high concentrations of methyl bromide by inhalation. (1,3)
- Tests involving acute exposure of rats and mice have demonstrated methyl bromide to have high acute toxicity from inhalation and oral exposure. (4)

Chronic Effects (Noncancer):

- Data from an occupational study suggest that mild functional neurological impairment may result in humans chronically exposed to methyl bromide by inhalation exposure, but this is not conclusive due to concurrent exposure to other chemicals and inadequate quantitation of exposure levels and durations. (1,3,5)
- Neurological effects, including lethargy, forelimb twitching, tremors, and paralysis, have also been observed in animal studies. (3,6)
- Degenerative and proliferative lesions in the nasal cavity developed in rats chronically exposed to methyl bromide by inhalation. (3)
- The Reference Concentration (RfC) for methyl bromide is 0.005 milligrams per cubic meter (mg/m^3) based on degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious noncancer effects during a lifetime. It is not a direct estimator of risk but rather a reference point to gauge the potential effects. At exposures increasingly greater than the RfC, the potential for adverse health effects increases. Lifetime exposure above the RfC does not imply that an adverse health effect would necessarily occur. (3)
- EPA has medium confidence in the study on which the RfC was based because even though the study was well conducted, it did not identify a no-observed-adverse-effect level (NOAEL); high confidence in the database because there is a chronic inhalation study in two species supported by subchronic inhalation studies in several species and because data are available on the developmental and reproductive effects of bromomethane as well as its pharmacokinetics following inhalation exposure; and, consequently, high confidence in the RfC. (3)
- The Reference Dose (RfD) for methyl bromide is 0.0014 milligrams per kilogram body weight per day (mg/kg/d) based on epithelial hyperplasia of the forestomach in rats. (3)
- EPA has medium confidence in the study on which the RfD was based because it used the preferred route of administration for derivation of an oral RfD, the study was adequately conducted, and the determination of epithelial hyperplasia of the forestomach was independently confirmed; medium confidence in the database; and, consequently, medium confidence in the RfD. (3)

Reproductive/Developmental Effects:

- No information is available on the reproductive or developmental effects of methyl bromide in humans.
- Information from animal studies suggest that methyl bromide does not cause birth defects and does not interfere with normal reproduction except at high exposure levels. (1)
- Chronic inhalation exposure of male animals has resulted in effects on the testes at high concentrations. (1,3)

- Inhalation exposure of animals during gestation has not resulted in significant developmental effects, even when there was severe maternal toxicity. (1,3,5)

Cancer Risk:

- In a human mortality study, a higher incidence of death from testicular cancer was identified in men occupationally exposed to methyl bromide. However, methyl bromide could not be established as the causative agent because the individuals in the study were exposed to a wide variety of brominated chemicals. (1,3,5)
- There was no evidence of carcinogenic activity in mice in a National Toxicology Program (NTP) chronic inhalation study. (6)
- EPA has classified methyl bromide as a Group D, not classifiable as to human carcinogenicity, based on inadequate human and animal data. (3,5)

Physical Properties

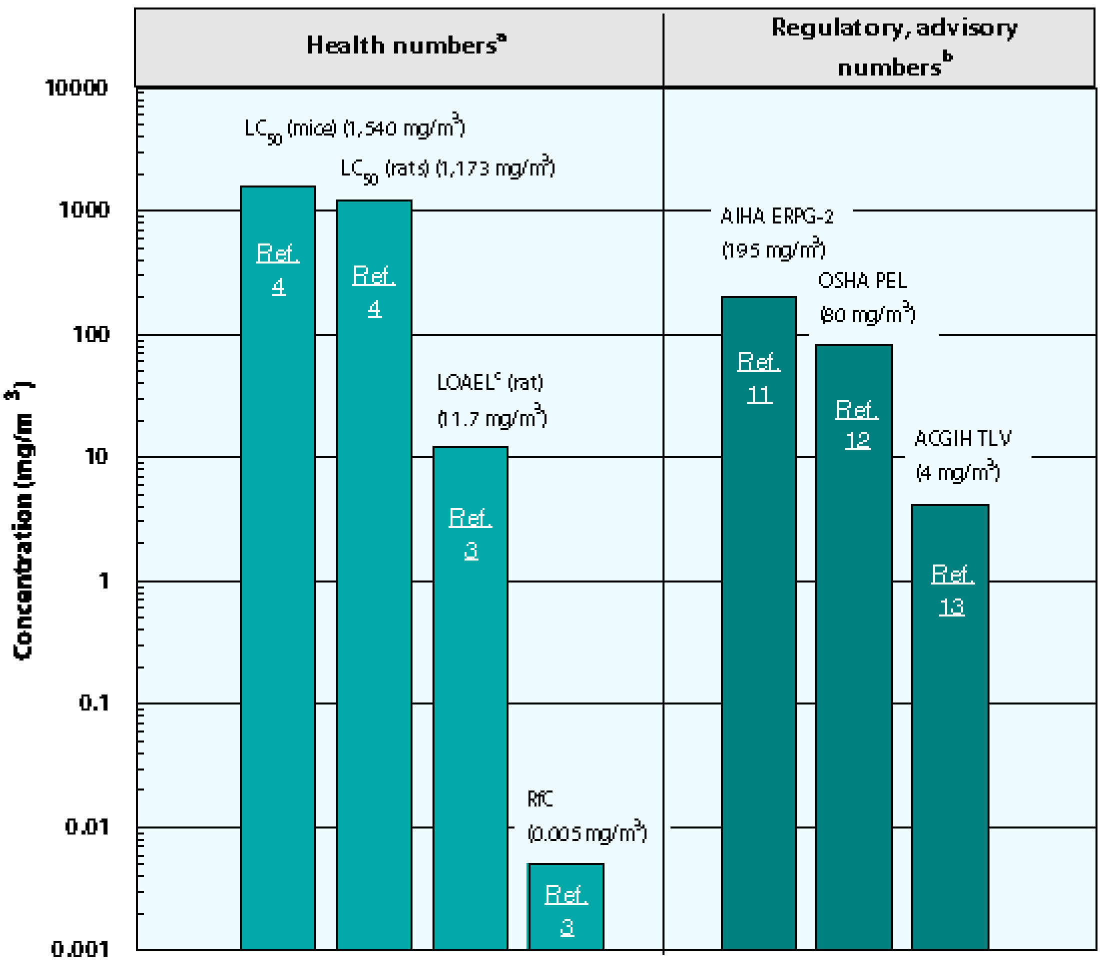
- The chemical formula for methyl bromide is CH_3Br, and it has a molecular weight of 94.95 g/mol. (7)
- Methyl bromide occurs as a colorless and highly volatile gas that is slightly soluble in water. (7,8)
- Methyl bromide is practically odorless but has a sweetish chloroform-like odor at high concentrations with an odor threshold of 80 mg/m^3. (3,7,9)
- The vapor pressure for methyl bromide is 1,420 mm Hg at 20 °C, and it has a log octanol/water partition coefficient (log K_{ow}) of 1.1. (1)

Conversion Factors:

To convert concentrations in air (at 25 °C) from ppm to mg/m^3: mg/m^3 = (ppm) × (molecular weight of the compound)/(24.45). For methyl bromide: 1 ppm = 3.9 mg/m^3.

Health Data from Inhalation Exposure

Methyl Bromide



AIHA ERPG--American Industrial Hygiene Association's emergency response planning guidelines. ERPG 2 is the maximum airborne concentration below which it is believed nearly all individuals could be exposed up to one hour without experiencing or developing irreversible or other serious health effects that could impair their abilities to take protective action.

ACGIH TLV--American Conference of Governmental and Industrial Hygienists' threshold limit value expressed as a time-weighted average; the concentration of a substance to which most workers can be exposed without adverse effect.

LC_{50} (Lethal Concentration $_{50}$)--A calculated concentration of a chemical in air to which exposure for a specific length of time is expected to cause death in 50% of a defined experimental animal population.

LOAEL--Lowest-observed-adverse-effect level.

OSHA PEL--Occupational Safety and Health Administration's permissible exposure limit expressed as a time-weighted average; the concentration of a substance to which most workers can be exposed without adverse effect averaged over a normal 8-h workday or a 40-h workweek.

The health and regulatory values cited in this factsheet were obtained in December 1999.

[a] Health numbers are toxicological numbers from animal testing or risk assessment values developed by EPA.

[b] Regulatory numbers are values that have been incorporated in Government regulations, while advisory numbers are nonregulatory values provided by the Government or other groups as advice. OSHA numbers are regulatory, whereas ACGIH and AIHA numbers are advisory.

[c] This LOAEL is from the critical study used as the basis for the EPA RfC.

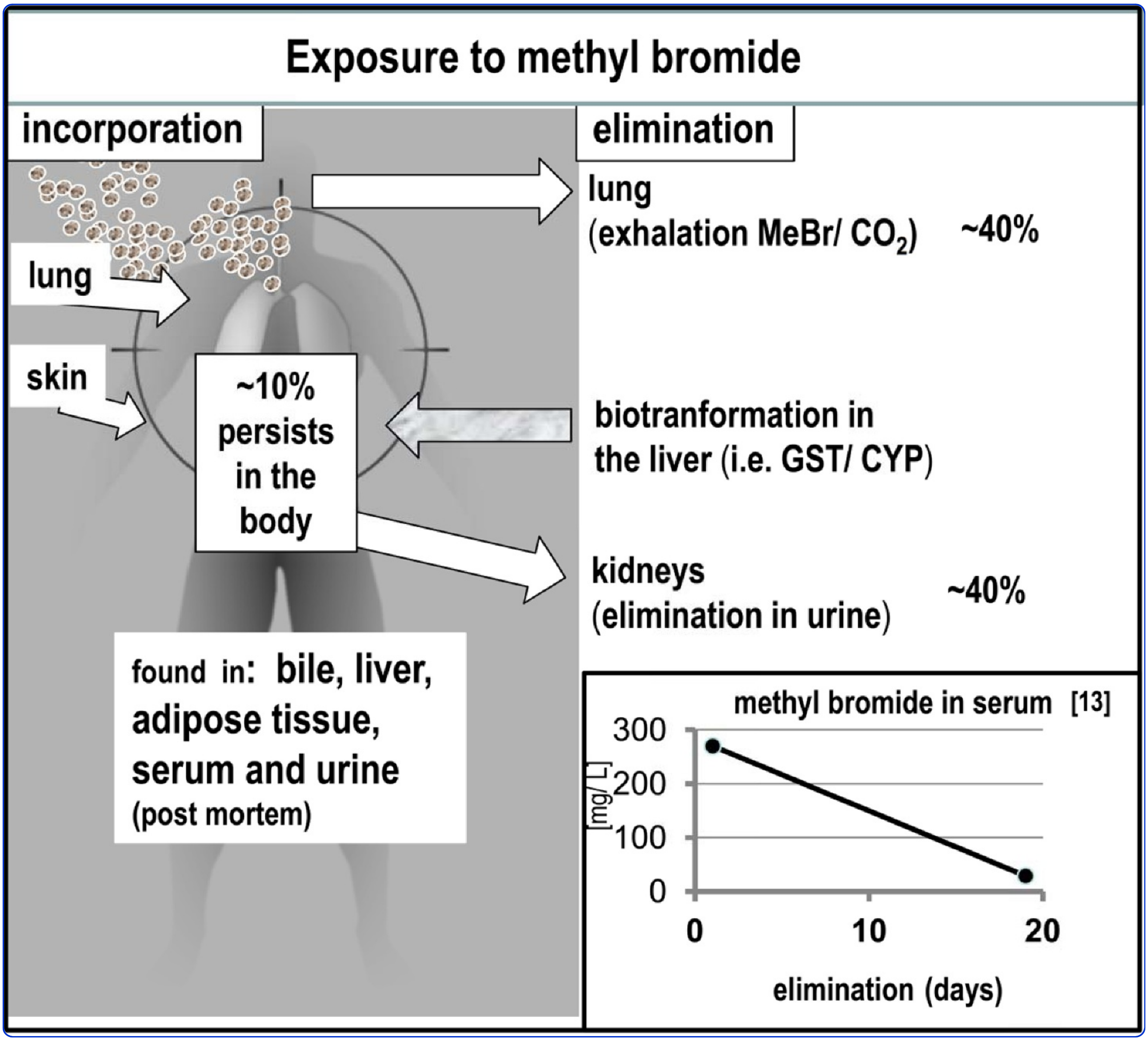
References

Summary created in April 1992, updated January 2000

1. Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological Profile for Bromomethane. U.S. Public Health Service, U.S. Department of Health and Human Services, Atlanta, GA. 1992.
2. U.S. Environmental Protection Agency. Bromomethane Health Advisory. Office of Drinking Water, Washington, DC. 1989.
3. U.S. Environmental Protection Agency. Integrated Risk Information System (IRIS) on Bromomethane. National Center for Environmental Assessment, Office of Research and Development, Washington, DC. 1999.
4. U.S. Department of Health and Human Services. Registry of Toxic Effects of Chemical Substances (RTECS, online database). National Toxicology Information Program, National Library of Medicine, Bethesda, MD. 1993.
5. U.S. Environmental Protection Agency. Health Effects Assessment for Bromomethane. EPA/600/8-88/022. Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Office of Research and Development, Cincinnati, OH. 1988.
6. National Toxicology Program. Toxicology and Carcinogenesis Studies of Methyl Bromide (CAS No. 74-83-9) in B6C3F1 Mice (Inhalation Studies). Technical Report No. TR-385. 1992.
7. The Merck Index. An Encyclopedia of Chemicals, Drugs, and Biologicals. 11th ed. Ed. S. Budavari. Merck and Co. Inc., Rahway, NJ. 1989.
8. International Agency for Research on Cancer (IARC). IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans: Some Halogenated Hydrocarbons and Pesticide Exposures. Volume 41. World Health Organization, Lyon. 1986.
9. U.S. Department of Health and Human Services. Hazardous Substances Data Bank (HSDB, online database). National Toxicology Information Program, National Library of Medicine, Bethesda, MD. 1993.
10. M. Sittig. Handbook of Toxic and Hazardous Chemicals and Carcinogens. 2nd ed. Noyes Publications, Park Ridge, NJ. 1985.
11. American Industrial Hygiene Association (AIHA). The AIHA 1998 Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Guides Handbook. 1998.
12. Occupational Safety and Health Administration (OSHA). Occupational Safety and Health Standards, Toxic and Hazardous Substances. Code of Federal Regulations 29 CFR 1910.1000. 1998.
13. American Conference of Governmental Industrial Hygienists (ACGIH). 1999 TLVs and BEIs. Threshold Limit Values for Chemical Substances and Physical Agents. Biological Exposure Indices. Cincinnati, OH. 1999.

Attachment 2

ENVIRONMENTAL HEALTH



Prostate cancer and toxicity from critical use exemptions of methyl bromide: Environmental protection helps protect against human health risks

Budnik *et al.*

BioMed Central

Budnik *et al. Environmental Health* 2012, **11**:5
http://www.ehjournal.net/content/11/1/5 (27 January 2012)

Budnik et al. Environmental Health 2012, 11:5
http://www.ehjournal.net/content/11/1/5

ENVIRONMENTAL HEALTH

REVIEW Open Access

Prostate cancer and toxicity from critical use exemptions of methyl bromide: Environmental protection helps protect against human health risks

Lygia T Budnik[1*], Stefan Kloth[1], Marcial Velasco-Garrido[2] and Xaver Baur[3]

Abstract

Background: Although ozone-depleting methyl bromide was destined for phase-out by 2005, it is still widely applied as a consequence of various critical-use-exemptions and mandatory international regulations aiming to restrict the spread of pests and alien species (e.g. in globalized transport and storage). The withdrawal of methyl bromide because of its environmental risk could fortuitously help in the containment of its human toxicity.

Methods: We performed a systematic review of the literature, including in vitro toxicological and epidemiological studies of occupational and community exposure to the halogenated hydrocarbon pesticide methyl bromide. We focused on toxic (especially chronic) or carcinogenic effects from the use of methyl bromide, on biomonitoring data and reference values. Eligible epidemiological studies were subjected to meta-analysis.

Results: Out of the 542 peer reviewed publications between 1990-2011, we found only 91 referring to toxicity of methyl bromide and 29 using the term "carcinogenic", "neoplastic" or "mutagenic". Several studies provide new additional data pertaining to the mechanistic aspects of methyl bromide toxicity. Few studies have performed a detailed exposure assessment including biomonitoring. Three evaluated epidemiological studies assessed a possible association between cancer and methyl bromide. Overall, exposure to methyl bromide is associated with an increased risk of prostate cancer OR, 1.21; 95% CI (0,98-1.49), $P = 0.076$. Two epidemiological studies have analyzed environmental, non-occupational exposure to methyl bromide providing evidence for its health risk to the general public. None of the epidemiological studies addressed its use as a fumigant in freight containers, although recent field and case reports do refer to its toxic effects associated with its use in shipping and storage.

Conclusions: Both the epidemiological evidence and toxicological data suggest a possible link between methyl bromide exposure and serious health problems, including prostate cancer risk from occupational and community exposure. The environmental risks of methyl bromide are not in doubt, but also its health risks, especially for genetically predisposed subjects, should not be underestimated.

Keywords: methyl bromide, bromomethane, fumigant, halomethane, pesticide, toxic effect, carcinogenic risk, critical use exemptions

Background

Fumigation with pesticides is a widely used defensive measure against the multitude of pests responsible for destroying foodstuffs and other natural commodities during storage and transport. Necessarily, pesticide chemicals are highly toxic to pests, but present also a substantial risk to both human health and the environment [1-5]. The methyl and ethyl halides, in particular methyl bromide (IUPAC name: bromomethane), are highly effective fumigants and are often used as pesticides, both during and after the harvest. Methyl bromide is a broad spectrum pesticide with a long history of use as a fumigant in farming (stripping the soil of pathogens) and for disinfecting furniture, wood, barges, warehouses, buildings and cargo ships [1-3,5]. Its use has accelerated more recently because of increased globalization and the perceived threat of invasion by alien species. Recent regulations requiring fumigation with methyl bromide (or

* Correspondence: L.Budnik@uke.uni-hamburg.de
Full list of author information is available at the end of the article

heat treatment) of wooden packaging, flooring and wooden goods in imported freight containers [6] have resulted in an epidemic of freight container fumigation.

To be set against the desirable characteristics of this almost perfect fumigant is its remarkable potency as a depleter of atmospheric ozone. Methyl bromide and related ozone-depleting compounds were banned in the 1987 Montreal and 1997 Kyoto Protocols [4] and methyl bromide was destined for a phase-out of production within the current decade (2005 by industrial nations and 2015 by developing nations). The ocean is a net sink for atmospheric methyl bromide, where it is slowly degraded by chemical and biological processes [7].

Although more than 15 industrialized nations have claimed not to fumigate with methyl bromide anymore, most continue to do so under the auspices of a critical use exemptions (CUE) clause. The CUE allows continued use of methyl bromide where no adequate alternative is available, thus assuring its unremitting popularity and widespread use as a fumigant. In 2003, methyl bromide was the most commonly used pesticide among California growers [8,9] and since 2001 it is required for fumigation of grapes in the US [10]. This pesticide is still being used in agriculture [11], in urban pest control [12-14], and for processing onboard ship [15,16]. Also in major ports worldwide, several hundred tons of methyl bromide continue to be used annually for the fumigation of containers destined for export, representing a substantial environmental and human health risk [17-19]. Fumigation of freight containers with methyl bromide is a standard procedure, particularly in Asia [17,18], though adequate alternatives like heat treatment are known. The imported containers and the fumigated products are shipped deep within an importing country before being opened, unloaded, distributed and used by workers and the general public. The primary routes for methyl bromide exposure are by inhalation and by dermal absorption from direct skin contact [20,21]. Exposure due to off gassing is likely since methyl bromide persists on clothes, leather, and rubber brought home or when entering storage facilities where highly fumigated products are stored [3,11,21]. The most common consequences of a transient exposure to methyl bromide are nervous system symptoms, including headache, nausea, vomiting, dizziness, blurred vision, impairment of coordination and twitching. Acute massive or prolonged exposure ultimately leads to permanent debilitation or death [22]. A link between methyl bromide exposure and cancer has been demonstrated experimentally and is also documented clinically, which is not surprising considering its recognized genotoxic effects [23,24]. From animal studies, the National Institute for Occupational Safety and Health (NIOSH) lists methyl bromide as a potential occupational carcinogen [1,4]. However, the interpretation of toxicological data is often limited by various shortcomings in the available studies. First, the hazard data from animal experiments may not always be immediately relevant to human beings because of the acknowledged physiological and catabolic differences in methyl bromide activity [24]. In addition, several epidemiological studies are vague about the actual pesticide(s) under investigation. Furthermore, inadequate exposure assessment precludes the efficient identification of any causal inferences between a given pesticide and subsequent cancer [25].

For the current study, we performed a systematic review of the literature addressing the risks associated with the exposure to methyl bromide, including the available in-vitro toxicology assessments, in-vivo animal experiments and population-based epidemiological studies. We provide evidence that this pesticide should be phased out not only because of environmental concerns but also because of its human health risks.

Methods

A Pubmed search for peer-reviewed studies on methyl bromide was performed for the period 1990-2011 [26]. Several combinations of the following MeSH terms were utilized in the search: "methyl bromide", "bromomethane", "halogenated hydrocarbon pesticide", "fumigant", "poisoning", "toxicity", "cancer", "neoplasm" "mutagenic" and "tumour". We selected studies according to the following inclusion criteria:

- original studies published in English or German between June 1990 and July 2011
- in-vivo and in-vitro studies on the toxicity of methyl bromide
- papers analyzing molecular mechanisms underlying possible links between methyl bromide exposure and toxic or cancer risk
- cohort or case-control studies analyzing the association between exposure to halogenated hydrocarbon methyl bromide used as fumigant and the incidence of cancer (any site of cancer)
- studies providing data on exposure assessment and bioavailability.

The results from in vitro and in vivo toxicity studies are summarized in an evidence table and discussed further. The results from the included epidemiological studies were summarized quantitatively. Summary odds ratio (OR), with its corresponding 95% confidence interval, was calculated using both fixed and random effects models [26,27]. We calculated I^2 to assess the degree of heterogeneity across studies. Values of I^2 under 25% indicate low, up to 60% medium, and over 75% considerable heterogeneity [27]. Meta-analysis results are presented as a forest plot. All calculations were performed with the software Comprehensive Meta-Analysis 2.0. (Biostat™, Englewood, USA).

Results

The initial electronic database search yielded 543 publications on methyl bromide. 442 were considered not relevant for the review (because they considered the chemical synthesis of methyl bromide, its bacterial or chemical degradation, pest control issues and regulations or did not contribute new information). Among the included studies, 91 matched the terms toxic, toxicological effects or poisoning and 30 matched the terms cancer or DNA damage. We identified only 5 publications reporting epidemiological studies addressing an association between methyl bromide exposure and cancer or toxicity. Two publications reported data from the same study [28,29], three studies addressed the risk of prostate cancer [28,30,31] and were included in the meta-analysis. One additional epidemiological study analyzed the toxic effects of methyl bromide only, but did not report on possible carcinogenic effects [32] and a further one only considered safety issues [33].

Toxicity of methyl bromide

Methyl bromide, like other methyl halides (i.e. methyl chloride, methyl iodide), has pronounced acute and chronic toxicity (EPA toxicity class I) [4]. It is known as a developmental, neurologic and respiratory toxin [34-36]. Other known target organs are the heart, adrenal glands, liver, kidneys and testis [24]. Chronic low exposure to methyl bromide causes depression of the central nervous system and injury to the kidney. Methyl bromide is a dangerous cumulative poison with the initial symptoms from damage of the nervous system often delayed by 48 hours to several months. The symptoms of acute poisoning vary depending on the concentration and duration of exposure. In sublethal poisoning, the most serious effects involve the central nervous system (with first symptoms including headache, nausea, vomiting, dizziness, malaise and visual disturbances, followed by peripheral neuropathies or neuropsychiatric abnormalities (Table 1). Throat irritation, chest pain and shortness of breath are the most likely first respiratory symptoms with inflammation of the bronchi or lung edema after severe acute exposure. Death may result from respiratory and cardiovascular failure [13,22].

Chronic and acute exposure to methyl bromide may cause respiratory problems, and irritate the skin and eyes. Central nervous system toxicity and early peripheral neuropathy following dermal exposure to methyl bromide [36] confirm the earlier data (see below). Central neurological disorders and chronic toxic encephalopathy were documented in Korean workers after exposure to methyl bromide [37]. Other studies describe motor neuron disease [16], cerebro-vestibular and pyramidal neuropathy, and paresthesia (see Table 1 for details). One clinical case report implicates erectile dysfunction in humans [38].

Structurally similar ethyl halides (i.e. ethylene dichloride, ethyl chloride, ethyl bromide) show less acute toxicities than their methyl counterparts, but more pronounced chronic toxicity [24].

The effects of methyl bromide on regional brain glutathione-S-transferase has been well documented [39]. Human data from accidental poisoning show that the conjugator status plays an important role in the expression of toxicity in humans, with non-conjugators being apparently relieved of the acute neurotoxic effects (see below for more details). They may not be subjectively aware of the toxic exposure, which may lead them into a false sense of security, especially as silent genotoxic effects may only become clinically manifest years after exposure [40-43].

Genotoxic and carcinogenic effects of methyl bromide

Methyl bromide is genotoxic in vitro, as shown in bacteria [23], animals [44] and human cell culture tests [54] (Table 1). The strong alkylating potency of methyl bromide is primarily responsible for its cytotoxic effect, causing this pesticide to be classified as a potent stimulator of cell growth and, therefore, a potential tumor promoter. Distinguishing alkylation from metabolic incorporation provides proof for the direct genotoxic effect of methyl bromide, methyl iodide and other methyl halides [46-48]. Based on in-vivo and in-vitro studies, methyl bromide induces gene mutations in bacteria, mice and humans. No systemic genotoxic effect was seen with methyl chloride [46,47] in animal experiments. Effects such as DNA single strand breaks after methyl halide intoxication can, however, point to both genotoxic as well as non-genotoxic mechanisms [24]. Methyl bromide causes DNA methylation in rats and mice with concominant decreases in the activity of O^6-alkylguanine-DNA-alkyltransferase [48]. Interestingly more recent data show that O^6-alkylguanine-DNA-alkyltransferase has opposing effects in modulating the genotoxicity of dibromomethane, suggesting a pathway which is alternative to the well-recognized pathway that involves activation by GSTs [49]. Conversely, deficiencies in nucleotide excision repair have been shown to strongly potentiate the mutagenic effects of methyl bromide [44]. A clear DNA-alkylating potential of methyl bromide can be demonstrated directly with [^{14}C]-methyl bromide binding to DNA in various animal studies [24]. Three additional methylated bases (3-methyl-adenine, 7-methyl-guanine, O^6-methyl guanine) were also recognized along with further unidentified DNA adducts found in liver, lung and stomach [46].

Table 1 Toxic effects of methyl bromide (data 1990-2011)

Effect observed	Ref.
in vitro	
chromosomal aberration (mammalian cells exposed to gaseous methyl bromide)	[54]
Sister chromatid exchange and chromosome aberrations in lymphocytes	
O-6-alkylguanine-DNA-alkyltransferase	[49]
genotoxic in bacteria (Ames test)	[23]
Genotoxicity in workers exposed to methyl bromide	[88]
in vivo	
toxic encephalopathies (animal experiments)	[65]
immunoreactive HSP 70 in rat olfactory receptor neurone	[64]
DNA methylation (rat, mice)	[48]
reduction in the white blood cells (rat)	[89]
increase in SCOT, SGPT activities (mice)	[89]
hepatic and glomerular injuries (mice)	[89]
MMP-9, matrix-metalloproteinase -9 and -2, MMP-2 expression in olfactory bulb following methal bromide gas exposure (mice)	[66]
human	
irritation of eyes, skin, respiratory system; muscle weakness, coordination loss, visual disturbance, dizziness; nausea, vomiting, headache; malaise (vague feeling of discomfort); hand tremor; convulsions; dyspnea (breathing difficulty); skin vesiculation; liquor frostbite; [potential occupational carcinogen]	[11,34]
acute poisoning: ataxia, behavioral changes, seizures, coma chronic low level exposure: peripheral neuropathy, electroencephalogram abnormalities, deficits on the Wechsler memory scale (on 2-point discrimination at the index scale)	[90]
headache, dizziness, nausea	[11,34]
chronic exposure: central and peripheral system disorders, cerebro-vestibular and pyramidal neuropathy of lower	
limbs, paresthesia cerebro-vestibular and pyramidal neuropathy of lower limbs, paresthesia	
motor neuron disease	[16]
acute exposure (high concentration): refractory seizures, intermittent fever, multiorgan system failure, death	[13]
liver degenerative changes	[1]
reduction of lung function, chest pain, shortness of breath, inflammation of the lung	[1]
erectile dysfunction	[38]
central nervous system toxicity and early peripheral neuropathy following dermal exposure	[36]
diffuse lesions in the spleen of the corpus callosum	[91]

DNA single strand breaks, liberation of reactive oxygen species and enhanced cell proliferation were detected both in vivo (animal studies) and in vitro using cell-based assays [24,50]. Older studies reported that methyl bromide induces squamous cell papillomas and carcinomas in the forestomach of the rat [4,46]. No carcinogenic effect was observed in further studies applying methyl bromide orally with gavages [51]. A technical report from the US National Toxicology Program showed no evidence of carcinogenic activity in mice exposed to methyl bromide by inhalation [52]. Bolt and Gansewendt [24] explained the negative results in animal experiments by the different or deficient catabolic conjugation pathways for methyl bromide in different species. They also considered that the conclusions from these animal experiments could not be extrapolated to human non-conjugators, since these particular individuals are unable to metabolize methyl bromide as quickly as a rodent can [24]. Other studies report pre-carcinogenic sister chromatid exchange and the induction of chromosome aberrations after exposure to methyl bromide [53,54].

Recent data from Koutros et al. has highlighted the association between the single nucleotide polymorphisms (SNP) in genes coding for xenobiotic-metabolizing enzyme (enzymes of oxidative stress and phase I/II enzymes) and the risk of prostate cancer after exposure to pesticides [55]. The authors could link the enhanced prostate cancer risk after methyl bromide exposure with a SNP in rs93322959 gene coding for the microsomal GST1 enzyme (OR, 3.1; 95% CI (1.3-7.5) and SNP in rs5764318 of cytosolic sulfotransferase, SULT4A1 (OR, 2.2; 95% CI (1.0-4.5). Such polymorphisms may lead to an imbalance in the oxidative stress/antioxidant status, resulting in DNA/chromosome damage and/or induction of possible epigenetic or tumor suppressor gene alterations [55].

Possible molecular mechanisms

According to the alkylation hypothesis, the methylating activity of methyl bromide should play an important role in the molecular mechanism of toxicity for methyl bromide. Besides this, epigenetic damage [57] may be the most important fundamental cause of degenerative diseases and it can induce carcinogenic lesions (see Figure 1 for a simple model summarizing the current knowledge on non-linear response relationships between the exposure to halomethane methyl bromide, oxidative stress status, DNA damage and pre-carcinogenic lesions).

The conjugation with glutathione, is regarded as the main initiation pathway of methyl bromide: upon inhalation of [^{14}C]-methyl bromide, some radioactivity was covalently attached to haemoglobin [56]. The presence of S-methyl-cysteine in the haemoglobin of workers exposed to methyl bromide has been demonstrated [42]. Humans accidentally exposed to either methyl bromide, methyl iodide, methyl chloride in Japan, The Netherlands or in the US showed similar S-methyl-cysteine levels after exposure suggesting similar metabolism of methyl halides in older literature.

Although metabolism of methyl bromide, methyl chloride and methyl iodide has been studied in different systems and to different extents, it has been suggested that the general metabolic scheme is valid for all methyl halides. The tissue specificity and the degree of toxicity of the organic halides are manifested either by the parent compound or their metabolic or catabolic products. The genotoxic effects of methyl bromide appear to be caused by the direct alkylation of macromolecules, producing adducts [40] and sister chromatid exchange [41]. Conversely, the neurotoxic effects appear to arise after the alkylation of methyl bromide by conjugation with glutathione, producing acutely toxic catabolites that preferentially target the nervous system [42].

Data collected within the last five years point to an intriguing association between the alkylation activity of

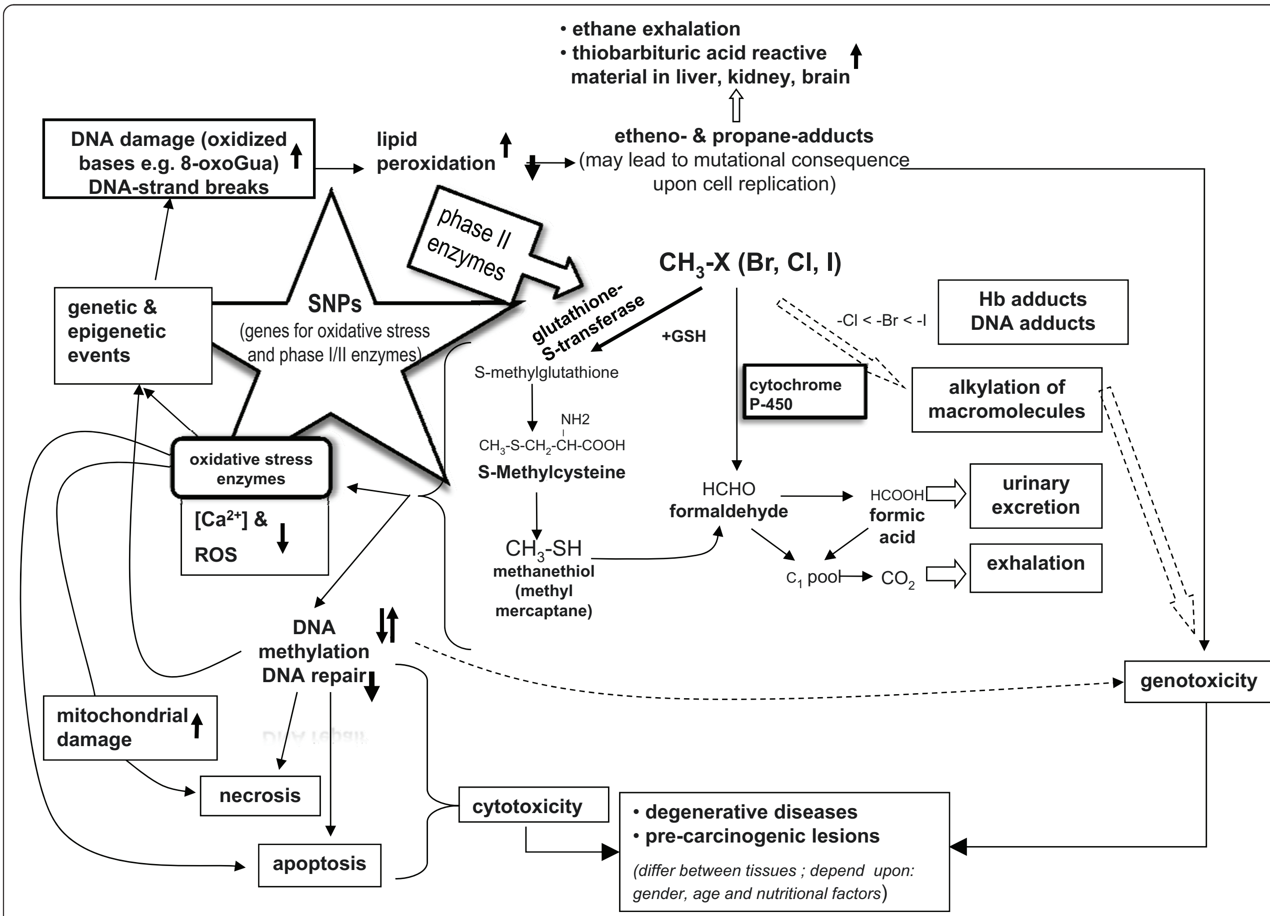


Figure 1 Scheme summarizing available literature data on possible molecular mechanisms of methyl bromide effects leading to either degenerative diseases or pre-carcinogenic lesions.

methyl bromide (which is modulated by the expression of various isoforms of GST) and the development of prostate cancer. Two gene products seem to be involved in the epigenetic changes caused by methyl bromide. Pi-class glutathione S-transferases (GSTP1) protect the cell from cytotoxic and carcinogenic agents and have been found to be hypermethylated and silenced in prostate cancer tissue [57,58]. The glutathione *S*-transferase *theta* (GSTT1) gene, whose activity can be influenced by methyl bromide in human erythrocytes, was reported to be positively associated with the risk of prostate cancer [59-61], although other studies have not found these associations [62,63]. It must be pointed out that glutathione S-transferases may also undergo complex epigenetic changes, such as hyper/hypomethylation, depending on the stage of the carcinogenic progression of the prostate cancer.

The molecular mechanisms responsible for the neurotoxic effects of methyl bromide (either alone or with other halo-methanes or halo-ethanes) have been elucidated to great extent [50]. Methyl halides (and probably also ethyl halides) readily react with GST causing its depletion in several cerebellum cell types and lowering the antioxidant status of these cells [50]. There is a marked cooperation between neurones and astrocytes with regard to maintenance of GSH. GSH is toxic to isolated cerebellar granule cells in culture and to astrocytes. The mechanism of neuronal cell loss with methyl halides appears to involve DNA damage, methylation and inhibition of DNA repair, plus depletion of the intracellular antioxidant GSH and oxidative stress; the apoptotic pathways and neuronal cell death may be switched on [50].

Additionally, recent data provide evidence for the mechanistic aspects of methyl bromide neurotoxicity and point to its ability to alter epithelial density and expansion of bulbar projections [64], to inhibit creatine kinase in rat brain [65] or its effects on matrix metalloproteinase-9 and -2 in the olfactory bulb following methyl bromide gas exposure [66].

Epidemiological studies addressing methyl bromide exposure

No epidemiological studies analysing the potential carcinogenic effects from the exposure to methyl bromide

Table 2 Overview of epidemiological studies on methyl bromide effects (1990-2011)

Reference	Study design	Magnitude of study	Specified measure 1			Exposure to methyl bromide	cases			p value high vs. low
study	year			sample size	location		cancer (prostate)	Odds Ratio adjusted	95% CI	
[28]	2003	cohort study	occupational agriculture, farmers	55, 332	USA, IA, NC	exposed/controls *84/482	84	1.10	0.77, 1.36	0.004
						low exposure	6	2.73	1.18, 6.33	
						high exposure	5	3.47	1.37, 8.76	
[29]	2010	data analysis	occupational agriculture, farmers	55, 332	USA, IA, NC		5	3.47	1.37, 8.76	0.004
[30]	2003	case-control study	occupational agriculture, Hispanic farm workers	1, 332	USA, CA	exposed/controls 121/1110	64	1.17	0.77, 1.75	0.25
						low exposure	37	1.20	0.66, 2.18	
						high exposure	32	1.59	0.77, 3.30	
[31]	2011	case-control study	population, near intensive agricult. areas		USA, CA	exposed/controls 173/162	87	1.62	1.02, 2.59	0.1
						low exposure	45	1.81	1.03, 3.18	
						high exposure	42	1.45	0.82, 2.57	
[29]	2010	data analysis	occupational agriculture, farmers	55, 332	USA, IA, NC		5	3.47	1.37, 8.76	0.004
							toxic effects			
[32]	2006	cohort study	population, farmers' wives		USA, CA	exposed/controls *145/797		1.82	1.02-3.24	

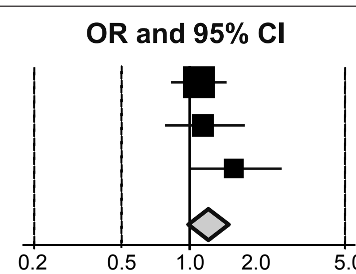
contaminants (or any other pesticide) due to its use in shipping and storage (i.e. in the atmosphere of containers) have been published to date. Most of the epidemiological studies analysing the causal link between methyl bromide exposure and the development of cancer have focused on the agricultural use of pesticides. However, the first clue implicating methyl bromide in a carcinogenic effect was from a study of chemical industry workers who were exposed to methyl halides. In this cohort study, an increased mortality from testicular cancer was reported in association with long-term occupational exposure to methyl bromide in a chemical plant [3]. There were only 3 more recent studies analysing the association between exposure to methyl bromide and cancer or toxicity. Two were cohort studies and one a case-control study. The main characteristics and results of the included studies are summarized in Table 2. All of them addressed exposure in relation to the use of methyl bromide in agriculture, either as occupational or environmental. One of the studies, the Agricultural Health Study (AHS), is a long-term cohort study of pesticide applicators and their spouses [28]. A report from the US National Cancer institute [35] stated that a few of the 45 evaluated pesticides showed evidence of a possible association with prostate cancer in the pesticide applicators. While methyl bromide was linked with the risk of prostate cancer in the entire group, exposure to six other pesticides was only associated with an increased risk of prostate cancer among those men with a family history of the disease [35]. Alavanja et al. reported a slightly increased relative risk among farmers occupationally exposed to methyl bromide [28]. This study demonstrated a gradient for the risk of prostate cancer with increasing level of exposure to methyl bromide, with the greatest risks among the two highest exposure categories (OR 3.47 95%-CI 1.37-8.76 for the highest exposure category) [28]. The risk was two to four times higher than for men who were never exposed to methyl bromide [28,35]. Among the 45 specific pesticides evaluated, only methyl bromide was associated with a statistically significant exposure-response trend. This effect was not seen among those without a family history of prostate cancer [35]. Mills and Yung also showed an association between methyl bromide exposure and prostate cancer with OR, 1.17; 95% CI (0.77-1.75), P = 0.45 although statistically non-significant [30]. Control subjects were age and location-matched farm workers without prostate cancer. The risk was associated with relatively high levels of exposure to methyl bromide. In a first study on prostate cancer and non-occupational exposure to pesticides, Cockurn et al. [31] confirmed the data from Alavanja et al. and provided evidence for an association between prostate cancer and the environmental exposure to methyl bromide in and around homes in highly agricultural areas [31]. Our meta-analysis shows a slight increase in prostate cancer risk after exposure to methyl bromide with OR, 1.21; 95% CI (0.98-1.49), P= 0.07. The results of the included studies are homogeneous (I^2 = 0%, thus we report results from the fixed effects model (see Figure 2, Table 2)). The model choice did not affect the results.

A further epidemiological study [32] of intoxication cases showed an association with chronic low-dose methyl bromide pollution and chronic bronchitis with OR, 1.82; 95% CI (1,02-3.24), P = 0.04, due to non-occupational exposure.

Related population-based epidemiological studies

Studies evaluating exposure to pesticides in general (i.e. without differentiating between compounds) have reported rather contradictory results, with some indicating an increase in cancer risk with risk increases ranging from 1.1 to 2.73 [9,67-70] and others showing rather lower cancer risks after pesticide exposure, ranging from 0.7 to 0.93 [67] for both workers and the community. Based on cohorts exposed to pesticides, 8 studies explored a possible association with increased cancer risk. Some reports identified an insignificant slightly decreased risk and others a significantly increased risk of cancer from pesticide exposure [9,68-70]. Yet, a declaration on carcinogenicity was not always available; similarly, retrospective personal or

Study	OR	95% CI	p- value
Alavanja 2003 [28]	1.100	0.828 - 1.462	0.511
Mills 2003 [30]	1.170	0.776 - 1.764	0.453
Cockburn 2011 [31]	1.620	1.017 - 2.581	0.042
Summary	*1.208*	*0.980 - 1.489*	*0.076*



Risk of prostate cancer (exposed vs. non-exposed to methyl-bromide).OR>1 indicates increased risk.

Figure 2 Meta-analysis of cancer risk after exposure to methyl bromide. The data showing all epidemiological studies clearly related to methyl bromide exposure (1990-2011) was analysed as described in the methods.

apocryphal reporting of product use (or misclassification of the degree of exposure or constitution of the chemical mixtures) is notoriously inadequate for risk association and assessments. Marusek et al. [39] concluded that this might also lead to misestimating of exposure level for control groups, especially when family members, generally considered as bystanders in farming activities, were used as controls. It has been reported that farmers tend to be at higher risk for cancers of the lip, brain, prostate, stomach, connective tissue melanoma and for carcinogenic changes in lymphatic and hematopoietic systems than the general population [71,72]. Several case-control studies have reported elevated relative risks of prostate cancer in agricultural workers [73]. Both in Italy and the USA [74-76], case control studies (though very inhomogeneous in nature) do report a slight increase in prostate cancer risk after pesticide exposure (with RR of 1.69 and RR 2.13). One US study reported a significantly increased risk of cancer in association with farming activities RR, 2.17; 95% CI (1.18-3.98), although the authors suggest a possible association with methyl bromide exposure, they acknowledged that another, as yet unidentified, factor may be involved [77]. More recent studies focused on cancer risk associated with pesticide use including methyl bromide: Issa et al. analysed two differently exposed groups of pesticide users in a retrospective study (1998-2006) [33]. To estimate prevalence differences between the two populations, directly exposed (farmers) and bystanders (farmers' wifes), the authors focused mainly on the change of habits, such as the use of the protective equipment or the applied dosage, concluding that there were some positive changes in the handling of pesticides amongst participants. The authors listed methyl bromide as one of the fumigant used but its possible carcinogenic effects were not addressed. A review by Weichenthal et al. [29] provided a comprehensive summary for most of the pesticides evaluated in the AHS.

The authors concluded that the data outside the study was still limited, but that the animal toxicity findings support the biological plausibility of a cancer risk. In addressing the issue of the link between the methyl bromide use and the incidence of the prostate cancer risk, the authors referred to the AHS study included in our meta-analysis and highlighted the increased risk of prostate cancer in methyl bromide applicators in the highest category of intensity-weighted exposure-days (Table 2).

Bioavailability

The routes of absorption of methyl bromide are the lungs and skin with elimination routes via the lung, urine and faeces. The available animal biotransformation data in vivo show that seventy two hours after exposure to [^{14}C]-methyl bromide, 43% was found in urine, ~40% was exhaled and 14-17% remained in the body (not only in fat tissue, but mainly in liver and kidneys). Notably, the animal data may not be directly extrapolated to humans (the serum half-life of bromide in humans is 12-16 days but only 1.5-3.5 days in the rat). Rats and mice metabolize methyl halides more rapidly than humans, so that the information on exposure concentration/duration and the association between the exposure concentration and symptoms cannot be directly extrapolated to humans. Fatal cases resulting from home fumigation exposure to humans were reported early [21]. One reported fatal case [13] provided both biomonitoring (exposure biomonitoring) and bioavailability data that showed initial serum methyl bromide levels on day 1 of 270 mg/L and of 29 mg/L on day 19 after exposure (at post mortem); the urine bromide concentration was 62 mg/L (normal <16 mg/L) one day after the exposure. Post-mortem (19 days after exposure) bromide levels were 17 mg/L in the bile, 24 μg/g in the liver and 28 μg/g in adipose tissue; urine formic acid was 58 μg/L (normal 50-360 μg/L). It needs to be noted that, as a consequence of the unrecognized first intoxication symptoms, the patient was presumed to have the flu and took bromide-containing flu medication. While this could have influenced the elimination kinetics, this data is important in highlighting differences between human and animal bioavailability.

Exposure assessment and biomonitoring

On a short time scale, the assessment of possible methyl bromide intoxication can be performed by air (ambient) monitoring or exposure biomonitoring [78]. Ambient monitoring data, associated with intoxication incidents, revealed values of 2-10 ppm methyl bromide in storage units (measured in cold-storage facilities, where off-gassing grapes were stored) [10]. We have measured over 4000 import freight container units in Hamburg and Rotterdam (2007-2010) and found the following range of methyl bromide concentrations in air samples from containers arriving at the harbor customs for inspection: 0.005-50 ppm (11.5% incidence in 2006-2008) and 0.005-7.1 ppm (4.8% in 2009/2010) [18,19]. In 2006, 3 individual container atmospheres had methyl bromide levels exceeding 800 ppm [17]. It has to be noted that the container air samples had multiple contaminations with fumigants and/or toxic industrial chemicals (like benzene) [17-19,79].

If supported by toxicological validation, exposure assessment based on biomarkers [78,80] provides the most valuable information about possible methyl bromide intoxication (for the individual incorporation through the lungs and skin). with the parent methyl bromide, or its metabolite bromide, being used for the biomonitoring of methyl bromide exposure. In a 17-year follow-up study, urinary bromide concentrations in factory workers (using protective equipment) exposed to methyl bromide were 25.2 ± 18.7 mg/g creatinine (3.0-125 mg/g creatinine) [20]. The measured urine values of 32.4-68.7 mg bromide/mg creatinine and serum levels of 36.2-52.1 mg bromide/L (normal reference levels are <5 mg/L) were associated with technical incidents and could be correlated with reported episodes of dizziness [20]. Blood samples from greenhouse workers analyzed 11 days after the application of methyl bromide revealed 3.4-20.6 mg/L of serum bromide. The increased bromide values, observed in most applicators, were associated with reported symptoms of irritation to the eyes, coughing, neurological, psychiatric, respiratory and gastrointestinal symptoms [11]. Biological effect biomonitoring [78,80] provides useful information about prior intoxication and has implied an association between an increase in proximate pre-carcinogenic lesions after pesticide exposure and the cancer risk [81-83]. A prospective analysis of blood samples from more than 6700 agricultural and greenhouse workers revealed an elevation of cytogenetic biomarkers and enhanced cancer risk after pesticide exposure [81]; Several other studies using micronuclei (and other functional cytogenetic biological markers) revealed both an increase in cytogenetic damage after exposure to pesticide mixtures and their correlation with an increased cancer risk in several European populations [74,82,83].

Reference values, community exposure limits

The calculated reference concentration values (RfC) for non-carcinogenic effects of methyl bromide in humans [84] can be regarded as community exposure limits. The RfC is a reference point to gauge potential effects, the incidence of which increases for an exposure greater than RfC [45]. An RfC limit value of 0.210 ppm (0.210 mL/m^3) was recently estimated for acute inhaled exposure of methyl bromide [84]. Also, for a subchronic exposure to methyl bromide for 1 week, the RfC was estimated to be 0.129 ppm and 0.079 ppm for adults and children, respectively; while the chronic 6 week RfCs were estimated to be 0.002 ppm and 0.001 ppm for adults and children, respectively. The California Office of Environmental Health has also settled non-cancer reference dose (RfD) values for acute air exposure to methyl bromide at 0.05 ppm (neurologic targeted toxicity) and for chronic RfD for the respiratory tract target (based on degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity) to be 0.005 mg/m^3 (0.0012 ppm) [9]. Additionally, community exposure data, which showed air values of 0.005 ppm [9,69,85] due to pollution from farming activities, provides the basis for the estimation of hazard quotients (HQ) (defining non-cancer risk) [84,85]. These risk quotients were characterized for populations within a few miles of the air monitoring stations [9]. The HQ is defined as a ratio between the estimated intake of methyl bromide (in mg/kg/day) and the reference dose (RfD); the acute HQ was estimated to be 0.7 mg/kg/day (95% CI), the subchronic as 13.9 mg/kg/day (95% CI) and the HQ for chronic intake as 2.0 mg/kg/day [84].

Discussion

The halogenated hydrocarbon pesticide methyl bromide, which was designed for phase-out in 2005, remains in frequent use because of various critical use exemptions and new regulations. The exposure assessment data and epidemiological analysis indicate health risk concerns for both workers and the general public [31,32]. Recent case reports continue to demonstrate episodes of illness (with disabling neurological symptoms, memory difficulties and dizziness) in association with elevated levels of serum bromide [10,15].

Methyl bromide is at least as poisonous to humans as it is to the pests with genetic susceptibility (i.e. the conjugator status) or acquired single point mutations playing an essential role in humans. The conjugator status varies phenotypically between species and individuals and may help to explain the variation in toxicity observed (with data showing no immediate, otherwise expected, effects). In human non-conjugators, the absence of the glutathione S-transferase (GST) pathway pushes methyl bromide into alternative oxidation pathways [43], effectively reducing its acute neurotoxicity but concomitantly and insidiously exacerbating its chronic genotoxic effects [40-42].

The exposure to pesticides in agriculture is almost always additive in nature [35]. The possible additive or subadditive effects might be different for cases of exposure to fumigated container and contaminated goods however. We found not only methyl bromide but also high levels of contamination with ethylene dichloride, methylene chloride, ethylene dibromide or tetrachlorethanes in import containers (all halo-methanes or halo-ethanes that share signalling pathway disruption mechanisms). Many epidemiological studies refer to pesticide exposure but without discriminating between the different chemical entities nor their formulations, which differ not only chemically but also in their toxicity, patho-physiological mode of action, target organ, symptoms and possible carcinogenic status (with many not listed as carcinogenic nor even evaluated [35]. Retrospective personal or apocryphal reporting of product use, or misclassification of the degree of exposure or constitution of the chemical mixtures, all fail to contribute adequately to risk associations and assessments. Occupational circumstances associated with farming alone (as confounder) do not appear to provide a risk factor for prostate cancer; rather there is a perceived decrease in overall cancer incidence among unexposed farmers [87].

On the other hand, the community exposure risks to airborne agricultural pesticides have been documented [9] and the study from Cockburn et al. demonstrated an association between prostate cancer and the ambient non-occupational exposure to methyl bromide [31].

Our meta-analysis indicates an increased prostate cancer risk after exposure to methyl bromide. The International Agency for Research on Cancer (IARC) continues to classify methyl bromide in the carcinogenic category 3 (defined as unclassifiable as to its carcinogenicity to humans because of inadequate evidence in humans and limited evidence in experimental animals) [86]. Yet many studies provide evidence that application of this pesticide may not only elicit a number of toxic effects but also is associated with an increased risk of cancer [28-31]. However, the carcinogenicity of methyl bromide cannot be easily explained as a function of the concentration levels and the exposure period, especially with the limitations and disputed relevance of animal experimentation. More recent data delineate the role of single point mutations in enhanced prostate cancer risk after pesticide exposure, affecting genes which code for phase I/II and oxidative stress enzymes, [55].

The complicated and complex biotransformation pathways of methyl bromide in humans have only been partially elucidated. Human studies are rare and any extrapolation from animal data is difficult to justify. Further investigations are needed to explore the molecular mechanisms of the toxicological and carcinogenic effects of methyl bromide in more detail.

The exposure misclassification in many epidemiological studies may have caused an underestimation of the effects (especially when the control groups, such as family members, are also exposed). It has also to be emphasized that many available studies concern average risks and, therefore, do not represent the actual risks in genetically predisposed human subjects. We recommend further studies to redress this deficiency.

Conclusions

Both the epidemiological evidence and toxicological data suggest a link between methyl bromide exposure and serious health problems, including cancer risk (prostate cancer), from occupational and community exposure. The carcinogenic classification of methyl bromide should be reevaluated.

List of abbreviations

AHS: Agriculture Health Study; CUE: critical use exemtions: DNA: Deoxyribonucleic acid: EPA: Environmental Protective Agency; GSH: gluthatione ((2S)-2-amino-4-{[(1R)-1-[(carboxymethyl)carbamoyl]-2-sulfanylethyl]carbamoyl}butanoic acid); GST: Gluthatione S-transferase;GSTT1: Glutathione S-transferase theta;HQ: hazard quotient; IUPAC: International Union of Pure and Applied Chemistry; NTP: National toxicology program OD: odds ratio; ppm: parts per million (= mL/m^3); RfC: Reference concentration values; SNP: single nucleotide polymorphism.

Acknowledgements

We would like to thank Dr. Hui Zhang for supportive data extraction and Dr. Kevan Willey for critical appraisal of the manuscript. Part of the study was supported by the Federal Ministry of Labour, Germany (XB), the State Ministry for Health and Consumer Protection, Hamburg (XB, LTB) and is also part of a WHO GPA (global plan of action) project "New chemical health risks hazards in transportation and warehousing of marine cargo due to the process of globalization" (LTB).

Author details

[1]Division of Occupational Toxicology and Immunology, Institute for Occupational and Maritime Medicine (ZfAM), Medical Faculty, University of Hamburg, University Medical Center, Hamburg, Germany. [2]Division of Clinical Occupational Medicine, Institute for Occupational and Maritime Medicine (ZfAM), University Medical Center Hamburg-Eppendorf, Hamburg, Germany. [3]Chair for Occupational Medicine, Medical Faculty, University of Hamburg, University Medical Center, Hamburg, Germany.

Authors' contributions

XB and LTB made substantial contributions in the conception, design of the study and the interpretation of data. SK did the detailed literature search and building up the molecular model. LTB analyzed the toxicological data and MVG performed the analysis of epidemiological data and performed the meta-analysis. LTB wrote the manuscript. All authors approved the final version for submission.

Competing interests

The authors declare that they have no competing interests

Received: 22 September 2011 Accepted: 27 January 2012
Published: 27 January 2012

References

1. IPCS: **The WHO recomended classification of pesticides by hazard.** 2006 [http://www.whoint/entity/ipcs//pesticides_hazard/en/index.html].
2. IMO: **International Maritime Organization, Recommendations on the safe use of pesticides in ships. London: IMO, SOLAS.** *Consolidated Edition Consolidated Text of the International Convention for the Safety of Life at Sea, London* 2004.
3. FAO: **Food and Agriculture Organization of the United Nations, International standards for phytosanitary measures. Manual on Pesticides.** 2003 [http://www.fao.org/ag/AGP/.../qualitycontrol05.pdf].
4. EPA, Environmental Protective Agency: **The phase out of methyl bromide.** 2011 [http://www.epagov/ozone/mbr].
5. DHS.Hazard evaluation and information system: **Methyl bromide Fact sheet.** 2008 [http://www.dhscagov/ohb/HESIS/mebr.htm].
6. FAO: **Food and Agriculture Organization of the United Nations, International standards for phytosanitary measures. Guidelines for regulating wood packaging material in international trade.** *ISPM Pub* , ISPM No. 15. N° 6, FAO, Rome2007.
7. Goodwin KD, Tokarczyk R, Stephens FC, Saltzman ES: **Description of toluene inhibition of methyl bromide biodegradation in seawater and isolation of a marine toluene oxidizer that degrades methyl bromide.** *Appl Environ Microbiol* 2005, **71**:3495-3503.
8. McCook A: **The banned pesticide in our soil.** *The Scientist* 2006, **20**:40-47.
9. Lee S, McLaughlin R, Harnly M, Gunier R, Kreutzer R: **Community exposures to airborne agricultural pesticides in California: ranking of inhalation risks.** *Environ Health Perspect* 2002, **110**:1175-1184.
10. CDC: **Illness associated with exposure to methyl bromide-fumigated produce in california.** *MMWR Morb Mortal Wkly Rep* 2011, **60**:923-926.
11. Akca ET, Serpil S, Sezer U, Ozlem E, Ayse G, Canan C, Hakan B, Ozgur K, Banu O, Hulya G: **Health profiles of methyl bromide applicators in greenhouses in Turkey.** *Ann Acad Med Singapore* 2009, **38**:707-713.
12. MacFarlane E, Benke G, Goddard D, Sim M: **Urban pest control operators in Australia.** *Occup Environ Med* 2007, **64**:422-427.
13. Horowitz BZ, Albertson TE, O'Malley M, Swenson EJ: **An unusual exposure to methyl bromide leading to fatality.** *J Toxicol Clin Toxicol* 1998, **36**:353-357.

14. Breeman W: Methylbromide intoxication: a clinical case study. *Adv Emerg Nurs J* 2009, 31:153-160.
15. Preisser AM, Budnik LT, Hampel E, Baur X: Surprises perilous: Toxic health hazards for employees unloading fumigated shipping containers. *Sci Total Environ* 2011, 409:3106-3113.
16. Shaw I: Motor neurone disease - a methyl bromide exposure cluster points to a causal mechanism. *Hum Exp Toxicol* 2010, 29:241-242.
17. Baur X, Poschadel B, Budnik LT: High frequency of fumigants and other toxic gases in imported freight containers–an underestimated occupational and community health risk. *Occup Environ Med* 2010, 67:207-212.
18. Budnik LT, Fahrenholtz S, Kloth S, Baur X: Halogenated hydrocarbon pesticides and other volatile organic contaminants provide analytical challenges in global trading. *J Environ Monit* 2010, 12:936-942.
19. Fahrenholtz S, Hühnerfuss H, Baur X, Budnik LT: Determination of phosphine and other fumigants in air samples by thermal desorption and 2D heart cutting gas chromatography with synchronous SIM/Scan mass spectrometry and flame photometric detection. *Journal of Chromatography A* 2010, 1217:8298-8307.
20. Yamano Y, Tokutake T, Ishizu S, Nakadate T: Occupational exposure in methyl bromide manufacturing workers: 17-year follow-up study of urinary bromide ion concentration for biological monitoring. *Ind Health* 2011, 49:133-138.
21. CDC, NIOSH, Centers for Disease Control and Prevention: Methyl Bromide. 2011 [http://www.cdcgov/niosh/npg/npgd0400html/methyl bromide].
22. Langard S, Rognum T, Flotterod O, Skaug V: Fatal accident resulting from methyl bromide poisoning after fumigation of a neighbouring house; leakage through sewage pipes. *J Appl Toxicol* 1996, 16:445-448.
23. Ames BN, Gold LS: Animal cancer tests and cancer prevention. *J Natl Cancer Inst Monogr* 1992, 125-132.
24. Bolt HM, Gansewendt B: Mechanisms of carcinogenicity of methyl halides. *Crit Rev Toxicol* 1993, 23:237-253.
25. Maroni M, Fanetti AC, Metruccio F: Risk assessment and management of occupational exposure to pesticides in agriculture. *Med Lav* 2006, 97:430-437.
26. Cochrane.org: The Cochrane Collaboration Handbook for Systematic Reviews of Interventions.[http://www.cochraneorg/resources/handbook/].
27. Huedo-Medina TB, Sanchez-Meca J, Marin-Martinez F, Botella J: Assessing heterogeneity in meta-analysis: Q statistic or I2 index? *Psychol Methods* 2006, 11:193-206.
28. Alavanja MC, Samanic C, Dosemeci M, Lubin J, Tarone R, Lynch CF, Knott C, Thomas K, Hoppin JA, Barker J, *et al*: Use of agricultural pesticides and prostate cancer risk in the Agricultural Health Study cohort. *Am J Epidemiol* 2003, 157:800-814.
29. Weichenthal S, Moase C, Chan P: A review of pesticide exposure and cancer incidence in the Agricultural Health Study cohort. *Environ Health Perspect* 2010, 118:1117-1125.
30. Mills PK, Yang R: Prostate cancer risk in California farm workers. *J Occup Environ Med* 2003, 45:249-258.
31. Cockburn M, Mills P, Zhang X, Zadnick J, Goldberg D, Ritz B: Prostate cancer and ambient pesticide exposure in agriculturally intensive areas in California. *Am J Epidemiol* 2011, 173:1280-1288.
32. Hoppin JA, Valcin M, Henneberger PK, Kullman GJ, Umbach DM, London SJ, Alavanja MC, Sandler DP: Pesticide use and chronic bronchitis among farmers in the Agricultural Health Study. *Am J Ind Med* 2007, 50:969-979.
33. Issa Y, Sham'a FA, Nijem K, Bjertness E, Kristensen P: Pesticide use and opportunities of exposure among farmers and their families: cross-sectional studies 1998-2006 from Hebron governorate, occupied Palestinian territory. *Environ Health* 2010, 9:63.
34. Agency for Toxic Substances & Disease Registry: Medical Management Guidelines for Bromomethane. 2011 [http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=160].
35. National-Cancer-Institute: Agricultural Pesticide Use May Be Associated With Increased Risk of Prostate Cancer. 2010 [http://www.aghealthorg].
36. Lifshitz M, Gavrilov V: Central nervous system toxicity and early peripheral neuropathy following dermal exposure to methyl bromide. *J Toxicol Clin Toxicol* 2000, 38:799-801.
37. Kim EA, Kang SK: Occupational neurological disorders in Korea. *J Korean Med Sci* 2010, 25:S26-35.
38. Park HJ, Lee KM, Nam JK, Park NC: A case of erectile dysfunction associated with chronic methyl bromide intoxication. *Int J Impot Res* 2005, 17:207-208.
39. Davenport CJ, Ali SF, Miller FJ, Lipe GW, Morgan KT, Bonnefoi MS: Effect of methyl bromide on regional brain glutathione, glutathione-S-transferases, monoamines, and amino acids in F344 rats. *Toxicol Appl Pharmacol* 1992, 112:120-127.
40. Garnier R, Rambourg-Schepens MO, Muller A, Hallier E: Glutathione transferase activity and formation of macromolecular adducts in two cases of acute methyl bromide poisoning. *Occup Environ Med* 1996, 53:211-215.
41. Hallier E, Langhof T, Dannappel D, Leutbecher M, Schroder K, Goergens HW, Muller A, Bolt HM: Polymorphism of glutathione conjugation of methyl bromide, ethylene oxide and dichloromethane in human blood: influence on the induction of sister chromatid exchanges (SCE) in lymphocytes. *Arch Toxicol* 1993, 67:173-178.
42. Hallier E, Schroder KR, Asmuth K, Dommermuth A, Aust B, Goergens HW: Metabolism of dichloromethane (methylene chloride) to formaldehyde in human erythrocytes: influence of polymorphism of glutathione transferase theta (GST T1-1). *Arch Toxicol* 1994, 68:423-427.
43. Muller M, Bunger J, Voss M, Westphal G, Ruhnau P, Hallier E: Phenotyping of human glutathione S-transferase hGSTT1-1: a comparison of two ex vivo routine procedures. *Arch Toxicol* 2002, 76:634-642.
44. Ballering LA, Nivard MJ, Vogel EW: A deficiency for nucleotide excision repair strongly potentiates the mutagenic effectiveness of methyl bromide in Drosophila. *Mutagenesis* 1994, 9:387-389.
45. U.S. Environmental Protection Agency: Integrated Risk Information System (IRIS) on Bromomethane. National Center forEnvironmental Assessment. Office of Research and Development. Washington, DC; 1999.
46. Gansewendt B, Foest U, Xu D, Hallier E, Bolt HM, Peter H: Formation of DNA adducts in F-344 rats after oral administration or inhalation of [14C]methyl bromide. *Food Chem Toxicol* 1991, 29:557-563.
47. Gansewendt B, Xu D, Foest U, Hallier E, Bolt HM, Peter H: DNA binding of methyl iodide in male and female F344 rats. *Carcinogenesis* 1991, 12:463-467.
48. Pletsa V, Steenwinkel MJ, van Delft JH, Baan RA, Kyrtopoulos SA: Methyl bromide causes DNA methylation in rats and mice but fails to induce somatic mutations in lambda lacZ transgenic mice. *Cancer Lett* 1999, 135:21-27.
49. Liu L, Williams KM, Guengerich FP, Pegg AE: O6-alkylguanine-DNA alkyltransferase has opposing effects in modulating the genotoxicity of dibromomethane and bromomethyl acetate. *Chem Res Toxicol* 2004, 17:742-752.
50. Fonnum F, Lock EA: The contributions of excitotoxicity, glutathione depletion and DNA repair in chemically induced injury to neurones: exemplified with toxic effects on cerebellar granule cells. *J Neurochem* 2004, 88:513-531.
51. Mitsumori K, Maita K, Kosaka T, Miyaoka T, Shirasu Y: Two-year oral chronic toxicity and carcinogenicity study in rats of diets fumigated with methyl bromide. *Food Chem Toxicol* 1990, 28:109-119.
52. National-Toxicology-Program N: Toxicology and carcinogenesis studies of methyl bromide. *National Toxicology Program Tech Rep Ser* 2002, 385:1-212.
53. Garry VF, Nelson RL, Griffith J, Harkins M: Preparation for human study of pesticide applicators: sister chromatid exchanges and chromosome aberrations in cultured human lymphocytes exposed to selected fumigants. *Teratog Carcinog Mutagen* 1990, 10:21-29.
54. Asakura M, Sasaki T, Sugiyama T, Arito H, Fukushima S, Matsushima T: An improved system for exposure of cultured mammalian cells to gaseous compounds in the chromosomal aberration assay. *Mutat Res* 2008, 652:122-130.
55. Koutros S, Andreotti G, Berndt SI, Hughes Barry K, Lubin JH, Hoppin JA, Kamel F, Sandler DP, Burdette LA, Yuenger J, *et al*: Xenobiotic-metabolizing gene variants, pesticide use, and the risk of prostate cancer. *Pharmacogenet Genomics* 2011, 21:615-623.
56. Stirzaker C, Song JZ, Davidson B, Clark SJ: Transcriptional gene silencing promotes DNA hypermethylation through a sequential change in chromatin modifications in cancer cells. *Cancer Res* 2004, 64:3871-3877.
57. Xu DG, Peter H, Hallier E, Bolt HM: Hemoglobin adducts of monohalomethanes. *Ind Health* 1990, 28:121-123.

58. Lin X, Asgari K, Putzi MJ, Gage WR, Yu X, Cornblatt BS, Kumar A, Piantadosi S, DeWeese TL, De Marzo AM, Nelson WG: **Reversal of GSTP1 CpG island hypermethylation and reactivation of pi-class glutathione S-transferase (GSTP1) expression in human prostate cancer cells by treatment with procainamide.** *Cancer Res* 2001, **61**:8611-8616.
59. Mallick S, Romana M, Blanchet P, Multigner L: **GSTM1 and GSTT1 polymorphisms and the risk of prostate cancer in a Caribbean population of African descent.** *Urology* 2007, **69**:1165-1169.
60. Kote-Jarai Z, Easton D, Edwards SM, Jefferies S, Durocher F, Jackson RA, Singh R, Ardern-Jones A, Murkin A, Dearnaley DP, *et al*: **Relationship between glutathione S-transferase M1, P1 and T1 polymorphisms and early onset prostate cancer.** *Pharmacogenetics* 2001, **11**:325-330.
61. Rebbeck TR, Walker AH, Jaffe JM, White DL, Wein AJ, Malkowicz SB: **Glutathione S-transferase-mu (GSTM1) and -theta (GSTT1) genotypes in the etiology of prostate cancer.** *Cancer Epidemiol Biomarkers Prev* 1999, **8**:283-287.
62. Agalliu I, Lin DW, Salinas CA, Feng Z, Stanford JL: **Polymorphisms in the glutathione S-transferase M1, T1, and P1 genes and prostate cancer prognosis.** *Prostate* 2006, **66**:1535-1541.
63. Mo Z, Gao Y, Cao Y, Gao F, Jian L: **An updating meta-analysis of the GSTM1, GSTT1, and GSTP1 polymorphisms and prostate cancer: a HuGE review.** *Prostate* 2009, **69**:662-688.
64. McMillan Carr V, Ring G, Youngentob SL, Schwob JE, Farbman AI: **Altered epithelial density and expansion of bulbar projections of a discrete HSP70 immunoreactive subpopulation of rat olfactory receptor neurons in reconstituting olfactory epithelium following exposure to methyl bromide.** *J Comp Neurol* 2004, **469**:475-493.
65. Igisu H, Kinoshita Y: **Magnetic resonance for evaluation of toxic encephalopathies: implications from animal experiments.** *Neurotoxicology* 2007, **28**:252-256.
66. Bakos SR, Schwob JE, Costanzo RM: **Matrix metalloproteinase-9 and -2 expression in the olfactory bulb following methyl bromide gas exposure.** *Chem Senses* 2010, **35**:655-661.
67. Zhong Y, Rafnsson V: **Cancer incidence among Icelandic pesticide users.** *Int J Epidemiol* 1996, **25**:1117-1124.
68. Parker AS, Cerhan JR, Putnam SD, Cantor KP, Lynch CF: **A cohort study of farming and risk of prostate cancer in Iowa.** *Epidemiology* 1999, **10**:452-455.
69. Reynolds P, Von Behren J, Gunier RB, Goldberg DE, Hertz A, Harnly ME: **Childhood cancer and agricultural pesticide use: an ecologic study in California.** *Environ Health Perspect* 2002, **110**:319-324.
70. Kristensen P, Andersen A, Irgens LM, Laake P, Bye AS: **Incidence and risk factors of cancer among men and women in Norwegian agriculture.** *Scand J Work Environ Health* 1996, **22**:14-26.
71. Blair A, Zahm SH, Pearce NE, Heineman EF, Fraumeni JF Jr: **Clues to cancer etiology from studies of farmers.** *Scand J Work Environ Health* 1992, **18**:209-215.
72. Pearce N, Reif JS: **Epidemiologic studies of cancer in agricultural workers.** *Am J Ind Med* 1990, **18**:133-148.
73. Deschamps FJ, Turpin JC: **Methyl bromide intoxication during grain store fumigation.** *Occup Med (Lond)* 1996, **46**:89-90.
74. Forastiere F, Quercia A, Miceli M, Settimi L, Terenzoni B, Rapiti E, Faustini A, Borgia P, Cavariani F, Perucci CA: **Cancer among farmers in central Italy.** *Scand J Work Environ Health* 1993, **19**:382-389.
75. Settimi L, Comba P, Bosia S, Ciapini C, Desideri E, Fedi A, Perazzo PL, Axelson O: **Cancer risk among male farmers: a multi-site case-control study.** *Int J Occup Med Environ Health* 2001, **14**:339-347.
76. van der Gulden JW, Kolk JJ, Verbeek AL: **Work environment and prostate cancer risk.** *Prostate* 1995, **27**:250-257.
77. Krstev S, Baris D, Stewart P, Dosemeci M, Swanson GM, Greenberg RS, Schoenberg JB, Schwartz AG, Liff JM, Hayes RB: **Occupational risk factors and prostate cancer in U.S. blacks and whites.** *Am J Ind Med* 1998, **34**:421-430.
78. Budnik LT, Baur X: **The assessment of environmental and occupational exposure to hazardous substances by biomonitoring.** *Dtsch Arztebl Int* 2009, **106**:91-97.
79. Baur X, Budnik LT, Preisser AM: **Health risks from fumigant residues in import containers.** *Dtsch Med Wochenschr* 2010, **135**:516-521.
80. Budnik LT, Baur X: **Biomonitoring of toxic substances in the work environment. A complex diagnostic scheme with many players.** *The Praeger Handbook of Environmental Health* .
81. Bonassi S, Znaor A, Ceppi M, Lando C, Chang WP, Holland N, Kirsch-Volders M, Zeiger E, Ban S, Barale R, *et al*: **An increased micronucleus frequency in peripheral blood lymphocytes predicts the risk of cancer in humans.** *Carcinogenesis* 2007, **28**:625-631.
82. Lucero L, Pastor S, Suarez S, Durban R, Gomez C, Parron T, Creus A, Marcos R: **Cytogenetic biomonitoring of Spanish greenhouse workers exposed to pesticides: micronuclei analysis in peripheral blood lymphocytes and buccal epithelial cells.** *Mutat Res* 2000, **464**:255-262.
83. Pastor S, Creus A, Parron T, Cebulska-Wasilewska A, Siffel C, Piperakis S, Marcos R: **Biomonitoring of four European populations occupationally exposed to pesticides: use of micronuclei as biomarkers.** *Mutagenesis* 2003, **18**:249-258.
84. Wedge RM, Abt EN, Hobbs CH: **Methyl bromide risk characterization in California.** *J Toxicol Environ Health B Crit Rev* 2001, **4**:333-339.
85. Nuckols JR, Gunier RB, Riggs P, Miller R, Reynolds P, Ward MH: **Linkage of the California Pesticide Use Reporting Database with spatial land use data for exposure assessment.** *Environ Health Perspect* 2007, **115**:684-689.
86. Parent ME, Siemiatycki J: **Occupation and prostate cancer.** *Epidemiol Rev* 2001, **23**:138-143.
87. IRAC: **Evaluation of Carcinogenic risk to human.** *Monographs from the International Agency for Research on Cancer* 1999, **71**:721-735.
88. Calvert GM, Talaska G, Mueller CA, Ammenheuser MM, Au WW, Fajen JM, Fleming LE, Briggle T, Ward E: **Genotoxicity in workers exposed to methyl bromide.** *Mutat Res* 1998, **417**:115-128.
89. Mostafa IY, Zayed SM, Hazzaa NI, Hegazi B: **Bioavailability to rats and toxicity of bound residues in bean seeds fumigated with 14C-methyl bromide.** *J Environ Sci Health B* 1992, **27**:407-417.
90. Calvert GM, Mueller CA, Fajen JM, Chrislip DW, Russo J, Briggle T, Fleming LE, Suruda AJ, Steenland K: **Health effects associated with sulfuryl fluoride and methyl bromide exposure among structural fumigation workers.** *Am J Public Health* 1998, **88**:1774-1780.
91. Kang K, Song YM, Jo KD, Roh JK: **Diffuse lesion in the splenium of the corpus callosum in patients with methyl bromide poisoning.** *J Neurol Neurosurg Psychiatry* 2006, **77**:703-704.

doi:10.1186/1476-069X-11-5
Cite this article as: Budnik *et al.*: Prostate cancer and toxicity from critical use exemptions of methyl bromide: Environmental protection helps protect against human health risks. *Environmental Health* 2012 **11**:5.

Attachment 3

Environmental Research 158 (2017) 358–365

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Residential proximity to agricultural fumigant use and IQ, attention and hyperactivity in 7-year old children

Robert B. Gunier*, Asa Bradman, Rosemary Castorina, Nina T. Holland, Dylan Avery, Kim G. Harley, Brenda Eskenazi

Center for Environmental Research and Children's Health (CERCH), School of Public Health, University of California, Berkeley, CA, USA

ARTICLE INFO

Keywords:
Behavior
Children
Fumigants
Neurodevelopment
Pesticides

ABSTRACT

Objectives: Our objective was to examine the relationship between residential proximity to agricultural fumigant use and neurodevelopment in 7-year old children.

Methods: Participants were living in the agricultural Salinas Valley, California and enrolled in the Center for the Health Assessment of Mothers and Children Of Salinas (CHAMACOS) study. We administered the Wechsler Intelligence Scale for Children (4th Edition) to assess cognition and the Behavioral Assessment System for Children (2nd Edition) to assess behavior. We estimated agricultural fumigant use within 3, 5 and 8 km of residences during pregnancy and from birth to age 7 using California's Pesticide Use Report data. We evaluated the association between prenatal (n = 285) and postnatal (n = 255) residential proximity to agricultural use of methyl bromide, chloropicrin, metam sodium and 1,3-dichloropropene with neurodevelopment.

Results: We observed decreases of 2.6 points (95% Confidence Interval (CI): −5.2, 0.0) and 2.4 points (95% CI: −4.7, −0.2) in Full-Scale intelligence quotient for each ten-fold increase in methyl bromide and chloropicrin use within 8 km of the child's residences from birth to 7-years of age, respectively. There were no associations between residential proximity to use of other fumigants and cognition or proximity to use of any fumigant and hyperactivity or attention problems. These findings should be explored in larger studies.

1. Introduction

Methyl bromide, chloropicrin, metam sodium and 1, 3-dichloropropene (1,3-DCP) are common agricultural fumigants used primarily to reduce pathogens and pests in soil prior to planting crops. Approximately 44 – 51 million kilograms (kg) of these four fumigants are applied annually in the United States (Grube et al., 2011), and 13 million kg are applied annually in California (CDPR, 2016c), constituting one sixth of all pesticide use in California. Fumigants are more likely than other pesticides to drift from application sites due to their high vapor pressure (California Department of Pesticide Regulation, 2015, 2016a, 2016b). In 2012, California implemented a pesticide air monitoring network in several agricultural communities. Fumigants were frequently detected at each of the air monitoring sites, indicating repeated, low-level community exposures (CDPR, 2014). Acute human exposure to methyl bromide has produced symptoms including headaches, seizures, muscle weakness, memory problems (Bishop, 1992; Reidy et al., 1994), and neuropathy (Ben Slamia et al., 2006; Cavalleri et al., 1995). More attention and concentration problems have been reported in workers exposed to methyl bromide (Magnavita, 2009). Residents exposed to metam sodium after a train spill experienced increased psychological problems (e.g., depression and anxiety) (Bowler et al., 1994b). Symptoms of chloropicrin intoxication are also primarily neurologic, including tremors and seizures (TeSlaa et al., 1986). Although there is no evidence of neurotoxicity from limited human and animal research of 1,3-DCP (ATSDR, 2008), increased use of 1,3-DCP as a replacement for methyl bromide warrants further studies on the human health effects of this fumigant. A survey of pesticide related illnesses reported in 11 states from 1998 to 2006 found that soil applications of fumigants were responsible for the largest percentage of acute illnesses (45%) and non-occupational cases (61%) (Lee et al., 2011). In a risk assessment using California air monitoring data, these

Abbreviations: 1, 3-DCP, 1,3-dichloropropene; BASC-2, Behavioral Assessment System for Children 2; CHAMACOS, Center for the Health Assessment of Mothers and Children of Salinas; CI, confidence interval; DAP, dialkyl phosphate; DDT, *p, p′*-dichlorodiphenyltrichloroethylene; DDE, *p, p′*-dichlorodiphenyldichloroethylene; HOME, Home Observation for Measurement of the Environment; IQ, intelligence quotient; OP, organophosphate; OR, odds ratio; PBDE, polybrominated diphenyl ether; PPVT, Peabody Picture Vocabulary Test; TVIP, Test de Vocabulario en Imagenes Peabody; WISC-IV, Wechsler Intelligence Scale for Children, 4th edition

* Correspondence to: Center for Environmental Research and Children's Health (CERCH), School of Public Health, University of California at Berkeley, 1995 University Ave, Suite 265, Berkeley, CA 94704, USA.

E-mail address: gunier@berkeley.edu (R.B. Gunier).

http://dx.doi.org/10.1016/j.envres.2017.06.036
Received 7 March 2017; Received in revised form 30 May 2017; Accepted 27 June 2017
Available online 04 July 2017
0013-9351/

four high-use fumigants (methyl bromide, chloropicrin, metam sodium and 1,3-DCP) were the top four pesticides ranked in terms of chronic health risks and an estimated 5 million U.S. residents live in areas of high agricultural fumigant use (Lee et al., 2002).

Currently, there are no reliable biomarkers to assess human exposure to fumigants in epidemiologic studies (Hustinx et al., 1993; Magnavita, 2009; Verberk et al., 1979). Thus, residential proximity to fumigant use is currently the best method to characterize potential exposure. Since 1990, California has maintained a Pesticide Use Reporting (PUR) system which requires commercial growers to report all agricultural pesticide use to a one square mile (~259 ha) area (CDPR, 2016c). A study using PUR data showed that methyl bromide use within a 7 × 7 square mile area (~8 km radius) around monitoring sites explained 95% of the variance in methyl bromide air concentrations, indicating a direct relationship between nearby agricultural use and potential community exposure (Li et al., 2005). Several epidemiologic studies have used PUR data and observed associations between higher nearby agricultural pesticide use during pregnancy and adverse neurodevelopmental outcomes including birth defects (Carmichael et al., 2014; Rull et al., 2006; Yang et al., 2014), autism (Roberts et al., 2007; Shelton et al., 2014) and cognitive function (Gunier et al., 2016; Rowe et al., 2016).

We previously found that living within 5 km of methyl bromide use in the second trimester of pregnancy was associated with decreased birth weight, length, and head circumference (Gemmill et al., 2013). Methyl bromide was banned by the Montreal Protocol due to harmful effects on the ozone layer and is currently being phased out of use, resulting in increased usage of chloropicrin, metam sodium and1,3-DCP in recent years (CDPR, 2016c). In the present study, we investigate associations between residential proximity to agricultural use of four fumigants during the prenatal and postnatal periods and child neurodevelopment and behavior at age 7 in children participating in the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS), a longitudinal birth cohort study of primarily low-income Latino families living in the agricultural community of the Salinas Valley, California.

2. Methods

2.1. Study population

We enrolled 601 pregnant women between October 1999 and October 2000 as part of the CHAMACOS study. Women were eligible if they were ≥ 18 years of age, < 20 weeks gestation, eligible for California's subsidized low-income prenatal health care, spoke English or Spanish, and were planning to deliver at the county hospital. We followed the women through the delivery of 537 live born children. We excluded children with medical conditions that could affect neurodevelopmental assessment (n = 4, one child each with Downs syndrome, autism, deafness, and hydrocephalus). We included children who had a neurodevelopmental assessment at age 7 (n = 336) and excluded two participants who did not have prenatal measurements of dialkyl phosphate (DAP) metabolites of organophosphate pesticides (OPs) because a previous analysis in this cohort found that DAPs were associated with neurodevelopment (Bouchard et al., 2011). For analyses of proximity to fumigant use, we included participants whose residential location was known for at least 80% of the time during pregnancy (n = 285) for the prenatal period and from birth to the 7-year neurodevelopmental assessment (n = 255) for the postnatal period. Written informed consent was obtained from all women and oral assent from all children at age 7; all research was approved by the University of California, Berkeley, Committee for the Protection of Human Subjects prior to commencement of the study.

2.2. Maternal interviews and assessments

Bilingual interviewers conducted maternal interviews in Spanish or English twice during pregnancy (~13 and 26 weeks gestation), after delivery and when the children were 6 months and 1, 2, 3.5, 5 and 7-years of age. Interviews obtained demographic information including maternal age, education, country of birth, number of years lived in the United States, marital status, paternal education, and family income. We collected residential history information by asking participants if they had moved since the last interview and, if so, the dates of all moves. We conducted home visits shortly after enrollment (~16 weeks gestation) and when the child was 6 months and 1, 2, 3.5 and 5-years of age. For each visit, latitude and longitude coordinates of the participant's home were determined using a handheld global positioning system unit.

Mothers were administered the Peabody Picture Vocabulary Test (PPVT) for English speakers or the Test de Vocabulario en Imagenes Peabody (TVIP) for Spanish speakers at the six-month visit to assess verbal intelligence (Dunn and Dunn, 1981). If maternal PPVT or TVIP scores were unavailable from the 6-month visit, we used scores from the re-administration of the test conducted at a 9-year visit (n = 5) or assigned the mean score of the sample (n = 2). A short version of the HOME (Home Observation for Measurement of the Environment) inventory was completed during the 7-year visit (Caldwell and Bradley, 1984).

2.3. Cognitive and behavior assessments

We assessed cognitive abilities when the children were 7-years of age using the Wechsler Intelligence Scale for Children, 4th edition (WISC-IV) (Wechsler, 2003). All assessments were completed by a single bilingual psychometrician, who was trained and supervised by a pediatric neuropsychologist. Index scores for four domains were calculated based on the following subtests: Verbal Comprehension (composed of Vocabulary and Similarities subtests), Perceptual Reasoning (Block Design and Matrix Reasoning subtests), Working Memory (Digit Span and Letter-Number Sequencing subtests), and Processing Speed (Coding and Symbol Search subtests). We administered all subtests in the dominant language of the child using either the WISC-IV English or Spanish edition, which was determined through administration of the oral vocabulary subtest of the Woodcock–Johnson/Woodcock–Munoz Tests of Cognitive Ability (Woodcock and Munoz-Sandoval, 1990) in both English and Spanish at the beginning of the assessment as recommended in the WISC-IV Spanish Manual. The psychometrician was blinded to exposure status. We standardized WISC-IV scores against U.S. population–based norms for the English and Spanish versions of WISC-IV. We did not administer Letter-Number Sequencing or Symbol Search subtests for the first 3 months of assessments, therefore 27 participants lack scores for Processing Speed and Working Memory domains. A Full-Scale IQ was available for 255 children.

Children's behavior was assessed by maternal and teacher report at age 7 using the Behavior Assessment System for Children 2 (BASC-2) (Reynolds, 2004). The behavior assessments were interviewer-administered to the mother (due to low literacy rates) and self-administered by the child's teacher. The BASC-2 has been validated in English and Spanish. The BASC-2 Parent Rating Scale asks how often the child exhibits certain behaviors in the home setting (160 questions), while the Teacher Rating Scale asks about similar behaviors at school (139 questions). Scales of interest from the BASC-2 were hyperactivity and attention problems. Standardized T-scores were computed using age-standardized national norms, with higher values indicating more frequent problem behaviors.

2.4. Geographic-based estimates of agricultural fumigant use

To characterize potential exposure, we estimated agricultural fumigant use near each participant's residence during the prenatal (entire pregnancy) and postnatal (birth to 7-year assessment) time periods using California PUR data from 1999 to 2008 (CDPR, 2016c). We focused on methyl bromide, chloropicrin, metam sodium, and 1,3-DCP because they were the most commonly used agricultural fumigants (in kg applied) in our study area (Monterey County) during our study period (1999 – 2008). The PUR data included the amount (kg) of active ingredient applied, application date, location to a one-square mile section (1.6 km × 1.6 km) defined by the United States (U.S.) Public Land Survey System (PLSS). We edited the PUR data to correct for likely outliers that had unusually high application rates by replacing the amount of pesticide applied using the acres treated and the median application rate for that pesticide and crop combination (Gunier et al., 2001). Detailed descriptions of the equations and methods that we used to calculate nearby pesticide use have been published previously (Gunier et al., 2011).

For each participant, we estimated the amount of each fumigant used within 3, 5 and 8 km radii of residences during prenatal and postnatal periods using the latitude and longitude coordinates and a geographic information system. In all cases, the buffers around the homes included more than one PLSS section; therefore, we weighted the amount of pesticide applied in each section by the proportion of land area that was included in the buffer. We selected buffer distances of 3, 5 and 8 km for this analysis because these best capture the spatial scale of fumigant use most strongly correlated with measured fumigant concentrations in outdoor air samples (California Department of Pesticide Regulation, 2015; Li et al., 2005). To account for dispersion of fumigants from the application site, we summarized wind direction during the seven days (Cryer and van Wesenbeeck, 2011; Gao et al., 2013) after the application date using available wind direction data (CDWR, 2016), determined the direction of the residence relative to the PLSS section using GIS, and weighted fumigant use in each section by the proportion of time that the residence was downwind of Sections where fumigant applications occurred.

2.5. Data analysis

We log10-transformed continuous prenatal and postnatal fumigant use (kg/year) variables to reduce heteroscedasticity and the influence of outliers. We added one kg/year to the use prior to transforming so that the minimum $\log_{10}$ of use would be zero and all values would be positive. Scores for cognition and behavior were approximately normally distributed and were modeled as continuous outcomes. We used generalized additive models (GAMs) with a three-degrees-of-freedom cubic spline function to test for non-linearity. None of the digression from linearity tests were significant ($p < 0.2$), therefore we expressed fumigant use linearly (on the $\log_{10}$ scale) in separate multivariable linear regression models for each fumigant. Regression coefficients thus represent mean change in cognition or behavior scores for each ten-fold increase in fumigant use.

We selected model covariates *a priori* based on factors associated with child neurodevelopment in previous analyses [i.e., child's exact age at assessment, sex, maternal country of birth (Mexico vs. other) and HOME score at the 7-year visit (continuous)] (Bouchard et al., 2011; Gunier et al., 2016). We considered the following variables as additional covariates in our models: maternal age at delivery, maternal PPVT score (continuous), maternal education (≤ 6th grade vs. ≥ 7th grade), marital status at enrollment, and using the Centers of Epidemiological Studies Depression Scale (CES-D) maternal depression (≥16 on CES-D) at the child's 7-year visit (Davila et al., 2009). In addition, we considered covariates collected at each visit including housing density (number of persons per room), household poverty (< federal poverty level vs. ≥ federal poverty level) (Census, 2008), presence of father in the home (yes/no), maternal work status, location of neurodevelopmental assessment (field office or participant's home), and season of assessment. We imputed missing values (< 10% missing) at a visit point using data from the nearest available visit. We evaluated the average of DAP metabolites of OP insecticides measured in maternal urine samples (Bradman et al., 2005) collected during prenatal interviews at 13 weeks and 26 weeks gestation (n = 283) in all models since these metabolite levels were related to Full-scale IQ in a previous study of this cohort (Bouchard et al., 2011). We also evaluated agricultural use of OP insecticides within 1 km of the residence during pregnancy in all models because this was related to IQ in a recently published study in this cohort (Gunier et al., 2016). We retained covariates that were significant ($p < 0.2$) in the final multivariate regression models. We included child age, sex, maternal country of birth, HOME score at the 7-year interview, prenatal DAPs and agricultural use of organophosphates within 1 km of the residence during pregnancy in all models. We included maternal depression in all models except for those assessing BASC-2 teacher reports because we believed maternal depression could affect maternal rating of child behavior or cognitive performance of the child. In models for cognition, we also included language of assessment, maternal education, maternal intelligence (PPVT) and household poverty level from the 7-year interview.

In separate sensitivity analyses, we controlled for exposure to other neurotoxicants, which we have previously found to be related to child IQ or attention deficit/hyperactivity disorder in our cohort adjusting for the same covariates listed above (Eskenazi et al., 2013; Gaspar et al., 2015; Marks et al., 2010), including $\log_{10}$-transformed lipid-adjusted concentrations (ng/g-lipid) of *p, p′*-dichlorodiphenyltrichloroethylene (DDT), *p, p′*-dichlorodiphenyldichloro-ethylene (DDE) (n = 219) (Bradman et al., 2007) and polybrominated diphenyl ether flame retardants (PBDEs) (n = 221) measured in prenatal maternal blood samples (Castorina et al., 2011). We used the sum of the four major congeners (BDE-47, -99, -100, and -153) to estimate PBDE exposure (Eskenazi et al., 2013). In other sensitivity analyses, we excluded outliers identified with studentized residuals greater than three. To control for potential selection bias due to loss to follow-up, we ran regression models with weights determined as the inverse probability of inclusion in our analyses (Hogan and Lancaster, 2004). We determined probability of inclusion using multiple logistic regression models with baseline covariates as potential predictors. Since we evaluated many combinations of fumigants (4), buffer distances (3), time periods (2) and outcomes (3), we assessed adjustment for multiple comparisons to control for type 1 error rate using the Benjamini-Hochberg false discovery rate at $p < 0.05$ (Hochberg and Benjamini, 1990). Finally to assess the effect of methyl bromide and chloropicrin, two fumigants with highly correlated use, in the same model, we calculated the residuals from a regression model with one fumigant as the dependent variable and the other as the independent variable. We then included these residuals as an uncorrelated proxy for exposure in a multivariate model with the fumigant that was the independent variable (Mostofsky et al., 2012). Similarly, we assessed the effect of postnatal fumigant use while controlling for highly correlated prenatal use by calculating residuals from a regression model with postnatal fumigant use as the dependent variable and prenatal use as the independent variable and including the residuals from this model in a multivariate model with prenatal fumigant use.

3. Results

3.1. Demographics, fumigant use and neurodevelopmental scores

Most mothers were born in Mexico (88%), under 30 years of age at delivery (73%) and married or living as married (85%) at the time of enrollment (Table 1). Almost half of the mothers (46%) and most fathers (52%) had a 6th grade education or less, and most families (72%) were living below the poverty level at the time of the 7-year visit. (United States Bureau of the Census, 2008) Slightly more than half of the children were girls (54%) and most children completed their WISC-IV assessment in Spanish (68%). Mothers included in our analyses (n =

Table 1
CHAMACOS study cohort characteristics (n = 285).[a]

Cohort Characteristic	N (%)
Maternal Country of Birth	
Mexico	251 (88%)
United States and other	34 (12%)
Maternal Age at Delivery	
18 – 24	109 (38%)
25 – 29	99 (35%)
30 – 34	49 (17%)
35 – 45	28 (10%)
Maternal Education	
≤ 6th grade	132 (46%)
7th grade or more	153 (54%)
Marital Status at Enrollment	
Married/Living as married	241 (85%)
Not married	44 (15%)
Paternal Education	
≤ 6th grade	131 (52%)
7th grade or more	119 (48%)
Family Income at 7 y visit	
≤ Poverty level[b]	205 (72%)
> Poverty level[b]	80 (28%)
Maternal Depression at 7 y Visit	
Yes	79 (28%)
No	206 (72%)
Sex	
Girl	153 (54%)
Boy	132 (46%)
Language of WISC-IV tests	
Spanish	193 (68%)
English	92 (32%)

[a] Included in analyses for prenatal fumigant use.
[b] Poverty thresholds for 2008 (Census, 2008).

285) were older at delivery (27 vs. 25 years old), more likely to be Latina (99% vs. 94%) and married (83% vs. 77%), and were less likely to smoke (4% vs. 8%) than mothers with liveborn children that were not included in our analyses (n = 252); otherwise the two populations were demographically similar.

The most heavily used fumigants within 8 km of children's residences during both the prenatal and postnatal periods were methyl bromide and chloropicrin, with mean ± SD postnatal wind-adjusted use of 89,200 kg ± 59,800 and 97,800 kg ± 67,700, respectively (Table 2). The distributions of WISC-IV and BASC-2 T-scores at 7-years of age are also presented in Table 2. The mean ± SD was 104 ± 14 for Full-scale IQ and similar for the subscales, except for Working Memory which was 93 ± 13. The mean ± SD BASC-2 T-scores for both parent and teacher report of attention and hyperactivity were all around 50 ± 10.

3.2. Correlation of fumigant use

Agricultural fumigant use (log10-transformed) was moderately to highly correlated ($p < 0.001$) at the three buffer distances we evaluated (Table 3). There was moderate to high correlation between postnatal fumigant use within 3 and 5 km (0.54 – 0.9), moderate to high correlation between fumigant use within 3 and 8 km (0.23 – 0.84) and high correlation between use within 5 and 8 km (0.78 – 0.99). Correlations were similar for prenatal fumigant use at different buffer distances (data not shown). Correlation was relatively high between prenatal and postnatal time periods for individual fumigants. For use within 8 km of residences, there was high correlation ($p < 0.001$) between prenatal and postnatal use for chloropicrin ($r = 0.82$) and methyl bromide ($r = 0.82$), but no correlation for metam sodium and a negative correlation ($r = -0.47$) for 1,3-DCP. There was weak to high correlation ($p < 0.05$) between the use of different fumigants. Postnatal use of metam sodium was weakly correlated with methyl bromide and chloropicrin (0.15 – 0.22), there was moderate correlation between 1,3-DCP and the other three fumigants (0.56 – 0.73), while methyl bromide and chloropicrin use was highly correlated (0.96).

3.3. Fumigant use and neurodevelopment

Table 4 shows the associations of wind-adjusted prenatal and postnatal fumigant use within 8 km of the home and IQ (associations within 3 and 5 km are shown in Supplemental Tables S1 and S2). There were no significant relationships between wind-adjusted prenatal fumigant use within 5 or 8 km and Full-Scale IQ or any of the WISC-IV subscales (Table 4 and Supplemental Table S1). However, we observed some associations between prenatal fumigant use within 3 km and IQ. Specifically, a ten-fold increase in wind-adjusted prenatal methyl

Table 2
Distributions of wind-weighted agricultural fumigant use (kg) within 8-km of residence and neurodevelopmental assessment scores at 7-years of age.

	N	Mean ± SD	25th	50th	75th	Max.
Prenatal[a] pesticide use (kg)						
Methyl bromide	285	13,400 ± 10,900	2350	13,600	21,100	56,400
Chloropicrin	285	8690 ± 7120	1210	8690	13,800	35,000
Metam sodium	285	525 ± 1500	0	0	6	8640
1,3-DCP	285	914 ± 1810	5	52	806	8230
Postnatal[b] pesticide use (kg)						
Methyl bromide	255	89,200 ± 59,800	20,500	111,000	136,000	349,000
Chloropicrin	255	97,800 ± 67,700	10,600	128,000	152,000	287,000
Metam sodium	255	9940 ± 9440	1180	5240	21,400	54,600
1,3-DCP	255	60,200 ± 45,100	17,500	60,300	99,200	154,000
WISC-IV						
Full-scale IQ	257	104 ± 14	92	105	114	144
Perceptual Reasoning	285	103 ± 16	92	100	112	141
Processing Speed	258	109 ± 13	100	109	118	136
Verbal Comprehension	285	107 ± 17	95	108	121	152
Working Memory	258	93 ± 13	83	91	99	132
BASC-2 Parent Report[c]						
Attention	284	50 ± 11	42	50	59	78
Hyperactivity	284	46 ± 9	40	44	50	79
BASC-2 Teacher Report[c]						
Attention	234	51 ± 8	45	51	56	69
Hyperactivity	234	49 ± 10	41	47	55	86

[a] Prenatal period during pregnancy (1999 – 2001).
[b] Postnatal period from birth to 7-year visit (2000 – 2008).
[c] BASC-2 general sex combined T-scores. Abbreviation: 1,3-DCP = 1,3-dichloropropene.

Table 3
Pearson correlations of log-transformed agricultural fumigant use (kg) by distance, time period and active ingredients.

Comparison	N	Methyl Bromide	Chloropicrin	Metam Sodium	1,3-DCP
Correlations by distance					
Postnatal 3 and 5 km	255	0.86**	0.90**	0.54**	0.74**
Postnatal 3 and 8 km	255	0.79**	0.84**	0.23**	0.47**
Postnatal 5 and 8 km	255	0.99**	0.97**	0.73**	0.86**
Correlations by time period					
Prenatal and Postnatal 8 km	255	0.82**	0.82**	−0.01	−0.47**
Correlations between fumigants					
Methyl Bromide Postnatal 8 km	255	–	–	–	–
Chloropicrin Postnatal 8 km	255	0.96**	–	–	–
Metam Sodium Postnatal 8 km	255	0.15*	0.22**	–	–
1,3-DCP Postnatal 8 km	255	0.68**	0.73**	0.56**	–

Abbreviation: 1,3-DCP = 1,3-dichloropropene.
* $p < 0.05$.
** $p < 0.001$.

bromide use within 3 km (Supplemental Table S1) was marginally associated with lower Full-scale IQ (β = −1.3; 95% CI: −2.7, 0.1), and reduced Processing Speed [β = −1.5; 95% confidence interval (CI): −2.9, −0.2], while a ten-fold increase in prenatal chloropicrin use within 3 km was marginally associated with a lower Processing Speed (β = −1.4; 95% CI: −2.8, 0.1).

With postnatal exposure, IQ scores were generally lower across all domains with increasing wind-adjusted use of methyl bromide, chloropicrin, and 1,3-DCP within 8 km (Table 4), with a marginally significant decrease of 2.6 points (95% CI: −5.2, 0.0) in Full-scale IQ for each ten-fold increase in postnatal methyl bromide use and a decrease of 2.4 points (95% CI: −4.7, −0.2) for each ten-fold increase in postnatal chloropicrin use. Results were similar for postnatal use of methyl bromide and chloropicrin within 5 km and generally null for postnatal use of all fumigants within 3 km and use of metam sodium or 1,3-DCP at any distance (Supplemental Table 2).

Since postnatal use of methyl bromide and chloropicrin within 8 km of residences were both associated with Full-scale IQ, we assessed the effect of postnatal chloropicrin use controlling for methyl bromide use to determine which fumigant is driving the association with Full-scale IQ since methyl bromide and chloropicrin are often used together and are highly correlated; importantly, methyl bromide is currently being replaced by chloropicrin throughout California (CDPR, 2016c). In the model evaluating residuals of postnatal methyl bromide when controlling for postnatal chloropicrin use, the effect of a ten-fold increase in postnatal chloropicrin use within 8 km of residences changed directions and was no longer significant (β = 1.2; 95% CI: −7.7, 10.1). In the model evaluating residuals of postnatal chloropicrin when controlling for postnatal methyl bromide use, however, the effect of a ten-fold increase in postnatal chloropicrin use within 8 km of residences was similar in direction and magnitude to the original single fumigant model for chloropicrin, but with much wider confidence intervals (β = −3.4; 95% CI: −11.1, 4.3) suggesting that proximity to use of chloropicrin was more influential. The relationship between postnatal chloropicrin use and Full-scale IQ was also similar (β = −3.0; 95% CI: −6.7, 0.7) when controlling for highly correlated prenatal use of chloropicrin (β = −1.1; 95% CI: −2.6, 0.4), suggesting that postnatal use may capture the more critical time period.

There was no relationship between wind-adjusted prenatal or postnatal fumigant use within 8 km of residences and BASC-2 maternal or teacher report of hyperactivity or attention problems (Table 5). There were no associations between prenatal (Supplemental Table 3) or postnatal (Supplemental Table 4) fumigant use within 3 or 5 km of the residence and hyperactivity or attention problems.

Results were similar for fumigant use within 8 km and WISC-IV cognition scales with and without the inclusion of DDT, DDE and PBDEs (not shown) even though the sample sizes were smaller for the models that included these covariates (e.g., n = 176 for Full-scale IQ). Excluding the relatively few outliers for postnatal metam sodium use (n = 2) and 1,3-DCP use (n = 3) did not change our results and there were no outliers with studentized residuals > 3 for models with methyl bromide or chloropicrin use. Associations between postnatal fumigant use and Full-scale IQ were slightly weaker, but similar for both methyl bromide (β = −2.3; 95% CI: −4.7, 0.1) and chloropicrin (β = −2.2; 95% CI: −4.2, −0.3) when we used inverse probability weighting to adjust for potential selection bias. After adjusting for multiple comparisons, which is not common practice in environmental epidemiological studies, none of our associations reached significance at the critical p-value = 0.003.

4. Discussion

We observed a suggestive association between Full-Scale IQ and postnatal proximity to agricultural use of methyl bromide and chloropicrin during childhood. Adjusted for covariates and other exposures, a ten-fold increase in methyl bromide or chloropicrin use within 8 km of the residence during the child's lifetime was associated with an approximately 2.5 point decrease in Full-Scale IQ. In our population, fumigant use increased 100-fold from the 5th to the 95th percentiles of the distribution for both methyl bromide and chloropicrin suggesting a potentially five point decrease in Full-Scale IQ, or one third of a standard deviation, for children with the highest use of these fumigants near their residences during their lifetime. Including both methyl bromide and chloropicrin in the same model using residuals suggests that use of chloropicrin is more influential, but the use of these fumigants was highly correlated and difficult to disentangle in this cohort. We observed a marginal association between proximity to higher prenatal use of methyl bromide and chloropicrin within 3 km and poorer Processing Speed; there were no other relationships between prenatal fumigant use and cognition. There were no associations between prenatal or postnatal fumigant use and attention or hyperactivity. These results need to be replicated in a larger study with sufficient power to evaluate multiple comparisons of fumigant use and neurodevelopment.

Previous studies observed poorer neurologic test scores,(Acuna et al., 1997) more concentration and attention problems (Magnavita, 2009) and memory impairment (Acuna et al., 1997; Magnavita, 2009) in workers exposed to methyl bromide. A case study found problems with concentration, memory and processing as well as increased anxiety after exposure to methyl bromide from home fumigation (Reidy et al., 1994). Among pesticide applicators, those that applied fumigants had higher odds of reporting more neurologic symptoms including difficulty concentrating and absentmindedness [odds ratio (OR) = 1.5; 95% CI: 1.2 – 1.8] than those that did not apply fumigants (Kamel et al., 2005). Residents exposed to metam sodium after a spill reported higher levels of depression and anxiety than those that were not exposed (Bowler et al., 1994a). This is the first study to evaluate prenatal and

Table 4
Adjusted[a] association between a ten-fold increase in wind-adjusted fumigant use (kg) within 8-km of residence and 7-year WISC Scales.

	Full-Scale IQ				Verbal Comprehension				Working Memory				Perceptual Reasoning				Processing Speed			
	N	β	(95%CI)	p	N	β	(95%CI)	p	N	β	(95%CI)	p	N	β	(95%CI)	p	N	β	(95%CI)	p
Prenatal Exposure																				
Methyl Bromide	257	−0.9	(−2.5, 0.7)	0.26	285	−0.8	(−2.4, 0.7)	0.27	258	−0.3	(−2.0, 1.3)	0.68	285	−1.0	(−2.8, 0.9)	0.31	258	−0.7	(−2.3, 0.9)	0.41
Chloropicrin	257	−0.7	(−2.1, 0.6)	0.29	285	−0.6	(−1.9, 0.7)	0.37	258	−0.3	(−1.7, 1.1)	0.68	285	−0.9	(−2.5, 0.7)	0.28	258	−0.4	(−1.8, 1.0)	0.57
Metam Sodium	257	1.0	(−0.4, 2.3)	0.18	285	0.4	(−0.8, 1.6)	0.53	258	0.7	(−0.7, 2.0)	0.36	285	0.6	(−0.9, 2.1)	0.40	258	0.8	(−0.6, 2.2)	0.25
1,3-DCP	257	0.4	(−1.0, 1.8)	0.56	285	0.3	(−0.9, 1.6)	0.61	258	0.7	(−0.7, 2.2)	0.30	285	0.8	(−0.7, 2.4)	0.31	258	0.1	(−1.3, 1.5)	0.90
Postnatal Exposure																				
Methyl Bromide	228	−2.6	(−5.2, 0.0)	0.05	255	−1.1	(−3.5, 1.4)	0.40	229	−1.5	(−4.1, 1.1)	0.25	255	−2.7	(−5.6, 0.3)	0.08	229	−2.0	(−4.6, 0.6)	0.14
Chloropicrin	228	−2.4	(−4.7, −0.2)	0.04	255	−0.9	(−3.0, 1.2)	0.41	229	−1.8	(−4.1, 0.4)	0.11	255	−2.4	(−5.0, 0.2)	0.07	229	−1.8	(−4.0, 0.4)	0.12
Metam Sodium	228	−0.4	(−2.7, 1.9)	0.74	255	−0.8	(−2.9, 1.4)	0.50	229	0.0	(−2.2, 2.3)	0.97	255	−0.4	(−3.0, 2.2)	0.77	229	0.1	(−2.2, 2.3)	0.95
1,3-DCP	228	−2.8	(−6.5, 1.0)	0.15	255	−2.5	(−6.1, 1.2)	0.18	229	−1.7	(−5.4, 2.1)	0.38	255	−3.9	(−8.3, 0.5)	0.09	229	−0.4	(−4.2, 3.3)	0.82

[a] Adjusted for age at assessment, language of assessment, sex, maternal intelligence, maternal education, maternal depression at 7-years, maternal country of birth, HOME score, household poverty level at 7-years, prenatal DAPs and prenatal proximity to agricultural OP use.

postnatal residential proximity to agricultural fumigant use and cognitive development in children.

One challenge in utilizing PUR data to characterize exposure is selecting appropriate distances from the residence to summarize pesticide use. In this cohort, we previously reported associations between Full-scale IQ at 7-years of age and prenatal OP insecticide use within 1 km of maternal residences during pregnancy (Gunier et al., 2016; Rowe et al., 2016) and also with other potentially neurotoxic pesticides including carbamates, neonicotinoids, pyrethroids and maneb (Gunier et al., 2016). A study utilizing California PUR data observed higher odds of autism spectrum disorder (OR = 1.6; 95% CI: 1.0 – 2.5) with any use of OP insecticides within 1.5 km of their residence during the prenatal period (Shelton et al., 2014). Previous studies that have evaluated prenatal residential proximity to fumigant use using PUR data found no association with autism (Roberts et al., 2007) or neural tube defects (Rull et al., 2006) using a buffer distance of 1 km from the residence. However, for methyl bromide, reported use from PUR data within a 7 × 7 square mile area (~ 8 km) of the residence explained the largest amount of the variation (95%) in measured concentrations of methyl bromide in community air (Li et al., 2005). Other studies have also demonstrated fumigant drift far (5 – 20 km) from application sites (Cryer and van Wesenbeeck, 2011; van Wesenbeeck et al., 2016), suggesting that using smaller buffer distances (< 3 km) to summarize fumigant use underestimates exposure by excluding applications farther from the residence that influence air concentrations, resulting in exposure misclassification.

There are several limitations of this study. Residential proximity to agricultural fumigant use is not a direct measure of personal exposure. More research is needed to evaluate the relationship between reported fumigant use and measured concentrations in ambient and personal air samples. Additionally, we were unable to include potential exposure from fumigant use near schools, workplaces, or other locations where mothers and children spend significant amounts of time. Our samples size for this analysis was relatively small when restricted to participants with mostly complete residential history. We also made numerous statistical comparisons with four fumigants, two time periods, three distances and three health outcomes; therefore the associations we observed should be interpreted with caution.

Our study also had several strengths. Reporting agricultural fumigant applications is mandatory and closely regulated in California because these fumigants are restricted use pesticides, minimizing potential reporting bias. We incorporated wind direction for the seven days after fumigant applications to account for dispersion from the application site for these highly volatile compounds. Since validated biomarkers of environmental exposure are not available for these fumigants, residential proximity to agricultural applications from PUR data is one of the only methods for characterizing exposure. The CHAMACOS cohort is a relatively homogeneous population with extensive data on covariates and other environmental exposures that are related to cognition and behavior in children, allowing for better control of confounding. Our results were similar using inverse probability weighting; therefore we do not believe that there was a large impact from selection bias.

Future research is needed to develop better prediction models for human exposure using PUR data and existing measurements of fumigant concentrations in outdoor air. These fumigant exposure models could be used in larger epidemiological studies that combine cohorts or use available data to assess the relationship between agricultural fumigant use and neurodevelopment in children. There is also a need for further development of statistical methods for analyzing environmental exposures to highly correlated chemical mixtures (Rider et al., 2013).

5. Conclusions

We observed decreases in Full-scale intelligence quotient with increasing methyl bromide and chloropicrin use within 8 km of

Table 5
Adjusted association between a ten-fold increase in wind-adjusted fumigant use (kg) within 8-km of residences and BASC Attention Problems and Hyperactivity Standardized Scores at 7-years.

	Maternal Report[a]							Teacher Report[b]						
	Attention Problems				Hyperactivity			Attention Problems				Hyperactivity		
	N	β	(95%CI)	p	β	(95%CI)	p	N	β	(95%CI)	p	β	(95%CI)	p
Prenatal Exposure														
Methyl Bromide	284	0.1	(−1.1, 1.4)	0.83	0.0	(−0.9, 1.0)	0.95	234	0.0	(−1.0, 1.1)	0.94	0.1	(−1.2, 1.5)	0.87
Chloropicrin	284	−0.2	(−1.3, 0.9)	0.71	0.1	(−0.7, 0.9)	0.77	234	0.0	(−0.9, 0.9)	0.96	0.2	(−1.0, 1.3)	0.78
Metam Sodium	284	0.0	(−1.0, 0.9)	0.93	0.5	(−0.3, 1.2)	0.23	234	0.5	(−0.3, 1.2)	0.23	−0.3	(−1.4, 0.7)	0.53
1,3-DCP	284	−0.1	(−1.1, 0.9)	0.86	0.4	(−0.5, 1.2)	0.39	234	−0.1	(−1.0, 0.7)	0.73	−0.5	(−1.6, 0.6)	0.39
Postnatal Exposure														
Methyl Bromide	255	−0.5	(−2.5, 1.4)	0.60	−0.5	(−2.1, 1.0)	0.49	211	−0.6	(−2.3, 1.1)	0.51	−0.5	(−2.6, 1.6)	0.66
Chloropicrin	255	−0.4	(−2.1, 1.3)	0.64	0.2	(−1.0, 1.5)	0.72	211	−0.1	(−1.6, 1.3)	0.85	0.0	(−1.8, 1.8)	1.00
Metam Sodium	255	0.5	(−1.2, 2.3)	0.55	−0.1	(−1.4, 1.2)	0.88	211	−0.2	(−1.7, 1.2)	0.75	0.4	(−1.4, 2.3)	0.64
1,3-DCP	255	0.7	(−2.1, 3.6)	0.61	−1.1	(−3.2, 1.1)	0.34	211	−0.7	(−3.1, 1.8)	0.59	−0.2	(−3.2, 2.8)	0.89

[a] Adjusted for sex, age at assessment, maternal country of birth, maternal depression and HOME score at 7-years, prenatal DAPs and OP use.
[b] Adjusted for sex, age at assessment, maternal country of birth, HOME score at 7-years, prenatal DAPs and OP use.

residences during the child's lifetime. However, these results should be interpreted with caution until further explored in larger studies.

Statement of financial interest

Dr. Asa Bradman is a volunteer member of the Board for The Organic Center, a non-profit organization addressing scientific issues around organic food and agriculture. None of the other authors declares any actual or potential competing financial interest.

Acknowledgements

This study was funded by grant number R56ES023591 and P01 ES009605 from the National Institute of Environmental Health Sciences and R82670901 and RD83451301 from the U.S. Environmental Protection Agency.

Appendix A. Supplementary material

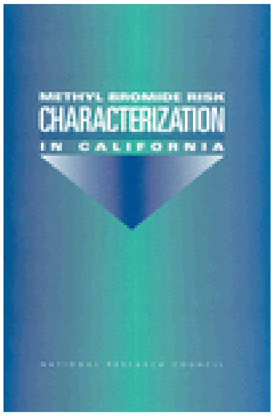
Supplementary material associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.envres.2017.06.036.

References

Acuna, M.C., Diaz, V., Tapia, R., Cumsille, M.A., 1997. Assessment of neurotoxic effects of methyl bromide in exposed workers. Rev. Med. Chil. 125, 36–42.
ATSDR, 2008. Toxicological Profile for Dichloropropenes. U.S. Department of Health and Human Services. Public Health Service Agency for Toxic Substances and Disease Registry, Available: 〈http://www.atsdr.cdc.gov/toxprofiles/tp40.pdf〉.
Ben Slamia, L., Harzallah, S., Lamouchi, T., Sakli, G., Dogui, M., Ben Amou, S., 2006. Peripheral neuropathy induced by acute methyl bromide skin exposure: a case report. Rev. Neurol. 162, 1257–1259.
Bishop, C.M., 1992. A case of methyl bromide poisoning. Occup. Med. 42, 107–109.
Bouchard, M.F., Chevrier, J., Harley, K.G., Kogut, K., Vedar, M., Calderon, N., Trujillo, C., Johnson, C., Bradman, A., Barr, D.B., Eskenazi, B., 2011. Prenatal exposure to organophosphate pesticides and IQ in 7-year-old children. Environ. Health Perspect. 119, 1189–1195.
Bowler, R.M., Mergler, D., Huel, G., Cone, J.E., 1994a. Aftermath of a chemical spill: psychological and physiological sequelae. Neurotoxicology 15, 723–729.
Bowler, R.M., Mergler, D., Huel, G., Cone, J.E., 1994b. Psychological, psychosocial, and psychophysiological sequelae in a community affected by a railroad chemical disaster. J. Trauma Stress 7, 601–624.
Bradman, A., Eskenazi, B., Barr, D.B., Bravo, R., Castorina, R., Chevrier, J., Kogut, K., Harnly, M.E., McKone, T.E., 2005. Organophosphate urinary metabolite levels during pregnancy and after delivery in women living in an agricultural community. Environ. Health Perspect. 113, 1802–1807.
Bradman, A.S., Schwartz, J.M., Fenster, L., Barr, D.B., Holland, N.T., Eskenazi, B., 2007. Factors predicting organochlorine pesticide levels in pregnant Latina women living in a United States agricultural area. J. Expo. Sci. Environ. Epidemiol. 17, 388–399.
Caldwell, B., Bradley, R., 1984. Home Observation for Measurement of the Environment. University of Arkansas, Little Rock, AR.
California Department of Pesticide Regulation, 2015. Correlating Agricultural Use With Ambient Concentration of The Fumigant Chloropicrin During The Period of 2011–2014 Sacramento, CA.
California Department of Pesticide Regulation, 2016a. Analysis of Agricultural Use and Average Concentrations of 1,3-Dichloropropene in Nine Communities of California in 2006 – 2015, and Calculation of a Use Limit (Township Cap), Sacramento, CA.
California Department of Pesticide Regulation, 2016b. Correlating Agricultural Use With Ambient Air Concentrations of Methyl Isothiocyanate During The Period of 2011–2014 Sacramento, CA.
Carmichael, S.L., Yang, W., Roberts, E., Kegley, S.E., Padula, A.M., English, P.B., Lammer, E.J., Shaw, G.M., 2014. Residential agricultural pesticide exposures and risk of selected congenital heart defects among offspring in the San Joaquin Valley of California. Environ. Res. 135, 133–138.
Castorina, R., Bradman, A., Sjodin, A., Fenster, L., Jones, R.S., Harley, K.G., Eisen, E.A., Eskenazi, B., 2011. Determinants of serum polybrominated diphenyl ether (PBDE) levels among pregnant women in the CHAMACOS cohort. Environ. Sci. Technol. 45, 6553–6560.
Cavalleri, F., Galassi, G., Ferrari, S., Merelli, E., Volpi, G., Gobba, F., Del Carlo, G., De Iaco, A., Botticelli, A.R., Rizzuto, N., 1995. Methyl bromide induced neuropathy: a clinical, neurophysiological, and morphological study. J. Neurol. Neurosurg. Psychiatry 58, 383.
CDPR, California Department of Pesticide Regulation, 2014. Air Monitoring Network Results, Sacramento, CA.
CDPR, California Department of Pesticide Regulation, 2016c. Pesticide Use Reporting (PUR), Sacramento, CA.
CDWR, California Department of Water Resources, 2016. California Irrigation Management Information System, Sacramento, CA.
Census, 2008. Poverty Thresholds, Current Population Survey. U.S. Bureau of the Census, Washington, D.C.
Cryer, S.A., van Wesenbeeck, I.J., 2011. Coupling field observations, soil modeling, and air dispersion algorithms to estimate 1,3-dichloropropene and chloropicrin flux and exposure. J. Environ. Qual. 40, 1450–1461.
Davila, M., McFall, S.L., Cheng, D., 2009. Acculturation and depressive symptoms among pregnant and postpartum Latinas. Matern Child Health J. 13, 318–325.
Dunn, L., Dunn, L., 1981. Peabody Picture Vocabulary Test, Revised. American Guidance Service, Circle Pines, MN.
Eskenazi, B., Chevrier, J., Rauch, S.A., Kogut, K., Harley, K.G., Johnson, C., Trujillo, C., Sjodin, A., Bradman, A., 2013. In utero and childhood polybrominated diphenyl ether (PBDE) exposures and neurodevelopment in the CHAMACOS study. Environ. Health Perspect. 121, 257–262.
Gao, S., Ajwa, H., Qin, R., Stanghellini, M., Sullivan, D., 2013. Emission and transport of 1,3-dichloropropene and chloropicrin in a large field tarped with VaporSafe TIF. Environ. Sci. Technol. 47, 405–411.
Gaspar, F.W., Harley, K.G., Kogut, K., Chevrier, J., Mora, A.M., Sjodin, A., Eskenazi, B., 2015. Prenatal DDT and DDE exposure and child IQ in the CHAMACOS cohort. Environ. Int. 85, 206–212.
Gemmill, A., Gunier, R.B., Bradman, A., Eskenazi, B., Harley, K.G., 2013. Residential proximity to methyl bromide use and birth outcomes in an agricultural population in California. Environ. Health Perspect. 121, 737–743.
Grube, A., Donaldson, D., Kiely, T., Wu, L., 2011. Pesticides industry sales and usage 2006 & 2007 market estimates. In: Agency, U.S.E.P. (Ed.), Washington D.C.
Gunier, R.B., Bradman, A., Harley, K.G., Kogut, K., Eskenazi, B., 2016. Prenatal residential proximity to agricultural pesticide use and IQ in 7-year-old children. Environ. Health Perspect.
Gunier, R.B., Harnly, M.E., Reynolds, P., Hertz, A., Von Behren, J., 2001. Agricultural pesticide use in California: pesticide prioritization, use densities, and population distributions for a childhood cancer study. Environ. Health Perspect. 109, 1071–1078.
Gunier, R.B., Ward, M.H., Airola, M., Bell, E.M., Colt, J., Nishioka, M., Buffler, P.A., Reynolds, P., Rull, R.P., Hertz, A., Metayer, C., Nuckols, J.R., 2011. Determinants of agricultural pesticide concentrations in carpet dust. Environ. Health Perspect. 119,

970–976.
Hochberg, Y., Benjamini, Y., 1990. More powerful procedures for multiple significance testing. Stat. Med. 9, 811–818.
Hogan, J.W., Lancaster, T., 2004. Instrumental variables and inverse probability weighting for causal inference from longitudinal observational studies. Stat. Methods Med. Res. 13, 17–48.
Hustinx, W.N., van de Laar, R.T., van Huffelen, A.C., Verwey, J.C., Meulenbelt, J., Savelkoul, T.J., 1993. Systemic effects of inhalational methyl bromide poisoning: a study of nine cases occupationally exposed due to inadvertent spread during fumigation. Br. J. Ind. Med. 50, 155–159.
Kamel, F., Engel, L.S., Gladen, B.C., Hoppin, J.A., Alavanja, M.C., Sandler, D.P., 2005. Neurologic symptoms in licensed private pesticide applicators in the agricultural health study. Environ. Health Perspect. 113, 877–882.
Lee, S., McLaughlin, R., Harnly, M., Gunier, R., Kreutzer, R., 2002. Community exposures to airborne agricultural pesticides in California: ranking of inhalation risks. Environ. Health Perspect. 110, 1175–1184.
Lee, S.J., Mehler, L., Beckman, J., Diebolt-Brown, B., Prado, J., Lackovic, M., Waltz, J., Mulay, P., Schwartz, A., Mitchell, Y., Moraga-McHaley, S., Gergely, R., Calvert, G.M., 2011. Acute pesticide illnesses associated with off-target pesticide drift from agricultural applications: 11 States, 1998–2006. Environ. Health Perspect. 119, 1162–1169.
Li, L., Johnson, B., Segawa, R., 2005. Empirical relationship between use, area, and ambient air concentration of methyl bromide. J. Environ. Qual. 34, 420–428.
Magnavita, N., 2009. A cluster of neurological signs and symptoms in soil fumigators. J. Occup. Health 51, 159–163.
Marks, A.R., Harley, K., Bradman, A., Kogut, K., Barr, D.B., Johnson, C., Calderon, N., Eskenazi, B., 2010. Organophosphate pesticide exposure and attention in young Mexican-American children: the CHAMACOS study. Environ. Health Perspect. 118, 1768–1774.
Mostofsky, E., Schwartz, J., Coull, B.A., Koutrakis, P., Wellenius, G.A., Suh, H.H., Gold, D.R., Mittleman, M.A., 2012. Modeling the association between particle constituents of air pollution and health outcomes. Am. J. Epidemiol. 176, 317–326.
Reidy, T.J., Bolter, J.F., Cone, J.E., 1994. Neuropsychological sequelae of methyl bromide: a case study. Brain Inj. 8, 83–93.
Reynolds, C.R., Kamphaus, R.W., 2004. BASC-2: Behaviour Assessment System for Children, Second edition manual. AGS Publishing, Circle Pines, MN.
Rider, C.V., Carlin, D.J., Devito, M.J., Thompson, C.L., Walker, N.J., 2013. Mixtures research at NIEHS: an evolving program. Toxicology 313, 94–102.
Roberts, E.M., English, P.B., Grether, J.K., Windham, G.C., Somberg, L., Wolff, C., 2007. Maternal residence near agricultural pesticide applications and autism spectrum disorders among children in the California Central Valley. Environ. Health Perspect. 115, 1482–1489.
Rowe, C., Gunier, R., Bradman, A., Harley, K.G., Kogut, K., Parra, K., Eskenazi, B., 2016. Residential proximity to organophosphate and carbamate pesticide use during pregnancy, poverty during childhood, and cognitive functioning in 10-year-old children. Environ. Res. 150, 128–137.
Rull, R.P., Ritz, B., Shaw, G.M., 2006. Neural tube defects and maternal residential proximity to agricultural pesticide applications. Am. J. Epidemiol. 163, 743–753.
Shelton, J.F., Geraghty, E.M., Tancredi, D.J., Delwiche, L.D., Schmidt, R.J., Ritz, B., Hansen, R.L., Hertz-Picciotto, I., 2014. Neurodevelopmental disorders and prenatal residential proximity to agricultural pesticides: the CHARGE study. Environ. Health Perspect. 122, 1103–1109.
TeSlaa, G., Kaiser, M., Biederman, L., Stowe, C.M., 1986. Chloropicrin toxicity involving animal and human exposure. Vet. Hum. Toxicol. 28, 323–324.
United States Bureau of the Census, 2008. Poverty Thresholds 2008, Current Population Survey.
van Wesenbeeck, I.J., Cryer, S.A., de Cirugeda Helle, O., Li, C., Driver, J.H., 2016. Comparison of regional air dispersion simulation and ambient air monitoring data for the soil fumigant 1,3-dichloropropene. Sci. Total Environ. 569–570, 603–610.
Verberk, M.M., Rooyakkers-Beemster, T., de Vlieger, M., van Vliet, A.G., 1979. Bromine in blood, EEG and transaminases in methyl bromide workers. Br. J. Ind. Med. 36, 59–62.
Wechsler, D., 2003. Wechsler Intelligence Scale for Children - Fourth Edition (WISC-IV) Administration and Scoring Manual. Harcourt Assessment Incorporated, San Antonio, TX.
Woodcock, R., Munoz-Sandoval, A., 1990. Woodcock-Johnson Psycho-Educational Battery - Revised. Riverside Publishing, Itasca, IL.
Yang, W., Carmichael, S.L., Roberts, E.M., Kegley, S.E., Padula, A.M., English, P.B., Shaw, G.M., 2014. Residential agricultural pesticide exposures and risk of neural tube defects and orofacial clefts among offspring in the San Joaquin Valley of California. Am. J. Epidemiol. 179, 740–748.

Attachment 4



Methyl Bromide Risk Characterization in California

Subcommittee for the Review of the Risk Assessment of Methyl Bromide, Committee on Toxicology, Board on Environmental Studies and Toxicology, National Research Council

ISBN: 0-309-56958-3, 112 pages, 6 x 9, (2000)

METHYL BROMIDE RISK CHARACTERIZATION IN CALIFORNIA

Subcommittee for the Review of the Risk Assessment of Methyl Bromide
Committee on Toxicology
Board on Environmental Studies and Toxicology
Commission on Life Sciences
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C.

NATIONAL ACADEMY PRESS 2101 Constitution Ave., N.W. Washington, D.C. 20418

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This project was supported by Agreement No. 98–0316 between the National Academy of Sciences and the California Department of Pesticide Regulation. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the organizations or agencies that provided support for this project.

International Standard Book Number 0-309-07087-2
Additional copies of this report are available from: National Academy Press 2101 Constitution Ave., NW Box 285 Washington, DC 20055 800–624–6242 202–334–3313 (in the Washington metropolitan area) http://www.nap.edu

Printed in the United States of America

THE NATIONAL ACADEMIES

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

www.national-academies.org

SUBCOMMITTEE ON METHYL BROMIDE

CHARLES H.HOBBS *(Chair),* Lovelace Respiratory Research Institute, Albuquerque, New Mexico
JANICE E.CHAMBERS, Mississippi State University, College of Veterinary Medicine, Mississippi State, Mississippi
FRANK N.DOST, Professor Emeritus, Oregon State University, Corvallis, Oregon
DALE B.HATTIS, Clark University, Worcester, Massachusetts
MATTHEW C.KEIFER, University of Washington, Seattle, Washington
ULRIKE LUDERER, University of California-Irvine, Irvine, California
GLENN C.MILLER, University of Nevada, Reno, Nevada
SYLVIA S.TALMAGE, Oak Ridge National Laboratory, Oak Ridge, Tennessee

Staff

ROBERTA M.WEDGE, Project Director
EILEEN N.ABT, Research Associate
ROBERT J.CROSSGROVE, Editor
MIRSADA KARALIC-LONCAREVIC, Information Specialist
LUCY V.FUSCO, Project Assistant

Sponsor

CALIFORNIA DEPARTMENT OF PESTICIDE REGULATION

COMMITTEE ON TOXICOLOGY

BAILUS WALKER, JR. *(Chair),* Howard University Medical Center, Washington, D.C.
MELVIN E.ANDERSEN, Colorado State University, Fort Collins, Colorado
GERMAINE M.BUCK, State University of New York at Buffalo
GARY P.CARLSON, Purdue University, West Lafayette, Indiana
JACK H.DEAN, Sanofi Pharmaceuticals, Inc., Malverne, Pennsylvania
ROBERT E.FORSTER II, University of Pennsylvania, Philadelphia, Pennsylvania
PAUL M.D.FOSTER, Chemical Industry Institute of Toxicology, Research Triangle Park, North Carolina
DAVID W.GAYLOR, U.S. Food and Drug Administration, Jefferson, Arkansas
JUDITH A.GRAHAM, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina
SIDNEY GREEN, Howard University, Washington, D.C.
WILLIAM E.HALPERIN, National Institute for Occupational Safety and Health, Cincinnati, Ohio
CHARLES H.HOBBS, Lovelace Respiratory Research Institute and Lovelace Biomedical and Environmental Research Institute, Albuquerque, New Mexico
FLORENCE K.KINOSHITA, Hercules Incorporated, Wilmington, Delaware
MICHAEL J.KOSNETT, University of Colorado Health Sciences Center, Denver, Colorado
MORTON LIPPMANN, New York University School of Medicine, Tuxedo, New York
THOMAS E.MCKONE, University of California, Berkeley, California
ERNEST E.MCCONNELL, ToxPath, Inc., Raleigh, North Carolina
DAVID H.MOORE, Battelle Memorial Institute, Bel Air, Maryland
GÜNTER OBERDÖRSTER, University of Rochester, Rochester, New York
JOHN L.O'DONOGHUE, Eastman Kodak Company, Rochester, New York
GEORGE M.RUSCH, AlliedSignal, Inc., Morristown, New Jersey
MARY E.VORE, University of Kentucky, Lexington, Kentucky
ANNETTA P.WATSON, Oak Ridge National Laboratory, Oak Ridge, Tennessee

Staff

KULBIR S.BAKSHI, Program Director
SUSAN N.J.PANG, Program Officer
ABIGAIL STACK, Program Officer
RUTH E.CROSSGROVE, Publications Manager
KATHRINE J.IVERSON, Manager, Toxicology Information Center
LUCY V.FUSCO, Project Assistant
LEAH PROBST, Project Assistant

BOARD ON ENVIRONMENTAL STUDIES AND TOXICOLOGY

GORDON ORIANS *(Chair),* University of Washington, Seattle, Washington
DONALD MATTISON *(Vice Chair),* March of Dimes, White Plains, New York
DAVID ALLEN, University of Texas, Austin, Texas
INGRID C.BURKE, Colorado State University, Fort Collins, Colorado
WILLIAM L.CHAMEIDES, Georgia Institute of Technology, Atlanta, Georgia
JOHN DOULL, University of Kansas Medical Center, Kansas City, Kansas
CHRISTOPHER B.FIELD, Carnegie Institute of Washington, Stanford, California
JOHN GERHART, University of California, Berkeley, California
J.PAUL GILMAN, Celera Genomics, Rockville, Maryland
BRUCE D.HAMMOCK, University of California, Davis, California
MARK HARWELL, University of Miami, Miami, Florida
ROGENE HENDERSON, Lovelace Respiratory Research Institute, Albuquerque, New Mexico
CAROL HENRY, Chemical Manufacturers Association, Arlington, Virginia
BARBARA HULKA, University of North Carolina, Chapel Hill, North Carolina
JAMES F.KITCHELL, University of Wisconsin, Madison, Wisconsin
DANIEL KREWSKI, University of Ottawa, Ottawa, Ontario
JAMES A.MACMAHON, Utah State University, Logan, Utah
MARIO J.MOLINA, Massachusetts Institute of Technology, Cambridge, Massachusetts
CHARLES O'MELIA, Johns Hopkins University, Baltimore, Maryland
WILLEM F.PASSCHIER, Health Council of the Netherlands
KIRK SMITH, University of California, Berkeley, California
MARGARET STRAND, Oppenheimer Wolff Donnelly & Bayh, LLP, Washington, D.C.
TERRY F.YOSIE, Chemical Manufacturers Association, Arlington, Virginia

Senior Staff

JAMES J.REISA, Director
DAVID J.POLICANSKY, Associate Director and Senior Program Director for Applied Ecology
CAROL A.MACZKA, Senior Program Director for Toxicology and Risk Assessment
RAYMOND A.WASSEL, Senior Program Director for Environmental Sciences and Engineering
KULBIR BAKSHI, Program Director for the Committee on Toxicology
LEE R.PAULSON, Program Director for Resource Management
ROBERTA M.WEDGE, Program Director for Risk Analysis

COMMISSION ON LIFE SCIENCES

Staff

OTHER REPORTS OF THE BOARD ON ENVIRONMENTAL STUDIES AND TOXICOLOGY

Copper in Drinking Water (2000)
Ecological Indicators for the Nation (2000)
Waste Incineration and Public Health (1999)
Hormonally Active Agents in the Environment (1999)
Research Priorities for Airborne Particulate Matter: I. Immediate Priorities and a Long-Range Research Portfolio (1998); II. Evaluating Research Progress and Updating the Portfolio (1999)
Ozone-Forming Potential of Reformulated Gasoline (1999)
Risk-Based Waste Classification in California (1999)
Arsenic in Drinking Water (1999)
Brucellosis in the Greater Yellowstone Area (1998)
The National Research Council's Committee on Toxicology: The First 50 Years (1997)
Toxicologic Assessment of the Army's Zinc Cadmium Sulfide Dispersion Tests (1997)
Carcinogens and Anticarcinogens in the Human Diet (1996)
Upstream: Salmon and Society in the Pacific Northwest (1996)
Science and the Endangered Species Act (1995)
Wetlands: Characteristics and Boundaries (1995)
Biologic Markers (5 reports, 1989–1995)
Review of EPA's Environmental Monitoring and Assessment Program (3 reports, 1994–1995)
Science and Judgment in Risk Assessment (1994)
Ranking Hazardous Waste Sites for Remedial Action (1994)
Pesticides in the Diets of Infants and Children (1993)
Issues in Risk Assessment (1993)
Setting Priorities for Land Conservation (1993)
Protecting Visibility in National Parks and Wilderness Areas (1993)
Dolphins and the Tuna Industry (1992)
Hazardous Materials on the Public Lands (1992)
Science and the National Parks (1992)
Animals as Sentinels of Environmental Health Hazards (1991)
Assessment of the U.S. Outer Continental Shelf Environmental Studies Program, Volumes I-IV (1991–1993)
Human Exposure Assessment for Airborne Pollutants (1991)
Monitoring Human Tissues for Toxic Substances (1991)
Rethinking the Ozone Problem in Urban and Regional Air Pollution (1991)
Decline of the Sea Turtles (1990)

Copies of these reports may be ordered from the National Academy Press (800) 624–6242 or (202) 334–3313

www.nap.edu

Preface

One of the most widely used pesticides in California is methyl bromide, a gaseous fumigant that is used on a variety of crops primarily as a preplant soil insecticide, on post-harvest commodities, and in some residences as a fumigant. Although methyl bromide is a recognized stratospheric ozone depleter and is scheduled to be phased out completely by 2005 under the United Nations Montreal Protocol, it continues to be of concern for the health of agricultural workers and exposed residents.

The California Department of Pesticide Regulation (DPR) is responsible for the development of regulations that determine the site-specific permit conditions for the application of pesticides in the state. California is currently in the process of proposing new regulations for issuing methyl bromide permits that require submission of a worksite plan by the property operator, provide extra protection for children in nearby schools, establish minimum buffer zones around application sites, require that nearby residents receive prior notification of the application of methyl bromide, and set new limits on hours that fumigation employees may work. To develop these regulations, the DPR prepared a risk-characterization document to evaluate the toxicity and exposure potential for workers and residents resulting from the inhalation of this pesticide.

Under Section 57004 of the California Health and Safety Code, the scientific basis of the proposed regulations is subject to external peer review by the National Academy of Sciences, the University of California, or other similar institution of higher learning or group of scientists. This report addresses that regulatory requirement by reviewing the DPR risk-characterization document that supports the proposed regulations.

The National Research Council (NRC), the operating arm of The National Academies, assigned the task of preparing this report to its Committee on Toxicology, which convened the subcommittee for the review of the risk as sessment of methyl bromide. The subcommittee was charged with the following tasks: (1) determine whether all relevant data were considered, (2) determine the appropriateness of the critical studies and endpoints used in the risk assessment and in the derivation of exposure limits, (3) consider the mode of action of methyl bromide and its implications in risk assessment, and (4) determine the appropriateness of the exposure assessment and mathematical models used. The subcommittee also identified data gaps and made recommendations for further research relevant to setting exposure limits for methyl bromide.

To prepare this report, the subcommittee reviewed the materials supplied by DPR, additional supporting materials received from other individuals and organizations, and the information gathered at a public meeting held in Irvine, California, on October 4, 1999. The subcommittee wishes to thank the following members of the California Department of Pesticide Regulation—Paul Gosselin, Acting Chief Deputy Director, Lori Lim, and Thomas Thongsinthusak —for providing the subcommittee with information on methyl bromide toxicology and exposure data and models, for their presentation at the public meeting, and for responding to follow up requests from the subcommittee members. We also gratefully acknowledge Vincent J.Piccirillo, NPC, Inc., Bill Walker, Environmental Working Group, and Amy Kyle, Consulting Scientist, for providing background information and for making presentations to the subcommittee, and Jodi Kuhn, Methyl Bromide Industry Panel of the Chemical Manufacturers Association, for providing background materials as well.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures for reviewing NRC reports approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The content of the final report is the responsibility of NRC and the study subcommittee, and not the responsibility of the reviewers. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals, who are neither officials nor employees of NRC, for their participation in the review of the report: Dana Barr, Centers for Disease Control and Prevention; David Dorman, Chemical Industry Institute of Toxicology; David Gaylor, National Center for Toxicological Research; Craig Harris, University of Michigan; John Morris, University of Connecticut; and P.Barry Ryan, Emory University. These reviewers have provided many constructive comments and suggestions; it must be emphasized, however, that responsibility for the final content of this report rests entirely with the authoring subcommittee and NRC.

I am also grateful for the assistance of NRC staff in the preparation of this report. In particular, the subcommittee wishes to acknowledge Roberta Wedge, staff officer for the subcommittee, and Eileen Abt, research associate, with the Board on Environmental Studies and Toxicology. Other staff members who contributed to this effort are Robert Crossgrove, editor, Lucy Fusco, project assistant, and Kulbir Bakshi, program director for the Committee on Toxicology.

Finally, I would like to thank the members of the subcommittee for their valuable expertise and dedicated efforts throughout the preparation of this report. Their efforts are much appreciated.

Charles H.Hobbs, D.V.M.

Chair, Subcommittee on the Review of the Risk Assessment for Methyl Bromide

Contents

METHYL BROMIDE RISK CHARACTERIZATION IN CALIFORNIA

Executive Summary

Methyl bromide is a gaseous pesticide used to fumigate soil, crops, commodity warehouses, and commodity-shipping facilities. Up to 17 million pounds of methyl bromide are used annually in California to treat grapes, almonds, strawberries, and other crops. Methyl bromide is also a known stratospheric ozone depleter and, as such, is scheduled to be phased out of use in the United States by 2005 under the United Nations Montreal Protocol.

In California, the use of methyl bromide is regulated by the Department of Pesticide Regulation (DPR), which is responsible for establishing the permit conditions that govern the application of methyl bromide for pest control. The actual permits for use are issued on a site-specific basis by the local county agricultural commissioners. Because of concern for potential adverse health effects, in 1999 DPR developed a draft risk characterization document for inhalation exposure to methyl bromide. The DPR document is intended to support new regulations regarding the agricultural use of this pesticide. The proposed regulations encompass changes to protect children in nearby schools, establish minimum buffer zones around application sites, require notification of nearby residents, and set new limits on hours that fumigation employees may work.

THE SUBCOMMITTEE'S TASK

The State of California requires that DPR arrange for an external peer review of the scientific basis for all regulations. To this end, the National Research Council (NRC) was asked to review independently the draft risk characterization document prepared by DPR for inhalation exposure to methyl bromide. NRC assigned the task to the Committee on Toxicology, which convened the Subcommittee for the Review of the Risk Assessment of Methyl Bromide. The subcommittee was asked to review the data, determine the appropriateness of the critical studies, consider the mode of action of methyl bromide and its implications in risk assessment, determine the appropriateness of the exposure assessment and the mathematical models, and identify data gaps and make recommendations for further research.

THE SUBCOMMITTEE'S EVALUATION

The 1999 risk characterization document prepared by DPR is a revision of a 1992 preliminary risk assessment that addressed acute inhalation exposure of residents reentering fumigated homes. The 1999 document updates the toxicity information on methyl bromide and provides a more extensive review of the worker and residential exposure data gathered by the methyl bromide manufacturers and applicators and DPR itself over the past several years. The toxicity and exposure data were combined to establish margins of exposure[1] for agricultural workers, residents living near fumigated fields, and residents reentering fumigated homes. The subcommittee's comments on the DPR risk characterization document and its recommendations for further studies are summarized below under three broad categories: toxicology, exposure assessment, and risk characterization.

Toxicology

The DPR risk characterization document presents information on the toxicokinetics and toxicity of methyl bromide, including its acute, subchronic, chronic, developmental, reproductive, neurological, and genotoxic effects. The subcommittee agrees with DPR that the critical target organ for acute exposure to methyl bromide is the nervous system. Methyl bromide also appears to be a developmental and possibly a reproductive toxicant.

The DPR report appropriately summarizes the available toxicokinetic data on methyl bromide in terms of its absorption, distribution and excretion, but it provides only a limited discussion of the metabolism of the pesticide. That discussion is particularly important, because in some individuals there appears

[1]Margin of exposure is a ratio of the concentration at which adverse effects occur to the estimate of concentration found in the workplace or ambient air.

to be a more effective reaction between methyl bromide and glutathione transferase, which can alter the sensitivity of those individuals to its toxic effects. Although DPR adequately reviewed the available literature on the genotoxicity of methyl bromide, it failed to elucidate the relationship between the mutagenicity of methyl bromide and its potential carcinogenicity.

When possible, the DPR report identified the no-observed-adverse-effect level (NOAEL)[2] or the lowest-observed-adverse-effect level (LOAEL)[3] following acute, subchronic, and chronic exposures. The subcommittee agrees with the critical studies and NOAELs selected by DPR in developing the reference concentrations for acute, subchronic, and chronic exposures. For acute toxicity, DPR chose 40 parts per million (ppm) as a NOAEL based on a developmental toxicity study in which rabbits exposed in utero exhibited fused breastbones and gallbladder agenesis (lack of gallbladder development). This NOAEL resulted in an acute inhalation reference concentration[4] (RfC) of 210 parts per billion (ppb) for humans. For subchronic toxicity, 1-week and 6-week RfCs were derived. The subcommittee supports DPR's 1-week RfC of 120 ppb and 70 ppb for adults and children, respectively, based on a NOAEL of 20 ppm for convulsions, paresis, and death in pregnant rabbits. The subcommittee also supports DPR's 6-week RfCs of 2 ppb and 1 ppb for adults and children, respectively, based on a LOAEL of 5 ppm for decreased responsiveness and spleen weight in dogs. The subcommittee notes that the reported neurotoxic effects (lack of responsiveness in two of eight dogs) seen in the subchronic toxicity dog study used to derive the 6-week RfC, because the observations were not part of the study protocol and were not dramatic. Nevertheless, the subcommittee believes that the reported effects may be indicative of neurotoxicity.

DPR used a 29-month rat inhalation study for the derivation of the chronic exposure RfC of 2 ppb for adults and 1 ppb for children. The LOAEL of 3 ppm identified in that study was based on an increase in the number of cells and a change in cell type and function in the nasal cavity. The subcommittee

---

[2]NOAEL is an exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control.

[3]LOAEL is the lowest exposure level at which there are statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control.

[4]A reference concentration is an estimate of the concentration of a substance that is unlikely to cause noncancer health effects in humans during a lifetime. It is used by DPR as a regulatory value for establishing buffer zones to protect residents from adverse effects of methyl bromide exposure.

notes that although the effects seen in the adult rats were dose-related and statistically significant, they were slight or equivocal and only observed in aged rats. Nevertheless, the subcommittee agrees with DPR that this is the correct study to use for a chronic exposure RfC.

DPR concluded that 3 ppm was a NOAEL in two rat reproductive toxicity studies, although the subcommittee questions whether the reduction in fertility observed in the F1 generation was of reproductive origin or developmental origin. Studies conducted in rats and rabbits indicate that in utero exposure to methyl bromide results in developmental toxicity. In rats this was manifested by reduced body and brain weights in pups and reduced fertility in gestationally exposed offspring. In rabbit offspring, gallbladder agenesis, reduced fetal weights, and increased frequency of fused sternebrae were seen. Although the subcommittee recognizes that any of those effects individually might be considered equivocal, together they suggest that methyl bromide has the potential to be a developmental toxicant.

Recommendations

- Studies should be conducted to confirm the neurotoxic effects seen in dogs following subchronic exposures.
- The developmental and reproductive effects of methyl bromide should be further investigated to determine whether it is a direct-acting reproductive toxicant or a developmental toxicant to the reproductive system, whether methyl bromide is excreted in breast milk, and whether the gallbladder agenesis seen in offspring occurs following a single exposure during a critical period of development.
- Neurological testing of workers should be conducted to determine possible long-term or permanent effects following occupational exposure to methyl bromide.
- DPR should review the literature on methyl bromide and other methylating agents to assist them in understanding why methyl bromide, an in vitro mutagen, is not an in vivo carcinogen. This might also help elucidate the mechanism of methyl bromide toxicity.

Exposure

The DPR report presents a substantial amount of data on exposure estimates for a wide variety of worker and residential exposure scenarios. The majority of the exposure information is obtained from studies that were con ducted to establish permit conditions. This information was not always collected in a consistent and comprehensive manner, or in compliance with Good Laboratory Practices.

The DPR report addresses (1) exposures of workers, (2) exposures of individuals due to environmental transport of methyl bromide away from the site of direct application, and (3) exposures of residents returning to fumigated houses. DPR focuses principally on occupational exposure scenarios, presenting data on 160 exposure categories, with estimates for acute (daily), short-term (7 days), seasonal (90 days), and chronic (annual) exposures. The occupational exposures range widely from a high of 8,458 ppb to a low of 0.6 ppb. DPR provides data from two studies on exposures of residents of houses neighboring fumigated structures. No air sampling was conducted to assess individual exposures near commodity fumigation sites; DPR assumes that people are exposed to concentrations of 210 ppb. Exposure data on residents returning to fumigated homes are taken from five houses in southern California. Exposure modeling and field studies indicate that some worker exposures exceed protective levels by more than an order of magnitude, whereas potential exposures of residents living near fumigated fields and facilities are unquantified.

Although DPR compiled a large quantity of exposure data in its document, the subcommittee concludes that the exposure analysis is lacking in several respects. The DPR report fails to address several exposure scenarios, including exposures of residents living near fumigated fields and increased exposures of residents and workers resulting from methyl bromide treatment of several agricultural fields simultaneously or consecutively. In addition, the subcommittee concludes that there is considerable uncertainty concerning the analytical recovery methods used in the exposure assessment studies. Much of the data presented by DPR is based on single measurements, and no discussion of variability or uncertainty in the measurements is provided. The DPR report also fails to discuss the representativeness of the measurements to the actual exposures experienced by worker or residential populations. DPR makes numerous assumptions regarding durations and levels of exposures, which the subcommittee believes are not explained in sufficient detail to establish whether the assumptions are valid.

Recommendations

- Further data collection and analysis are necessary to accurately assess worker and residential exposures to methyl bromide.
- Improvement is needed in the collection of field data used by DPR to

assess worker exposure, particularly with regard to the analytical methods used to detect methyl bromide in ambient air and atmospheric conditions during sampling.

- Further work is needed to determine the best recovery method for methyl bromide and how field conditions affect the recovery of methyl bromide from air samples.
- Air sampling should be conducted for residents living near fumigated fields; these nonoccupational exposures are unqualified at present.
- DPR should reevaluate all existing exposure data for variability and uncertainty.

Risk Characterization

DPR characterized the risks associated with exposure to methyl bromide by using a margin-of-exposure (MOE) approach. DPR compared the human equivalent NOAEL determined from the available animal toxicity data with the anticipated or measured exposures of agricultural workers and residents located near fumigated fields and those entering fumigated homes. The subcommittee found the MOE approach to be generally acceptable for determining which workers and residents are likely to be exposed to potentially harmful concentrations of methyl bromide. However, the subcommittee believes that DPR did not conduct a complete risk assessment, because there was no quantification of the populations of workers that are likely to be exposed or the number of residents living near fields or entering houses.

The subcommittee found DPR's use of an MOE to be helpful for estimating risks to some populations, particularly workers. However, the subcommittee has concerns about DPR's use of these MOEs for protecting nonworkers, particularly people living near fumigated fields. The DPR document does not indicate how the MOEs are to be used to determine the protectiveness of the buffer zones specified in the application permits. The document also fails to characterize certain potentially sensitive populations, such as children in schools or living near fumigated fields, although the proposed regulations address the exposure of children by restricting the application times near schools. The subcommittee concludes that the uncertainties addressed by DPR in the report, including extrapolating from LOAELs to NOAELs and from animals to humans, although important, are only part of the uncertainties that need to be addressed in the risk characterization document. The subcommittee finds that DPR's use of a factor of 10 to account for intraspecies variation and a factor of 10 for differences in animal and human toxicity, as well as its use of a benchmark MOE of 100, is consistent with generally accepted risk management practices. The subcommittee concluded that an additional safety factor for infants and children was not necessary, because the NOAELs were adequately conservative.

Recommendations

- DPR should quantify the number and distribution of workers and residents potentially exposed to methyl bromide.
- Buffer zones should be derived based on reasonable worst-case exposure scenarios.
- DPR should be more explicit in linking its MOE analysis to the development of regulatory levels and should indicate how its regulatory goals will be met by its risk characterization.

1

Introduction

BACKGROUND

Methyl bromide is a gaseous fumigant that kills insects, rodents, nematodes, weeds, and organisms that cause plant diseases. It is used for pest control in structures such as warehouses, ships, freight cars, and homes, in preplant treatment of soil, and in post-harvest treatment of commodities. Between 1993 and 1997, 14 to 17 million pounds of methyl bromide were used annually in California. Methyl bromide is released into the air during and after its use, and therefore, inhalation exposure to agricultural workers and the general population is of considerable concern. The primary health effect of acute methyl bromide exposure is neurotoxicity.

Methyl bromide is a Class I ozone depleter and, as such, it is regulated by the Clean Air Act and the United Nations Montreal Protocol. It is scheduled to be phased out of use in the United States by 2005. Because of its toxicity, several federal agencies have established inhalation exposure levels for methyl bromide. The U.S. Environmental Protection Agency (EPA) reference concentration is 5×10^{-3} milligrams per cubic meter (mg/m^3) (1.3 parts per billion). The Agency for Toxic Substances and Disease Registry has minimum risk levels of 50, 50 and 5 ppb for acute, intermediate, and chronic exposure scenarios, respectively. The Occupational Safety and Health Administration has an 8-hr time-weighted average permissible exposure limit (PEL) of 20 parts per million (ppm), whereas California's PEL is 5 ppm, with a ceiling of 20 ppm (Title 8, California Code of Regulations 1998, Section 5155). For structural fumigation in California, the reentry level is 1 ppm within wall voids (i.e., the cavity inside of walls). The American Conference of Governmental Industrial Hygienists (ACGIH) has a Threshold Limit Value of 1 ppm (3.89 mg/m^3) (ACGIH 1997), and the National Institute of Occupational Safety and Health has an immediately-dangerous-to-life-or-health level of 250 ppm.

CALIFORNIA REGULATIONS

In California, the use of methyl bromide is regulated by permit conditions because it is classified as a restricted material. The California Department of Pesticide Regulation (DPR) develops the permit conditions based on analyses of exposure and toxicity data. The permit conditions specify the minimum mitigation measures that must be used when applying methyl bromide. Permits for methyl bromide use at a specific site and time are issued by local county agricultural commissioners.

In 1992, DPR conducted a preliminary risk assessment on methyl bromide to address acute inhalation exposures of residents reentering fumigated homes. Based on that risk assessment, permit conditions were developed to reduce acute exposures of workers and residents living near fumigated fields. These changes included promulgation of emergency regulations by DPR to require a longer aeration period following fumigation and lowering the reentry level from 5 ppm to 1 ppm in the wall voids. DPR further required that Fact Sheets explaining the potential human hazards of methyl bromide fumigation be distributed to those potentially exposed.

In 1999, DPR conducted another risk assessment that reevaluated the 1992 acute exposure assessment and also considered subchronic and chronic inhalation exposures to methyl bromide from all uses. This revised risk assessment, which incorporates new health effects studies, additional air monitoring data, and newly refined computer models for estimating methyl bromide emissions, is intended to assist DPR in establishing new regulations for permitting the use of methyl bromide (Title 3, California Code of Regulations).

The proposed regulations are designed to enhance protection for children in schools, establish minimum buffer zones around application sites, and set new limits on work hours for fumigation employees (Title 3, California Code of Regulations). In addition to specifications for application rates and depths, tarpaulin thickness, field size, application timing, and duration of fumigation, the proposed regulations include the following specifications: (1) permit applicants must submit a work plan detailing the proposed fumigation to the county agricultural commissioner before methyl bromide use will be approved; (2) neighbors living on sensitive sites (i.e., homes, schools, hospi tals, employee housing centers) that are within 300 feet of the outer boundary of the buffer zone must be notified of fumigations, and they also have a right to ask for a second notification 48 hr before the scheduled fumigation; (3) the establishment of minimum buffer zones of 50 feet for workers and 60 feet for residents to replace the suggested minimums of 30 feet (workers) and 100 feet (residents) that are now advisory; and (4) a requirement that injection of methyl bromide be completed 36 hr prior to the start of a school session.

The need for new regulations for permits has been driven by several factors. The primary factor is a California Superior Court decision ordering DPR to adopt more specific regulations on the field fumigation use of methyl bromide by June 2000. In addition, recently conducted toxicological and air-monitoring studies (DPR 1999) have generated new data. The current DPR risk characterization document incorporates these new data for the determination of the risks to workers and the general public from methyl bromide use.

However, for this risk characterization document to be used to support the proposed regulations, DPR is required to “conduct an external scientific peer review of the scientific basis of any new rule” (California Health and Safety Code § 57004). Consequently, DPR requested that the National Research Council conduct a review of its draft risk characterization document and provide a critique addressing the issues identified in the assigned task. This task was assigned to the Committee on Toxicology, which convened the Subcommittee for the Review of the Risk Assessment of Methyl Bromide (see Appendix A for biographical information). In addition, California DPR's risk characterization document has undergone internal review by the California Office of Environmental Health Hazard Assessment (OEHHA), part of the California Environmental Protection Agency. Furthermore, DPR has also requested that the EPA review the document.

THE SUBCOMMITTEE'S TASK

The task given to NRC's subcommittee on methyl bromide states the following: The subcommittee will perform an independent scientific review of the California Environmental Protection Agency's risk assessment document on methyl bromide. The subcommittee will (1) determine whether all relevant data were considered, (2) determine the appropriateness of the critical studies, (3) consider the mode of action of methyl bromide and its implications in risk assessment, and (4) determine the appropriateness of the exposure assessment and mathematical models used. The subcommittee will also identify data gaps and make recommendations for further research relevant to setting exposure limits for methyl bromide.

DPR provided the subcommittee with the draft report to be reviewed *Methyl Bromide: Risk Characterization Document for Inhalation Exposure* (DPR 1999). This report evaluates the toxicological and exposure data on methyl bromide that characterize risks at current exposure levels for field workers and nearby residents. This document comprised the basis for the subcommittee's review. The subcommittee also reviewed much of the primary toxicology literature cited in the risk characterization document, as well as other supporting materials provided by DPR (OEHHA 1999; Seiber 1999).

In addition to DPR's report and supplemental materials, the subcommittee held a public meeting on October 4, 1999, to gather information from DPR and other interested individuals and organizations. At this meeting, formal presentations were made by Paul Gosselin, Lori Lim, and Thomas Thongsinthusak of DPR; Vincent Piccirillo of NPC, Inc.; Bill Walter of the Environmental Working Group; and Amy Kyle of the California Rural Legal Assistance Foundation. A list of materials provided to the subcommittee may be found in Appendix B.

ORGANIZATION OF THE REPORT

The remainder of this report contains the subcommittee's analysis of DPR's risk characterization for methyl bromide. In Chapter 2, the critical toxicological studies and endpoints identified in the DPR document are evaluated. Chapter 3 summarizes DPR's exposure assessment, and the data quality and modeling techniques employed in its assessment are critiqued. Chapter 4 provides a review of DPR's risk assessment, including the adequacy of the toxicological database DPR used for hazard identification, an analysis of the margin-of-exposure data, and appropriateness of uncertainty factors used by DPR. Chapter 5 contains the subcommittee's conclusions about DPR's risk characterization, highlights data gaps, and makes recommendations for future research.

2

Toxicology and Hazard Identification

In this chapter, the National Research Council's subcommittee on methyl bromide reviews the toxicokinetic and toxicological information on methyl bromide as presented in the California Department of Pesticide Regulation's (DPR's) October 1999 draft report *Methyl Bromide: Risk Characterization Document for Inhalation Exposure* (DPR 1999). The information reviewed by the subcommittee is presented in Section III, "Toxicology Profile," and Appendices B and D, of the DPR draft report. In the sections below, the subcommittee comments on DPR's selection of the critical study and toxicological endpoints for acute, subchronic, and chronic exposures. In Table 2–1 below, taken from the DPR risk characterization document (DPR 1999, p. 10), the critical no-observed-adverse-effect levels (NOAELs),[1] toxicity endpoints, and reference concentrations[2] (RfCs) are summarized.

---

[1]The subcommittee has used the term no-observed-adverse-effect level (NOAEL) rather than DPR's term no-observed-effect level (NOEL). NOAEL is defined as an exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control. Many organizations use the terms interchangeably.

[2]A reference concentration (RfC) is an estimate of the concentration of a substance that is unlikely to cause noncancer health effects in humans during a lifetime. It is used by DPR as a regulatory value for establishing buffer zones to protect residents from adverse effects of methyl bromide exposure.

TABLE 2–1 Summary of Critical NOAELs Used by DPR

Scenario	Experimental NOAEL (ppm)	Human Equivalent NOAEL (ppm)[a]		RfC (ppb)[b]	Effect in Animal Studies	Reference
		Adult	Child			
Acute	40	21	na	210	Developmental toxicity (pregnant rabbit)	Breslin et al. 1990b
	103	45	25		Neurotoxicity (dog)	Newton 1994b
Subchronic: 1 wk	20	12	7	120 (adult) 70 (child)	Neurotoxicity (pregnant rabbit)	Sikov et al. 1981
6 wk	0.5 (estimated)	0.2	0.1	2 (adult) 1 (child)	Neurotoxicity (dog)	Newton 1994b
Chronic	0.3 (estimated)	0.2	0.1	2 (adult) 1 (child)	Nasal epithelial hyperplasia (rat)	Reuzel et al. 1987, 1991

[a]The human equivalent NOAEL in parts per million (ppm) is derived from the experimental NOAEL, taking into account the relative breathing rates and exposure durations of animals and humans.

[b]The inhalation reference concentration (RfC), in parts per billion (ppb) is the ratio of the human equivalent NOAEL and an uncertainty factor of 100.

NOTE: na=not applicable.

Source: Adapted from DPR 1999, p. 10.

PHARMACOKINETICS

The absorption, distribution, and, to some extent, the biotransformation and excretion of methyl bromide are reviewed in the DPR report. Following inhalation or ingestion, methyl bromide was absorbed rapidly and distributed to most tissues in the body, based on a ^{14}C label, which can reflect either parent or metabolite (Bond et al. 1985). After 6 hr of nose-only inhalation, rats absorbed 38% to 48% of the methyl bromide concentrations at 1.6 to 170 ppm, but only 27% at 310 ppm (Medinsky et al. 1985); dogs absorbed approximately 40% after 3 hr of exposure to concentrations at 174 to 361 ppb (Raabe 1986, as cited in DPR 1999); and humans absorbed 52% to 55% of concentrations of 18 ppb after 2 hr of exposure (Raabe 1988, as cited in DPR 1999). In rats, a radioactive label (radiolabel) was found in the nasal turbinates, lungs, testes, brain, thymus, and adrenal glands of the rat (Medinsky et al. 1984; Bond et al. 1985; Jaskot et al. 1988). The tissues with the highest radioactivity were lung, liver, and nasal turbinates. Following oral administration in rats, more than 90% of the dose was absorbed (Medinsky et al. 1984). Following a high-dose accidental exposure of a man who died 4 hr later, methyl bromide was detected in all tissues, except the spleen, at an autopsy 1 hr after death (Michalodimitrakis et al. 1997 as cited in DPR 1999).

Methyl bromide is rapidly biotransformed following inhalation (Bond et al. 1985). In rats, more than 75% of the inhaled dose was excreted within 65 hr (Bond et al. 1985). Over 90% of the inhaled radioactivity in rats was associated with metabolites with an elimination half-life from tissues of 1.5 to 8 hr (Bond et al. 1985). About half of the inhaled dose in rats is excreted as exhaled CO_2 with a biphasic half-life of approximately 4 hr and 11 to 17 hr; less than 5% is exhaled as methyl bromide (Medinsky et al. 1985). About 20% of the absorbed radioactivity is excreted in the urine and only about 1% via the feces. The estimated clearance half times of the radiolabels in dogs and humans are about 41 hr and 72 hr, respectively (Raabe 1986, as cited in DPR 1999).

Although the discussion on the absorption, distribution, and excretion of ^{14}C-labeled methyl bromide (based on following the radiolabel) in the DPR reports appears complete, there is only limited discussion of its metabolism. The studies on the excretion of ^{14}C following the inhalation of radiolabeled methyl bromide are consistent with the hypothesis that the methyl group of methyl bromide joins the 1-carbon pool after metabolism. Thus, it is important that the literature on the metabolism of methyl bromide be reviewed in the DPR document. The metabolism of methyl bromide could have implications for its toxicity and subsequent risk assessment, especially for some segments of the population, as noted below.

Following absorption, conjugation with glutathione—a common detoxification mechanism—appears to be the primary metabolic pathway for monohalomethanes, including methyl bromide (Hallier et al. 1990; Peter et al. 1989; Bonnefoi et al. 1991). Methylglutathione is then metabolized to S-methyl-cysteine by transpeptidases. In turn, S-methylcysteine is metabolized to methanethiol through methylthioacetic acid. Methanethiol is oxidized to formaldehyde and hydrogen sulfide and then to formate and sulfate (Kornburst and Bus 1983).

The toxicity of methyl bromide might result from the direct methylation of cellular macromolecules or the toxic metabolites methanethiol, formaldehyde, or hydrogen sulfide. Exposure to methyl bromide has induced glutathione depletion in some in vivo and in vitro studies. It is possible that in cases of cumulative exposure to chemicals involving glutathione conjugation, less glutathione would be available to detoxify methyl bromide, resulting in more acute effects. Reports on the effect of glutathione depletion or administration of the glutathione precursor (N-acetylcysteine) on the toxicity of methyl bromide are not consistent and vary with the species and endpoint examined (Garnier et al. 1996). The reasons for these inconsistencies are not clear. However, it is evident that the interactions of methyl bromide with glutathione or the metabolites of methyl bromide play a role in its toxicity (Garnier et al. 1996).

A genetically determined polymorphism in glutathione transferase activity has been reported in humans (Hallier et al. 1993). Humans can have at least 14 classes of this enzyme with 11 subunits. Approximately 75% of humans have erythrocytes with a form of this enzyme, which is selective for the conjugation of methyl bromide with glutathione (fast conjugators), but about 25% of the population does not have this enzyme phenotype (slow conjugators). The specific class of glutathione transferase responsible for conjugating methyl bromide and its metabolites is thought to be glutathione transferase theta (GST T1–1) (Garnier et al. 1996). Ethnic differences in the prevalence of the genotype have been reported (Nelson et al. 1995).

In the case of sister chromatid exchanges in blood cells exposed in vitro to methyl bromide, cells from fast conjugators appeared to be protected from the production of sister chromatid exchanges, whereas cells from slow conjugators were not. On the other hand, in a single report involving one fast conjugator and one slow conjugator, the slow conjugator appeared to have considerably fewer and less severe neurological symptoms than did the fast conjugator, indicating that the proximate toxin might have been one of the metabolites of methyl bromide conjugated with glutathione as discussed above (Garnier et al. 1996). These very limited data suggest that the ability to quickly conjugate methyl bromide to glutathione might have profound ramifications on whether or not an exposed individual is likely to experience neurotoxic effects or be more susceptible to genotoxic effects. It is possible that the ability to conjugate methyl bromide with glutathione could influence the dose response for the carcinogenicity, mutagenicity, neurotoxicity, or other toxic effects for certain segments of the population who either possess or lack this polymorphism. Such differences in metabolism and toxic outcomes, if better substantiated, might be a factor in identifiying susceptible subpopulations that should receive special consideration in the risk assessment process (Hallier et al. 1993). In addition, animals used in toxicity studies might not mimic the polymorphisms seen in the human population.

GENOTOXICITY

Methyl bromide is a methylating agent and reacts with cellular macromolecules. As reviewed in Section III.E of the DPR report, methyl bromide is genotoxic in a number of in vitro and in vivo assays. In in vitro studies, it is a direct-acting mutagen in *Salmonella typhimurium* strains TA100 and TA1535, *Escherichia coli* strains Sd-4 and WP2hcr, and in *Saccharomyces cerevisiae* (Simmon et al. 1977, as cited in DPR 1999; Kramers et al. 1985, as cited in DPR 1999; Moriya et al. 1983; NTP 1992; Djalali-Behzad et al. 1982; Mortelmans and Sheperd 1980, as cited in DPR 1999). It produces a dose-dependent induction of sex-linked recessive lethality in *Drosophila melanogaster* (Kramers et al. 1985, as cited in DPR 1999; McGregor 1981, as cited in DPR 1999) and forward mutations in a mouse lymphoma assay (Kramers et al. 1985, as cited in DPR 1999). The DPR report states that, of the gene mutation studies summarized above and specifically cited in the document, only the study that used *Saccharomyces cerevisiae* was considered acceptable by DPR. DPR does not provide an explanation for this assessment, although the subcommittee finds that such an evaluation should be justified. The subcommittee is particularly concerned that DPR has implied that the gene mutation studies performed by National Toxicology Program (NTP) are not satisfactory. If this is the case, DPR should provide a detailed explanation as to why these tests are not acceptable.

DPR evaluated several in vivo assays. In female mice exposed to methyl bromide by inhalation at 100 and 200 ppm for 10 days, an increase of micronuclei was observed (NTP 1992). No increase of micronuclei was seen following intraperitoneal injection of methyl bromide at up to 123 mg/kg (Putnam and Morris 1991, as cited in DPR 1999). Dominant lethal mutations were not observed in rats exposed to methyl bromide by inhalation. A dose-related increase in the frequency of sister chromatid exchanges in bone marrow of female mice exposed to concentrations of methyl bromide at 100 or 200 ppm for 10 days was reported (NTP 1992). However, this was not seen in another study in which mice were exposed to a concentration of methyl bromide at 120 ppm for 12 weeks (NTP 1992). DNA adducts were detected in liver, lung, stomach, and forestomach of rats exposed to high concentrations of methyl bromide at 130 to 260 ppm by inhalation (Gansewendt et al. 1991). Bentley (1994, as cited by DPR 1999) exposed rats for 5 days to concentrations of methyl bromide up to 250 ppm and examined testicular damage. DPR determined that at 250 ppm, methyl bromide was considered positive for genotoxic potential to the DNA of testicular cells, whereas, at lower exposure levels, results were inconclusive. Because of the lack of raw data concerning this study, both DPR and the subcommittee consider this study to be unacceptable.

Although the available literature on the genotoxicity of methyl bromide appears to have been adequately reviewed in the DPR report, there is no discussion of the human erythrocyte polymorphism (Hallier et al. 1993). In addition, there is no mention of the significance of the genotoxicity of methyl bromide in relation to the potential carcinogenicity of methyl bromide. Because methyl bromide is a direct-acting mutagen, especially in in vitro systems, some discussion for its lack of correlation with carcinogenicity should be presented in the DPR report.

ACUTE TOXICITY

In Section III.B of the DPR report, four rat, one mouse, two dog and one guinea pig inhalation toxicity studies were examined for acute effects, as were one rat and one rabbit inhalation developmental studies, and one dog oral study. In addition, human effects from dermal exposures were analyzed. In general, dogs appear to be the most sensitive species of laboratory animals studied. The study by Newton (1994b) in which dogs were exposed via inhalation for 7 hr/day for 34 days over 6 weeks, was considered by DPR as a critical study for neurotoxicity endpoints. The NOAEL and lowest-observed-adverse-effect level (LOAEL) were 103 and 158 ppm, respectively, based on no recorded adverse effects until 9 days of exposure at 103 ppm, and decreased activity on the second day of exposure at 158 ppm, and brain lesions following 6 days of exposure at 158 ppm. This study appears to have been appropriate for selecting a NOAEL because the neurotoxicity endpoint is highly relevant to humans, and the critical signs of neurotoxicity (decreased activity) seen at the LOAEL were noted on the second day of exposure, and not following multiple days of exposure. In addition, most of the other studies would have identified higher NOAELs.

It should be noted that the DPR document is quite confusing with respect to its discussion of the acute critical studies. There is substantial discussion of acute effects under the section on acute toxicity, but the critical study (Newton 1994b) is discussed under the section on subchronic toxicity, probably because this was also the critical study for the subchronic NOAEL. The subcommittee recommends that DPR revise its acute toxicity section to include a discussion of these observations so that there is greater clarity on the endpoints selected for the critical study for the acute NOAEL. In addition, the observation of toxicity after the single dose was a functional one, that is, decreased activity, which is likely to be a more sensitive manifestation of toxicity than pathological lesions. A similar NOAEL was noted in a rat inhalation study with a single 6-hr exposure (Driscoll and Hurley 1993); however, the

LOAEL was considerably higher (350 ppm, based on deficits in a functional observational battery, which is also a functional endpoint similar to that of the critical dog study). Further discussion of the critical dog study (Newton 1994b) is found in the neurotoxicity section of this chapter.

The greater sensitivity of the dog compared with the rat makes the dog study the appropriate critical study for regulatory purposes. Also, inhalation exposure is more likely for acute effects than is oral exposure, and therefore, an inhalation study is more appropriate to designate as the critical study than an oral study. Human dermal exposure data were too limited to consider for regulatory purposes. Lower NOAELs and LOAELs were observed in some in vivo and in vitro studies (Honma et al. 1987 and 1991); however, a critical analysis of these data by DPR revealed a number of inconsistencies in the data sets, rendering them unsuitable as critical studies. The subcommittee concurs with DPR that the Honma et al. studies (1987, 1991) are not appropriate for regulatory purposes because these studies examined neurochemical endpoints that are not necessarily indicative of toxicity.

In addition to neurotoxicity, DPR also considered developmental toxicity for its acute exposure risk assessment, based on the assumption that only a single exposure at a critical time is necessary for the induction of a developmental effect. This is a well-accepted principle in developmental toxicology that has been incorporated into the U.S. Environmental Protection Agency's (EPA's) *Guidelines for Developmental Toxicity Risk Assessment* (1991). A developmental toxicity study in rabbits was considered by DPR as the critical study for developmental endpoints (Breslin et al. 1990b). The LOAEL and NOAEL were 80 and 40 ppm, respectively, with gallbladder agenesis, fused sternebrae, and reduced fetal weights observed at 80 ppm. This study was considered appropriate by the subcommittee for selection of the NOAEL for acute toxicity for women of childbearing age in the workforce and in the general population. This study is discussed in more detail in the developmental toxicity section.

SUBCHRONIC TOXICITY

A large number of studies were available for analysis by DPR for subchronic toxicity involving several species and dosing protocols. Eight rat, three mouse, seven rabbit, two dog, one guinea pig, and two monkey inhalation studies, and four rat oral studies were considered by DPR. As was true for acute toxicity, it is most appropriate to consider inhalation exposure because this route most accurately reflects the primary route of repeated exposures in humans. Because there is a convincing database on neurotoxic effects stemming from human exposures to methyl bromide, the subcommittee concludes that it is most appropriate to consider neurotoxicity as the critical endpoint in animal studies used for risk characterization of subchronic toxicity.

DPR selected two critical studies: a dog study of exposures of 7 hr/day for 34 days over 6 weeks (Newton 1994b), and a rabbit developmental study with exposures of 7 hr/day for gestation days 1 to 15 (Sikov et al. 1981). As with the acute toxicity considerations, nonrodents appear to be more sensitive to methyl-bromide-induced toxicity than are rodents, so selection of nonrodent studies is appropriate. The dog is particularly sensitive, and in the Newton (1994b) study, exposures of dogs provided a LOAEL of 5 ppm. No NOAEL was identified. The LOAEL was based on decreased responsiveness, that is, listlessness and quiescence, and also on the decreased spleen weight observed in female dogs at the end of week 6 of the exposure. The responsiveness, although a subjective observation, is a functional one, and indicates that this LOAEL was based on a highly sensitive endpoint. However, decreased responsiveness is a somewhat equivocal endpoint, in that it apparently was not part of the standardized test protocol, but was an additional observation volunteered by a veterinarian who observed the two female dogs (out of a total of four female and four male dogs). The observation was not dramatic, but because the veterinarian, who would be trained to notice abnormal behavior in dogs, felt that this was worthy of special note, the subcommittee must assume that the two dogs were, indeed, showing aberrant behavior, and that this is logically attributed to methyl bromide. Although there were only two non-responsive dogs, which is clearly a low number of observations, they represented half of this experimental group, suggesting that it was a significant observation. In addition, many of the other studies indicated reduced activity as one of the primary signs resulting from methyl bromide exposure, so the observations of reduced responsiveness in these two dogs are consistent with the overt signs of methyl bromide neurotoxicity observed in those other studies. Therefore, the subcommittee concurs with DPR's evaluation that these observations assessed a toxic response, that this dosage group constituted the LOAEL, and that this 6-week study should be the critical study for the risk assessment of subchronic toxicity. Additional details on the Newton (1994b) study are described in the Neurotoxicity section.

The rabbit developmental study (Sikov et al. 1981) was used as a 1-week subchronic critical study. This study identified a NOAEL and LOAEL of 20 and 70 ppm, respectively, based on convulsions and paresis in the dams; and it demonstrated a steep dose-response curve, based particularly on severe signs of toxicity. A rat study identified a lower NOAEL and LOAEL than the rabbit study, in which rats were exposed to concentrations of methyl bromide at 3 and 30 ppm for 6 hr/day, 5 days/wk for 132 to 145 days (American

Biogenics Corporation 1986). Thus, the LOAEL seen in rats exposed to 30 ppm for 132 to 145 days suggests that this species is less sensitive to methyl bromide than rabbits, which had a NOAEL of 20 ppm for a 7-day exposure. Another rat study also identified a lower NOAEL based on biochemical measures (i.e., decreased brain monoamine levels) (Honma et al. 1982); however, because it is unclear whether these biochemical changes genuinely reflect or correspond with any functional changes, and because of the concerns of design and consistency in the results from the series of Honma et al. studies, this is not a suitable study to select as a critical study. Therefore, the subcommittee concurs with the selection of studies by DPR as the critical studies for subchronic toxicity.

CHRONIC INHALATION AND ONCOGENICITY

Two chronic inhalation studies were reviewed by DPR for the assessment of the chronic toxicity and oncogenicity of methyl bromide (Section III.D). The first study (Reuzel et al. 1987, 1991) involved exposure of male and female Wistar rats to methyl bromide concentrations at 0, 3, 30, or 90 ppm for 6 hr/day, 5 days/wk, for 29 months. Each exposure group comprised 90 males and 90 females with interim sacrifices of 10 rats/sex/group at 13, 52, and 104 weeks. Body weights, clinical signs, hematology, biochemistry, and gross and microscopic effects were examined at these times. Exposure to 90 ppm was clearly toxic with early mortalities reported (not statistically significant at the terminal sacrifice); body weights of both sexes in this exposure group were significantly lower than those of the respective control groups throughout most of the study. At terminal sacrifice, effects on the heart were apparent in the 90-ppm exposure group. Statistically significant higher incidences of heart lesions in this group included cartilaginous metaplasia (males only), moderate to severe myocardial degeneration (females only), and thrombi (males and females). Myocardial degeneration also occurred in aged control rats. Therefore, when total incidences of myocardial degeneration were considered, incidences in the control and 90-ppm groups were similar for both sexes. At the 29-month sacrifice, the 3-ppm concentration was a NOAEL for endpoints of body weight and absolute and relative brain weight. The subcommittee noted that the absolute brain weights were significantly reduced for both sexes in the 3- and 30-ppm groups, but did not consider the reductions biologically significant (98% of control values for both sexes in the 3-ppm group, and 94% and 96% of control values for males and females, respectively, in the 30-ppm group), especially in the absence of histological correlates. DPR reevaluated the absolute brain-weight data by combining inci dences at 29 months with data from animals that died during the study. With the reevaluation they found that the NOAEL remained 3 ppm for the reduction in absolute brain weight.

Basal cell hyperplasia of the olfactory epithelium was present in both males and females in a dose-related manner at the 29-month terminal sacrifice, but not at the other time points. Incidences were statistically significant in the 3-ppm group at the 29-month terminal sacrifice when total incidences were considered (13 of 48 and 19 of 58 in males and female subgroups, respectively, compared with 4 of 46 and 9 of 58 in the respective control subgroups). In the 3-ppm group, the majority of lesions were characterized as “very slight”; the severity of these lesions became greater (“slight” to “moderate”) in the higher exposure groups. These lesions were not present in either males or females in the 3-ppm group at the 52-week interim sacrifice and were not significantly elevated over those of the respective control groups at the 104-week interim sacrifice. But these lesions were present in the female control group at the 104-week interim sacrifice at an incidence (4 of 10, 40%) similar to that in the female 3-ppm group at terminal sacrifice (19 of 48, 40%). At terminal sacrifice, the incidence of total olfactory lesions in males in the 3-ppm group was 13 of 48 (27%) compared with 4 of 46 (9%) in the male control group.

The subcommittee made the following observations regarding the nasal lesions: (1) they increased in control rats in an age-dependent manner from 12 to 29 months; (2) all but one of the lesions were classified as slight or very slight in the 3-ppm group; and (3) one moderate lesion of the nasal mucosa was observed in controls at the 24-month observation (accompanied by a 40% incidence of total lesions in control females). The incidence in the control males at 24 months was 3 of 10 (30%). Therefore, the effect in the 3-ppm group at the 29-month terminal sacrifice, although dose-related and statistically significant, must be considered slight or equivocal. This study was well conducted, used a relevant route of administration, used adequate numbers of rats of both sexes, and examined all relevant endpoints of methyl bromide toxicity. In addition, the same critical endpoint of more pronounced lesions, was observed in rats exposed for shorter periods of time at higher concentrations (Eustis et al. 1988; Hurtt et al. 1988). Therefore, the subcommittee concurs that this study should be the critical study for the chronic risk assessment. A separate chronic RfC for children based on this study is not necessary because the endpoint is not applicable or relevant to children. The study shows that the endpoint occurs in aged rats; children exposed throughout their childhood will not show this particular endpoint.

The second chronic inhalation study reviewed by DPR was conducted by the National Toxicology Program (NTP 1992). This chronic study with B5C3F1 mice included neurobehavioral evaluations at 3-month intervals and was an equally suitable study for derivation of the RfC. In this study, each group of 70 male and 70 female mice was exposed to concentrations of methyl bromide at 0, 10, 33, or 100 ppm for two years—the typical duration of chronic studies. Sixteen mice (eight males and eight females) per group were used for neurotoxicity testing only. Interim sacrifices of 10 mice/sex/ group took place at 6 and 15 months. The exposure to 100 ppm was discontinued after 20 weeks because of neurotoxicity and early mortalities. This study identified the same organ and tissue endpoints as the Reuzel et al. (1987, 1991) study, the nose, heart, and brain, and also included an endpoint for affected bone. Aside from increased mortality in the 100-ppm dose group, statistically significant LOAELs and NOAELs for target organ effects were cerebellar and cerebral degeneration, 100 and 33 ppm; myocardial degeneration and chronic cardiopathy,100 ppm and 33 ppm; sternal dysplasia, 100 ppm and 33 ppm (increased but not statistically significant for either males or females over controls in the 33-ppm group); and olfactory metaplasia or necrosis, 100 ppm and 33 ppm. It was noted that, similar to results observed in rats at the 3-ppm exposure group in the Reuzel et al. (1987, 1991) study, no olfactory lesions were present in mice at the end of 24 months.

DPR identified a LOAEL of 10 ppm for neurotoxicity in the NTP (1992) study based on statistically decreased locomotor activity at 6 and 12 months. The subcommittee disagrees with DPR that the LOAEL for neurotoxicity is 10 ppm. A statistically significant decrease occurred at only 1 of 8 time periods for each sex (6 months for males and 12 months for females) and these decreases were offset by random nonstatistically significant increases over control values at other test times. The authors of the NTP study found “no consistent neurobehavioral differences in animals from the two lower dose groups” (10 and 33 ppm). Therefore, the LOAEL for neurotoxicity is 100 ppm. The NTP Peer Review Panel concurred with the findings of the authors of the NTP study with one member advising caution in the interpretation of the behavioral and functional neurotoxicity results. The Peer Review Panel comments are incorporated into the NTP report.

DPR also reviewed the chronic inhalation study of Gotoh et al. (1994, as cited in DPR 1999). This study was not considered acceptable by either DPR or the subcommittee because the study was reported in summary form and individual data were not available for evaluation. The two-generation reproduction study by American Biogenics Corporation (1986) can also be considered when evaluating chronic toxicity. However, the NOAEL and LOAEL of 3 ppm and 30 ppm, respectively, for reduced growth of neonatal rats were higher than in the Reuzel et al. (1987, 1991) study.

In addition to the two chronic inhalation studies, DPR reviewed four dietary studies. One was a study in which rats were administered encapsu lated methyl bromide for 2 years (Mertens 1997, as cited in DPR 1999), another was a study in which rats were administered fumigated feed for 2 years (Mitsumori et al. 1990), and the other two were studies in which beagle dogs were administered fumigated feed for 1 year (Rosenblum et al. 1960; Newton 1996, as cited in DPR 1999). Although the oral exposure route is not the most appropriate for deriving an inhalation RfC, such studies can be used to identify target organs and potential carcinogenic effects. The studies in which animals were administered fumigated feed suffered from various defects, including lack of analytical determination of methyl bromide concentrations. DPR correctly considered three of these studies unacceptable or supplemental (Mitsumori et al. 1990; Rosenblum et al. 1960; and Newton 1996, as cited in DPR 1999). In the Mertens (1997) study (as cited in DPR 1999), which DPR considered acceptable, nominal methyl bromide concentrations at 0 (basal diet), 0 (placebo microcapsules), 0.5, 2.5, 50, or 250 ppm were administered in the feed to rats for 2 years. DPR estimated a conservative LOAEL in this study of 0.5 ppm based on splenomegaly in male rats (0 ppm, basal diet: 2 of 50; 0 ppm, placebo: 2 of 50; 0.5 ppm: 7 of 50; 2.5 ppm: 10 of 50; 50 ppm: 11 of 50, and 250 ppm: 3 of 50). The subcommittee reviewed the Mertens (1997) study (as cited in DPR 1999) and, based on the absence of (1) a clear dose-response relationship for splenomegaly, (2) histological correlates in the spleen, and (3) effects on hematology and clinical chemistry parameters, disagrees with DPR's assessment. Based on early effects on body weight, the subcommittee believes the LOAEL is 250 ppm of methyl bromide in the feed and the NOAEL is 50 ppm.

DPR also evaluated the carcinogenicity of methyl bromide. It concluded that although methyl bromide is genotoxic without metabolic activation and has been shown to alkylate DNA in different organs in in vivo studies, there is no clear evidence of oncogenicity under the experimental conditions used in the chronic inhalation studies with rats and mice (Reuzel et al. 1987, 1991; NTP 1992). The subcommittee reviewed the chronic studies for oncogenicity in male and female rats and mice and agrees with DPR's conclusion. The chronic oral study with rats (Mertens 1997, as cited in DPR 1999) also was negative for oncogenicity, supporting the conclusion drawn from the two chronic inhalation studies.

REPRODUCTIVE TOXICITY

Two reproductive toxicity studies were evaluated in Section III.F of the DPR report. Both studies used rats as the experimental animals; one was an inhalation study (American Biogenics Corporation 1986; Hardisty 1992, as cited in DPR 1999; Busey 1993, as cited in DPR, 1999), and the other was an oral study (Kaneda et al. 1993). The inhalation study was a two-generation study designed to investigate the reproductive toxicity of methyl bromide at concentrations of 3, 30, and 90 ppm for 6 hr/day, 5 days/wk. Exposure to these concentrations did not affect the fertility indices of the F0 animals for two separate mating trials, nor did it affect the fertility index of the F1 animals for the first mating trial. However, for the second mating trial of the F1 animals, the fertility indices (number of pregnancies per number of copulations) in the 30- and 90-ppm groups were reduced to 66.7% and 68.2% from 85% to 100% in the other mating trials. In the DPR report, the fertility index for the 30 ppm group is correctly given as 66.7% (based on our calculation from the original data). It is incorrectly given as 70% in Table 8 of the original study (American Biogenics Corporation, 1986). According to the DPR document, this reduction approached statistical significance in both cases (0.056 and 0.066, respectively); however, the DPR report does not state what statistical test was used. The subcommittee calculated p-values of 0.12 (Pearson's chi square) and 0.06 (Mantel-Haenszel test for linear association) for the effect of treatment on whether or not a copulation resulted in pregnancy.

The reduced-fertility indices in the second mating trial of the F1 parents were considered evidence of an effect of methyl bromide on fertility by DPR, although not by the authors of the study, who stated only that there was no significant effect of treatment on the fertility index. Although of borderline statistical significance, the fact that the reduction in fertility occurred in both of the higher-dose groups and only after 90 to 105 days of exposure to methyl bromide (as compared with 40 to 55 days for the first mating) suggests that this was a real effect on fertility. However, this might represent a developmental effect on the reproductive system rather than a reproductive effect because it only occurred in the F1 generation, suggesting that gestational or early postnatal exposure is required to manifest the effect. At the time of sacrifice of the F1 parents at about 250 days, ovary weights were not affected by methyl bromide exposure, but there was a downward trend in absolute testicular plus epididymal weights and a significant reduction in the relative testicular plus epididymal weight in the 30-ppm group. Reproductive organ histology performed on the control and 90-ppm F1 parental animals was reported to be normal. In conclusion, the data suggest that exposure to methyl bromide concentrations at 30 and 90 ppm might be associated with reproductive toxicity; however, the effects were of borderline statistical significance, and the study design does not allow the subcommittee to sort out whether the putative effect was a reproductive or developmental effect of methyl bromide. Therefore, the subcommittee concludes that although 3 ppm was clearly a NOAEL for reproductive toxicity, it is not clear that 30 or 90 ppm were LOAELs.

In addition to the effects on fertility, effects on offspring body weights, organ weights, and brain weight and dimensions are discussed in Section III.F.1 of the DPR report. These should also be mentioned in Section III.G under developmental effects. The significant, dose-dependent reductions in the body weights during lactation of the offspring of all four mating trials might be due to gestational or lactational exposure to methyl bromide. The latter is suggested by the fact that pup weights were not decreased consistently on post-natal day 0 or day 4, but were decreased on postnatal days 14, 21, and 28 in the 30- and 90-ppm groups. In the F2a and F2b progeny, pup weights were also significantly reduced on postnatal days 0, 4, and 7, suggesting that at least some of the effect on pup weight was due to gestational exposure. Methyl bromide exposure of the dams was temporarily halted from gestational day 21 until postnatal day 4, and exposure of the pups was not begun until weaning at postnatal day 28 in all four trials. Therefore, from post-natal days 4 through 28 the pups would have been exposed to methyl bromide only via the breast milk. A literature search revealed no data on the excretion of methyl bromide in breast milk; however, as a lipophilic molecule, it might well be excreted in breast milk. (Data are available that suggest that bromide, that is, sodium bromide, will be excreted in milk [Disse et al. 1996].) The body weight differences did not remain significant in the F1b animals during adulthood. None of the F1a, F2a, or F2b animals was followed into adulthood. The body weights of the F0 females were not affected by methyl bromide exposure beginning in early adulthood (62 days old), but the 90-ppm F0 males showed decreased body weights compared with controls from exposure week 3 (around 80 days old) until the final sacrifice (about 250 days old).

The offspring of the F1b and F2b mating trials and the F0 adult males showed dose-related reductions in brain weights, which were significant for the 90-ppm F0 males, the 90-ppm F1b males and females that were sacrificed as adults, and the 90-ppm F2b females sacrificed at 28 days. Unfortunately, brain weights and other organ weights were not measured in the F1a or F2a offspring. Brain weights were not significantly reduced in the subset of F1b offspring that were sacrificed at 28 days (p=0.17, analysis of variance [ANOVA] performed by the subcommittee; see Table 2–2). Cerebral cortex widths were measured in the 0- and 90-ppm groups of the adult F0 and F1b animals, and were significantly reduced only in the 90-ppm F1b animals. Absolute organ weights (heart, kidney, liver), but not organ weights adjusted for body weight, were significantly reduced in the 90-ppm F2b female progeny and nonsignificantly reduced in the male F2b progeny (kidney, liver, testis). Taken together, the cortex width data, the body and organ weight data, and the fertility data suggest that the developing rat is more sensitive to methyl bromide toxicity than adults are. The subcommittee concurs with DPR that the developmental NOAEL for this study is 3 ppm, based on significant body-weight reductions in the offspring of the 30- and 90-ppm groups.

TABLE 2–2 Brain-Weight Summary for F1b Weanlings Sacrificed at 28 Days, by Exposure Level

F1b weanlings	0 ppm	3 ppm	30 ppm	90 ppm
Males[a]	1.51±0.14 g	1.52±0.11g	1.47±0.10 g	1.50±0.09g
Females[a]	1.48±0.09g	1.42±0.12 g	1.41±0.12 g	1.45±0.06g

[a]No statistically significant differences by ANOVA.

The second reproductive study (Kaneda et al. 1993) discussed in Section III.F.2 of the DPR report was designed to test the effects of methyl-bromide-fumigated feeds. Because the feeds were allowed to aerate for 21 days after fumigation, the doses of methyl bromide were quite low (maximally 200 ng/kg/day, actual doses not determined) compared with the bromine doses (about 110 to 730 μg/kg/day). No effects on mating index or fertility index were observed. The concluding sentence of this paragraph, is confusing “[s]ince the actual methyl bromide concentration in each dose is not known, it is not possible to determine whether the effects were due to bromine or methyl bromide” (DPR 1999, p. 72). It would be more accurate to say that the study cannot be used to establish NOAELs for reproductive effects for methyl bromide because the actual doses of methyl bromide were not determined. Moreover, the inhalation route of exposure is more relevant to humans.

In addition to the two reproductive studies reviewed by DPR, there is another study (Sikov et al. 1981), reviewed by DPR as a developmental toxicity study, which provides some additional information about the reproductive effects of methyl bromide. The report describes a study of pregestational and gestational inhalation exposure of female Wistar rats to nominal concentrations of methyl bromide at 0, 20, and 70 ppm for 7 hr/day, 5 days/wk. The pregestational exposures occurred for 3 weeks before mating with untreated males. No significant effects were observed on fertility rates (92% to 100% in the exposed groups compared with 98% in the controls), on corpora lutea per dam, implants per litter, or implants per corpus luteum. These data are consistent with the results of the inhalation study discussed above (American Biogenics Corporation 1986; Hardisty 1992, as cited in DPR 1999; Busey 1993, as cited in DPR 1999) that found no effects on fertility indices of the F0 generation exposed for up to 105 days before mating.

The subcommittee found DPR's discussion of the reproductive studies of methyl bromide to be somewhat contradictory. In Section II of the DPR re port, DPR found that methyl bromide is a direct reproductive toxicant; however, in Section IV, in its discussion of the risk assessment of methyl bromide, DPR suggested that the reduced fertility seen in the American Biogenics Corporation (1986) study might be the result of developmental effects on the reproductive system, resulting in altered reproductive function in adult life. The subcommittee concurs with DPR's latter conclusion that, taken together, the results of the Sikov et al. (1981) and American Biogenics Corporation (1986) studies suggest that methyl bromide might affect the development of the reproductive system, but the subcommittee does not agree that the studies support DPR's conclusion that methyl bromide is a direct reproductive toxicant in adult animals.

DEVELOPMENTAL TOXICITY

Four inhalation and two oral exposure studies in two species were reviewed by DPR for the assessment of the developmental toxicity of methyl bromide (Section III.G). The developmental aspects of the rat inhalation study (American Biogenics Corporation 1986; Hardisty 1992, as cited in DPR 1999; Busey 1993, as cited in DPR 1999) discussed in Section III.F.1 of the DPR report should also have been discussed in Section III.G.

The inhalation study described above (Sikov et al. 1981) also examined developmental endpoints in rats. This study examined the effects of exposure to methyl bromide at 0, 20, and 70 ppm before or during gestation. Minimal maternal toxicity, in the form of reduced gestational body weights on some gestational days in the dams exposed to 70 ppm during gestation, was observed. The investigators also observed higher, although not statistically significant, rates of various ossification defects in the rat fetuses whose dams were exposed to methyl bromide, compared with those who were not. For the most part, these did not show a clear dose-related pattern. However, for the supraoccipital, interparietal, and parietal bones of the skull, the percent of litters and the percent of fetuses that displayed ossification defects were higher in the 20- and 70-ppm gestationally exposed groups than in the controls or in the groups with only pregestational exposure (see Table 2–3). Although such ossification defects are often considered to represent variants when they are consistently elevated in the experimental groups in a manner that suggests dose-dependency, there should be concern about subtle developmental effects (EPA 1991; Sikov et al. 1981). The skull ossification defects, as well as the total skeletal anomalies and total ossification defects listed in Table 2–3, fulfill the consistency criterion (all gestationally exposed groups have higher rates than the controls), but the dose-dependency criterion is only fulfilled for supraoccipital ossification and total ossification defects. In summary, these data suggest that methyl bromide might be a developmental toxicant at doses as low as 20 ppm; however, they do not unequivocally establish it as a developmental toxicant. Therefore, this study should not be used to set a developmental NOAEL.

The same paper (Sikov et al. 1981) also described an inhalation study in rabbits using similar exposure regimens that were planned to continue for gestation days 1 to 24, without pregestational exposure. All of the does in the 70-ppm group manifested severe toxicity, and all but one of them died, even though the exposures were terminated early, on gestation day 15. The NOAEL for maternal toxicity was 20 ppm. No adverse effects were observed in the offspring of the 20-ppm group or of the one survivor in the 70-ppm group. However, because the exposures were terminated early in all groups, this study was not considered to be a valid study of developmental toxicity by DPR. Nonetheless, it provides evidence that gestational exposure to 20 ppm methyl bromide from gestation days 1 to 15 does not cause developmental toxicity in rabbits.

TABLE 2–3 Summary of Skull Ossification Defects in Sikov et al. (1981) Rat Substudy

Ossification defect	Exposure levels in ppm (pre-mating/gestation)						
	0/0	20/0	70/0	0/20	0/70	20/20	70/70
Supraoccipital	2.7[a]	11.8	0	6.5	19.4	5.3	19.4
	0.5[b]	1.9	<0.4	1.1	4.3	0.8	8.7
Interparietal	13.5[a]	14.7	13.9	29.0	19.4	21.1	38.9
	2.9[b]	2.3	2.1	7.0	3.9	3.7	8.7
Parietal	8.1[a]	5.9	11.1	12.9	13.9	28.9	19.4
	1.9[b]	1.4	4.1	4.3	2.6	8.2	4.8
Total skeletal	0.18[c]			0.30	0.19	0.22	0.26
anomalies	1.1[d]	1.4	1.2	1.3	1.7		
Total	0.03[e]	0.06	0.07	0.07	0.11		
ossification defects	0.24[f]	0.48	0.61	0.68	0.81		

[a]Percent litters with defect
[b]Percent pups with defect
[c]Number of skeletal anomalies/fetus
[d]Number of skeletal anomalies/litter
[e]Number of ossification defects/fetus
[f]Number of ossification defects/litter

A preliminary study by Breslin et al. (1990a) examined the effects of inhalation exposure in rabbits to methyl bromide at 0, 10, 30, or 50 ppm (Part 1) and at 0, 50, 70, and 140 ppm (Part 2) for 6 hr/day on gestation days 7 to 19. The exposure regimens used in both Parts 1 and 2 of the study were designed to assess the levels at which maternal toxicity and embryo lethality might occur. No toxicity was observed in the dams or in the offspring in Part 1. In Part 2, the dams exposed to 140 ppm showed severe neurotoxicity with meningeal inflammation and midbrain necrosis, and were sacrificed early on gestation day 17. The dams exposed to 70 ppm exhibited statistically significant decreased body weight at gestation day 16 and decreased weight gain on gestation days 13 to 16 only. Information on maternal weight gain corrected for gravid uterine weight was not given. Therefore, the subcommittee cannot judge whether the effects on maternal weight gain represented maternal or fetal toxicity or both. This study was appropriately considered supplemental by DPR.

A definitive study by Breslin et al. (1990b) exposed rabbits to methyl bromide at 0, 20, 40, or 80 ppm (Part 1) and at 0 or 80 ppm (Part 2) for 6 hr/day from gestation days 7 to 19. Part 2 of the study was designed to determine whether observations made in Part 1 could be replicated. In Part 1, at the 80-ppm dose, 3 of 26 does exhibited clinical signs of neurotoxicity beginning on the last day of exposure. One of these rabbits delivered its litter early, on gestation day 27. Unfortunately, the brains of these animals were not examined. No maternal neurotoxicity was observed in Part 2, but one doe died of undetermined causes in the 80 ppm group. Statistically significant decreases in maternal weights in the 80-ppm group were observed on gestation days 13 and 16 in Part 1, but not at all in Part 2. The two animals with the largest weight losses in Part 1 were also two of the three that displayed neurotoxicity. Statistically significant decreases in maternal weight gains were observed for the interval gestation days 13 to 16 in Part 1 and for the interval gestation days 10 to 13, 7 to 20, and 0 to 28 in Part 2. However, fetal and gravid uterine weights were also significantly decreased in Part 2 and gravid uterine weights were nonsignificantly reduced in the 40- and 80-ppm groups compared with controls in Part 1, suggesting that the reduced maternal weight gain might represent a developmental effect rather than or in addition to a maternal effect. In Section I.C of the DPR report (1999, p. 6), maternal weight gain corrected for gravid uterine weight—a better indicator of strictly maternal toxicity—was described as being unaffected by treatment; however, it does not appear in the results sections of the Breslin et al. (1990b) report. If DPR calculated this parameter from data in the study, the results of the calculation should be included in an appendix.

Fetal malformations were observed primarily in the 80-ppm groups in both

Parts 1 and 2 (Breslin et al. 1990b). The total rate of malformations in Part 1 was 14.5% in the 80-ppm fetuses, compared with 2.1% in the sham-treated control fetuses. In Part 2, a similar rate was observed in the 80-ppm fetuses (14.1%), but a much higher rate was observed in the sham-treated controls (12.3%) compared with Part 1 and compared with the naive controls in Part 2 (5.9%). Malformations included statistically significant increases in gallbladder agenesis and fused sternebrae in Part 1. These defects were observed in fetuses from dams with and without neurotoxicity. A similar incidence of gallbladder agenesis was observed in Part 2, although it did not reach statistical significance with a smaller number (N) of animals.

Although it is not considered to be a major malformation by some experts (Tyl 1991; OEHHA 1993), several arguments favor considering the increased incidence of gallbladder agenesis in the Breslin et al. (1990b) study to be evidence of developmental toxicity of methyl bromide. First, it represents the failure of an entire organ to form. Second, the 8.2% incidence at 80 ppm (affected fetuses/total fetuses) of gallbladder agenesis in Part 1 was statistically significantly elevated over the control incidence of 1.1%. The incidence of 4.3% at 80 ppm in Part 2, although not statistically significant, was nearly 5 times higher than the 0.9% incidence observed in the sham-treated control group. Moreover, the incidence of gallbladder agenesis in the methyl-bromide-treated fetuses is much higher than the 0.09% to 0.19% observed in historically untreated control New Zealand White rabbits from Dow Chemical Company (where the Breslin study was performed), WIL Research Laboratories, the Middle Atlantic Reproduction and Teratology Association, and Stadler et al. (1983) (summarized in Tables 5–8, Appendix B of the DPR report). Third, the same laboratory which performed the Breslin et al. (1990b) study (Dow Chemical Company) has reported gallbladder agenesis as a possible treatment-induced effect of other test compounds (DPR 1999, Appendix B, p. 179).

Kaneda et al. (1998) studied the developmental toxicity of oral methyl bromide exposure in rats (at 0, 3, 10, or 30 mg/kg/day, gestation days 6 to 15) and rabbits (at 0, 1, 3, or 10 mg/kg/day, gestation days 6 to 18). Maternal toxicity in the form of erosion and thickening of the stomach wall and adhesions between stomach and other organs was observed in the rats given 30 mg/kg. Fetuses from that group exhibited statistically nonsignificant increases in microphthalmia and skeletal variations. No maternal effects were noted in the rabbits. In the fetuses, skeletal malformations were observed more frequently in the methyl-bromide-treated groups than in controls, but the increases were not dose-dependent or statistically significant. Because the oral route of exposure to methyl bromide is less significant than the inhalation route for humans, these studies were appropriately considered supplemental informa tion by DPR. To better be able to compare the inhalation with the oral developmental studies, it would be useful to calculate the estimated absorbed doses for these studies.

In conclusion, DPR found that the currently available evidence suggests that methyl bromide might be a developmental toxicant by the inhalation route in two species. In rats, this evidence includes significant, dose-dependent reductions in pup body and brain weights and cerebral cortex widths and a nonsignificant reduction in fertility in gestationally exposed offspring (American Biogenics Corporation 1986; Hardisty 1992, as cited in DPR 1999; Busey 1993, as cited in DPR 1999). As this was a two-generation study, it is not possible to determine the critical period or periods for exposure for these effects. However, the patterns of occurrence are consistent with developmental effects. In a separate rat developmental study, a nonsignificant, but consistent, increase in the incidence of skull ossification defects was observed in gestationally exposed animals (Sikov et al. 1981). In rabbits, the evidence for developmental toxicity includes gallbladder agenesis, reduced fetal weights, and increased frequency of fused sternebrae (Breslin et al. 1990b). Taken alone any of these studies could be considered equivocal; however, taken together, the subcommittee agrees with DPR that they suggest that methyl bromide might be a developmental toxicant.

NEUROTOXICITY

There is ample evidence that neurotoxicity is the most prominent type of toxicity elicited by methyl bromide in humans. Therefore, selection of neurotoxic endpoints for the critical studies in the risk characterization is most consistent with protection of humans from the adverse effects of methyl bromide. Many of the studies did not include neurobehavioral analysis as their endpoints. The critical studies selected for acute and subchronic exposures were based on functional endpoints, and thus appear to reflect the most sensitive indicators measured. The subcommittee finds that a change in behavior (of the dogs in the Newton [1994b] study) is a functional one, which might be more sensitive than a pathological endpoint, because the functional change might be due to a biochemical deficit (or change) even though a histological change has not occurred. As mentioned above, some of the observations in the subchronic study (Newton 1994b) were equivocal, such as the two non-responsive dogs at the lowest concentration tested; there were low animal numbers in this experiment, not a good dose-response relationship, and the observations were outside the standardized protocol. Nevertheless, the observation of low levels of responsiveness is very consistent with the nervous sys tem depression observed in a number of the animal studies, and therefore is believed to reflect a true neurotoxic response.

One possible exception to DPR's use of the most sensitive functional data available as the critical study would be DPR's rejection of the Honma et al. studies (1987, 1991) on mechanisms for use in the risk characterization. These studies investigated neurochemical endpoints in an attempt to elucidate the mechanisms by which methyl bromide exerts its neurotoxic effects, and implicated primarily the monoaminergic and catecholaminergic systems as potential targets. However, changes in neurochemistry alone do not necessarily indicate toxicity (Overstreet et al. 1974), and these studies did not appear to correlate these neurochemical changes with functional deficits; therefore, the significance of these neurochemical changes cannot be discerned. In addition, there were serious concerns raised by the DPR staff about the design of these experiments because the descriptions of design and methods were overly brief, and it was not clear to the staff whether confounders that could have caused the observed effects had been ruled out. Such issues as contradictions in the data sets obtained or lack of clear dose-response relationships leave these data sets suspect with respect to their suitability for use in a risk characterization. Therefore, the subcommittee concurs with DPR's conclusions that these Honma et al. studies, although suggesting highly sensitive endpoints, are not suitable for use in a risk characterization.

Therefore, neurotoxicity appears to be a prominent form of toxicity elicited by methyl bromide in a variety of laboratory animal studies and is consistent with evidence of neurotoxicity from human studies. Of particular note are studies indicating neurological deficits occurring in those occupationally exposed to methyl bromide at apparently relatively low exposure levels (Anger et al. 1986); these human observations suggest toxic endpoints that need to be considered for a health-protective risk characterization.

SELECTION OF CRITICAL EFFECTS FOR ACUTE TOXICITY

The use of a developmental toxicity study for the assessment of the risks of acute exposure to methyl bromide is a reasonable one, given the principle that a single gestational exposure is sufficient to produce an adverse developmental effect, and in light of the large numbers of women of childbearing age in the workforce. In fact, the EPA Guidelines for Developmental Toxicity Risk Assessment (EPA 1991) state that data from reproductive and developmental toxicity studies should be used in the overall assessment of risk of a compound.

DPR's rationale for using the developmental toxicity studies by Breslin et al. (1990a,b) for assessment of the risk of acute exposure in women of childbearing age is outlined in the document and will be briefly summarized here. First, gallbladder development in the rabbit occurs over 1 to 2 days beginning on gestation day 11.5. Therefore, the assumption that only a single exposure is necessary for the induction of adverse developmental effects is very likely to hold true for this particular effect. Second, the finding of gallbladder agenesis was confirmed when the experiment was repeated. Third, the developmental effects of gallbladder agenesis and fused sternebrae should not be discounted because maternal toxicity occurred in some does. Both defects occurred in offspring of does who did not exhibit neurotoxicity as well as in the offspring of the minority of does who did. In Part 2 of the study, none of the does exhibited neurotoxicity, yet a similar incidence of gallbladder agenesis was observed as in Part 1. In addition, signs of neurotoxicity appeared on gestation day 19, the day 12 of the 13-day exposure. Given that gallbladder development would have been completed 5.5 to 6.5 days before maternal toxicity occurred, it is unlikely that this defect was the result of the maternal toxicity. Moreover, it is not clear that the inconsistent maternal weight changes, which were observed in the 80-ppm groups (significantly lower maternal weight gain compared with controls on some, but not all, gestational days, primarily in Part 2), represented maternal rather than fetal toxicity, because the fetal weights and gravid uterine weights were also significantly lower in the 80-ppm group in Part 2. In addition to DPR's arguments, it should be noted that maternal toxicity has been associated with some developmental abnormalities, including fused sternebrae, but not gallbladder agenesis (Khera 1984; Khera et al. 1989). Moreover, a recent study found no correlation between maternal body-weight change as an indicator of maternal toxicity and various embryo or fetal parameters, including number of anomalies per litter and reduced fetal weight (Chahoud et al. 1999). Finally, another interpretation of the occurrence of maternal and fetal toxicity at the same dose level is that the threshold for toxicity of the test compound is similar in mother and fetus.

The subcommittee considers there to be several counterarguments to using the Breslin et al. (1990b) study to determine the critical NOAEL for acute exposure in women of childbearing age. One, alluded to above, is that the findings of this study, taken on their own, might be considered equivocal evidence for developmental toxicity. The three significant effects—fetal weight decline, fused sternebrae, and gallbladder agenesis—were not statistically consistent between Parts 1 and 2 of the study. Fetal weight was statistically significantly lower in Part 2 in the 80-ppm group, but not in Part 1; gallbladder agenesis was statistically significantly elevated only in Part 1; and skeletal examinations were only performed in Part 1. In addition, fused sternebrae are considered a morphological variation that occurs in 0.27% to 0.92% of untreated control New Zealand White rabbit fetuses (DPR 1999, Tables 5–7, Appendix B). Gallbladder agenesis is a less common developmental abnormality, but it is also considered a variation by some experts. These arguments against the Breslin et al. (1990b) study are weakened by the finding of probable developmental toxicity associated with methyl bromide exposure in another species, the rat, at nonmaternally toxic doses (American Biogenics Corporation 1986; Hardisty 1992, as cited in DPR 1999; Busey 1993, as cited in DPR 1999). Another counterargument is that developmental studies should not be used for acute exposure risk assessment if appropriately performed acute exposure studies exist for the agent in question. This argument ignores the possibility that fetuses might be more sensitive than adults to a given agent and that developmental effects caused by multiday gestational exposures would theoretically be caused by single exposures as well.

Based on the above considerations, DPR's use of the Breslin et al. (1990b) developmental toxicity study to determine the critical NOAEL for acute toxicity for workers and residents appears to be a conservative approach, but one that is justified in the absence of additional data that show that a single exposure at the time of gallbladder development does not cause gallbladder agenesis.

3

Exposure Assessment

BACKGROUND

The National Research Council (NRC) defines exposure to a contaminant as “an event that occurs when there is contact at a boundary between a human and the environment with a contaminant of a specific concentration for an interval of time; the units of exposure are concentration multiplied by time” (NRC 1991). To reliably estimate exposure, environmental monitoring should be conducted to determine contaminant levels, modeling can be used to supplement the monitoring, and potentially exposed populations must be identified and enumerated. Conducting a good exposure assessment requires characterizing the real variability in exposures that are experienced by different groups of people, and different individuals within those groups. In addition, a good exposure assessment integrates an analysis of the uncertainty of the exposure data.

The California Department of Pesticide Regulation's (DPR's) risk characterization document provides exposure estimates for a wide variety of worker and resident exposure scenarios in Sections IV.B, Risk Assessment, and V.C, Risk Characterization, as well as in Appendices F-K. Summary estimates of exposure to methyl bromide, listed in Tables 16–20 of the DPR report, correspond to occupational (Section IV.B.1) and residential (Section IV.B.2) exposure scenarios. The estimates of exposure presented in Tables 16–20 are based on exposure data contained in a report “Estimation of exposure of persons to methyl bromide during and/or after agricultural and non-agricultural uses” by Thongsinthusak et al. (1999) (HS-1659), which is included as Appendix F of the main document.

The exposure information collected in the DPR report came from numerous studies that were conducted for a variety of purposes by several registrants, and therefore were not conducted in a consistent manner nor were they part of a comprehensive and systematic monitoring plan. For instance, DPR points out that many of these studies were not conducted in compliance with Good Laboratory Practices as described in 40 CFR 160 (EPA 1997). Although a variety of analytical techniques were used to determine methyl bromide concentrations in the air samples, these were not reliably tested. In addition, data were collected under different sampling protocols and field conditions (e.g., temperature, relative humidity). For some exposure scenarios, DPR used “default” values due to the lack of specific data on the specific exposure scenarios.

In addition to the limitations described above, DPR acknowledges that the exposure data set is incomplete, as not all potential exposure scenarios are discussed. As stated in the Thongsinthusak et al. (1999) report, “The Department of Pesticide Regulation does not have data to assess all worker exposure scenarios or potential exposure to the public from all methyl bromide applications.” However, DPR fails to enumerate what these data gaps are. The lack of a discussion in the DPR report of the limitations of the exposure data set, including the data gaps, undermines the subcommittee's confidence in the data presented by DPR.

The remainder of this chapter addresses the following three aspects of an exposure assessment; (1) the scenarios used to characterize different exposure groups; (2) the quality of data available for characterizing exposures, including the analytical methods used to quantify the air concentrations, and the representativeness of the available air sampling that was conducted; and (3) the modeling used to estimate exposures that were not directly measured. For each of these items, the subcommittee assesses DPR's treatment of the data and its methodology for estimating exposure.

LIKELY EXPOSURE SCENARIOS

The DPR document describes a wide variety of occupational and some residential exposure scenarios. DPR presents valuable information on the uses of methyl bromide in Tables 2 through 5 of Appendix E (pp. 248–250), which provide an understanding of where the most likely exposures might occur. Approximately 95% of the methyl bromide consumed in California is used in soil fumigation, so this mode of use is necessarily a major focus of the analysis. Structural fumigation comprises about 3% to 4% of the methyl bromide use, and commodity fumigation comprises a relatively minor proportion, about 1% to 2%. Based on these use data for methyl bromide, the committee believes that it is important to describe the exposure scenarios within the following categories: (1) occupational; (2) residential, school, and other; and (3) residents returning to fumigated houses. Each of these categories and DPR's coverage of these exposure groups is addressed below.

"Occupational" refers to people who work directly in or around fumigation operations. These individuals are likely to have the most intense exposures and include such labor categories as field applicators (soil fumigators— including pilots, copilots, shovelmen, and workers who remove tarps), structural applicators, and commodity fumigators and aerators. The occupational exposure estimates presented in the DPR report are based on measurements conducted in soil fumigation and commodity fumigation scenarios. The jobs evaluated for exposure and the corresponding estimates of exposure are listed in Tables 16–20 (DPR 1999, pp. 96–106), which include estimates for acute (daily), short-term (7-day), seasonal (90-day), and chronic exposures (annual). A total of 160 exposure categories are listed. Most of the exposure data were measured with personal monitoring devices. The exposure estimates are reported in parts per billion (ppb) and the acute exposure category includes both high and mean values. All other exposure categories are listed as mean values. The 24-hr time-weighted maximal exposures range from a high of 8,458 ppb for sea-container aerators to a low of 0.6 ppb for shallow-shank nontarped bed shovelmen. Numerous job exposures are listed as "n/a," which the table footnote explains as either "not applicable" or "no exposure information available." Unfortunately, it is not clear to the subcommittee which situation applies for a given job category and there is no explanation as to why certain categories of exposure are not applicable to certain jobs.

"Residential, school, and other exposures" refers to people who are exposed to methyl bromide due to its atmospheric transport from the site of direct application. This category specifically includes residents in houses, students in schools, and occupants of buildings near fumigated fields, structures, or near fixed commodity fumigation facilities. This category is expected to contain the most sensitive groups of potentially exposed persons, because it is a cross section of the entire population, and therefore would include the very young and old, as well as other persons that might have heightened sensitivity.

DPR provides no data on exposures to individuals in homes or other buildings near fumigated fields; however, it does provide exposure data on structural fumigations. Gibbons et al. (1996a,b, as cited in DPR 1999) measured methyl bromide concentrations for 24-hr periods in houses located within 50 to 100 feet of fumigated houses. Air sampling in the nonfumigated houses was conducted in rooms closest to the fumigated houses. The measured concentrations range from 0.024 parts per million (ppm) (the limit of detection) to

0.406 ppm. It is unclear from the DPR report how many samples were non-detects. Mean concentration values were 0.024 ppm for nearby houses and 0.060 ppm for "downwind" houses. Downwind is not defined in the DPR report.

Information on exposures to people in residences, schools, and unrelated workplaces near commodity fumigation facilities is based on exposure estimates for workers in those facilities (Haskel 1998a,b). No actual air sampling was conducted to evaluate this nonworker scenario. The assumptions used in this scenario (DPR 1999, Appendix H, page 343) specify that residents are exposed to methyl bromide concentrations at 210 parts per billion (ppb) (24-hr time-weighted average), the maximum permissible exposure level specified in the permit. The subcommittee considers the information provided by DPR insufficient for evaluating the quality of the data used for this assumption and for evaluating the validity of extrapolating from worker exposures to exposures of nearby residents.

"Residents returning to fumigated houses" can be subjected to a wide variety of concentrations, depending on the characteristics of the house and the retention of methyl bromide in spaces in the houses, such as wall voids. This exposure group includes highly-susceptible individuals such as children (NRC 1993), the ill, the elderly, and those with genetic polymorphisms (see Chapter 2). DPR presents exposure measurements from five houses in southern California that were fumigated on a single day followed by 24-hr of active aeration, such as with a fan. (These data are discussed in greater detail below in the section entitled "Exposure of Residents in a Fumigated House".)

In addition to DPR's coverage of the three exposure scenarios above, there are other population groups and exposure scenarios that are never addressed by DPR. For example, DPR never describes or provides data on exposures to children and the elderly, who might be more sensitive to methyl bromide than the worker or general adult populations. Furthermore, DPR never addresses exposure scenarios for residents living near fumigated fields, because these homes were considered to be outside of the permit buffer zone. Therefore, DPR assumed that the maximum concentration to which these individuals could be exposed was 210 ppb. However, the DPR report fails to provide any monitoring data that supports this assumption.

Other exposure scenarios not covered by DPR include elevated exposures that occur when multiple agricultural fields are treated during the same time period in one area (e.g., many strawberry fields treated simultaneously or consecutively in Salinas county). It is possible that workers and individuals living near the treated fields could experience higher exposure levels than predicted by the permit conditions. For example, there are no data on 6-week to 3-month exposures that individuals who live in agricultural areas might re ceive if multiple methyl bromide applications occur during a season. A reasonable worst-case scenario could be described as multiple nearby fields being treated simultaneously with the air mass moving towards a residential neighborhood located in a lower area of a valley. The subcommittee is not confident that under these conditions, exposures of children and adults to methyl bromide concentrations above the 6-week reference concentrations of 1 and 2 ppb, respectively, do not, or are unlikely to, occur.

Finally, DPR does not address less common exposure scenarios that might occur under unique weather and terrain conditions, such as when a low-level temperature inversion or other similar low-wind condition prevents the dilution of methyl bromide that would normally be expected to occur. Workers and residents living in such an area could be exposed to high methyl bromide concentrations. DPR describes such an exposure scenario in Appendix F, page 253, where 35 bystanders experienced methyl bromide poisoning as a result of low winds and a temperature inversion during and following the applications.

The subcommittee recognizes the difficulty DPR would have in considering all these potential exposure scenarios. However, the subcommittee believes that these likely scenarios need to be evaluated, either by collection of additional monitoring data or by appropriate modeling. Only by doing so can the public have confidence in DPR's assertion that the concentrations to which they are exposed are consistently below regulatory levels.

QUALITY OF DATA AVAILABLE FOR CHARACTERIZING EXPOSURES

This section addresses issues relating to the quality of data available for characterizing exposures, including (1) the analytical methods used in quantifying methyl bromide concentrations; (2) the representativeness of available exposure measurements; (3) the appropriateness of normalizing assumptions used by DPR for different application rates; and (4) the appropriateness of exposure-duration assumptions used in the risk characterization document.

Analytical Methods

The subcommittee has serious concerns about the analytical methods used by DPR and others to determine atmospheric concentrations of methyl bromide. For the most part, these concerns focus on the fact that the initial field-sampling studies were conducted prior to the development of standardized analytical recovery methodologies. In addition, the lack of information on the atmospheric conditions under which the field samples were collected calls into question the recovery values that were used to calculate actual concentrations of methyl bromide in ambient air.

The uncertainty in the recovery values is expressed in a report by Biermann and Barry (1999), which was written after collection of all of the field-sampling data for methyl bromide between 1992 and 1998. Although the analytical method for extracting methyl bromide from the samples had been used previously, it appears that a rigorous testing of the method has not been conducted. The primary uncertainty with the analytical method centers on the procedure for recovering methyl bromide from the charcoal tubes that are used to collect ambient air samples. Prior to the Biermann and Barry (1999) study, recovery values were determined by adding a known amount of methyl bromide in solution to the charcoal, followed by extraction of the charcoal with an organic solvent. It was assumed that addition of methyl bromide in solution to the charcoal was identical to collecting methyl bromide from the gas phase through the charcoal. The percent of methyl bromide recovered from the solution application was considered by DPR to be identical to the percent of methyl bromide recovered from the charcoal in the actual air samples. Biermann and Barry (1999) demonstrated that recovery of air-trapped methyl bromide from the charcoal is only about 50%, whereas the recovery of solution-added methyl bromide from charcoal was reported to be 69% in the field tests. Therefore, the field sample concentrations determined prior to the Biermann and Barry (1999) study were assumed by DPR to have been underestimated by approximately 50%. In its report, DPR calculated the expected concentrations for all the sampling data using the 50% recovery value, based on the Biermann and Barry (1999) study.

The subcommittee considers the 50% recovery estimate of Biermann and Barry (1999) to be questionable for many of the air samples. The 50% recovery estimate is based on samples collected under normal laboratory conditions with ambient air temperatures of between 20 °C and 25 °C and 20% and 80% relative humidity. However, when Biermann and Barry (1999) took the test system outdoors and did air sampling during the warm daytime temperatures, recoveries were as low as 21% to 26%. In contrast, when the same tests were conducted during the night, recovery estimates were 45% to 48%. Furthermore, when air samples were taken at very low relative humidity (0%), recoveries of methyl bromide were only 0% to 3%. Because relative humidity and air temperature were not considered when the exposure- assessment data were compiled by DPR, and because the sampling data were primarily collected during the daytime, the actual recoveries might be lower than the 50% used by DPR. In addition, the recovery of methyl bromide from the charcoal tubes appears to be dependent on the initial methyl bromide concentration. For instance, in the storage-stability experiment described in Biermann and Barry (1999), recoveries of methyl bromide concentrations at 95 ppb were 5% to 10% lower than recoveries of concentrations at 710 ppb. At even lower concentrations (Biermann and Barry 1999, Table 11), charcoal spiked with 19 ppb methyl bromide yielded 0% recovery; however, only one sample at this low concentration was examined. This 19-ppb concentration was twofold higher than the reporting (detection) limit of the California Department of Food and Agriculture laboratory that did the analysis. The subcommittee is concerned about the lack of reliable recovery estimates at low methyl bromide concentrations, because the reference concentrations (RfCs) for subchronic and chronic exposures to children and adults are 1 and 2 ppb, respectively. The subcommittee believes that DPR and other analytical laboratories might not be able to adequately measure atmospheric concentrations of methyl bromide at or near these RfCs.

The recovery study by Biermann and Barry (1999) provides quantitative information on several environmental factors (e.g., humidity, concentration, temperature) that appear to affect the reliability of ambient air-sampling results of methyl bromide in the field. The field-sampling data presented in the DPR report were collected by at least six different groups, during several time periods (July 1992; October 1992; November 1992; February 1993; and March 1993) and at various locations in California (Santa Maria, Arvin, Chowchilla, Salinas, Hayward, Watsonville, and Madera). Because of the different times and locations at which the air sampling was conducted, it is to be expected that the temperature and humidity levels for each study varied considerably. Daytime temperatures in July and August in the Central Valley of California are often above 100°F, probably near the temperature at which the outdoor recovery study of Biermann and Barry (1999) was conducted, for which reported methyl bromide recoveries were 21 to 26%. Air samples obtained in the cooler months of the year (November-April) were probably collected at temperatures reflective of the 50% recovery of the Biermann and Barry (1999) laboratory samples.

Several of the studies by Siemer and Associates, TriCal, Inc., and AG-Industrial reported that the sampling data was initially adjusted for a recovery of 69% (DPR 1999). However, the DPR report presents no information on whether these 69% recoveries were based on actual samples taken at the time these studies were conducted, or were based on a standardized recovery value. The subcommittee believes that it is unlikely that the 69% recovery used by the several researchers was based on actual laboratory testing, given the uniformity of the recovery estimates. Furthermore, DPR states that, “a field fortification recovery study was not carried out in many of the exposure studies”

(DPR 1999, Appendix H, p. 274). Radian Corporation conducted an additional sampling study and used a slightly different analytical technique (head-space gas chromatography) to determine the methyl bromide air concentrations, but did not report a recovery value (DPR 1999). Air Toxics Limited conducted yet another study using charcoal tubes and a limited number of stainless steel (SUMMA) canisters, which do not have the same recovery problems as charcoal[1]. Recoveries were reported to be in the range of 74% to 125%. Finally, DPR itself conducted residential exposure studies in fumigated houses. Average recoveries were reported to be 71.4%, with a range of 49% to 102%. The location, temperature, and relative humidity for each house appears to be subject to the same variability and uncertainty as for the outdoor air-sampling studies discussed previously.

The analytical data from these studies are clearly compromised by the lack of a robust analytical method for measuring methyl bromide concentrations in air. Because of the ease and lower cost of methyl bromide collection using charcoal as compared with stainless steel canisters, the charcoal method will probably continue to be the method of choice. Therefore, the subcommittee finds that (1) a systematic study should be conducted to assess the usability of the previous sampling data obtained with charcoal tubes and (2) a sampling method should be developed that will provide reliable air concentration data. To accomplish these goals, the following issues should be addressed:

1. Are there types of charcoal (e.g., coconut shell) that give more reliable recoveries than the petroleum-based charcoal used for many of the reported exposure studies?
2. What are the effects of temperature on recovery values? Should the charcoal tubes be maintained at some specific temperature (e.g., 15– 18°C) during sampling to minimize degradation of methyl bromide during long (e.g., 12 hr) collection times?
3. Are there methods to minimize the effect of humidity on sample recovery?
4. For each sampling trip, what is the minimum number of samples that should be taken using an alternative method (e.g., stainless steel canisters) to compare recoveries?
5. How does the recovery vary with time of sampling and concentration? What is the limit of detection?

[1]Stainless steel canisters are generally evacuated and the sample is captured by allowing air to flow into the canisters. The only surfaces that the methyl bromide comes into contact with in these canisters is the relatively inert stainless steel surface, which is distinctly different from the very large and complex surface of charcoal.

6. A routine method for conducting field-recovery studies should be developed that permits direct air sampling, rather than solvent spiking. Conducting a recovery study using gaseous samples would reduce the uncertainty in the available exposure data.

The subcommittee recognizes the difficulties faced by DPR in using the available sampling data for the exposure assessment. Because the initial field sampling was conducted prior to the critical recovery study, DPR was obliged to use a single recovery study to reevaluate a large number of sampling studies. The air concentrations used in the exposure assessment include an undetermined level of uncertainty due primarily to the uncertainty in the actual analytical recoveries obtained when the samples were collected under field conditions. Nevertheless, the subcommittee feels the data are still very useful and provide important information on methyl bromide emissions from treated areas. With the caveats mentioned previously about air temperature, humidity, and concentration effects on recovery, the 50% adjustment used by DPR appears to be reasonable for most of the samples collected in the cooler months and for concentrations that are greater than 50 ppb. For air samples taken at higher temperatures, the methyl bromide concentrations are probably underestimated, potentially by a factor of 2. If, for example, the outdoor recovery values of 21% to 26% were to prove typical, then the average methyl bromide concentrations would be expected to be about double those estimated by DPR. Because this data set was the primary information used to develop the exposure assessment, and it appears to be the bulk of the information presently available, it is important to place some level of uncertainty on the data. For these purposes, the subcommittee suggests that the actual exposures might be considerably higher than even the adjusted estimates presented by DPR.

Representativeness of Available Exposure Measurements

A representative sample of a diverse group of exposures is a sample that is constructed such that the central tendency (mean) and distribution (standard deviation) of exposure levels observed in the sample are likely to be free of systematic differences from actual exposures that are being assessed. The data presented by DPR reflect a wide variety of occupational exposure scenarios and explicitly represent differences in such factors as soil application methods, depth of application, type of tarping, and soil characteristics. However, even within the occupational exposure groupings, the data indicate very large ranges in exposure concentrations, often of several orders of magnitude. For instance, 24-hr time-weighted average exposures varied widely: for preplant soil injection of methyl bromide they ranged from 0.6 to 835 ppb, for fumigation of grain products from 6 to 6,039 ppb, and for residents downwind of a fumigated house exposures were estimated to range from 40 to 296 ppb. The sources of these variability ranges have not been characterized in the DPR report.

However, aside from these broad ranges in variability, the measurements made for individual scenarios frequently reflect only a single set of samples collected on a single day for one type of exposure. There is little or no discussion in the DPR analysis of how well factors affecting the air sampling, such as air temperature, soil type, wind conditions, and humidity, reflect the actual exposure level distributions in practice for the occupational groups studied. In general, there is an absence of information on the conditions (e.g., temperature, wind conditions, humidity) under which air-concentration measurements were made. Therefore, the subcommittee believes that there is considerable uncertainty about how accurately the observed measurements represent the real distributions of exposure concentrations and durations in the occupational groups that were studied.

Appropriateness of Normalizing Assumptions for Different Application Rates

To estimate occupational exposure levels from soil fumigation, DPR made a simple linear adjustment from the application rates used to the maximum permitted application rates. For example, if the maximum permitted application rate was 400 lb/acre, but only 200 lb/acre was used on the field, where the air concentrations were measured, DPR adjusted the measured air concentrations upward by twofold.

The subcommittee has two reservations about this procedure: the first pertains to the physical transport and transformation of methyl bromide, and the second pertains to the stated goals of the exposure analysis. In the first case, a simple linear adjustment is reasonable if one assumes that the only important mechanisms involved in the transport of methyl bromide between the sites of soil injection and the workers' breathing zones are mixing and dilution, which lead to simple first-order loss independent of concentration. However, if physical sorption to soil particles, and chemical reactions with soil constituents are important, then it is possible that there could be a distribution of sites of high affinity adsorption, or high rate reaction, and that these preferential binding/reaction sites would not be available during methyl bromide soil applications. In this case, methyl bromide applied at higher rates could encounter less effective sorption or reaction in the soil than methyl bromide applied at lower rates, and relatively more methyl bromide could be expected to be available for inhalation by workers. Therefore, there is some risk that the worker exposures at maximally permitted application rates could be somewhat understated.

In the second case, if the goal of the exposure analysis is to represent exposures under the worst-case conditions permitted by the pesticide labels, then the subcommittee agrees that some adjustment for application rates should certainly be made. However, if the goal of the exposure analysis is to represent the distributions of exposure levels that actually exist for the workers, then DPR's goal should be to assure that the exposure data collected appropriately reflect the actual distribution of application rates that are used in practice. If the collected data differ from the exposure distribution being studied, then adjustments should be made to reflect the actual distribution of application rates.

Appropriateness of Exposure-Duration Assumptions

To calculate exposures for durations longer than a single day, DPR has made a large number of assumptions (some of which might be considered relatively conservative) about how many days workers might be exposed at mean levels observed in 1-day studies (DPR 1999, Appendix F, pp. 284–289). The explanation for these assumptions is contained in a single paragraph on page 261:

> Calculations of exposure rely on factors, including application rates, work periods specified in the current California permit conditions, frequency and duration of exposure. Types of tarpaulins, application equipment, and injection depth are used in the permit conditions to determine the maximum daily work time for each type of soil injection fumigation. DPR has requested registrants to provide frequency and duration of exposure for acute and non-acute exposures (Donahue 1997, as cited in DPR 1999). So far, registrants have provided some data as requested. Consequently, default frequency and duration of exposure for many exposure scenarios were generated from data obtained from various sources and the use of professional judgment (Haskell 1998a,b, as cited in DPR 1999). These default values are shown in Appendix A [of the DPR document].

Without more explicit documentation of the specific derivation of the numbers in Appendix F, and the overall goals of this exposure analysis, the subcommittee cannot readily assess the appropriateness of the exposure duration assumptions used.

ACCURACY AND APPROPRIATENESS OF AVAILABLE MODELING TOOLS

Exposure Estimates Based on Modeling

Modeling is an essential tool of risk analysis. It allows us to use our mechanistic understanding of a system to draw inferences about exposure levels and associated risks, even in cases in which we do not have an extensive set of direct observational data. As discussed in more detail below, the subcommittee concludes that in general the basic structure of the residential indoor air dilution and outdoor air dispersion models used in the DPR exposure assessment are appropriate. However, the subcommittee finds that in some cases important questions about the variability of modeled exposures have not been addressed in the DPR report. For example, the subcommittee questions whether DPR has made an appropriate effort to juxtapose model predictions with field observations to characterize the quantitative uncertainties in the model predictions. The subcommittee questions whether DPR has used its models to assess the relevant variability in exposures and risks to different individuals and populations.

DPR presents exposure estimates for individuals in fumigated homes or living near commodity-fumigation facilities in Table 19 (DPR 1999, p. 105) of the report. Several of these estimates are based either on regulatory permit levels that are apparently derived from modeling or on model projections themselves; these include exposures of (1) residents in a fumigated house (Table 19-c), (2) residents living near commodity fumigation facilities (Table 19-d), and (3) residents living near fumigated fields (Table 19-e). The modeling approaches supporting each of these cases are addressed below, with (2) and (3) discussed concurrently.

Exposure of Residents in a Fumigated House

The data for the analysis of exposure of residents in a fumigated house were drawn from air concentrations measured in five houses in southern California fumigated on a single day (April 7, 1992) at 1.5 lb/1000 ft^3, and actively aerated using fans for 24 hr before closing the windows. (Data for a sixth house were excluded, reportedly because of a relatively short sampling time.) The data, consisting of a total of 32 methyl bromide concentration measurements made at times ranging from 3 to 92 hr after the end of the initial 24-hr aeration period, are presented in Table 36 (Columns 1 and 2) (DPR 1999, Appendix F). DPR used a single-compartment, simple-dilution model to esti mate methyl bromide concentrations after 72 hr of active aeration using the aggregate data from all five homes. This was done by fitting a simple linear regression line to a plot of the logarithm of the observed concentrations versus time. The fitted line (Equation 3–1) is

$$\mathrm{Log(MB)}=-0.008195\times(t)-0.148086 \quad r^2=0.34955, \quad (3\text{–}1)$$

where MB is concentration of methyl bromide (in ppm), t is number of hours after 24-hour aeration, and r^2 is correlation coefficient.

DPR used this fitted regression line to predict residential exposures for a 1-week period (168 hr) beginning at either 48 or 49 hr after the 24-hr active ventilation (72 hr after the fumigation) without apparent further adjustment for the possibly greater reduction in concentrations that might occur from the 48 additional hours of active ventilation. (DPR requires that active ventilation be carried out for 72 hr after the fumigation, although for these data active ventilation was only done for 24 hr.) To estimate exposure concentrations in northern California, where the fumigation rate is twofold higher (3.0 lb methyl bromide/1,000 ft^3) than in southern California, a simple linear twofold adjustment was made to the methyl bromide concentrations (DPR 1999, Table 36, Columns 4 and 5).

The subcommittee reproduced the regression equation above and derived confidence limits on the rate of exponential decline in methyl bromide concentration over time in Equation 3–2 below.

$$\mathrm{Log\ (MB)}=-0.008197 \pm 0.00204\times(t\pm\text{std error}) -0.1480 \quad r^2=0.3497, \quad (3\text{–}2)$$

where MB is concentration of methyl bromide (in ppm), t is number of hours after 24-hr aeration, and r^2 is correlation coefficient.

This regression equation allowed the subcommittee to verify the stated 7-day mean concentrations and associated confidence limits in Table 37 (DPR 1999, Appendix F) of 86±73 ppb (15–229) and 172±147 ppb (30–458) for southern and northern California, respectively. It also permitted the subcommittee to determine 24-hr estimates of methyl bromide concentrations to compare with the regulatory target level of 210 ppb that is assumed to apply for the 24 hr immediately following the reentry of residents into their homes. These data are presented in Table 3–1, in which the estimated average methyl bromide concentrations for 1 day and 7 days after the 24-hr ventilation period are shown, along with the standard errors.

A comparison of the subcommittee projections of the central tendency and upper 95% confidence limits for the 7-day average exposure levels (Table 3– 1) with the data in Table 37 (DPR 1999, Appendix F) shows that the values correspond closely. However, DPR appears to have made a twofold error in transposing these 7-day results to Table 19c (DPR 1999, p. 105) where the values are given as 172±146 and 344±294 ppb for southern and northern California, respectively.

Aside from the apparent transposition error for the 7-day results, there appear to be deeper problems with DPR's analysis. The grouping of data from five different houses yields, at best, a central estimate of the concentration levels that is likely to be present for residents reentering an average house. This estimate does not reflect the variability among houses in air exchange rates between contaminated wall spaces and the main living areas, and between the living areas and outdoor air. The subcommittee believes that separate analyses of data from each of the five houses would have allowed DPR to make a first-cut assessment of the differences among houses in both initial concentrations of methyl bromide (following 24 hr of active ventilation) and the rates of decline. Because the average methyl bromide concentrations are already relatively high in relation to the regulated target level of 210 ppb (Table 3–1), neglecting this variability raises some concern, although the concern is somewhat mitigated by the fact that DPR apparently made no adjustment for the increased active ventilation period that might occur in practice (i.e., 72 hr versus 24 hr of active ventilation).

Finally, DPR's assumption that the acute 24-hr exposure limit of 210 ppb is achieved is not supported by even the central tendency (median) estimate from the modeled data for the northern California application rate (Table 3–1). This 210-ppb level is based on a calculation that assumes that methyl bromide

TABLE 3–1 Projected 1- and 7-Day Average Methyl Bromide Concentrations (ppb) for Residents Reentering Fumigated Homes

	−2 SE[a]	−1 SE	Median Estimate	+1 SE	+2 SE
Southern California 7-day mean	39	57	87	138	226
Southern California 1-day mean (48 to 72 hr following 24-hr ventilation)	133	175	231	305	404
Northern California 7-day mean	77	114	174	275	452
Northern California 1-day mean (48 to 72 hr following 24-hr ventilation)	266	351	463	611	808

[a]1 and 2 standard error (SE) departures from the central estimate of the regression slope.

concentrations measured at electrical outlets or other enclosed spaces within the wall of a home will be equal to or less than 3 ppm when reentry is permitted. The 210-ppb level also implies that these within-wall measurements accurately reflect the average concentration in a well-mixed wall volume that represents only about 5.6% of the volume of the house, and that the 24-hr average concentrations for the residents reflects immediate mixing of the wall volume contents with those of the living areas of the house, and no loss of methyl bromide from the house during the first 24 hr. Several of these assumptions appear incompatible with the direct observations made from the analysis of the five houses modeled above.

First, the slope of the exponential decline in methyl bromide concentrations (Equation 3–2) reflects a half-life of about 37 hr (with 95% confidence limits of 24 to 73 hr). The average air exchange rate, a general method for expressing ventilation, is 0.019 exchanges per hour (95% confidence limits of 0.009 to 0.028 air changes/hr) in these houses (see Appendix C of this report). This air exchange rate estimate is considerably lower than rates observed in the living areas of other homes. (For example, EPA (1996) reported 24-hr average air exchange rates from approximately 0.33 to 2.2 air changes/hr (10% to 90% range) for 175 houses in Riverside, California.) The low air exchange rates observed for these five homes indicate that the controlling factor for the overall decline of methyl bromide concentrations over time (as observed in DPR 1999, Table 36, Appendix F) cannot be attributed to general house ventilation, but probably reflects slow transfer of methyl bromide between the wall spaces and the living areas. Given this, and the convoluted geometry of wall spaces, the subcommittee questions DPR's assumption that measurements made at one or a few enclosed spaces within the wall are representative of a well mixed space.

The subcommittee also has concerns with the fact that all the data used in the analysis (DPR 1999, Table 36, Appendix F) come from fumigations made on the same day in a similar area of southern California. This means that the data do not account for differences in varying external temperatures, wind conditions, and humidity, and possibly, house structural characteristics in different areas of California and at different times of the year.

Because of the uncertainties surrounding the current data set on exposures of residents returning to fumigated homes, the subcommittee finds that DPR's conclusion that current fumigation practices result in methyl bromide concentrations that do not exceed the regulatory exposure level of 210 ppb does not seem warranted. Further data collection and analysis of exposure concentrations in routinely fumigated homes at different seasons and for different types of homes in various areas of California seems necessary if methyl bromide use as a house fumigant is to be continued with confidence.

Exposure of Residents Downwind from Soil Fumigations

The other major modeling effort in the DPR exposure analysis examines whether residents living near fumigated fields and commodity fumigation facilities are exposed to methyl bromide concentrations that exceed the acute (24-hr) regulatory limit of 210 ppb. These exposures are regulated by an extensive set of permit requirements implemented at the county level and are based on assumptions about the rate of air emissions from soil fumigation operations of various types. A standard air dispersion modeling system, the Industrial Source Complex-Short Term computer model (EPA 1995), is used to calculate the size of buffer zones that are required to prevent methyl bromide concentrations at the boundary from exceeding 210 ppb. DPR used the 210-ppb value to represent the acute exposures of residents near fumigated fields and commodity fumigation facilities in Table 19-d (DPR 1999, p. 105). This 210 ppb value represents an assumption by DPR that the permitting system as currently implemented is working. However, DPR fails to enumerate any underlying conservative assumptions used in their modeling, and does not describe the variability or uncertainty associated with the actual implementation of the permits.

The subcommittee attempted to evaluate DPR's assumption that the 210-ppb exposure level is not being exceeded at the buffer zone boundary. To conduct this analysis, empirical data contained in Table H1 (DPR 1999, Appendix H) of the DPR report were compared with the 210-ppb limit. Table H1 lists 39 maximum methyl bromide concentrations measured between 1992 and 1998 at or near buffer-zone boundaries at field fumigation sites. DPR describes the sampling methodology used to generate these data as follows (DPR 1999, Appendix H, p. 357):

> In these studies, air monitoring was conducted using personal air sampling pumps equipped with activated charcoal tubes. The samplers were set up around the field at a distance of 30 feet from the edge of the field and at the permit condition buffer zone determined for the application. Sampling was initiated at the start of the application and continued for one to seven days, with each sampling interval 6–12 hr. The air flow rate for all samplers was calibrated to approximately 15 mL/min. Wind speed, wind direction, air temperature, and relative humidity were recorded every five minutes with a Met-1 meteorological station.

In Table 3–2, some of the data from Table H1 (DPR 1999, Appendix H) have been reproduced, showing the sampling year, sampling distance, permit condition buffer zone, and methyl bromide concentration (Columns b, c, d, and g, respectively). Additional calculations have been made by the subcommittee, including Column e, the absolute distance between sampling distance

TABLE 3–2 Maximum Methyl Bromide Air Concentrations from Different Application Methods

(a) Case Number in Table H1	(b) Year	(c) Sampling Distance (ft)	(d) Permit Condition Buffer (ft)	(e) Permit Buffer-Sampling Distance	(f) Sampling Distance as Fraction of Permit Buffer	(g) 24-hr Max MB Concen. (ppm)
1	92	300	390	90	0.77	0.042
2	92	300	330	30	0.91	0.260
3	92	50	330	280	0.15	0.550
4	98	200	200	0	1.00	0.150
5	92	600	1060	460	0.57	0.700
6	92	600	1170	570	0.51	0.610
7	98	510	510	0	1.00	0.110
8	93	200	2010	1810	0.10	0.560
9	93	200	940	740	0.21	0.340
10	95	80	780	700	0.10	0.110
…	…	…	…	…	…	…[a]
30	97	625	420	−205	1.49	0.590
31	92	300	300	0	1.00	0.060
32	96	330	550	220	0.60	1.700
33	97	360	360	0	1.00	0.160
34	97	360	360	0	1.00	0.550
35	98	60	200	140	0.30	0.160
36	98	30	100	70	0.30	0.066
37	98	30	100	70	0.30	0.072
38	98	30	100	70	0.30	0.065
39	98	30	100	70	0.30	0.042
Mean	0.260					
Std. Deviation	0.332					
Std. Error	0.052					
Geom. Mean	0.145					
Geom. Std. Dev.	2.882					

[a]Case numbers 11–29 have been deleted.

Source: Adapted from DPR 1999, Appendix H, Table H-1, pp. 358–360.

(Column c) and the buffer boundary (Column d), and Column f, the ratio of the sampling distance (Column c) to the buffer boundary (Column d). The discussion of these data in the DPR report (DPR 1999) notes that:

> of the 39 applications monitored, seven exceeded the 0.21 ppm target level at the buffer zone distance…Tarpaulin-bedded applications and applications using "very high barrier" tarpaulins appeared to have higher air concentrations than originally assumed in the permit conditions. Of the seven tarpaulin-bedded applications monitored, four exceeded the 0.21 ppm target level at the original buffer zone distance. Of the five very high barrier tarpaulin applications monitored, three exceeded the target level at the original buffer zone distance. None of the other application methods exceeded the target level at the buffer zone distance.

In addition, a footnote in Appendix H (DPR 1999, p. 361) notes that "DPR revised the buffer zones in 1997 and 1998 to provide a higher margin of safety. Under the revised buffer zones, none of the 39 fields monitored exceed 0.21 ppm at the buffer zone distance." Unfortunately, aside from this footnote in the report, no details are provided on the nature and extent of the modifications of buffer zones for the individual cases listed in Table 3–2, nor does DPR indicate how they adjusted the measured data to arrive at their conclusion that none of the cases would have exceeded 0.21 ppm had measurements been taken at the new buffer-zone boundaries.

In Table 3–3, the subcommittee has summarized the data presented in Table 3–2. Methyl bromide concentrations are stratified by distances greater or less than 90% of the buffer zone for pre-1998 and 1998 periods. The data in Table 3–3 suggest that in 1998, methyl bromide concentrations at the prescribed buffer-zone boundaries were lower than those measured prior to 1998. Forty-three percent of the pre-1998 concentrations at the buffer-zone boundary were expected to exceed the regulatory limit of 210 ppb, whereas only 7% of the 1998 concentrations were expected to be over this limit.

Overall, if the 1998 data presented in Tables 3–2 and 3–3 are representative of current permit conditions, the percentage of soil fumigation operations that would result in methyl bromide concentrations at the buffer-zone boundary of greater than 210 ppb is expected to be relatively modest. To make such a conclusion, the subcommittee finds that further data are needed. The 1998 data set of measurements at or near the buffer zones of 30 and 100 feet is very limited. As indicated in Table 3–3, there are only four measurements taken in 1998 at distances greater than or equal to 90% of the buffer zone boundaries. Data collected prior to 1998 suggest that the modeling program estimated methyl bromide concentrations at the buffer-zone boundary that are at or near

TABLE 3–3 Summary Statistics for the Distribution of Methyl Bromide Measurements Near Buffer Zone Boundaries

Sample Group	Pre-1998, distances <90% of buffer	1998, distances <90% of buffer	Pre-1998, distances >90% of buffer	1998, distances >90% of buffer
Arithmetic mean (ppm)	0.422	0.070	0.286	0.083
Arithmetic standard error (ppm)	0.135	0.012	0.082	0.028
Number of measurements	12	9	13	4
Geometric mean (ppm)	0.239	0.065	0.177	0.067
Geometric standard deviation	3.255	1.469	2.756	2.167
Percent expected to exceed 210 ppb	54	<1	43	7
Projected 90th percentile (ppm)	1.1	0.11	0.65	0.18
Projected 95th percentile (ppm)	1.7	0.12	0.94	0.24
Projected 98th percentile (ppm)	2.7	0.14	1.4	0.33

the 210-ppb limit. This is supported by the arithmetic and geometric concentration means of 0.286 ppm and 0.177 ppm, respectively. However, the subcommittee notes that there is a certain proportion of the measurements that exceed 210 ppb at the buffer-zone boundary, occasionally by several-fold, as indicated by concentrations of 0.65 ppm, 0.94 ppm, and 1.4 ppm at the projected 90th, 95th, and 98th percentiles, respectively.

The subcommittee reviewed two DPR documents that update the material provided in Appendix H of the DPR report (Segawa et al. 2000a,b). These documents provide detailed directions for calculating flux rates and buffer-zone distances for the proposed regulations. Although it is not within the subcommittee's task to comment on the appropriateness of the proposed regulations, it is relevant to the foregoing analysis to note DPR's comparison of buffer-zone distance with monitoring data (Segawa et al. 2000a, p. 8). The authors state that, based on new modeling for 34 applications examined,

> buffer zone table distance was greater than the distance to 0.21 ppm estimated by the ISC [Industrial Source Complex] model for 33 of the 34 applications. On average, the buffer zone table distance exceeded the distance to 0.21 ppm by 520%, with a median of 400% (Table 3). We made these calculations when the monitoring data were originally analyzed using unadjusted air concentrations of the first version of the ISC model. DPR is updating these calculations using adjusted air concentrations and version 3 of the ISC model.

Segawa et al. (2000b) contains a table similar to Table H1 in Appendix H of DPR's report showing maximal concentrations measured at 30 feet, application rates, and proportions calculated to be volatilized using both unadjusted and adjusted measurement recoveries. However, there is no direct presentation analogous to Table H1 of methyl bromide concentrations expected at the revised buffer-zone distances. Therefore, the subcommittee cannot determine the frequency distribution for maximally observed concentrations at the revised buffer-zone distances based on the available information. Accordingly, the subcommittee is unable to fully evaluate the accuracy of the modeling used for estimating off-site residential exposures in the DPR report, nor can the subcommittee determine if the proposed, or even current, buffer zones actually protect nearby residents from exposures to methyl bromide concentrations greater than 210 ppb.

SUMMARY

The DPR report contains a large compilation of exposure data, particularly on worker exposures. However, the subcommittee finds that DPR's exposure analysis is lacking in several respects. Certain exposure scenarios are not dealt with at all in the report, including exposures to residents living near fumigated fields and potentially elevated exposures to residents and workers resulting from methyl bromide application to several fields simultaneously. The subcommittee believes that it is extremely important for DPR to address such exposures, considering that 95% of methyl bromide is used in soil fumigation. Furthermore, there is considerable uncertainty surrounding the analytical recovery methods used in the exposure-assessment studies. Much of the data presented by DPR is based on single air-concentration measurements. There is no discussion of the representativeness of these measurements to the actual exposures experienced by the potentially exposed populations. In addition, DPR makes numerous assumptions regarding durations and levels of exposures, which the subcommittee believes are not explained in sufficient detail to understand their appropriateness. The subcommittee believes that further data collection and analysis are necessary to accurately assess both worker and residential exposures to methyl bromide.

4

Risk Characterization

In this chapter, the National Research Council's (NRC's) subcommittee on methyl bromide considers the material covered in Sections IV and V of the California Department of Pesticide Regulation's (DPR's) risk characterization document. In Section IV, “Risk Assessment,” DPR justifies the selection of the toxicological endpoints and the critical no-observed-adverse-effect levels (NOAELs) used in the risk characterization, presents the exposure assessment in the form of tables of exposure measurements for different occupational and residential exposure categories, and presents margins of exposure for each of those categories based on the critical NOAELs and the exposure measurements. In Section V, “Risk Appraisal,” DPR addresses the uncertainties in the toxicological and exposure databases, discusses the factors used for intraspecies and interspecies extrapolation, and discusses issues related to the Food Quality Protection Act.

RISK CHARACTERIZATION GOALS

As defined by the NRC (1994) “risk characterization combines the assessments of exposure and response under various exposure conditions to estimate the probability of specific harm to an exposed individual or population. To the extent feasible, this characterization should include the distribution of risk in the population.” To properly perform a risk assessment, the hazard posed by the agent must be assessed in terms of the adverse health effects it can cause, the dose-response must be characterized, and the intensity, frequency, and duration of exposure should be determined. The quality of information available for each of these risk characterization components governs the quality of the eventual estimate of risk to individuals by the use of methyl bromide. DPR has addressed each of these risk assessment components in its risk characterization document. In the sections below, the subcommittee reviews DPR's presentation of the information it gathered and analyzed in assessing the risk to agricultural workers and the general population from methyl bromide exposures.

HAZARD IDENTIFICATION

DPR has presented a substantial amount of experimental information on the toxicology of methyl bromide, including the response to various concentrations of the chemical. A number of observations in humans following methyl bromide exposure have been made but preclude a determination of a dose-response relationship. Furthermore, the actual absorbed dosage of methyl bromide is difficult to determine in either animal studies or reports of human exposure. Obviously, in the absence of true dose-response information, the concentration-response is a usable guide for judging, with high confidence, the ambient levels of the chemical that can be expected to represent no harm to humans.

Acute Toxicity Database

The database for the derivation of an acute reference concentration (RfC) includes a single exposure inhalation study with the rat (Driscoll and Hurley 1993), a repeated exposure study with the dog (Newton 1994b), and two well-conducted developmental toxicity studies in different species, the rabbit (Breslin et al. 1990b) and the rat (Sikov et al. 1981). In addition, there is a supporting two-generation reproductive study in the rat and pharmacokinetic studies following inhalation exposure. Therefore, the subcommittee considers the database for the derivation of an acute RfC to be good.

The subcommittee believes that DPR's use of a study with repeated exposures (Newton 1994b) as the critical study on which to base an acute RfC for children is conservative and ensures safety. The NOAEL from a study that uses a single exposure rather than repeat exposures is sufficient to derive an acute RfC provided that there is quantitative dose-response information, the study is conducted with the most sensitive species, and there is a sufficient database of supplemental toxicological information. However, because the rodent study with a single exposure to methyl bromide (Driscoll and Hurley 1993) resulted in a NOAEL that was three times higher than the NOAEL derived from the critical study with the dog (Newton 1994b), the rodent study would have resulted in a less conservative RfC.

With respect to the developmental studies by Breslin et al. (1990a,b), the subcommittee also considered it appropriate for determining an acute NOAEL for the assessment of the risks of acute occupational and residential exposure to methyl bromide. This is plausible given that a single gestational exposure is theoretically sufficient to produce an adverse developmental effect (EPA 1991), particularly blockage of gallbladder development (gestation day 11.5 to 12.5), which occurs over the course of approximately 24 hr in the rabbit. Furthermore, there are large numbers of women of childbearing age in the workforce. Finally, the maternal toxicity that occurred in the Breslin et al. studies (1990 a,b) should not negate the observed developmental effects because gallbladder development occurred 5 to 6 days before the dams displayed toxicity and because only a minority of the dams displayed toxicity. The lowest-observed-adverse-effect level (LOAEL) (80 parts per million (ppm)) used by DPR was based on the dose at which gallbladder agenesis, fetal weight declines, and fused sternebrae were noted. The NOAEL was 40 ppm, resulting in an RfC of 210 ppb.

Subchronic Toxicity Database

In addition to the above-cited developmental endpoints, there were also neurotoxic endpoints selected as critical effects for both the acute and the subchronic time periods. These endpoints were both from a single dog study (Newton, 1994b) in which the dogs at the lowest doses showed signs of depressed activity and the dogs at the higher doses and longer exposure periods showed severe signs of neurotoxicity. Because neurotoxic signs are a prominent feature of human methyl bromide intoxication, this neurotoxicity study in the dog appears to be reasonably selected as the critical study. The acute endpoint was for a NOAEL of 103 ppm, with human equivalent NOAELs of 45 ppm and 25 ppm for adults and children, respectively. Because these were higher than the human equivalent NOAEL calculated from the rabbit developmental study, an RfC was not calculated from this study.

The database for the subchronic studies appears to be quite extensive; there were numerous studies that DPR had an opportunity to evaluate to select a critical study for subchronic toxicity. DPR's selection appears to be appropriate in that they selected a study performed for regulatory purposes that was carefully designed and conducted according to the contract laboratory's standard operating procedures. The one drawback about this study (Newton 1994b) is that it was conducted to establish dose levels for a proposed chronic study (which was subsequently not performed) and not originally planned as a formal subchronic study. As a result, there were decisions made midway through the study by the authors to change the study design with respect to duration or dose levels. There were only four dogs of each sex per treatment group, which is a very small number of replications. The critical observation was made outside the standard operating procedures by a trained veterinarian on two female dogs only, which leaves the observation somewhat equivocal. However, to be conservative, the subcommittee agrees that this still appears to be the most suitable critical study out of a total of 26 studies presented as possibilities by DPR. On the other hand, the subcommittee notes that if these observations on the two dogs at 5 ppm are not considered real manifestations of methyl-bromide-mediated neurotoxicity, selection of another study (e.g., Sikov et al. 1981) as the critical one would raise the NOAEL by approximately an order of magnitude, that is, to 20 ppm (see Table 2–1).

The subchronic estimated LOAEL of 5 ppm is equivocal because of the lack of a dose-response curve at the lower dose levels, the observation of depressed activity in two of eight dogs outside the standard protocol procedures, and the low number of replications. However, the seriousness of the neurotoxicity observed in humans and the potential long-term nature of the neurological effects makes this equivocal observation reasonable as a conservative endpoint.

Chronic Toxicity Database

The existing database identified by DPR for derivation of an RfC for chronic toxicity includes two well-conducted chronic studies with different species, supported by subchronic studies in several species, a two-generation reproduction study, other data on developmental and reproductive effects, and pharmacokinetic studies employing inhalation exposure. The subcommittee considers the database available for derivation of a chronic RfC for methyl bromide good and neither of the key studies had major inadequacies.

The chronic LOAEL (3 ppm) used by DPR was based on the lowest dose that caused changes in the olfactory epithelium in rats exposed to methyl bromide for 29 months (Reuzel et al. 1987, 1991). No effects were observed in the tracheobronchial or pulmonary regions of the respiratory tract and no other exposure-related effects were noted at this concentration. The LOAEL was 30 ppm for all other more adverse effects. The NOAEL and LOAEL for respiratory effects, and also for all other effects, in the NTP study (1992) with mice were 33 ppm and 100 ppm, respectively. The critical endpoint selected from the Reuzel et al. study (1987) is appropriate as more pronounced nasal lesions have been observed at higher concentrations in shorter-term studies (Eustis et al. 1988; Hurtt et al. 1988); however, the critical endpoint in this case is observed at increased incidences only in aged rats, making it an equivocal endpoint. The Hurtt et al. (1988) study indicated that the lesions observed after exposure to methyl bromide at 200 ppm, 6 hr/day for 105 days, were largely reversible. Another consideration is the endpoint of reduced growth of neonatal rats. The NOAEL and LOAEL for reduced growth of neonatal rats in the two-generation reproduction study by American Biogenics Corporation (1986) were 3 and 30 ppm, respectively. Therefore, the Reuzel et al. study (1987) has the lowest LOAEL of the studies considered appropriate for derivation of the RfC. The subcommittee agrees with DPR's choice of this endpoint, with the notation that at the 3-ppm concentration the effects are mild and increased incidences (but not necessarily severity) are observed only in aged rats.

Developmental Neurotoxicity

Methyl bromide is clearly a neurotoxicant in human adults; neurotoxic signs are prominent following high-level human exposures and one study suggests that mild neurotoxic effects might also occur at low levels (Anger et al. 1986). Methyl bromide also is a developmental toxicant as indicated by laboratory animal studies. Therefore, there is reason to suspect that methyl bromide could be a developmental neurotoxicant, which suggests that data from a developmental neurotoxicity test would be informative to the risk assessment. However, the subcommittee finds that the developmental neurotoxicity test, as it is currently described in the U.S. Environmental Protection Agency (EPA) guidelines (EPA 1991), might be inadequate to identify and characterize specific developmental neurotoxicants. Therefore, the utility of data from such a test for DPR's regulatory needs is unclear, and the subcommittee finds that the risk characterization conducted on the currently available database by DPR is probably sufficient for identifying appropriate NOAELs.

EXPOSURE ASSESSMENT

Although DPR has assembled a large data set of occupational exposure studies for methyl bromide, the exposure assessment based on that data set has a number of shortcomings. First, the methyl bromide concentrations in air are compromised by the lack of a robust analytical method for making such measurements. Although the 50% recovery adjustment used by DPR appears to be reasonable for many of the samples, the subcommittee considers it likely that the actual concentrations in air are underestimated rather than overestimated. The measured exposure data for any one occupational exposure category are variable and sparse and nonexistent for residents living near fumigated fields. For approximately one-third of the exposure groups assessed, the data consist of a single measurement. The variability in the exposure measurements reflects the inherent variability in environmental measurements as well as the lack of a comprehensive and systematic sampling program. The subcommittee realizes that DPR was constrained to work with the available monitoring data that was often collected by outside parties, such as growers and manufacturers, for different purposes.

In the exposure assessment, DPR uses various categories of exposure, including acute (24-hr), short-term (7-day), seasonal (subchronic), and chronic. DPR's treatment of these durations and the subcommittee's consideration of them is presented below.

Appropriateness of Acute-Exposure Definition

DPR's use of an acute (24-hr) exposure period is more reasonable for the residential exposure scenario than for an acute occupational (8-hr) exposure scenario. Some individuals, such as infants, young children, or elderly persons, might indeed spend most of a given 24-hr period inside the residence. However, it is unlikely that a worker will be exposed for 24 hr. For the occupational acute-exposure scenario, a shorter duration approximating the length of a work shift (8 hr) would have been more appropriate. This is particularly true for the exposure assessments and the margin of exposure analyses. For example, from the acute neurotoxicity study in dogs (Newton et al. 1994a,b, summarized in Table 3 of DPR 1999, p. 42), it can be seen that a 24-hr exposure to 50 ppm would not be the toxicological equivalent of a 6-hr exposure to 200 ppm. In dogs, a 24-hr exposure to 50 ppm is well tolerated, whereas a 6-hr exposure to 200 ppm would likely cause acute neurological signs. This becomes even more problematic for very short exposures. The 24-hr time-weighted average of a 1-hr exposure to 1,200 ppm is also 50 ppm, but based on the dog neurotoxicity study and the LC_{50} data presented in Table 1 of the DPR report (p. 35), this is likely to be a lethal exposure for at least some of the animals. The subcommittee believes that humans would not respond differently from laboratory animals in this regard.

As a practical matter, because DPR normalized both the methyl bromide concentrations from the exposure assessment studies and the methyl bromide concentrations from the toxicity studies to 24 hr, the end effect might be that the two cancel each other out for the occupational exposure scenario, and the result might lead to a more conservative risk assessment for the residential exposure scenario. This is because the studies that DPR used to determine the critical NOAELs for acute toxicity all used exposure durations of 6 to 8 hr. DPR then normalized the NOAEL concentrations to 24 hr using concentration/exposure duration relationships. Thus, the actual exposure durations used in the studies were good approximations for an acute occupational exposure, and the two normalizations essentially canceled one another out when the margins of exposure (MOEs) were calculated. On the other hand, as already mentioned, a 6-hr exposure to 200 ppm is likely to be more acutely toxic than a 24-hr exposure to 50 ppm. Thus, the 24-hr normalized NOAEL might be lower than a NOAEL derived from actual 24-hr exposures would be. Because the residential exposure measurements should be made over 24 hr, and therefore would not have to be normalized, the MOEs for the residential exposure scenarios would be more conservative than the occupational MOEs. As discussed in Chapter 3 of this report, the fact that few actual exposure measurements were made for the residential exposure scenarios is a separate problem with the risk assessment.

Subchronic Exposure

DPR defines two categories of subchronic exposure: short-term and seasonal. The subcommittee agrees with DPR that it is appropriate to have a subchronic exposure category to describe worker exposures in preplant soil fumigation and commodity fumigation, and that a subchronic category might also be appropriate for residents of fumigated houses or residents who live near fumigation facilities. As outlined in Section IV of the DPR report (Table 19, p. 105) residents might have short-term exposures by virtue of moving back into a fumigated house. Residents may also have seasonal exposures as a result of living near fumigation facilities. The subcommittee also believes that it is plausible that residents living near fumigated fields might be exposed to methyl bromide for periods lasting longer than 24 hr, and therefore, that Section IV should include an exposure assessment for short-term and seasonal exposures to residents near fumigated fields.

The subcommittee does not believe that it is appropriate to assume, based on the short half-life of unmetabolized methyl bromide, that the effects of methyl bromide are completely reversed a few days after cessation of expo sure. The subcommittee bases this statement on the fact that toxicology studies suggest that longer exposures are associated with lower NOAELs than shorter studies, indicating that some processes involved in methyl bromide toxicity are not likely to be quickly (within a few days) or completely reversible. Therefore, the subcommittee concurs with DPR that the seasonal exposure category is an appropriate one for workers who have repeated exposures to methyl bromide, separated by periods up to several days, over the course of a season.

As stated in Table 15 (DPR 1999, p. 92) and the description of the exposure durations in the DPR report (DPR 1999, p. 10), the durations for the short-term and seasonal scenarios appear to be 1 week and 6 weeks, respectively. These are the treatment durations at which effects were observed in the two critical subchronic studies identified by DPR (Sikov et al. 1981; Newton et al. 1994b). However, elsewhere in the document, DPR states that the seasonal exposure duration is “greater than one month” (DPR 1999, p. 90), and still elsewhere as 90 days (DPR 1999, Section IV.B, p. 93). The subcommittee believes that the appropriate duration is 90 days because the seasonal uses noted above are likely to last longer than 1 month or 6 weeks. The distinction between the duration of the critical studies and the actual durations of exposure for the scenarios should be clarified in Tables 15 to 20. The subcommittee concurs with the point made in the DPR report (p. 90) that the seasonal NOAEL might have been lower if the dogs in the critical study had been exposed for longer than 6 weeks (Newton et al. 1994b). However, as already discussed in this report, the subchronic RfC derived from that study is a fairly conservative one, and therefore, probably protective even for longer exposure durations.

Chronic Exposure

Chronic exposure generally refers to a 70-year (lifetime) continuous exposure to the chemical of concern. There does not appear to be chronic nonoccupational exposures for any populations associated with field agricultural applications, because the application of methyl bromide is on a seasonal basis, not year round. However, the subcommittee believes that chronic nonoccupational exposures could be possible for residents near commodity-fumigation facilities or transport facilities, where fumigation of commodity storage warehouses or shipping containers might occur on a year-round basis. Fumigation workers also might have chronic exposures.

The subcommittee believes that DPR's normalization of the 6 hr/day, 5 days/wk, exposure of the lifetime study for rats to a 24-hr/day lifetime expo sure for humans is appropriate, but notes that it adds another layer of conservativeness to the derived value. The RfC should be applied to lifetime exposures. The subcommittee disagrees with DPR's definition of chronic exposure for humans as “a year or more” (DPR 1999, p. 4), because this definition does not agree with the accepted EPA definition (EPA 1989) of chronic exposure as a period between 7 years (approximately 10% of a human lifetime) and a lifetime. Subchronic exposures are defined by EPA as ranging from several months to several years.

MARGIN-OF-EXPOSURE ANALYSIS

DPR has done a tremendous amount of work in pulling together a very large amount of exposure information to compare with methyl bromide concentrations and durations of toxicological concern. DPR has chosen to use an MOE, a ratio of the critical human equivalent NOAEL to the estimated human exposure levels, to characterize the risks posed to agricultural workers, nearby residents, and residents returning to fumigated homes. Nevertheless, the MOE analysis is one of the least satisfying aspects of the DPR document.

The risk characterization document, as reviewed by the subcommittee, contains neither a statement of DPR's information objectives or data needs, nor does it indicate how the MOE methodology used is related to those needs. There is minimal quantitative treatment of variability and no apparent quantitative analysis of uncertainty (both discussed below). The subcommittee believes that it is critical that DPR explicitly state how these important issues could affect the analysis to produce information that is helpful for decision-making. DPR appears to be using the exposure data to make a large number of binary comparisons (e.g., safe and dangerous) directly from the observed data, with adjustments to the maximum permissible application rate, and assumptions about the repetition of exposures from day to day. The level of concern for safe or dangerous exposure is an MOE of 100; when MOEs are greater than 100, the populations are assumed to have little risk of adverse effects, and when the MOEs are less than 100, there is a cause for concern for potential adverse effects. DPR appears to be asking, “Do the single-day exposure data that have been directly observed for particular groups, such as applicators, indicate that when methyl bromide is used at the maximum permissible application rate, these workers or residents will be exposed to concentrations that provide a less than a 100-fold margin below the projected human-equivalent NOAEL for acute exposures (21 to 45 ppm)?” and “Do the acute exposure data indicate a less than 100-fold margin for the longer-term endpoints based on DPR's assumptions for weekly and seasonal exposures?” In all, the Tables 16–19 (pp. 96–105) of the DPR report give exposure data for

160 different worker and residential groups, and an additional five cases are based on modeling. Even within a specific exposed group, exposure levels for a particular duration are both considerably variable and, depending on the database, uncertain.

"Variability" in modern risk assessment is defined as real differences among cases (Cullen and Frey 1999; Hattis and Anderson 1999; Hattis and Barlow 1996; Hattis and Burmaster 1994; Thompson 1999). Breaking the data down into different kinds of exposed groups, as in DPR's set of 160 exposure categories, addresses one source of variability. However, characterizing the real variability in exposures experienced by different people within an exposed group is also critical for an informative risk evaluation. This especially applies for a toxicant with a highly upward turning nonlinearity in its population dose-response curve because the individuals at the high-end concentration of the exposure distribution are generally at much larger potential risk for more serious adverse effects than more typical members of the exposed group. Variability in exposures is usually characterized by some measure of dispersion, such as the geometric standard deviation for usual unimodal lognormal distributions.

"Uncertainty," in contrast, reflects the imperfection in our knowledge about the true value of a parameter—including parameters characterizing variability. Uncertainty can be reduced by better and more extensive data, improved models, and so forth. Characterizing uncertainty is important in a risk analysis to frankly convey how confident the audience should be in the results and conclusions presented. Commonly used measures of uncertainty include the standard error of the mean or the standard error of the estimate of a regression coefficient in a standard multiple regression analysis (Cullen and Frey 1999; Hattis and Anderson 1999; Hattis and Barlow 1996; Hattis and Burmaster 1994; Thompson 1999).

Of the 160 worker categories presented, the exposure estimates for 59 categories are based on a single air-concentration measurement; 43 categories are assessed based on only two measured air values, and the remaining 58 categories had more than two measurements. The subcommittee finds that the treatment of data from worker and general population groups with these differing amounts of data is neither consistent nor designed to produce useful estimates of exposures of concern with respect to variability and uncertainty. The subcommittee comments on each of these cases below.

Categories with More than Two Data Points

DPR has summarized acute exposures for worker categories when there are more than two data points as the range of the data directly observed (after adjustments for such things as application rates) plus a simple arithmetic mean and arithmetic standard deviation. However, DPR did not appear to calculate a consistent percentile from the observed data. In the current analysis, DPR has implicitly treated with greater conservatism cases in which there are more data points (a higher percentile is used) than cases in which there are fewer data points. Moreover, basing calculations on the highest of N values introduces statistical instabilities into the analysis. Finally, DPR has not provided a rationale for their choice of arithmetic means and arithmetic standard deviations, rather than more typical lognormal statistics. Analyses of data for some groups (e.g., copilots, applicators, tarp removers) by the subcommittee (see Appendix C) indicates that in general lognormal distributions would be more appropriate than would normal distributions, as is usual for exposure distributions. (For further discussion of the use of lognormal distributions for describing the variability in exposures, see Cullen and Frey (1999); Hattis and Burmaster (1994); Thompson (1999).)

Categories with One or Two Data Points

In most cases, DPR has calculated a mean (if there were two points) and listed the higher of two points as the high value. However, in some other cases, a “95^{th} percentile” value is calculated by assuming an arithmetic standard deviation equal to the mean of the one observed data point. DPR does not explain why this is done for some single-point exposure categories and not others. For cases in which there are only one or two data points, the subcommittee encourages DPR to either gather additional data or consolidate related exposure categories on an a priori basis (i.e., not based on the measured levels but based on similarity of the processes generating the exposures) to assemble greater numbers of data points for basic statistical treatment within groups.

UNCERTAINTY ISSUES

In Section V, “Risk Appraisal,” of the DPR report, DPR discusses the limitations of its risk characterization for methyl bromide and how it quantitatively and qualitatively dealt with the specific uncertainties The subcommittee comments upon these limitations and DPR's approach to them below.

Derivation of Reference Concentrations

DPR has developed inhalation RfCs for acute, subchronic, and chronic exposures. When derived from NOAELs, the RfCs reflect 100-fold uncertain ties, with a 10-fold uncertainty for species differences and a 10-fold uncertainty for variations among humans. When NOAELs were estimated from LOAELs, a 10-fold uncertainty was used. DPR states that it is their policy to use a default 10-fold uncertainty factor to estimate a NOAEL from a LOAEL. The subcommittee in general agrees with this application of a default uncertainty factor of 10, particularly where the endpoint is an adverse effect such as neurotoxicity or developmental toxicity. In the case of the chronic RfC, the LOAEL was so mild as to be close to a NOAEL. In that case, the subcommittee suggests that a three-fold uncertainty factor be considered. However, the subcommittee realizes that DPR is constrained to have a chronic RfC no higher that the EPA's chronic RfC of 1.3 ppb. Therefore, DPR's chronic RfC for adults of 2 ppb is reasonable. The subcommittee also agrees that the interspecies and intraspecies uncertainty factors of 10 (for each) applied to the acute and subchronic RfCs are appropriate.

The subcommittee notes that DPR used an older method than EPA's current method for the derivation of its RfCs (EPA 1994). DPR derived separate values for adults and children; this is not possible with the current EPA method. It is interesting to note that although different methodologies were used, the RfCs derived by DPR for adults and children, 2 ppb and 1 ppb, respectively, are similar to EPA's value of 1.3 ppb.

Sensitive Subpopulations

The Food Quality Protection Act of 1996 mandated that the EPA use an additional 10-fold safety factor for infants and children, unless it could be determined from available data that a different factor would be safe. The subcommittee considered the methyl bromide database in light of the three criteria used by EPA to determine the safety factor. The first criterion concerns the completeness and reliability of the toxicology database. As discussed at length in Chapter 2 and earlier in this chapter, the subcommittee finds that the toxicology database for methyl bromide was good overall. The second criterion concerns the completeness and reliability of the exposure database. As discussed in Chapter 3, the exposure database, though flawed, is quite extensive for occupational exposures. In contrast, for residential exposures, the category into which most exposures to children and infants would fall, the database is inadequate. Limited data are available only for residential exposures during fumigation of the residence, not for residents living next to fumigated fields or fumigation facilities. The final criterion concerns the potential for prenatal and postnatal toxicity. The two-generation rat reproduction study (American Biogenics Corporation 1986) and the rabbit and rat developmental toxicity studies (Breslin et al. 1990a,b; Sikov et al. 1981) indicate that methyl bromide is not a potent teratogen, but that it can cause developmental toxicity. The teratogenic effect, gallbladder agenesis, is considered to be a minor malformation and this effect was seen only at doses that caused maternal toxicity. The subcommittee expects that a potent teratogen would cause multiple malformations at doses that do not cause maternal toxicity. As noted in the DPR report, there is some evidence for increased sensitivity of the developing organism to adverse effects of methyl bromide compared with the mothers in rats (American Biogenics Corporation 1986), but not in rabbits (Breslin et al. 1990a,b). Although good otherwise, the reproductive and developmental database lacks a developmental neurotoxicity study. According to DPR (DPR 1999, p. 126), EPA has added an additional uncertainty factor of 3 in the absence of such a study in its recent time-limited tolerances for pesticides.

Given that the NOAELs used for the various exposure scenarios are already quite conservative, the subcommittee felt that an additional safety factor for infants and children was not necessary.

Multiple Exposures

Although DPR acknowledges that workers might receive multiple exposures from methyl bromide, there is only a limited discussion on the potential exposure of residents who live in areas where multiple fields might be fumigated simultaneously or within a short period of time. Because the majority of methyl bromide is used in field applications, residents near treated fields are subject to frequent exposures during the fumigation season. The subcommittee notes that it would be unrealistic to assume that most residents in agricultural areas live near only one treated field. Therefore, the buffer zones established by DPR to be protective of residents adjacent to one field might not be sufficient should the residents be near multiple treated fields. Although these exposures were commented upon in Chapter 3, the subcommittee reiterates that this is a significant data gap in the exposure assessment.

In addition, the subcommittee has concerns regarding repeated exposures of workers, such as soil or structural fumigators, because soil fumigators might have repeated exposures on consecutive days for several months or structural fumigators might be engaged in multiple fumigations on a single day (Anger et al. 1986). The potential that such repeated exposures might occur raises concerns in light of results from Anger et al. (1986) that suggest that relatively low exposure levels (<2 to 3 ppm) of methyl bromide from fumigation might produce slight neurotoxic effects in workers. Additional data on the neurotoxic effects of methyl bromide in exposed workers are needed.

The proposed regulations provide for a 36-hr waiting period between the application of methyl bromide to a field near a school and when school is in session. In practical terms, this means that fumigation of fields near schools are limited to Friday evenings and Saturday. However, DPR makes no provision for school activities that might occur during weekends at the school, particularly outdoor activities such as sports. Such exposures should not be ignored, because children might have greater susceptibility to effects from methyl bromide exposures, and because data suggest that slight neurotoxic effects might occur at low concentrations (Anger et al. 1986).

SUMMARY

DPR characterized the risks associated with exposure to methyl bromide by using an MOE approach. The subcommittee found this approach to be reasonable for determining which workers or residents are likely to be exposed to potentially harmful methyl bromide concentrations. However the subcommittee had concerns about DPR's use of MOEs for risk characterizations and for protecting nonworkers, in particular, people living near fumigated fields. DPR has not indicated how the MOEs are to be used to determine the protectiveness of the buffer zones specified in the application permits. Nor has DPR characterized certain potentially sensitive populations, such as children in schools or living near fumigated fields, although the proposed regulations address the exposure of children by restricting the application times near schools. The subcommittee feels that the uncertainties addressed by DPR in the report, including extrapolating from LOAELs to NOAELs, and from animals to human, although important, are only part of the uncertainties that need to be dealt with in the document.

5

Conclusions and Recommendations

The California Department of Pesticide Regulation (DPR) has put considerable time and effort into the development of its risk characterization document for methyl bromide. The subcommittee agrees that development of a risk characterization, and subsequent risk assessment, is an appropriate approach to be used to protect agricultural workers and the general population from potential adverse effects associated with this widely used pesticide. Below are specific conclusions reached by the subcommittee based on DPR's presentation of the toxicology, exposure, and risk assessment and risk appraisal information for methyl bromide as detailed in DPR's report. Recommendations on improving both the data quality and the analytical approaches used in the risk assessment are presented as a means to assist DPR in identifying at-risk populations and, subsequently, developing regulations to protect them.

TOXICOLOGICAL INFORMATION

Conclusions

- The subcommittee agrees with DPR's selection of the toxicological endpoints and the NOAELs used to derive the inhalation reference concentrations (RfC). The subcommittee considers the NOAELs to be protective and conservative.

- The subcommittee agrees that it is appropriate to use a developmental study for the derivation of an acute RfC for the general population.
- DPR's selection of the dog study (Newton 1994b) with a neurotoxicity endpoint is appropriate for developing a subchronic RfC, but the subcommittee is concerned about whether the decrease in responsiveness seen at exposure to 5 ppm of methyl bromide in two of eight dogs is a true LOAEL or even an effect at all. Nevertheless, the subtle neurological deficits observed in occupationally exposed humans (Anger et al., 1986) supports these animal data that neurotoxic responses can occur at low exposure concentrations. Therefore, the subcommittee concurs with the conservative assignment of the 5 ppm value in this dog study as a LOAEL.
- The rabbit developmental study had toxicity endpoints of gallbladder agenesis and fused sternebrae, which are not considered major malformations; however, the subcommittee feels that these are indicators of developmental toxicity, and therefore, are appropriate endpoints for the developmental RfC (Breslin et al. 1990b).
- The subcommittee agrees with DPR's selection of nasal epithelial hyperplasia as the toxicity endpoint for the chronic RfC, but notes that the effect is mild and might be closer to a NOAEL than a LOAEL.
- In general, DPR's presentation of the toxicological information is clear and easy to follow and permits the reader to follow DPR's logic in selecting critical studies and NOAELs.

Recommendations

- Methyl bromide is a methylating agent that is a direct-acting mutagen in vitro. However, there are good animal studies that indicate it is not carcinogenic. DPR should review the literature for any discussion on methyl bromide and other methylating agents as to why an in vitro mutagen is not an in vivo carcinogen. This could aid in understanding the mechanism of methyl bromide toxicity and lend confidence when extrapolating from the animal data to humans.
- The dog study from which the 6-week subchronic RfC is derived (Newton 1994b) had a small number of animals and some subjective observations that led to a LOAEL of 5 ppm. The subcommittee recommends that a new study be conducted to verify the neurotoxicity endpoints of decreased responsiveness at 5 ppm.
- Further developmental studies on methyl bromide would help to clarify several major issues

- —Does in utero or early postnatal exposure to methyl bromide affect adult reproductive function? This question arises from the observation of apparently reduced fertility in the F1 offspring, but not the F0 parents in a two-generation study (American Biogenics Corporation 1986; Hardisty 1992; Busey 1993).

- —What are the critical exposure periods for expression of reduced pup weights found during lactation and decreased offspring brain weights and dimensions (i.e., are they due to gestational or lactational exposure to methyl bromide?)
- —Is methyl bromide excreted in breast milk? This question could be answered by measuring methyl bromide concentrations in the breast milk of lactating animals exposed to methyl bromide by inhalation.
- —Does gallbladder agenesis occur following a single exposure to methyl bromide during the critical period for gallbladder development?

EXPOSURE ASSESSMENT

Conclusions

- Although the exact levels of exposure for workers and residents are not known, DPR has collected a substantial amount of data that indicate that some of these exposures are significant, exceeding current regulatory limits, and therefore are of concern.
- The measures of exposure are frequently based on a single value with no accompanying information on ambient air temperature, relative humidity, and wind conditions. The lack of representativeness of the measurements is not assessed in the main text of the DPR report and is only acknowledged as a possible confounder in an appendix.
- In general, the subcommittee is highly critical of the analysis and presentation of the available exposure data, finding it seriously deficient in understanding and application of modern concepts of variability and uncertainty, and in the fair evaluation of the magnitude and distribution of existing exposures relative to exposure levels intended to be achieved by current regulatory controls.
- There is considerable room for improvement in the methods used by DPR to obtain monitoring data, particularly with regard to good measurement techniques and sampling strategies that assess variability of actual exposure.
- Information is lacking on exposures to residents living near application areas and exposures for populations subject to aggregate applications (e.g,, those living in basin area where multiple fields have been treated). Available data and modeling suggest that for some populations, exposures might exceed regulatory limits.

- A substantial ambiguity exists for current methods used to measure methyl bromide in air, particularly with respect to recovery values and the field conditions during air sampling. As a result, actual measured air concentrations of methyl bromide and potential exposure levels are uncertain.
- DPR's use of 24-hr averaging for 8-hr exposures adds a further uncertainty to the protectiveness of the regulations.
- DPR's documentation of their exposure assessment is difficult to follow and requires searching through numerous appendices and other documents (many of which were requested by the subcommittee at a later date) to determine the data sources used by DPR and the approach that was used to evaluate and model the data. A roadmap of the information in the appendices and a more systematic presentation of the data would be helpful to the reader. In particular, DPR's discussion of buffer zones and the measurements taken at them, is confusing and appears to be missing important pieces of information.

Recommendations

- DPR should explicitly state what populations or subpopulations are expected to be represented by the scenarios.
- Identify the best analytical methods for determining methyl bromide concentrations in air under a variety of field conditions. The entire risk assessment process is fundamentally dependent on the quality of the analytical information on exposure conditions. A substantial effort is needed to develop rigorous and robust field analytical methods for determining concentrations of methyl bromide. This will require a complete multilaboratory series of tests that can allow a determination of the reliability of analytical information from field samples.
- Conduct systematic recovery analyses of field and laboratory air samples under a variety of air temperature, wind, and relative humidity conditions.
- Establish a new sampling program to determine the representativeness of exposure data with an emphasis on residential (including house fumigations) and high-exposure occupations.
- DPR should consider quantifying—at the very least—the potentially exposed populations in its occupational categories, and if possible, the number of residents near fields, fumigation facilities, and residents returning to fumigated homes.
- DPR should evaluate its exposure data using modern distributional concepts—including both variability and uncertainty to quantify how accurately the observed measurements represent the real distributions of exposure concentrations and durations. The subcommittee believes that analyses intended to support regulations should frankly disclose the expected degree of confi

dence the public should have that real exposures will be kept below regulatory levels for defined percentiles of exposed populations.

RISK CHARACTERIZATION

Conclusions

- The subcommittee overall agrees with the risk characterization for inhalation exposure of methyl bromide. The subcommittee believes that the toxicity endpoints used might be overly conservative due to their equivocal nature, but also believes that the exposure assessments might understate the actual exposures, particularly for residents living near fields where methyl bromide is applied.
- The subcommittee agrees that DPR's use of factors of 10 for intraspecies variation and for animal to human variation, as well as a benchmark margin of exposure (MOE) of 100, is consistent with traditional risk management practices.
- The subcommittee believes that the uncertainties associated with DPR's exposure levels call into question the validity of its MOE values. Given the likelihood that the error in the measurements will underestimate some exposures, the subcommittee anticipates that some MOEs will be lower than those calculated by DPR, some of which already indicate there is a cause for concern (i.e., they are currently less than 100).
- Given the lack of information on methyl bromide drift off-site from fumigated fields, it is unclear to the subcommittee how DPR can develop a coherent and protective plan for buffer zones and injection times for field fumigation as specified in Section 6450 of Title 3 of the California Code of Regulations.
- The subcommittee concludes that DPR has failed to conduct a true risk assessment in that it does not combine both exposure assessments and dose-response assessments to estimate the probability of specific harm to exposed individuals or populations. Furthermore, DPR does not characterize the distribution of risk to the exposed populations.

Recommendations

- Buffer zones should be derived so that they appropriately protect those persons who might spend appreciable amounts of time near treated areas (e.g., residential, schools, offices). These buffer zone distances will need to be based on reasonable worst-case scenarios. Additional field studies should be undertaken to validate these buffer zones.

- At the very least, DPR should characterize occupational and residential exposures with distributions, that is, estimate how many people are likely to be exposed at what levels relative to levels of concern for a given duration of exposure. DPR should also conduct some uncertainty analyses to determine what level of confidence in the exposure values is appropriate given the existing data.
- More neurological testing among those occupationally exposed, particularly at various time intervals after methyl bromide exposures have occurred (instead of during exposures), would enable DPR to look for possible long-term or permanent effects.
- To protect workers and residents from the adverse effects of methyl bromide, DPR must be more explicit about linking its methodology for exposure and MOE analysis to the regulatory levels that are based upon the risk assessment or MOE values. The subcommittee recommends that DPR state at the beginning of its risk characterization document the regulatory goals it hopes to achieve and how its risk characterization will meet them.

In conclusion, the subcommittee recognizes that conducting additional toxicity testing and exposure monitoring is somewhat problematic given the phase-out of methyl bromide in the United States by 2005. Nevertheless, the subcommittee believes that extensive use of this pesticide at this time in California and elsewhere warrants an acknowledgment of existing data gaps that must be addressed to ensure that agricultural workers and residents living near areas where methyl bromide is used are protected against the short-term and long-term health effects of this pesticide. These data gaps might require the combined efforts of regulatory agencies such as DPR and the methyl bromide industry, including manufacturers and pesticide applicators.

References

ACGIH (American Conference of Governmental Industrial Hygienists). 1997. Methyl Bromide in: Supplements to the Sixth Edition Documentation of the Threshold Limit Values and Biological Exposure Indices. Cincinnati, OH: ACGIH.

American Biogenics Corporation. 1986. Two-Generation Reproduction Study Via Inhalation in Albino Rats Using Methyl Bromide. Study 450– 1525. Submitted to Methyl Bromide Panel, c/o Great Lakes Chemical Corporation, W.Lafayette, IN. American Biogenics Corporation, Decatur, IL.

Anger, K.W., L.Moody, J.Burg, W.S.Brightwell, B.J.Taylor, J.M.Russo, N. Dickerson, J.V.Setzer, B.L.Johnson and K.Hicks. 1986. Neurobehavioral evaluation of soil and structural fumigators using methyl bromide and sulfuryl fluoride. Neurotoxicology 7(3):137–156.

Bentley, K.S. 1994. Detection of Single Strand Breaks in Rat Testicular DNA by Alkaline Elution Following in Vivo Inhalation Exposure to Methyl Bromide. Haskell Laboratory Report No. 54–94. Chemical Manufacturers Association. DPR Vol. 123–188 #162362.

Biermann, H.W. and T.Barry. 1999. Evaluation of Charcoal Tube and SUMMA Canister Recoveries for Methyl Bromide Air Sampling. Environmental and Pest Management Branch. DPR. EH99–02 (Appendix K of DPR 1999).

Bond, J.A., J.S.Dutcher, M.A.Medinsky, R.F.Henderson, and L.S. Birnbaum. 1985. Disposition of ^{14}C methyl bromide in rats after inhalation. Toxicol. Appl. Pharmacol. 78(2):259–267.

Bonnefoi, M.S., C.J.Davenport, and K.T.Morgan. 1991. Metabolism and toxicity of methyl iodide in primary dissociated neural cell cultures. Neurotoxicology. 12(1):33–46.

Breslin, W.J., C.L.Zablotny, G.J.Bradley, K.D.Nitschke, and L.G.Lomax. 1990a. Methyl Bromide Inhalation Teratology Probe Study in New Zealand White Rabbits. Final Report. K-000681–032. Study prepared by The Toxicology Research Laboratory, The Dow Chemical Company, Midland, MI for The Methyl Bromide Industry Panel, Chemical Manufacturers Association, Washington, DC.

Breslin, W.J., C.L.Zablotny, G.J.Bradley, and L.G.Lomax. 1990b. Methyl Bromide Inhalation Teratology Study in New Zealand White Rabbits. Final Report. K-000681–033. Study prepared by The Toxicology Research Laboratory, The Dow Chemical Company, Midland, MI for The Methyl Bromide Industry Panel, Chemical Manufacturers Association, Washington, DC.

Busey, W.M. 1993. Neuropathological Evaluation of Brains from F0 and F1 Rats in Two-generation Reproduction Study with Methyl Bromide Pathology Report. EPL project number 303–007. DPR Vol. 123–153 #125516.

Chahoud, I., A.Ligensa, L.Dietzel and A.S.Faqi. 1999. Correlation between maternal toxicity and embryo/fetal effects. Reprod. Toxicol. 13(5):375– 381.

Cullen, A.C. and H.C.Frey. 1999. Probabilistic Techniques in Exposure Assessment. A Handbook for Dealing with Variability and Uncertainty in Models and Inputs. New York: Plenum Press.

Disse, M., F.Joo, H.Schulz and J.R.Wolff. 1996. Prenatal exposure to sodium bromide affects the postnatal growth and brain development. J. Hirnorsch. 37(10):127–134.

Djalali-Behzad, G., S.Hussain, S.Osterman-Golkar, and D.Segerback. 1981. Estimation of genetic risks of alkylating agents. VI. Exposure of mice and bacteria to methyl bromide. Mutat. Res. 84(1):1–9.

Donahue, J.M. 1997. DPR letters dated November 12. (Letters were sent to six MB registrants requesting data on frequency and duration of exposure). WH&S. DPR.

DPR (Department of Pesticide Regulation). 1992. Toxicology Review Prompts Changes in Structural Fumigations. Release no. 92–07. Department of Pesticide Regulation, California Environmental Protection Agency.

DPR (Department of Pesticide Regulation). 1999. Methyl Bromide, Risk Characterization Document for Inhalation Exposure. Draft RCD 99–02. Department of Pesticide Regulation, California Environmental Protection Agency. October 1999.

Driscoll, C.D. and J.M.Hurley. 1993. Methyl Bromide: Single Exposure Vapor Inhalation Neurotoxicity Study in Rats. Lab. Project ID 92N1197. Study prepared by Bushy Run Research Center, Union Carbide Chemicals and Plastics Company, Export, PA for The Methyl Bromide Industry Panel, Chemical Manufacturers Association, Washington, DC.

EPA (U.S. Environmental Protection Agency). 1989. Risk Assessment Guidance for Superfund, Vol. I. Human Health Evaluation Manual, Part A. EPA/540/1–89/002. Washington, DC: EPA, Office of Emergency and Remedial Response.

EPA (U.S. Environmental Protection Agency). 1991. Guidelines for Developmental Toxicity Risk Assessment. EPA/600/FR-91/001. Washington, DC: EPA, Office of Research and Development.

EPA (U.S. Environmental Protection Agency). 1994. Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry. EPA/600/8–90/066F. Washington, D.C.: EPA, Office of Research and Development.

EPA (U.S. Environmental Protection Agency). 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models. Volume 1. User Instructions. U.S. EPA Office of Air Quality Planning and Standards; Emissions, Monitoring and Analysis Division, Research Triangle Park, North Carolina. Online. Available: www.epa.gov/ttn/scram/

EPA (U.S. Environmental Protection Agency). 1996. The Particle TEAM (PTEAM) Study: Analysis of the Data: Final Report. Volume III. EPA/600/R-95/098. Research Triangle Park, NC: EPA, Office of Research and Development.

EPA (U.S. Environmental Protection Agency). 1997. Good Laboratory Practices. 40 Code of Federal Regulations, Part 160.

Eustis, S.L., S.B.Haber, R.T.Drew, and R.S.Yang. 1988. Toxicology and pathology of methyl bromide in F344 rats and B6C3F1 mice following repeated inhalation exposure. Fundam. Appl. Toxicol. 11(4):594–610.

Gansewendt, B., U.Foest, D.Xu, E.Hallier, H.M.Bolt, and H.Peter. 1991. Formation of DNA adducts in F-344 rats after oral administration or inhalation of [^{14}C] methyl bromide. Food Chem. Toxicol. 29(8):557–563.

Garnier, R., M.O.Rambourg-Schepens, A.Muller and E.Hallier. 1996. Glutathione transferase activity and formation of macromolecular adducts in two cases of acute methyl bromide poisoning. Occup. Environ. Med. 53(3):211–215.

Gibbons, D.B., H.R.Fong, R.Segawa, S.Powell and J.Ross. 1996a. Methyl Bromide Concentrations in Air Downwind During Aeration of Fumigated Single-Family Houses. HS-1713. March 20, 1996. Worker Health and Safety Branch. Department of Pesticide Regulation. California Environmental Protection Agency, Sacramento, CA.

Gibbons, D.B., H.R.Fong, R.Segawa, S.Powell, and J.Ross. 1996b. Methyl Bromide Concentrations in Air Near Fumigated Single-Family Houses. HS-1717. March 20, 1996. Worker Health and Safety Branch. Department of Pesticide Regulation. California Environmental Protection Agency. Sacramento, CA.

Gotoh, K., T.Nishizawa, T.Yamaguchi, H.Kanou, T.Kasai, M.Ohsawa, H. Ohbayashi, S.Also, N.Ikawa, S.Yamamoto, T.Noguchi, K.Nagano, M. Enomoto, K.Nozaki, and H.Sakabe. 1994. Two-Year Toxicological and Carcinogenesis Studies of Methyl Bromide in F344 rats and BDF1 Mice. Proceedings of the Second Asia-Pacific Symposium on Environmental and Occupational Health held 22–24 July, 1993 in Kobe, Japan.

Hallier, E., S.Deutschmann, C.Reichel, H.M.Bolt and H.Peter. 1990. A comparative investigation of the metabolism of methyl bromide and methyl iodide in human erythrocytes. Int. Arch. Occup. Environ. Health. 62(3): 221–225.

Hallier, E., T.Langhof, D.Dannappel, M.Leutbecher, K.Schroder, H.W. Goergens, A.Muller and H.M.Bolt. 1993. Polymorphism of glutathione conjugation of methyl bromide, ethylene oxide and dichloromethane in human blood: influence on the induction of sister chromatid exchanges (SCE) in lymphocytes. Arch. Toxicol. 67(3):173–178.

Hardisty, J.F. 1992. Histopathological Evaluation of Brains From Rats-Inhalation Study of Methyl-Bromide. EPL project number 303–007. DPR Vol. 123–142 #113606.

Haskell, D. 1988a. Methyl bromide fumigation with various commodities. A memorandum dated May 11 to Thomas Thongsinthusak. WH&S, DPR. HSM-98003.

Haskell, D. 1988b. Response to DAR request for additional information regarding frequency and duration of methyl bromide fumigations. A memorandum date August 24 to Thomas Thongsinthusak. WH&S, DAR. HSM-98006.

Hattis, D. and E.Anderson. 1999. What should be the implications of uncertainty, variability, and inherent ‘biases'/'conservatism' for risk management decision making? Risk Anal. 19 (1):95–107.

Hattis, D. and K.Barlow. 1996. Human interindividual variability in cancer risks-technical and management challenges. Human Ecol. Risk Asssess 2(1):194–220.

Hattis, D. and D.E.Burmaster. 1994. Assessment of variability and uncertainty distributions for practical risk analyses. Risk Anal. 14(5):713–730.

Honma, T., M.Miyagawa, and M.Sato. 1987. Methyl bromide alters catecholamine and metabolite concentrations in rat brain. Neurotoxicol. Teratol. 9(5):369–375.

Honma, T., M.Miyagawa, and M.Sato. 1991. Inhibition of tyrosine hydroxylase activity by methyl bromide exposure. Neurotoxicol. Teratol. (13)1:1–4.

Honma, T., A Sudo, M.Miyagawa, M.Sato, and H.Hasegawa. 1982. Significant changes in monoamines in rat brain induced by exposure to methyl bromide. Neurobehav. Toxicol. Teratol. 4(5):521–524.

Hurtt, M.E., D.A.Thomas, P.K.Working, T.M.Monticello, and K.T.Morgan. 1988. Degeneration and regeneration of the olfactory epithelium following inhalation exposure to methyl bromide: Pathology, cell kinetics, and olfactory function. Toxicol. Appl. Pharmacol. 94(2):311–328.

Jaskot, R.H., E.C.Grose, B.M.Most, M.G.Menache, T.B.Williams, and J.J. Roycroft. 1988. The distribution and toxicological effects of inhaled methyl bromide in the rat. J. Am. Coll. Toxicol. 7(5):631–642.

Kaneda, M., N.Hatakenaka S.Teramoto, and K.Maita. 1993. A two-generation reproduction study in rats with methyl bromide-fumigated diets. Food Chem. Toxicol. 31(8):533–542.

Kaneda, M., H.Hojo, S.Teramoto, and K.Maita. 1998. Oral teratogenicity studies of methyl bromide in rats and rabbits. Food Chem. Toxicol. 36(5):421–427.

Khera, K.S. 1984. Maternal toxicity: a possible factor in fetal malformations in mice. Teratology 29 (3):411–16.

Khera, K.S., H.C.Grice HC, and D.J.Clegg, eds. 1989. Current Issues in Toxicology, Interpretation and Extrapolation of Reproductive Data to Establish Human Safety Standards. New York: Springer.

Kornburst, K.S., and J.S.Bus. 1983. The role of glutathione and cytochrome P-450 in the metabolism of methyl chloride. Toxicol. Appl. Pharmacol. 67(2):246–56.

Kramers, P.G., C.E.Voogd, A.G.Knaap, and C.A.van der Heijden. 1985. Mutagenicity of methyl bromide in a series of short-term test. Mutat. Res. 155(1–2):41–47.

McGregor, D.B. 1981. Tie II Mutagenic Screening of 13 NIOSH Priority Compounds. National Institute for Occupational Safety Health. Inveresk Research Int. Ltd. DAR Vol. 123–103 #66718, #66719, #66720, #66721, and #66722.

Medinsky, M.A., J.A.Bond, J.S.Dutcher, and L.S.Birnbaum. 1984. Disposition of [^{14}C] methyl bromide in Fischer-344 rats after oral or intraperitoneal administration. Toxicology. 32 (3):187–196.

Medinsky, M.A., J.S.Dutcher, J.A.Bond, R.F.Henderson, J.L.Mauderly, M.B.Snipes, J.A.Mewhinney, Y.S.Cheng, and L.S.Birnbaum. 1985. Uptake and excretion of [14C] methyl bromide as influenced by exposure concentration. Toxicol. Appl. Pharmacol. 78 (2):215–225.

Mertens, J.J.W.M. 1997. A 24-Month Chronic Dietary Study of Methyl Bromide in Rats. Laboratory Study no. WIL-49014. WIL Research Laboratories. DAR Vol. 123–179 #158746.

Michalodimitrakis, M.N., A.M.Tsatsakis, M.G.Christakis-Hampsas, N. Trikillis, and P.Christodoulou. 1997. Death following intentional methyl bromide poisoning: toxicological data and literature review. Vet. Hum. Toxicol. 39(1):30–34.

Mitsumori, K., K.Maita, T.Kosaka, T.Miyaoka, and Y.Shirasu. 1990. Two-year oral chronic toxicity and carcinogenicity study in rats of diets fumigated with methyl bromide. Food Chem. Toxicol. 28(2):109–119.

Moriya, M., T.Ohta, K.Watanabe, T.Miyazawa, K.Kato, Y.Shirasu. 1983. Further mutagenicity studies on pesticides in bacterial reversion assay systems. Mutat. Res. 116(3–4):185–216.

Mortelmans, K.E., and G.F.Shepherd. 1980. In Vitro Microbiological Mitotic Recombination Assay of Methyl Bromide Using S. cereisiae D3. SRI International. DAR Vol. 123–044 #913095.

NRC (National Research Council). 1991. Human Exposure Assessment for Airborne Pollutants: Advances and Opportunities. Washington, DC: National Academy Press.

NRC (National Research Council). 1993. Pesticides in the Diets of Infants and Children. Washington, DC: National Academy Press.

NRC (National Research Council). 1994. Science and Judgement in Risk Assessment. Washington, DC: National Academy Press.

Nelson, H.H., J.K.Wiencke, D.C.Christiani, T.J.Cheng, Z.F.Zuo, B.S. Schwartz, B.K.Lee, M.R.Spitz, M.Wang, X.Xu, et al. 1995. Ethnic differences in the prevalence of the homozygous deleted genotype of glutathione S-transferase theta. Carcinogenesis 16 (5):1243–1245.

Newton, P.E. 1994a. An Up-and-Down Acute Inhalation Toxicity Study of Methyl Bromide in the Dog. Study no. 93–6067 prepared by Pharmaco LSR, East Millstone, NJ for Chemical Manufacturers Association, Washington, DC.

Newton, P.E. 1994b. A Four Week Inhalation Toxicology Study of Methyl Bromide in the Dog. Study no. 93–6068 prepared by Pharmaco LSR, East Millstone, NJ for Chemical Manufacturers Association, Washington, DC.

Newton, P.E. 1996. A Chronic (12-Month) Toxicity Study of Methyl Bromide Fumigated Feed in the Dog. Study no. 94–3186. Huntingdon Life Science. DAR Vol. 123–175. #143945.

NTP. (National Toxicology Program). 1992. Toxicology and Carcinogenesis Studies of Methyl Bromide (CAS No. 74–83–9) in B6C3F1 Mice (Inhalation Studies). Tech. Rep. Series No. 385. Research Triangle Park: U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health.

OEHHA (Office of Environmental Health Hazard Assessment). 1993. Proposition 65: Safe Use Determination Workshop for Methyl Bromide (Tuesday November 30, 1993.) Transcript. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment. 205 pp.

OEHHA (Office of Environmental Health Hazard Assessment). 1999. Com ments on the Department of Pesticide Regulation's Draft Risk Characterization Document for Inhalation Exposure to the Active Ingredient Methyl Bromide. From Anna M.Fan, California Office of Environmental Health Hazard Assessment, to Gary T.Patterson, California Department of Pesticide Regulation, September 1, 1999 (Appendix L of DPR 1999).

Overstreet, D.H., R.W.Russell, B.J.Vasquez, and F.W.Dalglish. 1974. Involvement of muscarinic and nictonic receptors in behavioral tolerance to DFP. Pharmacol. Biochem. Behav. 2 (1):45–54.

Peter, H., S.Deutschmann, C.Reichel, and E.Hallier. 1989. Metabolism of methyl chloride by human erythrocytes. Arch. Toxicol. 63(5):351–5.

Putnam, D.L. and M.J.Morris. 1991. Micronucleus Cytogenetic Assay in Mice. Microbiological Assoc. Inc. DAR Vol. 123–136 #99090.

Raabe, O.G. 1986. Inhalation Uptake of Selected Chemical Vapors at Trace Levels. University of California, Davis, C A. Submitted to The Biological Effects of Research Section, California Air Resources Board, Sacramento, CA.

Raabe, O.G. 1988. Retention and Metabolism of Toxics. Inhalation uptake of Xenobiotic Vapors by People. University of California, Davis, CA. Submitted to The Biological Effects Research Section, California Air Resources Board, Sacramento, CA.

Reuzel, P.G.J., C.F.Kuper, H.C.Dreef-van der Meulen, V.M.H.Hollanders. 1987. Chronic (29-Month) Inhalation Toxicity and Carcinogenicity Study of Methyl Bromide in Rats. Report No. V86.469/221044. Zeist, The Netherlands: TNO-CIVO Toxicology and Nutrition Institute.

Reuzel, P.G.J., H.C.Dreef-van der Meulen, V.M.H.Hollanders, C.F.Kuper, V.J.Feron, and C.A. and van der Heijden. 1991. Chronic Inhalation Toxicity and Carcinogenicity Study of Methyl Bromide in Wistar Rats. Food Chem. Toxicol. 29(1):31–39.

Rosenblum, I., A.A.Stein, and G.Eisinger. 1960. Chronic ingestion by dogs of methyl bromide-fumigated food. Arch. Environ. Health 1:316–323.

Segawa, R., T.Barry, and B.Johnson. 2000a. Recommendations for Methyl Bromide Buffer Zones for Field Fumigations. Memo to John S.Sanders, Chief, Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, January 21, 2000.

Segawa, R., B.Johnson, and T.Barry. 2000b. Summary of off-site air monitoring for methyl bromide field fumigations. Memo to John S.Sanders, Chief, Environmental Monitoring and Pest Management Branch, Department of Pesticide Regulation, January 21, 2000.

Seiber, J.N. 1999. Letter to Douglas Y.Okumura, Acting Assistant Director, Division of Enforcement, Environmental Monitoring and Data Manage ment, Department of Pesticide Regulation. Comments on report, Evaluation of Charcoal Tube and SUMMA Canister Recoveries for Methyl Bromide Air Monitoring, from James N.Seiber, University of Nevada, May 5, 1999.

Sikov, M.R., W.C.Cannon, D.B.Carr, R.A.Miller, L.F.Montgomery, and D.W.Phelps. 1981. Teratologic Assessment of Butylene Oxide, Styrene Oxide and Methyl Bromide. Contract no. 210–78–0025. Battelle, Pacific Northwest Lab. Submitted to the Division of Biomedical and Behavioral Science, National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, Cincinnati, OH.

Simmon, V.F., K.Kauhanen, R.G.Tardiff. 1977. Mutagenic activity of chemicals identified in drinking water. Pp. 249–258 in: Progress in Genetic Toxicology, D.Scott, B.A.Bridges, and F.H.Sobels, eds. Amsterdam: Elsevier/North Holland Biodmedical Press. DAR Vol 123–109 #87801.

Stadler, J., M.J.Kessedjian, and J.Perraud. 1983. Use of the New Zealand white rabbit in teratology: Incidence of spontaneous and drug-induced malformations. Food Chem. Toxicol. 21 (5):631–636.

Thompson, K.M. 1999. Developing univariate distributions from data for risk analysis. Human Ecol. Risk Assess. 5(4):755–783.

Thongsinthusak, T., D.Haskell, and J.Ross. 1999. Estimation of exposure of persons to methyl bromide during and/or after agricultural and non-agricultural uses. California Environmental Protection Agency, Department of Pesticide Regulation. HS-1659 (Appendix F of DPR 1999).

Tyl, R. 1991. Comments on Methyl Bromide Inhalation Teratology Study in New Zealand White Rabbits, W.J.Breslin, C.L.Zablotny, G.J.Bradley, and L.G.Lomax, Toxicology Research Laboratory, Health and Environmental Sciences, The Dow Chemical Company, Midland, MI: Study No. K-000681–033, Final Report, June 18, 1990 by R.W.Tyl, Senior Program Director, Research Triangle Institute to Dr. R.Franklin Handy, Methyl Bromide Industry Panel, Great Lakes Chemical Corporation, dated February 25, 1991. 31pp.

Appendix A

Biographical Information on the Subcommittee for the Review of the Risk Assessment of Methyl Bromide

CHARLES H.HOBBS (Chair) is director of the Toxicology Division at the Lovelace Respiratory Research Institute. He received his D.V.M. from Colorado State University. His research focuses on the long-term biological effects of inhaled materials and the mechanisms by which they act. He is a diplomate of the American Board of Toxicology and certified in general toxicology. Dr. Hobbs serves as a member of the Committee on Toxicology and previously served on the Committee on Toxicological and Performance Aspects of Oxygenated fuels.

JANICE E.CHAMBERS is professor and director of the Center for Environmental Health Sciences in the College of Veterinary Medicine at Mississippi State University. She received her Ph.D. in animal physiology from Mississippi State University. Her research focuses on neurotoxicology of insecticides including neurochemical and behavior studies and insecticide metabolism. She is a diplomate of the American Board of Toxicology. Dr. Chambers previously served as a member of the NRC's Panel on Life Sciences for postdoctoral fellowships.

FRANK N.DOST is professor emeritus from the Department of Agricultural Chemistry at Oregon State University and affiliate professor in the Department of Environmental Health at the University of Washington. He received his D.V.M. from Washington State University. Dr. Dost's research interests include the estimation of environmental and occupational chemical exposure and risk assessment and the metabolic fate of toxicants. Previously, Dr. Dost served on the NRC committee on toxicology of hydrazines.

DALE B.HATTIS is research professor in the Center for Technology, Environment, and Development at Clark University. He received his Ph.D. in genetics from Stanford University. His research focuses on the development and application of methodologies to assess the health impacts of regulatory options with an emphasis on incorporating interindividual variability data into risk assessments for both cancer and non-cancer endpoints. Previously, Dr. Hattis was a member of the NAS/IOM Committee on Evaluation of the Safety of Fishery Products and the NRC Committee on Neurotoxicology and Risk Assessment.

MATTHEW C.KEIFER is co-director of the Pacific Northwest Agricultural Safety and Health Center and director of the occupational medicine program at the University of Washington. He received his M.D. from the University of Illinois and his M.P.H. from the University of Washington. Dr. Keifer's research interests focus on the health of agricultural workers with specific focus on the health effects of occupational pesticide exposure. He is a diplomate of the American Board of Internal Medicine.

ULRIKE LUDERER is assistant professor with the Center for Occupational and Environmental Health at the University of California at Irvine. She received her M.D. and Ph.D. from Northwestern University and her M.P.H. from the University of Washington. Dr. Luderer's research focuses on reproductive effects and neuroendocrine alterations as a result of exposure to environmental toxicants, particularly volatile organics. She is a diplomate of the American Board of Internal Medicine.

GLENN C.MILLER is director of the Center for Environmental Sciences and Engineering at the University of Nevada, Reno. He received his Ph.D. in Agricultural Chemistry from the University of California at Davis. Dr. Miller's research focuses on the fate and transport of airborne pesticides following major uses and the effects of deposited residues on soils including their photodegradation.

SYLVIA S.TALMAGE is a toxicologist in the Life Sciences Division at Oak Ridge National Laboratory. She received her Ph.D. in ecology/environ mental toxicology from the University of Tennessee. Dr. Talmage's research focuses on the sources, fate, and toxicity of chemical warfare agents. She is a diplomate of the American Board of Toxicology and certified in general toxicology.

Appendix B

Public Access Materials

The following materials (written documents) were made available to the committee at or after its first meeting, October 4, 1999, Beckman Center:

1. California Environmental Protection Agency, Department of Pesticide Regulation. 1999. Methyl Bromide: Risk Characterization Document for Inhalation Exposure. Draft. March 1, 1999. 149 pp. with 9 appendices.
2. Memorandum from Lori Lim and Stephen Rinkus, California Department of Pesticide Regulation to Gary Patterson, California Department of Pesticide Regulation. Subject: Methyl Bromide Assignment #98– 0507. Dated September 25, 1998. 23 pp.
3. Methyl Bromide Industry Panel. 1998. Toxicological Endpoint Evaluation and Exposure Assessment for Methyl Bromide. August 18, 1998. 33 pp. With 2-pg cover letter from David Weinberg to James Wells, Department of Pesticide Regulation.
4. Comments on the Department of Pesticide Regulation's Draft Risk Characterization Document for Inhalation Exposure to the Active Ingredient Methyl Bromide. From Anna M.Fan, California Office of Environmental Health Hazard Assessment, to Gary T.Patterson, California Department of Pesticide Regulation, dated September 1, 1999. 21 pp.

5. Risk Assessment of Methyl Bromide. Presented by Lori O.Lim and Thomas Thongsinthusak, California Department of Pesticide Regulation. October 4, 1999. 29 pp.
6. Chemical Manufacturers Association, Methyl Bromide Industry Panel. Presented by Vincent Piccirillo, NPC, Inc. October 4, 1999. 28 pp.
7. Methyl Bromide Use in California: Public Health Concerns for Residents near Fumigated Agricultural Fields. Presented by Bill Walker, Environmental Working Group. October 4, 1999. 135 pp.
8. Public Health Concerns in the Methyl Bromide Reassessment. Presented by Amy Kyle, Consulting Scientist for the California Rural Legal Assistance Foundation. October 4, 1999. 19 pp.
9. California Environmental Protection Agency, Department of Pesticide Regulation. 1999. Methyl Bromide: Risk Characterization Document for Inhalation Exposure. Draft. October 1999. 467 pp.
10. Letter from James N.Seiber, University of Nevada, to Douglas Okumura, California Department of Pesticide Regulation, dated May 5, 1999. Comments on report “Evaluation of Charcoal Tube and SUMMA Canister Recoveries for Methyl Bromide Air Monitoring.” 54 pp.
11. Heinz's responses to Jim Seiber's comments. Draft. Undated. 3 pp.
12. Mini-Memo from Terri Barry to Kean Goh, dated May 19, 1999. Draft. Responses to comments on statistical aspects of the report entitled “Evaluation of Charcoal Tube and SUMMA Canister Recoveries for Methyl Bromide Air Sampling.” 4 pp.
13. U.S. EPA. 1991. Guidelines for Developmental Toxicity Risk Assessment. U.S. Environmental Protection Agency, Office of Research and Development, Risk Assessment Forum. EPA/600/ FR-91/001. 67 pp.
14. Letter from Courtney Price, Vice President CHEMSTAR, on behalf of the Chemical Manufacturers Association's Methyl Bromide Industry Panel to Dr. Charles Hobbs, NRC Subcommittee on Methyl Bromide. Dated November 8, 1999. 8 pp. with 2 attachments of published article by Medinsky et al. (1985) and bar chart.

15. California Rural Legal Assistance Foundation. 1999. Letter From Anne Katten and J.Felix de la Torre of the CRLAF to Roberta Wedge, NRC, regarding review of California Department of Pesticide Regulation Risk Characterization for Methyl Bromide. Dated December 23, 1999. 2 pp. With attachment "Technical Comments of California Rural Legal Assistance Foundation: The NAS Review of the CDPR Methyl Bromide Risk Characterization, December 1999." 10 pp.
16. Letter from Gary T.Patter, Division of Registration and Health Evaluation, California Department of Pesticide Registration to Roberta Wedge, NRC, regarding an issue paper submitted by the Methyl Bromide Industry Panel (MBIP) on the pharmacokinetics and metabolism of methyl bromide. Dated January 7, 2000. 2 pp. With 3 attachments including; 1) the issue paper, 2) review and comments of the issue paper by the DPR staff; and 3) questions posed by DPR to the MBIP at a meeting where the issue paper was presented.
17. Letter from Jodi Kuhn, Methyl Bromide Industry Panel (MBIP) to Roberta Wedge, NRC with comments from the MBIP to the California Department of Pesticide Regulation. Dated January 21, 2000. 1 pg. With an attached letter from MBIP to Paul Helliker, CDPR, dated January 11, 2000 (1 pg) and a 3 page attachment entitled "Methyl Bromide: Supplemental Information on Metabolism."
18. Memorandum from Lori Lim, Department of Pesticide Regulation (DPR), to Gary Patterson, DPR, regarding methyl bromide assignment #98–0408. Dated July 3, 1998. 2 pp. With an attached memorandum from Linnea J. Hansen, U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances, Health Effects Division, to Margaret Stasikowski, Health Effects Division, entitled "Methyl Bromide: Review of Draft Toxicology and Hazard Identification Document Prepared by the Department of Pesticide Regulation, California Environmental Protection Agency. Dated June 11, 1998. 6 pp.
19. Letter from Cindy Tuck, Law Offices of William Thomas, Sacramento, CA, to Roberta Wedge, NRC, regarding methyl bromide recovery rate: new document for review by NRC subcommittee on methyl bromide. With an attached memorandum from Jay Gan, ARS USDA, to Dr. Duafain on DPR study and methyl bromide recovery rates. Dated March 21, 2000. 5 pp.

Appendix C

Calculation of Air Exchange Rates

Air exchange rates are defined in terms of a general one-compartment model of air exchange with immediate and perfect mixing of air inside residences. For any contaminant in the assumed well-mixed pool of air in the living spaces, this leads to an expectation of simple exponential decline of air concentrations with time:

$$C(t)=C(0)e^{-kt},$$

where C(0) is the initial concentration of the contaminant inside the house, C(t) is the concentration of the contaminant at any specific time after t=0, and k is a rate constant in units of reciprocal time (i.e., if time is expressed in hours, k is in reciprocal hours, or, by convention, "air changes per hour"). The relationship between the rate constant k and the half-life (the time required to reduce the air concentration by half) is easily derived by setting C(t) to one-half of C(0):

$$C(t_{1/2})=.5C(0)=C(0)e^{-kt1/2},$$

After the cancellation of the C(0)'s, and taking the natural logarithm of both sides of the equation:

$$\ln(.5)=-kt_{1/2}$$
$$t_{1/2}=\ln(2)/k \text{ or } k=\ln(2)/t_{1/2}$$

ILLUSTRATIVE LOGNORMAL TREATMENT OF DATA FOR SELECTED OCCUPATIONAL EXPOSURES

Figure A–1 shows lognormal probability plots of the individual data points for several groups of workers in the shallow-shank tarp method application of methyl bromide. In this type of plot, correspondence of the points to the re

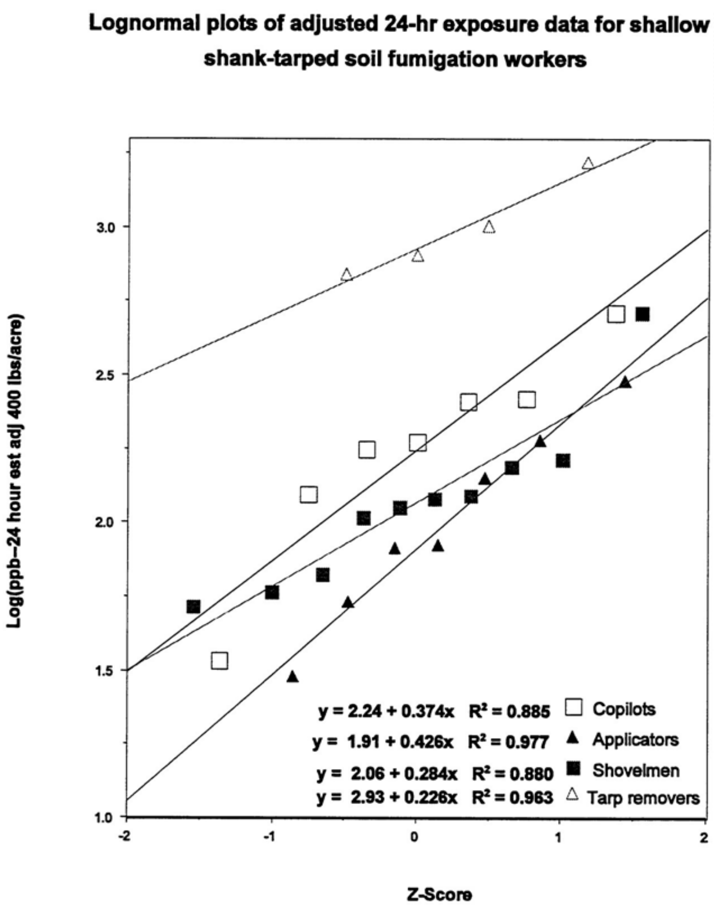


FIGURE A–1

gression line is a quick qualitative indicator of the degree to which the data points are well described by the chosen distribution. In these cases, the fits are far from perfect, suggesting some possible heterogeneity in the data, but the lognormal plots in Figure A–1 are generally better than corresponding normal distribution fits (Figure A–2). For these same worker groups, Table A–1 below compares the reported highest observed values with 95th percentile values calculated from the fitted normal and lognormal distributions. In general, the lognormal fits project somewhat higher 95th percentiles than the normal fits.

TABLE A–1 Comparison of Observed Values with 95th Percentile Values

Occupational Group	Number of Data Points (Including Non-Detects)	Highest Observed Acute (24 hr) Exposure	95th Percentile Calculated from Normal Fit	95th Percentile Calculated from Lognormal Fit
Copilots	7	518	479	716
Applicators	8	303	293	408
Shovelmen	10	515	330	337
Tarp Removers	5	1659	1820	1990

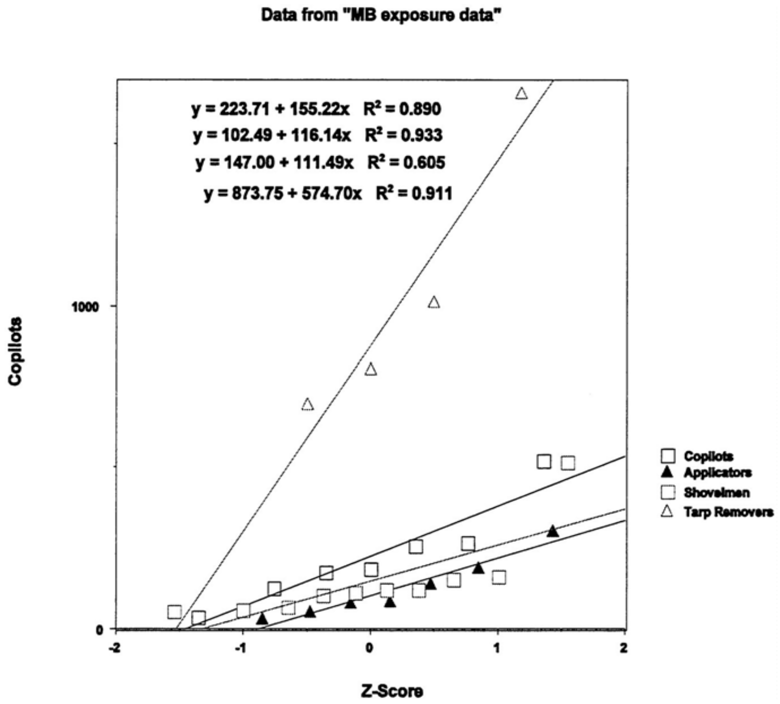

Data from "MB exposure data"
y = 223.71 + 155.22x R² = 0.890
y = 102.49 + 116.14x R² = 0.933
y = 147.00 + 111.49x R² = 0.605
y = 873.75 + 574.70x R² = 0.911
Copilots
1000
0
-2
-1
0
1
2
Z-Score
Copilots
Applicators
Shovelmen
Tarp Removers

Figure A–2

Attachment 5

United States General Accounting Office

GAO

Report to the Ranking Minority Member, Committee on Commerce, House of Representatives

December 1995

PESTICIDES

The Phaseout of Methyl Bromide in the United States

GAO/RCED-96-16

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and Economic Development Division

B-261602

December 15, 1995

The Honorable John D. Dingell
Ranking Minority Member
Committee on Commerce
House of Representatives

Dear Mr. Dingell:

Emissions of various chemicals are depleting the stratospheric ozone layer, which shields the earth from the sun's harmful ultraviolet rays.[1] According to the Environmental Protection Agency (EPA), increased ultraviolet radiation reaching the earth's surface can, over time, raise the incidence of skin cancer and cataracts and weaken the immune system in humans, as well as damage the environment.

To protect the ozone layer, 24 nations, including the United States, signed the Montreal Protocol in September 1987, agreeing to place controls on and perform further assessments of major ozone-depleting substances. In 1990, the Congress amended the Clean Air Act to, among other things, require EPA to identify ozone-depleting substances and phase out their production. In December 1993, EPA issued regulations under these provisions to phase out methyl bromide, a widely used agricultural pesticide identified by scientists as an ozone-depleting substance. EPA's regulations freeze the production and importation of methyl bromide at 1991 levels until January 1, 2001; after this date, the pesticide can no longer be produced or imported into the United States for domestic use. The Montreal Protocol—now signed by over 150 countries—freezes methyl bromide's production at 1991 levels but does not require a phaseout.

Methyl bromide has been used in agriculture since the 1930s, principally as a fumigant to control pests in the soil before planting various crops, to protect stored agricultural commodities, and to treat commodities being shipped in international trade.[2] In response to your questions about the consequences of banning methyl bromide for these purposes, we agreed to provide you with information on (1) the scientific evidence that emissions from human uses of methyl bromide are depleting the ozone layer, (2) the

[1]There are three types of ultraviolet radiation classified according to their wavelength. UV-C, the most harmful, does not reach the earth's surface. UV-B, which is somewhat less harmful, is partially absorbed by stratospheric ozone. UV-A, the least harmful, reaches the earth with little obstruction.

[2]Similarly, methyl bromide is used to fumigate certain commodities shipped between states such as California and Florida.

availability of economical and effective alternatives to the pesticide's agricultural uses, (3) the effects of banning the pesticide on U.S. trade in agricultural commodities, and (4) EPA's authority under the Clean Air Act to exempt essential uses from the phaseout.

Results in Brief

World scientists participating in the United Nations Environment Programme's assessment of ozone-depleting substances have concluded that emissions from human uses of methyl bromide contribute significantly to ozone depletion and should be controlled. Although some complex atmospheric processes are not fully understood, scientists know from laboratory measurements that bromine, a major component of methyl bromide, is very efficient in destroying ozone.

Various chemical and nonchemical pest-control alternatives are available, but none is as economical and effective as methyl bromide for its many uses. Hence, a combination of these alternatives will likely have to replace methyl bromide. The agricultural community is concerned that federal research to identify the most cost-effective alternatives or combination of alternatives is not adequately funded or coordinated. For some uses, such as treating certain commodities in trade and destroying certain organisms in the soil that can cause plant diseases, alternatives have not yet been identified.

If other countries continue to use methyl bromide after it is phased out in the United States, they may have an unfair advantage in international markets for the various agricultural commodities produced with the substance. At the next meeting of the parties to the Montreal Protocol in November 1995, U.S. officials plan to propose a worldwide phaseout similar to the U.S. one. The officials believe that the parties are likely to agree on some additional controls but not to a phaseout. In addition, a U.S. phaseout could mean that some commodities, which must now be fumigated with methyl bromide to kill pests that might damage U.S. crops, could no longer be imported into this country. Other countries have similar requirements that might affect U.S. exports.

The Clean Air Act does not authorize EPA to grant exemptions from the ban on producing and importing methyl bromide except for use in medical devices and for export to developing countries that have signed the Montreal Protocol. The Clean Air Act would have to be amended before EPA could grant exemptions from the January 1, 2001, ban for other uses.

Background

During the past decade, both international and national efforts have been made to control ozone-depleting chemicals. Shortly after the United Nations Environment Programme (UNEP) developed the Montreal Protocol on Substances that Deplete the Ozone Layer (Protocol), the Congress added title VI to the Clean Air Act to supplement the Protocol's terms and conditions. Amendments to the Protocol and regulations implementing title VI have since expanded the restrictions on individual ozone-depleting chemicals.

An ozone depletion potential (ODP) index is used under the Protocol and the Clean Air Act to gauge a substance's relative potential to deplete stratospheric ozone. This index primarily reflects the substance's (1) likely lifetime in the atmosphere and (2) efficiency in destroying ozone compared with chlorofluorocarbon-11 (CFC-11), a widely used refrigerant and major ozone depleter that is being phased out under the Protocol and the Clean Air Act. On the basis of scientific assessments performed in December 1991 and updated in June 1992, UNEP calculated that methyl bromide has an ODP of 0.7, or 70 percent of CFC-11's ozone-depleting potential.

The Protocol originally placed controls on eight major ozone depleters—five chlorofluorocarbons (CFC) and three halons—and provided for technical and scientific assessments of potential ozone-depleting substances to be undertaken at least every 4 years.[3] In November 1992, following the update of UNEP's 1991 assessment, the parties to the Protocol first imposed controls on methyl bromide. They agreed to accept UNEP's calculation of methyl bromide's ODP as 0.7, and they amended the Protocol to freeze production of the substance at 1991 levels, beginning in January 1995.[4] They did, however, create an exemption for the substance's preshipment and quarantine uses.[5] The parties also agreed to decide by January 1, 1996, how the freeze would affect the consumption of methyl bromide in developing countries. (The Protocol allows methyl bromide producers to produce 10 percent above 1991 levels for export to

[3]Halons have been used primarily as fire extinguishers in ships, planes, and military vehicles, as well as in computer facilities, telephone switching centers, and other places where materials would be damaged by the use of water or foam fire extinguishers.

[4]The agreement technically froze member countries' "consumption" levels of methyl bromide, that is, the amounts produced plus the amounts imported minus the amounts exported.

[5]Preshipment use generally refers to the treatment with methyl bromide of commodities being exported to meet the phytosanitary and sanitary (plant and animal health) requirements of the importing country. Quarantine use refers to the treatment performed or authorized by a national plant, animal, environmental protection, or health authority to prevent the introduction, establishment, or spread of harmful pests that are (1) not yet present or (2) present but not widely distributed and being officially controlled.

developing countries.) The parties further agreed to consider imposing additional controls on methyl bromide at their November 1995 meeting, after they had reviewed the results of UNEP's next round of scientific and technical assessments. These assessments were completed in late 1994.

Title VI of the Clean Air Act identifies many substances that EPA is to list as ozone depleting and requires the agency to list any others that have an ODP of 0.2 or that it finds may reasonably be anticipated to cause harm to the ozone layer. These substances are to be listed as either class I or class II, depending primarily on their ODP. The title authorizes EPA to add substances to either list and requires the agency to update both periodically. Substances that have an ODP of 0.2 or greater are to be listed as class I, and EPA is to take action to phase out their production no later than 7 years after they are listed. The schedule for phasing out the less threatening class II substances is less stringent.

In December 1991, three environmental groups petitioned EPA under the Clean Air Act to list methyl bromide as a class I substance. EPA concluded, in large part on the basis of UNEP's calculation, that methyl bromide has an ODP of 0.7, well above the act's 0.2 threshold for listing as a class I substance. In December 1993, EPA issued a rule first freezing and then banning the production and importation of methyl bromide. The freeze, which is at 1991 levels, took effect on January 1, 1994. No further reduction from 1991 levels is required until January 1, 2001, when the ban is mandated to begin. EPA imposed no further reductions during this 7-year period because it recognized that the loss of methyl bromide would be costly and it wanted to allow as much time as possible for the development of alternatives. (In promulgating the rule, EPA estimated both the costs and benefits of phasing out methyl bromide. The U.S. Department of Agriculture (USDA) and the University of California at Berkeley and the University of Florida have also estimated the costs of banning methyl bromide's agricultural uses. App. I summarizes these studies.)

Table 1 compares the controls placed on methyl bromide by the Montreal Protocol and by EPA's regulation.

Table 1: Comparison of Controls Placed on Methyl Bromide

Provision	Montreal Protocol	U.S. regulation
Freeze on production and importation	Production and importation were frozen at 1991 levels, effective January 1, 1995.	Production and importation were frozen at 1991 levels, effective January 1, 1994.
Exemptions to the freeze	Preshipment and quarantine uses were exempted. Methyl bromide producers can generally exceed their 1991 levels by 10 percent for export to developing countries. The Protocol parties are to decide by January 1, 1996, how the freeze will affect developing countries.	No exemptions have been granted yet, but EPA has the authority to grant exemptions for use in medical devices and for export to developing countries.
Ban on production and importation	No ban has been approved.	A ban on production and importation becomes effective January 1, 2001.

Methyl bromide is a highly effective fumigant used to control a broad spectrum of pests—insects, nematodes (parasitic worms), weeds, pathogens (bacteria, fungi, and viruses), and rodents. The agricultural community today uses it for over 100 crops. U.S. production in 1993 was over 60 million pounds.[6] About 80 percent is used to fumigate the soil before planting crops.[7] Another 19 percent is used to fumigate harvested agricultural commodities during storage—including those being exported from and imported into the United States—and to fumigate structures such as food processing plants, warehouses, mills, and grain elevators. A small amount is used in the production of other chemicals.

According to EPA, methyl bromide is a very toxic substance whose effects on human health depend on the concentration and duration of the exposure. Exposure to the pesticide can damage the lungs, eyes, and skin and, in severe cases, cause the central nervous and respiratory systems to fail. Gross permanent disabilities or death may result. Agricultural field workers and structural fumigators have developed respiratory, gastrointestinal, and neurological problems, including inflammation of nerves and organs and degeneration of the eyes. EPA officials told us that exposures to high concentrations have resulted in deaths.

[6] Chemical Marketing Reporter, Vol. 245, No. 1 (Jan. 3, 1994).

[7] According to a 1994 USDA report, five crops—tomatoes, strawberries, peppers, ornamentals, and tobacco—account for over 80 percent of the methyl bromide used for soil fumigation.

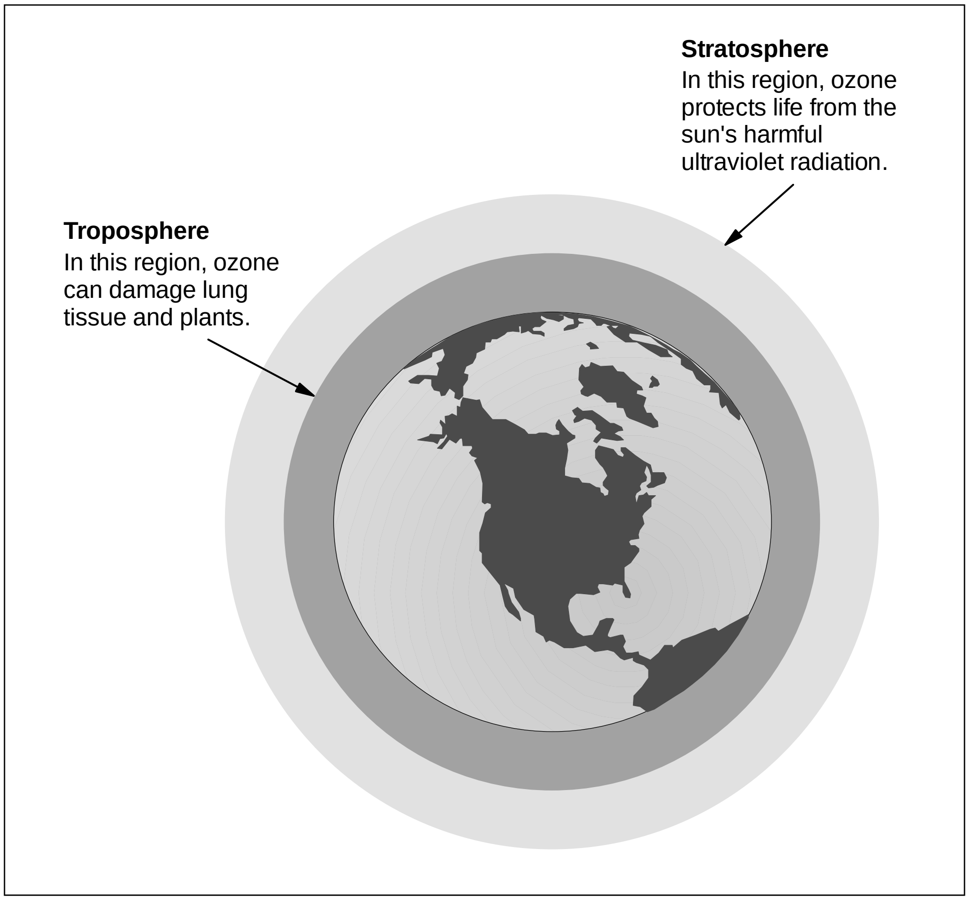
Scientific Evidence of Methyl Bromide's Role in Ozone Depletion

UNEP's scientific assessments of ozone-depleting substances have concluded that methyl bromide is a significant ozone depleter.[8] Although some uncertainties are involved in these assessments, the participating scientists are confident that methyl bromide's ODP will not drop below the 0.2 level that triggers the phaseout of the pesticide as a class I substance under the Clean Air Act.

The atmosphere is made up of distinct layers, each of which has its own composition of gases and natural processes. The troposphere extends from the earth's surface up to about 6 miles, and the stratosphere extends from the troposphere to about 30 miles above the surface. Although ozone can be harmful in the troposphere—it is a primary constituent of smog—in the stratosphere it helps protect life on earth from the sun's ultraviolet radiation. (See fig. 1.)

[8]According to the Montreal Protocol's 1992 assessment update report, modeling results suggest that emissions of methyl bromide from human activities could have accounted for about 5 to 10 percent of the current observed stratospheric ozone loss. The modeling results further suggest that this amount could grow to about 17 percent by the year 2000 if emissions continue to increase at the present rate of 5 to 6 percent per year.

Figure 1: Ozone in the Earth’s Atmosphere



Ozone is continuously being produced naturally in the stratosphere by a photochemical reaction caused by the sun’s rays. It is also continuously being removed by other chemical reactions. According to scientists involved in the UNEP assessment, the production and destruction of ozone are normally in balance. However, as emissions from human uses of ozone-depleting chemicals reach the stratosphere, more ozone is lost than is created, and the ozone layer is thinned. Similarly, methyl bromide is continuously being produced and removed from the atmosphere by natural processes—scientists estimate that up to 60 percent or more of the methyl bromide in the atmosphere may be released from the oceans. Again, the UNEP scientists believe that the amounts produced and removed by natural processes tend to be in balance. Therefore, their concern about methyl bromide as an ozone depleter is focused on emissions from human uses.

The scientific basis for the Montreal Protocol's freeze and EPA's phaseout was principally a 1992 assessment completed under the auspices of UNEP. This assessment, which scientists from around the world performed for the parties to the Montreal Protocol, concluded that the best estimate of methyl bromide's ODP was 0.7. The 1994 UNEP scientific assessment found that the pesticide's ODP is 0.6.

Producers of methyl bromide and members of the agricultural community have expressed concern about UNEP's estimate of the substance's ODP. More specifically, they have questioned UNEP's calculation of methyl bromide's "lifetime" in the atmosphere, which the 1994 UNEP assessment calculated to be about 1 year.[9] This calculation is important because the less time the substance is in the atmosphere, the less chance it has of reaching the stratosphere and depleting the ozone layer. UNEP's calculation of the pesticide's lifetime assumes that significant amounts of methyl bromide are being removed from the atmosphere through chemical reactions in the troposphere and through interaction with the oceans. However, some in industry and the agricultural community have suggested that soil and vegetation may also remove significant amounts of methyl bromide from the atmosphere. Scientists who participated in the UNEP assessment believe that the range of uncertainty factored into their estimates of methyl bromide's lifetime is sufficient to allow for the possibility that the substance may be removed by soil and vegetation.

The other major part of the ODP measurement is the relative efficiency of methyl bromide in destroying ozone. On the basis of laboratory measurements, the scientists who participated in the UNEP assessment estimate that bromine, a major component of methyl bromide, is about 50 times more efficient in destroying ozone than the chlorine in chlorofluorocarbons.

Additional research is addressing the scientific uncertainties currently involved in calculating methyl bromide's ODP. At this point, the scientists associated with the UNEP assessment anticipate only a further refinement of the ODP calculation. They are confident that the research results will not bring the ODP below 0.3.

[9]Various physical and chemical processes tend to break down and remove chemicals in the atmosphere. Atmospheric lifetime is a measure of how long a gas stays in the atmosphere before it is removed by these processes. Atmospheric lifetimes are commonly modeled as e-folding lifetimes, which means that the concentration of a gas is assumed to decay exponentially.

Availability of Economical and Effective Alternatives

EPA, USDA, and industry representatives generally agree that chemical substitutes and other alternatives are available today to manage many of the pests currently controlled with methyl bromide. They further agree that no one substitute or alternative is available for methyl bromide's many uses and that research is needed to identify the alternatives or combinations of alternatives that can economically and effectively replace the pesticide's individual uses. USDA and the agricultural community, however, are less optimistic than EPA that economical and effective alternatives will be identified by the time the ban on methyl bromide goes into effect in 2001. EPA, USDA, and industry are sponsoring or conducting research on alternatives, but it is not clear at this point what this research will be able to achieve over the next 5 years.

Effectiveness of Efforts to Identify Replacements Is Unclear

According to EPA, there are many chemical and nonchemical alternatives to methyl bromide. These include fumigants that can kill a range of pests similar to those killed by methyl bromide. Other chemicals—for example, insecticides, fungicides, and herbicides—with a more limited range are also available. Nonchemical alternatives include techniques such as rotating crops to avoid a buildup of pests, using plants that are more pest-resistant, and using organisms like parasitic bacteria to control weeds and nematodes.

These alternatives, according to EPA, are technically capable of controlling many of the pests currently controlled by methyl bromide. (In its 1994 report, UNEP's Methyl Bromide Technical Options Committee said that it had identified a technically feasible alternative, either currently available or at an advanced stage of development, for over 90 percent of the uses being made of methyl bromide in 1991.[10] According to the report, alternatives were not identified for controlling some soilborne viruses and other pathogens and for some quarantine procedures.) The key question—assuming that the alternatives do not pose any unmanageable health and environmental risks—is which alternative or combination of alternatives is most effective and economical in a given situation.

According to USDA officials, alternatives are not currently available for some important uses, such as treating certain quarantined commodities and responding to certain incidents or emergencies. The officials noted, for example, that ships carrying infested commodities may dock at U.S.

[10]The Methyl Bromide Technical Options Committee is one of the technical committees operating under the Technology and Economic Assessment Panel, which was established under the Montreal Protocol to perform the technical and economic assessments needed for the parties to consider controls on ozone-depleting substances.

ports, military equipment contaminated with soilborne pests may be brought back to the United States, or a destructive pest, such as the Mediterranean fruit fly, may be found in an area of California or another state. In these circumstances, they said, fumigation with methyl bromide is the only effective way to deal with the pests.

USDA officials also pointed out that numerous scientific, economic, and environmental variables have to be considered in evaluating potential replacements. Selecting a replacement can be further complicated because a use can be quite specific. For example, alternatives for preplant soil fumigation (a technique for killing pests in the soil before planting) will need to be selected on the basis of such factors as the crop grown, the pests present in the soil, the climate, and the geographical location. Government and industry researchers believe that considerable research and field testing are needed to define the alternatives' efficacy, applicability, and cost-effectiveness in given situations.

To fund research on alternatives to methyl bromide, EPA and USDA spent about $13.3 million in fiscal year 1995 and, according to agency officials, a similar amount has been requested for fiscal year 1996. However, the Crop Protection Coalition[11] estimates that about $60 million is needed annually for this research. According to the Coalition, the public sector has not mobilized sufficient resources and funds to achieve meaningful results before 2001 in either preplant or postharvest applications. The Coalition also believes that this research needs to be more effectively coordinated.

The Coalition, with USDA's and EPA's cooperation, is attempting to consolidate federal and private research activities into a single agenda reflecting a consensus on priorities. In July 1995, the Coalition issued a report on the status of research activities to (1) help prioritize projects for funding, (2) identify gaps in current research, and (3) improve the transfer of technology to users of methyl bromide.[12] According to a USDA official, the Coalition's report and research agenda will be discussed at an international research conference on alternatives and methods for reducing methyl bromide emissions that the Department is cosponsoring in November 1995 with the Coalition and EPA.

[11]A national organization of about 30 fresh fruit and vegetable producers, associations, cooperatives and related industries. During action on USDA's fiscal year 1995 appropriation, the Senate Appropriations Committee expressed its expectation that the Department would work with the Coalition on directing funds for methyl bromide research (Senate Report 103-290, June 23, 1994, p. 23).

[12]Status of Methyl Bromide Alternatives Research Activities, Crop Protection Coalition (July 1995).

New Chemical Substitutes Appear Unlikely

USDA, the Methyl Bromide Working Group—which represents methyl bromide producers and distributors—and the Crop Protection Coalition believe that very few new chemical alternatives will be available when the ban on methyl bromide goes into effect. They said that substantial development costs, research requiring multiple planting cycles, and federal/state regulatory reviews are involved in putting a new chemical on the market. They noted that moving a new pesticide from development to commercialization can take up to 10 years and cost a manufacturer from $50 million to $70 million. As part of this process, the manufacturer must develop the health and safety data that EPA requires to register a pesticide for use.

Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), EPA decides whether to register a pesticide after assessing, among other things, the potential effects on human health and the environment of using a pesticide product according to the directions on the label. A separate registration is required for each new chemical, and an existing registration has to be amended for a new or different use. The registration process can take many years, depending on the type of substance, the complexity of the testing needed, the gaps in the data, and the nature of EPA's findings from the health and safety data submitted for the agency's review. However, EPA recently established an expedited system for reviewing alternatives to methyl bromide.[13] According to EPA, to date, no new chemicals and only a few new uses of existing chemicals have been submitted to EPA as potential alternatives to methyl bromide.

Under 1988 amendments to FIFRA, all pesticides registered before November 1984 must be reviewed for reregistration and the data supporting their registrations must be brought up to current scientific standards. Methyl bromide and a number of pesticides that have been approved for use on pests now controlled by methyl bromide are included in this group of chemicals. USDA has identified six of these chemicals as potential alternatives to methyl bromide.[14]

[13]In a July 13, 1995, pesticide regulation notice (No. 95-4), EPA explained the expedited review process and invited the submission of potential alternatives. In this notice, EPA said that if all necessary data have been submitted, the agency will work to ensure that decisions are made within 6 months on petitions for new food uses for registered pesticides, within 8 months on applications to register biological pesticides, and within 12 months on applications to register new active ingredients as reduced-risk pesticides.

[14]These chemicals are 1,3-dichloropropene, dazomet, metam-sodium, chloropicrin, phosphine, and dichlorvos.

For each of the alternatives identified by USDA, EPA has found potentially serious environmental and/or health and safety concerns. According to USDA officials, regulatory actions by EPA to ban or limit the use of these or other pesticides because of health and environmental concerns could exacerbate the economic effects of the methyl bromide phaseout by eliminating potentially effective alternatives. However, EPA officials told us that, under FIFRA, the agency balances risks and benefits, and if the benefits of using a pesticide outweigh the potential risks to people and the environment, then EPA may register or reregister the pesticide. The officials said that EPA is likely to reregister many of the chemical alternatives to methyl bromide after adopting appropriate risk mitigation measures, such as label changes. (App. II lists these and other potential alternatives to methyl bromide's agricultural uses and describes various concerns raised by EPA and others. The appendix also lists recent studies and reports by EPA, USDA, industry, and environmental groups that provide additional details on alternatives.)

Reducing Emissions and Recycling Are Not Alternatives Under the Clean Air Act

Some technically proven methods for reducing methyl bromide emissions, such as better sealing of fumigation enclosures, are available. In addition, industry is working to develop technology that can recapture and recycle a very high percentage of the methyl bromide used to fumigate commodities and structures. According to UNEP's Methyl Bromide Technical Options Committee, a few pieces of methyl bromide recovery equipment are already in use, and prototype systems capable of recycling recaptured gas for some uses will be evaluated by the end of 1995. Although using these technologies could substantially reduce emissions, the Clean Air Act does not exempt production for use in such systems from the ban. However, using recovery and recycling technology would extend the existing supply of methyl bromide when the ban on production and importation becomes effective.

Exemptions for Essential Uses May Be Necessary

In August 1995, EPA's Assistant Administrator for Air and Radiation said that the agency is aware of and understands the agricultural community's concern that it does not currently have satisfactory substitutes for all uses of methyl bromide.[15] The Assistant Administrator said that alternatives are available to effectively control many of the pests on which methyl bromide is used and that research on additional alternatives is taking place. According to the Assistant Administrator, the critical issue is whether

[15]Statement of the Assistant Administrator for Air and Radiation, EPA, before the Subcommittee on Oversight and Investigations, House Committee on Commerce (Aug. 1, 1995).

adequate alternatives will be available by the time the phaseout deadline arrives and, if they are not available, the agency will seek an appropriate solution. According to EPA, alternatives do not need to be identical to methyl bromide but they must be environmentally acceptable and must effectively and economically manage those pests that are now being controlled by the pesticide. (As discussed later, the Clean Air Act would have to be amended to give EPA the authority to grant exemptions from the ban.)

Potential Impact of Banning Methyl Bromide on U.S. Trade

Because methyl bromide is an important pesticide worldwide, a ban that took effect in the United States before similar actions were implemented in other countries could create an "uneven playing field" in international trade for U.S. producers of various agricultural commodities. The need to use more costly and/or less effective alternatives could increase the costs and reduce the yields for growers of U.S crops. In addition, some countries require certain U.S. commodities to be treated with methyl bromide as a condition of entry. These exports would likely be lost unless acceptable alternatives could be agreed upon with the importing countries. Likewise, the United States requires treatment with methyl bromide as a condition of entry for certain imports. The impact of the U.S. ban on agricultural trade, however, will depend on the controls other countries have placed on methyl bromide and on the cost-effectiveness of the alternatives available when the U.S. ban goes into effect in 2001.

Use May Continue in Many Countries

Although the parties to the Montreal Protocol are to consider placing additional controls on methyl bromide at their November 1995 meeting, they may not agree to ban the pesticide. According to U.S. officials, the United States will propose a ban, but contacts with representatives of other countries indicate that a wide range of proposals will be made at the meeting. For example, the technical assessment report prepared for the parties by UNEP's Methyl Bromide Technical Options Committee states that individual committee members estimated feasible reductions in methyl bromide emissions ranging from 50 percent by 1998 to only a few percent by 2001.

Even if the parties agree to a ban, they may give developing countries special consideration. The parties have recognized that these countries may not have the technical or financial resources to switch to alternatives or that a change may have a greater economic impact on them than on more developed countries. For example, in addition to financial and technical assistance, the Protocol gave these countries a 10-year grace period to implement the controls on CFCs and halons. The Methyl Bromide Technical Options Committee is presenting several options for the parties to consider if additional controls are placed on methyl bromide. One proposal would establish a 9-year grace period for developing countries, with reviews every 3 years to determine whether the grace period should be adjusted. Another option would cap or freeze the quantities used by developing countries and grant exemptions for preshipment and quarantine uses.

A few countries have acted independently to control their methyl bromide emissions. According to EPA, the Netherlands phased out its use of methyl bromide for soil fumigation in 1992 because of concerns that the pesticide contaminates groundwater. Germany and Switzerland have also prohibited its use on soil. Denmark and Sweden plan to phase out the pesticide's uses by 1998, as does Italy by 2000, although Italy plans to retain essential uses. The European Union plans a 25-percent reduction in use by 1998, and Canada has drafted controls calling for a 25-percent reduction by 1998.

Loss for Soil Fumigation Could Hurt U.S. Competitiveness

In response to a 1994 survey by the Methyl Bromide Technical Options Committee, 39 countries reported information on their use of methyl bromide for preplant soil fumigation. The committee also obtained estimates from industry for nine additional countries. Although the use of methyl bromide in many of these countries is small (developing countries account for about 18 percent of its use), the crops produced with it are primarily high-value cash crops, usually for export. Because these crops—for example, strawberries, tomatoes, peppers, cucumbers, and various other produce—are similar to those grown in the United States with methyl bromide, producers in these countries potentially compete with U.S. growers for both domestic and international markets for these commodities.

Studies done by USDA and for California and Florida, the two states that are the largest users of methyl bromide for soil fumigation, have concluded that alternatives to the substance are less effective in controlling soil pests and often cost more (see app. I). According to USDA officials, the higher costs and reduced yields would put U.S. growers at a disadvantage if growers in other countries could continue to use methyl bromide. For example, the Florida study stated that the use of methyl bromide is critical because of the state's environment. According to the study, producers faced with substantially reduced revenues would reduce their acreage for fresh fruit, vegetable, and fresh citrus crops. The study concluded that the primary beneficiary would be Mexico, which, the study assumed, would be given longer, as a developing country, to use methyl bromide under any future agreement reached under the Montreal Protocol. If Mexico or other developing countries expand their use of methyl bromide, the environmental benefits gained by phasing out the pesticide's use in the United States would be at least partially offset.

EPA's Methyl Bromide Program Director told us that the U.S. agricultural community's concerns about the uneven playing field may be valid. He said that Mexico may increase its production of such fruits and vegetables as tomatoes and strawberries, which are major crops for California and Florida. He added, however, that additional study would be needed to determine whether Mexico could realistically market increased amounts of these commodities in the United States. For example, could strawberries be shipped to market in time to maintain the necessary freshness? And would these fruits and vegetables be grown in Mexico at the same time of year as in the United States?

According to USDA officials, the Florida study and two recent USDA studies document the competition that the United States faces from developing countries, especially Mexico, in markets for crops whose production relies heavily on the use of methyl bromide.[16] The officials said, for example, that such competition occurs in the cucumber market in March and April, in the bell pepper market from January through March, and in the tomato market from January through April. The officials also said that Mexico has supplied nearly all of the strawberries imported into the United States over the last 5 years.

Treatment With Methyl Bromide Is Required for Certain Exports and Imports

Although less than 1 percent of the methyl bromide produced in the United States is used to treat quarantined commodities, this use is important because it permits trade in these commodities. During quarantine treatments, which are usually done at international borders, the commodities are fumigated to kill pests that could cross geographical barriers and infect susceptible crops or commodities. Quarantine requirements are negotiated between the importing and exporting countries for individual commodities, and the treatments are governed by strict regulations that require very high efficacy levels. For example, USDA's Animal and Plant Health Inspection Service (APHIS) requires efficacy levels

[16]The two USDA studies, issued by the Economic Research Service, are Competition in the U.S. Winter Fresh Vegetable Industry, Agricultural Economic Report No. 691 (July 1994), and The U.S. Strawberry Industry Statistical Bulletin No. 914 (Jan. 1995).

of 99.9968 percent for most treatments. To meet these efficacy levels, APHIS requires that certain imports be treated with methyl bromide because of its effectiveness, and some other countries, notably Japan, likewise require this treatment for certain imports from the United States.

APHIS currently requires fumigation with methyl bromide or an alternative treatment as a condition of entry into the United States for 19 fruits, 14 vegetables, and 7 nuts, seeds, and miscellaneous foods coming from certain countries (see app. III).[17] (APHIS also requires these treatments for various nonfood imports, including unprocessed seeds and nuts, hays and straw, cotton products, gums, bagging, and brassware.) About 90 percent of some U.S. imports, including apricots, nectarines, grapes, peaches, plums, and yams, are affected by these requirements. According to APHIS officials, acceptable alternatives are generally not available and the loss of methyl bromide will lead APHIS to ban imports of many economically important commodities.[18]

An April 1993 USDA study of nine imported fruits found that the loss of imports would reduce supplies and increase prices.[19] According to the study, the higher prices would increase the revenues to U.S. producers by $3.0 billion to $3.3 billion over 5 years. However, the losses to U.S. consumers from paying the higher prices would range from $4.7 billion to $5.0 billion over 5 years. The study further found that many of the imported items fill an important niche in U.S. supplies. For example, the study said that apricots, grapes, nectarines, peaches, and plums from Chile enter the United States during the winter when none or nearly none of these items are produced domestically.

In addition, U.S. exports worth over $400 million were fumigated with methyl bromide in 1994 (see app. IV). If the United States bans methyl bromide, an acceptable alternative treatment must be negotiated with the receiving countries. According to USDA officials, these negotiations can take several years and may not be successful, especially if other producers can continue to use methyl bromide and meet the quarantine requirements. EPA officials told us that they are more optimistic than USDA officials that acceptable alternatives will be available for imports and can be agreed upon for exports.

[17]According to APHIS officials, the agency will approve alternatives to methyl bromide if the exporting country can document that the alternatives will meet the required efficacy levels.

[18]According to USDA officials, import and export requirements may change from year to year.

[19]The Biologic and Economic Assessment of Methyl Bromide, National Agricultural Pesticide Impact Assessment Program, USDA (Apr. 1993).

EPA's Authority to Grant Essential Use Exemptions

On the basis of our review, we have concluded that the Clean Air Act does not currently authorize EPA to grant exemptions from the ban on methyl bromide for domestic agricultural uses, including preshipment and quarantine treatments. Supplies of methyl bromide available when the ban goes into effect on January 1, 2001, can be used, but no additional amounts can be produced or imported for domestic uses.

The Congress, in section 604 of the act, specified the conditions under which EPA may grant exemptions from the production phaseout of class I ozone-depleting substances, including methyl bromide. This section details six categories of substances for which exemptions may be granted. For four of the six categories, the exemptions are restricted to specific chemicals named in the relevant provisions, none of which is methyl bromide. For the remaining two categories—chemicals used in medical devices and exports to developing countries—EPA is authorized to promulgate exemptions for any class I substance after giving notice and an opportunity for public comment. Neither section 604 nor any other provision of title VI grants EPA general authority to issue essential use exemptions.

We identified no current uses of methyl bromide in medical devices, and it appears that an exemption for this purpose would not be applicable. However, methyl bromide could qualify for an exemption under the export provision of section 604(e). That provision imposes only three limits on the availability of the exemption: (1) it authorizes the production of only "limited quantities" (not defined in the provision), (2) the substance may be exported only to developing countries that are parties to the Montreal Protocol, and (3) the export may be only for the purpose of "satisfying the basic domestic needs of such countries."

Conclusions

UNEP's scientific assessments indicate that emissions from human uses of methyl bromide cause significant ozone depletion and should be controlled. However, a phaseout of the substance could adversely affect some parts of U.S. agriculture and trade unless adequate—that is, environmentally acceptable, effective, and economical—alternatives are identified before the ban takes effect in 5 years. More progress in identifying alternatives is being made for some uses of methyl bromide than for others. If adequate alternatives are not available by the time the ban takes effect, exemptions from the ban may be needed for some domestic uses until alternatives can be developed. However, EPA does not currently have the authority to grant exemptions for the continued production and/or importation of methyl bromide for domestic uses.

Recommendation

To provide for an orderly phaseout of methyl bromide, we recommend that the Administrator, EPA, seek changes to the Clean Air Act to authorize the agency to grant exemptions from the ban for essential uses. This authority should provide for EPA to grant exemptions after determining that adequate alternatives for a particular use are not available and that the adverse impact of not having methyl bromide for that use outweighs the negative effects on human health and the environment of further production and importation.

Agency Comments

We provided copies of a draft of this report to EPA and USDA for their review and comment. On November 3, 1995, we met with USDA officials, including the Chairman of the USDA Ad Hoc Committee for Alternatives to Methyl Bromide and the Deputy Director of the National Agricultural Pesticide Impact Assessment Program. The USDA officials generally agreed with the report's findings. The officials said that overall the report is balanced and presents the important issues and viewpoints associated with the use of methyl bromide. The officials again stressed their positions that practical or cost-effective alternatives are not available for many of methyl bromide's uses and that a unilateral ban on the pesticide is likely to hurt U.S. competitiveness in world agricultural markets.

On November 7, 1995, we met with EPA officials, including the Methyl Bromide Program Director in the Office of Air and Radiation and the Deputy Director of the Policy and Special Projects Staff in the Office of Pesticide Programs. The officials described the report's summarization of available information on the agricultural, economic, environmental, and health effects of the planned phaseout of methyl bromide as generally accurate. However, they expressed concern that the report leaves the impression that the outlook for finding alternatives to methyl bromide is more dire than warranted. In their view, the fact that no single chemical or other alternative is expected to replace methyl bromide for all of its uses does not mean that viable, economical alternatives will not be available for most uses by 2001. Furthermore, they added, even though viable, economical alternatives may not be found for some uses by 2001, current projections of large losses resulting from the phaseout cannot be relied on by any means.

EPA officials indicated that the agency would look at the need for exemptions and determine whether EPA has the authority to grant them as the deadline for the ban approaches. The officials stated that the focus now should be on identifying alternatives.

We believe that our report accurately depicts the availability of alternatives to methyl bromide at this time. We have made no judgment as to whether the alternatives will prove to be inadequate for many uses, as USDA officials have suggested, or for only a few, as EPA officials have suggested. In either case, we believe that EPA will need authority to grant exemptions. Although EPA could wait to seek such authority until the deadline approaches, it will need some lead time to propose changes to the Clean Air Act, have them approved, and issue implementing regulations.

EPA and USDA also provided some technical comments on our draft report. We have revised our report as appropriate in response to these comments.

We conducted our work from November 1994 through November 1995 in accordance with generally accepted government auditing standards. We interviewed officials from EPA, USDA, the Executive Office of the President, and the United Nations Environment Programme. We also interviewed representatives of the Methyl Bromide Working Group (producers and distributors) and the Crop Protection Coalition (a broad spectrum of methyl bromide users). In addition, we reviewed available studies on methyl bromide's contribution to the depletion of the ozone layer and economic and technical assessments of a phaseout. We also reviewed applicable laws and regulations and public comments during the proposal stage of EPA's phaseout regulation. Moreover, we attended conferences on alternatives to methyl bromide and on the status of scientific knowledge concerning methyl bromide's role in ozone depletion. Appendix V more fully discusses our scope and methodology.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 7 days after the date of this letter. At that time, we will send copies to the Secretary of Agriculture, the Administrator of EPA, and other interested parties. We will make copies available to others upon request.

Please call me at (202) 512-6112 if you or your staff have any questions. Major contributors to this report are listed in appendix VI.

Sincerely yours,

Peter F. Guerrero
Director, Environmental
Protection Issues

Contents

Abbreviations

APHIS	Animal and Plant Health Inspection Service
CFC	chlorofluorocarbon
EPA	Environmental Protection Agency
ODP	ozone depletion potential
UNEP	United Nations Environment Programme
USDA	U.S. Department of Agriculture

Studies of the Economic Impact of Phasing Out Methyl Bromide for Agricultural Uses

Methyl bromide is used primarily for agricultural purposes, principally for fumigating (1) the soil before planting (preplant soil fumigation) and (2) commodities after harvesting (commodity fumigation). The costs and benefits of a ban on these uses were analyzed by the Environmental Protection Agency (EPA) during the promulgation of its phaseout rule. We also identified three other studies of the potential economic impact of a phaseout on agricultural users. The U.S. Department of Agriculture's (USDA) National Agricultural Pesticide Impact Assessment Program studied the effects of a phaseout on 21 crops in six states, and the University of California at Berkeley and the University of Florida examined the impact of a phaseout in their states. Each of these studies compared the projected costs and crop yields for likely replacements with those for methyl bromide and found that growers would incur significant losses because of a ban on agricultural uses of methyl bromide. The USDA study also found that consumers would suffer a loss because supplies would be reduced and prices would be higher. Each study based its economic estimates on alternatives available at the time the study was conducted. The economic impact could change if more effective or less costly alternatives are identified in the future.

The studies by EPA and USDA arrived at substantially different estimates of the impact of a ban on methyl bromide. However, these estimates could not be easily compared because the studies made different assumptions, differed in their scope, and used different methodologies and cost data. The California and Florida studies were more limited in their scope than either the EPA or USDA studies. We did not independently evaluate these studies.

EPA's Analysis of Costs and Benefits

In 1993, EPA reviewed the costs and benefits of its regulatory action to phase out the production and importation of methyl bromide.[1] This study included information on the costs and effectiveness of potential new alternatives by the year 2001 and on the costs and benefits of improving the use of existing alternatives. On the basis of this study, EPA estimated that the total costs of a phaseout of methyl bromide between 1994 and 2010 would be \$1.7 billion to \$2.3 billion.[2] EPA's cost analysis examined the likely range of costs for the alternatives and coupled these assumptions with a monte carlo analysis, presenting a set of costs (median, mean,

[1]The Cost and Cost-Effectiveness of the Proposed Phaseout of Methyl Bromide, EPA (1993).

[2]The year 2010 was chosen as the end point in estimating the costs because the study team believed that forecasting the course of technological innovation and identifying alternatives to methyl bromide would be difficult beyond this date.

minimum, and maximum) that could be expected with a methyl bromide phaseout in 2001. The $1.7 billion figure represented the estimated median cost, and the $2.3 billion figure represented the mean cost. The minimum and maximum costs were estimated at approximately $7 million and roughly $16 billion, respectively. According to EPA, some available alternatives, if used after 2001, may indeed prove to be more expensive than methyl bromide, and their users may receive lower profits if the increases cannot be passed on to consumers. However, EPA said that it has found that the effects of regulatory actions that remove pesticides from the market are mitigated over time as new pest control technologies are introduced and adjustments are made to compensate for the loss of the pesticide through alternative pest control practices.

EPA estimated that the benefits of the phaseout would be between $244 billion and $952 billion. This estimate was based primarily on avoided cases of nonmelanoma cancers. According to the study, in the longer term (until 2160), a total of 2,800 skin cancer fatalities in the United States would be avoided because of the phaseout. The benefits for the period from 1994 through 2010 were estimated to be between $14 billion and $56 billion. The analysis reflected key assumptions about emissions of methyl bromide from human activities, the impact of bromine on ozone, and the likely growth in use of methyl bromide without regulations. The range in values for benefits results from different estimates of the value of a human life.

EPA recognized but did not calculate the benefits of avoiding other health and environmental problems caused by increased ultraviolet radiation, such as damage to plants and animals. EPA also did not consider the possible adverse effects on humans, plants, and animals of contact with methyl bromide during its application.

USDA's National Agricultural Pesticide Impact Assessment Program Study

In 1993, USDA published a study of the effects on U.S. agriculture of banning methyl bromide, under the National Agricultural Pesticide Impact Assessment Program.[4] The study showed that actions to ban or restrict methyl bromide's use in the United States would be costly because currently available alternative control practices are less effective or more expensive than using methyl bromide. The study estimated that the annual economic loss to producers and consumers from banning the agricultural uses of methyl bromide included in this study would be about $1.3 billion

[4] The Biologic and Economic Assessment of Methyl Bromide, National Agricultural Pesticide Impact Assessment Program (Apr. 1993).

to $1.5 billion. Of this amount, $800 million to $900 million would be attributed to the loss of methyl bromide for soil fumigation and $450 million to its loss for the fumigation of quarantine imports. An additional economic loss of about $200 million would occur if Vorlex—the alternative identified as having the most potential for succeeding methyl bromide—were no longer available. (The manufacturer had indicated to EPA that it planned to stop producing Vorlex because of high reregistration costs.)

According to the study, a phaseout, rather than an immediate ban, of methyl bromide would postpone annual losses and provide time for potential alternatives to be developed and for consumers and producers to adjust. The study concluded, however, that the likelihood of developing new, effective fumigant alternatives appears very remote.

The results of USDA's study were presented to EPA as part of the Department's comments on the agency's proposed phaseout rule. According to EPA, the study would be a useful analysis if methyl bromide were being banned immediately, but it does not consider alternatives that may be developed before the ban goes into effect. EPA also said that the study considers only alternatives that duplicate methyl bromide's ability to kill a wide range of pests and that other alternatives could be used in combination to achieve similar results. USDA officials believe that no alternatives are available for many uses.

Study by the University of California at Berkeley

A 1993 study by the University of California at Berkeley for the California Department of Food and Agriculture examined the role of methyl bromide in the state's agriculture and the impact on growers of regulatory action to further restrict or ban its use.[5] The University examined background information on the patterns and intensity of methyl bromide's uses for preplant soil and postharvest fumigation and then used a model to measure the financial impact on California growers of canceling agricultural uses of methyl bromide.

According to the University's report on the study, in the short term, the loss of methyl bromide for preplant soil fumigation would reduce net farm income in California by more than $233.8 million annually. The most significantly affected crops would be strawberries, nursery products (cut flowers and rose, fruit, vine, nut, and strawberry plants), and grapes, and

[5]Economic Impacts of Methyl Bromide Cancellation, Department of Agricultural and Resource Economics, University of California at Berkeley (Feb. 1993).

estimated net annual farm income losses would be $105.8 million, $71.7 million, and 31.3 million, respectively. Net income losses reflect differences in production costs from using alternative treatments, which are more costly for some crops, and lower revenues from reduced yields.

The report also found that the cancellation of methyl bromide for postharvest applications would have a significant impact on the profitability of California's fresh fruit and dried nut crops in the short run because fumigation by another method would cost more and take longer. For example, producers of cherries sell their highest-quality fruit on the export market and receive a premium price. If the cancellation of methyl bromide diverts all of the cherries previously sold on the export market to the domestic market, growers will lose $7.3 million annually. Likewise, walnut producers will have to ship more products to the domestic market instead of the holiday markets abroad because alternative techniques could not be used to fumigate the walnuts quickly enough to meet the holiday markets' needs. As a result, walnut producers would lose about $36.8 million annually. However, according to the study, trade negotiations could, in the long term, remove the requirements for quarantine treatments for cherries or approve alternative techniques. For walnuts, the expansion of holiday markets or earlier harvesting could help meet producers' needs.

Study by the University of Florida

A University of Florida study of the economic impact of losing methyl bromide on Florida's agriculture concluded that the environment that prevails in the state makes the use of methyl bromide critical to the competitiveness of the state's fruit and vegetable crops in U.S. and international markets.[6] The University surveyed extension specialists in the production areas and reviewed previous work on methyl bromide to identify existing production systems and possible alternatives to the use of methyl bromide. To analyze the economic impact of the ban, the University developed mathematical models of the North American winter fresh vegetable market and the world market for Florida grapefruit.

According to the study, the loss of methyl bromide would have a devastating effect on Florida's winter fresh vegetable producers. Because no viable alternatives can be effectively substituted for methyl bromide, Florida is estimated to lose over $620 million in the value of fresh fruit, vegetables, and fresh citrus (measured at the time of shipping) worth over $1 billion in total sales and more than 13,000 jobs. The study concludes

[6]The Use of Methyl Bromide and the Economic Impact of Its Proposed Ban in the Florida Fresh Fruit and Vegetable Industry, Institute of Food and Agricultural Sciences Bulletin No. 898, University of Florida at Gainesville (Nov. 1995).

that producers in the state would reduce the acreage allocated to these crops by 43 percent, from about 126,000 acres to 71,500 acres. Tomato production would decline by more than 60 percent, pepper production by 63 percent, and cucumber production by 46 percent without methyl bromide. The study also predicted that Mexico, in particular, would expand its production of vegetables, increasing its tomato production by 80 percent and its pepper production by 54 percent because, as a developing country, it was expected to have longer to use methyl bromide in producing and marketing its crops.

Potential Alternatives to Methyl Bromide for Agricultural Uses

Research is currently being conducted by governmental and academic institutions, as well as by the private sector, to ensure that alternative materials and methods will be proven viable and available to the agricultural community before methyl bromide is phased out. Tables II.1 and II.2, together with the accompanying descriptions, briefly profile various alternatives to methyl bromide being evaluated by USDA and other researchers for methyl bromide's preplant and postharvest end uses and note various concerns that need to be resolved during the 5 years before the ban goes into effect.

Table II.1: Potential Alternatives for Methyl Bromide's Preplant End Uses

	Soil use areas		
Alternatives	**Small fruit and vegetable farms**	**Nurseries**	**Orchards and vineyards**
Chemical			
1,3-Dichloropropene	x	x	x
Dazomet	x	x	x
Metam-sodium	x	x	x
Sodium tetrathiocarbonate	x		x
Formalin/formaldehyde	x	x	x
Chloropicrin	x	x	x
Nonfumigant narrow-spectrum pesticides	x	x	x
Future and preliminary research alternatives	x	x	x
Nonchemical			
Steam	x	x	
Solar heating	x	x	x
Hydroponics	x	x	
Organic matter	x	x	x
Plant modification	x	x	x
Crop rotation	x		
Future and preliminary research alternatives	x	x	x
Integrated pest management	x	x	x

Source: EPA and USDA studies, conference proceedings, and discussions between GAO and representatives of government and industry organizations.

Descriptions of Potential Alternatives for Methyl Bromide's Preplant End Uses

1,3-Dichloropropene. A broad-spectrum liquid fumigant comparable to methyl bromide for controlling most soil pests but less effective for controlling weeds. A potential groundwater contaminant. Classified by EPA as a probable human carcinogen. Under special review by EPA because of concerns about cancer for workers and residents in and around treated fields. Use permits previously suspended by California because of health and safety concerns but currently allowed for limited use.

Dazomet. A broad-spectrum granular fumigant comparable to methyl bromide for controlling most soil pests but can be less effective for controlling nematodes (parasitic worms). Currently registered for some food crops, but approval may not be sought for all uses of methyl bromide (e.g., crops with low production acreage). Small fruit and orchard uses restricted to the propagation or outplanting of nonbearing berry, vine, fruit and nut crops and similar nonbearing plants, according to EPA. Concerns about potential genotoxicity raised by EPA. Releases methyl isothiocyanate (MITC), a potential groundwater contaminant. Concerns expressed by United Nations Environment Programme (UNEP) about contamination of groundwater.

Metam-sodium. A broad-spectrum liquid fumigant comparable to methyl bromide for controlling most soil pests but may be less effective as a nematicide. Identified by EPA as a known teratogen (i.e., cause of developmental malformations). Classified by EPA as a probable human carcinogen. Efficacy dependent on the availability of water (irrigation) to ensure even distribution in the soil. Releases methyl isothiocyanate (MITC), a potential groundwater contaminant. Concerns about contamination of groundwater expressed by EPA and UNEP.

Sodium tetrathiocarbonate. A broad-spectrum liquid fumigant found effective for many soilborne pests but not for weeds. Is considered less effective than methyl bromide for controlling nematodes. Currently registered for use on grapes and citrus and registration being sought for almonds, prunes, and peaches. Efficacy dependent on the availability of water (irrigation) to ensure even distribution in the soil. Concerns about groundwater contamination expressed by UNEP. Groundwater concerns addressed by EPA through label restrictions.

Formalin/formaldehyde. A broad-spectrum granular (paraformaldehyde) or liquid (formalin) fumigant comparable to methyl bromide for controlling fungi but less effective for controlling nematodes and weeds. Registration voluntarily canceled because of health, safety, and environmental concerns. Efficacy dependent on the availability of water (irrigation) to ensure even distribution in the soil and prevent toxicity to plants.

Chloropicrin. A broad-spectrum liquid fumigant principally used as a fungicide. Comparable to methyl bromide for controlling many soil pests but less effective for controlling nematodes and weeds. Also used for tear gas, has a pungent/noxious odor, and can be very unpleasant or even hazardous to handle. Concerns about toxicity and effects of exposure on humans raised by EPA.

Nonfumigant narrow-spectrum pesticides. Include granular or liquid nonfumigant nematicides, herbicides, and fungicides spread or sprayed on the soil before or after planting to control specific pests (nematodes, weeds, insects, fungi, or bacteria). Less effective than methyl bromide. Registered uses specific to crops and locations, varying from state to state. Some reregistration concerns raised (e.g., registered nematicides such as aldicarb, carbofuran, and oxamyl are potential groundwater contaminants).

Future and preliminary chemical research alternatives. Include new and modified pesticides (e.g., bromonitromethane and carbonyl sulfide) being researched. Will require registration and are in varying stages of research. Will take time to completely develop products and assess their suitability as replacements.

Steam. Technically feasible for soil applications and can be as effective as methyl bromide, depending on methods of application and soil conditions/temperatures. Concerns about viability raised by USDA. May be impractical for large-scale (more than 2-acre) applications because it is labor-, equipment-, and energy-intensive and current estimated costs per acre are about two to five times higher than for methyl bromide. Related equipment and services may not be readily available. Feasibility dependent in some areas on availability of energy resources and fuel costs, according to EPA.

Solar heating. Technically feasible for soil applications, depending on geographic location and climate. Can be as effective as methyl bromide, depending on application methods and soil conditions/temperatures. Requires long treatment periods and may therefore be impractical for sterilizing soil in areas with short growing seasons (e.g., northern United

States). Is likely, for the most part, to be used in combination with other alternatives (e.g., soil fumigants) rather than by itself.

Hydroponics. Relatively new plant production systems that eliminate soilborne pests by eliminating soil as the growing medium. Instead, technology uses water-retaining substrates to deliver nutrients. Cannot be used for root crops (e.g., carrots), can have high start-up costs, requires significant support services, and, in the long run, could take many years to become widely accepted and economical.

Organic matter. Incorporates soil amendments, such as compost, green waste, straw, sawdust, and animal manure, into the soil to build soil health and control some soilborne pests (e.g., nematodes and weeds). Information on efficacy generally lacking. Some amendments as or more effective than some nonfumigant pesticide alternatives used to control nematodes and possibly viable for use in combined treatments.

Plant modification. Includes techniques such as crossbreeding plants, grafting orchard and vineyard rootstocks, and changing plants' genetic makeup to obtain high resistance to pests and desirable production characteristics. Extensive research required to determine potential of some techniques as alternatives. Considered an important source of viable alternatives by USDA and as having an already demonstrated potential in breeding plants for pest resistance.

Crop rotation. Can be effective in suppressing damage by soilborne pests. Effectiveness can be improved by including plants that produce fungicidal and nematicidal substances. Limitations include land availability and required knowledge of pest dynamics, general ecology, and appropriate rotational crops in specific production areas. Research under way to address these concerns.

Future and preliminary nonchemical research alternatives. Include biocontrol methods (e.g., egg-destroying fungi) and genetic engineering (e.g., altering organisms to control plant pathogens). Registration and further research required for most. Time needed to complete development and assess suitability as replacements.

Integrated pest management. Prevents pest populations from reaching damaging levels through the use of chemical and/or nonchemical treatments and management practices, as appropriate. Requires strict monitoring of pest populations and knowledge of soil ecosystem/crop production interactions. For effective implementation, requires intensive research, training for growers, and use of some chemical control methods that require regulatory approval and may involve health, safety, and environmental concerns. Research needed to determine effective combinations. Choices potentially limited by concerns about registering or reregistering chemicals.

Table II.2: Potential Alternatives for Methyl Bromide's Postharvest End Uses

	Uses			
Alternatives	**Perishable commodities**	**Nonperishable commodities**	**Quarantine**	**Structures**
Chemical				
Phosphine		x	x	x
Sulfuryl fluoride			x	x
Dichlorvos		x		
Previously used/limited-use alternatives			x	
Nonchemical				
Irradiation	x	x	x	
Controlled/ modified atmosphere	x	x	x	x
Thermotherapy	x	x	x	x
Combination treatments	x	x	x	x

Source: EPA and USDA studies, conference proceedings, and discussions between GAO and representatives of government and industry organizations.

Descriptions of Potential Alternatives for Methyl Bromide's Postharvest End Uses

Phosphine. A gas produced when aluminum or magnesium phosphide is exposed to moisture. Primarily used to fumigate grains but can be used to control numerous pests on a wide variety of commodities and in some structures. Commodities include raw agricultural foods (e.g., grains and almonds), processed foods (e.g., cereal flours), animal feeds, and nonfood commodities (e.g., tobacco). Structural uses include disinfesting grain storage facilities, such as silos and grain bins, and other structures that are not sensitive to phosphine's highly corrosive properties, which can damage switches or electronic equipment. Also used as a quarantine treatment for nonfood commodities, such as tobacco exports and cotton products. Effectiveness comparable to methyl bromide's for allowed treatments. Not suitable for some agricultural commodities (e.g., toxic to fresh fruits and vegetables and can decrease efficiencies when longer treatment times are required, according to USDA). Poses concerns for EPA about effects of exposure on workers, mutagenicity, and neurotoxicity. Risk of corrosion can be reduced and penetration and toxicity can be enhanced by combining low doses with heat and carbon dioxide, according to EPA.

Sulfuryl fluoride. Applied as a liquid that converts to a gas and can be used for some nonfood quarantine treatments and for disinfesting some structures empty of food and food products. Effectiveness comparable to methyl bromide's but poses concerns for EPA about mutagenicity, carcinogenicity, and reproductive effects.

Dichlorvos. A volatile liquid compound with limited penetrative powers. Used primarily to control pests in nonperishable foods (e.g., dried fruits and nuts, grains, and milled products) stored in warehouses, including raw and processed products. Classified by EPA as a possible human carcinogen and under special review because of concerns about neurotoxicity and carcinogenicity.

Previously used/limited-use alternatives. Include ethylene oxide and other quarantine fumigants (hydrogen cyanide, ethylene dibromide, carbon disulfide, and ethylene dichloride) that pose concerns about health and safety. As effective as methyl bromide for quarantine treatments, but may need emergency-use permits such as USDA formerly obtained to control specific pests on specified commodities. Also include methyl bromide recovery systems being researched for quarantine applications, since use of the recycled chemical is not banned after 2001. Preliminary research indicates feasibility of designing fumigation chambers to achieve 95-percent recovery. But full development of these systems may extend beyond 2001 and poses liability concerns involving yet-to-be-established operational and performance tolerances.

Irradiation. Uses low-level gamma radiation to sterilize or kill pests in quarantine and nonquarantine applications. Can be used on most foods and grains and can be equal in effectiveness to methyl bromide. Requires considerable investment in facilities and equipment, entails additional costs to dispose of spent cobalt, and poses capacity limitation concerns. USDA concerned about some commodities' sensitivity to treatment. Still requires USDA's approval for quarantine uses, and public's acceptance is uncertain.

Controlled/modified atmosphere. Uses decreased amounts of oxygen and/or increased amounts of carbon dioxide or nitrogen to suffocate pests. May require sealed facilities. Has most potential for treating nonperishable commodities. Use in combination with other treatments being evaluated for improving efficacy levels. Requirements for sealing facilities and long treatment times can pose cost considerations. Controlled atmospheres and low temperatures used more cost-effectively than methyl bromide by the Department of Defense to successfully ship perishables, according to EPA.

Thermotherapy. Can be used to control a broad spectrum of pests infesting commodities and structures and is comparable in effectiveness to methyl bromide. Treatments include vapor heat, dry heat, hot water, quick freeze, and cold. Length of required treatment, treatment facility's size, and commodities' sensitivities to temperature pose limitations. Experimentation begun with various techniques. Combination treatments likely to be required for some combinations of pests.

Combination treatments. Chemical and/or nonchemical combinations potentially usable to control pests on many commodities and in quarantine treatments. Combinations not yet identified for all commodities or pests. Chemical and nonchemical pest control combinations indicate the best potential for controlling pests now managed by methyl bromide, according to EPA.

Sources of Detailed Information on Potential Alternatives

Listed below are recent studies and reports that provide more detailed information on these and other potential alternatives for methyl bromide's many agricultural uses, the status of their availability as viable substitutes, and research priorities for meeting users' short-, mid-, and long-term needs.

- Alternatives to Methyl Bromide: Research Needs for California, California Department of Food and Agriculture (Sacramento: Sept. 1995).
- Status of Methyl Bromide Alternatives Research Activities, Crop Protection Coalition (July 1995).
- Alternatives to Methyl Bromide: Ten Case Studies—Soil, Commodity, and Structural Use, EPA, EPA430-R-95-009 (Washington, D.C.: July 1995).
- Out of the Frying Pan, Avoiding the Fire: Ending the Use of Methyl Bromide—An Analysis of Methyl Bromide Use in California and the Alternatives, Ozone Action, Inc. (Washington, D.C.: 1995).

- 1994 Report of the Methyl Bromide Technical Options Committee for the 1995 Assessment of the Montreal Protocol on Substances That Deplete the Ozone Layer, UNEP (Nairobi, Kenya: Nov. 1994).
- Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, sponsored by Methyl Bromide Alternatives Outreach (Orlando, Fla.: Nov. 1994).
- Alternatives to Methyl Bromide, ICF Incorporated for EPA (Washington, D.C.: Sept. 1993).
- Alternatives to Methyl Bromide: Assessment of Research Needs and Priorities, USDA (Arlington, Va.: June/July 1993).
- Methyl Bromide Substitutes and Alternatives: A Research Agenda for the 1990s, USDA (Arlington, Va.: Jan. 1993).

Food Imports Requiring Fumigation With Methyl Bromide or an Alternative Treatment as a Condition of Entry Into the United States

Fresh fruits and vegetables	Other foods
Apples	Chestnuts, unprocessed or shelled
Apricots	Citrus, frozen unpeeled or frozen peel
Asparagus	Cucurbit seeds, unprocessed, dried, roasted, or salted
Avocado	Cumin, unprocessed, roasted, or ground
Beans	Faba beans, unprocessed
Blueberries	Lentils, unprocessed
Cabbage (Brassica Oleraceae)	Peppers, dried
Cactus (Opuntia)	
Cherries	
Cipollino	
Ethrog	
Garlic	
Grapes	
Grapefruit	
Horseradish	
Kiwi fruit	
Lemons	
Lettuce	
Limes	
Nectarines	
Okra	
Oranges	
Peaches	
Pears	
Peas	
Pigeon peas	
Pineapples	
Plums	
Quinces	
Roselle	
Tangerines	
Thyme	
Yams	

Source: USDA's Animal and Plant Health Inspection Service.

Value of U.S. Exports for Which Receiving Countries Require Treatment With Methyl Bromide, 1994

Dollars in thousands

Commodity	Receiving country	Dollar value
Apples	Japan	$5,986
Blueberries	Mexico	12
Cherries	Japan	92,427
	Korea	535
Cotton	Mexico	198,399
	Bangladesh	15,867
	Pakistan	36,695
	El Salvador	18,536
	Guatemala	16,990
	Peru	10,869
Oaklogs	European Union	21,209
	Mexico	4,331
Peaches/nectarines	Japan	25
	Mexico	6,864
Strawberries	Australia	426
Walnuts in shell	Japan	1,349
Walnuts, shelled	Korea	990
Total		**$431,510**

Source: USDA.

Objectives, Scope, and Methodology

The Ranking Minority Member of the House Committee on Commerce asked that we review the concerns of the U.S. Department of Agriculture and the agricultural community about phasing out the U.S. production and importation of methyl bromide. Specifically, we agreed to develop information on (1) the scientific evidence that human uses of methyl bromide contribute to the depletion of the stratospheric ozone layer, (2) the availability of economical and effective alternatives to methyl bromide, (3) the impact of the ban on U.S. trade in agricultural commodities, and (4) EPA's authority under the Clean Air Act, as amended, to grant exemptions to the ban for essential uses. We conducted our work from November 1994 through November 1995 in accordance with generally accepted government auditing standards.

To review the scientific evidence, we consulted the reports of the United Nations Environment Programme (UNEP) on its 1991, 1992 (update of 1991), and 1994 scientific assessments of ozone depletion. We discussed the results of these studies with the Associate Director of Environment, Office of Science and Technology Policy in the Executive Office of the President and with scientists at the National Aeronautics and Space Administration who participated in the 1994 assessment. We also discussed the results with officials of USDA and EPA, including EPA's Methyl Bromide Program Director. We further discussed the scientific evidence with the Methyl Bromide Working Group, which was formed by methyl bromide producers and distributors to address scientific issues related to the phaseout, and with the Crop Protection Coalition, which represents methyl bromide users. Finally, we discussed the phaseout with a representative of the Natural Resources Defense Council, which is coordinating methyl bromide issues for various environmental groups, including the Friends of the Earth and the Environmental Defense Fund.

In addition, we reviewed scientific studies, reports, and other information either prepared by EPA or submitted by others during EPA's promulgation of the methyl bromide phaseout rule. Furthermore, we attended the "1995 Methyl Bromide State of the Science Workshop" held in June 1995. At the conference, which was sponsored by the Methyl Bromide Global Coalition in cooperation with the National Aeronautics and Space Administration, various papers were presented on the latest research developments.

At EPA, we discussed concerns about alternatives to methyl bromide with officials of the Stratospheric Protection Division and Office of Pesticide Programs. At USDA, we interviewed officials of the Agricultural Research Service, Economic Research Service, and Animal and Plant Health

Inspection Service, including the Chair of USDA's Ad Hoc Committee for Alternatives to Methyl Bromide. We further discussed substitutes for and alternatives to methyl bromide with the Methyl Bromide Working Group, the Crop Protection Coalition, the California Strawberry Commission, and several strawberry growers in California. In addition, we reviewed studies, reports, and other information on the availability and suitability of substitutes and alternatives provided by these officials. We also reviewed the assessment reports of UNEP's Technology and Economics Assessment Panel, Methyl Bromide Technical Options Committee, and Economics Committee and attended the "Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions," which was held in November 1994. Furthermore we reviewed the applicable EPA supporting documents and the information submitted to the agency during the promulgation of the phaseout rule.

We discussed the trade implications of the phaseout with officials of USDA's Economic Research Service, Agricultural Research Service, and Animal and Plant Health Inspection Service; EPA's Methyl Bromide Program; the Crop Protection Coalition; and the Methyl Bromide Working Group. In addition, we reviewed studies, reports, and other documents prepared by these organizations on the phaseout's effects on trade in agricultural commodities. We also reviewed the 1994 assessment reports of UNEP's Technology and Economics Assessment Panel, Methyl Bromide Technical Options Committee, and Economics Committee. Finally, we obtained information from the Animal and Plant Health Inspection Service on U.S. imports and exports of commodities treated with methyl bromide.

To determine whether the Clean Air Act provides EPA with the authority to grant essential use exemptions to the phaseout rule, our Office of General Counsel reviewed the Clean Air Act and its legislative history.

Major Contributors to This Report

Resources, Community and Economic Development Division, Washington, D.C.

Lawrence Dyckman, Associate Director
Edward A. Kratzer, Assistant Director
J. Kevin Donohue, Assistant Director
Raymond H. Smith, Jr., Senior Evaluator
J. Kenneth McDowell, Senior Evaluator
Donald E. Pless, Senior Evaluator
Frank J. Gross, Senior Evaluator

Office of General Counsel

Richard P. Johnson, Attorney Advisor

Ordering Information

The first copy of each GAO report and testimony is free. Additional copies are $2 each. Orders should be sent to the following address, accompanied by a check or money order made out to the Superintendent of Documents, when necessary. Orders for 100 or more copies to be mailed to a single address are discounted 25 percent.

Orders by mail:

U.S. General Accounting Office
P.O. Box 6015
Gaithersburg, MD 20884-6015

or visit:

Room 1100
700 4th St. NW (corner of 4th and G Sts. NW)
U.S. General Accounting Office
Washington, DC

Orders may also be placed by calling (202) 512-6000
or by using fax number (301) 258-4066, or TDD (301) 413-0006.

Each day, GAO issues a list of newly available reports and testimony. To receive facsimile copies of the daily list or any list from the past 30 days, please call (202) 512-6000 using a touchtone phone. A recorded menu will provide information on how to obtain these lists.

For information on how to access GAO reports on the INTERNET, send an e-mail message with "info" in the body to:

info@www.gao.gov

United States
General Accounting Office
Washington, D.C. 20548-0001

Bulk Rate
Postage & Fees Paid
GAO
Permit No. G100

Official Business
Penalty for Private Use $300

Address Correction Requested

Attachment 6

All *EHP* content is accessible to individuals with disabilities. A fully accessible (Section 508–compliant) HTML version of this article is available at http://dx.doi.org/10.1289/ehp.121-a198.

Getting the Drift

Methyl Bromide Application and Adverse Birth Outcomes in an Agricultural Area

Although occupational exposures to the pesticide methyl bromide are associated with numerous health problems,[1] little is known about the potential effects to the general population of chronic low-level exposure. However, agricultural drift has been associated with prostate cancer in one study of adult males,[2] and a handful of animal studies have suggested potential developmental toxicity, including reduced birth weight.[3] A new study in *EHP* based on modeled methyl bromide exposure in a human population now reports associations consistent with experimental findings.[4]

Some uses of methyl bromide were phased out in 2005 under the Montreal Protocol on Substances that Deplete the Ozone Layer.[5] However, the protocol permits several continued agricultural applications, or "critical uses," due to a lack of technically and economically viable alternatives.[6] One reason methyl bromide is so difficult to replace is that none of the alternatives have such broad activity at a cost growers can afford. There has been some research on combining other compounds, but so far there aren't any cost-effective options that work as well.[7] More than 1.75 million kg of the pesticide was applied in California in 2010.[8]

"Before we even started our research, we looked to see what was already known about this chemical, which is such an important pesticide in California agriculture," says Kim Harley, study coauthor and associate director for health effects research at the Center for Environmental Research and Children's Health, University of California, Berkeley. "There was very limited evidence for reproductive and developmental toxicity; there was almost nothing." To learn more, Harley and her colleagues drew on data collected through the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) Study. This longitudinal cohort study began in 1999–2000 with the enrollment of 601 pregnant women living in the Salinas Valley, an agricultural area in Northern California, and was designed to assess children's exposure to pesticides and other chemicals and potential related effects.

The researchers paired CHAMACOS Study data for a subset of 442 women with information from California's Pesticide Use Reporting system, which logs detailed information about the timing, location, and amount of pesticide applications. Interviews with the women at baseline and during the course of their pregnancies provided demographic and health information. The Global Positioning System coordinates of their homes were meshed with data from the Pesticide Use Reporting system to reveal methyl bromide amounts applied within 1, 3, 5, and 8 km of each residence. Medical records included pregnancy duration and newborns' length, weight, and head circumference.

The primary analysis focused on methyl bromide use within 5 km of a residence during each trimester of pregnancy. During the second trimester—a critical period of fetal growth—there were estimated decreases in average birth weight, length, and head circumference of 21.4 g, 0.16 cm, and 0.08 cm, respectively, for each 10-fold increase in methyl bromide use within 5 km.

Clinically, the estimated changes would be considered insignificant; however, the association suggests a downward shift in the overall distribution of growth variables with exposure during the second trimester. More highly exposed women had babies estimated to average 113.1 g (about 4 oz) lighter than those of unexposed mothers. By comparison, Harley says, smokers have babies that are about 150–250 g lighter than nonsmokers, "so this is not a trivial difference in birth weight that we're seeing in the high-exposed groups versus the unexposed group."

"The data are interesting," says Lygia Budnik, a professor in the Division of Occupational Toxicology and Immunology, Institute for Occupational and Maritime Medicine, University Hospital Hamburg-Eppendorf, Germany. "The critical-use exemption aspect is very important." Budnik emphasizes that in addition to use in agriculture, other uses of methyl bromide are still permitted, such as fumigation of freight containers. "We believe that more people are or were exposed than has been [reported], and many people might not be aware of the exposure and the resulting health problems," she says.

The study's strengths included detailed information about the women and their babies and about methyl bromide use near their homes. However, effects of other pesticides, especially chloropicrin, which is often combined with methyl bromide, could not be ruled out. Additionally, individuals' actual exposure could not be assessed.

"That's what's really hard about methyl bromide—we don't have a biomarker," says Harley. Residential proximity to application sites provides a good estimate of exposure, but it only applies to exposure at home; exposure levels away from home are unknown. Budnik and her colleagues are currently working on a potential biomarker based on increased blood levels of mitochondrial DNA in individuals exposed to methyl bromide and other fumigants.[9]

A strawberry field outside Salinas, California. Strawberries are one of several crops for which methyl bromide may still be used.
© AP Photo/Gosia Wozniacka

Julia R. Barrett, MS, ELS, a Madison, WI–based science writer and editor, has written for *EHP* since 1996. She is a member of the National Association of Science Writers and the Board of Editors in the Life Sciences.

REFERENCES

1. Budnik LT, et al. 2012. Prostate cancer and toxicity from critical use exemptions of methyl bromide: environmental protection helps protect against human health risks. Environ Health 11:5 (2012); http://dx.doi.org/10.1186/1476-069X-11-5.
2. Cockburn M, et al. Prostate cancer and ambient pesticide exposure in agriculturally intensive areas in California. Am J Epidemiol 173(11):1280–1288 (2011); http://dx.doi.org/10.1093/aje/kwr003.
3. National Research Council, Board on Environmental Studies and Toxicology, Committee of Toxicology, Subcommittee for the Review of the Risk Assessment of Methyl Bromide. Methyl Bromide Risk Characterization in California. Washington, DC:National Academy Press (2000); http://www.nap.edu/catalog.php?record_id=9849.
4. Gemmill A, et al. Residential proximity to methyl bromide use and birth outcomes in an agricultural population in California. Environ Health Perspect 121(6):737–743 (2013); http://dx.doi.org/10.1289/ehp.1205682.
5. EPA. The Phaseout of Methyl Bromide [website]. Washington, DC:U.S. Environmental Protection Agency (updated 25 Jan 2013). Available: http://www.epa.gov/ozone/mbr/ [accessed 15 May 2013].
6. EPA. Methyl Bromide: List of Critical Uses [website]. Washington, DC:U.S Environmental Protection Agency (updated 7 Dec 2012). Available: http://www.epa.gov/ozone/mbr/cueuses.html [accessed 15 May 2013].
7. Starkey TE. The history and future of methyl bromide alternatives in the southern United States. USDA Forest Service Proceedings, RMRS-P-68 (2012). Available: http://www.fs.fed.us/rm/pubs/rmrs_p068/rmrs_p068_031_035.pdf [accessed 15 May 2013].
8. DPR. The Top 100 Pesticides Used Pounds of Active Ingredients Statewide in 2010 (All Sites Combined). Sacramento, CA:California Department of Pesticide Regulation (2012). Available: http://goo.gl/RSMvW [accessed 15 May 2013].
9. Budnik LT, Kloth S, Baur X, Preisser AM, Schwarzenbach H. 2013. Circulating mitochondrial DNA as a biomarker linking environmental chemical exposure to early preclinical lesions. PLoS ONE. In press.

All *EHP* content is accessible to individuals with disabilities. A fully accessible (Section 508–compliant) HTML version of this article is available at http://dx.doi.org/10.1289/ehp.121-a198.

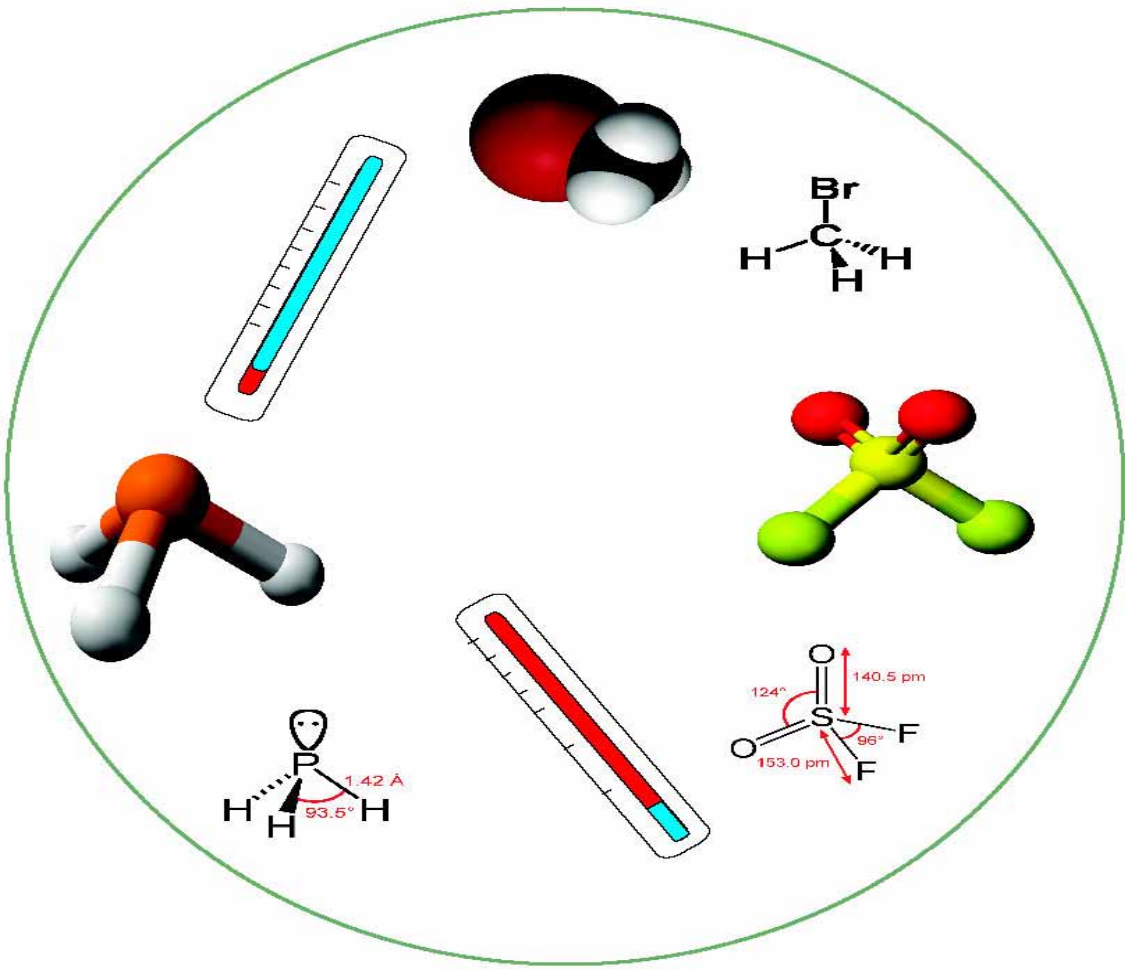
Erratum: "Getting the Drift: Methyl Bromide Application and Adverse Birth Outcomes in an Agricultural Area"

In the June 2013 News article "Getting the Drift: Methyl Bromide Application and Adverse Birth Outcomes in an Agricultural Area" [Environ Health Perspect 121:A198 (2013)], Lygia Budnik was identified as an assistant professor when she is, in fact, a full professor. *EHP* regrets the error.

Attachment 7

United States Department of Agriculture

Treatment Manual



Contents

Treatment Manual

Figures

Tables

1

Treatment Manual

Introduction

Contents

Purpose

The procedures and treatment schedules listed in this manual are administratively authorized for use in Plant Protection and Quarantine (PPQ). The treatment of listed commodities prevents the movement of agricultural pests into or within the United States. An officer may determine that other commodities require treatment to prevent similar pest movement.

Restrictions

Treatment recommendations listed in this manual are based on uses authorized under provisions of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended. Directions appearing on the label, Section 18 Emergency Exemptions, and manual instructions must be followed. Nevertheless, some treatments may damage commodities.

PPQ personnel may **not** make any warranty or representations, expressed or implied, concerning the use of these pesticides.

The occasional use of registered trade names in this manual does **not** imply an endorsement of those products or of the manufacturers by the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (USDA, APHIS).

Scope

What the Manual Covers

This manual covers treatments for quarantine significant plant pests for imported and domestic commodities.

Important

> **Do not** treat unlisted commodities until consulting and receiving approval from the USDA-APHIS-PPQ-S&T-CPHST-AQI in Raleigh, North Carolina.
>
> Approval from CPHST-AQI **must** be obtained each time a treatment schedule is used that is **not** an approved schedule from this manual.

This manual is broadly divided into ten sections:

- Chemical Treatments
- Nonchemical Treatments
- Residue Monitoring
- Treatment Schedules
- Certifying Facilities
- Emergency Aid and Safety
- Equipment
- Glossary
- Appendixes
- Index

Each section contains a Table of Contents, an Overview, and where appropriate, a Methods and Procedures section. The Overview is a broad, general description of what is covered in the section. Methods and Procedures cover the "how to" of that particular activity as well as procedural and reference material for performing tasks associated with each activity.

The Appendixes contain information directly associated with treatment activities, but are placed in the back so they do **not** interfere with the flow of procedural instructions.

What the Manual Does Not Cover

This manual does **not** cover treatments conducted in the United States for export to a foreign country. Export treatments are based on the importing countries' requirements and may be obtained from the Phytosanitary Export Database (PExD) or official communication from the importing country.

With exports, PPQ does not have the authority to require more restrictive measures than the importing country requires. When certifying that an export treatment has occurred, ensure that the mandatory components of the treatment are met, and that all safety guidelines are followed. Importing countries treatment requirements are provided through published regulations, import permits, and other official communication. Maintain quality assurance at the local level to ensure that all treatment are conducted according to the importing country's requirements.

Mandatory components to consider relating to an export treatment:

1. Follow the current pesticide label.
2. Ensure the safety of the employee.
3. Base the treatment on the foreign country's import requirements.

For more information, contact the PPQ Export Certification Specialist in your state or state of export. You can also visit the Export Services Program web site or email the general Export Services mailbox: ppqexportservices@aphis.usda.gov.

Users

This manual is used primarily by PPQ officers, headquarters personnel, and State cooperators involved in conducting treatments. The secondary users of this manual are other government agencies, fumigators, pest control operators, foreign governments, and other interested parties.

Related Documents

The following documents are related to this manual:

- APHIS Safety and Health Manual
- Code of Federal Regulations (CFR)
  - Title 7 (Agriculture)
  - Title 46 (Shipping) Chapter 1, Part 147—Interim Regulations for Shipboard Fumigation
- Federal Insecticide, Fungicide, Rodenticide Act as amended
- Material Safety Data Sheets (MSDS)
- Pesticide labels and labeling
- Plant import manuals (Propagative and Nonpropagative)

- Occupational Safety and Health Administration (OSHA) Technical Manual

Application

This manual serves both as a field manual for employees conducting treatments and as a reference for PPQ officers, program managers, and staff officers. Under APHIS policy, only certified pesticide applicators may conduct or monitor treatments. This manual will also serve as a reference for researching the types of treatments available for imports and to answer questions from importers, industry, and foreign countries.

How to Use This Manual

Review the content of this manual to get a feel for the scope of material covered. Glance through the section that you will be using and familiarize yourself with the organization of information.

Use the Table of Contents at the beginning of each chapter to find the information you need. If the Table of Contents is **not** specific enough, then refer to the Index to find the topic and corresponding page number.

Reporting Problems with or Suggestions for the Manual

If you want to suggest an improvement or identify a problem with the content of this manual, email josie.cooley@aphis.usda.gov or call (240) 529-0358. If you disagree with the guidelines or policies contained in this manual, contact Quarantine Policy, Analysis and Support (QPAS) through channels.

Conventions

The following are terms that are widely recognized and used throughout this manual:

Indicates that people can easily be hurt or killed

Indicates that people could possibly be hurt or killed

CAUTION

Indicates that people could possibly be endangered and slightly hurt

NOTICE

Indicates a possibly dangerous situation, goods might be damaged

Important

Indicates helpful information

EXAMPLE: indicates additional information that helps to clarify the content in the manual

Treatment schedules which are FIFRA Section 18 Exemptions (such as the sample below) are followed by an "Important" note to help you determine the current exemption status.

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hrs	2 hrs	3 hrs	3.5 hrs
90 °F or above	2 lbs	26	19	19	—
80-89 °F	2.5 lbs	32	24	24	—
70-79 °F	3 lbs	38	29	24	—
60-69 °F	3 lbs	38	29	—	24

Important

Do not use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

Manual Updates

The PPQ Manuals Unit issues and maintains manuals electronically on the Manuals Unit Web site. The online manuals contain the most up-to-date information. Immediate update revisions to this manual are distributed via the APHIS Stakeholder Registry to anyone who has subscribed to receive Treatment Manual updates. To subscribe to the Stakeholder Registry, register here.

Each update contains the following information:

- Link to access and download the on line manual
- List of the revised page number(s)
- Purpose of the revision
- Transmittal number

Ordering Additional Manuals and Revisions

Although using the on line manuals is the preferred method, APHIS employees may order hard copies of manuals from the APHIS Printing, Distribution, and Mail Services Center in Riverdale, MD. Visit the Riverdale Print Shop Web site for detailed information and printing costs. The Manuals Unit is not responsible for printing costs.

2

Treatment Manual

Chemical Treatments

Overview

Contents

Introduction

The Chemical Treatments section of this manual is organized by chemicals tabbed as follows:

- Fumigants
- Aerosols and Micronized Dust

Use the Contents in this section to quickly find the information you need. The subjects listed in the Contents are also marked on the tabs in this manual. If the Contents is **not** specific enough, then turn to the Index to find the topic and its page number.

2

Treatment Manual

Chemical Treatments

Fumigants

Contents

Introduction

Fumigation is the act of releasing and dispersing a toxic chemical so it reaches the target organism in a gaseous state. Chemicals applied as aerosols, smokes, mists, and fogs are suspensions of particulate matter in air and are not fumigants.

The ideal fumigant would have the following characteristics:

- Highly toxic to the target pest
- Nontoxic to plants and vertebrates (including humans)
- Easily and cheaply generated
- Harmless to foods and commodities
- Inexpensive
- Nonexplosive
- Nonflammable
- Insoluble in water
- Nonpersistent
- Easily diffuses and rapidly penetrates commodity
- Stable in the gaseous state (will not condense to a liquid)
- Easily detected by human senses

Unfortunately, no one fumigant has all the above properties, but those used by APHIS and PPQ have many of these characteristics.

The toxicity of a fumigant depends on the respiration rate of the target organism. Generally, the lower the temperature, the lower the respiration rate of the organism which tends to make the pest less susceptible. Fumigation at lower temperatures requires a higher dosage rate for a longer exposure period than fumigation at higher temperatures.

Fumigants vary greatly in their mode of action. Some kill rapidly while others kill slowly. In sublethal dosages, some fumigants may have a paralyzing effect on the pest while others will not allow the pest to recover. Some fumigants have no effect on commodities while others are detrimental even at low concentrations. Commodities vary in their sorption of fumigants and in the effort required to aerate the commodities after fumigation.

Due to the reduction in number of labeled fumigants, there is seldom a choice in selecting fumigants. When there is a choice, factors such as the commodity to be treated, pest and stages present, type of structure, and cost should be considered in selecting a fumigant.

The only authorized fumigants are the following:

- Methyl bromide (MB)
- Sulfuryl fluoride (SF) (Vikane)
- Phosphine (PH) (There are two chemicals used for phosphine, AP—aluminum phosphide and MP—magnesium phosphide)

Much of the information on fumigants is based on MB with modification as needed for the other fumigants.

Monitoring of Quarantine Treatments

Monitoring of program fumigations is performed to ensure that effective fumigant concentration levels are maintained throughout the treatment to prevent the introduction of quarantine pests. Quarantine fumigations employing restricted use pesticides require careful monitoring to assure efficacy and personal safety, to maintain pesticide residues within acceptable limits, and to preserve commodity quality. These requirements are included in the fumigant label, and it is a violation of Federal law to use fumigants and pesticides in a manner inconsistent with its labeling.

Nonperishable Commodities in Temporary Enclosures

PPQ officers will provide onsite monitoring from introduction of the fumigant through completion of the 2 hour gas concentration readings. Half hour and two hour readings are required for these treatments. These readings and general observations permit the officer to determine how a particular treatment is progressing and to make necessary corrections to the enclosure or fumigant concentration level.

Perishable Commodities in Temporary Enclosures

The monitoring officer will remain on the site through the entire fumigation of perishable commodities. Continuous monitoring allows the officer to alert the pest control operator at any time to implement necessary corrective measures. Due to the nature of the commodity and the length of treatment, onsite monitoring of yam and chestnut fumigations may be interrupted after the 2 hour reading when efficacy and safety considerations warrant.

These instructions do not prevent the officer from leaving the immediate fumigation site for brief periods when it is necessary and safe to do so. The pest control operator must be notified of the PPQ officer's intended absence. These absences would normally be limited to 20 minutes (e.g., restroom breaks or a medical condition) and do not constitute a break in service. These practices are in place in many locations and will require only minor modifications in other areas.

Fumigation Guidelines

The following fumigation guidelines are in common usage throughout this manual:

- Dosage rate is based on 1,000 cubic feet of enclosure space, whether chamber, tarpaulin, van, freight car, ship hold, etc. Dosage should be calculated from the volume of the tarped fumigation enclosure.
- Dosages are listed by weight in the Treatment Schedules. If liquid measures are needed, convert from weight to volume by using the conversion figures.
- Ounces per 1,000 cubic feet (oz/1000 ft^3) is equal to milligrams per liter (mg/liter) and is equal to grams per cubic meter (g/m^3).
- Volume of commodity being treated should **not** exceed two-thirds of enclosure volume unless otherwise specified in a schedule.
- Specified vacuum should be held throughout the exposure period.

- Blowers or fans should be operated as follows:
  - for propagative material (T200-series schedules), the entire period of exposure, whether NAP or vacuum
  - under tarpaulin (and vacuum fumigation for other than propagative material), fans should operate for 30 minutes after gas introduction, or until an APHIS-approved gas detection device indicates uniform gas distribution
  - for all bulk material, forced recirculation is required, check for uniform gas distribution by taking gas readings at four or five locations including at least three from the commodity

Important

Phosphine fumigations do **not** require fans.

- In this section, all NAP treatments that refer to chamber fumigations should be conducted in USDA-approved chambers. (Refer to ***Certification of Vacuum Fumigation Chambers*** on **page 6-2-1** or ***Certifying Atmospheric Fumigation Chambers*** on **page 6-3-1**).
- Methyl bromide treatment schedules are indicated as "MB." MB generally refers to any methyl bromide label. Specific MB label restrictions are noted in this manual for the "Q" label. Always check the label of the fumigant to be sure the commodity is listed on the label. Commodities that are not listed on the fumigant's label are not authorized for fumigation with the manufacturer's gas.

Physical Properties of Fumigants

Fumigant	Chemical Formula	Boiling Point	Specific Gravity[1]	Flammability Limits in Air
Methyl Bromide	CH_3Br	3.6 °C 40.1 °F	3.27	Normally nonflammable. Flame propagation at 13.5 to 14.5 percent by volume only in the presence of an intense source of ignition.
Phosphine	PH_3	–87.4 °C –126 °F	1.214	1.79 percent by volume
Sulfuryl fluoride	SO_2F_2	–55.2 °C –67 °F	2.88	Nonflammable

1 Air = 1, anything greater is heavier than air.

Fumigant	Odor	Effects on Metals	General
Methyl Bromide	No odor at low concentration. Strong musty or sweet at high concentrations.	Reacts with aluminum, may damage electronic equipment	Discharged from cylinders, 1.5 lb cans
Phosphine	Garlic-like or carbide due to impurities	Copper, brass, gold and silver severely damaged; electronic equipment damaged. Other metals slightly affected in high humidity.	Evolved from aluminum phosphide or magnesium phosphide preparations
Sulfuryl fluoride	None	Non-corrosive	Discharged from cylinders

2

Treatment Manual

Chemical Treatments

Fumigants • Methyl Bromide

Contents

Properties and Use

Methyl bromide (MB) (CH_3Br) is a colorless, odorless, nonflammable fumigant. MB boils at 38.5 °F and has a very low solubility in water. As a gas, MB is three times heavier than air. As a liquid at 32 °F, 1 pound of MB is equivalent to 262 ml. For ease in transportation and handling, MB is compressed and stored in metal cylinders as a liquid.

MB is an effective fumigant for treating a wide variety of plant pests associated with a wide variety of commodities. MB is the most frequently used fumigant in quarantine fumigations. MB may also be used to devitalize plant material. MB is effective in treating the following pests:

- Insects (all life stages)
- Mites and ticks (all life stages)
- Nematodes (including cysts)
- Snails and slugs
- Fungi (such as oak wilt fungus)

MB is effective over a wide range of temperatures (40 °F and above). In general, living plant material tolerates the dosage rate specified, although the degree of tolerance varies with species, variety, stage of growth, and condition of the plant material. MB accelerates the decomposition of plants in poor condition.

Since MB is three times heavier than air, it diffuses outward and downward readily, but requires fans to ensure upward movement and equal gas distribution. Fan circulation also enhances penetration of MB into the commodity. A volatilizer is used to heat the liquid MB in order to speed up its conversion to a gas. Once the gas is evenly distributed, it maintains that condition for the duration of the treatment unless an outside event such as excessive leakage occurs.

Section 18 Exemption Treatment Schedules

Methyl bromide fumigants, except those with “Q” labels, may be subject to requirements of the FIFRA Section 18 Quarantine Exemption. When commodities intended for food or feed are fumigated with methyl bromide under the FIFRA Section 18 Quarantine Exemption, one additional EPA *requirement* must be met: PPQ must monitor aeration by sampling the gas concentration to determine when a commodity may be released.

The EPA defines a Federal quarantine exemption (40 CFR 166.2(b)) as “A quarantine exemption may be authorized in an emergency condition to control the introduction or spread of any pest new to or not theretofore known to be widely prevalent or distributed within and throughout the United States and its territories.”

The section 18 Crisis Exemption has been amended to permit treatment of commodities that are at risk for carrying Federal quarantine pests. This means that treatments are permitted not only for imported commodities, but also for domestic commodities growing in areas under quarantine for a regulated pest. This exemption does not authorize treatments of domestically grown commodities for export certification **unless** the treatment is necessary to move the commodity out of quarantine, i.e. the target pests must be Federally regulated pests.

In this manual, fumigation schedules under the FIFRA Section 18 Quarantine Exemption are followed by an “Important” note to help you determine the current exemption status. For example:

Example Treatment Schedule Table			

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

Table 2-3-1 is a list of commodities covered by the FIFRA Section 18 exemption. This list will expire on March 01, 2020.

Table 2-3-1 List of Commodities Covered by FIFRA Section 18 Exemption

Commodity	Minimum Temperature (F)	Maximum Dosage Range (lb/1000 ft^3)	Exposure Period (hours)
Avocado	70	4	4
Banana and Plantain (fruit)	40	4	2
Banana leaf	40	4	2
Blueberry and unlabeled commodities from the berry and small fruit crop group 13-07	40	4	4
Cacti, edible (includes Opuntia)	40	4	3.5
Coffee bean (green, unroasted)	40	9	12
Coconut (unprocessed, whole coconut without husk)	60	2.5	2
Cottonseed (for animal feed)	40	7	24
	40	5	48
Cucurbit seed (unprocessed)	40	9	12
Dasheen (root and tuber)	40	4	4
Figs, fresh	40	4	3
Flowers, squash and lorocco	40	4	2
Genip (Spanish Lime)	40	4	4
Herbs and spices, fresh (crop group 19)	40	4	4
Ivy gourd	40	4	2
Kaffir lime leaves	40	4	2
Kola nut (cola)	40	6	6
Longan	60	4	2
Lychee fruit	40	4	2
Mango	40	4	2
Mint, dried	40	3	24
Mint, fresh	40	4	2
Oilseed (crop group 20)	40	9	12
Persimmon	40	4	2
Pitahaya (pitaya or dragon fruit)[1]	40	4	2
Pomegranate, fresh	40	4	3
Pointed gourd	40	4	2
Rambutan	60	4	2
Seeds in the family Malvaceae for food use, including hibiscus and kenaf seed	40	3.5	2
Unlabeled commodities in the leaves of legume vegetable crop group 7[2]	40	4	2.5
Unlabeled commodities in the root and tuber crop group 1[2]	60	3	3.5
Unlabeled commodities in the stone fruit crop group (12-12)[2] (i.e. pluot, plumcot, aprium, cherrycot, peachcot)	40	4	3

Table 2-3-1 List of Commodities Covered by FIFRA Section 18 Exemption (continued)

Commodity	Minimum Temperature (F)	Maximum Dosage Range (lb/1000 ft^3)	Exposure Period (hours)
Unlabeled commodities in the Bulb Vegetable crop group (3-07) [2]	40	4	4
Unlabeled commodities in the stalk, stem, and leaf petiole crop group 22[2]	40	4	3.5
Unlabeled commodities in the following crop groups[2]: ◆ Brassica leafy vegetables (crop group 5) ◆ Curcurbit vegetables (crop group 9) ◆ Edible podded legume vegetables (crop group 6A) ◆ Fruiting vegetable (crop group 8-10) ◆ Leafy vegetables (except Brassica) (crop group 4) ◆ Leaves of roots and tubers (i.e. chicory) (crop group 2) ◆ Tropical and subtropical fruit, edible peel (crop group 23) ◆ Tropical and subtropical fruit, inedible peel (crop group 24)	40	4	2

1 Dragon fruit is also known as pitahaya or pitaya. Refer to the *List of Scientific Names of Admissible Dragon Fruit* for more information.

2 The EPA crop groups are listed in Appendix F on **page F-1** for quick reference. Refer to 40 CFR 180.41 Crop Group Tables for the official list of commodities within each crop group. **NOTE:** If you have questions regarding what commodities are covered by a particular crop group or whether or not a commodity is labeled or unlabeled, CONTACT Field Operations at 919-855-7336.

The EPA only authorizes fumigation of commodities if they are listed on the label of the gas being used for the fumigation. The fumigator is responsible for ensuring that the commodity, its dosage, and the treatment duration is listed either on the product label or within the Section 18 authorization letter, which the PPQ officer should have readily available for any fumigator who requests it. The methyl bromide products that fumigators are authorized to use for Section 18 treatments are identified within the Section 18 authorization letter. To comply with State requirements, the fumigator is responsible for ensuring that the fumigant is registered in the State where it is being used.

Fumigation schedules in this publication are more detailed than what is provided in commercial labels in order to ensure that the phytosanitary treatments of imported commodities are efficacious.

When the treatment schedule is marked “MB”, **any** methyl bromide fumigant may be used for the fumigation as long as the commodity, its dosage, and treatment duration are on the fumigant label.

Leak Detection and Gas Analysis

Require the fumigator to use an APHIS-approved gas detection device to measure gas concentration levels in tarpaulins. Require the fumigator to use an APHIS-approved leak detection device primarily to check for leaks around tarpaulins, chambers, application equipment, and as a safety device around the fumigation site. For a partial list of manufacturers of detection devices, refer to **Reference Guide to Commercial Suppliers of Treatment and Related Safety Equipment**. Colorimetric tubes, which are supplied by the fumigator, are used to measure gas concentration levels during aeration.

2016 Methyl Bromide Label Information

In 2015, the Environmental Protection Agency (EPA) directed all methyl bromide (MB) registrants to amend the use directions on the labels of all 100% MB products. EPA required the changes in order to reflect recommendations in an EPA report.[1]

These amendments modify the use directions for fumigation and aeration procedures, modify respiratory requirements and equipment and update gas monitoring equipment. EPA requires all labels on newly manufactured MB to reflect these recommendations effective **October 01, 2016**; however, EPA is allowing existing stocks of MB to be used in accordance with the use directions on the existing stock's (older) labels.

PPQ officials and fumigators **must** closely examine gas cylinder labels in order to validate that the dosage, exposure, and commodity are either on the cylinder label or covered by a FIFRA Section 18 exemption. If a label is **not** affixed to the cylinder, DO NOT allow the fumigator to use that cylinder.

New Buffer Zone Requirements

All 2016 MB labels now require both a treatment and an aeration buffer zone. Both the treatment and aeration buffer zones are specific to the enclosure being fumigated and **must** be determined by visiting a website link[2] provided in every MB label. The fumigators are responsible for using this website to determine the buffer zones and reporting both buffer zones to the PPQ official. If the treatment buffer zone is determined to be less than 30 feet, the PPQ official will maintain PPQ's standard 30 foot treatment buffer zone; otherwise, the new treatment buffer zone **must** be observed.

1 "Report of Food Quality Protection Act (FQPA) Tolerance Reassessment and Risk Management Decision (TRED) for methyl bromide, and Reregistration Eligibility Decision (RED) for Methyl Bromide's Commodity Uses", dated August 2006. (https://archive.epa.gov/pesticides/reregistration/web/pdf/methyl_bromide_tred.pdf)

2 https://www.epa.gov/pesticide-registration/mbcommoditybuffer

If the aeration buffer zone is determined to be less than 200 feet, then PPQ's standard "200 feet for 10 minutes" aeration buffer zone **still** applies for the first 10 minutes of aeration. The fumigator **must** refer to EPA's website to determine the minimum aeration buffer zone to be maintained until the aeration period is complete and the fumigator has verified that gas concentration levels meet the conditions in the MB label.

Transiting through buffer zones

The label permits vehicles to transit through both treatment and aeration buffer zones under specific conditions found in the label; it is up to the fumigator determine how or whether vehicles may transit in accordance with the label.

When using the newer 2016 MB label, changes to certain procedures and equipment in this chapter are displayed in a NOTICE box with a heading titled "MB 2016 Label".

MB 2016 Label (example)

NOTICE

Use this information when the fumigator is using the 2016 MB label.

When using existing stocks, follow the equipment and procedural guidance that is displayed in the body of the text (outside of the NOTICE box).

If there is no "MB 2016 Label" NOTICE box, then the instructions apply to all MB labels, 2016 and older.

MB 2016 Label

NOTICE

The PPQ official and the fumigator must use the following leak detection and gas analysis equipment:

- An air purifying NIOSH certified half-mask or full face piece respirator when gas concentrations are between 1 and 5 ppm
- A self contained breathing apparatus (SCBA) NIOSH approved prefix TC-13F when gas concentrations are 5 ppm or above
- An APHIS-approved continuous real time gas monitoring device that is permanently mounted in PPQ owned facilities or a portable photoionization detector to monitor gas concentrations in the breathing space
- An APHIS-approved direct read gas detection device, such as colorimetric tubes, to determine gas concentrations when aerating and releasing the commodity

For a list of manufacturers and approved models refer to **Reference Guide to Commercial Suppliers of Treatment and Related Safety Equipment**.

PPQ policy is to wear appropriate respiratory protection when air concentrations are above 1 ppm. However, the new MB labels allow workers to be present without respiratory protection for specific time limits over a 24-hour period when air concentrations are:

- >3 to 5 ppm (90 minutes),
- >2 to 3 ppm (160 minutes),
- >1 to 2 ppm (4 hours), and
- >0 to 1 ppm (8 hours).

These permissible work-time allowances will give the PPQ official sufficient time to calmly locate and don the appropriate respiratory protection should their PID (alarm set to go off at 1 ppm) indicate the presence of MB in the air.

Effects of Temperature and Humidity

MB is effective at the same temperatures plants are generally handled (usually 40 °F and above). In general, increases in temperature give a corresponding increase in the effectiveness of MB. All treatment schedule temperatures are listed with the corresponding dosage rate. Follow the dosage rates listed. A Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Section 3 registration (the labeled rate of MB provided), or a Section 18 Exemption must be in effect at the time of treatment.

For live plant material which is actively growing or with leaves, maintain a high percentage of humidity (above 75 percent) in the chamber by placing wet sphagnum or excelsior in the chamber or by wetting the chamber walls and floor. Protect actively growing or delicate plants from the direct air flow of fans. Do **not** add any moisture to the chamber when fumigating seeds. Too much moisture on the material to be fumigated may prevent the fumigant from reaching some of the pests.

Penetration and Aeration of Boxes and Packages

Plastic wrappings such as cellophane, films, and shrink wrap, and papers that are waxed, laminated, or waterproofed are **not** readily permeable and **must** be perforated, removed, or opened before fumigation. Approved packaging materials may be layered as long as perforations allow adequate MB penetration.

Important

Inform prospective importers that all packaging used in USDA quarantine fumigations **must** comply with these Manual specifications or be approved by CPHST AQI

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606
919-855-7450

The following is a partial list of approved packaging materials:

- Dry cloth
- Dry, non-waxed or non-painted cardboard
- Dry, non-waxed or non-painted non-glossy paper

- Dry, woven fabrics and plastics
  - Woven polypropylene bags that are **not** laminated with plastic or paper inside or out (these bags are typically used for holding seeds or grains)
  - Bags containing a large quantity of seeds or grains (>2,000 lbs.) are referred to as "super sacks" or "totes" and must have the top of the bag opened to aid in fumigant dispersal and aeration
- Dupont™ Tyvek® Air Cargo Covers (refer to Chapter 8—Equipment **Dupont™ Tyvec® Air Cargo Covers** for more information)
- Pac-Armor™ (Safeguard Global LLC)
- Perforated plastics with evenly distributed holes on all sides and 0.93 percent open area of surface, for example:
  - Holes that are 3/16-inch in diameter every 3 square inches
  - Holes that are 1/4-inch in diameter every 4 square inches
  - 49+ pinholes per square inch
- Plastic clamshells
  - Evenly distributed holes on all sides and 0.93 percent open area of surface
  - Holes on top and bottom must not be blocked when clamshells are stacked (i.e. clamshells must have recesses or ridges to prevent blockage)
- Seed packets (from Thompson & Morgan (UK) Ltd.)
- SmartPac liner with 0.3% vented area (Quimas S.A. Chile)
- Wooden boxes (lids removed if tightly sealed)

If a commodity is NOT undergoing fumigation, a consignment cannot be rejected because of packaging.

Important

Inform prospective importers that the wrappings on their shipments may have to be perforated according to PPQ specifications, removed, or opened if PPQ requires fumigation. PPQ is not responsible for opening or perforating the wrapping.

To expedite commodity movement, importers should send a complete bag/wrap sample to CPHST-AQI for inspection and approval.

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606
919-855-7450

Sorption

Sorption is the process of chemically or physically binding free MB on or within the fumigated commodity. Sorption makes the fumigant unavailable to kill the plant pest. There are three types of sorption—absorption, adsorption, and chemisorption. Sorption rate is high at first, then gradually reduces to a slow rate. Sorption increases the time required for aeration.

Commodities known or believed to be highly sorptive should not be fumigated in chambers unless concentration readings can be taken to ensure the required minimum concentration is met. Additional readings may be necessary in order to properly monitor gas concentration sorptive commodities in chambers.

For tarpaulin fumigation, additional gas readings are necessary to monitor concentration of gas to determine the rate of sorption. The following is a partial list of commodities known to be highly sorptive:

- Burlap bales
- Carpet backing
- Cinnamon quills
- Cocoa mats
- Cotton
- Flour and finely milled products
- Gall nuts
- Hardboard (Masonite™)
- Incense
- Myrobalan
- Pistachio nuts
- Polyamide waste
- Polystyrene foam (Styrofoam)
- Potato starch
- Rubber (crepe or crude)
- Vermiculite
- Wood products (unfinished)
- Wool (raw, except pulled)

Contact CPHST if you are concerned about the sorptive properties of other commodities.

Residual Effect

MB may adversely affect the shelf life of fresh fruits and vegetables, the viability of dormant and actively growing plants, and the germination of seed. Although MB may adversely affect some commodities, it is a necessary risk in order to control pests. Some dosage rates are near the maximum tolerance of the commodity, so care must be exercised in choosing the proper treatment schedule and applying the treatment.

MB may also adversely affect nonplant products. In general, articles with a high sulfur content may develop "off-odors" on contact with MB. In some commodities the odors are difficult or impossible to remove by aeration. If possible or practical, remove from the area to be fumigated any items that are likely to develop an undesirable odor.

Ordinarily, the following items should **not** be fumigated:

- Any commodity **not** listed on the label or lacking a FIFRA Section 18 Exemption
- Any commodity lacking a treatment schedule
- Automobiles
- Baking powder
- Blueprints
- Bone meal
- Butter, lard, or fats, unless in airtight containers
- Charcoal (highly sorptive)
- Cinder blocks or mixed concrete and cinder blocks
- CO^2 scrubbers (calcium hydroxide and calcium carbonate; MAXtend®)[3]
- EPDM rubber (ethylene propylene diene M-class; a type of synthetic rubber)
- Electronic equipment[4]
- Ethylene absorbers (potassium permanganate sachets used to remove ethylene from an enclosure, usually a container loaded with fruit)
- Feather pillows
- Felt

3 If the scrubbers are removed prior to fumigation, the consignment may be fumigated.
4 Electronic equipment may be fumigated as long as it is properly sealed to protect against internal fluid contamination by the MB gas. Ensure that the liquid MB is completely volatilized before it is introduced into the area to be fumigated. Obtain a waiver from the importer agreeing to release the USDA from any damages.

- Furs
- High-protein flours (soybean, whole wheat, peanut)
- Horsehair articles
- Leather goods
- Machinery with milled surfaces
- Magazines and newspapers (made of wood pulp)
- Magnesium articles (subject to corrosion)
- Paper with high rag or sulfur content
- Photographic chemicals and prints (**not** camera film or X-rays)
- Polyurethane foam
- Natural rubber goods, particularly sponge rubber, foam rubber, and reclaimed rubber including pillows, mattresses, rubber stamps, and upholstered furniture
- Neoprene
- Rug pads
- Silver polishing papers
- Woolens (especially angora), soft yarns, and sweaters; viscose rayon fabrics
- Yak rugs

2

Treatment Manual

Chemical Treatments

Fumigants • Methyl Bromide • Tarpaulin Fumigation

Contents

Methods and Procedures

The procedures covered in this section provide PPQ officials and commercial fumigators with the methods, responsibilities, and precautions for tarpaulin fumigation.

2016 Methyl Bromide Label Information

In 2015, the Environmental Protection Agency (EPA) directed all methyl bromide (MB) registrants to amend the use directions on the labels of all 100% MB products. EPA required the changes in order to reflect recommendations in an EPA report.[1]

These amendments modify the use directions for fumigation and aeration procedures, modify respiratory requirements and equipment and update gas monitoring equipment. EPA requires all labels on newly manufactured MB to reflect these recommendations effective **October 01, 2016**; however, EPA is allowing existing stocks of MB to be used in accordance with the use directions on the existing stock's (older) labels.

PPQ officials and fumigators **must** closely examine gas cylinder labels in order to validate that the dosage, exposure, and commodity are either on the cylinder label or covered by a FIFRA Section 18 exemption. If a label is **not** affixed to the cylinder, DO NOT allow the fumigator to use that cylinder.

New Buffer Zone Requirements

All 2016 MB labels now require both a treatment and an aeration buffer zone. Both the treatment and aeration buffer zones are specific to the enclosure being fumigated and must be determined by visiting a website link[2] provided in every MB label. The fumigators are responsible for using this website to determine the buffer zones and reporting both buffer zones to the PPQ official. If the treatment buffer zone is determined to be less than 30 feet, the PPQ official will maintain PPQ's standard 30 foot treatment buffer zone; otherwise, the new treatment buffer zone **must** be observed. If the aeration buffer zone is determined to be less than 200 feet, then PPQ's standard "200 feet for 10 minutes" aeration buffer zone **still** applies for the first 10 minutes of aeration. The fumigator **must** refer to EPA's website to determine the minimum aeration buffer zone to be maintained until the aeration period is complete and the fumigator has verified that gas concentration levels meet the conditions in the MB label.

Transiting through buffer zones

The label permits vehicles to transit through both treatment and aeration buffer zones under specific conditions found in the label; it is up to the fumigator determine how or whether vehicles may transit in accordance with the label.

1 "Report of Food Quality Protection Act (FQPA) Tolerance Reassessment and Risk Management Decision (TRED) for methyl bromide, and Reregistration Eligibility Decision (RED) for Methyl Bromide's Commodity Uses", dated August 2006. (https://archive.epa.gov/pesticides/reregistration/web/pdf/methyl_bromide_tred.pdf)

2 https://www.epa.gov/pesticide-registration/mbcommoditybuffer

When using the newer 2016 MB label, changes to certain procedures and equipment in this chapter are displayed in a NOTICE box with a heading titled “MB 2016 Label”.

MB 2016 Label (example)

NOTICE

Use this information when the fumigator is using the 2016 MB label.

When using existing stocks, follow the equipment and procedural guidance that is displayed in the body of the text (outside of the NOTICE box).

If there is no “MB 2016 Label” NOTICE box, then the instructions apply to all MB labels, 2016 and older.

Materials Needed

PPQ Official Provides

- APHIS-approved leak detection device
- Calculator (optional)
- Forms (PPQ Form 429 and APHIS Form 2061 if necessary)
- Self-contained breathing apparatus (SCBA) or supplied air respirator

MB 2016 Label

NOTICE

In addition to the bulleted list on page 2-4-3, the PPQ official must provide:

- Air purifying respirator NIOSH certified half-mask or full face piece with a cartridge for concentrations between 1 and 4 ppm
- APHIS-approved continuous real time gas monitoring device
  - Permanently mounted in PPQ owned facilities only, PureAire Monitoring Systems, Inc. model Air check Advantage[1]
  - Portable Photoionization Detector (PID), RAE Systems, Inc. model MiniRAE 3000[2]
- Self contained breathing apparatus (SCBA) NIOSH approval prefix TC-13F or supplied air respirator NIOSH approval prefix TC-19C

1 The Air Check Advantage can be calibrated either by the manufacturer or by the PPQ official. Calibrate according to the manufacturer's User Guide. Refer to Chapter 8: Equipment for more information.

2 The MiniRae 3000 must be calibrated by the PPQ official according to the manufacturer's User's Guide. Refer to Chapter 8: Equipment for more information.

Fumigator Provides

- APHIS-approved gas detection device[3] (e.g. thermal conductivity device, infrared device, etc.)
- Auxiliary pump for purging long gas sample tubes
- Carbon dioxide filter (e.g., Ascarite®)
- Colorimetric tubes (Refer to ***Gas Detector Tube (colorimetric) and Apparatus* on page E-1-31** for a list of APHIS-approved product ranges)
- Desiccant (e.g., Drierite®)
- Electrical wiring (grounded, permanent type), three prong extension cords
- Exhaust blower and ducts
- Fans (circulation, exhaust, and introduction)
- Framework and supports

3 The methyl bromide monitor must be calibrated annually. Refer to Chapter 8: Equipment for calibration information. If using a thermal conductivity (TC) analyzer, Drierite® and Ascarite® must be used.

- Gas introduction line
- Gas sampling tubes
- Heat supply
- Insecticides and spray equipment
- Loose, wet sand
- Methyl bromide
- Padding
- Sand or water snakes or adhesive sealer
- Scales or dispensers[4]
- Self-contained breathing apparatus (SCBA) or supplied air respirator
- Tape
- Tape measure
- Tarpaulin
- Temperature recorder and temperature sensors[5]
- Thermometer[6]
- Volatilizer (filled with water or antifreeze)
- Warning signs/Placarding

4 All scales must be calibrated by the State, a company that is certified to conduct scale calibrations, or by the fumigator under the supervision of PPQ. The source and date of calibration must be posted in a visible location on or with the scale at all times. The scale must be calibrated a following every repair or minimum of every year.
5 Temperature sensors must be calibrated annually by the manufacturer or National Institute of Standards and Technology (NIST) within the range of 40 °F to 80 °F (4.4 °C to 26.7 °C)
6 The thermometer must be calibrated or replaced annually.

MB 2016 Label

NOTICE

In addition to the items in the bulleted list on page 2-4-4 and page 2-4-5, the fumigator must also provide:

- Air purifying respirator NIOSH certified half-mask or full face piece with a cartridge for concentrations between 1 and 4 ppm
- APHIS-approved direct read gas detection device
  - Colorimetric tubes (e.g. Draeger, Sensidyne)
- APHIS-approved continuous real time gas monitoring device[1]
  - Permanently mounted in PPQ owned facilities only (PureAire)
  - Portable Photoionization Detector (PID) RAE Systems, Inc. MiniRAE 3000
- Self contained breathing apparatus (SCBA) NIOSH approved prefix TC-13F or supplied air respirator NIOSH approval prefix TC-19C

1 These devices must be calibrated according to the manufacturer's User Guide. Refer to Chapter 8: Equipment for more information.

Preparing to Fumigate

Step 1—Selecting a Treatment Schedule

The PPQ official will select a treatment schedule to effectively eliminate the plant pest.

Turn to the Treatment Schedule Index and look up the available treatment schedule(s) by commodity (example—apples, pears, or citrus) or by pest (e.g., Mediterranean fruit fly). Some commodities may have several treatment schedules. Refer to ***Residual Effect* on page 2-3-11** for a list of those commodities which may be damaged by MB. Each treatment schedule lists the target pest or pest group (e.g., *Ceratitis capitata*, surface feeders, wood borers...), commodity, or both pest and commodity. If there is no schedule, the commodity may **not** be fumigated. Refer to **Table 2-3-1 on page-2-3-3** to determine if a schedule is available under a FIFRA Section 18 Exemption. If a treatment is required, go to **Table 2-4-1**.

Table 2-4-1 Determine Reporting Requirements

If a treatment is required:	Then:
As a result of a pest interception	GO to Step 2
As a condition of entry	GO to Step 3

Step 2—Issuing a PPQ Form 523 (Emergency Action Notification)

When an intercepted pest is identified and confirmed by a PPQ Area Identifier as requiring action, the CBP or PPQ official will issue a Form 523 (Emergency Action Notification - EAN) to the owner, broker, or representative. The EAN will list all treatment options. Refer to Appendix A in the *Manual for Agricultural Clearance* for instructions on completing and distributing the EAN.

Step 3—Determining Section 18 Exemptions and Sampling Requirements

After selecting the treatment schedule, the PPQ official will be able to determine which treatment schedules are FIFRA Section 18 Exemptions. The FIFRA schedule will be followed by an "IMPORTANT" note to help determine the current exemption status. Some treatment schedules are only FIFRA Section 18 Exemptions at specific temperature ranges. Check the treatment schedule and temperature to determine if the fumigation will be a FIFRA Section 18 Exemption. Refer to Table 2-3-1 on page 2-3-3 for a list of commodities covered under the FIFRA Section 18.

Step 4—Selecting a Fumigation Site

The PPQ official and the fumigator must consider the following factors in selecting a fumigation site:

- Well-ventilated, sheltered area
- Ability to heat area (in colder areas)
- Impervious surface
- Nonwork area that can be effectively marked and safeguarded or isolated
- Electrical power supply
- Water supply
- Well-lighted area
- Aeration
- Multiple fumigation buffer zone overlap

Well-Ventilated, Sheltered Area

The PPQ official and the fumigator must select sites that are well-ventilated and sheltered. A well-ventilated site is required for exhausting gas before and when the tarpaulin is removed from the stack. Most piers and warehouses have high ceilings and a number of windows/doors which can be used for ventilation. Some gas will escape from the tarpaulin even in the best conditions. Avoid areas where strong drafts are likely to occur.

In warehouses, the fumigator must provide an exhaust system to exhaust MB to the outside of the building. The fumigator must ensure that the exhausted gas does not reenter the building nor endanger people working outdoors.

When treatments are conducted in a particular location on a regular basis, the PPQ official must ensure that the fumigator designates a permanent site. At such sites, the fan used to remove the fumigant from the enclosure during aeration may be connected to a permanent stack extending above the roof level.

If fumigations are conducted outside, ensure that the fumigator selects a site that is semi-sheltered such as the leeward side of a warehouse, pier, or building that offers some protection from severe winds. Severe winds are defined as sustained winds or gusts of 30 m.p.h. or higher for any time period. Do not allow the fumigator to proceed if there is a forecast from the National Weather Service of severe winds and/or thunderstorms at the beginning of or for the entire length of the fumigation.

Ability to Heat Area

When cooler temperatures (below 40 °F) are expected, the fumigator must ensure that the commodity temperature is maintained above 40 °F. The PPQ official will take the ambient (air) temperature 12 inches above the floor.

For treatments lasting 6 hours or longer, temperatures **must** be maintained at or above the starting treatment temperature for the entire duration of the treatment. Additionally, the PPQ official will monitor the temperature of the enclosure using temperature sensors and a temperature recorder. The temperature recording system for treatments lasting 6 hours or longer **must** meet the following specifications:

- Accurate to within ± 0.6 °C or ±1.0 °F in the treatment temperature range of 4.4 °C to 26.7 °C (40 °F to 80 °F)
- Calibrated annually by the National Institute of Standards and Technology (NIST) or by the manufacturer
  - The calibration certificate will list a correction factor, if needed, and the correction factor would be applied to the actual temperature reading to obtain the true temperature.
- Capable of printing all temperature readings or downloading data to a secure source **once per hour** throughout the entire treatment (all temperature data must be accessible at a safe distance during the fumigation)

- Tamper-proof

If one or more of the temperature readings go below the minimum temperature specified in the treatment schedule, the fumigation will be considered a failed treatment. The commodity must be re-treated, returned to the country of origin, reexported, or destroyed.

CAUTION

Commodities used for food or feed may not be re-treated. If commodities fall into this category, the only options are the following:

- Return to the country of origin
- Reexported to another country if they will accept the shipment
- Destroy by incineration

The PPQ official ensures that the fumigator places the thermocouples evenly throughout the enclosure or container. The placement of the temperature sensors will vary depending on the item fumigated and the configuration of the fumigation site. Contact the Center for Plant Health Science & Technology (CPHST) (919-855-7450) in Raleigh, North Carolina for instructions regarding exact placement of the temperature sensors. Use **Table 2-4-2** to determine the number of temperature sensors needed based on size of the enclosure:

Table 2-4-2 Number of Temperature Sensors

Size of Enclosure (ft^3)	Number of Temperature Sensors
Up to 10,000	3
10,001 - 25,000	6
25,001 - 55,000	9
Larger than 55,000	12

NOTICE

Do **not** use flame or exposed electrical element heaters under the tarpaulin during treatment because MB may cause the formation of hydrogen bromide. Hydrogen bromide (hydrobromic acid) is a highly corrosive chemical which can cause damage to the heater and to surrounding materials including the commodity. Hot air or radiator type heaters can be used for heating under tarpaulins. When using space heaters to heat warehouses, there must be adequate ventilation.

Impervious Surface

Select an asphalt, concrete, or tight wooden surface—**not** soil, gravel, or other porous material. If you must fumigate on a porous surface, require the fumigator to cover the surface with plastic tarpaulins. For large fumigations, covering the surface is **not** usually practical because the tarpaulin may be damaged when the pallets are rearranged. On docks, wharfs, and piers, require the fumigator to seal cracks, holes, and manhole covers which will allow the MB to escape through the floor.

Nonwork Area—MB 2016 Label

MB 2016 Label

NOTICE

The fumigator will determine the treatment buffer zone in accordance with EPA's fumigation buffer zone tables (https:www.epa.gov/pesticide-registration/mbcommoditybuffer).

The treatment buffer zone surrounds the area where access is limited during treatment. If the fumigator determines that the buffer zone is less than 30', then PPQ requires a 30' buffer zone. If the fumigator determines that the buffer zone is greater than 30', then PPQ must observe the prescribed buffer zone.

The treatment buffer zone extends from the perimeter of the enclosure to a distance determined by the fumigator in accordance with the label. Entry by any person except the PPQ official and the fumigator is **prohibited** except as provided in the "Exceptions to Buffer Zone Entry Restrictions" section of the label.

The treatment buffer zone begins when the fumigant is introduced into the enclosure and ends when aeration begins, at which point the aeration buffer zone requirements apply.

The fumigator must define treatment and aeration buffer zone perimeters using physical barriers (such as walls, ropes, etc.) and placards to limit access to the buffer zone. Placards must meet all label requirements regarding specific warnings, information, and language.

The fumigator will permit transiting through buffer zones in accordance with the "Transit Exception" section of the label.

Buffer Zone Overlap for Multiple Enclosures

For multiple enclosures where buffer zones overlap, the fumigator must recalculate both the treatment and aeration buffer zones in accordance with the label and supply them to the PPQ official.

Nonwork Area

The PPQ official and the fumigator must select a secure area where traffic and people are restricted from entering and which is isolated from people working. A nonwork area is preferred to help prevent accidents such as a forklift piercing a tarpaulin. The fumigation area is the area 30 feet surrounding the tarpaulin and is separated from the non-fumigation area by a physical barrier such as ropes, barricades, or walls. If a wall of gas-impervious material is less than 30 feet from the tarpaulin, the wall may serve as the edge of the secured area. The fumigator must placard within the perimeter of the secured area. Placards must meet label requirements regarding specific warnings, information, and language. Placards generally include the name of the fumigant, the fumigation date, time, and the name of the company conducting the fumigation. The fumigator must restrict access to the fumigation area to the fumigator's employees and PPQ employees monitoring the treatment. Use rope or marker tape to limit access within 30 feet of the enclosure. Unless you (PPQ) authorize their use, do **not** allow motor vehicles (including forklifts) to operate within 30 feet of the enclosure and aeration area during the fumigation and aeration periods. The area outside the 30-foot perimeter is usually regarded as a safe distance from the tarpaulin. Gas concentrations exceeding 5.0 ppm (TLV for MB) are seldom recorded by gas monitoring, except during aeration. The 30-foot perimeter is **not** specifically mentioned on the MB label, but is required for PPQ supervised fumigations. When space is tight, it is permissible to overlap two adjoining 30-foot perimeters. When multiple fumigations are occurring simultaneously, there must be sufficient space for a person wearing SCBA to walk between the tarpaulins.

Electrical Power Supply

An adequate electrical source must be available to run the circulation fans and the gas detection device. A separate line should be available for the gas detection device. Electrical outlets must be grounded and conveniently located in relation to the fumigation area. PPQ does not allow generators as a power source except under emergency conditions.

Water Supply

A water supply is necessary for safety purposes. Water is necessary for washing off MB if the liquid form is spilled on someone. If no permanent water is present on site, the fumigator must provide a 5-gallon supply of potable, unfrozen water.

Well-Lighted Areas

The fumigator will ensure that the area has adequate lighting for safety purposes and for reading gas detection units, thermometers, and determining whether a tarpaulin has holes or tears.

Aeration Requirements

The fumigator is responsible for all aspects of aeration. When the fumigation is a Section 18 exemption fumigation, the PPQ official is required to verify the final gas concentration reading(s). Refer to ***Aerating the Enclosure* on page 2-4-36** for more information.

Step 5—Arranging the Stack

Break Bulk Cargo

Ensure that the fumigator arranges the cargo in a square or rectangular shape, if possible, to make it easy to cover and to calculate the volume of the stack. An even shaped stack is easy to tarp. The height of the stack should be uniform so dosage can be calculated accurately. For loose cargo, the tarpaulin should be 2 feet above the load and one foot from the sides and ends. Unless specified in the treatment schedule, cargo should **not** exceed two-thirds of the volume of the area to be fumigated. The PPQ official must contact the CPHST-AQI to get approval for any enclosures larger than 25,000 ft^3. For large enclosures, it may be necessary to:

- Add more sampling tubes
- Install extra circulation fans
- Introduce the fumigant at several sites, using multiple volatilizers
- Run the circulation fans longer than just the first 30 minutes, if the difference between the highest and lowest gas concentration readings exceeds 4 ounces

Once CPHST-AQI has approved the site and enclosure, it does **not** require additional approvals for subsequent fumigations. The PPQ official must ensure that the commodity is on pallets to permit air movement along the floor and between the cargo. Allow an inch or more of space between pallets. By arranging the stack evenly and with space between pallets or cartons, the fumigant will be effectively distributed and dosage calculation should be easier and more accurate. Dosages are easier to calculate when the dimensions are uniform.

When the fumigation involves multiple stacks, PPQ will ensure that the fumigator allows 10 feet of space between each uncovered stack. After the stack is tarped, there should be approximately 5 feet between enclosures.

Containerized Cargo

Ensure that the fumigator places no more than eight containers that are 20 to 40 feet in length under a single tarpaulin. APHIS does not allow containers to be stacked. Stacking may create too great a safety risk to the person placing the tarp, fans, and gas monitoring leads. If fumigating multiple containers in a single row, ensure that the fumigator has all the doors opening on a center aisle toward each other (see ***Figure 2-4-1*** on **page 2-4-13**). The aisle must be at least 3 feet wide. All doors should be completely open, if possible.

However, APHIS will allow fumigation of containerized cargo with one door open on each container using a configuration such as the one shown in ***Figure 2-4-2*** on **page 2-4-14**, or in a single row of eight containers. Require the fumigator to introduce gas at both ends of this long row configuration, either at the same time or half at one end and half at the other end. In any case, the single open door on each container must be kept from closing during the fumigation, either taped or blocked open.

If perishable commodities are fumigated inside the container, it is possible that the commodity will be damaged because of the difficulty of removing the fumigant. For this reason, APHIS recommends that perishables be fumigated outside the container, but does allow fumigation inside the container. When a commodity is removed from the container, require the fumigator to spray the empty container according to T402-d as a precaution against hitchhiking pests.

To conserve MB use, CPHST-AQI recommends that containers be removed from their chassis prior to fumigation. If this is not done, then the space beneath the container must be calculated as part of the total volume being fumigated.

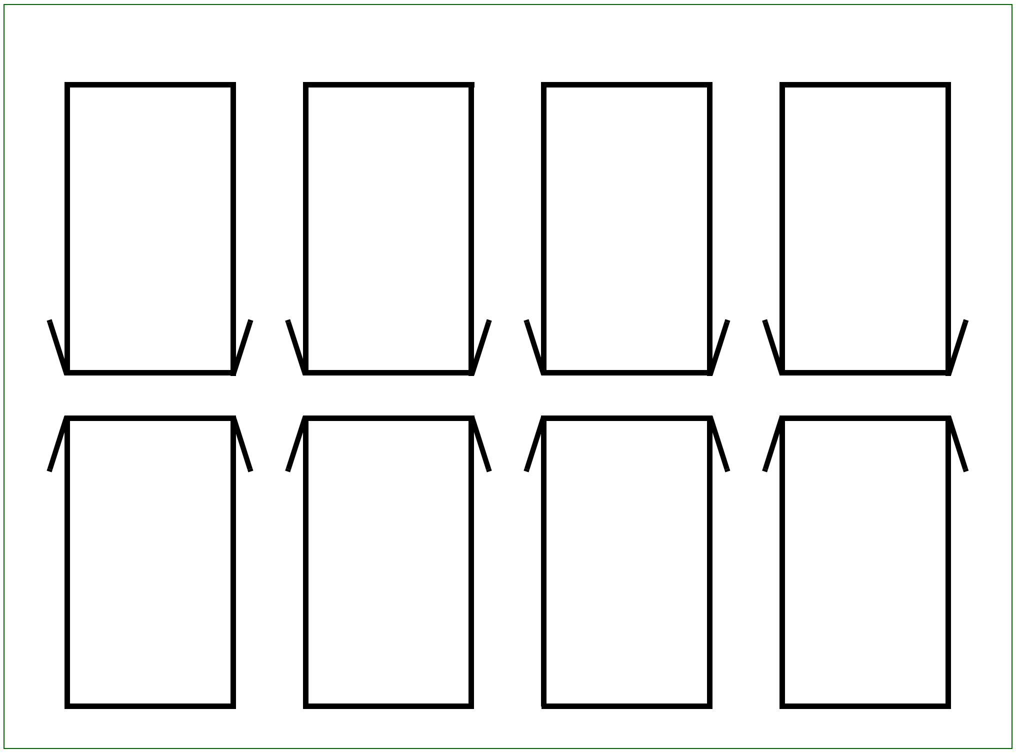


Figure 2-4-1 Container Arrangement in Two Rows—Both Doors Open

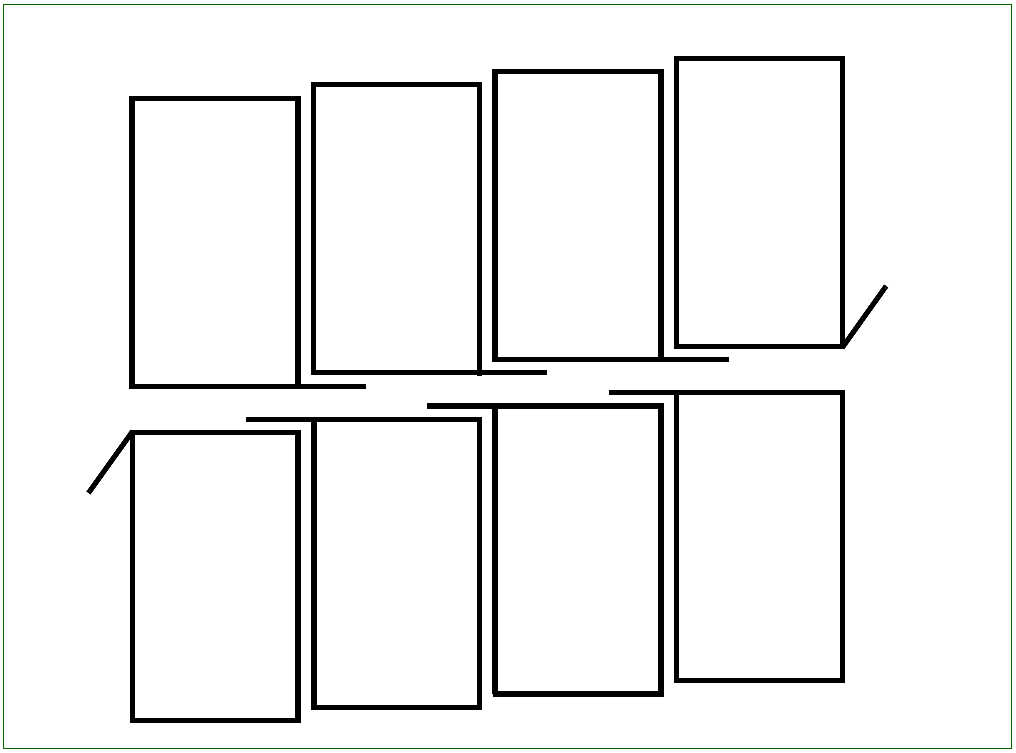


Figure 2-4-2 Container Arrangement in Two Rows—One Door Open

If fumigating multiple containers in a single row, require the fumigator to open the rear doors the same side of the stack. If containers are parked parallel to one another and close together, it is permissible to open only the door on the right side of each container, overlapping and taped to the closed left door of the container adjacent to it. If containers are not parked closely together, all doors must be completely open.

Ensure that the containers are not loaded beyond 80 percent of their capacity. Ensure that bulk commodities are placed in boxes or containers on pallets. The pallets must be loaded in the container so that there is at least two inches of space under the commodity and between each pallet. There must be a minimum of 18 inches above the commodity. This facilitates uniform gas distribution and allows a crawl space for placing the gas sampling tubes and fans. (Some restacking of cargo may be necessary to meet this requirement.) If the container is tarped, no additional head space is required between the roof of the container and the tarp, unless the pest is found on the outside of the container.

Gas Penetration and Distribution

MB will penetrate most cargo easily. Penetration is enhanced by the availability of free MB.

All packaging used in USDA quarantine fumigations must comply with the standards in ***Penetration and Aeration of Boxes and Packages* on page 2-3-8**. Some of the more common types of impermeable materials are cellophane, plastic, wax coated materials, laminated, and waterproofed papers. Tight wooden packing cases are also relatively gas tight. Impermeable materials will allow some gas to penetrate, but make it difficult to aerate and evacuate the gas. Require the fumigator to remove, perforate, or open all impermeable materials.

Step 6—Arranging and Operating Fans

Break Bulk Cargo

Require the fumigator to use fans that have the capacity to move a volume in cubic feet per minute equivalent to the total volume of the enclosure. For a 5,000 ft^3 enclosure, use two axial-type (blade) fans of approximately 2,500 cfm. Require the fumigator to place one fan on the floor at the rear of the stack facing the front and the other fan at the top front (where the gas is introduced) facing the rear. For enclosures from 5,000 to 7,500 ft^3, require the fumigator to add a third fan near the upper middle facing the rear. For enclosures from 7,501 to 10,000 ft^3, add a fourth fan on the floor near the middle facing the front. Enclosures from 10,001 to 25,000 ft^3 may require up to seven fans to provide adequate gas circulation. Enclosures larger than 25,000 ft^3 require approval from CPHST-AQI.

Require the fumigator to turn on all fans to make sure they work. The fans must be operated during gas introduction and for 30 minutes after the gas is introduced. If after taking gas concentration readings the fumigant is **not** evenly distributed (as indicated by concentration readings within 4 ounces of each other), require the fumigator to run the fans until the gas is evenly distributed. Require the fumigator to run fans when adding gas, but only long enough to get even gas distribution.

Containerized Cargo

Require the fumigator to use an appropriate number of fans which have the capacity to move the equivalent cubic feet per minute of the total volume of the enclosure. Use two fans in the container to circulate the gas. Place one fan of at least 2,500 cfm at the top of the load (near door) of each container facing the opposite end of the container. Place the second fan on top of the load facing the door.

Require the fumigator to place air introduction ducts for aeration into the far ends of each container opposite the doors and to place exhaust ducts on the ground in front of the doors of the containers. The fumigator must place the end of the ducts near the edge of the tarpaulin so they can be pulled under the tarpaulin when aeration begins.

Step 7—Placing the Gas Introduction Lines

MB is converted from a liquid into a gas by a volatilizer. Ensure that the hose that runs from the MB cylinder into the volatilizer is a 3000 PSI hydraulic high pressure hose with a 3/8 inch interior diameter (ID) or larger. From the volatilizer, MB gas is introduced into the structure by means of a gas introduction line. The gas introduction line must be a minimum of 350 PSI with a 1/2 inch ID or larger.

Break Bulk Cargo

Ensure that the fumigator places the gas introduction line directly above the upper front fan and attaches the line to the top of the fan to prevent movement. An unsecured introduction line could tear the tarpaulin, move the line, or direct it out of the airflow. Require the fumigator to attach the fan firmly to the cargo or have a base that prevents it from toppling (not a pedestal type). Require the fumigator to place a piece of impermeable sheeting over the commodity and to the front of each gas supply line. The sheet will prevent any liquid MB from coming in contact with the cargo.

Containerized Cargo

The number and placement of gas introduction lines will depend upon the number and arrangement of containers to be fumigated.

For single containers, ensure that the fumigator installs the introduction line directly above the fan near the door of the container.

For multiple containers, ensure that the fumigator places the appropriate number of introduction lines to ensure even gas distribution.

If you are fumigating five or more containers under one tarpaulin, then require the fumigator to use a minimum of two gas introduction lines to ensure even gas distribution.

Step 8—Placing the Gas Sampling Tubes

Break Bulk Cargo

Ensure that the fumigator installs a minimum of three gas sampling tubes for fumigations up to 10,000 ft^3 positioned in the following locations (see **Figure 2-4-3**):

- Front low—front of the load, 3 inches above the floor
- Middle center—center of the load, midway from bottom to top of load
- Rear high—rear of the load, at the extreme top of the load

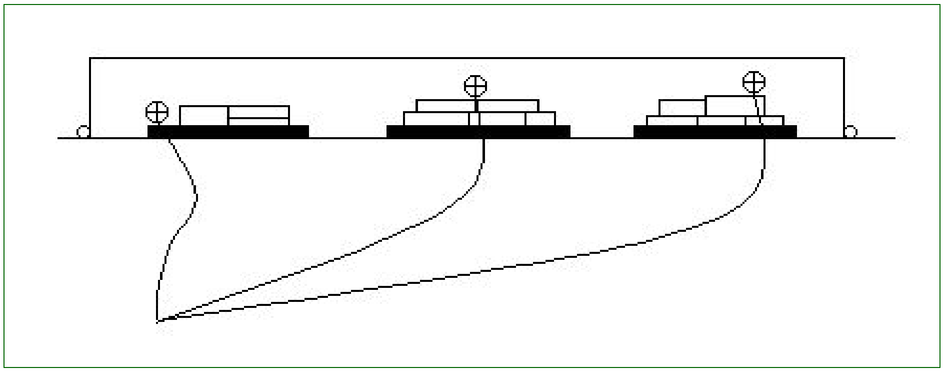


Figure 2-4-3 Example of the Position of Gas Sampling Tubes (Side View)

For fumigations from 10,001 to 25,000 ft^3, require the fumigator to use six gas sampling tubes, positioned in the following locations:

- Front low—front of the load, 3 inches above the floor
- Upper front quarter section
- Middle center—center of the stack, midway from bottom to top
- Upper rear quarter section
- Lower rear quarter section
- Rear high—rear of the stack, at the extreme top

The PPQ official must contact CPHST-AQI for approval of fumigations larger than 25,000 ft^3, for instructions for number of gas sampling tubes, and for other technical information.

Important

For khapra beetle cargo containing baled, packaged, finely milled, or closely packed commodities, require the fumigator to place two additional gas sampling tubes in the center of the bags, packages, or bales. Before placing gas sampling tubes in commodities, require the fumigator to place burlap over the end of the tube and secure the burlap to the tube with tape.

Containerized Cargo

For all containers (either 20 or 40 feet in length) under the same tarpaulin, require the fumigator to use at least three tubes per container, positioned as follows:

- Front low—near the floor at the door end of the container
- Rear high—rear of the load at the high end opposite the fan
- Middle center—mid way from front to back, at mid depth

If treating commodities for khapra beetle, require the fumigator to install the following additional gas sampling tubes:

- High (in the commodity)

- Low (in the commodity)

Require the fumigator to cover the end of the gas sampling tube with burlap taped to the tube before insertion into the commodity.

Break Bulk and Containerized Cargo

Require the fumigator use gas sampling tubes of sufficient length to extend from the sampling position inside the enclosure to at least 30 feet beyond the tarpaulin. Ensure that all the gas sampling tubes meet in one area for ease and safety in taking gas concentration readings. Do **not** permit gas sampling tubes to be spliced. Before starting the fumigation, check for gas sampling tube blockage or pinching by connecting each tube to a MityVac® hand pump or to the gas detection device for a short time. If the tube is blocked, the flow to the device will drop sharply. Require the fumigator to replace any defective gas sampling tubes.

Require the fumigator to secure all gas sampling tubes in place under the tarpaulin and label each one at the end where the gas concentration readings will be taken. By labeling each gas sampling tube, you will be able to record concentration readings easily.

Step 9—Padding Corners

Ensure that the fumigator looks for corners and sharp angles which could tear the tarpaulin. Do not allow the fumigator to use commodity to support the tarpaulin. If the sharp angles or corners cannot be eliminated, the fumigator must cover them with burlap or other suitable padding (e.g., old tires or cloth) (see **Figure 2-4-4**).

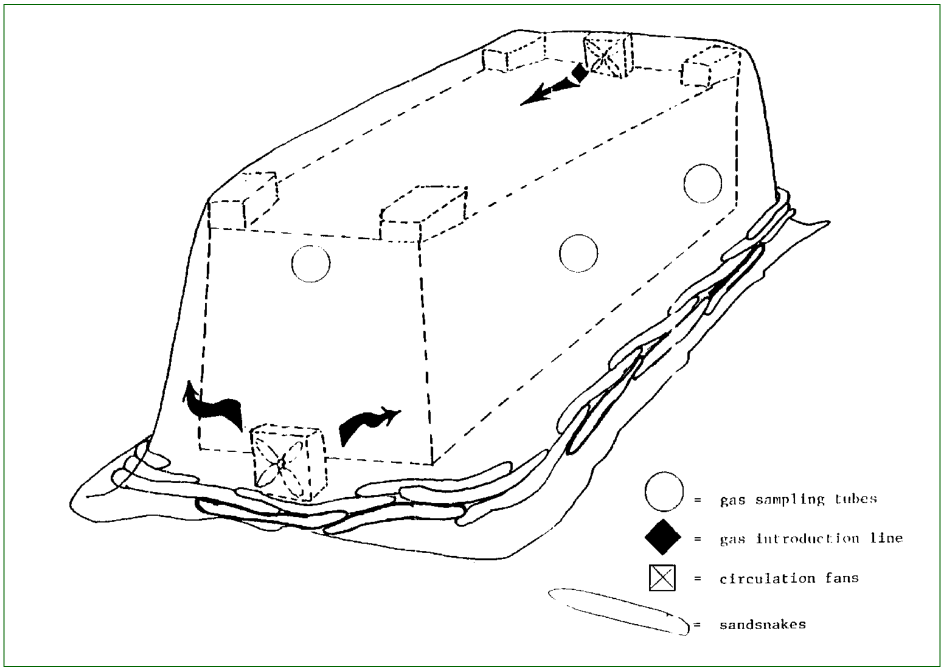


Figure 2-4-4 Typical Break Bulk Arrangement with Fans, Leads, Introduction Line, Padding, and Sand Snakes

Step 10—Measuring the Temperature

Important

Commodity and space temperatures must be 40 °F or above.

Temperature recordings should be rounded to the nearest tenth of a degree (°C or °F)

The PPQ official must determine the temperature of the commodity in order to select the proper dosage rate. Depending on whether or not you are fumigating a pulpy fruit or vegetable, **either** the commodity temperature **or** an average of the commodity and air temperatures will be used. A pulpy fruit or vegetable can support internal feeding insects, is fleshy and moist, and can be probed with a temperature measuring device. Examples include, but are not limited to peppers, onions, and grapes.

For pulpy fruits and pulpy vegetables, insert the thermometer into the pulp and use only the commodity temperature to determine the dosage rate. For commodities that have been refrigerated, probe the fruit that have the lowest pulp temperature. Again, fumigate only when the fruit pulp is at 40 °F or higher.

Important

Fresh fruits and vegetables that require fumigation treatment as a condition of entry, must meet the minimum temperature requirement of 40 °F (4.4 °C), at the time of discharge. This may require the gradual warming of the shipment over the later course of the voyage to ensure that the commodity achieves the proper minimum temperature of 40 °F (4.4 °C).

This process will facilitate whether or not the fumigation treatment of the cargo takes place on the same day of arrival.

If the commodity has no pulp (for example, peas, beans, grains, herbs, spices, etc.), take the temperature of the air space immediately surrounding the commodity as well as the commodity temperature and use **Table 2-4-3** to determine the correct temperature for use when selecting the proper dosage rate.

To take the temperature readings, use a calibrated bimetallic, mercury, or digital long-stem thermometer.

NOTICE

The presence of ice indicates temperatures below 40 °F. If ice is present anywhere in the box, pallet, or fumigation enclosure, DO **NOT** fumigate the commodity.

Table 2-4-3 Determine Whether to Use Commodity or Air Temperature for Determining Dosage Rate For Nonpulpy Commodities

If the air temperature is:	And:	Then, for commodities other than pulpy fruits, pulpy vegetables, or logs and lumber:
Higher than the commodity temperature	→	Use the single lowest commodity temperature for determining the dosage rate (Do **not** use the average commodity temperature).
Lower than the commodity temperature	By less than 10 degrees	
	By 10 degrees or more	Use the average of the single lowest air and commodity temperatures for determining the dosage rate (Never initiate a fumigation if any commodity temperature reads lower than 40 °F.)

EXAMPLE: You are about to fumigate a shipment of fresh herbs. The commodity temperature is 82 °F and the air temperature is 55 °F. Average the air and commodity temperatures to determine the dosage rate because the air is 27 degrees lower than the commodity temperature and the commodity is not pulpy. The average of the two temperatures is 68.5 °F. Use 68.5 °F to determine the dosage rate. (T101-n-2: use 2.5 lbs. for 2 hours)

Logs and Lumber

The PPQ official will select several representative locations within the stack at the ends of the logs or pieces of lumber. Require the fumigator to drill holes in them to accommodate a thermometer. After drilling, wait at least 10 minutes to allow the wood around the holes to cool. Insert the thermometer into the holes drilled. Record the temperature from each hole, and average the readings. All readings (not just the average) must be above 40 °F.

Base the dosage calculation on the lowest reading obtained. (Do **not** average temperatures.) All readings must be above 40 °F to initiate the fumigation. If not, the fumigation must be postponed.

The PPQ official must record the temperatures in Block 22 of the PPQ Form 429.

If using the electronic 429 database, record the temperatures in the space and commodity fields in the Treatment form.

Important

When the commodity and air temperature drastically differ, moisture may condense inside the gas sampling tubes or inside the gas detection device and cause inaccurate gas concentration readings. The fumigator is responsible for ensuring that the sampling tubes are free from water as described in the instrument instruction manual. The PPQ official must check the Drierite® and Ascarite® frequently, and change it as soon as it becomes saturated with water [turns pink], to obtain true gas concentration readings. Never fumigate commodities that are frozen.

Step 11—Covering the Stack

The fumigator must cover the stack, check the tarpaulin for rips, tears, and holes, look at the spots that have been taped, and verify they are properly sealed. If needed, the fumigator must repair all holes, rips, and tears.

The tarpaulin should be made of a material such as vinyl, polyethylene plastic, or coated nylon.

- 4 mil vinyl or polyethylene plastic tarpaulins are only approved for one usage
- 6 mil vinyl or polyethylene plastic tarpaulins may be used up to four times with the PPQ official's approval for each usage
- 10 to 12 mil vinyl or plastic coated nylon tarpaulins may be approved for multiple use with the PPQ official's approval for each usage.

The fumigator should cover all corners and sharp ends with burlap or other padding to prevent the tarpaulin from ripping. Have the fumigator pull the tarpaulin over the stack, being careful not to catch or tear the tarpaulin. Make sure there is sufficient structural support to raise the tarpaulin 2 feet above and 1 foot beyond the sides of the commodity.

The tarpaulin must be large enough to provide a floor overlap of at least 18 inches around all sides of the stack. The fumigator must carefully lay the tarpaulin out to prevent excess folds or wrinkles along the floor, especially around corners.

Important

Sealed containers and vans cannot be considered as “fumigation chambers,” and therefore **must be covered by a tarpaulin**, unless they can pass the pressure-leakage test. (Refer to Chapter 2-8.)

Step 12—Sealing the Tarpaulin

The fumigator must seal the tarpaulin with loose, wet sand, sand snakes, water snakes, adhesives, or a combination. If there is danger of crushing or crimping the gas sampling or introduction tubes, use the loose, wet sand. If using snakes, use two rows of snakes along the sides and three rows on the corners. The snakes should overlap each other by approximately 1 foot. The goal in sealing the tarpaulin is to get the tarpaulin to lie flat against the floor to prevent gas from leaking out. When wind is not a factor, plastic tape may be used for sealing the tarp. The tape must be at least 2 inches in width, and applied (only to a smooth surface) with the aid of high-tack spray adhesive.

The fumigator must seal corners by laying two sand snakes around the corner and working the tarpaulin until it is flat. Place a third snake on top of the two other snakes to provide additional weight to force the tarpaulin against the floor. Loose, wet sand can be used in the area where the gas introduction line, electrical cords, and gas sampling tubes extend from under the tarpaulin.

Step 13—Measuring the Volume

Using a 100-foot tape measure, the PPQ official and the fumigator must carefully measure the length, width, and height of the enclosure. *Never* estimate the measurements. An error in measurement of as little as 12 inches can result in miscalculation of the dosage by as much as 15 percent. When measuring, round off to the nearest quarter foot (example—3 inches =.25 feet). In the case of fumigations of edible commodities, an error can result in an unacceptable level of residue on the commodity. If the sides of the enclosure slope outward from top to bottom, measure both the top and bottom and average the two to determine the dimension. Enclosure height should always be uniform and not require adjustment.

Formula for determining volume:

Length × width × height = volume in cubic feet

EXAMPLE: A stack with measurements H=10′6″, L=42′3″, and W=10′9″ 10.50 × 42.25 × 10.75 = 4,768.9 ft^3 round to 4,769 ft^3

The PPQ official must record volume in Block 26 of the PPQ Form 429.

If using the electronic 429 database, record the length, width and height in the corresponding fields under the "AMT of Gas Introduced" heading on the Treatment form. The total volume of the enclosure will be calculated.

Step 14—Calculating the Dosage

The PPQ official must calculate dosage by doing the following:

1. Refer to the treatment schedule for the correct dosage rate (lbs./1,000 ft^3) based on temperature (°F) (Step 10).
2. Multiply by the dosage (lbs./1,000 ft^3) rate by the volume (ft^3) to get the dosage in pounds.
3. Rules for rounding. Round to nearest 1/4 pound.

Formula for calculating dosage:

$$\begin{aligned}\text{dosage (lbs.)} &= \text{volume}(\text{ft}^3) \times \text{dosage rate (lbs./1,000 ft}^3) \\ &= \frac{\text{volume}(\text{ft}^3) \times \text{dosage rate (lbs.)}}{1{,}000\ \text{ft}^3}\end{aligned}$$

Figure 2-4-5 Formula for Calculating Dosage for Tarpaulin Fumigations

If using the electronic 429 database, the PPQ official must enter the dosage rate in the "dosage" field and the total amount of gas required for the fumigation will be displayed in the "GAS REQUIRED" field.

EXAMPLE: You need to determine the dosage for a stack with a volume of 3,000 ft^3. For 72 °F (air and commodity temperatures), the treatment schedule lists the dosage rate at 2 pounds MB/1,000 ft^3. Determine dosage by doing the following:
1. Volume = 3,000 ft^3
2. Dosage rate = 2 lbs./1,000ft^3
3. 3,000 x 2/1,000 ft^3 = 6 lbs. MB

Step 15—Making a Final Check

Before introducing the gas, the PPQ official and the fumigator **must** ensure that the following activities are performed:

- Turn on all fans and APHIS-approved gas detection devices to make sure they work.
- Warm up and zero (if required) the APHIS-approved gas detection devices as described in ***Equipment* on page 8-1-1**.
- Start volatilizer and heat water to 200 °F or above. A minimum temperature of 150 °F is required at all times during the introduction process. Refer to ***Volatilizer* on page 8-1-15** for temperature monitoring procedures.
- Place fumigant cylinder with gas introduction line on scale and take initial weight reading.
  - Ensure the gas introduction hose is attached to the cylinder.
  - After obtaining the correct weight, subtract the dosage to be introduced into the enclosure.
  - After introducing the proper amount of gas, the scale will be balanced.
- Ensure that tarpaulin is placarded and the area is secured; only people working on the fumigation may be in the area.
- Ensure that the tarpaulin it is free from rips, holes, and tears.
- Ensure that all gas sampling tubes are labeled and are **not** crimped or crushed.
  - Visually inspect tubes or use an electric or Mityvac® hand pump to check tubes. A fumiscope or vacuum pump may also be used to test leads for unrestricted flow.


Important

When conducting fumigations with methyl bromide, erroneous readings may occur if the sampling tubes become blocked or crimped. It would be impossible to install a new sampling tubes during a fumigation treatment. Therefore, to avoid an unsuccessful fumigation, you should test sampling tubes before the treatment begins.

Use the following procedure to detect blocked sampling tubes with the use of a MityVac® hand-held pump (for supplier, see ***Vacuum Pump* on page E-1-71**):

1. Prior to fumigant introduction, connect the MityVac® hand-held vacuum pump to sampling tubes.
2. Squeeze the handle on the MityVac® unit. If the tube is blocked, a vacuum will be indicated on the vacuum gauge of the MityVac® unit. (The handle should be squeezed two or three times for sampling tubes longer than 25 feet. The MityVac® hand-held pump has the capacity to attain and hold 25 inches of Hg vacuum and a minimum of 7 psig pressure.)
3. Disconnect the MityVac® hand-held pump from the sampling tube, and repeat this procedure for each tube. (Connect sampling tubes to the gas analyzer prior to fumigant introduction.)

- Confirm that there is enough gas in the cylinder and if necessary, that other cylinders are available.
- Confirm that the gas introduction line connections are tight and free of leaks.
- Ensure that all safety equipment, especially SCBA, is available and in working order.
- If using a T/C monitor, install Drierite® and Ascarite® filters as stated in the instructions in this manual.

Important

Other gas detection devices may not require the use of Drierite® or Ascarite®.

Conducting the Fumigation

Step 1—Introducing the Gas

CAUTION

The PPQ official must wear SCBA anytime the MB concentration level in the air is unknown or greater than or equal to 5 ppm.

MB 2016 Label

NOTICE

If MB concentration levels are between 1-4 ppm, the PPQ official and fumigator may wear an air purifying respirator NIOSH certified half-mask or full face piece with a cartridge.

Require the fumigator to use SCBA while introducing and adding gas. The PPQ official is not required to be in the treatment buffer zone during the fumigation. The PPQ official must ensure that the fumigator turns on all fans before introducing the gas. When using large cylinders of MB, the fumigator should slightly open the cylinder valve, then close the valve.

DANGER

If the PPQ official or fumigator notices a cloud, plume, vapor, or mist coming from the introduction equipment during gas introduction, the fumigator must TURN OFF the valve on the gas cylinder, EVACUATE the area immediately, and ABORT the fumigation.

No person should place any part of their body into the cloud, plume, vapor, or mist. After the cloud plume has dissipated, measure gas concentration levels at the gas cylinder using any APHIS-approved continuous real time gas detection device. When gas concentration levels at the cylinder reach 5 ppm or less, the fumigator must identify the source of the leak and correct it before restarting the fumigation.

Any person within the treatment buffer zone must wear and use SCBA equipment during gas introduction and gas addition.

With an APHIS-approved continuous real time gas detection device, the fumigator must check all connections on the gas introduction hose (between the MB cylinder and the volatilizer) for leaks. If leaks are found, the fumigator must tighten the connections and repeat the test.

When no leaks are found, require the fumigator to open the valve to the point where 3 to 4 pounds of MB are being introduced per minute. The water temperature in the volatilizer should never go below 150 °F at any time during gas introduction. The water in the volatilizer can include an antifreeze and should be handled with the appropriate safeguards.

CAUTION

Don't touch the introduction line with your bare hands—you could get burned! Close the cylinder valve once the proper dosage has been introduced.

The fumigation time begins once all the gas has been introduced. The PPQ official must record the time gas introduction was started and completed in Block 32 on the PPQ Form 429.

If using the electronic 429 database, record the fumigation date, gas introduction start and finish time in the corresponding fields under the "GAS INTRODUCTION" heading on the Treatment form.

Require the fumigator to run the fans for 30 minutes to achieve even gas distribution. The PPQ official must take the initial concentration reading 30 minutes after all the gas has been introduced.

Important

Do **not** begin counting fumigation time until all the gas has been introduced and valve on the MB tank is closed.

Step 2—Testing for Leaks

Require the fumigator to wear the SCBA to test for leaks using an APHIS-approved leak detection device before the 30 minute reading or anytime when the concentration level is unknown or above 5 ppm.

MB 2016 Label

NOTICE

If MB concentration levels are between 1-4 ppm, the PPQ official may wear an air purifying respirator NIOSH certified half-mask or full face piece with a cartridge.

The fumigator must test around the perimeter of the tarpaulin on the floor, corners, and especially where electric cords, gas sampling tubes, or gas introduction lines are present. When the fumigator detects leaks, ensure that they are sealed using more sand or sand snakes for floor leaks and tape for sealing small holes in the tarpaulin. Loose, wet sand may be used to reduce leakage from electric cords, gas sampling tubes, gas introduction lines, or uneven flooring.

Important

If a PPQ employee encounters unsafe conditions (such as holes in the tarpaulin or a breach in safety protocol) and the condition(s) cannot be corrected in a timely manner, the employee may CANCEL the fumigation. Consult with a PPQ Supervisor prior to cancellation.

If the fumigator detects excessive leakage (concentration readings of 50 percent or less of the minimum concentration) do **not** attempt to correct the problem by adding more gas. For non-food, non-feed commodities, require the fumigator to quickly evacuate the remaining gas from the enclosure, eliminate the problem, and construct a new enclosure. Aerate as usual following procedures on ***Aerating the Enclosure* on page 2-4-36**. Restart the fumigation in the new enclosure.

CAUTION

Commodities used for food or feed may not be re-treated. If commodities fall into this category, the only options are the following:

- Return to the country of origin
- Reexported to another country if they will accept the shipment
- Destroy by incineration

Step 3—Taking Concentration Readings

Important

Before taking a reading, require the fumigator to purge sampling tubes with a mechanical or hand pump. If using a T/C unit, connect it to the sampling tube, adjust the gas flow rate to 1.0, and wait until the meter registering "ounces per thousand cubic feet" stabilizes before taking a reading. (This may take a minute or more, depending upon the length of the tubing and whether or not an auxiliary pump is used.).

The PPQ official must take concentration readings 30 minutes after gas introduction. Use an APHIS-approved gas detection device to determine the gas concentration and distribution within the enclosure. Allow gas concentration readings to stabilize; do not disconnect the sampling line from the gas detection device when the minimum concentration reading has been met. If the gas distribution is even (all readings within 4 ounces of each other) and meet the minimum concentration required by the treatment schedule, advise the fumigator to turn off the fans. Running the fans longer can contribute to gas leakage. If used, the PPQ official must check desiccant tubes before each reading and change Drierite® if its color is pink.

Important

Living plant and plant products generate carbon dioxide gas, which interferes with the MB reading from the T/C. In order to remove CO_2, install an Ascarite® tube in line with the Drierite® tube if fumigating living plant and plant products, including fruits and vegetables, timber, flowers, and seed.

Take concentration readings at the times designated in the treatment schedule[7]:

- 30 minutes
- 2 hours
- 4 hours
- 6 hours
- 12 hours
- 24 hours
- 36 hours
- 48 hours
- 72 hours
- Any final concentration reading

CAUTION

Avoid using hand-held two-way radios near the T/C unit. Using two-way radios near the T/C unit will interfere with an accurate concentration reading.

7 If fumigating oak logs or lumber, see "Special Procedures for Adding Gas to Oak Logs and Lumber."

Thirty-Minute Reading

The 30-minute reading shows the initial concentration and distribution of gas. The 30-minute reading can indicate leakage, sorption, incorrect dosage calculation, or error in fumigant introduction—all of which require immediate attention. If the 30-minute readings are below the minimum, require the fumigator to check for leaks around the perimeter of the tarpaulin.

Concentration readings should **not** differ more than 4 ounces among the leads. When concentration readings differ more than 4 ounces, run the fans to equalize the gas and record readings in the Remarks block on the APHIS 429. In some cases, several cycles of fan operation may be necessary to equalize the readings. The PPQ official will record all gas readings on the PPQ Form 429 or in the electronic 429 database.

Two-Hour Reading

In comparison with the 30-minute reading, the 2-hour reading also will indicate if the tarpaulin is leaking or the commodity is sorbing gas. Refer to **Table 2-4-7 on page-2-4-35** for detailed instructions.

EXAMPLE: Your dosage for the fumigation was 4 pounds (64 ounces). The 30 minute reading was 50 ounces. The 2-hour reading is 26 ounces. The 2-hour reading is low and according to Table 2-4-7, the fumigation would need to be extended by 30 minutes.

Final Reading

The final reading is required for all tarpaulin fumigations in order to determine if the fumigation has been successfully completed. You (the PPQ official) may start the final reading before the finishing time of the treatment so that aeration commences at the finishing time. Starting the final reading before finishing time is especially critical when fumigating perishables.

Additional Readings

Decide the need to take additional readings based on the following:

- Rate of gas concentration decrease
- Any condition which could change the gas concentration such as severe winds, or rain.

When concentration readings differ more than **4 ounces**, run the fans to equalize the gas and record readings in the Remarks block on the APHIS 429. Generally, gas should be evenly distributed, and you should not have to restart the fans unless you added gas. If readings continue to differ by more than 4 ounces, continue running the fans until the gas is evenly distributed.

If unpredicted severe winds occur, additional readings must be taken. Any sharp or unusual decreases of the readings in relation to previous readings is a clue to take corrective action and supplementary readings. Take additional readings every 30 minutes until problems are rectified.

Sorptive commodities may also require additional concentration readings.

Step 4—Determining the Need to Add Gas and Adjust Exposure

Use **Table 2-4-4** to determine when to add gas or extend the exposure period:

Table 2-4-4 Determine the Need to Add Gas and Adjust Exposure

If the lowest gas reading is:	And the schedule is:	Then:
Below the required minimum concentration	T101-a-1 or equivalent*	SEE ***Table 2-4-6*** on **page 2-4-34** for corrections at 0.5 hour, or ***Table 2-4-7*** on **page 2-4-35** for corrections at 2 hours
	Other than T101-a-1 or equivalent*	See ***Adding Gas and Extending Exposure Period to Commodities that are Fumigated Using Treatment Schedules other than T101-a-1 or Equivalent (may include perishables)*** on **page 2-4-30**
At or above required minimum concentration	T101-a-1* or equivalent*	SEE ***Table 2-4-6*** on **page 2-4-34** for corrections at 0.5 hour, or ***Table 2-4-7*** on **page 2-4-35** for corrections at 2 hours
	Other than T101-a-1 or equivalent*	No action necessary

Important

* T101-a-1 or equivalent treatment schedules are those schedules that are:

- ◆ **NOT** greater than 2 hours long (exposure time)
- ◆ **NOT** greater than 4 lbs. per 1000 ft^3 (dosage rate)
- ◆ Minimum concentration readings and temperature ranges match EXACTLY the readings in T101-a-1

If the minimum concentration readings do not meet these requirements, the schedule is NOT equivalent. When schedules are NOT equivalent, use **Table 2-4-5** to determine the length of time to extend exposure and use the formula in **Figure 2-4-6** to determine the amount of gas to add.

Special Procedures for Adding Gas and Extending Exposure Period[8]

Adding Gas and Extending Exposure Period to Commodities that are Fumigated Using Treatment Schedules other than T101-a-1 or Equivalent (may include perishables)

8 The MB label does allow the extension of exposure time due to low gas readings for non-food commodities.

Once you have determined that you need to add gas and extend time, use the formula in **Figure 2-4-6** to calculate the amount of gas to add and **Table 2-4-5** to determine how long to extend the exposure period.

$$1.6 \times \text{number of ounces below minimum} \times \frac{\text{volume in cubic feet}}{1000\text{cubic feet}} \times \frac{1}{16} = \text{pounds of gas to add}$$

Figure 2-4-6 Formula for Determining the Amount of Gas to Add to Schedules Not Equivalent to T101-a-1

Table 2-4-5 Determine the Extended Exposure Period

If the exposure time is:	And any individual reading is below minimum by:[1]	Then extend exposure:
Less than 12 hours	10 oz. or less	10 percent of the time lapse since gas introduction or the last acceptable reading
	11 oz. or more	30 minutes
12 hours or more	10 oz. or less	10 percent of the time lapse since gas introduction or the last acceptable reading
	11 oz. or more	2 hours or 10 percent of time lapse since last acceptable reading, whichever is greater

1 If any individual reading is 50 percent or more below the minimum concentration reading, then abort the treatment. For example, if the minimum reading is 38 ounces then the reading 50 percent below the minimum is 19 ounces [38 ounces − (38 ounces ×.50) = 19 ounces]. For oak logs (T312-a, T312-a-alternative), refer to ***Special Procedures for Adding Gas to Oak Logs Using T312-a or T312-a-Alternative* on page 2-4-36** for specific instructions.

When adding gas, require the fumigator to follow these steps:

1. Heat water in volatilizer.
2. Turn on fans.
3. Weigh the cylinder.
4. With SCBA on, open valve on cylinder and introduce the gas.
5. Close valve when the weight of the cylinder indicates that the needed amount of gas has been added.
6. The PPQ official must record quantity of fumigant added in Block 34 and the additional fan time in Block 30 of the PPQ Form 429.

7. When using the electronic 429, record the amount of gas added in the "Additional Gas Recommended" field and the actual amount of additional gas added in the "ACTUAL ADDITIONAL GAS" field. Record the additional fan time in the "TIME FANS OPERATED" field in the Treatment form.

Note the time the fumigator started introducing additional gas and the time the fumigator finished introducing gas and record in Block 40 (Remarks) of the PPQ Form 429 or in the "Remarks" form in the electronic 429 database. Require the fumigator to run the fans for 30 minutes. Turn off fans, then take a concentration reading. If all readings are above minimum concentration levels, then proceed as usual with the remaining scheduled concentration readings.

Adding Gas to Fruits, Vegetables, or Perishable Commodities Using Schedule T101-a-1 or Equivalent

Use ***Table 2-4-6*** on **page 2-4-34** and ***Table 2-4-7*** on **page 2-4-35** to determine if you need to add gas or extend or decrease the exposure time.Select the proper table based on the time of the gas reading (30 minutes or 2 hours).

Use the formula in **Figure 2-4-7** to determine the amount of gas to add.

$$1.6 \times \text{number of ounces below minimum} \times \frac{\text{volume in cubic feet}}{1000\,\text{cubic feet}} \times \frac{1}{16} = \text{pounds of gas to add}$$

Figure 2-4-7 Formula for Determining the Amount of Gas to Add to T101-a-1 or Equivalent Schedules

Important

DO **NOT** average the concentration readings before using the tables. Base your decision on whether to add gas from the LOWEST gas concentration of any individual gas reading.

CAUTION

Fresh fruits and vegetables are sensitive to MB so you should double check volume calculations and dosage measurements to avoid accidental overdoses.

When adding gas, require the fumigator to follow these steps:

1. Heat water in volatilizer.
2. Turn on fans.
3. Weigh the cylinder.
4. With SCBA on, open valve on cylinder and introduce the gas.

5. Close valve when the weight of the cylinder indicates that the needed amount of gas has been added.
6. The PPQ official must record quantity of fumigant added in Block 34 and additional fan time in Block 30 of the PPQ Form 429.
7. When using the electronic 429, record the amount of gas added in the "Additional Gas Recommended" field and the actual amount of additional gas added in the "ACTUAL ADDITIONAL GAS" field. Record the additional fan time in the "TIME FANS OPERATED" field in the Treatment form.

Note the time the fumigator started introducing additional gas and the time the fumigator finished introducing gas and record in Block 40 (Remarks) of the PPQ Form 429 or in the "Remarks" form in the electronic 429 database. Run the fans until there is even gas distribution throughout the stack. Turn off fans, then take a concentration reading 30 minutes after the gas has been introduced. If all readings are above minimum concentration levels, then proceed as usual with the remaining scheduled concentration readings.

Table 2-4-6 Determine Gas Concentration Values and Corrections for Fruits and Vegetables at the 30-Minute Reading of T101-a-1 or Equivalent Schedules

If the schedule is:	And the minimum concentration reading (oz.) in schedule is:	And the lowest concentration reading (oz.) is:	Then:
40-49 °F 4 lbs for 2 hrs	48	65 or greater	REDUCE exposure by 15 minutes
		64-48	TAKE 2 hour reading as scheduled
		Lower than 48	1. ADD gas, and 2. EXTEND exposure 15 minutes
50-59 °F 3 lbs for 2 hrs	38	52 or greater	REDUCE exposure by 15 minutes
		51-38	TAKE 2 hour reading as scheduled
		Lower than 38	1. ADD gas, and 2. EXTEND exposure 15 minutes
60-69 °F 2.5 lbs for 2 hrs	32	48 or greater	REDUCE exposure by 15 minutes
		47-32	TAKE 2 hour reading as scheduled
		Lower than 32	1. ADD gas, and 2. EXTEND exposure 15 minutes
70-79 °F 2 lbs for 2 hrs	26	37 or greater	REDUCE exposure by 15 minutes
		36-26	TAKE 2 hour reading as scheduled
		Lower than 26	1. ADD gas, and 2. EXTEND exposure 15 minutes
80-89 °F 1.5 lbs for 2 hrs	19	27 or greater	REDUCE exposure by 15 minutes
		26-19	TAKE 2 hour reading as scheduled
		Lower than 19	1. ADD gas, and 2. EXTEND exposure 15 minutes

Table 2-4-7 Determine Gas Concentration Values and Corrections for Fruits and Vegetables at the 2-Hour Reading of T101-a-1 or Equivalent Schedules

If the schedule is:	And the lowest concentration reading at 2 hours is:	Then do not add gas, but:
40-49 °F 4 lbs for 2 hours	38 and above	AERATE commodity
	37-28	EXTEND exposure by 15 minutes
	27-25	EXTEND exposure by 30 minutes
	Lower than 25	ABORT
50-59 °F 3 lbs for 2 hrs	29 and above	AERATE commodity
	28-24	EXTEND exposure by 15 minutes
	23-21	EXTEND exposure by 30 minutes
	Lower than 21	ABORT
60-69 °F 2.5 lbs for 2 hrs	24 and above	AERATE commodity
	23-21	EXTEND exposure by 15 minutes
	20-18	EXTEND exposure by 30 minutes
	Lower than 18	ABORT
70-79 °F 2 lbs for 2 hrs	19 and above	AERATE commodity
	18-16	EXTEND exposure by 15 minutes
	15-13	EXTEND exposure by 30 minutes
	Lower than 13	ABORT
80-89 °F 1.5 lbs for 2 hrs	14 and above	AERATE commodity)
	13-12	EXTEND exposure by 15 minutes
	11-10	EXTEND exposure by 30 minutes
	Lower than 10	ABORT

Special Procedures for Adding Gas to Oak Logs Using T312-a or T312-a-Alternative

There are two alternative treatments for the MB fumigation of Oak logs. Refer to ***Determine Gas Concentration Values and Corrections for Oak Log Fumigations using Schedule T312-a* on page 5-4-33** and ***Determine Gas Concentration Values and Corrections for Oak Log Fumigations using schedule T312-a-Alternative* on page 5-4-36** for actions to take during the fumigation of Oak Logs using T312-a or T312-a-Alternative.

Step 5—Exhausting the Gas

Require the fumigator to exhaust the gas at the completion of the exposure period. If the treatment schedule is a FIFRA Section 18 Exemption, then the PPQ official must verify the final gas concentration reading. Record detector tube readings and the time interval from the aeration in the corresponding fields in “DETECTOR READINGS”.

Aerating the Enclosure

The fumigator must:

- Arrange for the aeration to proceed once the treatment is completed.
- Consider the direction of the wind when pointing the exhaust duct, and face the duct outlet toward an open area away from people.
- Ensure that, during the first 10 minutes of aeration, no one is present within 200 feet downwind of the exhaust duct outlet
- Determine aeration buffer zones in accordance with EPA’s fumigation buffer zone tables (https:www.epa.gov/pesticide-registration/mbcommoditybuffer).
- Ensure that no one is present within the perimeter of the aeration buffer zone unless they are wearing SCBA.
- **See “Buffer Zone Overlap for Multiple Enclosures” on page-2-4-10**.
- Follow all label instructions, state, county, and local regulations, in addition to the instructions in this manual.
- Inform people located in occupied structures and personnel in the immediate area within the buffer zone that release of MB is about to take place and give them the option of leaving the area or remaining inside the building.
- Restrict access to the area where the exhaust duct extends beyond the enclosure.

Responsibility for Aerating the Commodity

The label requires that at least two people trained in the use of the fumigant must be present at all times during gas introduction, treatment, and aeration. The PPQ official, however, is **not** required to be present at the fumigation site throughout the aeration process unless specified by the label or by State or local regulations.

Table 2-4-8 Determine Responsibility for Aerating the Commodity

If the Treatment Schedule is:	Then:
A FIFRA Section 18 Exemption	1. PPQ official must be present at the initiation of aeration and to VERIFY the final aeration readings. 2. USE **Table 2-4-9** to determine which aeration procedure to follow
A labeled Treatment Schedule	1. RELEASE the fumigation to the fumigator to aerate according to **Table 2-4-9**. 2. RELEASE the commodity.

Refer to **Table 2-4-9** to determine which aeration procedure to use.

Table 2-4-9 Determine the Aeration Procedure

If:	And:	And:	Then:
Nonsorptive	Containerized	→	GO to **page 2-4-38**
	Noncontainerized	Fresh fruits and vegetables, and cut flowers	GO to **page 2-4-41**
		Other than fresh fruits and vegetables, and cut flowers	GO to **page 2-4-39**
Sorptive, including yams and chestnuts (See **See “Sorption” on page-2-3-10** for list of sorptive commodities)	Containerized	→	GO to **page 2-4-44**
	Noncontainerized	→	GO to **page 2-4-42**

Aeration Buffer Zones

The aeration buffer zones are determined by the fumigator in accordance with EPA’s fumigation buffer zone tables (https:www.epa.gov/pesticide-registration/mbcommoditybuffer).

Wearing Respiratory Protection

The fumigator must wear approved respiratory protection (SCBA, supplied air respirator, or combination unit) when:

- A risk of exposure to concentrations above 5 ppm exists; this includes any time the concentration is unknown
- Opening the tarpaulin for aeration
- Removing the tarpaulin if measured levels of fumigant are above 5 ppm
- Setting up the air introduction and exhaust systems (if they were not set up prior to gas introduction)

MB 2016 Label

NOTICE

If MB concentration levels are between 1-4 ppm, the PPQ official and the fumigator may wear an air purifying respirator NIOSH certified half-mask or full face piece with a cartridge.

Aerating Nonsorptive, Containerized Cargo—Indoors and Outdoors

Step 1—Installing Exhaust System

Advise the fumigator to:

1. Install an exhaust fan (minimum of 5,200 cfm capacity) to a 16 inch, or greater, diameter duct located at the floor near rear doors of the container.
2. Install an air introduction duct system consisting of a 3,750 cfm, or greater, fan attached to a 12 inch, or larger, duct which reaches two-thirds of the length of the container at the top of the load. Have the ducts installed prior to the start of the fumigation. For indoor fumigation, extend the exhaust duct at least 30 feet beyond the building or through a vertical stack extending through the roof. For outdoor fumigations, extend the exhaust duct at least 30 feet beyond the container.

Important

The exhaust fan(s) must be capable of a minimum air exchange rate (AER) of ten times per hour. Volume of enclosure (in cubic feet) divided by the sum of cubic feet per minute (cfm) of the exhaust fan(s) or exhaust blower equals the number of minutes required per complete gas volume exchange.

Step 2—Aerating the Commodity

Advise the fumigator to:

1. Connect the exhaust duct to the exhaust fan.
2. Start the exhaust fan(s) and lift the end of the tarpaulin opposite the end at which the exhaust fan and duct are located.
3. Aerate for **3 hours.**
4. Stop the aeration fans.

5. Use a colorimetric tube to take a concentration reading in the airspace around and, when feasible, within the carton or box**.** Exceptions may include compressed cotton and other very difficult to probe commodities. Obtain prior approval from CPHST for exceptions to this rule.

For FIFRA Section 18 exemptions, record the concentration reading (in ppm), date, and time in Block 39 of PPQ Form 429. If using the electronic 429 database, record the date, time and detector reading (in ppm) in the "Detector Readings" form.

Then use **Table 2-4-10** to determine when to release the commodity.

Table 2-4-10 Determine When to Release the Commodity for Nonsorptive Containerized Cargo

If the gas concentration level is:	Then:
5 ppm or less	RELEASE the commodity
6 ppm or more	1. CONTINUE aeration until the concentration is 5 ppm or less, then 2. RELEASE the commodity

Aerating Nonsorptive, Noncontainerized Cargo—Indoors and Outdoors

Step 1—Installing the Exhaust System

Advise the fumigator to:

1. Install an exhaust duct (minimally one 3,500 cfm capacity fan connected to an exhaust duct). An exhaust duct is optional for outdoor fumigations.
2. Extend the exhaust duct outlet to an outside area where there is adequate ventilation and at least 30 feet away from the building or through a vertical exhaust stack extending through the roof.

Important

The exhaust fan(s) must be capable of a minimum of four air exchanges per hour. Volume of enclosure (in cubic feet) divided by the sum of cubic feet per minute (cfm) of the exhaust fan(s) or exhaust blower equals the number of minutes required per complete gas volume exchange.

Step 2—Aerating the Commodity

Advise the fumigator to:

1. Start the exhaust fan.

2. Lift the end of the tarpaulin opposite the end with the exhaust fan and duct (if used).
3. Aerate the enclosure for **2 hours.**

Outdoor Fumigations

Advise the fumigator to:

1. Stop the fans.
2. Remove the tarpaulin.
3. Take concentration readings with colorimetric tubes in the airspace around and, when feasible, inside the box or cartons.

For FIFRA Section 18 exemptions, record the concentration reading (in ppm), date, and time in Block 39 of PPQ Form 429. If using the electronic 429 database, record the date, time and detector reading (in ppm) in the "Detector Readings" form. If using the electronic 429, record the time and detector reading (in ppm) in the "Detector Readings" form.

Then use **Table 2-4-11** to determine when to release the commodity.

Table 2-4-11 Determine When to Release the Commodity for Outdoor Fumigations

If the gas concentration level is:	Then:
5 ppm or less	RELEASE the commodity
6 ppm or more	1. CONTINUE aeration and take concentration readings until the level is 5 ppm or less, then 2. RELEASE the commodity

Indoor Fumigations

Advise the fumigator to:

1. Stop the fans.
2. Take concentration readings with colorimetric tubes in the airspace around and, when feasible, in the carton or box.

For FIFRA Section 18 exemptions, record the concentration reading (in ppm), date, and time in Block 39 of PPQ Form 429. If using the electronic 429, record the time and detector reading (in ppm) in the "Detector Readings" form.

Then use **Table 2-4-12** to determine when to release the commodity.

Table 2-4-12 Determine When to Release the Commodity for Indoor Fumigations

If the gas concentration level is:	Then:
5 ppm or less	1. ADVISE fumigator to REMOVE the tarpaulin, and 2. RELEASE the commodity
6 ppm to 99 ppm	1. ADVISE fumigator to REMOVE the tarpaulin, and 2. CONTINUE aeration until the concentration is 5 ppm or less, then 3. RELEASE the commodity
100 ppm or above	1. CONTINUE aeration and take concentration readings until the concentration level is below 100 ppm, then remove the tarpaulin, and 2. CONTINUE aeration until concentration is 5 ppm or less, then 3. RELEASE the commodity

Aeration Procedures for Fresh Fruits, Vegetables, and Cut Flowers—Indoors or Outdoors

Important

Do **not** use these procedures for fresh chestnuts or yams. (see procedures for sorptive commodities on **page 2-4-45**)

Step 1—Installing Exhaust System

Use **Table 2-4-13** to determine fan size.

Table 2-4-13 Determine Number of Fans for Aeration of Fresh Fruits, Vegetables, and Cut Flowers

If the enclosure is:	Then:
Up to 1000 cu ft	USE one fan, 67-350 cfm
1001-15,000 cu ft	USE one or 2 fans. The volume of the enclosure divided by the sum of the cfm of the fans should equal a figure of 15 or less. Connect fan(s) to 3-ft diameter exhaust duct(s) 3 ft in diameter.
15,001-25,000 cu ft	USE two fans, each 1,000 to 5,000 cfm. The volume of the enclosure divided by the sum of the cfm of the fans should equal a figure of 15 or less. Connect fan(s) to exhaust duct(s) 3 ft in diameter.
More than 25,000 cu ft	CONTACT the CPHST-AQI for advice prior to conducting the first fumigation.

An alternate procedure to using exhaust fans and ducts is to aerate through a vertical stack.

Important

The exhaust fan(s) must be capable of a minimum of four air exchanges per hour. Volume of enclosure (in cubic feet) divided by the sum of cubic feet per minute (cfm) of the exhaust fan(s) or exhaust blower equals the number of minutes required per complete gas volume exchange.

Step 2—Aerating the Commodity

Advise the fumigator to:

1. Connect the exhaust duct to the exhaust fan.
2. Start the exhaust fan(s) and lift the end of the tarpaulin opposite the end at which the exhaust fan and duct are located.
3. Aerate for **2 hours.**
4. Remove the tarpaulin and allow **2 hours** for passive aeration.
5. Stop the fans and take concentration readings with colorimetric tubes in the airspace around and, when feasible, inside the cartons or boxes.

For FIFRA Section 18 exemptions, record the concentration reading (in ppm), date, and time in Block 39 of PPQ Form 429. If using the electronic 429, record the time and detector reading (in ppm) in the “Detector Readings” form.

Then use **Table 2-4-14** to determine when to release the commodity.

Table 2-4-14 Determine When to Release the Commodity After Aeration of Fresh Fruits, Vegetables, and Cut Flowers

If the gas concentration level is:	Then:
5 ppm or less	RELEASE the commodity
6 ppm or more	1. CONTINUE aeration and take concentration readings until the level is 5ppm or less, then 2. RELEASE the commodity

Aerating Sorptive, Noncontainerized Cargo—Indoors and Outdoors

Step 1—Installing the Exhaust System

Advise the fumigator to:

1. Install an exhaust duct (minimally one 3,500 cfm capacity fan connected to an exhaust duct).
2. Extend the exhaust duct outlet to an outside area where there is adequate ventilation and at least 30 feet away from the building or through a vertical exhaust stack extending through the roof.

Step 2—Aerating the Commodity

Outdoor Fumigations

Advise the fumigator to:

1. Lift both ends of the tarpaulin.
2. Start the circulation fans and exhaust fans (if available).
3. Aerate Oak logs and lumber a minimum of **48 hours**. If, after 48 hours, the concentration is 5 ppm or greater, continue aeration for 24 more hours. Continue this procedure until concentration readings are less than 5 ppm.
4. Run the fans for **4 hours** for commodities other than Oak logs and lumber.
5. Remove the tarpaulin.
6. Stop the fans and take concentration readings with colorimetric tubes in the airspace around and, when feasible, inside the cartons or boxes.

For FIFRA Section 18 exemptions, record the concentration reading (in ppm), date, and time in Block 39 of PPQ Form 429. If using the electronic 429 database, record the date, time and detector reading (in ppm) in the "Detector Readings" form.

Then use **Table 2-4-15** to determine when to release the commodity.

Table 2-4-15 Determine when to Release the Sorptive Noncontainerized Commodity for Outdoor Fumigations

If the gas concentration level is:	Then:
5 ppm or less	RELEASE the commodity
6 ppm or more	1. CONTINUE aeration and take concentration readings until the level is 5ppm or less, then 2. RELEASE the commodity

Indoor Fumigations

Advise the fumigator to:

1. Complete the installation of the exhaust duct.
2. Start the circulation fans and exhaust fans.
3. Lift the end of the tarpaulin opposite the exhaust fan.
4. Aerate Oak logs and lumber a minimum of **48 hours**. If, after 48 hours, the concentration is 5 ppm or greater, continue aeration for 24 more hours. Continue this procedure until concentration readings are less than 5 ppm.
5. Run the fans for **4 hours** for commodities other than Oak logs and lumber.

6. Stop the fans and take concentration readings with colorimetric tubes in the airspace around and, when feasible, inside the carton or box.
7. Remove the tarpaulin.

For FIFRA Section 18 exemptions, record the concentration reading (in ppm), date, and time in Block 39 of PPQ Form 429. If using the electronic 429 database, record the date, time and detector reading (in ppm) in the “Detector Readings” form.

Then use **Table 2-4-16** to determine when to release the commodity. Take successive readings at intervals of **not** less than 2 hours.

Table 2-4-16 Determine When to Release the Sorptive Noncontainerized Commodity for Indoor Fumigations

If the gas concentration level is:	Then:
5 ppm or less	1. REMOVE the tarpaulin, and 2. RELEASE the commodity
6 ppm to 99 ppm	1. REMOVE the tarpaulin, and 2. CONTINUE aeration until the concentration is 5 ppm or less, then 3. RELEASE the commodity
100 ppm or above	1. CONTINUE aeration and take concentration readings until the concentration level is below 100 ppm, then remove the tarpaulin, and 2. CONTINUE aeration until concentration is 5 ppm or less, then 3. RELEASE the commodity

Aerating Sorptive Commodities in Containers—Indoors and Outdoors

Step 1—Installing the Exhaust System

Advise the fumigator to:

1. Install an exhaust fan (minimum of 5,200 cfm capacity) to a 16 inch or greater diameter duct located at the floor near rear doors or the container.
2. Install an air introduction duct system consisting of a 3,750 cfm or greater fan attached to a 12 inch or greater duct which reaches two-thirds of the length of the container at the top of the load. Have the ducts installed prior to the start of the fumigation. For indoor fumigations, extend the exhaust duct at least 30 feet beyond the building or through a vertical stack extending through the roof. For outdoor fumigations, extend the exhaust duct 30 feet beyond the container.

Step 2—Aerating the Commodity

Indoors

Advise the fumigator to:

1. Complete installation of exhaust duct and begin exhaust fan operation.
2. Lift both ends of the tarpaulin and begin exhaust fan operation. Do **not** remove the tarpaulin until the gas concentration level is below 100 ppm (see **Table 2-4-17**).
3. Start the circulation and air introduction fans. Require a minimum of **4 hours** aeration for all sorptive commodities. Sorptive commodities generally require 12 hours or longer to aerate, however, since sorptive commodities vary in their rates of desorption, aeration may be completed in less than 12 hours.
4. Aerate Oak logs and lumber a minimum of **48 hours**. If, after 48 hours, the concentration is 5 ppm or greater, continue aeration for 24 more hours. Continue this procedure until concentration readings are less than 5 ppm.
5. Stop the fans and take concentration readings with colorimetric tubes in the airspace around and, when feasible, inside the carton or box.

For FIFRA Section 18 exemptions, record the concentration reading (in ppm), date, and time in Block 39 of PPQ Form 429. If using the electronic 429 database, record the date, time and detector reading (in ppm) in the "Detector Readings" form.

Then use **Table 2-4-17** to determine when to release the commodity.

Table 2-4-17 Determine when to Release the Sorptive Containerized Commodity for Indoor Fumigations

If the gas concentration level is:	Then:
5 ppm or less	1. ADVISE fumigator to REMOVE the tarpaulin, and 2. RELEASE the commodity
6 ppm to 99 ppm	1. HAVE fumigator REMOVE the tarpaulin, and 2. CONTINUE aeration until the concentration is 5 ppm or less, then 3. RELEASE the commodity
100 ppm or above	1. CONTINUE aeration and take concentration readings until the concentration level is below 100 ppm, then remove the tarpaulin, and 2. CONTINUE aeration until concentration is 5 ppm or less, then 3. RELEASE the commodity

Outdoors

Advise the fumigator to:

1. Complete installation of exhaust duct and begin exhaust fan.

2. Lift both ends of the tarpaulin that are furthest from exhaust fan.
3. Start the circulation and air introduction fans. Require a minimum of **4 hours** aeration for all sorptive commodities. Sorptive commodities generally require 12 hours or longer to aerate, however. since sorptive commodities vary in their rates of desorption, aeration may be completed in less than 12 hours.
4. Aerate Oak logs and lumber a minimum of **48 hours**. If, after 48 hours, the concentration is 5 ppm or greater, continue aeration for 24 more hours. Continue this procedure until concentration readings are less than 5 ppm.
5. Remove the tarpaulin after 4 hours aeration.
6. Stop the circulation fans and take concentration readings with colorimetric tubes in the airspace around and, when feasible, inside the cartons or boxes.

For FIFRA Section 18 exemptions, record the concentration reading (in ppm), date, and time in Block 39 of PPQ Form 429. If using the electronic 429 database, record the date, time and detector reading (in ppm) in the "Detector Readings" form.

Then use **Table 2-4-18** to determine when to release the commodity.

Table 2-4-18 Determine when to Release the Sorptive Containerized Commodity for Outdoor Fumigations

If the gas concentration level is:	Then:
5 ppm or less	RELEASE the commodity
6 ppm or more	1. CONTINUE aeration and take concentration readings until the level is 5ppm or less, then 2. RELEASE the commodity

2

Treatment Manual

Chemical Treatments

Fumigants • Methyl Bromide • Chamber Fumigation

Contents

Methods and Procedures

The procedures covered in this section provide commercial fumigators and chamber owners with the methods, responsibilities, and precautions for normal atmospheric pressure (NAP) and vacuum chamber fumigations.

The chamber owner is responsible for hiring a state certified fumigator and for ensuring that the chamber is certified for conducting PPQ quarantine treatments.

2016 Methyl Bromide Label Information

In 2015, the Environmental Protection Agency (EPA) directed all methyl bromide (MB) registrants to amend the use directions on the labels of all 100% MB products. EPA required the changes in order to reflect recommendations in an EPA report.[1]

1 “Report of Food Quality Protection Act (FQPA) Tolerance Reassessment and Risk Management Decision (TRED) for methyl bromide, and Reregistration Eligibility Decision (RED) for Methyl Bromide’s Commodity Uses”, dated August 2006. (https://archive.epa.gov/pesticides/reregistration/web/pdf/methyl_bromide_tred.pdf)

These amendments modify the use directions for fumigation and aeration procedures, modify respiratory requirements and equipment and update gas monitoring equipment. EPA requires all labels on newly manufactured MB to reflect these recommendations effective **October 01, 2016**; however, EPA is allowing existing stocks of MB to be used in accordance with the use directions on the existing stock's (older) labels.

PPQ officials and fumigators **must** closely examine gas cylinder labels in order to validate that the dosage, exposure, and commodity are either on the cylinder label or covered by a FIFRA Section 18 exemption. If a label is **not** affixed to the cylinder, DO NOT allow the fumigator to use that cylinder.

New Buffer Zone Requirements

All 2016 MB labels now require both a treatment and an aeration buffer zone. Both the treatment and aeration buffer zones are specific to the enclosure being fumigated and must be determined by visiting a website link[2] provided in every MB label. The fumigators are responsible for using this website to determine the buffer zones and reporting both buffer zones to the PPQ official. If the treatment buffer zone is determined to be less than 30 feet, the PPQ official will maintain PPQ's standard 30 foot treatment buffer zone; otherwise, the new treatment buffer zone **must** be observed. If the aeration buffer zone is determined to be less than 200 feet, then PPQ's standard "200 feet for 10 minutes" aeration buffer zone **still** applies for the first 10 minutes of aeration. The fumigator **must** refer to EPA's website to determine the minimum aeration buffer zone to be maintained until the aeration period is complete and the fumigator has verified that gas concentration levels meet the conditions in the MB label.

Transiting through buffer zones

The label permits vehicles to transit through both treatment and aeration buffer zones under specific conditions found in the label; it is up to the fumigator determine how or whether vehicles may transit in accordance with the label.

2 https://www.epa.gov/pesticide-registration/mbcommoditybuffer

When using the newer 2016 MB label, changes to certain procedures and equipment in this chapter are displayed in a NOTICE box with a heading titled “MB 2016 Label”.

MB 2016 Label (example)

NOTICE

Use this information when the fumigator is using the 2016 MB label.

When using existing stocks, follow the equipment and procedural guidance that is displayed in the body of the text (outside of the NOTICE box).

If there is no “MB 2016 Label” NOTICE box, then the instructions apply to all MB labels, 2016 and older.

Materials Needed

PPQ Official Provides

- APHIS-approved leak detection device
- Calculator (optional)
- Forms (PPQ Form 429 and APHIS Form 2061 if necessary)
- Self-contained breathing apparatus (SCBA) or supplied air respirator

MB 2016 Label

NOTICE

In addition to the bulleted list on page 2-5-3, the PPQ official will provide:

- Air purifying respirator NIOSH certified half-mask or full face piece with a cartridge for concentrations between 1 and 4 ppm
- APHIS-approved continuous real time gas monitoring device
  - Permanently mounted in PPQ owned facilities only, PureAire Monitoring Systems, Inc. model Air check Advantage[1]
  - Portable Photoionization Detector (PID), RAE Systems, Inc. model MiniRAE 3000[2]
- Self contained breathing apparatus (SCBA) NIOSH approval prefix TC-13F or supplied air respirator NIOSH approval prefix TC-19C

1 The Air Check Advantage can be calibrated either by the manufacturer or by the PPQ official. Calibrate according to the manufacturer's User Guide. Refer to Chapter 8: Equipment for more information.

2 The MiniRae 3000 must be calibrated by the PPQ official according to the manufacturer's User's Guide. Refer to Chapter 8: Equipment for more information.

Fumigator Provides

- APHIS-approved gas detection device[3] (e.g. thermal conductivity device, infrared device, etc.)
- APHIS-approved leak detection device
- Auxiliary pump for purging long gas sample tubes
- Carbon dioxide filter (e.g., Ascarite®)
- Colorimetric tubes (Refer to *Gas Detector Tube (colorimetric) and Apparatus* on page E-1-31 for a list of APHIS-approved product ranges)
- Desiccant (e.g., Drierite®)
- Electrical wiring (grounded, permanent type), three prong extension cords
- Gas introduction line
- Heat supply

3 The methyl bromide monitor must be calibrated annually. Refer to Chapter 8: Equipment for calibration information. If using a thermal conductivity (TC) analyzer, Drierite® and Ascarite® must be used.

- Methyl bromide
- Scale or graduated cylinder for volume (liquid measurements)[4]
- SCBA or supplied air respirator
- Temperature recorder and temperature sensors[5]
- Thermometer[6]
- Volatilizer
- Warning signs/Placarding

MB 2016 Label

NOTICE

In addition to the bulleted list on page 2-5-4 and page 2-5-5, the fumigator will provide:

- Air purifying respirator NIOSH certified half-mask or full face piece with a cartridge for concentrations between 1 and 4 ppm
- APHIS-approved continuous real time gas monitoring device[1]
    - Permanently mounted in PPQ owned facilities only, PureAire Monitoring Systems, Inc. model Air check Advantage
    - Portable Photoionization Detector (PID), RAE Systems, Inc. model MiniRAE 3000
- APHIS-approved direct read gas detection device
    - Colorimetric tubes (e.g. Draeger, Sensidyne)
- Self contained breathing apparatus (SCBA) NIOSH approval prefix TC-13F or supplied air respirator NIOSH approval prefix TC-19C

1 These devices must be calibrated according to the manufacturer's User Guide. Refer to Chapter 8: Equipment for more information.

4 All scales must be calibrated by the State, a company that is certified to conduct scale calibrations, or by the fumigator under the supervision of PPQ. The source and date of calibration must be posted in a visible location on or with the scale at all times. The scale must be calibrated a following every repair or minimum of every year.

5 Temperature sensors must be calibrated annually by the manufacturer or National Institute of Standards and Technology (NIST) within the range of 40 °F to 80 °F (4.4 °C to 26.7 °C)

6 The thermometer must be calibrated or replaced annually.

Refer to ***Certification of Vacuum Fumigation Chambers* on page 6-2-1** and ***Certifying Atmospheric Fumigation Chambers* on page 6-3-1** for guidelines on chamber certification.

Conducting the Fumigation

Step 1—Selecting a Treatment Schedule

The PPQ official will select an appropriate treatment schedule to effectively eliminate the plant pest without damaging the commodity to be fumigated.

Turn to the treatment schedule Index and look up by commodity or by pest the treatment schedule(s) available. Treatment schedules which are approved for chambers will be listed as either "NAP" (normal atmospheric pressure) or as "vacuum."

Step 2—Issuing a PPQ Form 523 (Emergency Action Notification)

When an intercepted pest is identified and confirmed by a PPQ Area Identifier as requiring action, the CBP or PPQ official will issue a Form 523 (Emergency Action Notification - EAN) to the owner, broker, or representative. The EAN will list all treatment options. Refer to Appendix A in the *Manual for Agricultural Clearance* for instructions on completing and distributing the EAN.

Step 3—Determining Section 18 Exemptions and Sampling Requirements

After selecting the treatment schedule, the PPQ official will determine which treatment schedules are FIFRA Section 18 Exemptions. The schedule will be followed by an "IMPORTANT" note to help you determine the current exemption status. Some treatment schedules are only FIFRA Section 18 Exemptions at specific temperature ranges. Check the treatment schedule and temperature to determine if the fumigation will be a FIFRA Section 18 Exemption.

Residue monitoring by taking samples of the commodity prior to the start of the fumigation and after aeration is no longer required.

Step 4—Setting up the Fumigation Site

MB 2016 Label

NOTICE

The PPQ official and the fumigator must select a secure area where traffic and people are restricted from entering and which is isolated from people working. A nonwork area is preferred to help prevent accidents.

The treatment and aeration buffer zones are determined by the fumigator in accordance with EPA's fumigation buffer zone tables (https:www.epa.gov/pesticide-registration/mbcommoditybuffer).

The buffer zones surround the area where access is limited during treatment. If the fumigator determines that the buffer zone is less than 30', then PPQ requires a 30' buffer zone. If the fumigator determines that the buffer zone is greater than 30', then PPQ must observe the prescribed buffer zone.

The treatment and aeration buffer zones extend from the perimeter of the enclosure to a distance determined by the fumigator in accordance with the label. Entry by any person except the PPQ official and the fumigator is **prohibited** except as provided in the "Exceptions to Buffer Zone Entry Restrictions" section of the label.

The treatment buffer zone begins when the fumigant is introduced into the enclosure and ends when aeration begins, at which point the aeration buffer zone requirements apply.

The fumigator must define the treatment and aeration buffer zone perimeters using physical barriers (such as walls, ropes, etc.) and placards to limit access to the buffer zone. Placards must meet all label requirements regarding specific warnings, information, and language.

The fumigator will permit transiting through buffer zones in accordance with the "Transit Exception" section of the label.

Buffer Zone Overlap for Multiple Enclosures

For multiple enclosures where buffer zones overlap, the fumigator must recalculate both the treatment and aeration buffer zones in accordance with the label and supply them to the PPQ official.

Step 5—Measuring the Temperature

The PPQ official must determine the temperature of the commodity in order to select the proper dosage rate. Depending on whether or not you are fumigating a pulpy fruit or vegetable, you may use **either** the commodity temperature **or** an average of the commodity and air temperatures. A pulpy fruit or vegetable can support internal feeding insects, is fleshy and moist, and can be probed with a temperature measuring device. Examples include, but are not limited to peppers, onions, and grapes.

Determine the temperature to use in selecting the proper dosage rate:

- For fruits, pulpy vegetables, or logs use only the commodity temperature.
- For all other commodities use both the commodity and air temperature.

To take the temperature readings, use a bimetallic, mercury, or digital long-stem thermometer that has been calibrated. Use **Table 2-5-1** to determine which temperature to use when selecting the proper dosage rate for commodities other than fresh fruits, vegetables, or logs. Record the temperatures in Block 22 of the PPQ Form 429.

If using the electronic 429 database, record the temperatures in the space and commodity fields in the Treatment form.

NOTICE

The presence of ice indicates temperatures below 40 °F. If ice is present anywhere in the box, pallet, or fumigation enclosure, DO **NOT** fumigate the commodity.

Important

Commodity and space temperatures must be 40 °F or above.

Table 2-5-1 Determine Whether to Use Commodity or Air Temperature for Determining Dosage Rate

If the air temperature is:	And:	Then, for commodities other than fresh fruits or vegetables or logs and lumber[1]:
Higher than the commodity temperature	→	Use the single lowest commodity temperature for determining the dosage rate (Do Not use the average commodity temperature).
Lower than the commodity temperature	By less than 10 degrees	
	By 10 degrees or more	Use the average of the single lowest air and commodity temperature for determining the dosage rate

1 Use commodity temperature for fresh fruits or vegetables or logs and lumber.

Step 6—Calculating the Dosage

In order to calculate dosage, the PPQ official must have the following information:

- Treatment schedule
- Volume of the fumigation chamber (ft^3)
- Temperatures of commodity and air (°F)

The PPQ official must refer to the specific treatment schedule to determine the dosage rate (pounds/ft^3).

Use the formula in **Figure 2-5-1** to calculate the dosage:

$$\text{dosage (lbs.)} = \text{volume}(\text{ft}^3) \times \text{dosage rate (lbs./1,000 ft}^3)$$
$$= \frac{\text{volume}(\text{ft}^3) \times \text{dosage rate (lbs.)}}{1{,}000\ \text{ft}^3}$$

Figure 2-5-1 Formula for Calculating Dosage for Chamber Fumigations

EXAMPLE: Using a fumigation chamber which has a volume of 500 ft^3, you determine the temperature of the commodity and space is 72 °F. The treatment schedule requires 2 lbs. MB/1,000 ft^3 at 70 °F or above. To calculate dosage multiply the volume (500 ft^3) by the dosage rate (2 lbs. MB/1,000 ft^3). This equals 1.0 lbs. of MB needed for the dosage.

Step 7—Conducting the Fumigation

Since fumigation chambers vary by manufacturer and model, refer to the manufacturer's operating manual to determine how to use the chamber. In NAP chambers, circulation fans **must** run for 15 minutes following introduction of the gas.

Taking concentration readings is **not** required when conducting chamber fumigations.

Step 8—Leak Detection

Turn on any leak detection devices prior to gas introduction and ensure that they run throughout the entire fumigation and aeration.

Aerating the Chamber

The fumigator must:

- Arrange for the aeration to proceed once the treatment is completed.

- Consider the direction of the wind when pointing the exhaust duct, and face the duct outlet toward an open area away from people.
- Ensure that, during the first 10 minutes of aeration, no one is present within 200 feet downwind of the exhaust duct outlet.
- Determine aeration buffer zones in accordance with EPA's fumigation buffer zone tables (https:www.epa.gov/pesticide-registration/mbcommoditybuffer).
- Ensure that no one is present within the perimeter of the aeration buffer zone unless they are wearing SCBA.
- **See "Buffer Zone Overlap for Multiple Enclosures" on page-2-5-7**.
- Follow all label instructions, state, county, and local regulations, in addition to the instructions in this manual.
- Inform people located in occupied structures and personnel in the immediate area within the buffer zone that release of MB is about to take place and give them the option of leaving the area or remaining inside the building.
- Restrict access to the area where the exhaust duct extends beyond the enclosure.
- Secure the fumigation area and allow only the chamber operator and the PPQ official monitoring the fumigation into the secure area.

WARNING

Do ***not*** allow motorized vehicles to operate within the secure area.

Responsibility for Aerating the Commodity

Responsibility for aerating the chamber and releasing the commodity depends on whether the treatment schedule used was a labeled use or FIFRA Section 18 Exemption. Use **Table 2-5-2** to determine responsibility for aerating the commodity

Table 2-5-2 Determine the Responsibility for Aerating the Commodity During Chamber Fumigations

If the fumigation chamber is:	And the treatment schedule is:	Then:
Privately or State owned	A labeled treatment	RELEASE the fumigation to the fumigator to aerate and release the commodity.
	A FIFRA Section 18 Exemption (noted in the treatment schedules)	1. PPQ official must be present at the initiation of aeration and to verify the final aeration readings 2. USE **Table 2-5-3** to determine which aeration procedures to follow.
PPQ owned	→	

Table 2-5-3 Determine the Aeration Procedure for Chamber Fumigations

If the chamber is:	Then:
NAP	Use the procedures on **page 2-5-12**
Vacuum	Use the procedures on **page 2-5-12**

Each chamber must be equipped with at least one permanent, metal gas sampling tube to allow the fumigator to take colorimetric tube readings during the aeration. Any extensions of the gas sampling tube or flexible connectors must be made of Teflon™ tubing or metal. The extensions of the sampling tube must run from an area in between the treated boxes and end outside the chamber to allow for colorimetric tube readings.

Wearing Respiratory Protection

The fumigator must wear approved respiratory protection (SCBA, supplied air respirator, or combination unit) when there is a risk of exposure to concentrations above 5 ppm; this includes any time the concentration is unknown.

MB 2016 Label

NOTICE

If MB concentration levels are between 1-4 ppm, the PPQ official and the fumigator may wear an air purifying respirator NIOSH certified half-mask or full face piece with a cartridge.

Normal Atmospheric Pressure Chamber—Aerating Noncontainerized Cargo

Advise the fumigator to:

1. While wearing SCBA, turn on the chamber fans.
2. Aerate a minimum of 3 hours for all commodities.
3. Stop the fans and take concentration readings with colorimetric tubes in the airspace around the box and, when feasible, within the carton or box.

Use **Table 2-5-4** to determine when to release the commodity.

Table 2-5-4 Determine When to Release the Commodity After NAP Fumigation

If the gas concentration level is:	Then:
5 ppm or less	1. CONTINUE aeration for 30 minutes. 2. REQUIRE the fumigator to confirm that gas concentrations remain at 5 ppm or less. 3. RELEASE the commodity
6 ppm or more	1. REQUIRE the fumigator to conduct two additional air washes. 2. TAKE gas concentration readings. 3. If concentration readings are 5 ppm or less, CONTINUE aeration for 30 minutes. 4. REQUIRE the fumigator to confirm that gas concentrations remain at 5 ppm or less. 5. RELEASE the commodity.

For FIFRA Section 18 exemptions, record the concentration reading (in ppm), date, and time in Block 39 of PPQ Form 429. If using the electronic 429 database, record the date, time and detector reading (in ppm) in the “Detector Readings” form.

Vacuum Fumigation Chambers—Aerating Containerized and Noncontainerized Cargo

Advise the fumigator to:

1. Adjust any vacuum remaining at the end of the fumigation to zero by temporarily opening the air intake valve, then closing it.
2. Draw a 15 inch vacuum and adjust it to zero.
3. Repeat this process of drawing a 15 inch vacuum and releasing it a **minimum** of four times.

4. Take concentration readings using a colorimetric tube in the airspace around the box, and when feasible, **within the carton or box.**

For FIFRA Section 18 exemptions, record the concentration reading (in ppm), date, and time in Block 39 of PPQ Form 429. If using the electronic 429 database, record the date, time and detector reading (in ppm) in the "Detector Readings" form.

Use **Table 2-5-5** to determine when to release the commodity.

Table 2-5-5 Determine When to Release the Commodity After Vacuum Fumigation

If the gas concentration is:	Then:
5 ppm or less	1. CONTINUE aeration for 30 minutes. 2. REQUIRE the fumigator to confirm that gas concentrations remain at 5 ppm or less. 3. RELEASE the commodity
6 ppm or above	1. REQUIRE the fumigator to conduct two additional air washes. 2. TAKE gas concentration readings. 3. If concentration readings are 5 ppm or less, CONTINUE aeration for 30 minutes. 4. REQUIRE the fumigator to confirm that gas concentrations remain at 5 ppm or less. 5. RELEASE the commodity. 6.

2

Treatment Manual

Chemical Treatments

Fumigants • Methyl Bromide • Ship Fumigation for Emergency Situations

Contents

Methods and Procedures

The procedures covered in this section provide the methods, responsibilities, and precautions for the fumigation of dry stores, galleys, and crew quarters infested with Khapra beetle and other pests that require treatment.

Emergency fumigation for other pests and commodities **may** be approved on a case-by-case basis. Contact the USDA APHIS PPQ Field Operations National Operations Manager (919-855-7336) for more information.

Even though ship fumigations are allowed by the manufacturers of methyl bromide, APHIS policy PROHIBITS fumigation of bulk commodities in the ship hold because of the difficulty in meeting APHIS standards.

2016 Methyl Bromide Label Information

In 2015, the Environmental Protection Agency (EPA) directed all 100% methyl bromide (MB) registrants to amend the use directions on the labels of all MB products. EPA required the changes in order to reflect recommendations in an EPA report.[1]

1 "Report of Food Quality Protection Act (FQPA) Tolerance Reassessment and Risk Management Decision (TRED) for methyl bromide, and Reregistration Eligibility Decision (RED) for Methyl Bromide's Commodity Uses", dated August 2006. (https://archive.epa.gov/pesticides/reregistration/web/pdf/methyl_bromide_tred.pdf)

These amendments modify the use directions for fumigation and aeration procedures, modify respiratory requirements and equipment and update gas monitoring equipment. EPA requires all labels on newly manufactured MB to reflect these recommendations effective **October 01, 2016**; however, EPA is allowing existing stocks of MB to be used in accordance with the use directions on the existing stock's (older) labels.

PPQ officials and fumigators **must** closely examine gas cylinder labels in order to validate that the dosage, exposure, and commodity are either on the cylinder label or covered by a FIFRA Section 18 exemption. If a label is **not** affixed to the cylinder, DO NOT allow the fumigator to use that cylinder.

New Buffer Zone Requirements

All 2016 MB labels now require both a treatment and an aeration buffer zone. Both the treatment and aeration buffer zones are specific to the enclosure being fumigated and must be determined by visiting a website link[2] provided in every MB label. The fumigators are responsible for using this website to determine the buffer zones and reporting both buffer zones to the PPQ official. If the treatment buffer zone is determined to be less than 30 feet, the PPQ official will maintain PPQ's standard 30 foot treatment buffer zone; otherwise, the new treatment buffer zone **must** be observed. If the aeration buffer zone is determined to be less than 200 feet, then PPQ's standard "200 feet for 10 minutes" aeration buffer zone **still** applies for the first 10 minutes of aeration. The fumigator **must** refer to EPA's website to determine the minimum aeration buffer zone to be maintained until the aeration period is complete and the fumigator has verified that gas concentration levels meet the conditions in the MB label.

Transiting through buffer zones

The label permits vehicles to transit through both treatment and aeration buffer zones under specific conditions found in the label; it is up to the fumigator determine how or whether vehicles may transit in accordance with the label.

2 https://www.epa.gov/pesticide-registration/mbcommoditybuffer

When using the newer 2016 MB label, changes to certain procedures and equipment in this chapter are displayed in a NOTICE box with a heading titled “MB 2016 Label”.

MB 2016 Label (example)

NOTICE

Use this information when the fumigator is using the 2016 MB label.

When using existing stocks, follow the equipment and procedural guidance that is displayed in the body of the text (outside of the NOTICE box).

If there is no “MB 2016 Label” NOTICE box, then the instructions apply to all MB labels, 2016 and older.

Materials Needed

PPQ Official Provides

- APHIS-approved leak detection device
- Calculator (optional)
- PPQ Form 429 (if not using the electronic 429 Commodity Treatment Information System)
- SCBA or supplied air respirator

MB 2016 Label

NOTICE

In addition to the bulleted list on page 2-6-3, the PPQ official must provide:

- Air purifying respirator NIOSH certified half-mask or full face piece with a cartridge for concentrations between 1 and 4 ppm
- APHIS-approved continuous real time gas monitoring device
  - Permanently mounted in PPQ owned facilities only, PureAire Monitoring Systems, Inc. model Air check Advantage[1]
  - Portable Photoionization Detector (PID), RAE Systems, Inc. model MiniRAE 3000[2]
- Self contained breathing apparatus (SCBA) NIOSH approval prefix TC-13F or supplied air respirator NIOSH approval prefix TC-19C

1 The Air Check Advantage can be calibrated either by the manufacturer or by the PPQ official. Calibrate according to the manufacturer's User Guide. Refer to Chapter 8: Equipment for more information.

2 The MiniRae 3000 must be calibrated by the PPQ official according to the manufacturer's User's Guide. Refer to Chapter 8: Equipment for more information.

Fumigator Provides

- Adhesive sealer, tape, and putty or other pliable material for sealing off holes around pipes
- APHIS-approved gas detection device [3] (e.g. thermal conductivity device, infrared device, etc.)
- Auxiliary pump for purging long gas sample tubes
- Carbon dioxide filter (Ascarite®)
- Colorimetric tubes (Draeger/Kitagawa)
- Desiccant (Drierite®)
- Electrical wiring (ground, permanent type), three prong extension cords
- Exhaust blower and ducts
- Fans (circulation, exhaust, and introduction)

3 The methyl bromide monitor must be calibrated annually. Refer to Chapter 8: Equipment for calibration information. If using a thermal conductivity (TC) analyzer, Drierite® and Ascarite® must be used.

- Framework and supports
- Gas sampling tubes (leads)
- Gas supply line
- Heat supply
- Insecticides and spray equipment
- Methyl bromide
- Padding
- Sand or water snakes
- Scales or dispensers[4]
- SCBA or supplied air respirator
- Tape
- Tarpaulin and supports
- Temperature recorder and temperature sensors[5]
- Thermometer[6]
- Volatilizer
- Warning signs/Placarding

4 All scales must be calibrated by the State, a company that is certified to conduct scale calibrations, or by the fumigator under the supervision of PPQ. The source and date of calibration must be posted in a visible location on or with the scale at all times. The scale must be calibrated a following every repair or minimum of every year.
5 Temperature sensors must be calibrated annually by the manufacturer or National Institute of Standards and Technology (NIST) within the range of 40 °F to 80 °F (4.4 °C to 26.7 °C)
6 The thermometer must be calibrated or replaced annually.

MB 2016 Label

NOTICE

In addition to the items in the bulleted list on **page 2-6-4** and **page 2-6-5**, the fumigator must also provide:

- Air purifying respirator NIOSH certified half-mask or full face piece with a cartridge for concentrations between 1 and 4 ppm
- APHIS-approved direct read gas detection device
  - Colorimetric tubes (e.g. Draeger, Sensidyne)
- APHIS-approved continuous real time gas monitoring device[1]
  - Permanently mounted in PPQ owned facilities only (PureAire)
  - Portable Photoionization Detector (PID) RAE Systems, Inc. MiniRAE 3000
- Self contained breathing apparatus (SCBA) NIOSH approved prefix TC-13F or supplied air respirator NIOSH approval prefix TC-19C

1 These devices must be calibrated according to the manufacturer's User Guide. Refer to Chapter 8: Equipment for more information.

PPQ official and fumigator should be prepared to use auxiliary power if shore power is **not** available as most ships' power is 220 volts.

Taking Safety Measures When Fumigating Ships

The most important consideration when fumigating ships is the protection of human life. The commercial fumigator has the following safety responsibilities when fumigating ships:

- Observe all safety precautions while fumigating
- Prevent access of unauthorized personnel, including the ship's crew, to the fumigated area
- Conduct fumigation properly to result in an effective treatment
- Evacuate gas from ship and aerate when fumigation is completed
- Test, with a gas detector, all areas aboard ship to ensure freedom from MB before allowing crew members access to the ship

The commercial fumigator must abide by the following guidelines when fumigating ships:

- Have a representative present throughout the entire fumigation. The representative must be familiar with directions for using the fumigant, warnings, antidotes, etc., shown on the label, on the gas cylinder, and contained in the manufacturer's application manual.
- Have adequate first-aid equipment, SCBA, and other safety equipment available
- Have all areas of the ship tested with a gas detector prior to crew reentry. Pay particular attention to all fumigated areas, crew quarters, and the engine rooms
- Provide for immediate contact with the responsible ship's officer to provide information and access to areas of the ship which may be needed to assure a safe fumigation

Preparing to Fumigate

Step 1—Meeting With Ship's Captain and Agent

When planning a ship fumigation, the PPQ official must meet with the ship's captain, agent, and the fumigation company representative to discuss the conditions of the fumigation. If cargo is present in an area about to be fumigated, determine if any materials might be adversely affected by the fumigant. (see ***Residual Effect* on page 2-3-11** for a list of commodities adversely affected by MB) Notify the ship's agent of possible effects and if conditions permit, allow removal of the material for an alternate treatment.

Discuss plans for removing all crew from the ship. Prior to fumigating a vessel, the master of the vessel and the fumigator must determine whether it is suitably designed to allow for safe occupancy by the ship's crew. If it is determined that it does not allow for safe occupancy, then all crew members must be removed.

It is the responsibility of the commercial fumigator to comply with all label requirements, and with State, local, and U.S. Coast Guard regulations (see ***Coast Guard Regulations*** on **page B-B-1**) concerning shipboard fumigation.

Step 2—Selecting a Treatment Schedule

Refer to ***T402—Miscellaneous Areas Where Fumigation is Not Possible* on page 5-5-3** for the correct treatment. Select a treatment schedule based on the plant pest and commodity to be fumigated. Consider all the commodities present in the area to be fumigated when determining the best treatment available. In the case of Khapra beetle fumigation, determine if finely milled products (example—flour) will be fumigated. To ensure all life stages have been mitigated, have all fumigated commodities destroyed either by incineration or by sterilization after the fumigation has been completed.

Treating Deck Areas

Areas which may be pest contaminated or suspected of being contaminated, such as the deck, hatch covers, drain channels, crevices around hatches, hallways, and similar areas that cannot be fumigated, should be treated according to **T402-b-3-1**.

Step 3—Determine Buffer Zones

MB 2016 Label

NOTICE

The fumigator will determine the treatment buffer zone in accordance with EPA's fumigation buffer zone tables (https:www.epa.gov/pesticide-registration/mbcommoditybuffer).

The treatment buffer zone surrounds the area where access is limited during treatment. If the fumigator determines that the buffer zone is less than 30', then PPQ requires a 30' buffer zone. If the fumigator determines that the buffer zone is greater than 30', then PPQ must observe the prescribed buffer zone.

The treatment buffer zone extends from the perimeter of the enclosure to a distance determined by the fumigator in accordance with the label. Entry by any person except the PPQ official and the fumigator is **prohibited** except as provided in the "Exceptions to Buffer Zone Entry Restrictions" section of the label.

The treatment buffer zone begins when the fumigant is introduced into the enclosure and ends when aeration begins, at which point the aeration buffer zone requirements apply.

The fumigator must define treatment and aeration buffer zone perimeters using physical barriers (such as walls, ropes, etc.) and placards to limit access to the buffer zone. Placards must meet all label requirements regarding specific warnings, information, and language.

The fumigator will permit transiting through buffer zones in accordance with the "Transit Exception" section of the label.

Buffer Zone Overlap for Multiple Enclosures

For multiple enclosures where buffer zones overlap, the fumigator must recalculate both the treatment and aeration buffer zones in accordance with the label and supply them to the PPQ official.

Step 4—Preparing Areas to Be Fumigated

Open all bins, drawers, and cupboards. Stack all bagged commodities on pallets to facilitate gas distribution and penetration.

Step 5—Arranging and Operating Fans

Storerooms normally require a minimum of two, 1,800 cfm fans. Ensure that the fumigator places one fan at a low level and the other at a high level. Fans with capacity above 1,800 cfm create strong air currents which could result in gas leakage around the seals. If you are fumigating an area which includes the galley and adjoining storerooms, ensure that the fumigator places the fans to evenly distribute gas. Make certain that fans can be turned on and off from an area outside the fumigation site.

Require the fumigator to test all fans to ensure that they are in good operating condition. Operate fans during the gas introduction and for 30 minutes after introduction is completed.

Step 6—Placing Gas Sampling Tubes

The fumigator must place gas sampling tubes in areas and commodities which will give representative samples within the fumigated area. Require the fumigator to bring sampling tubes to one central point outside the treatment buffer zone of the area being fumigated. Label all gas sampling tubes so they can be easily identified when you take concentration readings. Label each tube by identifying the level of the hold and whether the gas sampling tube is in a commodity or space.

The fumigator must place a minimum of two gas sampling tubes in open space and at least one gas sampling tube within the commodity considered to be the most difficult for the fumigant to penetrate.

Step 7—Placing the Gas Introduction Lines

Numerous gas introduction lines may be necessary in order to obtain even gas distribution throughout the fumigation area. Require the fumigator to place the gas introduction line directly through an opening from the outside (example—a door or window) directly above a fan. The introduction line must be securely attached to the top of the fan to prevent movement of the hose. An unsecured introduction line could move the line out of the airflow. Require the fumigator to place a piece of nonpermeable sheeting (example—plastic or vinyl canvas) over the commodity in front of and below each gas supply line. The nonpermeable sheet will prevent any liquid MB from coming in contact with commodities and will prevent damage.

Step 8—Measuring the Temperature

The PPQ official must determine the temperature of the commodity and the air (space) in order to select the proper dosage rate using a calibrated thermometer. Record the temperatures in Block 22 on the PPQ Form 429.

If using the electronic 429 database, record the temperatures in the space and commodity fields in the Treatment form.

If the temperature is below the minimum listed for the treatment schedule, then require the fumigator to heat the hold or other space to be fumigated.

Step 9—Sealing Stores

One of the most important steps in preparing for a ship fumigation is sealing all openings and areas which have the potential to leak gas. Consider the entire area to be fumigated as a natural atmospheric chamber and make the area as gastight as possible. The most important task is to locate all openings (e.g., drain pipes, bilge drain holes, or air ducts) and seal them.

Ensure that the fumigator does **not** seal or make gastight recessed areas, ducts, or similar apertures which may harbor an infestation. In some cases it is better to seal sources of leaks on the outside of the area to be fumigated. Require the fumigator to use caulking compound or tape for sealing small spaces, doors, and other openings. For sealing larger areas, such as hatch cover openings, use polyethylene or similar material secured with tape or adhesive spray. When practical, seal air ventilation ducts on the outside of the space being fumigated so sealing tape can be removed when the fumigator evacuates the gas and begin aeration.

Require the fumigator to look for and seal off the following ship areas when preparing a ship for fumigation:

- Air vents
- All passageways, engine room, and other crew areas for electric pipeline or other duct work common with cargo holds
- Bilge and drainwell vents and drains to all cargo holds sometimes common with more than one hold or engine room bilges
- CO_2 piping to all cargo holds; degassing systems (older ships) which usually run from hold to hold
- Drains
- Dumb-waiter openings
- Emergency escape hatches from shaft alley and escape hatches from all holds
- Engine room—recirculation air systems controlled from and common with the engine room areas—especially on newer ships; check for drilled holes or other openings in fore and aft bulkheads of engine room spaces, all engine room vent systems, and housing or casing leading into spaces to be fumigated
- Galley intake and exhaust systems (may be common with the dry stores)
- Heating, air conditioning, electrical, communication, and ventilation systems

- Inner bottom and deep tank covers to ensure that they are closed prior to fumigating
- Pipes and other utility conduits through decks and bulkheads
- Fire and smoke detector systems from fumigated areas
- Steam-smothering systems for connection between holds
- Vents in shaft alley and gear lockers to holds; breaks in bulkhead
- Wall plates

Step 10—Measuring Volume

Obtain the volume of the dry stores, galleys, and crew quarters from the chief mate, the captain, the ship's plan, or by measuring the actual dimensions.

Step 11—Calculating Dosage

The formula for calculating dosage is:

$$\text{dosage (lbs.)} = \text{volume}(\text{ft}^3) \times \text{dosage rate (lbs./1,000 ft}^3)$$
$$= \frac{\text{volume}(\text{ft}^3) \times \text{dosage rate (lbs.)}}{1{,}000\ \text{ft}^3}$$

Figure 2-6-1 Formula for Calculating Dosage for Vessel Fumigations

EXAMPLE: The dry storage area is infested with Khapra beetle. The volume is 8,000 ft^3, and the temperature is 65 °F. The treatment schedule lists the dosage rate as 6 lbs. MB/1,000 ft^3. To calculate the dosage multiply the volume (8,000 ft^3) by the dosage rate (6 lbs./1,000 ft^3). This equals 48 lbs. of MB needed for the dosage.

Step 12—Making a Final Check

Just before introducing the gas, the PPQ official and the fumigator must ensure that the following activities are performed:

- Take gas concentration readings to determine if any contaminant gases are present
- Turn on all fans and gas detection devices to make sure they work
- Start volatilizer and heat water to 200 °F or above
- Place fumigant cylinder with gas introduction line on scale and take initial weight reading. Make sure the gas introduction line is attached to the cylinder. After obtaining the correct weight, subtract the dosage to be introduced into the enclosure. When the entire dosage has been introduced, the scale will be balanced.

- Check to make sure the ship's gangway and areas to be fumigated are properly placarded and the area is secured. A guard should be present at the entrance to the gangway to restrict access to the ship. If the crew has been removed, walk through the quarters and other areas to make sure no one is aboard.
- Check all sealed areas to make sure they are securely taped and free from holes
- Check the gas introduction line connections to make sure they are tight
- Check to make sure all safety equipment is available and in working order

Conducting the Fumigation

Step 1—Introducing the Gas

CAUTION

The PPQ official must wear SCBA anytime the MB concentration level in the air is unknown or greater than or equal to 5 ppm.

MB 2016 Label

NOTICE

If MB concentration levels are between 1-4 ppm, the PPQ official and fumigator may wear an air purifying respirator NIOSH certified half-mask or full face piece with a cartridge.

Require the fumigator to use SCBA while introducing and adding gas. Require the fumigator to turn on all fans while introducing the gas. When using large cylinders of MB, have the fumigator slightly open the valve then close the valve. Using an APHIS-approved continuous real time gas detection device, check all connections on the gas introduction line for leaks. If leaks are found, the fumigator must tighten the connections and repeat the test. When no leaks are found, require the fumigator open the valve to the point where 3 to 4 pounds of MB are being introduced per minute. The water temperature in the volatilizer should never go below 150 °F at any time during gas introduction. The water in the volatizer can include an antifreeze and should be handled with appropriate safeguards.

CAUTION

Do **not** touch the introduction line with your bare hands—you may get burned! Have the fumigator close the cylinder valve once the proper dosage has been introduced.

The fumigation time begins when all the gas has been introduced. The PPQ official must record the time gas introduction was started and completed in Block 32 on the PPQ Form 429.

If using the electronic 429 database, record the fumigation date, gas introduction start and finish time in the corresponding fields under the “GAS INTRODUCTION” heading on the Treatment form.

Require the fumigator to run the fans for 30 minutes after all the gas has been introduced. The PPQ official must take the initial concentration reading 30 minutes after all the gas has been introduced.

When using cylinders, getting the final amounts of gas out of the cylinder may take a long time. Consider taking gas concentration readings 30 minutes after the gas is first introduced. If the gas distribution is even (all readings within 4 ounces of each other) and at an adequately high concentration, then require the fumigator to turn off the fans. Running the fans longer may contribute to gas leakage. Allow the remainder of the gas to discharge at its slow rate with intermittent running of the fans for dispersal.

Step 2—Taking Concentration Readings

The PPQ official must take concentration readings with an APHIS-approved gas detection device to determine the gas concentration and distribution within the area being fumigated. If using a T/C, check Drierite® tubes before each reading and change Drierite® if its color is pink. Take concentration readings at the times prescribed in the treatment schedule.

Consult the treatment schedule being used for the actual concentration readings. You may start the final concentration reading 30 minutes prior to the end of the exposure period.

Take additional readings when there is indication that the gas is **not** properly distributed or the minimum gas concentration is **not** being maintained. Record readings on PPQ Form 429.

Step 3—Testing for Leaks

Require the fumigator to wear the SCBA and use an APHIS-approved continuous real time gas detection device to test for leaks after all the gas has been introduced. Test around the perimeter of the area being fumigated, especially where doors, windows, pipes, electric cords, gas sampling tubes, and gas introduction lines are present. If the fumigator detects leaks, ensure that they are sealed with additional tape, adhesive, or by placing more polyethylene and adhesive over the leaking areas.

Step 4—Adding Gas and Extending Exposure

If you determine that you need to add gas and extend time, use the formula in **Figure 2-6-2** to calculate the amount of gas to add and **Table 2-6-1** to determine how long to extend the exposure period.

$$1.6 \times \text{number of ounces below minimum} \times \frac{\text{volume in cubic feet}}{1000\,\text{cubic feet}} \times \frac{1}{16} = \text{pounds of gas to add}$$

Figure 2-6-2 Formula for Determining the Amount of Gas to Add for Vessel Fumigation

EXAMPLE: You are fumigating a ship's storeroom for Khapra beetle and the minimum concentration for the 2-hour reading is listed at 50 oz., but your readings average 45 oz. The volume of the storeroom is 1,500 ft^3. Using the formula in **Figure 2-6-2**, you would figure the following:

1.6×5 (oz. below min.) $\times$ 1,500/1,000

$8 \times 1.50 = 12$ oz. gas to be added

Extending Exposure Period

Use **Table 2-6-1** to determine how long to extend the exposure period:

Table 2-6-1 Determine Time for Extended Exposure

If the exposure time is:	And the reading is below minimum by:	Then extend exposure:
12 hours or more	10 oz. or less	10 percent of the time lapse since gas introduction or the last reading
	11 oz. or more	2 hours or 10 percent of time lapse since last reading, whichever is greater

Step 5—Exhausting the Gas

Require the fumigator to exhaust the gas at the completion of the exposure period.Record detector tube readings and the time interval from the aeration in the corresponding fields in "DETECTOR READINGS" the PPQ Form 429.

Removal of the fumigant is facilitated by using an outside blower to force fresh air through portable canvas, plastic, or similar ducts. Another method is to use compressed air hoses to force fresh air into the area. Require the fumigator to use suction type fans with portable ducts to evacuate gas from storerooms to outside, downwind areas away from crew areas, preferably on the offshore side of the ship. Ensure that the fumigator does **not** point the ducts upward, since dissipation onto the deck may occur. Use the ship's aeration/ventilation equipment if possible. Make sure that use of ship's equipment will **not** distribute the exhausted gas to other areas within the ship.

Aerating the Dry Store, Galley, or Crew Quarters

The fumigator must:

- Arrange for the aeration to proceed once the treatment is completed.
- Consider the direction of the wind when pointing the exhaust duct, and face the duct outlet toward an open area away from people.
- Ensure that, during the first 10 minutes of aeration, no one is present within 200 feet (downwind of the exhaust duct outlet.
- Determine aeration buffer zones in accordance with EPA's fumigation buffer zone tables (https:www.epa.gov/pesticide-registration/mbcommoditybuffer).
- Ensure that no one is present within the perimeter of the aeration buffer zone unless they are wearing SCBA.
- Follow all label instructions, state, county, and local regulations, in addition to the instructions in this manual.
- Inform people located in occupied structures and personnel in the immediate area within the buffer zone that release of MB is about to take place and give them the option of leaving the area or remaining inside the building.
- Restrict access to the area where the exhaust duct extends beyond the enclosure.

Wearing Respiratory Protection

The fumigator must wear approved respiratory protection (SCBA, supplied air respirator, or combination unit) when there is a risk of exposure to concentrations above 5 ppm; this includes any time the concentration is unknown.

MB 2016 Label

NOTICE

If MB concentration levels are between 1-4 ppm, the PPQ official and the fumigator may wear an air purifying respirator NIOSH certified half-mask or full face piece with a cartridge.

Aerating the Area

Advise the fumigator to:

1. Wearing the SCBA, open doors, hatches, tarpaulins, and areas to facilitate aeration.
2. Connect the exhaust system.
3. Start the exhaust system (minimum 3,500 cfm exhaust fan connected to an exhaust duct).
4. Aerate until gas concentrations are 5 ppm or less.
5. Stop the aeration fans.
6. While wearing SCBA, take a concentration reading with a colorimetric tube in the airspace within the fumigated area.

The PPQ official must record the date, concentration reading, and time on PPQ Form 429. If using the electronic 429 database, record the time and detector reading (in ppm) in the corresponding fields on the “Detector Readings” form.

2

Treatment Manual

Chemical Treatments

Fumigants • Methyl Bromide • Structure Fumigation

Under Construction.

The information in this chapter has been temporarily removed. For more information, contact USDA PPQ Field Operations at 919-855-7336.

Under Construction.

2

Treatment Manual

Chemical Treatments

Fumigants • Methyl Bromide • Special Procedures for Container Fumigations Without a Tarpaulin

Contents

Introduction

APHIS allows the fumigation of a refrigerated container WITHOUT a tarpaulin provided the containers are located outdoors and can be shown to be structurally sound. For cut flower, fresh fruit and vegetable treatments of 4 hours duration or less, APHIS may approve on a case-by-case basis the use of containers without the use of a tarpaulin. The commercial fumigator should contact the local PPQ office to initiate the process for container approval. Refer to **Table 2-8-1** for detailed responsibilities.

The integrity of these containers (ability to hold methyl bromide adequately) is predetermined by passing a pressure test. (**See "Container Prepping and Pre-Testing" on page-2-8-15**.)

2016 Methyl Bromide Label Information

In 2015, the Environmental Protection Agency (EPA) directed all 100% methyl bromide (MB) registrants to amend the use directions on the labels of all MB products. EPA required the changes in order to reflect recommendations in an EPA report.[1]

These amendments modify the use directions for fumigation and aeration procedures, modify respiratory requirements and equipment and update gas monitoring equipment. EPA requires all labels on newly manufactured MB to reflect these recommendations effective **October 01, 2016**; however, EPA is allowing existing stocks of MB to be used in accordance with the use directions on the existing stock's (older) labels.

PPQ officials and fumigators **must** closely examine gas cylinder labels in order to validate that the dosage, exposure, and commodity are either on the cylinder label or covered by a FIFRA Section 18 exemption. If a label is **not** affixed to the cylinder, DO NOT allow the fumigator to use that cylinder.

New Buffer Zone Requirements

All 2016 MB labels now require both a treatment and an aeration buffer zone. Both the treatment and aeration buffer zones are specific to the enclosure being fumigated and must be determined by visiting a website link[2] provided in every MB label. The fumigators are responsible for using this website to determine the buffer zones and reporting both buffer zones to the PPQ official. If the treatment buffer zone is determined to be less than 30 feet, the PPQ official will maintain PPQ's standard 30 foot treatment buffer zone; otherwise, the new treatment buffer zone **must** be observed. If the aeration buffer zone is determined to be less than 200 feet, then PPQ's standard "200 feet for 10 minutes" aeration buffer zone **still** applies for the first 10 minutes of aeration. The fumigator **must** refer to EPA's website to determine the minimum aeration buffer zone to be maintained until the aeration period is complete and the fumigator has verified that gas concentration levels meet the conditions in the MB label.

Transiting through buffer zones

The label permits vehicles to transit through both treatment and aeration buffer zones under specific conditions found in the label; it is up to the fumigator determine how or whether vehicles may transit in accordance with the label.

1 "Report of Food Quality Protection Act (FQPA) Tolerance Reassessment and Risk Management Decision (TRED) for methyl bromide, and Reregistration Eligibility Decision (RED) for Methyl Bromide's Commodity Uses", dated August 2006. (https://archive.epa.gov/pesticides/reregistration/web/pdf/methyl_bromide_tred.pdf)
2 https://www.epa.gov/pesticide-registration/mbcommoditybuffer

When using the newer 2016 MB label, changes to certain procedures and equipment in this chapter are displayed in a NOTICE box with a heading titled “MB 2016 Label”.

MB 2016 Label (example)

NOTICE

Use this information when the fumigator is using the 2016 MB label.

When using existing stocks, follow the equipment and procedural guidance that is displayed in the body of the text (outside of the NOTICE box).

If there is no “MB 2016 Label” NOTICE box, then the instructions apply to all MB labels, 2016 and older.

Responsibilities

Refer to **Table 2-8-1** for the processes and responsible parties when approving a container for tarpless fumigation.

Table 2-8-1 Responsibilities for Approving Tarpless Container Fumigations

Action:	Responsible Party: Local PPQ Field Office	Field Operations Hub (FO-H)	QPAS	CPHST-AQI
1. Receives request from fumigator about tarpless fumigation. Request includes fumigator contact information and details of fumigation location	X			
2. Local field office sends details of the inquiry to:		X		
3. FO-H sends details of the inquiry to:			X	X
4. Acknowledges receipt of request via email to the fumigator; sends requirements for pressure testing (see Container Prepping and Pre-Testing) and ensures that the requirements are understood		X	X (if non-routine)	X (if non-routine)
5. Fumigator submits proposed protocol to:		X		
6. Once protocol is agreed upon, fumigator is notified whether the protocol is approved or denied by:		X		
7. When fumigator is ready for on sight approval, dates for testing are scheduled by:		X		X (if non-routine)
8. On sight approval audit conducted, trip report, including recommendation, sent to CPHST AQI and QPAS by:		X	X (if non-routine)	
9. Concurrence reached over whether approval is granted		X	X	X
10. Notification of approval in writing sent by:		X		
11. Training of local PPQ officials (pressure testing) by:		X		
12. Follow up audits conducted if needed.		X	X (if non-routine)	

Methods and Procedures

The procedures covered in this section provide PPQ officials and commercial fumigators with the methods, responsibilities, and precautions for container fumigation without a tarpaulin.

A refrigerated container may be used for fumigations without a tarpaulin provided the following requirements are met:

- Air exchange vents must be closed and taped if any openings are visible
- Air introduction and exhaust ducts installed
- Container must be a refrigerated sea container or refrigerated over-the-road freight trailer with metal flooring
- Container must have three gas monitoring leads in the front-high, middle-middle, and rear-low of the container (the “rear” is considered to be at the doors)
- Container must be packed (in some cases repacked) so that two circulation fans can be placed on top of the commodity; one in the front and one in the back
- Packing will ensure a minimum of 18 inches of air space above the commodity
- Rear fan (at the doors) has the gas introduction hose attached to it and is referred to as the gas introduction fan
- Use fans that have the capacity to move a volume of air in cubic feet per minute equivalent to the total volume of the container
- Container must have all drainage holes (corner drip holes) sealed
- Container must not have side doors or rear doors with damaged/missing gaskets
- Container must successfully complete the **Official Pressure Test** described in this chapter
- Container must have all refrigeration units turned off during pressure testing and when under fumigation

Materials Needed

PPQ Official Provides

- Calculator (optional)
- PPQ Form 429

- Self-contained breathing apparatus (SCBA) or supplied air respirator
- Stopwatch

MB 2016 Label

NOTICE

In addition to the bulleted list above, the PPQ official must provide:

- Air purifying respirator NIOSH certified half-mask or full face piece with a cartridge for concentrations between 1 and 4 ppm
- APHIS-approved continuous real time gas monitoring device
  - Permanently mounted in PPQ owned facilities only, PureAire Monitoring Systems, Inc. model Air check Advantage[1]
  - Portable Photoionization Detector (PID), RAE Systems, Inc. model MiniRAE 3000[2]
- Self contained breathing apparatus (SCBA) NIOSH approval prefix TC-13F or supplied air respirator NIOSH approval prefix TC-19C

1 The Air Check Advantage can be calibrated either by the manufacturer or by the PPQ official. Calibrate according to the manufacturer's User Guide. Refer to Chapter 8: Equipment for more information.

2 The MiniRae 3000 must be calibrated by the PPQ official according to the manufacturer's User's Guide. Refer to Chapter 8: Equipment for more information.

Fumigator Provides

- Aeration fans with ducts
- APHIS-approved methyl bromide monitor[3] (e.g. thermal conductivity device, infrared device, etc.)
- Auxiliary pump or Mighty Vac for purging long gas sampling tubes
- Colorimetric tubes (See "Gas Detector Tube (colorimetric) and Apparatus" on page-E-1-31 for a list of APHIS-approved product ranges)
- Electrical wiring (grounded, permanent type), three-prong extension cords
- Ducts (introduction and exhaust)

3 Methyl bromide monitor must be calibrated annually. See "Equipment" on page-8-1-1 for calibration information. If using a thermal conductivity (T/C) analyzer, Drierite® and Ascarite® must be used.

- Fans (circulation and introduction)
- Gas introduction hose
- Gas sampling tubes
- Methyl bromide
- Pressure testing equipment
  - Any device or equipment with the ability to pressurize a container (for example, blowers, compressors, tanks, manifolds)
  - Manometer
  - Sealing putty
- Scales or dispensers[4]
- Self-contained breathing apparatus (SCBA) or supplied air respirator
- Tape
- Temperature recorder and temperature sensors[5]
- Thermometer[6]
- Volatilizer
- Warning signs/Placarding

4 All scales must be calibrated by the State, a company that is certified to conduct scale calibrations, or by a state-certified fumigator under the supervision of PPQ. The source and date of calibration must be posted in a visible location on or with the scale at all times. The scale must be calibrated a minimum of every year.

5 Temperature sensors must be calibrated annually by the manufacturer or National Institute of Standards and Technology (NIST) within the range of 40 °F to 80 °F (4.4 °C to 26.7 °C)

6 The thermometer must be calibrated or replaced annually.

MB 2016 Label

NOTICE

In addition to the items in the bulleted list on page 2-8-6 and page 2-8-7, the fumigator must also provide:

- Air purifying respirator NIOSH certified half-mask or full face piece with a cartridge for concentrations between 1 and 4 ppm
- APHIS-approved direct read gas detection device
  - Colorimetric tubes (e.g. Draeger, Sensidyne)
- APHIS-approved continuous real time gas monitoring device[1]
  - Permanently mounted in PPQ owned facilities only (PureAire)
  - Portable Photoionization Detector (PID) RAE Systems, Inc. MiniRAE 3000
- Self contained breathing apparatus (SCBA) NIOSH approved prefix TC-13F or supplied air respirator NIOSH approval prefix TC-19C

1 These devices must be calibrated according to the manufacturer's User Guide. Refer to Chapter 8: Equipment for more information.

Preparing to Fumigate

Step 1: Selecting the Container

The fumigator must obtain a letter of authorization from the owner of the container prior to attempting to gain access through the container doors or making any structural changes to the containers. The fumigator will maintain the letters of authorization and provide copies to the local PPQ office upon request. PPQ is not responsible for any damage incurred by the fumigator due to modification or manipulation of a container's original condition.

Step 2: Selecting a Fumigation Site

The PPQ official and the fumigator must consider the following factors when selecting a fumigation site:

- Aeration requirements
- Electrical power supply
- Nonwork area that can be effectively marked and safeguarded or isolated
- Water supply

- Well-lighted area
- Well-protected area
- Buffer Zone Overlap for Multiple Enclosures

Aeration Requirements

The fumigator must restrict access to the area where the exhaust duct extends beyond the container. Before a fumigation begins, the fumigator must ensure the exhaust duct is located in a safe place. During the first 10 minutes of aeration, the fumigator must not allow anyone within 200 feet downwind of the exhaust duct outlet. The fumigator is responsible for planning the fumigation so that aeration can be safely conducted immediately following the fumigation.

MB 2016 Label

NOTICE

The fumigator is responsible for all aspects of aeration. When the fumigation is a Section 18 exemption fumigation, the PPQ official is required to verify the final gas concentration reading(s). Refer to ***Aerating Tarpless Containers* on page 2-8-26** for more information.

Electrical Power Supply

Require the fumigator to supply an adequate electrical source to run the circulation fans and the gas detection unit. A separate line should be available for the gas detection unit. Electrical outlets must be grounded and conveniently located in relation to the fumigation area. PPQ does not allow the use of generators as a power source, except under emergency conditions.

Nonwork Area—MB 2016 Label

MB 2016 Label

NOTICE

The fumigator will determine the treatment buffer zone in accordance with EPA's fumigation buffer zone tables (https:www.epa.gov/pesticide-registration/mbcommoditybuffer).

The treatment buffer zone surrounds the area where access is limited during treatment. If the fumigator determines that the buffer zone is less than 30', then PPQ requires a 30' buffer zone. If the fumigator determines that the buffer zone is greater than 30', then PPQ must observe the prescribed buffer zone.

The treatment buffer zone extends from the perimeter of the enclosure to a distance determined by the fumigator in accordance with the label. Entry by any person except the PPQ official and the fumigator is **prohibited** except as provided in the "Exceptions to Buffer Zone Entry Restrictions" section of the label.

The treatment buffer zone begins when the fumigant is introduced into the enclosure and ends when aeration begins, at which point the aeration buffer zone requirements apply.

The fumigator must define the treatment and aeration buffer zone perimeters using physical barriers (such as walls, ropes, etc.) and placards to limit access to the buffer zone. Placards must meet all label requirements regarding specific warnings, information, and language.

The fumigator will permit transiting through buffer zones in accordance with the "Transit Exception" section of the label.

Buffer Zone Overlap for Multiple Enclosures

For multiple enclosures where buffer zones overlap, the fumigator must recalculate both the treatment and aeration buffer zones in accordance with the label and supply them to the PPQ official.

Nonwork Area

The PPQ official and the fumigator must select a secure area where traffic and people are restricted from entering and that is isolated from people working. A nonwork area is preferred to help prevent accidents such as a forklift piercing a container. The fumigation area is the area 30 feet surrounding the container(s) and is separated from the non-fumigation area by a physical barrier such as ropes, barricades, or walls.

Restrict access to the fumigation and aeration areas to the fumigator's employees and PPQ employees monitoring the treatment. The area outside the 30-foot perimeter is usually regarded as a safe distance from the fumigation. The fumigator must placard within the perimeter of the secure area (including the entrance) with the appropriate DANGER/PELIGRO signs. Make sure the placards meet the appropriate fumigant label or labeling requirements. The skull and crossbones should be present as well as "AREA UNDER FUMIGATION, DO NOT ENTER/NO ENTRE"; date of the fumigation; name of the fumigant used; and the name, address, and telephone number of the fumigator. Unless you (PPQ) authorize their use, do not allow motorized vehicles to operate within 30 feet of the fumigation and aeration areas. The 30-foot perimeter is not specifically mentioned on the MB label, but is required for PPQ officials.

When multiple containers are being fumigated, there must be sufficient space for a person wearing SCBA to walk between the containers.

Water Supply

A water supply is necessary for safety purposes. Water is necessary for washing off MB if the liquid form is spilled on someone. If no permanent water is present on site, the fumigator must provide a five-gallon supply of potable, unfrozen water.

Well-Lighted Area

The fumigator will ensure that the area has adequate lighting for safety purposes and for ease in reading gas detection units, thermometers, and for determining whether a container has holes or places where the MB may leak.

Well-Ventilated, Sheltered Area

The PPQ official and the fumigator must select sites that are well-ventilated and sheltered. A well-ventilated site is required for exhausting gas. Avoid areas where strong drafts are likely to occur.

Ensure that the fumigator selects a site that is semi-sheltered such as the leeward side of a warehouse or pier to offer some protection from severe winds. Severe winds are defined as sustained winds or gusts of 30 m.p.h. or higher for any time period. Do not allow the fumigation to proceed if there is a forecast from the National Weather Service of severe winds and/or thunderstorms at the beginning of or for the entire length of the fumigation.

Important

Nontarped containerized fumigations cannot be conducted in a warehouse

Some gas will escape from the container even in the best conditions. The fumigator must ensure that the exhausted gas does not endanger people working outdoors. When treatments are conducted in a particular location on a regular basis, a permanent site should be designated.

Step 3: Arranging the Containers

Ensure that the containers are not loaded beyond 80 percent of their capacity. There must be a space of a minimum of 18 inches above the commodity. This allows a crawl space for placing the gas sampling tubes and fans, and facilitates uniform gas distribution. (Some restacking of cargo may be necessary to meet this requirement.) Require the commodity to be on pallets to allow adequate space (at least 2 inches) below the commodity.

APHIS does not allow stacking of containers. Stacking creates a safety risk to the person(s) installing fans, sampling lines, and aeration ducts.

Step 4: Arranging and Operating Fans

Require the fumigator to use a minimum of two 2,500 cfm fans for efficient gas circulation. Ensure that the fans are placed on top of the palletized commodity; one fan at the doors (rear) and one fan in the front. The rear fan is the gas introduction fan and should be pointed into the container. The front fan is pointing in the opposite direction.

Important

Do **not** run the container's fan or refrigeration unit during the fumigation.

Step 5: Placing the Gas Introduction Line

MB is converted from a liquid into a gas by a volatilizer. The hose that runs from the MB cylinder into the volatilizer must be 3000 PSI hydraulic high pressure hose with a 3/8 inch inner diameter (ID) or larger. From the volatilizer, MB gas is introduced into the container by means of a gas introduction line. The gas introduction line must be a minimum of 350 PSI with a 1/2 inch ID or larger. Ensure that the fumigator places the introduction line directly above the fan at the rear door of the container. Each container must have a gas introduction line.

Step 6: Placing the Gas Sampling Tubes

Ensure that the fumigator installs at least three gas sampling tubes per container. Insert the gas introduction line and sampling tubes between the closed rear door gaskets, or in some other location that does not interfere with successful pressure testing. Position the gas sampling tubes as follows:

- Front low — near the floor at the door end of the container

- ◆ Rear high — rear of the load at the high end opposite the fan
- ◆ Middle center — mid way from front to back, at mid depth

Require the fumigator to use gas sampling tubes of sufficient length to extend from the sampling position inside the container to at least 30 feet beyond the container. Ensure that all the gas sampling tubes meet in one area for ease and safety in taking gas concentration readings. Do not permit gas sampling tubes to be spliced. Before starting the fumigation, check for gas sampling line blockage or pinching by connecting each tube to the gas detection device for a short time. If the line is blocked, the flow to the device will drop sharply. Tubes can also be checked with a MityVac® hand pump or other air pump device. Require the fumigator to replace any defective gas sampling tubes.

Step 7: Measuring the Temperature

The PPQ official must determine the temperature of the commodity in order to select the proper dosage rate. To take the temperature readings, use a calibrated bimetallic, mercury, or digital long-stem thermometer.

Depending on whether or not you are fumigating a pulpy fruit or vegetable, you may use either the commodity temperature or an average of the commodity and air temperatures. A pulpy fruit or vegetable can support internal feeding insects, is fleshy and moist, and can be probed with a temperature measuring device. Examples include, but are not limited to peppers, onions, and grapes.

For pulpy fruits and pulpy vegetables, insert the thermometer into the pulp and use the only the commodity temperature to determine the dosage rate. For commodities that have been refrigerated, probe the fruits that have the lowest pulp temperature. Again, fumigate only when the fruit pulp is at 40°F or higher.

If the commodity has no pulp (e.g., peas, beans, grains, herbs, spices, etc.), take the temperature of the air space immediately surrounding the commodity as well as the commodity temperature and use **Table 2-8-2** to determine the correct temperature to use when selecting the proper dosage rate.

NOTICE

The presence of ice indicates temperatures below 40 °F. If ice is present anywhere in the box, pallet, or fumigation enclosure, DO **NOT** fumigate the commodity.

Important

Do not fumigate at temperatures below 40°F.

The presence of ice indicates temperatures below 40°F. If ice is present anywhere in the box, pallet, or container, do not fumigate the commodity.

Table 2-8-2 Determine Whether to Use Commodity or Air Temperature for Determining Dosage Rate For Nonpulpy Commodities

If the air temperature is:	And:	Then:
Higher than the commodity temperature	→	Use the single lowest commodity temperature for determining the dosage rate (DO **NOT** use the average commodity temperatures).
Lower than the commodity temperature	By less than 10 degrees	
	By 10 degrees or more	Use the average of the single lowest air and commodity temperatures for determining the dosage rate (Never initiate a fumigation if any temperature reads lower than 40°F.)

Step 8: Measuring the Volume

Using a 100-foot tape measure, the PPQ official and the fumigator must carefully measure the length, width, and height of the container. *Never* estimate the measurements. An error in measurement of as little as 12 inches can result in miscalculating the dosage by as much as 15 percent. When measuring, round off to the nearest quarter foot (e.g., 2 1/4 inches = 0.25 feet). In the case of fumigations of edible commodities, an error can result in an unacceptable level of residue on the commodity.

Formula for determining volume:

length × width × height = volume in cubic feet

A stack with measurements H=10'6", L=42'3", and W=10'9"

10.50 x 42.25 x 10.75 = 4,768.9 ft^3 round to 4,769 ft^3

The PPQ official must record volume in Block 26 of PPQ Form 429. If using the electronic 429 database, record the length, width, and height in the corresponding fields under the "AMT of Gas Introduced" heading on the treatment form.

Step 9: Calculating the Dosage

The PPQ official must calculate dosage by doing the following:

1. Refer to the treatment schedule for the correct dosage rate (lbs/1,000 ft^3) based on temperature (°F).
2. Multiply by the dosage (lbs/1,000 ft^3) rate by the volume (ft^3) to get the dosage in pounds.
3. Round to the nearest quarter pound.

Formula for calculating dosage:

$$\text{dosage (lbs.)} = \text{volume}(\text{ft}^3) \times \text{dosage rate (lbs./1,000 ft}^3)$$
$$= \frac{\text{volume}(\text{ft}^3) \times \text{dosage rate (lbs.)}}{1{,}000\ \text{ft}^3}$$

Figure 2-8-1 Formula for Calculating Dosage for Container Fumigations Without a Tarpaulin

If using the electronic 429 database, the PPQ official must enter the dosage rate in the “dosage” field and the total amount of gas required for the fumigation will be displayed in the “Gas Required” field.

Step 10: Container Pressure Testing

In order to ensure that the container can maintain the required gas concentrations, it must be pressure tested. Sea containers or over-the-road freight trailers may be considered for pressure testing and tarpless fumigation if they possess solid metal walls and ceilings, a channeled solid metal floor, and were originally manufactured with two rear doors. Side doors are not permitted.

Any process for pressure testing or tarpless container fumigation which requires modification or a structural change to the container will require a letter of authorization from the owner. The fumigator shall maintain the letters of authorization and provide copies to the local PPQ office upon request. The container owners must agree to repair any container with modified drain holes before they are used for tarpless fumigation.

Required Equipment

The fumigator must supply the following equipment for the pressure test:

- Any device or equipment with the ability to pressurize a container (for example, blowers, compressors, tanks, manifolds) (reference Appendix 6 in the Australian Fumigation Accreditation Scheme (AFAS) [http://www.agriculture.gov.au/SiteCollectionDocuments/biosecurity/import/general-info/qtfp/afas-fumi-standard.pdf])
- A manometer for recording the internal container pressure during the test. The units may be either Pascals (Pa) or inches of water, and must be able to reach a minimum of 250 Pa or 1.0 inch of water.
- Sealing putty for plugging around drain holes, gaps between door gaskets, and sealing around pressure insertion hose.

Container Prepping and Pre-Testing

In preparation for the pressure test, the fumigator must:

1. Close vents and turn off refrigeration unit
2. Seal corner drain holes

3. Repair any visible damage to the container or any parts potentially impacting air tightness
4. Attach a pressurization and monitoring apparatus to the container
5. Pressurize the container to a minimum pressure of 250 Pa (1.0 inch of water)
6. Monitor the pressure to ensure that the decrease from 200 Pa to 100 Pa (0.8 inches to 0.4 inches) takes at least 15 seconds
7. Identify and repair leaks

After the fumigator has conducted a successful pressure test, PPQ will observe and record the official time for the final pressure test.

Official Pressure Test

The PPQ official will:

1. Observe the fumigator pressurizing the container to 250 Pa (1.0 inches).
2. Allow the pressure to decrease to 200 Pa and then record the time it takes to decrease from 200 Pa to 100 Pa (0.8 inches to 0.4 inches) with a stopwatch.

A successful (passing) test is defined by a minimum of 15 seconds transpiring while pressure decreases from 200 Pa to 100 Pa (0.8 inches to 0.4 inches). The PPQ official should confirm a passing test before permitting the fumigator to proceed with a tarpless fumigation. Record the passing test time on PPQ Form 429, and enter it into the Fumigation Form 429 Database. This data field is in the "Treatment" tab of the fumigation report in the "Setup" section. If "Approved Tarpless Container" is selected as the "Enclosure" type, then two additional fields appear in the report, "Was the pressure test conducted?" and "Pressure Test Time (seconds)." Record the time it takes the pressure to drop from 200 to 100 Pa and enter the time (in seconds) into the fumigation report. Officials are not to stop timing after the time exceeds 15 seconds; continue timing until the pressure reaches 100 Pa or 90 seconds have elapsed. If the latter occurs, record "90" seconds as pressure loss interval.

If the container fails the pressure test (as defined by not holding pressure for a minimum of 15 seconds), record the time lapse in the "REMARKS" block in the electronic PPQ Form 429 database. Tarp the container and fumigate according to this manual, Chapter 2-4-Chemical Treatments, Fumigants, Methyl Bromide, Tarpaulin Fumigation.

Ensure that the fumigator places three gas sampling tubes within the container as described in Step 6-**Placing the Gas Sampling Tubes**. Ensure the placement of the lines where they exit the container so the integrity of the sealed container is maintained. For example, an acceptable location for sampling lines is along the sill of the container below the left door, pressed onto a small snake of plumbers putty to make a good seal with the sill and door gasket.

Step 11: Making a Final Check

Before introducing the gas, the PPQ official and the fumigator must ensure that the following activities are performed:

- Turn on all circulation fans and APHIS-approved methyl bromide gas detection monitors to make sure they work.
- Warm up and zero (if required) the APHIS-approved methyl bromide gas detection monitor as described in the **Equipment** chapter of this manual.
- Start volatilizer and heat water to 200°F or above (Refer to ***Volatilizer* on page 8-1-15** for temperature monitoring procedures.) A minimum temperature of 150°F is required at all times during the introduction process.
- Place fumigant cylinder with gas introduction hose on scale and take initial weight reading.
- Ensure the gas introduction hose is attached to the cylinder.
- After obtaining the correct weight, subtract the dosage to be introduced into the container.
- After introducing the proper amount of gas, the scale will be balanced.
- Ensure the container is placarded and the area is secured; only people working on the fumigation can be in the area.
- Ensure that any vents or holes in the container are sealed.
- Ensure that all gas sampling tubes are labeled and are **not** crimped or crushed.
    - Visually inspect tubes or use an electric or Mityvac® hand pump to check tubes. A fumiscope or vacuum pump may also be used to test leads for unrestricted flow.

Important

When conducting fumigations with methyl bromide, erroneous readings may occur if the sampling tubes become blocked or crimped. It would be impossible to install a new sampling tubes during a fumigation treatment. Therefore, to avoid an unsuccessful fumigation, you should test sampling tubes before the treatment begins.

Use the following procedure to detect blocked sampling tubes with the use of a MityVac® hand-held pump (for supplier, see ***Vacuum Pump* on page E-1-71**):

1. Prior to fumigant introduction, connect the MityVac® hand-held vacuum pump to sampling tubes.
2. Squeeze the handle on the MityVac® unit. If the tube is blocked, a vacuum will be indicated on the vacuum gauge of the MityVac® unit. (The handle should be squeezed two or three times for sampling tubes longer than 25 feet. The MityVac® hand-held pump has the capacity to attain and hold 25 inches of Hg vacuum and a minimum of 7 psig pressure.)
3. Disconnect the MityVac® hand-held pump from the sampling tube, and repeat this procedure for each tube. (Connect sampling tubes to the gas analyzer prior to fumigant introduction.)

- Confirm that there is enough gas in the cylinder and if necessary, that other cylinders are available.
- Ensure that all safety equipment, especially SCBA, is available and in working order.
- Confirm that the gas introduction line connections are tight and free of leaks.
- If using a T/C monitor, install Drierite® and Ascarite® filters as stated in the instructions in this manual.

Conducting the Fumigation

Step 1: Introducing the Gas

CAUTION

The PPQ official must wear SCBA anytime the air concentration is unknown or greater than or equal to 5 ppm.

MB 2016 Label

NOTICE

If MB concentration levels are between 1-4 ppm, the PPQ official and fumigator may wear an air purifying respirator NIOSH certified half-mask or full face piece with a cartridge.

Require the fumigator to use SCBA while introducing and adding gas. The PPQ official is not required to be in the treatment buffer zone during the fumigation. The PPQ official must ensure that the fumigator turns on all circulation fans before introducing the gas. When using large cylinders of MB, the fumigator should slightly open the cylinder valve, then close the valve.

Important

If the official or fumigator notices a cloud, plume, vapor, or mist coming from the introduction equipment during gas introduction, the fumigator must TURN OFF the valve on the gas cylinder, EVACUATE the area immediately, and ABORT the fumigation.

No person should place any part of their body into the cloud, plume, vapor, or mist. After the cloud plume has dissipated, measure gas concentration levels at the gas cylinder using any APHIS-approved continuous real time gas detection device. When gas concentration levels at the cylinder reach 5 ppm or less, the fumigator must identify the source of the leak and correct it before restarting the fumigation.

Any person within the treatment buffer zone must wear and use SCBA equipment during gas introduction and gas addition.

With an APHIS-approved continuous real time gas detection device, the fumigator must check all connections on the gas introduction hose (between the MB cylinder and the volatilizer) for leaks. If leaks are found, advise the fumigator to tighten the connections and repeat the test. If no leaks are found, require the fumigator to open the valve to the point where three to four pounds of MB are introduced per minute.

The water temperature in the volatilizer should never go below 150°F at any time during gas introduction. The water in the volatilizer can include an antifreeze and should be handled with the appropriate safeguards. Refer to **Volatilizer** in the **Equipment** chapter for temperature monitoring procedures.

CAUTION

Do not touch the introduction line with your bare hands — you could get burned! Close the cylinder valve once the proper dosage has been introduced.

The fumigation time begins once all the gas has been introduced. The PPQ official must record the time gas introduction was started and completed in Block 32 on PPQ Form 429. If using the electronic 429 database, record the fumigation date, gas introduction start and finish time in the corresponding fields under the "GAS INTRODUCTION" heading in the Treatment form.

Require the fumigator to run the fans for 30 minutes to achieve even gas distribution. The PPQ official must take the initial concentration reading 30 minutes after all the gas has been introduced.

When evacuating large cylinders, getting the final amount of gas out may take a long time. Consider taking a gas concentration reading 30 minutes after the gas was first introduced. If the gas distribution is even (all readings within 4 ounces of each other) and at a significantly high concentration, advise the fumigator to turn off the fans. Running the fans longer can contribute to gas leakage. Allow the remainder of the gas to discharge while intermittently running the fans. Normally, all the gas should be introduced within 30 minutes.

Important

Do not begin counting fumigation time until all the gas has been introduced and the valve on the MB tank is closed.

If the fumigator detects excessive leakage (concentration readings of 50 percent or less of the minimum concentration) is detected, do not attempt to correct the problem by adding more gas. Aerate the container and return, re-export, or destroy the commodity. Commodities used for food or feed cannot be retreated.

Step 2: Taking Concentration Readings

The PPQ official must take concentration readings 30 minutes after gas introduction. Use an APHIS-approved gas detection device to determine the gas concentration and distribution within the container. Allow gas concentration readings to stabilize; do not disconnect the sampling line from the gas detection device when the minimum concentration reading has been met.

Important

Before taking a reading, always purge sampling lines with a mechanical or hand pump. If using a T/C unit, connect it to the sampling line, adjust the gas flow rate to 1.0, and wait until the meter registering "ounces per thousand cubic feet" stabilizes before taking a reading. (This may take a minute or more, depending upon the length of the tubing and whether or not an auxiliary pump is used.)

Take concentration readings at the times designated in the treatment schedule. Concentration readings should not differ more than 4 ounces among the lines. When concentration readings differ more than 4 ounces, run the fans to equalize the gas and record readings in the Remarks block on the APHIS 429. In some case, several cycles of fan operation may be necessary to equalize the readings. The PPQ official must record all gas readings on the PPQ form 429 or in the electronic 429 database.

Important

Avoid using hand-held, two-way radios near a T/C unit. Using two-way radios near a T/C unit will interfere with accurate concentration readings.

Step 3: Determining the Need to Add Gas and Adjust Exposure

Use **Table 2-8-3** to determine when to add gas or extend the exposure period.

Table 2-8-3Determine the Need to Add Gas and Adjust Exposure

If the lowest gas reading is:	And the schedule is:	Then:
Below the required minimum concentration	T101-a-1 or equivalent*	SEE Table 2-8-5 for corrections at 0.5 hour, or Table 2-8-6 for corrections at 2 hours
	Other than T101-a-1 or equivalent*	**See "Adding Gas and Extending Exposure to Commodities that are Fumigated Using Treatment Schedules Other Than T101-a-1 or Equivalent (may include perishables)" on page-2-8-22**.
At or above required minimum concentration	T101-a-1 or equivalent*	SEE Table 2-8-5 for corrections at 0.5 hour, or Table 2-8-6 for corrections at 2 hours
	Other than T101-a-1 or equivalent*	NO ACTION necessary

Important

*T101-a-1 or equivalent treatment schedules are those schedules that are:

- NOT greater than 2 hours long (exposure time)
- NOT greater than 4 lbs. per 1000 ft3 (dosage rate)
- Minimum concentration readings and temperature ranges match EXACTLY the readings in T101-a-1

If the minimum concentration readings do not meet these requirements, the schedule is NOT equivalent. When schedules are NOT equivalent, use **Table 2-8-2** to determine the length of time to extend exposure and use the formula in **Figure 2-8-2** to determine the amount of gas to add.

Adding Gas and Extending Exposure to Commodities that are Fumigated Using Treatment Schedules Other Than T101-a-1 or Equivalent (may include perishables)

Once you have determined that you need to add gas and extend time, use the formula in **Figure 2-8-2** to calculate the amount of gas to add and **Table 2-8-4** to determine how long to extend the exposure period.

$$1.6 \times \text{number of ounces below minimum} \times \frac{\text{volume in cubic feet}}{1000\,\text{cubic feet}} \times \frac{1}{16} = \text{pounds of gas to add}$$

Figure 2-8-2 Formula for Determining the Amount of Gas to Add For Schedules Not T101-a-1 Equivalent and Conducted in a Container Without a Tarpaulin

Table 2-8-4 Determine the Extended Exposure Period to Commodities that are Not T101-a-1 Equivalent

If any individual reading is below minimum by:	Then extend exposure:
10 oz. or less	10 percent of the time lapse since gas introduction or the last acceptable reading
11 oz. or more	30 minutes

Adding Gas

When adding gas, require the fumigator to follow these steps:

1. Heat water in volatilizer.
2. Turn on fans.
3. Weigh the cylinder.
4. With SCBA on, open valve on cylinder and introduce the gas.
5. Close valve when the weight of the cylinder indicates that the needed amount of gas has been added.

The PPQ official must record quantity of fumigant added in Block 34 and additional fan time in Block 30 of PPQ Form 429.

If using the electronic 429, record the amount of additional gas listed in the Treatment Manual in the added in the “Additional Gas Recommended” field and the actual amount of additional gas added in the “Actual Additional Gas” field. Record the additional fan time in the “TIME FANS OPERATED” field in the Treatment form.

Note the time the fumigator started and finished introducing additional gas and record in Block 40 (Remarks) of PPQ Form 429 or in the “Remarks” form in the electronic 429 database. Require the fumigator to run the fans until there is even gas distribution throughout the stack. Turn off fans, then take a concentration reading 30 minutes after the gas has been introduced. If all readings are above minimum concentration levels, proceed as usual with the remaining scheduled concentration readings.

Adding Gas to Fruits, Vegetables, or Perishable Commodities Using Schedules T101-a-1 or Equivalent

Use Table 2-8-5 on page-2-8-25 and Table 2-8-6 on page-2-8-26 to determine if you need to add gas or extend or decrease the exposure time. Select the proper table based on the time of the gas reading (30 minutes or 2 hours). Use the formula in Figure 2-8-3 to determine the amount of gas to add.

$$1.6 \times \text{number of ounces below minimum} \times \frac{\text{volume in cubic feet}}{1000\,\text{cubic feet}} \times \frac{1}{16} = \text{pounds of gas to add}$$

Figure 2-8-3 Formula for Determining the Amount of Gas to Add For T101-a-1 Equivalent Schedules for Container Fumigations Without a Tarpaulin

Important

DO NOT average the concentration readings before using the tables. Base your decision on whether to add gas from the LOWEST gas concentration of any individual gas reading.

Important

Fresh fruits and vegetables are sensitive to MB so you should double check volume calculations and dosage measurements to avoid accidental overdoses.

Adding Gas

When adding gas, require the fumigator to follow these steps:

1. Heat water in volatilizer.
2. Turn on fans.
3. Weigh the cylinder.
4. With SCBA on, open valve on cylinder and introduce the gas.

5. Close valve when the weight of the cylinder indicates that the needed amount of gas has been added.

The PPQ official must record quantity of fumigant added in Block 34 and additional fan time in Block 30 of PPQ Form 429.

If using the electronic 429, record the amount of additional gas listed in the Treatment Manual in the added in the “Additional Gas Recommended” field and the actual amount of additional gas added in the “Actual Additional Gas” field. Record the additional fan time in the “TIME FANS OPERATED” field in the Treatment form.

Note the time the fumigator started and finished introducing additional gas and record in Block 40 (Remarks) of PPQ Form 429 or in the “Remarks” form in the electronic 429 database. Require the fumigator to run the fans until there is even gas distribution throughout the stack. Turn off fans, then take a concentration reading 30 minutes after the gas has been introduced. If all readings are above minimum concentration levels, proceed as usual with the remaining scheduled concentration readings.

Table 2-8-5 Determine Gas Concentration Values and Corrections for Fruits and Vegetables at the 30-Minute Reading of T101-a-1 or Equivalent Schedules

If the schedule is:	And the minimum concentration reading (oz.) in schedule is:	And the lowest concentration reading (oz.) is:	Then:
40-49 °F 4 lbs for 2 hrs	48	65 or greater	REDUCE exposure by 15 minutes
		64-48	TAKE 2 hour reading as scheduled
		Lower than 48	1. ADD gas, and 2. EXTEND exposure 15 minutes
50-59 °F 3 lbs for 2 hrs	38	52 or greater	REDUCE exposure by 15 minutes
		51-38	TAKE 2 hour reading as scheduled
		Lower than 38	1. ADD gas, and 2. EXTEND exposure 15 minutes
60-69 °F 2.5 lbs for 2 hrs	32	48 or greater	REDUCE exposure by 15 minutes
		47-32	TAKE 2 hour reading as scheduled
		Lower than 32	1. ADD gas, and 2. EXTEND exposure 15 minutes
70-79 °F 2 lbs for 2 hrs	26	37 or greater	REDUCE exposure by 15 minutes
		36-26	TAKE 2 hour reading as scheduled
		Lower than 26	1. ADD gas, and 2. EXTEND exposure 15 minutes
80-89 °F 1.5 lbs for 2 hrs	19	27 or greater	REDUCE exposure by 15 minutes
		26-19	TAKE 2 hour reading as scheduled
		Lower than 19	1. ADD gas, and 2. EXTEND exposure 15 minutes

Table 2-8-6 Determine Gas Concentration Values and Corrections for Fruits and Vegetables at the 2-Hour Reading of T101-a-1 or Equivalent Schedules

If the schedule is:	And the lowest concentration reading at 2 hours is:	Then do not add gas, but:
40-49 °F 4 lbs for 2 hours	38 and above	AERATE commodity
	37-28	EXTEND exposure by 15 minutes
	27-25	EXTEND exposure by 30 minutes
	Lower than 25	ABORT
50-59 °F 3 lbs for 2 hrs	29 and above	AERATE commodity
	28-24	EXTEND exposure by 15 minutes
	23-21	EXTEND exposure by 30 minutes
	Lower than 21	ABORT
60-69 °F 2.5 lbs for 2 hrs	24 and above	AERATE commodity
	23-21	EXTEND exposure by 15 minutes
	20-18	EXTEND exposure by 30 minutes
	Lower than 18	ABORT
70-79 °F 2 lbs for 2 hrs	19 and above	AERATE commodity
	18-16	EXTEND exposure by 15 minutes
	15-13	EXTEND exposure by 30 minutes
	Lower than 13	ABORT
80-89 °F 1.5 lbs for 2 hrs	14 and above	AERATE commodity
	13-12	EXTEND exposure by 15 minutes
	11-10	EXTEND exposure by 30 minutes
	Lower than 10	ABORT

Step 4: Exhausting the Gas

Require the fumigator to exhaust the gas at the completion of the exposure period. If the treatment schedule is a FIFRA Section 18 Exemption, then the PPQ official must verify the final gas concentration reading of the commodity. Detector tube readings and the time interval from the aeration must be recorded in the corresponding fields in the “DETECTOR READINGS” form.

Aerating Tarpless Containers

The fumigator must:

- Arrange for the aeration to proceed once the treatment is completed.
- Consider the direction of the wind when pointing the exhaust duct, and face the duct outlet toward an open area away from people.

- ◆ Ensure that, during the first 10 minutes of aeration, no one is present within 200 feet downwind of the exhaust duct outlet.
- ◆ Determine aeration buffer zones in accordance with EPA’s fumigation buffer zone tables (https:www.epa.gov/pesticide-registration/mbcommoditybuffer).
- ◆ Ensure that no one is present within the perimeter of the aeration buffer zone unless they are wearing SCBA.
- ◆ **See “Buffer Zone Overlap for Multiple Enclosures” on page-2-8-10**.
- ◆ Follow all label instructions, state, county, and local regulations, in addition to the instructions in this manual.
- ◆ Inform people located in occupied structures and personnel in the immediate area within the buffer zone that release of MB is about to take place and give them the option of leaving the area or remaining inside the building.
- ◆ Restrict access to the area where the exhaust duct extends beyond the enclosure.

Responsibility for Aerating the Commodity

The label requires that at least two people trained in the use of the fumigant must be present at all times during gas introduction, treatment, and aeration. The PPQ official, however, is not required to be continuously present at the fumigation site throughout the aeration process unless specified by the label or by State or local regulations.

Refer to **Table 2-8-7** to determine who is responsible for aerating the commodity.

Table 2-8-7 Determine Responsibility for Aerating the Commodity for Tarpless Container Fumigation

If the Treatment Schedule is:	Then:
A FIFRA Section 18 Exemption	1. PPQ official must be present at the initiation of aeration and to VERIFY the final aeration readings.
A labeled Treatment Schedule	1. RELEASE the fumigation to the fumigator to aerate. 2. RELEASE the commodity.

Wearing Respiratory Protection

The fumigator must wear approved respiratory protection (SCBA, supplied air respirator, or a combination unit) when:

- ◆ A risk of exposure to concentrations above 5 ppm exists; this includes anytime the concentration is unknown

- Opening the container for aeration
- Setting up the air introduction and exhaust systems

MB 2016 Label

NOTICE

If MB concentration levels are between 1-4 ppm, the PPQ official and the fumigator may wear an air purifying respirator NIOSH certified half-mask or full face piece with a cartridge.

Step 1: Installing the Exhaust System

Advise the fumigator to:

1. Install an exhaust fan (minimum of 5,200 cfm capacity) with one end of a round ventilation duct at least 16 inches in diameter, oriented so that the fan pulls air through the duct. The fan dimensions should complement the diameter of ductwork chosen, fitting flush and tight so that no leaks exist between the fan and duct. The exhaust duct will be at least 30 feet in length with the fan end placed external and alongside the container extending toward the nose, so the exhaust air is directed away from the end of the container which is opened during aeration.

2. Install a fresh air introduction fan (minimum 3,750 cfm) with a round ventilation duct at least 12 inches in diameter, oriented so that the fan pushes the air through the duct. The fan dimensions should complement the diameter of ductwork chosen, fitting flush and tight so that no leaks exist between the fan and duct. Extend the introduction duct (non-fan end) along top of the load two-thirds of the length of the container.

Important

Install air introduction and exhaust ducts prior to fumigation in order to limit human exposure to the fumigant at the start of aeration.

Palletized Partial Loads

For palletized partial loads (where at least 2 feet of open space is present at the door end of the container), ensure that the fumigator extends the exhaust duct intake (non-fan end) on the container floor with the duct face flush against the bottom of the load along a side of the container. Store the remaining section of the exhaust duct and fan at the rear of the load so it is easily accessible at the start of aeration.

Full Loads

For full loads (where less than 2 feet of open space is available at the door end of the container and there is no central aisle between pallets), if there is room to store the duct inside the container during fumigation, ensure that the fumigator secures the duct (non-fan end) face flush against the load at the floor/pallet/commodity interface along a side of the container so it will not shift or twist during aeration. Use straps, ties, or other fasteners to secure this interface tightly. If there is not sufficient room to pre-install the duct prior to fumigation, the fumigator can carry out these steps at the start of aeration.

For partial or full loads where a central aisle exists between the pallets, ensure that the fumigator places the duct along the floor center and extend 1-2 feet into this space if possible.

Refer to **Figure 2-8-4** for detailed diagrams of air and exhaust ducts. In this diagram, air introduction ducts are blue and exhaust ducts are red.

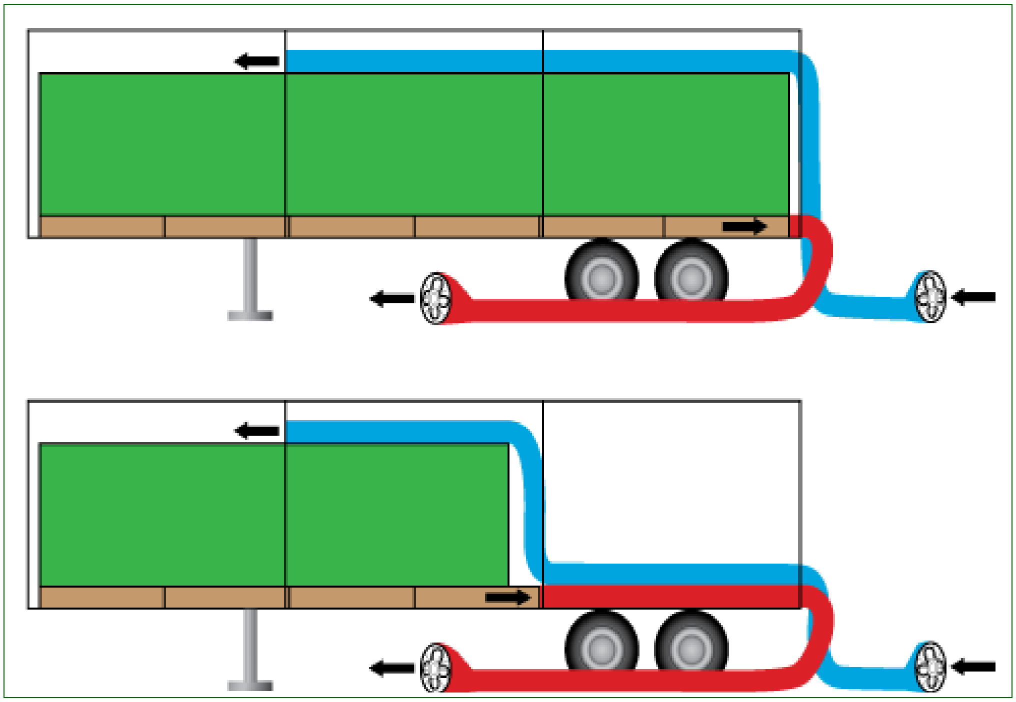


Figure 2-8-4 Ductwork configuration for aeration of untarped containers: full loads (top) and partial loads (bottom)

Step 2: Aerating the Commodity

Advise the fumigator to:

1. While wearing SCBA, open the doors of each container.
2. Turn on all fumigant circulation fans inside the container and leave them on throughout the aeration.
3. Start the container introduction and exhaust ducts fans.
4. Require a minimum of 4 hours aeration for all sorptive commodities.
5. Stop the fans and take concentration readings with colorimetric tubes in the airspace around and, when feasible, within the commodity.

6. RELEASE the commodity when the concentration reading is 5 ppm or less.

2

Treatment Manual

Chemical Treatments

Fumigants • Methyl Bromide • Closed-door Container Fumigation

Contents

Methods and Procedures

The procedures covered in this section provide PPQ officials and commercial fumigators with the methods, responsibilities, and precautions for closed-door container fumigations.

2016 Methyl Bromide Label Information

In 2015, the Environmental Protection Agency (EPA) directed all 100% methyl bromide (MB) registrants to amend the use directions on the labels of all MB products. EPA required the changes in order to reflect recommendations in an EPA report.[1]

These amendments modify the use directions for fumigation and aeration procedures, modify respiratory requirements and equipment and update gas monitoring equipment. EPA requires all labels on newly manufactured MB to reflect these recommendations effective **October 01, 2016**; however, EPA is allowing existing stocks of MB to be used in accordance with the use directions on the existing stock's (older) labels.

1 "Report of Food Quality Protection Act (FQPA) Tolerance Reassessment and Risk Management Decision (TRED) for methyl bromide, and Reregistration Eligibility Decision (RED) for Methyl Bromide's Commodity Uses", dated August 2006. (https://archive.epa.gov/pesticides/reregistration/web/pdf/methyl_bromide_tred.pdf)

PPQ officials and fumigators **must** closely examine gas cylinder labels in order to validate that the dosage, exposure, and commodity are either on the cylinder label or covered by a FIFRA Section 18 exemption. If a label is **not** affixed to the cylinder, DO NOT allow the fumigator to use that cylinder.

New Buffer Zone Requirements

All 2016 MB labels now require both a treatment and an aeration buffer zone. Both the treatment and aeration buffer zones are specific to the enclosure being fumigated and must be determined by visiting a website link[2] provided in every MB label. The fumigators are responsible for using this website to determine the buffer zones and reporting both buffer zones to the PPQ official. If the treatment buffer zone is determined to be less than 30 feet, the PPQ official will maintain PPQ's standard 30 foot treatment buffer zone; otherwise, the new treatment buffer zone **must** be observed. If the aeration buffer zone is determined to be less than 200 feet, then PPQ's standard "200 feet for 10 minutes" aeration buffer zone **still** applies for the first 10 minutes of aeration. The fumigator **must** refer to EPA's website to determine the minimum aeration buffer zone to be maintained until the aeration period is complete and the fumigator has verified that gas concentration levels meet the conditions in the MB label.

Transiting through buffer zones

The label permits vehicles to transit through both treatment and aeration buffer zones under specific conditions found in the label; it is up to the fumigator determine how or whether vehicles may transit in accordance with the label.

2 https://www.epa.gov/pesticide-registration/mbcommoditybuffer

When using the newer 2016 MB label, changes to certain procedures and equipment in this chapter are displayed in a NOTICE box with a heading titled “MB 2016 Label”.

MB 2016 Label (example)

NOTICE

Use this information when the fumigator is using the 2016 MB label.

When using existing stocks, follow the equipment and procedural guidance that is displayed in the body of the text (outside of the NOTICE box).

If there is no “MB 2016 Label” NOTICE box, then the instructions apply to all MB labels, 2016 and older.

Materials Needed

PPQ Official Provides

- APHIS-approved leak detection device
- Calculator (optional)
- Forms (PPQ Form 429 and APHIS Form 2061 if necessary)
- Self-contained breathing apparatus (SCBA) or supplied air respirator

MB 2016 Label

NOTICE

In addition to the bulleted list on page 2-9-3, the PPQ official must provide:

- Air purifying respirator NIOSH certified half-mask or full face piece with a cartridge for concentrations between 1 and 4 ppm
- APHIS-approved continuous real time gas monitoring device
  - Permanently mounted in PPQ owned facilities only, PureAire Monitoring Systems, Inc. model Air check Advantage[1]
  - Portable Photoionization Detector (PID), RAE Systems, Inc. model MiniRAE 3000[2]
- Self contained breathing apparatus (SCBA) NIOSH approval prefix TC-13F or supplied air respirator NIOSH approval prefix TC-19C

1 The Air Check Advantage can be calibrated either by the manufacturer or by the PPQ official. Calibrate according to the manufacturer's User Guide. Refer to Chapter 8: Equipment for more information.

2 The MiniRae 3000 must be calibrated by the PPQ official according to the manufacturer's User's Guide. Refer to Chapter 8: Equipment for more information.

Fumigator Provides

- APHIS-approved gas detection device[3] (e.g. thermal conductivity device, infrared device, etc.)
- Auxiliary pump for purging long gas sample tubes
- Carbon dioxide filter (Ascarite®)
- Colorimetric tubes (Refer to ***Gas Detector Tube (colorimetric) and Apparatus* on page E-1-31** for a list of APHIS-approved product ranges)
- Desiccant (Drierite®)
- Electrical wiring (grounded, permanent type), three prong extension cords
- Exhaust blower and ducts
- Fans (circulation, exhaust, and introduction)
- Framework and supports

3 The methyl bromide monitor must be calibrated annually. Refer to Chapter 8: Equipment for calibration information. If using a thermal conductivity (TC) analyzer, Drierite® and Ascarite® must be used.

- Gas introduction line
- Gas sampling tubes (leads)
- Heat supply
- Insecticides and spray equipment
- Loose sand
- Measuring Tape
- Methyl bromide
- Padding
- Sand or water snakes or adhesive sealer
- Scales or dispensers[4]
- Self-contained breathing apparatus (SCBA) or supplied air respirator
- Tape
- Tape measure
- Tarpaulin and supports
- Temperature recorder and temperature sensors[5]
- Thermometer[6]
- Volatilizer
- Warning signs/Placarding

4 All scales must be calibrated by the State, a company that is certified to conduct scale calibrations, or by the fumigator under the supervision of PPQ. The source and date of calibration must be posted in a visible location on or with the scale at all times. The scale must be calibrated a minimum of every six months.
5 Temperature sensors must be calibrated annually by the manufacturer or National Institute of Standards and Technology (NIST) within the range of 40 °F to 80 °F (4.4 °C to 26.7 °C)
6 The thermometer must be calibrated or replaced annually.

MB 2016 Label

NOTICE

In addition to the items in the bulleted list on pages 2-9-3 and 2-9-4, the fumigator must also provide:

- Air purifying respirator NIOSH certified half-mask or full face piece with a cartridge for concentrations between 1 and 4 ppm
- APHIS-approved direct read gas detection device
  - Colorimetric tubes (e.g. Draeger, Sensidyne)
- APHIS-approved continuous real time gas monitoring device[1]
  - Permanently mounted in PPQ owned facilities only (PureAire)
  - Portable Photoionization Detector (PID) RAE Systems, Inc. MiniRAE 3000
- Self contained breathing apparatus (SCBA) NIOSH approved prefix TC-13F for concentrations >5 ppm
- Supplied air respirator NIOSH approval prefix TC-19C

1 These devices must be calibrated according to the manufacturer's User Guide. Refer to Chapter 8: Equipment for more information.

Preparing to Fumigate

APHIS has historically required dry box ocean containers (non-refrigerated containers with a tongue-and-groove flooring) be fumigated under tarp with the doors open. The total methyl bromide gas introduced is based on the entire volume under the tarpaulin. This is referred to as "open-door container fumigation."As an alternative to the "open-door" procedure, APHIS also allows for the fumigation of wood products (includes logs, lumber, and bamboo) in dry box containers with the doors closed. This procedure eliminates the need to include the empty space under the container as part of the total volume fumigated. This procedure is referred to as "closed-door container fumigation" and can be used ONLY with the following treatment schedules:

- T312-a
- T312-a-Alternative
- T312-b
- T404-b-1-1

- T404-d
- T404-e-1

Step 1—Selecting the Container

The fumigator must obtain a letter of authorization from the owner of the container prior to attempting to gain access through the container doors or making any structural changes to the containers. The fumigator will maintain the letters of authorization and provide copies to the local PPQ office. PPQ will not be held responsible for any damage incurred by the fumigator due to modification or manipulation of a container's original condition.

No dry box container will be permitted to be fumigated using this procedure if it has side doors, if the rear gasket is missing, or if the gasket is damaged such that gas lines cannot be placed effectively with the doors closed. PPQ officials must ensure that all vents are sealed on each container to be fumigated. If this cannot be accomplished, the fumigator will be required to fumigate with the doors open.

Step 2—Selecting a Fumigation Site

The PPQ official and the fumigator must consider the following factors when selecting a fumigation site:

- **Well-ventilated, Sheltered Area**
- **Impervious Surface**
- **Ability to Heat**
- **Nonwork Area**
- **Electrical Power Supply**
- **Water Supply**
- **Well-Lighted Areas**
- **Aeration Requirements**
- **Buffer Zone Overlap for Multiple Enclosures**

Well-ventilated, Sheltered Area

The PPQ official and the fumigator must select sites that are well-ventilated and sheltered. A well-ventilated site is required for exhausting gas before and when the tarpaulin is removed from the container(s). Most warehouses have high ceilings and a number of windows/doors which can be used for ventilation. Some gas will escape from the tarpaulin even in the best conditions. Avoid areas where strong drafts are likely to occur.

In warehouses, the fumigator must provide an exhaust system to exhaust MB to the outside of the building. The fumigator must ensure that the exhausted gas does not reenter the building nor endanger people working outdoors.

When treatments are conducted in a particular location on a regular basis, the PPQ official must ensure that the fumigator designates a permanent site. At such sites, the fan used to remove the fumigant from the enclosure during aeration must be connected to a permanent stack extending above the roof level.

If fumigations are conducted outside, ensure that the fumigator selects a site that is semi-sheltered such as the leeward side of a warehouse, pier, or building that offers some protection from severe winds. Severe winds are defined as sustained winds or gusts of 30 m.p.h. or higher for any time period. Do not allow the fumigator to proceed if there is a forecast from the National Weather Service of severe winds and/or thunderstorms at the beginning of or for the entire length of the fumigation.

Impervious Surface

Select an asphalt, concrete, or tight wooden surface—**not** soil, gravel, or other porous material. If you must fumigate on a porous surface, require the fumigator to cover the surface with plastic tarpaulins. For large fumigations, covering the surface is **not** usually practical because pallets must be rearranged and heavy equipment used to move the commodity. On docks, wharfs, and piers, require the fumigator to seal cracks, holes, and manhole covers which will allow the MB to escape through the floor.

Ability to Heat

When cooler temperatures (below 40 °F) are expected, the fumigator must ensure that the commodity temperatures are maintained above 40 °F. The PPQ official will take the ambient (air) temperature 12 inches above the ground. Temperatures must be maintained at or above the starting treatment temperature for the entire duration of the treatment. Additionally, PPQ official will monitor the temperature of the container using a temperature sensor and a temperature recorder. Specifications for the temperature recording system are as follows:

- Accurate to within ± 0.6 °C or ±1.0 °F in the treatment temperature range of 4.4 °C to 26.7 °C (40 °F to 80 °F)
- Calibrated annually by the National Institute of Standards and Technology (NIST) or by the manufacturer
  - The calibration certificate will list a correction factor, if needed, and the correction factor would be applied to the actual temperature reading to obtain the true temperature.
- Capable of printing all temperature readings or downloading data to a secure source **once per hour** throughout the entire treatment (all temperature data must be accessible at a safe distance during the fumigation)

- Tamper-proof

If one or more of the temperature readings dip below the minimum temperature required for the selected dosage rate in the treatment schedule, the fumigation will be considered a failed treatment. The container must be heated to the minimum temperature in the treatment schedule and the fumigation restarted. The gas remaining in the container does not need to be evacuated, but additional gas may need to be added to meet the required concentration readings for a new fumigation. There are two options for re-treatment, depending on the treatment schedule used.

1. Reheat the container and restart the fumigation at the original dosage rate. The gas remaining in the container does not need to be evacuated, but additional gas may need to be added to meet the required concentration readings for a new fumigation.
2. Re-fumigate the container at the lower temperature using the dosage required by this manual for that temperature. (This option may not be available for all schedules.) The gas remaining in the container does not need to be evacuated, but additional gas may need to be added to meet the required concentration readings for a new fumigation.

Require the fumigator to place one temperature sensor in each container in the coldest location in the container, which will be near the floor towards the middle of the container at the end of a log-stack. If there is only one log-stack in a container, require the fumigator to place the temperature sensor near the floor at the end of the stack closest to the container doors. Refer to **Figure 2-9-1** for further information on temperature sensor placement.

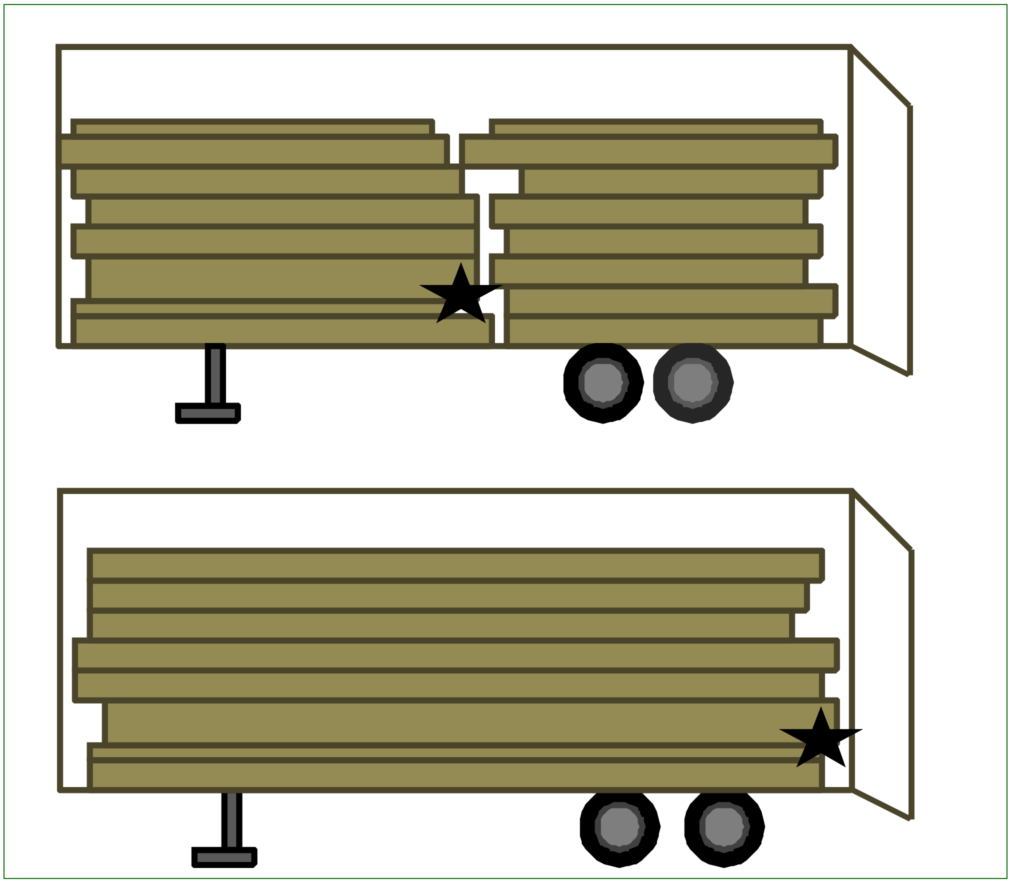


Figure 2-9-1 Diagram of placement of temperature sensors, represented by a star

Nonwork Area—MB 2016 Label

NOTICE

The fumigator will determine the treatment buffer zone in accordance with EPA's fumigation buffer zone tables (https:www.epa.gov/pesticide-registration/mbcommoditybuffer).

The treatment buffer zone surrounds the area where access is limited during treatment. If the fumigator determines that the buffer zone is less than 30', then PPQ requires a 30' buffer zone. If the fumigator determines that the buffer zone is greater than 30', then PPQ must observe the prescribed buffer zone.

The treatment buffer zone extends from the perimeter of the enclosure to a distance determined by the fumigator in accordance with the label. Entry by any person except the PPQ official and the fumigator is **prohibited** except as provided in the "Exceptions to Buffer Zone Entry Restrictions" section of the label.

The treatment buffer zone begins when the fumigant is introduced into the enclosure and ends when aeration begins, at which point the aeration buffer zone requirements apply.

The fumigator must define the treatment and aeration buffer zone perimeters using physical barriers (such as walls, ropes, etc.) and placards to limit access to the buffer zone. Placards must meet all label requirements regarding specific warnings, information, and language.

The fumigator will permit transiting through buffer zones in accordance with the "Transit Exception" section of the label.

Buffer Zone Overlap for Multiple Enclosures

For multiple enclosures where buffer zones overlap, the fumigator must recalculate both the treatment and aeration buffer zones in accordance with the label and supply them to the PPQ official.

Nonwork Area

The PPQ official and the fumigator must select a secure area where traffic and people are restricted from entering and which is isolated from people working. The fumigator must placard clearly in sight of all who come near. Placards must meet label requirements regarding specific warnings, information, and language. Placards generally include the name of the fumigant, the fumigation date, time, and the name of the company conducting the fumigation. The fumigator must restrict access to the warehouse to the fumigator's employees and PPQ employees monitoring the treatment. PPQ officials who work within the 30-foot perimeter must wear (and use) respiratory protection (SCBA), until the gas levels are safe to breathe and validated as safe by gas monitoring. The 30-foot perimeter is **not** specifically mentioned on the MB label, but is required for PPQ officials. When space is tight, it is permissible to overlap two adjoining 30-foot perimeters. However, there must be sufficient space for a person wearing SCBA to walk between the tarpaulins.

Electrical Power Supply

An adequate electrical source must be available to run the circulation fans and the gas detection device. A separate line should be available for the gas detection device. Electrical outlets must be grounded and conveniently located in relation to the fumigation area. PPQ does not allow generators to be used as a power source except under emergency conditions.

Water Supply

A water supply is necessary for safety purposes. Water is necessary for washing off MB if the liquid form is spilled on someone. Water is also used to fill the volatilizer. If no permanent water is present on a temporary site, the fumigator must provide a portable shower that meets OSHA specifications or a 5-gallon supply of clean water. All permanent fumigation sites must have a safety shower/eyewash station installed and maintained in good working order throughout the year or when fumigations are performed at the site.

Well-Lighted Areas

The fumigator will ensure that the area has adequate lighting for safety purposes and for ease in reading gas concentration, thermometers, and for determining whether a tarpaulin has holes or tears.

Aeration Requirements

The fumigator is responsible for all aspects of aeration. Refer to ***Aerating Closed-door Containers—Indoors and Outdoors* on page 2-9-22** for more information.

Step 3—Arranging the Containers

Ensure that the fumigator places no more than 8 containers that are 20 to 40 feet in length under a single tarpaulin. APHIS does not allow stacking of containers. Stacking may create too great a safety risk to the person placing the tarp, fans, and gas monitoring leads.

Containers should not be loaded beyond 80 percent of their capacity. No additional head space is required between the roof of the container and the tarp, unless the pest is found on the outside of the container. If the pest is found on the exterior of the container, then DO NOT use this procedure. Go to ***Fumigants • Methyl Bromide • Tarpaulin Fumigation* on page 2-4-1**.

Step 4—Arranging and Operating Fans

For proper gas circulation, require the fumigator to place two axial-type (blade) fans in each container. The fans must have the capacity to move a volume in cubic feet per minute (CFM) equivalent to the total volume of the container. Require the fumigator to place one fan at the rear of the container (doors) pointed inward, and the second fan placed in the front (nose) of the container pointed in the opposite direction. In addition, require the fumigator to place the exhaust fans and ducts as instructed in ***Aerating Closed-door Containers—Indoors and Outdoors* on page 2-9-22**.

Step 5—Placing the Gas Introduction Lines

MB is converted from a liquid into a gas by a volatilizer. The hose that runs from the MB cylinder into the volatilizer must be 3000 PSI hydraulic high pressure hose with a 3/8 inch inner diameter (ID) or larger. From the volatilizer, MB gas is introduced into the structure by means of a gas introduction line. The gas introduction line must be a minimum of 350 PSI with a 1/2 inch ID or larger. Require the fumigator to place the introduction line directly above the fan at the rear door of the container. Each container must have a gas introduction line.

Step 6—Placing the Gas Sampling Tubes

Require the fumigator to install at least three gas sampling tubes per container, positioned as follows:

- Front low—near the floor at the door end of the container
- Rear high—rear of the load at the high end opposite the fan
- Middle center—mid way from front to back, at mid depth

If treating for khapra beetle, the fumigator must install the following additional gas sampling tubes:

- High (in the commodity)
- Low (in the commodity)

Require the fumigator to install gas sampling tubes of sufficient length to extend from the sampling position inside the container to at least 30 feet beyond the tarpaulin. Ensure that all the gas sampling tubes meet in one area for ease and safety in taking gas concentration readings. Do **not** splice gas sampling tubes. Before starting the fumigation, check for gas sampling tube blockage or pinching by connecting each tube to the gas detection device for a short time. If the line is blocked, the flow to the device will drop sharply. Tubes can also be checked with a MityVac® hand pump or other air pump device. Replace any defective gas sampling tubes.

Require the fumigator to secure all gas sampling tubes under the tarpaulin and label each one at the end where the gas concentration readings will be taken. By labeling each gas sampling tube, the PPQ official will be able to record concentration readings easily.

Step 7—Padding Corners

Ensure that the fumigator looks for corners and sharp angles which could tear the tarpaulin. Do not allow the fumigator to use the commodity to support the tarpaulin. If the sharp angles or corners cannot be eliminated, the fumigator must cover them with burlap or other suitable padding (e.g., old tires or cloth).

Step 8—Measuring the Temperature

The PPQ official must determine the temperature of the commodity in order to select the proper dosage rate using a calibrated bimetallic, mercury, or digital long-stem thermometer.

Important

Regardless of the commodity, never fumigate at temperatures below 40 °F.

Temperature recordings should be rounded to the nearest tenth of a degree (°C or °F)

Select several representative locations within the stack at the ends of the logs or pieces of lumber and drill holes in them to accommodate a thermometer. After drilling, wait at least 10 minutes to allow the wood around the holes to cool. Insert the thermometer into the holes drilled. All readings (not just the average) must be above 40 °F.

If fumigating multiple containers under one tarp, take temperature readings in each container under the tarp. Base the dosage calculation on the lowest reading obtained. (Do **not** average temperatures.) All readings must be above 40 °F to initiate the fumigation. If not, you must postpone it.

Record the temperatures in Block 22 of the PPQ Form 429.

If using the electronic 429 database, record the temperatures in the space and commodity fields in the Treatment form.

Important

When the commodity and air temperature drastically differ, moisture may condense inside the gas sampling tubes or inside the gas detection device and cause inaccurate gas concentration readings. Check the gas sampling tubes frequently for possible puddling of condensed water, and drain it off, as needed, before taking a reading. Also, check the Drierite frequently, and change it as soon as it becomes saturated with water [turns pink], to obtain true gas concentration readings. Never fumigate commodities that are frozen.

Step 9—Covering the Stack

The fumigator must cover the stack, check the tarpaulin for rips, tears, and holes, look at the spots that have been taped, and verify they are properly sealed. If needed, the fumigator must repair all holes.

The tarpaulin should be made of a material such as vinyl, polyethylene plastic, or coated nylon.

- 4 mil vinyl or polyethylene plastic tarpaulins are only approved for one usage
- 6 mil vinyl or polyethylene plastic tarpaulins may be used up to four times with the PPQ official’s approval for each usage
- 10 to 12 mil vinyl or plastic coated nylon tarpaulins may be approved for multiple use with the PPQ official’s approval for each usage

The fumigator should cover all corners and sharp ends with burlap or other padding to prevent the tarpaulin from ripping. Have the fumigator pull the tarpaulin over the containers, being careful not to catch or tear the tarpaulin.The tarpaulin must be large enough to provide a floor overlap of at least 18 inches around all sides of the stack. Carefully lay the tarpaulin out to prevent excess folds or wrinkles along the floor, especially around corners.

Step 10—Sealing the Tarpaulin

The fumigator must seal the tarpaulin with loose, wet sand, sand snakes, water snakes, adhesives, or a combination. If there is danger of crushing or crimping the gas sampling or introduction tubes, use the loose, wet sand. If using snakes, use two rows of snakes along the sides and three rows on the corners. The snakes should overlap each other by approximately 1 foot. The goal in sealing the tarpaulin is to get the tarpaulin to lie flat against the floor to prevent gas from leaking out. When wind is not a factor, plastic tape may be used for sealing the tarp. The tape must be at least 2 inches in width, and applied (only to a smooth surface) with the aid of high-tack spray adhesive.

The fumigator must seal corners by laying two sand snakes around the corner and working the tarpaulin until it is flat. Place a third snake on top of the two other snakes to provide additional weight to force the tarpaulin against the floor. Loose, wet sand can be used in the area where the gas introduction line, electrical cords, and gas sampling tubes extend from under the tarpaulin.

Step 11—Measuring the Volume

Using a 100-foot tape measure, the PPQ official and the fumigator must carefully measure the length, width, and height of the container. The area underneath the container is not included in the calculations. *Never* estimate the measurements. When measuring, round off to the nearest quarter foot (example—3 inches =.25 feet).

Formula for determining volume:

Length × width × height = volume in cubic feet

EXAMPLE: A stack with measurements H=10′6″, L=42′3″, and W=10′9″ 10.50 × 42.25 × 10.75 = 4,768.9 ft^3 round to 4,769 ft^3

The PPQ official must record volume in Block 26 of the PPQ Form 429.

If using the electronic 429 database, record the length, width and height in the corresponding fields under the “AMT of Gas Introduced” heading on the Treatment form. The total volume of the enclosure will be calculated.

Step 12—Calculating the Dosage

The PPQ official must calculate dosage by doing the following:

1. Refer to the treatment schedule for the correct dosage rate (lbs./1,000 ft^3) based on temperature (°F).
2. Multiply by the dosage (lbs./1,000 ft^3) rate by the volume (ft^3) to get the dosage in pounds.

Round to nearest 1/4 pound.

Formula for calculating dosage:

$$\text{dosage (lbs.)} = \text{volume}(\text{ft}^3) \times \text{dosage rate (lbs./1,000 ft}^3) = \frac{\text{volume}(\text{ft}^3) \times \text{dosage rate (lbs.)}}{1{,}000\ \text{ft}^3}$$

Figure 2-9-2 Formula for Calculating Dosage for Closed-door Container Fumigations

If using the electronic 429 database, the PPQ official must enter the dosage rate in the "dosage" field and the total amount of gas required for the fumigation will be displayed in the "GAS REQUIRED" field.

Step 13—Making a Final Check

Before introducing the gas, the PPQ official and the fumigator must ensure that the following activities are performed:

- Turn on all fans and APHIS-approved gas detection devices to make sure they work.
- Warm up and zero (if required) APHIS-approved gas detection devices as described in ***Equipment* on page 8-1-1**
- Start volatilizer and heat water to 200 °F or above. A minimum temperature of 150 °F is required at all times during the introduction process. Refer to ***Volatilizer* on page 8-1-15** for temperature monitoring procedures.
- Place fumigant cylinder with gas introduction line on scale and take initial weight reading.
  - Ensure the gas introduction hose is attached to the cylinder.
  - After obtaining the correct weight, subtract the dosage to be introduced into the enclosure.
  - After the fumigator has introduced the proper amount of gas, the scale will be balanced.
- Ensure that tarpaulin is placarded and the area is secured. Only people working on the fumigation may be in the area.
- Ensure that the tarpaulin is free from rips, holes, and tears.
- Ensure that all gas sampling tubes are labeled and are **not** crimped or crushed.
  - Visually inspect tubes or use an electric or Mityvac® hand pump to check tubes. A fumiscope or vacuum pump may also be used to test leads for unrestricted flow.

Important

When conducting fumigations with methyl bromide, erroneous readings may occur if the sampling tubes become blocked or crimped. It would be impossible to install a new sampling tubes during a fumigation treatment. Therefore, to avoid an unsuccessful fumigation, you should test sampling tubes before the treatment begins.

Use the following procedure to detect blocked sampling tubes with the use of a MityVac® hand-held pump (for supplier, see ***Vacuum Pump* on page E-1-71**):

1. Prior to fumigant introduction, connect the MityVac® hand-held vacuum pump to sampling tubes.
2. Squeeze the handle on the MityVac® unit. If the tube is blocked, a vacuum will be indicated on the vacuum gauge of the MityVac® unit. (The handle should be squeezed two or three times for sampling tubes longer than 25 feet. The MityVac® hand-held pump has the capacity to attain and hold 25 inches of Hg vacuum and a minimum of 7 psig pressure.)
3. Disconnect the MityVac® hand-held pump from the sampling tube, and repeat this procedure for each tube. (Connect sampling tubes to the gas analyzer prior to fumigant introduction.)

- Confirm that there is enough gas in the cylinder and if necessary, that other cylinders are available.
- Confirm that the gas introduction line connections are tight and free of leaks.
- Ensure that all safety equipment, especially SCBA, is available and in working order.
- If using a T/C, install Drierite® and Ascarite® as stated in the instructions in this manual.

Important

Other gas detection devices may not require the use of Drierite® or Ascarite®.

Conducting the Fumigation

Step 1—Introducing the Gas

CAUTION

The PPQ official must wear SCBA anytime the MB concentration level in the air is unknown or greater than or equal to 5 ppm.

MB 2016 Label

NOTICE

If MB concentration levels are between 1-4 ppm, the PPQ official and fumigator may wear an air purifying respirator NIOSH certified half-mask or full face piece with a cartridge.

Require the fumigator to use SCBA while introducing and adding gas. Ensure that the fumigator turns on all fans before introducing the gas. When using large cylinders of MB, the fumigator should slightly open the cylinder valve, then close the valve. With an APHIS-approved continuous real time gas detection device, the fumigator must check all connections on the gas introduction hose for leaks. If leaks are found, the fumigator must tighten the connections and repeat the test. When no leaks are found, require the fumigator to open the valve to the point where 3 to 4 pounds of MB are being introduced per minute. The water temperature in the volatilizer should never go below 150 F at any time during gas introduction. The water in the volatilizer may include antifreeze and should be handled with the appropriate safeguards.

The fumigation time begins once all the gas has been introduced. The PPQ official must record the time gas introduction was started and completed in Block 32 on the PPQ Form 429.

If using the electronic 429 database, record the fumigation date, gas introduction start and finish time in the corresponding fields under the "GAS INTRODUCTION" heading on the Treatment form.

Require the fumigator to run the fans for **60 minutes** to achieve even gas distribution. After gas is evenly distributed, require the fumigator to turn the fans off. The PPQ official must take the initial concentration reading **60 minutes** after all the gas has been introduced.

Important

Do **not** begin counting fumigation time until all the gas has been introduced and valve on the MB tank is closed.

Step 2—Testing for Leaks

Require the fumigator to wear the SCBA while checking for leaks. The fumigator must use an APHIS-approved leak detection device to test for leaks before the 60 minute reading or anytime when the concentration level is unknown or above 5 ppm. The fumigator must test around the perimeter of the tarpaulin on the floor, corners, and especially where electric cords, gas sampling tubes, or gas introduction lines are present. When the fumigator detects leaks, ensure that they are sealed using more sand or sand snakes for floor leaks and tape for sealing small holes in the tarpaulin. Use loose, wet sand to reduce leakage from electric cords, gas sampling tubes, gas introduction lines, or uneven flooring.

Important

> If an employee encounters unsafe conditions (such as holes in the tarpaulin or a breach in safety protocol) and the condition(s) cannot be corrected in a timely manner, the employee may CANCEL the fumigation. Consult with a PPQ Supervisor prior to cancellation.

If the fumigator detects excessive leakage (concentration readings of 50 percent or less of the minimum concentration) in a tarpaulin which cannot be corrected in a practical way, do **not** attempt to correct the problem by adding more gas. Require the fumigator to quickly evacuate the remaining gas from the enclosure, eliminate the problem, and construct a new enclosure. Aerate as usual following procedures on **page 2-9-22**. Record the aborted fumigation in Block 40 (Remarks) of the PPQ Form 429 or in the "Remarks" form in the electronic 429 database. Restart the fumigation in the new enclosure.

Any "closed-door" treatment that is aborted cannot be retreated until the remaining containers have completed treatment and all have aerated for a minimum of 48 hours. Refumigate aborted containers with both container doors open. Report aborted fumigations in the 429 as required by the Environmental Protection Agency.

Step 3—Taking Concentration Readings

Important

> Before taking a reading, always purge sampling lines with a mechanical or hand pump. If using a T/C unit, connect it to the sampling lead, adjust the gas flow rate to 1.0, and wait until the meter registering "ounces per thousand cubic feet" stabilizes before taking a reading. (This may take a minute or more, depending upon the length of the tubing and whether or not an auxiliary pump is used.)

The PPQ official must take concentration readings with an APHIS-approved gas detection device to determine the gas concentration and distribution within the enclosure. If used, check desiccant tubes before each reading and change Drierite® if its color is pink. Allow gas concentration readings to stabilize; do not disconnect the sampling line from the gas detection device when the minimum concentration reading has been met.

Take concentration readings at the times designated in the treatment schedule. Concentration readings should **not** differ more than **10 ounces** among the leads. If they do, run the fans for an additional 30 minutes and take another reading to verify that gas concentration levels have equalized. In some cases, several cycles of fan operation may be necessary to equalize the readings.

Record all gas readings on the PPQ form 429 or in the electronic 429 database. Regardless of the number of containers under each tarp, every container must have a separate 429 record.

CAUTION

Avoid using hand-held two-way radios near the T/C unit. Using two-way radios near the T/C unit will interfere with an accurate concentration reading.

Step 4—Determining the Need to Add Gas and Adjust Exposure

If the lowest gas reading is BELOW the required minimum indicated by the treatment schedule, you must add gas and extend the exposure period.

Use the formula in **Figure 2-9-3** to determine the amount of gas to add:

$$1.6 \times \text{number of ounces below minimum} \times \frac{\text{volume in cubic feet}}{1000\,\text{cubic feet}} \times \frac{1}{16} = \text{pounds of gas to add}$$

Figure 2-9-3 Formula for Determining the Amount of Gas to Add to Closed-Door Containerized Cargo

Use the **Table 2-9-1** to determine how long to extend the exposure period.

Table 2-9-1 Determine the Extended Exposure Period for Closed-Door Containerized Cargo

If any individual reading is below minimum by:[1]	Then extend exposure:
10 oz. or less	10 percent of the time lapse since gas introduction or the last acceptable reading
11 oz. or more	2 hours or 10 percent of time lapse since last acceptable reading, whichever is greater

1 If any individual reading is 50 percent or more below the minimum concentration reading, then abort the treatment. For oak logs (T312-a, T312-a-alternative), refer to **Table 5-4-2 on page-5-4-33** or **Table 5-4-3 on page-5-4-36** in the section ***Special Procedures for Adding Gas to Oak Logs Using T312 or T312-a-Alternative*** **on page 5-4-32**.

Require the fumigator to follow these procedures when adding gas:

1. Heat water in volatilizer.
2. Turn on fans.
3. Weigh the cylinder.
4. With SCBA on, open cylinder valve and introduce the gas.

5. Close valve when the weight of the cylinder indicates that the needed amount of gas has been added.

The PPQ official must record quantity of fumigant added in Block 34 and the additional fan time in Block 30 of the PPQ Form 429.

If using the electronic 429, record the amount of additional gas listed in the Treatment Manual in the “Additional Gas Recommended” field and the actual amount of additional gas added in the “ACTUAL ADDITIONAL GAS” field. Record the additional fan time in the “TIME FANS OPERATED” field in the Treatment form.

Note the time the fumigator started introducing additional gas and the time the fumigator finished introducing gas and record in Block 40 (Remarks) of the PPQ Form 429 or in the “Remarks” form in the electronic 429 database. Run the fans for **30 minutes**. Turn off fans, then take a concentration reading. If all readings are above minimum concentration levels and within **10 ounces** of each other, then proceed as usual with the remaining scheduled concentration readings. If the readings are not above the minimum or within 10 ounces of each other, run the fans for another 30 minutes. It may take several cycles to stabilize the gas concentration.

Step 5—Exhausting the Gas

Require the fumigator to exhaust the gas at the completion of the exposure period.

Aerating Closed-door Containers—Indoors and Outdoors

The fumigator must:

- Arrange for the aeration to proceed once the treatment is completed.
- Consider the direction of the wind when pointing the exhaust duct, and face the duct outlet toward an open area away from people.
- Ensure that, during the first 10 minutes of aeration, no one is present within 200 feet downwind of the exhaust duct outlet.
- Determine aeration buffer zones in accordance with EPA’s fumigation buffer zone tables (https:www.epa.gov/pesticide-registration/mbcommoditybuffer).
- Ensure that no one is present within the perimeter of the aeration buffer zone unless they are wearing SCBA.
- **See “Buffer Zone Overlap for Multiple Enclosures” on page-2-9-11**.

- Follow all label instructions, state, county, and local regulations, in addition to the instructions in this manual.
- Inform people located in occupied structures and personnel in the immediate area within the buffer zone that release of MB is about to take place and give them the option of leaving the area or remaining inside the building.
- Restrict access to the area where the exhaust duct extends beyond the enclosure.

Wearing Respiratory Protection

The fumigator must wear approved respiratory protection (SCBA, supplied air respirator, or a combination unit) when:

- A risk of exposure to concentrations above 5 ppm exists; this includes any time the concentration is unknown
- Setting up the air introduction and the exhaust systems
- Opening the container door(s)
- Opening the tarpaulin for aeration

MB 2016 Label

NOTICE

If MB concentration levels are between 1-4 ppm, the PPQ official and the fumigator may wear an air purifying respirator NIOSH certified half-mask or full face piece with a cartridge.

Advise the fumigator to:

- Install an exhaust fan (minimum of 5,200 cfm capacity) with one end of a round ventilation duct at least 16 inches in diameter, oriented so that the fan pulls air through the duct. The fan dimensions should complement the diameter of ductwork chosen, fitting flush and tight so that no leaks exist between the fan and duct. For indoor fumigations, extend the exhaust duct (fan end) at least 30 feet beyond the building or into a vertical stack extending through the roof. For outdoor fumigations, the exhaust duct will be at least 30 feet in length with the fan end placed external and alongside the container extending toward the nose, so the exhaust air is directed away from the end of the container which is opened during aeration.

Palletized Partial Loads

For palletized partial loads (where at least 2 feet of open space is present at the door end of the container), extend the exhaust duct intake (non-fan end) on the container floor with the duct face flush against the bottom of the load along a side of the container. Store the remaining section of the exhaust duct and fan at the rear of the load so it is easily accessible at the start of aeration.

Full Loads

For full loads (where less than 2 feet of open space is available at the door end of the container and there is no central aisle between pallets), if there is room to store the exhaust duct inside the container during fumigation, secure the exhaust duct intake (non-fan end) face flush against the load at the floor/pallet/commodity interface along a side of the container so it will not shift or twist during aeration. Use straps, ties, or other fasteners to secure this interface tightly. If there is not sufficient room to pre-install the exhaust duct prior to fumigation, carry out these steps at the start of aeration.

For partial or full loads where a central aisle exists between the pallets run the exhaust intake duct along the floor center and extend 1-2 feet into this space if possible. Store the remaining section of the exhaust duct and fan at the rear of the load so it is easily accessible at the start of aeration.

Non-palletized Logs

For non-palletized logs, secure the duct face flush against the load at the floor/interface on a side of the container so it will not shift or twist during aeration.

Important

If commodities other than logs are not palletized, consult CPHST-AQI before treatment.

- Integrate an air introduction fan (minimum 3,750 cfm) with a round ventilation duct at least 12 inches in diameter, oriented so that the fan pushes the air through the duct. The fan dimensions should complement the diameter of ductwork chosen, fitting flush and tight so that no leaks exist between the fan and duct. Extend the introduction duct (non-fan end) along top of the load two-thirds of the length of the container. For partial loads, the intake duct may run along the container floor, with the end placed on top of the load. Store the remaining introduction duct and fan at the rear of the load so it is easily accessible at the start of aeration.
- Integrate an additional exhaust fan (minimum of 5,200 cfm capacity) with one end of a round ventilation duct at least 16 inches in diameter, oriented so that the fan pulls air through the duct. The fan dimensions should complement the diameter of ductwork chosen, fitting flush and tight so that no leaks exist between the fan and duct. This duct will be used to aerate the space between the container and tarp prior to tarp removal. The duct length should be approximately 10 feet and should remain outside the tarp during fumigation.

NOTICE

Install introduction and exhaust ducts prior to fumigation in order to limit human exposure to the fumigant at the start of aeration.

Refer to **Figure 2-9-4** for detailed diagrams of air and exhaust ducts. In this diagram, air introduction ducts are blue and exhaust ducts are red.

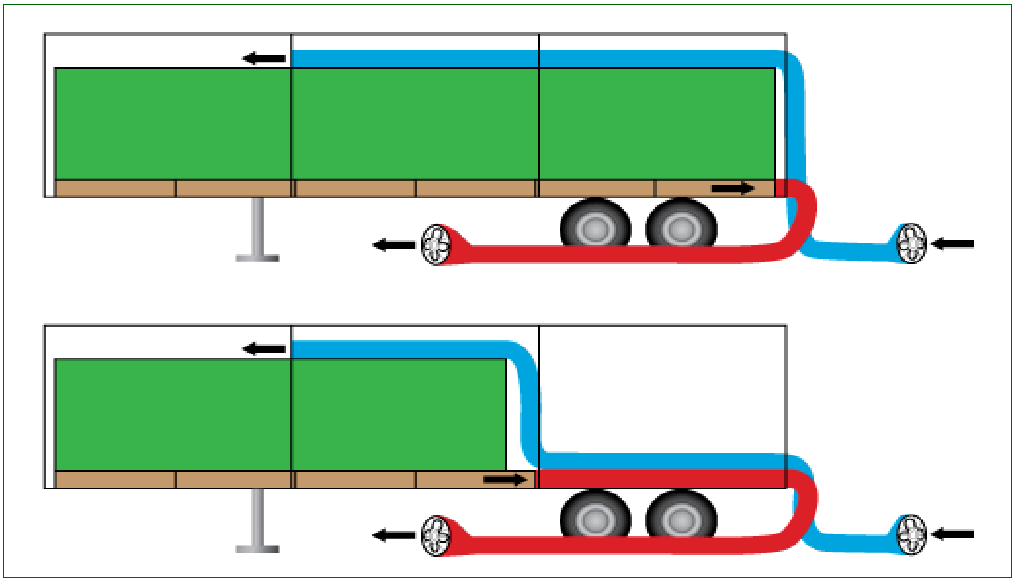


Figure 2-9-4 Ductwork configuration for aeration of closed door containers: full loads (top) and partial loads (bottom)

Step 6—Aerating the Commodity

Advise the fumigator to:

1. While wearing SCBA, insert a spacer (at least 16 square inches in area) to vent the tarpaulin at the nose end of the container. At the opposite end of the tarp, insert the additional exhaust duct 5 feet under the tarp and turn the fan on.
2. Exhaust the gas from underneath the containers before opening the doors of the containers for at least 15 minutes or until the gas concentration level underneath the containers is below 5 ppm.
3. While wearing SCBA, remove the tarp when the gas concentration level underneath the containers is below 5 ppm.
4. With the tarp removed and while wearing SCBA, turn off the fan used to aerate the space and open the doors of each container.
5. Turn on all fumigant circulation fans inside the container and leave them on throughout the aeration.
6. Start the container introduction and exhaust ducts fans. Require a minimum of **4 hours** aeration for all sorptive commodities. Sorptive commodities generally require 12 hours or longer to aerate, however, since sorptive commodities vary in their rates of desorption, aeration may be completed in less than 12 hours.

7. Aerate Oak logs and lumber a minimum of **48 hours**. If, after 48 hours, the concentration is 5 ppm or greater, continue aeration for 24 more hours. Continue this procedure until concentration readings are less than 5 ppm.
8. Stop the fans and take concentration readings with colorimetric tubes in the airspace around and, when feasible, within the log stack.
9. RELEASE the commodity when the concentration reading is 5 ppm or less.

2

Treatment Manual

Chemical Treatments

Fumigants • Sulfuryl Fluoride

Contents

Consult the Vikane[1] Gas Fumigant label and Structural Fumigation Manual for more detailed instructions and additional supportive information.

Properties and Use

Sulfuryl fluoride (SF) is a compressed-gas fumigant which is used primarily against insects that attack wood. The following characteristics make this fumigant especially desirable:

- 2.88 times heavier than air
- High vapor pressure —13,442 mm Hg @ 770 °F
- Low solubility in water and low sorption by soil or commodity
- Odorless, colorless, and nonflammable

1 Trademark of Dow Agro Sciences

- Penetrates wood better than any other commercial fumigants, including methyl bromide
- Relatively nonreactive
- Very low loss through plastic tarpaulins

SF boils at minus 67 °F. SF is **not** registered for use on foodstuffs or on living plant material.

SF is effective at very low dosages on Drywood termites where control of the adult stage is the only concern (typically 0.5 to 1.0 lbs/$1,000^2$). Higher dosages are required for control of the egg stage of other insects (typically 3 to 5 lbs/ $1,000^2$). Consult treatment schedules in this manual for specific dosages.

Leak Detection

Interscan (Model GF 1900) or Miran gas analyzers (these units are portable) may be used to detect SF in the range of 0 to 150 ppm respectively. Consult the Vikane Structural Fumigation Manual for further instructions. Colorimetric (“detector”) tubes are **not** available for detecting SF gas leaks around tarpaulins, chambers, and application equipment.

Tarpaulin Fumigation

Important

Refer to the Vikane label and Vikane Structural Fumigation Manual for a detailed discussion of proper procedures.

Also, refer to the **Fumigants • Methyl Bromide • Tarpaulin Fumigation** for additional information on the following:

- selecting fumigation sites
- placing gas sampling lines
- sealing tarpaulins
- taking concentration readings
- securing fumigation areas

Sealing

The commodity to be fumigated should be placed onto a relatively even and non-porous surface, such as concrete, asphalt, or macadam. Special attention should be given to the seal along the ground or floor. The inspector should have tape, sand, or water snakes properly positioned.

Circulation

Fans are necessary to distribute SF and to help prevent condensation. The number of fans depends upon the cubic volume of the enclosure being treated, and the arrangement of cargo. Axial fans of approximately 5,000 cfm have proven effective. Usually 2 fans are used, one on either end facing the lower center and upper center of the load. If the enclosure is over 35 feet long, additional fans should be used. It is usually **not** necessary to run fans longer than 15 minutes after the gas has been introduced.

Prevention of Condensation

In cool weather, moisture may condense under tarpaulins if the sun is shining directly on the load. Continuous air circulation can prevent this from occurring. Do **not** tarp or seal any item while it is wet.

Gas Sampling Lines

A thermal conductivity unit calibrated for Vikane must be available for readings. Sampling lines should be arranged so that gas samples are drawn from representative parts of the fumigation area and lead to a common point.

A minimum of 3 sampling lines should be placed in enclosures of up to 10,000 ft^3 at the following locations:

- Front of the load, 3 inches from the floor
- Center of the load, midway from the bottom to the top of the load
- Rear of the load, at the top.

When 10,000 to 15,000 ft^3 are being treated, 2 additional lines should be appropriately deployed.

Gas Introduction

Unlike methyl bromide, SF does **not** require the use of a volatilizer to speed up its conversion from a liquid to a gas. The gas introduction tube should be placed directly in the air flow of a fan away from the cargo. Also, place a drip cloth under the tube. The introduction rate is controlled by the introduction line length and diameter. A 1/8-inch-inside-diameter by 100-foot-long hose will allow a flow rate of approximately 2 pounds per minute while a 25-foot-long hose will allow approximately 4 pounds per minute.

Table 2-10-1 Effect of Hose Inside Diameter on Rate of Gas Introduction through a 25-Foot Hose (approximates, depending on cylinder pressure)

Inside Diameter (inches)	Vikane Per Minute (pounds)
1/8	4
1/4	20
1/2	45

Table 2-10-2 Effect of Hose Length on Rate of Gas Introduction through a 1⁄8 inch Inside Diameter Hose

Hose Length (in feet)	Pounds Vikane Per Minute
25 ft	4.0
50 ft	2.8
100 ft	2.0[1]

1 Where fumigant introduction rates lower than 2 lbs/min are needed, a longer hose can be used, e.g., 200 ft.

It is important **not** to overshoot the ability of the fan to rapidly disperse the cool air near the fumigant introduction site. Fan capacity should be at least 1,000 cfm for each lb of Vikane introduced per minute. In addition, a volatilizer (heat exchanger) may be used in fumigating containers or small chambers to prevent a "fog-out" (condensation) which could cause corrosion or damage to the contents. The last few pounds of fumigant will turn to gas within the cylinder before moving out, and the flow rate will be reduced. The cylinder and tubing will often become frosted. Be certain that no open flame or glowing hot surfaces above 400 °C are present since corrosive substances (mainly hydrofluoric acid) are formed when SF is exposed to such conditions. To avoid possible damage, do **not** apply the fumigant directly to any surface.

Dosage Rate

To control a particular pest, locate the proper fumigation schedule to be followed in the Treatment Manual. The three variables in these schedules are temperature, dosage, and exposure duration. Treatment is **not** recommended below 50 °F. Dosages are in pounds per 1,000 feet^3 of space. To determine the total amount of fumigant required by weight in pounds, divide the total volume of space by 1,000. Then multiply the resulting figure by the dosage rate schedule expressed in pounds (per 1,000 feet^3). The cylinder should be placed on a scale, and the flow of gas is controlled by the valve and introduction line until the desired cylinder end-weight is obtained. The valve should be turned fully open to fill the fumigant introduction hose with liquid SF. Initially, the valve should be opened slightly until flow has begun and then opened about one full turn which should give full flow through the 1/8″ fumigant introduction hose.

Measure Gas Concentrations

During the course of fumigation, minimum concentrations must be maintained according to the schedules used. Readings on the T/C unit (Fumiscope or Gow-Mac) if **not** calibrated for Vikane must be multiplied by a factor to obtain the actual ounces per 1,000 feet^3 present. Contact USDA-APHIS-PPQ-S&T-CPHST-AQI in Raleigh, North Carolina, for calibration information. Be certain that the reading without the multiplied factor is also registered on PPQ Form 429, however. Do **not** use filters containing sodium hydroxide (Ascarite) with SF. Fresh desiccant (Drierite) should be used with the T/C unit. Desiccant should be changed at appropriate intervals to insure accurate readings.

Replacing Lost Gas

When it appears that additional SF will be needed, the officer should use their best judgment to determine the amount of gas to add, according to the prevailing conditions of tarpaulin tightness or wind conditions. Usually, 1.6 oz of gas should be added for every ounce of deficiency in the minimum concentration required.

Aeration

For detailed guidelines, consult the Vikane Gas Fumigant label, Vikane Structural Fumigation Manual, and the "***Aerating the Enclosure*** **on page 2-4-36**" in chapter ***Fumigants • Methyl Bromide • Tarpaulin Fumigation*** **on page 2-4-1**. The threshold limit value for SF is 5 ppm (20 mg/cubic meter), the same as for MB. Since no colorimetric ("detector") tubes are available for SF, a suitable instrument must be used, such as the Interscan GF 1900 or Miran (calibrated for SF).

Structural Fumigation

Refer to the section on MB structural fumigation (or aeration) in this manual, the Vikane label, and Vikane Structural Fumigation Manual for a detailed discussion of proper procedures.

When preparing a structure for fumigation with SF, the surrounding soil should be watered thoroughly at the base of trees, shrubs, and other ornamental plants around the perimeter of the structure to prevent loss of fumigant into the soil. Watering around the plants will protect the roots; however, plants and grass closer than 1 foot may die even if this precaution is taken.

Before placing the tarpaulin over the structure, be sure to remove items for which the use of SF is **not** registered. These include food, feed, drugs, and medicines. Extinguish all flames (including pilot lights), unplug all heating elements, and turn off all lights. Open all internal doors.

Chamber Fumigation

Refer to the section on MB chamber fumigation (and aeration) in this manual, the Vikane label, and Vikane Structural Fumigation Manual for a detailed discussion of proper procedures.

CAUTION

Trying to measure out a small quantity of SF in a graduated glass tube (sight gauge)—which is common practice with MB chamber fumigations—should never be attempted with SF because the cylinder pressure is much greater, and the glass gauge may explode and shatter.

The gas will generally be introduced through a volatilizer or heat exchanger in order to prevent a "fog-out" which could damage the contents. Introducing a very small amount of gas into a small chamber, however, is difficult to do with precise accuracy because the amount introduced must be calculated by weight loss from the cylinder. The scale used beneath the cylinder must be readable in ounces or grams, **not** just in pounds or kilograms.

Shipboard Fumigation

Refer to the section on MB ship fumigation (and aeration) in this manual, the Vikane label, and Vikane Structural Fumigation Manual for a detailed discussion of proper procedures. Surface ships (only those in port) must be fumigated at dock side, and **not** when the vessels are underway. Shipboard fumigation is also regulated by the U.S. Coast Guard (Department of Transportation). That regulation appears as 46CFR 147A.

Safety and First Aid

Read and understand all directions and safety precautions on Vikane label before applying. Additional information is presented in Vikane Structural Fumigation Manual. There is no known antidote for SF. Vikane is odorless. However, the chance of lethal exposure is not probable unless an individual actually enters the fumigation space. An SCBA must be worn by anyone in the fumigated areas when the level exceeds 5 ppm.

Protective Clothing

Wear goggles or full face shield for eye protection during introduction of the fumigant. Do **not** wear gloves or rubber boots. Do **not** reuse clothing or shoes that have become contaminated with liquid SF until thoroughly aerated and cleaned.

If SF Is Inhaled

An individual who has inhaled high concentrations of SF may exhibit the following symptoms:

- Difficulty breathing
- Dulled awareness
- Nausea
- Numbness in the extremities
- Slowed body movements
- Slowed or garbled speech

If any of the above symptoms appear, immediately do the following:

- Remove the victim to fresh air
- Put victim at complete rest
- Keep the victim warm and see that breathing is normal and unhampered; if breathing has stopped, give artificial respiration
- Do **not** give anything by mouth to an unconscious person
- Obtain medical assistance

If Liquid SF Is Spilled on the Skin

Immediately apply water to the contaminated area of clothing before removing. Wash contaminated skin thoroughly or shower.

If Liquid SF Is in the Eyes

Flush with plenty of water for at least 20 minutes, and get medical attention. Damage to the eye may result from cold or freezing temperatures.

2

Treatment Manual

Chemical Treatments

Fumigants, Phosphine

Contents

Properties and Use

There are a number of phosphine formulations registered with the United States Environmental Protection Agency (EPA) to control a variety of insects currently infesting raw agricultural commodities, processed foods, animal feed, feed ingredients, and nonfood commodities, including tobacco. Aluminum phosphine (AP), magnesium phosphide (MP), $ECO_2FUME^®$ and $VAPORPH_3OS^®$ are phosphine formulations that are currently approved for use by the Plant Protection and Quarantine (PPQ). Always refer to this manual to determine if there is an available treatment. There are commodities and pests listed on the labels that are **not** authorized for treatment by USDA PPQ.

AP and MP are solid products and are available under various trade names (***Figure 2-11-2*** on **page 2-11-9**) as tablets, pellets, prepacs, bags, or plates. In the presence of moisture, phosphine (hydrogen phosphide, PH_3), a colorless gas, is emitted from the solid product

The flash point of PH is 212 °F. Direct contact with a liquid could cause spont aneous combustion. In case of fire, a CO_2 dry chemical fire extinguisher should be used. *Never use water to extinguish a PH-ignited fire.* PH has an odor somewhat like garlic, which enables the gas to serve as its own warning agent. However, under some conditions, the odor can be lost, even at high toxic concentrations.

ECO$_2$FUME® fumigant gas is a nonflammable, premixed mixture of phosphine and carbon dioxide. The phosphine is liquefied and mixed with carbon dioxide in high-pressure cylinders for shipment. Phosphine, the active ingredient, makes up 2 percent by weight (2.6 percent by volume) of the product. The carbon dioxide is used as a propellant and a flame inhibitor, making the product nonflammable in air. Do **not** store the fumigant near heat or open flame. Do **not** drop, puncture, or incinerate the cylinder.

Under pressure, ECO$_2$FUME® is a poisonous liquefied gas. The product is withdrawn from the cylinder as a liquid, but dispensed as a gas. When expanding from a liquid to a gas, ECO$_2$FUME's volume is multiplied by hundreds. Proper dispensing equipment (See ***Dispensing ECO2FUME® Fumigant Gas*** on **page 2-11-11**) is necessary to ensure a safe and effective fumigation; therefore, always contact the manufacturer concerning proper dispensing equipment for the fumigant. Fumigators should provide PPQ with all **Cytec®** equipment authorization documentation. The documentation should be on file and available for periodic audits by the USDA.

The rate at which phosphine is dispensed is **not** dependent on temperature or humidity, but on the dispensing equipment used. Unlike metal phosphide fumigants, the phosphine is **not** generated through a chemical reaction and its release is instantaneous. The choice of dispensing methods will depend on the type and duration of the fumigation planned.

VAPORPH$_3$OS® consists of 100 percent phosphine gas packaged in high-pressure gas cylinders. Unlike solid phosphide fumigants, the phosphine is **not** generated through a chemical reaction and its release is instantaneous. Phosphine is pyrophoric and will spontaneously ignite in air. Phosphine is dispensed as a gas from the cylinder and can be safely blended with carbon dioxide to less than 3 percent volume (30,000 ppm) or diluted with the surrounding air to 1 percent volume (10,000 ppm) to eliminate the flammability hazard. Contact the manufacturer for approved blending equipment necessary to ensure a safe and effective fumigation. Never store the cylinders where the temperature will exceed 125ºF. Fumigators should provide PPQ with all **Cytec®** equipment authorization documentation. The documentation should be on file and available for periodic audits by the USDA.

Phosphine

Phosphine (PH) is highly toxic to humans and other animals. Avoid exposure to nontarget organisms. The current U.S. OSHA Permissible Exposure Limit (PEL) for phosphine is 0.3 ppm as an 8-hour time weighted average. The Short Term Exposure Limit (STEL) for phosphine is 1 ppm as a 15-minute time weighted average.

Phosphine is colorless and, at concentrations below the OSHA PEL, has the odor of decaying fish or garlic. Intermittent low concentration exposure may cause headaches, malaise, ringing of ears, fatigue, nausea, and chest pressure. Moderate exposure causes weakness, vomiting, and pain in the stomach and chest with difficult breathing. Phosphine gas reacts with moisture to form phosphoric acid, which causes pulmonary edema.

Phosphine may spontaneously ignite in air at levels above its lower flammability limit of 1.8 percent v/v (18,000 ppm). Do **not** exceed this concentration because, under these conditions, explosions can occur that could cause severe personal injury. Never allow the buildup of phosphine to exceed explosive concentrations.

Under high vacuum conditions, phosphine gas can cause an explosive hazard. **Do not apply either fumigant in vacuum chambers.**

Phosphine can react with certain metals and cause corrosion (especially at higher temperatures and lower relative humidity). **Gold, silver, copper, brass, and other copper alloys are susceptible to corrosion**.

CAUTION

Remove or protect the following items prior to fumigation:

- Batteries and battery chargers
- Brass sprinkler heads
- Communication devices
- Computers
- Electric motors
- Electronic or electrical equipment
- Fork lifts
- Smoke detectors
- Switching gears
- Temperature monitoring systems

Fans and blowers used with phosphine products should be manufactured from materials resistant to the fumigant. Aluminum or plastic wheels and housings are preferred. For phosphine fumigations, always contact the manufacturer for recommended fan and blower types.

Carbon Dioxide

In a liquefied state and when contact is made with exposed areas of the body, carbon dioxide can cause frostbite and freeze burns. Overexposure to carbon dioxide at low levels can cause headache, nausea, weakness, confusion, and labored breathing. Overexposure to higher concentrations can cause excitation, dizziness, euphoria, loss of consciousness, coma, and death.

The current U.S. OSHA PEL for carbon dioxide is 5,000 ppm as an 8-hour time weighted average.

Leak Detection: Gas Analysis

Phosphine levels can be detected using either colorimetric detector tubes or any approved electronic instrument such as the “Porta-Sens” detector. (See ***Equipment*** on **page 8-1-1** for instructions on how to use the Porta-Sens.) This equipment is used to determine both the high (fumigation concentration) and low (personnel safety) levels of PH. Do **not** use thermal conductivity (T/C) units (e.g., Gow-Mac or fumiscope) for PH.

Safety

Applicator Requirements

Before using $ECO_2FUME^®$ and $VAPORPH_3OS^®$, all users (fumigators) are required to attend the fumigant gas product stewardship course offered by **Cytec®** Industries. PPQ Officers are **not** required to attend the stewardship courses, but attendance is recommended.

It is a violation of federal law to use AP, MP, $ECO_2FUME^®$ and $VAPORPH_3OS^®$ fumigants in a manner inconsistent with their labeling. These fumigants are **Restricted Use Pesticides** that can only be used by certified applicators. Prior to using the fumigants, submit to PPQ all documentation concerning applicator certification and stewardship program completion by personnel working for the fumigation company. The documentation should be on file and available for periodic audits by the USDA.

A certified applicator must be physically present, responsible for, and maintain visual and/or voice contact with all fumigation workers during the application of the fumigants and during the initial opening of the fumigation structure for aeration.

Storage and Handling

Although PH is flammable and can ignite when exposed to excessive moisture, the commercial precautions of AP and MP are considered fire safe and explosion safe when used in accordance with the manufacturer's instruction. Place no more than 10 pellets of Phostoxin in a single envelope, which is supplied by the manufacturer. A Fumi-Cel plate should **not** contact another Fumi-Cel plate or the commodity.

Store containers of AP and MP in a cool, dry, locked, ventilated, protected area **not** subject to extremes of temperature. Never allow water to come in contact with AP or MP. The shelf life of unopened containers is virtually unlimited. When a tube or container is first opened, the odor of PH (garlic) and ammonia will be noticeable and a blue flame sometimes occurs. However, the quantity of free PH present within that container should **not** be considered dangerous.

When planning a storage area for ECO$_2$FUME® and VAPORPH$_3$OS® cylinders, consider the needs of the local authorities. Provide all emergency response personnel with Material Safety Data Sheets (MSDS) and detailed information regarding the quantities of product stored and the nature and location of the storage area.

Develop an Emergency Response Plan that defines procedures and outlines responsibilities in the event of an accident. Train all site personnel in the plan. Store all cylinders with the valve discharge cap securely in place.

In addition to instructions and precautions found on the label, be certain to:

- Study and follow the recommended application procedure
- Comply with all regulations
- Allow only properly trained personnel to conduct fumigations under the supervision of certified pesticide applicator(s)
- Ensure that first aid equipment, MSDS sheets, and fumigant labels are readily available at the fumigation site
- Placard the area to be fumigated and an area extending 30 feet from the fumigation enclosure—refer to the fumigation label for appropriate wording on all placards
- Always work in pairs, never alone—a minimum of two people must be present during the introduction, sampling, and aeration of the fumigant
- Never eat, drink, or smoke when handling PH products

- Remove placards when aeration is complete and concentrations are below the TLV
  - Only certified pesticide applicators or individuals under the direct supervision of the certified applicator should remove placards
- Do **not** apply either PH fumigant in vacuum chambers
- Wear leather or leather-faced cotton gloves when connecting or disconnecting ECO$_2$FUME and VAPORPH$_3$OS®cylinders from the dispensing or blending equipment
- Wear dry cloth gloves when handling AP or MP products
- Wear steel-toed shoes
- Always wear safety glasses when handling pressurized equipment
- Read and understand sections XI. STORAGE OF CYLINDERS and XII. TRANSPORT in the ECO$_2$FUME® and VAPORPH$_3$OS® Application Manual

First Aid Treatment

Mild inhalation exposure causes:

- Malaise
- Ringing of the ears
- Fatigue
- Nausea
- Pressure in chest

Moderate inhalation exposure causes:

- Weakness
- Vomiting
- Epigastric pain
- Chest pain
- Diarrhea
- Dyspnea (difficulty breathing)

Severe inhalation poisoning can occur within a few hours or up to several days—symptoms may be:

- Pulmonary edema (fluid in lungs)
- Dizziness
- Cyanosis (blue or purple skin color)
- Unconsciousness
- Death

Get the victim to fresh air, treat for shock, and call a physician.

Respiratory Protection

When applying AP, MP, $ECO_2FUME^{®}$ and $VAPORPH_3OS^{®}$, respiratory protection must be available at the site. An adequate number of NIOSH-approved self-contained breathing apparati (SCBA) with full face piece and operated in pressure-demand mode must be available.

The slow evolution of PH from the AP or MP enables the operator to dispense the tablets, pellets, packets, plates, or pre-pack ropes safely, usually without the need for wearing an SCBA.

However, wear SCBA during exposure to concentrations in excess of permitted limits (**Table 2-11-1**) or when concentrations are unknown. If the concentration of phosphine is unknown or known to exceed the STELs for phosphine and/or carbon dioxide, wear SCBA during troubleshooting for leaks. Use respiratory protection according to local regulations, including regular worker training in using respiratory protection equipment properly, medical clearance for respirator use, fit testing, inspection, maintenance, and cleaning and storage of respiratory protection equipment.

Table 2-11-1 NIOSH-Recommended Respiratory Protection When Applying Phosphine

Phosphine Gas (ppm)	Minimum Respiratory Protection
0.3 - 3.0	Supplied-air respirator
3.1 - 7.5	Supplied-air respirator operated in a continuous-flow mode
7.6 - 15	1. SCBA with full face piece OR 2. Supplied-air respirator with full face piece OR 3. Air-purifying full face piece respirator (gas mask) with chin style front or back-mounted canister
16 - 50	1. Supplied-air respirator with a full face piece and operated in pressure-demand mode OR 2. SCBA with a full face piece and operated in pressure-demand mode

MP, AP, $ECO_2FUME^{®}$ and $VAPORPH_3OS^{®}$

Packaging

AP and MP are packaged in a variety of ways, depending on the manufacturer. Use Table 2-11-2 to determine the amount of phosphine liberated by each product.

Table 2-11-2 Amount of Phosphine Liberated by Various Products

Product	Type	Unit and weight in grams	Grams of phosphine
Degesch Fumi-Cel	MP	1 plate; 117.0	33.0
Degesch Fumi-Strip	MP	20 plates; 2340.0	660.0
Degesch Phostoxin	AP	1 tablet; 3.0	1.0
Degesch Phostoxin Tablet Prepac Rope	AP	1 prepac; 99.0 (strip or rope of 33 tablets)	33.0
Detia	AP	1 tablet; 3.0	1.0
Detia Rotox AP	AP	1 pellet; 0.6	0.2
Detia Gas EX-B	AP	1 bag or sachet; 34.0	11.4
Fumiphos tablets	AP	1 tablet; 3.0	1.0
Fumiphos pellets	AP	1 pellet; 0.6	0.2
Fumiphos bags	AP	1 bag; 34.0	11.0
Fumitoxin	AP	1 tablet; 3.0	1.0
Fumitoxin	AP	1 pellet; 0.6	0.2
Fumitoxin	AP	1 bag; 34.0	11.0
Gastoxin	AP	1 tablet; 3.0	1.0
Gastoxin	AP	1 pellet; 0.6	0.2
"L" Fume	AP AP	1 pellet; 0.5 1 pellet; 0.6	0.18 0.22
Phos-Kill	AP	1 tablet; 3.0	1.1
Phos-Kill	AP	1 pellet; 0.6	0.22
Phos-Kill	AP	1 bag; 34.0	12.0

ECO_2FUME® fumigant gas is packaged in a steel compressed gas cylinder designed, manufactured, maintained, and filled in compliance with regulations established by the United States Department of Transportation (DOT). (**Figure 2-11-1**) The product flows to the dispensing equipment through the cylinder outlet valve, which is equipped with a “dip tube.” This tube extends to the bottom of the cylinder to facilitate the withdrawal of the liquefied gas mixture. As liquid is withdrawn from the cylinder, some of the product vaporizes to fill the remaining space in the cylinder. Through this vaporization, the cylinder pressure is maintained.

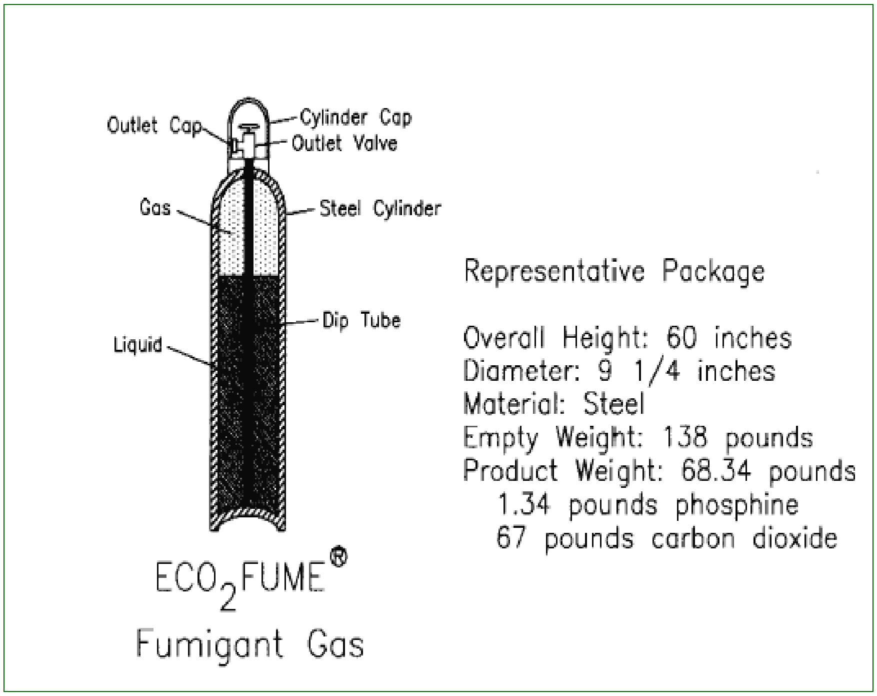


Figure 2-11-1 Diagram of ECO_2FUME® Gas Cylinder

The capacity of one ECO_2FUME® cylinder at 200 and 500 ppm is 78,000 and 31,100 ft^3 respectively. With the volume of ECO_2FUME® at 500 ft^3, the internal volume of the cylinder is 49 liters. The maximum cylinder pressure is 2,400 psig.

The Compressed Gas Association (CGA) established the valve outlet fitting as a CGA350. The valve outlet is protected by a threaded gas tight outlet cap, which must be secured whenever the cylinder is **not** in use. To dispense ECO_2FUME® fumigant gas at the time of fumigation, attach only **Cytec®**-provided (or approved) dispensing equipment to the cylinder valve outlet. Using any other dispensing equipment is prohibited.

Most compressed gas cylinder valves are equipped with a safety device that releases the cylinder contents due to fire exposure or over-pressurization. Because ECO$_2$FUME® and VAPORPH$_3$OS® fumigant gases are poisonous, Hazard Class A, the DOT regulations prohibit using such a device.

Each cylinder is supplied with a cylinder cap designed to protect the outlet valve. Secure this cap whenever a cylinder is **not** in use. It is unlawful to transport an ECO$_2$FUME® or VAPORPH$_3$OS® fumigant gas cylinder without the valve outlet cap and the cylinder cap securely in place.

ECO$_2$FUME® and VAPORPH$_3$OS® fumigant gas cylinders can only be refilled by authorized distributors. They can be filled countless times within a five-year period. Every five years, however, the cylinder is required, by law, to be tested by a qualified facility.

VAPORPH$_3$OS® is packaged in much the same way as ECO$_2$FUME® with two critical exceptions. First, VAPORPH$_3$OS® does **not** contain a dip tube, which means the fumigant is withdrawn from the cylinder directly through the outlet valve. Second, the capacity of one VAPORPH$_3$OS® cylinder at 200 and 500 ppm is 2.25M and 900,000 ft^3 respectively. With the volume of VAPORPH$_3$OS® at 500 ft^3, the internal volume of the cylinder is 49 liters. The maximum cylinder pressure is 2,400 psig. One VAPORPH$_3$OS® cylinder contains 18,000 grams of phosphine and is capable of fumigating 2.25M ft^3.

WARNING

ECO$_2$FUME® cylinders are painted yellow with a dark green shoulder and cap. If you receive a cylinder of a different color or without a **Cytec®** ECO$_2$FUME® label, do not use the cylinder. Contact your distributor or **Cytec®** with the cylinder serial number.

WARNING

VAPORPH$_3$OS® cylinders are painted silver with a red shoulder. If you receive a cylinder of a different color or without a VAPORPH$_3$OS® label, do not use the cylinder. Contact your distributor or CYTEC with the cylinder serial number.

Dispensing ECO$_2$FUME® Fumigant Gas

The following instructions are intended to provide general guidelines for typical ECO$_2$FUME® fumigation. There are a number of critical factors involved in the design of dispensing equipment. (See ***Figure 2-11-2*** on **page 2-11-12**) As such, dispensing equipment must meet both high-pressure standards and chemical compatibility requirements. Improper or inappropriate use of dispensing equipment can result in severe injury or death. Application inconsistent with the labeling and Application Manual is a violation of federal law. Buyer assumes all risk should the product be used contrary to label or Application Manual instructions.

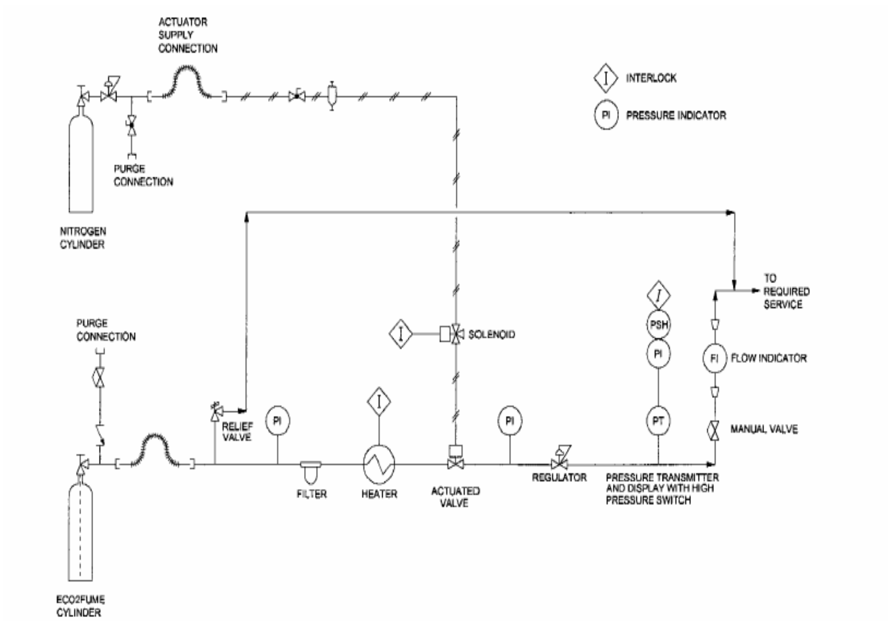


Figure 2-11-2 Diagram of One Type of Dispensing Equipment

Equipment Specification and Use

The equipment used to dispense $ECO_2FUME^{®}$ provides a means of containing the gas during the fumigation and controlling the release of the product into the desired space. While some dispensing equipment has been developed and used to date, it cannot be expected to cover all possible fumigation scenarios. The development of suitable dispensing equipment is an ongoing process based on the needs of the users and available technology.

The design of dispensing equipment must account for a number of technical issues including pressure rating, material compatibility, temperature limitations and operator safety. For this reason, use only appropriate equipment when dispensing $ECO_2FUME^{®}$. Only persons trained in the proper use of $ECO_2FUME^{®}$ and the dispensing equipment shall be permitted to use $ECO_2FUME^{®}$ for fumigation. Consult the instruction materials provided with the dispensing equipment for their proper use and maintenance.

Unapproved Dispensing Methods

It has been common practice, with other cylinderized fumigants, to place the cylinder in the space to be fumigated and the cylinder outlet valve opened to allow the fumigant to release. This is **not** an approved dispensing method and should **not** be used with $ECO_2FUME^{®}$.

Approved Dispensing Methods

The approved dispensing methods for $ECO_2FUME^®$ include using pressure-reducing regulators for slow release and selected piping components for quick release. The slow release of $ECO_2FUME^®$ is generally used for fumigating bulk storage facilities such as silos or bins, or for small fumigation chambers or spaces and for fumigating stacked materials under tarpaulins. The quick release method is used for space fumigation, or where the commodity to be treated is warehoused. The selection of the dispensing method will depend on the size of the fumigation, the time required, and facility limitations.

Two gas regulators, ambient and heated, have been developed for use with $ECO_2FUME^®$. Each of the regulators is designed to reduce the high cylinder pressure (less than 30 psig) and provide the heat necessary to vaporize the fumigant. Once reduced to this lower pressure, the fumigant can be distributed to the desired dispensing points using inexpensive and easy-to-use materials, such as plastic tubing. Flow indicators are used with regulated dispensers to measure and set the dispensing rate.

Ambient Heater Regulated Dispenser

The slower of the two dispensers relies on ambient heat to vaporize the fumigant and is limited to a dispensing rate of about one-half pound of $ECO_2FUME^®$ per hour.

Heated Regulated Dispenser

The heated regulator uses an external heating vaporizer to provide the energy required to vaporize the liquid fumigant at a much higher rate than the ambient heat regulator. This regulator is limited to a dispensing rate of about 24 pounds of $ECO_2FUME^®$ per hour. The equipment is designed for a service pressure up to 3,000 psig. From the cylinder, the liquid mixture flows down a flexible hose or pigtail through a filter and into a heater. The heater is thermostatically controlled and the temperature setting can be adjusted. Exiting the heater, $ECO_2FUME^®$ gas flows through an actuated valve that can be used for emergency shutdown purposes. $ECO_2FUME^®$ gas then flows through a gas regulator that drops the pressure to 30 psig. A diaphragm valve is used to control the gas flow at any desired value up to 100 liters/minute as indicated by the flow rotameter. The heater provides 1,000 watts of power that can vaporize a maximum of 100 ppm. Lower rotameter ranges are possible. $ECO_2FUME^®$ regulator assemblies, equipped with basic features, are available through authorized $ECO_2FUME^®$ distributors. Multiple regulators may be used together to achieve higher fumigant flows than available through a single regulator and custom equipment can be developed for specific types of applications.

Quick-Release Dispensing Equipment

When the fumigation space is very large, such as a mill, warehouse, or large fumigation chamber, using a number of cylinders is anticipated, a quick means of dispensing $ECO_2FUME^®$ is available. Specially selected components can be used to direct the cylinder discharge into the fumigation space, without the need to enter the space during the fumigation. Using this method, a single cylinder can be completely discharged in as little as 15 minutes. Unlike the regulated dispensing methods, the dispensing rate is **not** adjustable and generally, entire cylinders are emptied using this process. If partial cylinder contents are needed, the $ECO_2FUME^®$ cylinder can be placed on a weight scale and the amount of released fumigant can be measured. The quick release method must **not** be used for fumigation of small-sized stacked materials under tarpaulins, however, the quick dispensing method will be used for most applications. Three techniques of quick dispensing are presented in this section, with the major difference being the tubing size.

1. One technique uses high pressure tubing (stainless steel or hydraulic hose with a nylon core) connected directly to the cylinder valve. The tubing is then routed into the fumigation space. When the cylinder valve is opened the majority of the liquid will be dispensed in four to five minutes. The last few pounds below the cylinder internal dip pipe will require several additional minutes to vaporize and be dispensed. When the cylinder is empty of liquid, approximately 18 pounds of gas will remain in the cylinder. For larger fumigations, manifolds may be used with the cylinders to make the dispensing faster. Always leak test the dispensing piping and cylinder connection before opening the cylinder valve.
2. When a slower dispensing rate is desired, use smaller tubing (stainless steel or hydraulic hose with a nylon core). The fumigator must **not** throttle the cylinder valve to slow the dispensing rate; to do so will cause a high pressure drop through the valve. The pressure drop will result in cooling and dry ice formation. This solid dry ice formation will plug the dispensing pipe and possibly the cylinder valve. Attaching a short section of 1/8 inch tubing to the end of the 1/4 inch tubing will slow the dispensing rate to approximately 5 pounds/min. Use a calibrated scale to ensure the proper amount of product dispensed.
3. If a dispensing rate of less than 5 pounds/min is required, a small section of 1/16 inch tubing, 0.04 inch internal diameter (stainless steel or hydraulic hose with a nylon core) can be attached to the end of the 1/4 inch tubing to slow the dispensing rate to approximately 1.6 pounds/min. Use a scale to ensure the proper amount of product is dispensed. The tubing is also available in smaller internal diameters (I.D.) for reduced dispensing rates. When 1/8 inch tubing or 1/16 inch tubing is used a filter is recommended to prevent plugging of the smaller tubing.

Blending VAPORPH$_3$OS® Fumigant Gas

The following instructions are intended to provide general guidelines for typical fumigations. There are a number of critical factors involved in the design of blending equipment. As such, blending equipment must meet both high-pressure standards and chemical compatibility requirements. Improper or inappropriate use of blending equipment may result in severe injury or death. Application inconsistent with the labeling and Application Manual is a violation of federal law. Buyer assumes all risk should the product be used contrary to label or Application Manual instructions.

Equipment Specification and Use

The equipment used to blend VAPORPH$_3$OS® on site with carbon dioxide or surrounding air into a nonflammable gas mixture provides a means of containing the gas during the application and controlling the release of the product into the desired space. While some blending equipment has been developed and used to date, they cannot be expected to cover all possible fumigations scenarios. The development of suitable blending equipment is an ongoing process based on the needs of the users and available technology.

Blending equipment design must account for a number of technical issues, including pressure rating, material compatibility, temperature limitations and operator safety, and controlling the phosphine concentration between 2.0 and 2.9 percent volume for carbon dioxide blending and less than 10,000 ppm (1 percent volume) for dilution with air. For this reason, use only **Cytec®**-approved equipment in VAPORPH$_3$OS® blending. Only persons trained in the proper use of VAPORPH$_3$OS® and the dispensing equipment shall be permitted to use VAPORPH$_3$OS® for fumigation. These persons must also be licensed pesticide applicators.

Consult the instruction materials provided with the blending equipment or dilution equipment for their proper use and maintenance. FOSFOQUIM, the authorized manufacturer of the phosphine air blending equipment, will provide training and written instructions for the use and maintenance of its HDS equipment.

Unapproved Dispensing Methods

It has been common practice, with other cylinderized fumigants, to place the cylinder in the space to be fumigated and the cylinder outlet valve opened to allow the fumigant to release. This is **not** an approved dispensing method and should **not** be used with VAPORPH$_3$OS®. VAPORPH$_3$OS® phosphine fumigant is pyrophoric and will spontaneously ignite in air. VAPORPH$_3$OS® must be properly blended with carbon dioxide or diluted with air to eliminate the flammability hazard.

Blending Equipment for VAPORPH$_3$OS® and Carbon Dioxide

Phosphine gas (VAPORPH$_3$OS®) from high-pressure cylinders flows into the blender unit where it combines with carbon dioxide gas sourced from bulk storage, mobile bulk truck, semibulk, or cylinders. Various models of on-site blending equipment have been designed, built, and tested. All of the designs have incorporated engineering safeguards to ensure that the blended product is a nonflammable mixture.

One design uses a pressure regulator and flow control orifice on both the VAPORPH$_3$OS® and carbon dioxide gases to control the flow rate and to properly blend VAPORPH$_3$OS® with carbon dioxide. The size of each orifice is engineered for a specific fixed flow rate and, therefore, the blending rate cannot be adjusted. By controlling the pressure drop across the orifice plates, the phosphine concentration can be controlled around 2.5 percent v/v.

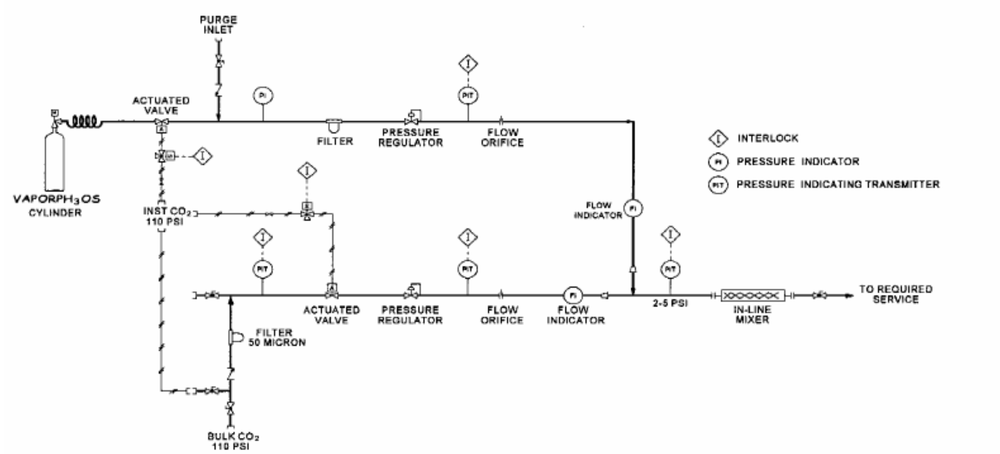


Figure 2-11-3 Diagram of One Type of Blending Equipment

A more sophisticated design uses mass meters, control valves, and the electronics to allow an adjustable blending rate while maintaining the proper blend of phosphine concentration from going outside the range of 2.0 to 2.9 percent volume (1.6 to 2.2 percent weight.) The product from this equipment is equivalent to ECO$_2$FUME® fumigant gas. Blending equipment is intended for large facilities that have on-site carbon dioxide bulk storage and vaporizing equipment or facilities where it is feasible to bring in bulk carbon dioxide and vaporizing equipment for the fumigation. The blending equipment is designed for use only with carbon dioxide gas; therefore, a bulk supply of liquid carbon dioxide must be equipped with suitable vaporizing equipment. Contact **Cytec®** Industries Incorporated for blending equipment design specifications and recommendations. For smaller fumigation jobs, it is recommended that preblended ECO$_2$FUME® cylinders be used. VAPORPH$_3$OS® fumigant gas can only be blended with registered carbon dioxide products. Never allow the buildup of phosphine to exceed explosive concentrations. When phosphine is blended with carbon dioxide, the LFL is raised to 3 percent v/v. The fumigator should always check with **Cytec®** for approved blending equipment. Fumigators should provide PPQ with all **Cytec®** equipment authorization documentation. The documentation should be on file and available for periodic audits by the USDA.

Blending Equipment for VAPORPH$_3$OS® and Forced Air

Phosphine gas (VAPORPH$_3$OS®) can spontaneously ignite in air if the concentration is greater than 1.8 percent (18,000 ppm). With specialized equipment, pure phosphine can be safely blended with a forced air stream to ensure the final concentration does **not** exceed 10,000 ppm (55 percent of the Lower Flammability Limit of 18,000 ppm). The equipment has incorporated engineering safeguards to ensure the flammable concentration is never exceeded.

Various models of phosphine/forced air blending equipment have been designed, built, and tested. The Horn Diluphos System (HDS) from FOSFOQUIM is approved by **Cytec®** and the **USDA-APHIS-PPQ-S&T-CPHST-AQI** to blend VAPORPH$_3$OS® with forced air (see section on HDS80 and HDS200 Blending Equipment). One design uses inert gas (nitrogen or carbon dioxide) to prepurge the phosphine lines and equipment. Once purged, phosphine flows through a pressure regulator and flow controller to the mixing point. Here, phosphine is safely blended into the forced air stream. The forced air can be supplied by various fans, blowers, or compressors. The air flow is measured and the phosphine flow will stop if the air flow is insufficient.

If the phosphine flow is stopped for any reason, post-purging of the phosphine lines and equipment is automatic.

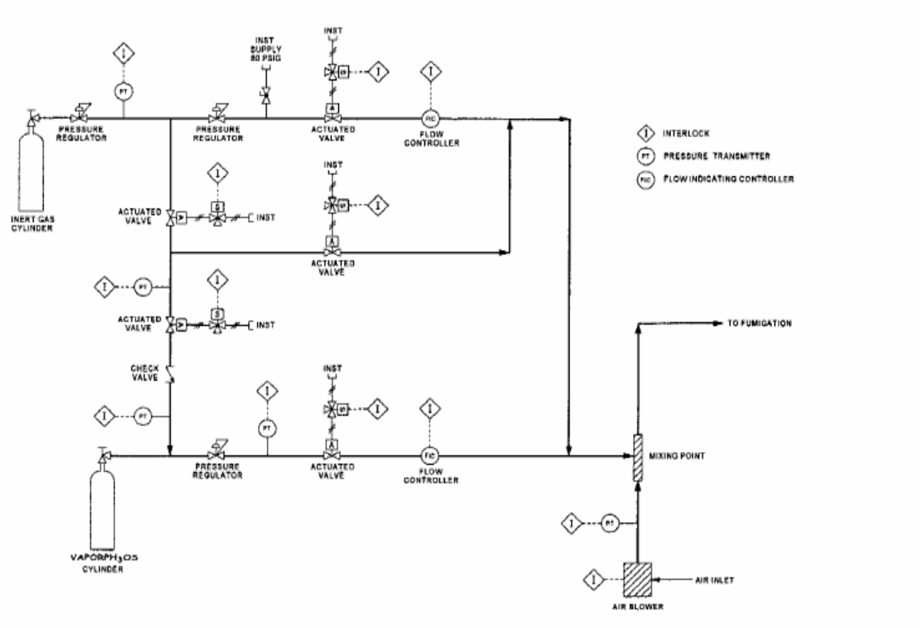


Figure 2-11-4 Diagram of VAPORPH$_3$OS® and Forced Air Blending Equipment

Dosage

The dosage rate for AP, MP, ECO$_2$FUME® and VAPORPH$_3$OS® is measured in grams per 1,000 cubic feet or grams per cubic meter and varies with the commodity, treatment temperature, and type of enclosure. The initial fumigant dose is determined by the volume of the space to be fumigated and the required phosphine dose rate needed to kill the target pest. ECO$_2$FUME®and VAPORPH$_3$OS® fumigant gas and carbon dioxide/forced air can be added if the desired target concentration changes due to a loss of the fumigant through leaks in the fumigation enclosure.

AP and MP

To calculate the number of tablets or pellets of AP or MP required for the fumigation:

Dosage Rate = the dosage rate from the treatment schedule (grams)
Volume of enclosure = Length * Width * Height (ft^3)
Grams of phosphine liberated = *Figure 2-11-2* on **page 2-11-9**

Step 1: Grams of PH$_3$ = (Dosage Rate* Volume of enclosure)/1,000 ft^3

Step 2: Number of Tablets or Pellets needed =
Grams of PH$_3$ / Grams of phosphine liberated

EXAMPLE: **T308-b-2.** Tobacco for Export in a warehouse requires 20 grams of phosphine per 1000 ft^3. The size of the warehouse is 100’ * 75’ * 50’. To determine the number of Fumiphos tablets and pellets to introduce, use the following procedure:

100 * 75 * 50 =375,000 ft^3
Step 1: (20 g * 375,000 ft^3)/1000 ft^3= 7500 g
Step 2:
Tablets: 7500/1.0 = 7500 tablets
Pellets: 7500/0.2 = 37,500 pellets

$ECO_2FUME^®$

Method 1:

- **1 gram of phosphine (PH3) = 25 ppm PH3/1000 ft^3**

To calculate the total amount of $ECO_2FUME^®$ required for each treatment:

- **Target concentration in ppm** = (Dosage rate in grams from Treatment schedule* 25 ppm)
- **Grams of PH3 =** (Target concentration * Volume of enclosure)/25,000
- **Pounds of $ECO_2FUME^®$ =** (Target concentration * Volume)/226,800

EXAMPLE: ***T301-d-1-2*** on **page 5-4-5**. Cotton and cotton products infested with boll weevil requires 36 g of phosphine per 1000 ft^3. The volume of this enclosure is 10’*10’*10*. To determine the pounds of $ECO_2FUME^®$ gas to introduce, follow these steps.

Step 1: Convert grams of phosphine to ppm:
36g * 25 = 900 ppm/1000 ft^3
Step 2: Determine total volume of the enclosure
10*10*100 = 1000 ft^3
Step 3: Apply the formula to determine the amount of $ECO_2FUME^®$ to introduce (900 ppm * 1000 ft^3) / 226,800 = 3.97 pounds

Therefore, 3.97 pounds of $ECO_2FUME^®$ will be introduced into the structure.

Method 2:

- **1 pound of $ECO_2FUME^®$ = 9.07 grams PH3**
- Divide the dosage rate from the treatment schedule (in grams) by 9.07.

EXAMPLE:
Assuming the same treatment schedule as the previous example (***T301-d-1-2*** on **page 5-4-5**):

36 / 9.07 = 3.97 pounds

NOTE: When the amount of gas introduced is less than 68 pounds, use a calibrated scale to determine when the proper amount of gas has been introduced into the space.

VAPORPH$_3$OS®

To calculate the amount of VAPORPH$_3$OS® required for the fumigation:

- **1 pound of VAPORPH$_3$OS® = 454 grams PH3**

Target concentration = the desired phosphine concentration (ppm) from the treatment schedule

Step 1:
Grams of PH$_3$ = (Target concentration*Volume of enclosure) / 25,000

<u>Blending with CO$_2$</u>

Once the amount of phosphine has been determined, the appropriate amount of carbon dioxide must be calculated. It is recommended that twice the amount of carbon dioxide be available to ensure an adequate supply for the initial dose, the addition of gas, and equipment purging.

To calculate the amount of carbon dioxide required for the fumigation:

Step 2:
Pounds of CO$_2$ = (Grams of PH$_3$/454) * 105.3

EXAMPLE: ***T301-d-1-2*** on **page 5-4-5**. Cotton and cotton products infested with Boll weevil requires 36 g of phosphine per 1000 ft^3. The volume of the enclosure is 75,000 ft^3. To determine the amount of VAPORPH$_3$OS® gas to introduce, follow these steps:

Step 1: (36g * 25 * 75,000 ft^3) / 25,000 = 2,700 grams PH$_3$
Step 2: (2700/454) * 105.3 = 626 pounds CO$_2$

<u>Blending with Forced Air</u>

When blending with forced air, only the amount of phosphine needs to be calculated. A closed circulation system is created if the air supply is sourced from inside the fumigation enclosure. This will prevent a positive pressure from developing within the fumigation space. If recirculation is **not** used the perimeter of the fumigation site will need to be monitored because the air will be displaced from the fumigation space. The HDS 80 blending equipment used with forced air dispenses at 50g/min. If the minimum air flow is **not** maintained, the blending equipment will automatically shut down and phosphine will no longer be dispensed.

Adding $ECO_2FUME^®$ and $VAPORPH_3OS^®$ Gas to an Enclosure

Depending on the sealability of the type of space to be fumigated, it may be necessary to add additional gas to the structure in order to maintain the target concentration required by the treatment schedule.

To calculate the amount of $ECO_2FUME^®/VAPORPH_3OS^®$ to be added:

Grams of PH_3 = (Target Concentration - Actual Concentration) * Volume/ 25,000

The target and actual concentrations are measured in ppm and must be monitored with a device approved by CPHST-AQI.

Preparing to Fumigate Break Bulk Cargo

Break bulk cargo has been unloaded from a ship hold, a container, or rail car. This cargo can be fumigated by covering the pallets, boxes, or raw cargo with an impervious tarpaulin.

Always check this manual to determine if there is an approved treatment schedule using either AP, MP, $ECO_2FUME^®$ or $VAPORPH_3OS^®$ fumigant for the infested commodity. Treatment schedules typically list the commodity to fumigate with its associated pest(s). If the commodity in question does **not** have a treatment schedule, contact the **USDA-APHIS-PPQ-S&T-CPHST-AQI** to determine if there is an alternative treatment available.

Step 1: Site Selection

Consider the following factors when selecting a fumigation site:

- Well ventilated, sheltered area
- Ability to heat (in colder areas)
- Impervious surface
- Nonwork area that can be effectively marked and safeguarded or isolated
- Electrical power supply
- Water supply
- Well-lighted area
- Aeration requirements

Well-Ventilated, Sheltered

Select sites that are well-ventilated and in a sheltered area. A well-ventilated site is required for exhausting gas before and when the tarpaulin is removed from the stack.

If fumigations are conducted outside, select a site that is semisheltered such as the leeward side of a warehouse, pier, or building that offers some protection from strong winds

Ability to Heat Area

When cool temperatures (below 40ºF) are expected, heat the site to maintain commodity temperatures above 40ºF; take the ambient temperature 12 inches above the floor.

The temperature of the enclosure **must** be monitored using a temperature recording system, consisting of temperature sensors and a data recorder. The temperature recording system **must** meet the following specifications:

- Accurate to within ± 0.6 °C or ±1.0 °F in the treatment temperature range of 4.4 °C to 26.7 °C (40 °F to 80 °F)
- Calibrated annually by the National Institute of Standards and Technology (NIST) or by the manufacturer
  - The calibration certificate will list a correction factor, if needed, and the correction factor would be applied to the actual temperature reading to obtain the true temperature.
- Capable of printing all temperature readings or downloading data to a secure source **once per hour** throughout the entire treatment (all temperature data must be accessible at a safe distance during the fumigation)
- Tamper-proof

If one or more of the temperature readings go below 40 °F the fumigation will be considered a failed treatment. The commodity must be re-treated, returned to the country of origin, reexported, or destroyed.

Place temperature sensors evenly throughout the enclosure. The placement of the sensors will vary depending on the item fumigated and the configuration of the fumigation site. Contact **USDA-APHIS-PPQ-S&T-CPHST-AQI** for instructions regarding the exact placement of the temperature sensors.

- Because phosphoric acid will be produced if phosphine is burned, never use flame or exposed electrical element heaters during treatment
  - Contact the **USDA-APHIS-PPQ-S&T-CPHST-AQI** for appropriate heating sources

An Impervious Surface

Select an asphalt, concrete, or tight wooden surface, not soil, gravel, or other porous surfaces. If you must fumigate on a porous surface, cover the surface with plastic tarpaulins.

For large fumigations, covering the surface is **not** usually practical because pallets must be rearranged and heavy equipment used to move the commodity.

On docks, wharfs, and piers, check for cracks, holes, and manhole covers that will allow the phosphine gas to escape through the floor.

Seal all cracks, holes, and manhole covers with plastic tarpaulins.

A Nonwork Area

Select a secure nonwork area where traffic and people are restricted from entering.

- The fumigation area is considered either the entire structure area or an area that extends 30 feet from the tarpaulin and is separated by a physical barrier such as ropes, barricades, or walls
- If a wall of gas-impervious material is less than 30 feet from the tarpaulin, the wall may serve as the edge of the secured area
- Additional guidelines may be required by some states Department of Agriculture. Some states, California, for example, require a 100-foot buffer zone
- Place placards clearly in sight of all who come near
    - Placards must meet label requirements regarding specific warnings, information, and language
    - Placards generally include the name of the fumigant, the fumigation date, time, and the name of the company conducting the fumigation
    - Restrict access to the fumigation area to the fumigator's employees and PPQ employees monitoring the treatment
    - Use rope or marker tape to limit access within 30 feet of the enclosure
    - Do **not** allow motor vehicles (including forklifts) to operate within 30 feet of the enclosure during fumigation and aeration periods
    - The area outside the 30-foot perimeter is usually regarded as a safe distance from the tarpaulin
    - The 30-foot perimeter is **not** specifically mentioned on the AP, MP, $ECO_2FUME^{®}$ and $VAPORPH_3OS^{®}$ labels, but is required for safety to PPQ Officers

Important

> Gas concentrations should never exceed 0.3 ppm phosphine and 5,000 ppm carbon dioxide in the safety zone (30 feet from the enclosure where officers are taking gas concentration readings).
>
> Use colorimetric tubes or other approved devices to measure gas concentrations.

Electrical Power Supply

An adequate electrical source must be available to run the dispensing equipment (ECO_2FUME® and VAPORPH_3OS® only).

- A separate line should be available for the dispensing and blending units
- Electrical outlets must be grounded and conveniently located in relation to the fumigation area
- Except under emergency conditions, do **not** use generators as a power source

Water Supply

A water supply is necessary for safety purposes; if no permanent water source is present on site, the fumigator must provide a portable, five-gallon supply of clean water.

Well-Lighted Areas

The area should have adequate lighting for safety purposes and for ease in reading the gas monitoring devices, thermometers, and for determining whether a tarpaulin has holes or tears.

Step 2: Arranging the Stack

- Arrange the cargo in a square or rectangular shape, if possible, to make it easy to cover and to calculate the volume of the stack
  - An even-shaped stack is easier to tarp
  - The height of the stack should be uniform so dosage can be calculated accurately
  - By arranging the stack evenly and with space between pallets or cartons, the fumigant will be effectively distributed
- The maximum size for an enclosure is 25,000 ft^3
  - Contact the **USDA-APHIS-PPQ-S&T-CPHST-AQI** to get approval for any enclosures larger than 25,000 ft^3
  - For very large enclosures it may be necessary to add more sampling leads or introduce the fumigant at several sites
- When the fumigation involves multiple stacks, allow 10 feet of space between each uncovered stack; after the stack is tarped, there should be approximately five feet between enclosures

Step 3: Padding the Corners

Examine all areas that typically tear tarpaulins, e.g., corners and sharp angles. If the sharp angles or corners cannot be eliminated, they must be covered with burlap or other suitable padding (e.g., old tires or cloth).

Step 4: Covering the Stack

After covering the stack, check the tarpaulin for rips, tears, and holes. Look at the taped areas and verify they are properly sealed. Have the fumigator repair all holes.

The tarpaulin must be made of a tough material such as vinyl, polyethylene plastic, or coated nylon. The tarpaulins should be a minimum of 2-mil thickness, however, it is recommended to use 6 mil tarpaulins whenever possible.

The tarpaulin must be large enough to provide a floor overlap of at least 18 inches around all sides of the stack. Carefully lay the tarpaulin out to prevent excess folds or wrinkles along the floor, especially around corners.

Step 5: Sealing the Tarp

The goal in sealing the tarpaulin is to get it to lay flat against the floor to prevent gas from leaking out. Seal the tarpaulin with loose, wet sand, sand snakes, water snakes, adhesives, or a combination. If there is danger of crushing or crimping the gas sampling or introduction tubes, use the loose, wet sand. If using snakes, use two rows of snakes along the sides and three rows on the corners. The snakes should overlap each other by approximately one foot. Seal corners by laying two sand snakes around the corner and working the tarpaulin until it is flat. To force the tarpaulin against the floor, place a third snake on top of the two other snakes to provide additional weight. Loose, wet sand can be used in the area where the gas introduction line, electrical cords, and gas sampling tubes extend from under the tarpaulin.

Step 6: Introducing the Gas

Depending upon the type of AP or MP formulation used, the gas may be dispensed in a variety of methods. Follow the Application Procedures from the manufacturer's label for detailed instructions on gas introduction.

For $ECO_2FUME^{®}$ and $VAPORPH_3OS^{®}$, install the gas introduction line(s) at ground level on the floor or secured onto a pallet. These lines should **not** be located in or attached to commodity package and should be secured to eliminate the movement of the line(s). Direct the discharge toward the center of the space being treated and away from equipment if possible. For tarpaulin enclosures, control the dispensing rate of the gas. The tarpaulin can become damaged and sealing undone if the fumigant is dispensed at high speeds. For small enclosures, a cylinder pressure less than 100 psig is recommended. A regulated dispenser with a pressure regulator and flow restricting nozzles are options to control the rate of the fumigant.

Place the fumigant cylinder with gas introduction line on a calibrated scale and take an initial weight reading. Ensure the gas introduction line is attached to the cylinder. After obtaining the correct weight, subtract the dosage to be introduced into the enclosure. After introducing the proper amount of gas, the scale will be balanced.

When no further fumigant is required to maintain target concentration levels, close all cylinder valves, depressurize the dispensing equipment, and disconnect all $ECO_2FUME^®$ or $VAPORPH_3OS^®$ cylinders. Replace the cylinder cap after the valve discharge cap is securely installed.

Step 7: Placing Gas Sampling Tubes

Place a minimum of 3 gas sampling tubes for fumigations up to 10,000 ft^3. Position the gas sampling tubes in the following locations:

- Front—low and front of the load, 3 inches above the floor
- Middle—center of the load (inside the box with the commodity), midway from bottom to top of load
- Rear—high and rear of the load, at the extreme top of the load

For fumigations from 10,001 to 25,000 ft^3, use 6 gas sampling tubes. Position the gas sampling tubes in the following locations:

- Front—low and front of the load, 3 inches above the floor
- Upper front quarter section (inside the box with the commodity)
- Middle—center of the stack (inside the box with the commodity), midway from bottom to top
- Upper rear quarter section
- Lower rear quarter section (inside the box with the commodity)
- Rear—high and rear of the stack, at the extreme top of the load

For approval of fumigations larger than 25,000 ft^3, contact the **USDA-APHIS-PPQ-S&T-CPHST-AQI** for instructions regarding the number of gas sampling tubes, and for other technical information.

Before inserting into the commodity, cover the end of the gas sampling tube with burlap or wire gauze taped to the tube.

Use gas sampling tubes of sufficient length to extend from the sampling position inside the enclosure to at least 30 feet beyond the tarpaulin. Connect all the gas sampling tubes in one area for ease and safety in recording gas concentration readings. Do **not** splice gas sampling tubes. Fix all gas sampling tubes securely in place under the tarpaulin and label each one where the gas concentration readings will be recorded. By labeling each gas sampling tube, concentration readings can be easily recorded.

Step 8: Testing For Leaks

To ensure they are within acceptable levels outside the fumigation area, monitor phosphine and carbon dioxide levels at the fumigation site and 30 feet from the fumigation enclosure. Phosphine and carbon dioxide levels can be detected using chemical-specific colorimetric tubes or electronic monitors, e.g., Draeger and PortaSens detection kits. Do **not** use a Gow-Mac or Fumiscope to record gas readings.

The fumigator should leak test all connections and fittings before opening the cylinder valve. Instructions concerning cylinder leak detection can be found under the section “Poison Gas Hazards-Leak Detection and Repair” of the $ECO_2FUME^®$ and $VAPORPH_3OS^®$ fumigant Application Manuals.

Step 9: Monitoring Gas Concentrations

Take concentration readings within the enclosure using sampling lines connected to an APHIS-approved phosphine monitoring device. The fumigation does **not** begin until all of the gas has been introduced. Monitoring must take place 30 feet or more from the enclosure.

Phosphine and carbon dioxide levels can be detected using chemical-specific colorimetric tubes or approved electronic monitors, e.g., Draeger and PortaSens detection kits. To determine if additional gas is needed, check gas concentration levels 30 minutes after the fumigant is added and periodically throughout the fumigation. Record gas concentration readings on PPQ Form 429 at the time intervals prescribed by the treatment schedule in this manual.

The 30-minute reading shows the initial concentration and distribution of gas and can indicate leakage, incorrect dosage calculation, or error in fumigant introduction.

If the desired phosphine concentration is met before all of the gas is introduced, stop the addition of $ECO_2FUME^®$ or $VAPORPH_3OS^®$ and check all calculations. When fumigating with $ECO_2FUME^®$, 200 ppm of phosphine will release 7,700 ppm of carbon dioxide.

NOTICE

Erroneous readings can occur if the monitoring leads become blocked or crimped. It would be impossible to install a new monitoring lead during a fumigation treatment; therefore, always test monitoring leads before the treatment begins.

In order to detect blocked monitoring leads, follow the procedure below using a MityVac® hand-held pump (for supplier see Vacuum Pump, **Appendix E**).

- Prior to fumigant introduction, connect the MityVac® hand-held vacuum pump to a monitoring lead
- Squeeze the handle on the MityVac® unit. If the lead is blocked, a vacuum will be indicated on the vacuum gauge of the MityVac® unit. For monitoring leads longer than 25 feet, squeeze the handle two or three times. The MityVac® hand-held pump has the capacity to attain and hold 25 inches of Hg vacuum and a minimum of 7 psig pressure
- Disconnect the MityVac® hand-held pump from the monitoring lead, and repeat this procedure for each monitoring lead. Connect monitoring leads to the gas analyzer prior to fumigant introduction

Preparing to Fumigate Containerized Cargo

Containers require small amounts of phosphine, therefore, AP, MP, or ECO$_2$FUME® fumigant gas (**not** VAPORPH$_3$OS®) is recommended for all container fumigations for which an approved treatment exists.

PPQ ***does allow*** the fumigation of nontarped containers provided the container can be completely sealed in order to prevent gas loss.

To fumigate containerized cargo, follow Steps 1through 9 in the previous section ***Preparing to Fumigate Break Bulk Cargo*** on **page 2-11-21**.

Additional Considerations for Fumigating Containerized Cargo

If fumigating a ***nontarped*** container:

- Close and secure one of the doors
  - Seal all openings and joints
  - If possible, caulk all joints and drape entire doorway with polyethylene sheeting, securing the edges to the inner walls, floor, and ceiling with duct tape
- Inspect the roof, floor, and walls for holes and cracks
  - Seal all openings with either duct tape or caulking compound
  - Containers require close inspection and a great deal of sealing to prevent fumigant leakage

- If possible, drape ***remaining*** doorway with polyethylene sheeting before the door is closed
  - Secure edges to door jams and floor
  - Close door and secure
  - If doorway is draped with polyethylene, it may **not** be necessary to seal the door from the outside
  - If doorway is **not** draped, seal all cracks, openings, and joints with masking tape and caulking compound from the outside
- Placard all doors of the container with the appropriate warnings before fumigation begins

If fumigating a ***tarped*** container:

- If unable to completely seal the container, use a tarpaulin to cover the entire container
- Use a 4, 6, 10, or 12 mil vinyl, polyethylene plastic, or coated nylon tarpaulin
- After covering the container with a tarpaulin check for rips, tears, and holes
  - Examine all taped areas and verify they are properly sealed
  - Have the fumigator repair all holes
- The tarpaulin must be large enough to provide a floor overlap of at least 18 inches around all sides of the container—carefully lay the tarpaulin out to prevent excess folds or wrinkles along the floor, especially around corners

Preparing to Fumigate Bulk Commodities

AP, MP, $ECO_2FUME^{®}$ and $VAPORPH_3OS^{®}$ can be used to fumigate any type of bulk commodity storage for which there is an approved treatment in this manual. These include, but are **not** limited to bins, tanks, flat storage, and bunkers. The most important aspects of a successful fumigation, as with any fumigant, are the degree to which the space is sealed and the assurance that the minimum fumigant concentrations are maintained for the required time.

To fumigate break bulk cargo, use the procedures outlined in the section, ***Preparing to Fumigate Break Bulk Cargo*** on **page 2-11-21**.

AP and MP Fumigation

Probing

When large quantities of grain or other commodity in bulk are to be treated, it will be necessary to "probe" tablets or pellets into the mass of the commodity for adequate distribution. Specially constructed probes made of steel tubing one and one-quarter inch in diameter are generally available as described below:

- **Head Piece**—Dosing device and numerical counter to indicate number of tablets used
- **Tubing**—Usually in three-foot sections that can be added to one another to provide the desired length
- **End Piece**—Cut obliquely and provided with a hinged flap, closing the entrance to the tube
  - When the tube is inserted into the commodity, the flap is closed and prevents the commodity from entering
  - When the probe is withdrawn, the flap opens due to the slightly larger diameter on the flap
    - The tablets or pellets are then released one at a time as the probe is withdrawn

Grain or other bulk or loose commodities up to 30 feet deep can be probed. Best results are obtained by probing twice every square foot and as regularly as possible. Penetration of phosphine is up to 10 feet below the area in which the tablets are placed. When large bulk grain stores are treated, many probes can be placed prior to treatment. One head piece can be moved from probe to probe, or pellets or tablets can be placed in the tubes by hand (use surgical or disposable thin rubber or polyethylene gloves).

Gas generation starts within four hours of placing the pellets or tablets (depending on relative humidity). Therefore, the whole procedure of pellet or tablet placement or tarpaulin covering must be accomplished within this time frame. It is possible to work in a probed area if the area is covered with a gas-proof tarpaulin. Monitor gas concentrations to determine if toxic levels are approached and take corrective action to prevent exposure.

Additional Considerations for Fumigating Bulk Commodities

- For large storage facilities (>25,000 ft^3), consider multiple dispensing points to assist in fumigant distribution
  - Contact the **USDA-APHIS-PPQ-S&T-CPHST-AQI** for a determination on the number of sampling lines for large fumigations
- Based on the size of the structure being fumigated, refer to the $ECO_2FUME^®$ and $VAPORPH_3OS^®$ Application Manuals for acceptable dispensing equipment

- If it is known ahead of time that grain or cottonseed will require treatment prior to placement in a means of conveyance or storage, properly seal the space before loading. Use tarpaulins of at least 6 mm thickness if walls are permeable since lighter tarpaulins may tear
- If a bulk shipment is in a large storage facility with a high roof, it may be better to tarp on top of the grain rather than seal the roof
  - When side walls of the facility are **not** gas impervious, place tarpaulins (minimum 6 mm thickness) around the outside of the facility to the height of the commodity

Aeration Requirements

Break Bulk, Containers, and Bulk Fumigations

Following completion of treatment, phosphine-treated commodities must be aerated using either electric exhaust fans or by passive aeration in the open air. Personnel are **not** allowed to enter or reenter fumigated areas until gas concentrations are determined to be below the Threshold Limit Values (TLV) for phosphine and carbon dioxide. Check ambient air and the air inside the box, carton, bin etc. of the commodity during aeration. Measure gas concentration levels with a sensitive gas detection device. Aerate all commodities to acceptable tolerance levels (**Table 2-11-3**). Because they can continue to release gas after the initial gas levels have dropped to acceptable levels, continue to monitor densely packed commodities. A certified applicator must be physically present, responsible for, and maintain visual and/or voice contact with all fumigation workers during the initial opening of the fumigation structure for aeration. Always follow the aeration instructions provided with the fumigant label.

Table 2-11-3 Phosphine Residue Tolerances

Commodity	Tolerance of Phosphine Residues (ppm)	Minimum Aeration Period (hours)
Animal Feeds, Grains, Nuts, and Dates	0.1	48
Processed Foods	0.01	48
Fresh fruits and Vegetables	0.01	48
Nonfood Commodities	<0.3	None
Tobacco	<0.3	48

Disposal of AP and MP Residue

Following treatment with AP, a powdery residue, essentially aluminum hydroxide, will remain. Collect this material and mix it in a container of water to which liquid detergent has been added (two tablespoons of detergent per gallon of water). The liquid should then be buried or deposited in an approved pesticide disposal landfill.

Following treatment with MP, dispose of the plates by burial in an approved landfill or by burning where approved by local ordinances.

Follow the manufacturer's label instructions for detailed disposal guidelines.

Contacts

Cytec®

Cytec Industries
5 Garret Mountain Plaza
West Patterson, NJ 07242
Phone: 973-357-3100
email: CUSTINFO@CYTEC.COM

USDA-APHIS-PPQ-S&T-CPHST-AQI

1730 Varsity Drive
Suite 300
Raleigh, NC 27606
Phone: 919-855-7450
FAX: 919-855-7493

Chemical Treatments

Aerosols

Contents

Introduction

The information in this section provides CBP and PPQ officials and commercial applicators the procedures and precautions for applying aerosol insecticides in aircraft.

PPQ uses aerosol insecticides to treat for Japanese beetle, Khapra beetle, and other hitchhiking pests. Respirators are recommended but not required by the chemical labels.

WARNING

Do **not** subject these chemicals to extreme temperatures.

There are currently two aerosols approved for use in aircraft passenger areas, aircraft cargo holds, and aircraft pods, Callington 1-Shot™ (2% d-phenothrin + 2% permethrin) and 10% d-phenothrin.

10% d-phenothrin

The application rate (**T409-b-1**) is 8 g/1,000 ft3. Without an extender tube, the aerosol can is calibrated to dispense 5 grams per second; therefore 8 grams per 1,000 cubic feet will take 1.6 seconds to dispense.

CAUTION

10% d-phenothrin is not approved for use in California, **except** in Federal installations such as military airports.

Apply 10% d-phenothrin in the cargo or passenger areas of the aircraft no more than one hour before loading.

The time needed to spray the aerosol is a function the following three things:

- Volume (in 1000 cubic feet) of a specific area in the aircraft
- Spray rate of the nozzle (in grams per second)
- Required application rate for the pesticide (in grams per 1000 cubic feet)

This relationship is shown in the formula in **Figure 2-12-1**:

$$Volume\ of\ Aircraft \times \left(\frac{Required\ Application\ Rate}{Spray\ Rate\ of\ Nozzle}\right) = Time\ Needed\ to\ Spray\ Aerosol$$

Figure 2-12-1 Formula for Calculating Aerosol Spray Time in Specific Areas of Aircraft

EXAMPLE: You are supervising the application of 10% d-phenothrin. The volume of the aircraft cabin is 10,800 ft^3: The required application rate is 8g/1,000 ft^3. The spray rate of the nozzle is 5.0 g/sec.
10,800/1,000 = 10.8 units of 1,000 ft3
8/5 = 1.6 seconds
1.6 seconds x 10.8 = 17.3 or 17 seconds of dispensing time

Passenger Compartment Application

Treatment of passenger compartments is under the authority of a compliance agreement between PPQ and the airline or other contractor.

CAUTION

Never treat passenger compartments when passengers are inside.

Ensure that the compliance holder follows these application procedures:

1. Vacuum the compartment before treatment.
2. Close flight deck windows.
3. Thoroughly inspect flight deck area and remove any insects. Keep windows closed until departure.
4. Close flight deck door to prevent aerosol from entering the flight deck.
5. Install barrier curtains (i.e. doors, plastic sheets, or prefabricated structures) in galley areas to prevent aerosol particles from entering the galley area.

NOTICE

Curtains must be full-length to prevent the entrance of aerosol particles into the galley. If the curtains are not full-length, use other means to seal the entrance. Airlines should provide materials, such as polyethylene, to seal galley areas.

6. Outside the galley areas, cover the following items with an impervious material, such as polyethylene.
   - Beverage and food preparation surfaces
   - Exposed oxygen masks
7. Open doors to bathrooms and carefully inspect. Remove any insects, then close bathroom doors.
8. Check aisles and remove all obstacles.
9. Put on safety glasses (and respirator, if desired).
10. Stop all aircraft ventilation systems.
11. Close aircraft entrance doors.
12. Treat at the rates in **T409-b-1**.
13. Start (perhaps with another applicator) 10 feet from the end of the aircraft. While backing slowly through the aircraft, dispense aerosol in a sweeping motion with cans pointing upward at a 45° angle. Keep the dispensing valve fully depressed. To avoid wetting surfaces, hold the nozzle at least 18 inches away from all surfaces.
14. When treating passenger aircraft with two aisles, it is recommended to have two individuals dispensing the material at the same time. When dispensing the aerosol, use a stopwatch, a wristwatch with a second hand, or count aloud using the technique 1001, 1002, etc. Accurate timing not only ensures the proper amount is dispensed, but also increases the likelihood of obtaining an equal distribution.
15. Exit the aircraft and close all doors.
16. Keep the aircraft closed for 15 minutes post-treatment.

17. After the 15-minute post-treatment period, start the aircraft ventilation system.
18. Ventilate the aircraft for 15 minutes before boarding passengers, crew, or ground personnel.

WARNING

The individual who starts the ventilation equipment must wear safety glasses.

19. If aerosol particles are still noted in the air after the ventilation period, continue aeration until the particles disappear.
20. After treatment and ventilation, safeguard the aircraft until departure.

Post-Treatment Cleanup Procedure

Ensure that the compliance holder follows these post-treatment clean up procedures:

- Do not open flight deck doors.
- Do not remove barriers from galleys until catering is completed; insects can enter during the catering process.
- Reinspect and collect all insects.
- Remove covers used to protect specific items outside the galley (e.g., drinking fountains).
- Thoroughly wash hands, faces, and arms before smoking, eating, or drinking.

Maintaining a Pest-Free Condition in the Passenger Compartment

After treating a passenger compartment, ensure that the aircraft is kept pest-free with the following procedures:

- Keep the barrier (closure, curtain, or door) from the galley to the inside of the aircraft closed until after catering. After catering, thoroughly inspect for insects in the galley area.
- Monitor the entrance to the aircraft to determine if insects are entering.
- Remove and destroy any insects that enter the aircraft.
- Use enclosed walkways to board passengers either from the terminal or from the vehicles carrying passengers to the aircraft.

Treating Baggage/Cargo Holds

Whenever possible, treat baggage/cargo holds before loading. Treatment before loading allows penetration of the insecticide to cargo areas that become inaccessible after loading.

Loaded aircraft that stand open during the day must be treated, regardless of loading time. Insects often fly into and remain in open aircraft.

NOTICE

Military (and other) cargo is often stored outside on pallets for lengthy periods. Insects (Japanese beetles in particular) often rest overnight on the cargo pallets. Loading the aircraft with infested pallets will infest the aircraft. Therefore, treat the aircraft holds containing cargo pallets that have been stored outside and are likely to be infested. After treatment, remove all insects.

Treating Loaded Baggage/Cargo Holds

To treat a loaded baggage/cargo hold, ensure that the compliance holder follows these application procedures:

1. Ensure that there are no live animals on board before treatment. (If there are, remove them (in cages or holding containers) to a protected area, away from the treatment environment.)
2. If possible, visually inspect baggage/cargo hold before loading; collect and destroy all insects found.
3. If possible, visually inspect all baggage or cargo as it is being loaded.
4. Put on safety glasses (and respirator, if desired).
5. Treat the baggage/cargo hold at the rates in **T409-b-1**.
6. In small holds, open the hatch just enough to allow a hand and the aerosol container inside; as an alternative, apply through an open porthole, if available, in the hatch. Many holds are small; therefore, applicators may treat these small areas by standing at the hatch and directing the spray either aft or forward.
7. If live animals are being shipped following treatment, keep baggage/cargo hold closed for 15 minutes.
8. Open the hold door(s); use a mechanical barrier to protect the treated hold.
9. Ventilate the baggage/cargo hold for 15 - 30 minutes.
10. If live animals are being shipped, check the animals and cages for live beetles before loading and then reload the animals.
11. Close hold door(s).

Treating Unloaded Baggage/Cargo Pods

To treat unloaded baggage/cargo pods, ensure that the compliance holder follows these application procedures:

1. Select relatively airtight pods in good condition and without hand holes.
2. Put on safety glasses (and respirator, if desired).
3. Slightly open the pod door.

4. Spray for 1 second.
5. Keep pod closed for 15 minutes.
6. Open and ventilate the pod for 15 - 30 minutes.
7. Load baggage or cargo.
8. Close pod.

Precautions for Aircraft Transiting Airports at High-Risk for Japanese Beetles

The following precautions must be used for aircraft transiting high-risk airports.

- Keep cargo holds closed except during loading and unloading.
- Keep flight deck windows closed.
- Seal off the galley(s) if the aircraft is to be catered at the hazardous airport. Inspect galleys after catering, but before removing barriers separating the galleys from the cabins.
- Use enclosed walkways to board passengers. Always keep the enclosed walkway tight against the aircraft.

2% d-phenothrin + 2% permethrin

Currently, there is one manufacturer of this aerosol, 1-Shot™, Callington Inc. 1-Shot™ is labeled for use only in aircraft.

The application rate (refer to **T409-b-3**) is 40 g/1,000 ft^3. One, 150-gram can treats 3,750 cubic feet and takes 75 seconds to dispense completely.

CAUTION

Do **not** apply in the passenger cabin area of the aircraft or when passengers or crew are present.

Apply using the following procedures:

1. Calculate the number of cans needed (refer to **Table 5-5-7** through **Table 5-5-29** or use the formula in **Figure 2-12-1** on **page-2-12-2**).
2. Prearrange cans in the treatment areas.
3. Dispense partial cans into the farthest parts of the cargo hold before dispensing full cans. Carefully remove the locking tab that keeps the nozzle depressed using caution not to damage the dispensing mechanism. (**Figure 2-12-2**)
4. Fully depress the nozzle when dispensing.
5. To dispense a full can, depress the spray nozzle on the top of the can until the locking tab engages. Once the locking tab is engaged, the can sprays continuously until empty. (**Figure 2-12-3**)
6. Ventilate the aircraft for 30 minutes before boarding passengers, crew, or ground personnel.

Figure 2-12-2 Preparing to Dispense a Partial Can of 2% d-phenothrin + 2% permethrin

Figure 2-12-3 Preparing to Dispense a Full Can of 2% d-phenothrin + 2% permethrin

Ordering Information

10% d-phenothrin

Currently, 10 percent d-phenothrin is available from USDA APHIS PPQ. For ordering and shipping information, contact your Field Operations Program Manager or the USDA APHIS PPQ Quarantine and Policy Analysis staff in Riverdale, Maryland.

CAUTION: 10% d-phenothrin is not approved for use in California, **except** in Federal installations such as military airports.

NOTICE: Supplies are limited.

10% d-phenothrin will be available only until existing supplies are depleted.

2% d-phenothrin + 2% permethrin

Purchase 1-Shot™ directly from the manufacturer (Callington Inc.) using a micropurchase card. Email the following information to orders@callington.com:

- Delivery address
- Method of payment

- Quantity (consider local storage capabilities)

Precautions

Refer to the manufacturer's labels and material safety data sheets for more detailed safety instructions, but in general:

- Do **not** apply when animals or people are present.
- Do **not** smoke or eat during application and not until after washing. Wash as soon as possible after application of pesticides.
- Remove or cover food, food preparation surfaces, and equipment prior to treatment.
- The applicator may wear a suitable respirator, approved by the National Institute of Safety and Health (NIOSH).
- The applicator may wear goggles or safety glasses if the applicator experiences any eye irritation.
- Wipe any pesticide residue noted on smooth surfaces after treatment using a clean damp cloth.

2

Treatment Manual

Chemical Treatments

Dips

Contents

Overview

As with other treatments, chemical dips require careful planning and preparation. Make sure you have all the necessary safety and treatment equipment and materials ready before you start the dip treatment procedure. When you handle pesticides, always comply with the pesticide Label instructions, and State and local regulations.

Safety and Dip Treatment Equipment and Materials

The following lists include safety equipment (Personal Protective Equipment, PPE) and basic material that you will need for dip treatments. However, other materials may be required by additional Label requirements that are specific to chemical being used.

Personal Protective Equipment (PPE)

Always check the Label and Material Safety and Data Sheet (MSDS) for additional requirements of personal protective equipment. The following is a basic list of PPE that you will need for dip treatments:

- chemical-resistant footwear (rubber or neoprene boots)
- chemical-resistant gloves (neoprene)
- chemical-resistant headgear for overhead exposure
- chemical-resistant rain suit with hood
- protective eye wear (goggles)
- respirator (per Label and MSDS requirements)

Dip Treatment Equipment and Materials

Always check the Label for additional requirements for equipment and materials. The following is a basic list of equipment and materials you will need for dip treatments:

- Newspaper or any other absorbent paper

Important

Place plastic backed paper on pallets prior to covering with paper and/or absorbent paper to preclude the pesticide being absorbed onto the wood.

- Pesticides

Important

Pesticides should be fresh (**not** over 1 year old). Labels and MSDS must be attached to the pesticide container and all instructions must be followed.

- Mixing containers and dipping containers must be provided with lids to prevent spills during transportation and storage.
- New boxes (when reconditioning or excess contamination of original boxes is **not** possible)
- Fans[1]

Important

A mechanical exhaust is the preferred method of aeration when it is specifically installed to remove chemical fumes from the treatment area. Fans may be used if they do **not** cause airborne pesticides to contaminate the treatment facility or the breathable air. The flow of air should be across the dip vat/container and away from people in the treatment area.

- Pallets[1]

Important

Place plastic backed paper on pallets prior to covering with paper and/or absorbent paper to preclude the pesticide being absorbed onto the wood.

- Plastic bags (4 to 6 mil plastic)[1]
- Shear scissors
- Sponges
- Liquid soap[1]
- Packing material[1]

1 This equipment will be provided by USDA when available.

Dip Treatment Procedures

Step 1—Plan for the Dip Treatment

Before you start the dip treatment, inform the customer (Broker/Importer) of the specific material and personal protective equipment (PPE) that will be needed to perform the dip treatment procedure. All required materials and equipment must be available at the time of treatment.

Step 2—Designate Restricted Use Areas

Designate the following restricted use areas:

- **Measuring and mixing area-** The measuring and mixing area for the specific pesticide(s) must be in a well ventilated area away from food preparation, eating areas, and offices. Areas that contain mechanical exhaust systems are preferred.
- **Plant material dipping area-** The plant material dipping area must be an area where access is limited by a barricade or warning signs. Areas that contain mechanical exhaust systems are preferred.
- **Plant material drying area-** The plant material drying area must have proper air circulation and exhaust ventilation. These areas should be closed to the dipping area. The route from the plant dipping area to the drying area should be lined with plastic backed absorbent paper or plastic and paper to catch excess pesticide solution.

Step 3—Prepare Plant Material

Prepare the plant material for the dip treatment according to the PPQ Treatment Manual and pesticide Label requirements.

Step 4—Prepare the Pesticide Solution

CAUTION

Wear personal protective equipment (PPE) and keep the exhaust system running when you are preparing pesticide solutions. To minimize your exposure to the pesticide dust or airborne particles, keep the pesticide between you and the exhaust.

1. Measure the amount of water required for the treatment.
2. Measure the amount of pesticide required for the treatment.

Important

It is important to use fresh chemicals for every solution. If questions arise during this procedure, stop and seek assistance from USDA-APHIS-PPQ-S&T-CPHST-AQI in Raleigh, North Carolina (Tel: 919-855-7450).

3. Prepare a pesticide paste as follows:
   - **A.** Add the previously measured amount of water into a clean and empty container, for example, an empty can or plastic container.

- **B.** Form a paste (with dry pesticides) by adding the measured pesticide to the small amount of water and mix gently
- **C.** Dilute the paste by slowly adding more water from the previously measured water
- **D.** Slowly add the concentrated solution(s) to the rest of the measured water

4. Add some drops of liquid soap to the solution (soap is used as a sticking agent).
5. Mix the final solution by stirring it gently.

Step 5—Dip the Plants in the Pesticide Solution

Dip the plants in the solution for the time required by this manual.

Step 6—Remove the Plants from the Pesticide Solution

Remove the plants from the solution and allow excess solution to drip into the dipping container.

Step 7—Dry the Plants

Place the plants on newspaper covered pallets and allow them to dry (make sure to space the plants out for maximum drying).

CAUTION	Thoroughly dry the plants before releasing them to the customer.

Step 8—Disinfect Original Shipping Containers

Disinfect the original shipping containers with a sponge containing the pesticide solution. The plant material may be packed with new packing material in a previously used container that has been disinfected.

Step 9—Clean Up the Treatment Area and Equipment

Discard all empty containers, excess pesticides, packing materials, plastic bags/backing materials, and newspaper/absorbent paper in compliance with instructions on the Label and State/Local regulations. Decontaminate all treatment areas and equipment while you are wearing your PPE.

Step 10—Release the Cargo

After the plant material is dry, release it to the customer or broker if agreed to by the airline and if it has been released by Customs.

Safety Responsibilities

The PPQ Officer is responsible for the following safety issues:

- Make the broker/importer aware of his or her responsibilities as it pertains to:
  - Materials
  - Personal Protective Equipment (PPE)
  - Health hazard and safety concerns when performing the dip treatment process
- All personnel involved in the dip treatment process are required to wear the appropriate and Label required PPE while performing the treatment. PPQ Officers may need to wear PPE if the dip treatment process area prevents them from observing the process from outside the restricted area.
- Designated dip treatment process areas must be located away from food preparation, eating areas, and offices. Make every effort to place dip treatment processes in an area containing a mechanical exhaust.
- The broker/importer personnel involved with treatments must be aware and briefed on the location of the emergency eyewash and all other required safety equipment. They also need to be aware of the areas that they will be limited to working within and any other specific restrictions determined by the PPQ Officer in charge of the process. The PPQ Officer monitoring the process should be aware of procedures to be followed in the event of an accidental release of the pesticide or an injury to one of the broker/importer's personnel.
- The broker/importer's personnel should shower as soon as possible after performing a dip treatment. The PPQ Officer should ensure that personnel are aware of the location and route to the shower. Guidance should also include instruction on how to disrobe and dispose of clothing used during dip treatment processes. All contaminated clothing and PPE must be removed before entering the shower room. Contaminated clothing should be placed in plastic bags and PPE in separate plastic bags.
- Inform the broker/importer personnel that clothes wore during treatment must be washed in hot water with detergent and that they should be washed separately from other clothes
- Release the plant material to the Broker/importer only if they are using or provide a vehicle that has a compartment physically separated from the cab, for example, a pick-up truck of tractor trailer.

2

Treatment Manual

Chemical Treatments

Dusts

Contents

This section for future development.

2

Treatment Manual

Chemical Treatments

Sprays

Contents

This section for future development.

3

Treatment Manual

Nonchemical Treatments

Overview

Contents

The Nonchemical Treatment section of this manual is organized by the following nonchemical categories:

- Heat
- Cold
- Irradiation

Use the Table of Contents that follows each tab to quickly find the information you need. If the Table of Contents is **not** specific enough, then turn to the Index to find the topic and its page number.

3

Treatment Manual

Nonchemical Treatments

Heat

Contents

Introduction

Heat treatments are generally based on maintaining the plant material at a specific temperature for a specified time. Heat treatments, as other quarantine treatments, are designed to kill plant pests without destroying or appreciably devaluing the infested commodity. The following heat treatments are described in this section:

- Hot Water Immersion Treatment
- Steam Treatments
- Vapor Heat and Forced Hot Air Treatment
- Forced Hot Air - Niger Seed

3

Treatment Manual

Nonchemical Treatments

Heat, Hot Water Immersion Treatment

Contents

Hot Water Immersion Treatment—Fruit Fly Host Commodities Such as Mangoes

Principle

Hot water immersion treatment (also called hydrothermal treatment) uses heated water to raise the temperature of the commodity to the required temperature for a specified period of time. This is used primarily for certain fruits that are hosts of fruit flies, but may also be used for nursery stock for a variety of pests.

Schedules

Refer to the appropriate section in the Treatment Manual for Treatment Schedules. The time/temperature relationship varies with the commodity and pest. Typically, the pulp temperature is raised using water heated to between 115 °F and 118 °F for a prescribed period of time.

Procedures

- Before the start of each treatment, examine the facility for proper operation of the heating, circulation, and recording equipment. Examine continuous flow equipment (submerged conveyor belt) at the start of each day or run
- Commodities subject to size restrictions require a preliminary culling procedure to eliminate oversized items prior to treatment
- Conduct all treatments in an approved tank

- Entire treatment will be under the general monitoring of APHIS, and may be further governed by a signed Work Plan (for foreign facilities) or Compliance Agreement (for domestic facilities)
- Load immersion tanks in a manner approved by the U.S. Department of Agriculture (USDA), usually using baskets with perforations that allow adequate water circulation and heat exchange
- Number each treatment container or lot before placing in the immersion tank
- Record the temperature and duration of each hot water dip with an automatic temperature recording system
  - A responsible employee of the packing company must indicate on the printed temperature record the starting time, lot number, duration of each treatment, and initial each entry
  - An alternative recording system can be used only with prior APHIS approval
  - During certification, the average pulp temperature becomes the minimum commercial treatment pulp temperature
  - During commercial treatments, the “Adjusted Tank Sensor Temperature” in is used as the lowest treatment temperature. Refer to ***Figure 6-5-1*** on **page 6-5-3** for more information.
- Stamp all boxes of hot water-treated fruit, *Treated with Hot Water, APHIS-USDA,* together with the numerical designation APHIS has assigned to the particular treatment facility
- When treatment is complete, promptly move commodities treated at origin to an insect-free enclosure
  - Maintain the insect-free commodities throughout the shipping process, this can be accomplished by using insect-proof containers, screened or enclosed rooms, doors with air-curtains, or some combination of the above

Checklist of USDA-APHIS Minimum Requirements for Hot Water Immersion Treatment Facilities: General Requirements

Proposal Submission

Follow guidance from the APHIS PPQ Preclearance and Offshore Programs when submitting proposals for new hot water facilities.

On-Site Inspection Option

When the construction is 75 percent complete, the firm can request APHIS to make an on-site inspection. This interim inspection is optional. However, a final inspection is required as well as performance tests of the equipment. All costs involved must be prepaid by the requesting firm.

Facility Design

APHIS does **not** provide construction details, but only this list of minimum requirements. Design and construction of the hot water facility is the responsibility of the owner, in consultation with an engineering firm. (Engineering firms and sources of supply are provided in ***Reference Guide to Commercial Suppliers of Treatment and Related Safety Equipment* on page E-1-1**.) To take into account variations in facility size, availability of materials, economic feasibility, and individual preference, APHIS allows a wide range of design flexibility.

Although each facility is somewhat unique, there are two basic designs for hot water facilities. The two types are referred to as the *batch system* and the *continuous flow system.*

Batch System (Sometimes Called "Jacuzzi System")

Most hot water immersion treatment facilities are the batch system type. In this system, baskets of fruit are loaded onto a platform, which is then lowered into the hot water immersion tank where the fruit remain at the prescribed temperature for a certain length of time, then are taken out, usually by means of an overhead hoist. In this system, the treatment chart must indicate (by an identifiable marking) when a fruit basket is prematurely removed from the tank. Other alternatives include a solenoid switch, sensor, or similar device that disengages whenever a basket is removed from the treatment tank, or a locking device to make it physically impossible to remove the fruit until the treatment is fully complete.

Continuous Flow System

In the continuous flow type of system, the fruit are submerged (either loosely or in wire or plastic mesh baskets) on a conveyor belt, which moves slowly from one end of the hot water tank to the other. Belt speed is set to ensure the fruits are submerged for the required length of time. This system requires an instrument to monitor the speed of the conveyor belt. This can be accomplished by attaching a speed indicator (encoder) to the gear mechanism. The belt speed is recorded on the same chart as the time and temperature, and also indicates whether the belt is moving or stopped during the treatment cycle. Smaller fruits require less treatment time than larger fruits. Therefore, conveyor belt speed should be adjustable to accommodate treatments of different lengths of time. As an alternative, the belt speed may remain constant, but the length of the submerged portion of the belt is adjusted according to the length of treatment time required for the particular size of fruit. The conveyor must prohibit either forward or backward movement of the fruit during treatment (due to flotation).

Some operators believe that treating fruit while it passes through the system on a conveyor belt is an advantage. Few new systems of this type were built after 1990, presumably because mechanical fruit damage (scratching of the peel) often occurs if the fruit are not in baskets. The system also occupies much more floor space in the plant than a batch system.

Water Quality

The water used for washing, dipping, hydrocooling or showering the fruit should be chlorinated at a level **not** to exceed 200 parts per million (ppm). This level is easier to maintain if the water is first filtered and run through a flocculation process to remove organic material that would otherwise bind with the chlorine.

The facility should check the water for microbial contamination on a regular basis. To maintain sanitary conditions, change water as necessary. Implement standard operating procedures to include water change schedules for all processes that use water. To ensure the safety of the fruit, the facility must clean and sanitize surfaces that come into contact with water, such as wash tanks, hot water tanks, and hydrocooling tanks as often as necessary. To ensure efficient operation, routinely inspect and maintain equipment designed to assist in maintaining water quality, such as chlorine injectors, filtration systems, and backflow devices.

CAUTION

Periodic monitoring by the facility is critical, because chlorine levels above 300 ppm can result in metal corrosion.

Electrical and Electronic Components

Wiring

Electrical wiring throughout the facility must meet both international as well as local safety code requirements. To eliminate shock hazard, earth grounding is required for all electrical wiring located in the vicinity of water. To prevent damage, shield wires inside metal or PVC conduit.

Computers and Microprocessors

To maintain accuracy and reliability, place computers and microprocessors in a climate-controlled (air-conditioned) room. This room should be above tank level, provide a clear view of the treatment tank(s), and be lockable. This room can also serve as an office for the inspector.

Commercial Line Conditioner (Surge Protector)

A commercial line conditioner is recommended for use with computers and microprocessors to provide protection from voltage irregularity (power surges), noise reduction, and harmonic distortion.

Electrical Generator

In the event of a power outage and to provide a secondary source of electricity to enable continued plant operation, an electrical generator is recommended as a backup power supply.

Fruit Sizing Equipment

In the Treatment Schedule, the duration of hot water immersion depends on the particular weight class and variety of the fruit being processed. The inspector must visually inspect and weigh the largest fruit until the inspector is satisfied that **all** of the fruit is within the weight class. The weight inspection must occur for each lot change (orchard or variety) to ensure the accuracy of the sizing equipment. **No** mangoes will be accepted that are over the weight class.

It is very important to have accurate sizing equipment that sorts the fruit into groups, either by diameter or by weight. (Weight sorting is the preferred method.) If the weight range is too broad, recalibrate the equipment.

Boilers and Thermostatic Controls

Adequate Water Heating Capacity

The hot water facility must have adequate water heating capacity (i.e., a powerful enough boiler), and accurate enough thermostatic controls to hold the water temperature at or above the temperatures prescribed in the Treatment Schedule for the given length of time.

Thermostatic Controls (Set Point)

APHIS requires that the thermostatic controls be automatic. The temperature set point(s) are determined and approved during the official performance test, and must be high enough to ensure the water in the treatment tank will meet or exceed the minimum treatment temperature prescribed for the fruit. Once approved, do **not** tamper with the temperature set points. Temperature set points must remain constant for the entire shipping season. However, if the operator of the facility requests a change in set points, the inspector should conduct a new performance test. If this test is unsuccessful, revert the tanks to their prior set points.

Multiple Set Point Option

Managers of some facilities use multiple set points for each tank. The initial set point is higher than the other set points. All set points will be selected by the facility manager or systems engineer based on results of the preliminary performance test.

Verify the set points during the official performance test, and the same procedure must be repeated on each subsequent commercial treatment. This system works only for tanks that treat only one cage (basket) of fruit at a time.

Important

> Tanks are **not** allowed to have any set point that is lower than the standard treatment temperature for the commodity being treated (115 °F in the case of mangoes).

Water Circulation

Install a water circulation system in the tank to provide uniform water temperatures throughout the treatment process and to avoid the formation of cool pockets during treatment. To guarantee that the equipment is **not** turned off during the treatment process, the controls for the circulation pumps or propellers must be tamper resistant. For the safety of personnel working in the area, shield pulleys on all pumps located within six feet of the floor.

After the first five minutes of treatment (with the tank sensor at “lowest temperature permitted at that set point”), differences in the lowest and highest actual temperature sensor readings of more than 1.8 °F may be accepted on a case-by-case basis.

Using a flotation barrier, keep the fruit at least 4 inches (10.2cm) below the water surface during the treatment.

Temperature Sensors

Type of Sensor

Permanently install platinum 100-ohm resistive thermal detectors (RTD sensors) in the lower third of the tank. The resistance of an RTD sensor linearly changes with temperature, whereas thermistors and thermocouples are nonlinear and less stable. Major advantages of RTD sensors include long-term stability, high signal levels, and overall accuracy of the system. Place the sensor unit within the distal 1 inch (2.54cm) of the sensor rod. The sensor must have an outer sheath of 0.25 inch (6.4mm) or less in diameter.

Number of Sensors Required and Their Placement

For continuous flow systems, the minimum number of sensors required is at least 10 per tank, which must be spaced throughout the length of the conveyor. For batch systems, the requirement is at least 2 sensors per tank. However, in tanks that treat multiple baskets (cages) of fruit, there must be at least 1 sensor per basket position. (A tank with 4 basket positions, for example, would require at least 4 sensors). In both the batch and continuous flow systems, install sensors in the lower third of the tank.

Tank Access for Temporary Placement of Portable Sensors

The hot water tank must be designed to accommodate the temporary placement of numerous portable sensors or probes to be used during the performance testing procedure required for certification or recertification. During the testing procedure and at the direction of the inspector who conducts the performance test, position the temporary sensors throughout the load of fruit. The facility is required to purchase and have available 24 portable thermistor or thermocouple sensors (each with its own flexible cord at least 10 feet in length), and a portable temperature monitor that reads to the nearest one-tenth of a degree.

Certified Glass-Mercury, Non-mercury, and Digital Thermometer

The treatment facility is required to have at least one high-accuracy, water-immersible, certified mercury, non-mercury, or digital thermometer on the premises at all times. This thermometer must be accurate to 0.1 °F (or C) and will cover the range between 113 °F and 118 °F (45 °C to 47.8 °C). It will be used as the standard against which all sensors are calibrated.

Temperature Recorder

Use an automatic temperature recorder (strip chart or data logger) to record the time and temperature during each treatment.

Automatic Operation

The instrument used for recording the time and temperature must be capable of automatic operation whenever the hot water treatment system is activated.

Long-Term Recording

The recording equipment must be capable of nonstop recording for an extended period of time. Continuous flow systems require recording equipment capable of operating for up to 12 consecutive hours.

Recording Frequency

The time interval between prints will be no less than once every two minutes. Alternatively, a strip chart system can be used that gives continuous color pen lines. The numerical print or pen line representing each temperature channel (sensor) must be uniquely identified by color, number, or symbol. It is **not** necessary to record temperatures from sensors located in portions of the tank **not** in use.

Accuracy

The accuracy of the temperature recording system (i.e., sensors and recorders) must be within 0.5 °F (0.3 °C) of the true temperature (as verified by a certified mercury, non-mercury, or digital thermometer). The temperature variation for the control sensors should be as close to zero as possible.

Repeatability

When used under field conditions over an extended period of time, the recording equipment must be capable of repeatability to within 0.1 °F (or C) of the true calibrated readings. Failure to maintain reliability, accuracy, and readability in a previously approved instrument will result in canceling approval. The design construction and materials must be such that the typical environmental conditions (including vibration) will **not** affect performance.

Calibration

Individually calibrate channels (sensors) against a certified mercury, non-mercury, or digital thermometer reading in tenths of a degree Fahrenheit or Centigrade, within the range of 113 °F to 118 °F (45 °C to 47.8 °C). The engineering firm that installs the recording equipment must also calibrate it. (Calibration equipment often used for this purpose includes, for example, a Decade instrument and relay range cards.) Calibrate the sensors at or near the fruit treatment temperature (around 115 °F), **not** at 32 °F.

Range

The recorder must be programmed to cover the entire range between 113 °F to 118 °F (45 °C to 47.8 °C), with a resolution of one-tenth of a degree. The range should **not** extend below 100 °F (37.8 °C) nor above 130 °F (54.4 °C). If the range band of the recorder is wider than this, restrict it (narrowed) with proper programming.

APHIS-Approved Recorder Models

Some recorder models currently on the market are **not** approved by APHIS for various reasons. For example, if the recorder only displays the sensor numbers and temperatures without making a printout on paper; or if it prints out the temperature data only after the treatment has been completed it is **not** approved by APHIS. (These are known as "memory loggers".) These two types of recorder models do **not** provide an adequate level of monitoring during treatment. Also, revolving circular charts are **not** acceptable because of the difficulty in reading fractions of one degree.

Temperature recorder models presently approved by APHIS are listed below. They can be either of the strip chart or data logger type. Some have adjustable chart speed s. Additional temperature recorder models may be added to this list upon petition to the **USDA-APHIS-PPQ-S&T-CPHST-AQI**. To seek APHIS approval for recorder models **not** listed, submit the manufacturer's technical brochure to the **USDA-APHIS-PPQ-S&T-CPHST-AQI** for evaluation.

Approved Strip Chart (Pen) Recorder Models

Important

Strip chart recorders are no longer approved for installation in new facilities or used to replace any style of recorder.

- Chessel 346
- Honeywell DPR 100A (3-channel capability)
- Honeywell DPR 100B (6-channel capability)
- Honeywell DPR 100C (3-channel capability)
- Honeywell DPR 100D (6-channel capability)
- Honeywell DPR 180 (36-channel capability)
- Honeywell DPR 1000 (6-channel capability)
- Honeywell DPR-3000, version D4 (32-channel capability)
- Molytek 2702
- Neuberger P1Y
- Toshiba AR201
- Tracor 3000

Approved Data Logger Recorder Models

- ASICS Systems B & C
- Chino AA Series
- Cole Parmer (32-channel capability)
- Contech (10-, 16-, and 32- channel capability)
  - Model: Smart Seda
- Flotek (must be attached to a printer)
- HACCP Warrior PTR- 4 (4-channel capability)
- HAACP Warrior PTR- 10 (10-channel capability)
- Hidrosoft
- Honeywell DPR I00B (6-channel capability)

- Honeywell DPR-1500 (30-channel capability)
- Honeywell DPR-3000, version D4 (32-channel capability)
- HyThsoft v2
- IBM-PC (must be attached to a printer)
- Koyo, Model Direct Logic DL 350, with Hidro Soft
- Nanmac H30-1
- National Instruments (all HTS models and Labview 6.1 software)
- NOJOXTEN-BR with software- Automation Studio V 3.09 IEC 61131-3-ST
- Omega OM-205
- Omega OM-503
- Ryan Data Mentor (12-channel capability)
- Tracor Westronics DDR10

Chart Paper Specifications

Celsius or Fahrenheit Scale

Temperature can be recorded either in Fahrenheit or Celsius, although Fahrenheit is preferred by APHIS.

Scale Deflection

Scale deflection on the strip chart paper must be at least 0.10 inches for each degree Fahrenheit, or at least 5mm for each degree Celsius. Greater width between whole degrees, however, is preferred. Between each line representing one degree, there must also be finer lines, each representing subdivisions of one-tenth or two-tenths of a degree, in the range of 113 °F to 118 °F (45 °C to 47.8 °C).

Sample Required

Submit a sample of the strip chart or numerical printout made by the recording equipment to **USDA-APHIS-PPQ-S&T-CPHST-AQI**. It should be in the exact format to be used at the facility during the treatment cycle. Each symbol on the print wheel (or ink color, in the case of strip charts) must correspond to and identify the particular sensor that it represents.

Chart Speed

Chart speed for strip chart recorders must be no less than 1 inch for every 5 minutes of treatment time.

Chart Length

The chart paper must be long enough to display at least 1 entire treatment. Continuous flow systems must contain enough chart paper to continuously record temperatures for up to 12 consecutive hours.

Alarm System

An alarm is required for all batch (Jacuzzi) systems, in order to notify packinghouse employees that a treatment has been completed for a particular basket (cage). This system can be an audible noise (such as a horn, buzzer, or bell) or a highly visible light attached to a timing device located on the equipment that indicates time and temperature. Some facilities use both a noise and a light. To avoid "overcooking," the alarm system alerts the operator of the hoist to remove a basket from the tank at the end of treatment.

Safeguarding the Treated Fruit

Layout and Flow Pattern

Design the flow pattern of the fruit moving through the hot water treatment process to ensure that fruit waiting to be loaded into the hot water immersion tank cannot become mixed with fruit that has already completed treatment. Submit a drawing showing the proposed layout of the packinghouse to **USDA-APHIS-PPQ-S&T-CPHST-AQI** for approval.

Garbage Disposal

In order not to attract fruit flies, place cut fruit, culled fruit, rotting fruit, and miscellaneous garbage into covered containers and remove from the premises daily.

Quarantine Area

Bring treated fruit to an insect-free enclosure immediately after treatment. The treated fruit must remain there until loading into insect-proof shipping containers. The designated enclosure is usually a screened room. Packing line equipment, hydrocooling equipment, and a cool storage room (if any), should be located in this area, but this equipment is **not** a requirement. To prevent the movement of untreated fruit (accidentally or intentionally) into the insect-free quarantine area enforce effective procedures.

Screening and Other Materials

Ordinary window screen or mosquito netting (at least 100 mesh per square inch) is sufficient to exclude fruit flies. Inspect it regularly and repair it as often as needed. Solid glass, concrete, drywall, or wooden walls are also acceptable.

Air Curtain

Place on the wall or ceiling prior to entering any quarantine area an apparatus that generates a high-velocity wind barrier or air curtain (such as fans or blowers and associated air-directing chambers or enclosures such as baffles, boxes, etc.). This device must exclude the possible entry of fruit flies into the insect-free enclosure. (For facilities approved prior to July 1, 1997, vertically hang clear plastic flaps, as minimally required, at the doors to the insect-free enclosure.

Loading of Treated Fruit

When **not** in use, close doors leading from the quarantine area to the loading dock. When loading, truck vans and containers must form a fly-proof seal with the exterior wall. Prior to loading, inspect and disinfect truck vans and containers. If wooden pallets are used, they must be completely free of wood-infesting insects and bark. Apply a numbered APHIS seal to each container before its departure.

Pretreatment Warming Options

Prewarming the fruit is sometimes desirable in order to meet the APHIS requirement that all fruit pulp temperatures be at least 70 °F before start of the certification performance test. At the very least, the fruit pulp temperature must reach the minimum pulp temperature stabilized during the certification test for commercial treatment. After prewarming, take pulp temperatures from the mangoes located at the coldest part of the crates and/or baskets. Do **not** take the pulp temperatures from the mangoes that are located on the outside of the basket or crate.

Post-Treatment Cooling Options

Cooling the fruit after hot water treatment is **not** an APHIS requirement. However, from the standpoint of fruit quality, many facilities choose to install a system to cool the fruit after removal from the hot water.

Hydrocooling of the treated mangoes is allowed after a waiting period of 30 minutes following treatment unless the original dip times indicated in the treatment schedule are extended for 10 minutes. Allowing the fruit to simply stand for at least 30 minutes after being removed from the hot water tank is thought to be helpful in killing immature stages of fruit flies because the mangoes complete their “cooking” process during that time.

Refrigerated Room

The recommended storage temperature for mangoes is between 55 °F and 57 °F (12.8 °C and 13.9 °C) at 85 percent to 90 percent relative humidity. These temperatures delay softening and prolong storage life to approximately 2 to 3 weeks.

Fans

APHIS allows the use of fans in the screen room to blow air over the fruit as soon as they are removed from the hot water tank (if desired). However, the ambient air cannot be less than 70 °F.

Hydrocooling

APHIS allows the use of a cool water tank or shower system, but with the following provisions:

- During the waiting period and hydrocooling period, safeguard the mangoes in a room or tunnel, separate from the hot water tanks
- Water temperature used during hydrocooling must be 70 °F or above
- Water used for hydrocooling should be chlorinated (not to exceed 200 ppm)
  - Any other chemicals, such as fungicides, are optional, but must be approved in advance by the FDA

Facility Changes

Hot water immersion treatment facilities whose construction was approved under earlier guidelines can continue to operate with APHIS approval. Newer facilities, however, are required to meet the current requirements outlined in this checklist, which in most cases are more strict.

Once **USDA-APHIS-PPQ-S&T-CPHST-AQI** has formally approved the plans and drawings for a hot water immersion treatment facility, the facility can make no further changes in the equipment without APHIS approval. Any proposed changes or improvements must be described in writing (with accompanying drawings, if necessary) and must be approved by APHIS in writing. Examples of proposed changes include adding additional treatment tanks, adding a cold storage room, and changing the model of the temperature recorder.

Safety and Health Checklist

- Adequate lavatory
- Admission of children or unauthorized persons into the treatment and packing areas prohibited if not accompanied by a responsible employee
- Approved safety ladders or walkways (catwalks, etc.) for observing treatment tank operations
- Electric power meets safety code requirements
  - Electrical wiring, including switches and other connections, contained in metal or PVC conduit and grounded to prevent electrical shock

- Engines, pulleys, drive belts, and other hazardous moving parts, if located within six feet of floor level, guarded with a safety shield or barrier
- Fire extinguisher located near the boiler
- First-aid kit located near moving machinery
- Hard hats for workers and visitors in the treatment and loading areas must wear (this is optional if not required by local regulations)
- Steam and hot water pipes insulated or otherwise protected
- Sufficient lighting provided in working areas

Work Plan

A Work Plan is a formal agreement signed by a representative of each treatment facility in a particular country, the Agriculture Ministry of the host government, and by USDA-APHIS. Work Plans govern the day-to-day operations of each facility and can be improved from one year to the next. Work Plans usually contain additional provisions not included in this checklist.

Fruit exporters are required to operate under general APHIS monitoring and to be in full compliance with all APHIS regulations as outlined in detail in the current Work Plan. The operator of the facility, as well as the inspector assigned to the facility, should each keep a copy available to resolve any disputes.

Plant Material Not Tolerant to Fumigation

Propagative material may be free from visible pests, but certain pathogens may cause undetectable symptoms.

Hot water dip treatment (52 °C/125.6 °F for 30 minutes), combined with hand removal of visible pests, is effective against numerous pests. **See “T201-p-4” on page-5-3-21** for a list of pests controlled.

Operational procedures and equipment specifications are under development.

Address for Technical Contact

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606
Tel: 919-855-7450
Fax: 919-855-7493

3

Treatment Manual

Nonchemical Treatments

Heat • Steam Treatments

Contents

Principle

Steam at a temperature of 212 °F will destroy most pathogenic microorganisms of the common vegetative forms or the spore types when in the growing or vegetative state in a short period of exposure. Some spores, however, are much more resistant and will withstand prolonged periods of exposure to steam at atmospheric pressure. Saturated steam at temperatures of 240 °F to 248 °F (10 to 15 lbs. pure steam pressure) will destroy the most resistant spores in a brief interval of exposure. However, near-complete air discharge from the autoclave or steam chamber is necessary. When steam is admitted to a chamber from which the air is completely evacuated, the temperature of the steam throughout the chamber will advance at once to the maximum range that can be attained for the pressure carried. If air remains in the chamber, the ultimate temperature will be reduced dependent upon the quantity of air remaining. Refer to a recording or indicating thermometer for correct chamber temperature-pressure relationships.

Detailed operational procedures and equipment specifications are under development.

Steam Pressure Sterilization

Live steam is introduced into a closed chamber containing the material to be treated until the required temperature and pressure are indicated. The temperature/pressure relationship is maintained at or above this point for the required exposure period. The exposure period will depend on the nature of the material, quantity, and its penetrable condition.

Loose Masses of Material

For loose masses of material, which permit rapid and complete penetration of steam to all parts of the mass, no initial vacuum is needed, but air must be released until steam vapor escapes, and exposure at 20 pounds pressure for 10 minutes, 15 lbs. for 15 minutes, or 10 lbs. for 20 minutes is sufficient.

Closely Packed Material

For closely packed material, such as soil or baled straw, special measures are needed to ensure rapid heat penetration to all parts of the material. Baled rice straw, for example, is required to have a density of less than 30 lbs. per cubic foot since penetration at higher densities is too slow to be practical. Soil, if in large containers, will not allow adequate treatment under normal sterilization exposure periods. Quicker penetration of the steam is obtained by first exhausting the air in the chamber to a high vacuum and then introducing live steam until the required positive pressure is reached.

Examples of the pressure-temperature relationships are listed in **Table 3-4-1**. The gauge pressure in pounds per square inch corresponds to the temperature of saturated steam in degrees Fahrenheit. Zero gauge pressure corresponds to an absolute pressure of 14.7 lbs. per square inch. The figures are based upon the complete replacement of air by steam. If air replacement is not complete the temperature for any given pressure will be less than the corresponding temperature.

Table 3-4-1 Pressure Temperature Relationships

Gauge Pressure (lbs. per sq. in.)	Temperature °F
10	239.4
15	249.8
20	258.8
30	274.1
40	286.7
50	297.7
60	307.4

Steam Jet Method

Live steam from a jet or nozzle is forced into or through a more or less loose and open mass of material in such amount and for such period required to raise the temperature of all parts of the mass to approximately 212 °F. This method takes advantage of the considerable latent heat liberated when steam condenses into water. This process does not effect complete sterilization since spore-forming bacteria are not always destroyed. Since no spore-forming bacteria are known that cause plant diseases, however, and fungi are readily killed by the temperatures reached, this process is effective for quarantine purposes if the necessary degree of heat is generated in all parts of the material.

3

Treatment Manual

Nonchemical Treatments

Heat • Vapor Heat and Forced Hot Air Treatment

Contents

Introduction

Vapor Heat (VH) and Forced Hot Air (FHA) treatments use heated air to warm fruit to temperatures that are lethal to target pests, primarily fruit flies. Generally, VH treatment differs from FHA only in the relative humidity of the air in the treatment chamber; higher humidity levels may preserve fruit quality. Unless otherwise noted, information in this chapter applies to both VH and FHA treatments for fruits and vegetables.

Each treatment facility is encouraged to develop automated data collection systems designed to automate treatment tracking and ensure that treatment specifications are met.

This chapter describes processes for routine (commercial) treatments for fresh fruits and vegetables at VH and FHA facilities. **See "Certification of Forced Hot Air and Vapor Heat Treatment Facilities" on page-6-7-1** for VH and FHA certification and equipment requirements.

VH treatment schedules can be found in ***T106—Vapor Heat* on page 5-2-74**. FHA treatment schedules can be found in ***T103—High Temperature Forced Air* on page 5-2-61**.

Procedures

Before any treatments are conducted at a facility, the authorized PPQ official or APHIS designated representative should familiarize themselves with the facility and the way the chamber functions. The official should also carefully review the treatment schedule for the commodity(ies) that will be treated, and any special requirements specified during certification, in the workplan or in the compliance agreement. The PPQ official or APHIS designated representative approving the facility has the option to increase the number of permanent temperature sensors based on testing performed at the facility.

Pretreatment

Prior to treatment, the PPQ official or APHIS designated representative must ensure that the facility and the chamber are in good working order and the temperature sensors are functioning properly. For the purposes of this chapter, the term "sensors" will refer to both permanent and portable temperature sensors. Conduct a brief facility inspection, including chamber and equipment, before any other steps in the treatment process are taken. During this inspection, the official verifies that all safeguarding and quarantine measures are in place and that there are no obvious problems that may affect the treatment. If any deficiencies are found, correct them prior to treatment. After the inspection, the official will assist facility personnel in the calibration of the sensors. Refer to the section ***Calibrating the Sensors* on page 6-7-4** for calibration procedures.

Before treatment, the official ensures that the commodity meets the requirements specified in this manual, the certification conditions, the workplan and/or the compliance agreement. These requirements generally include:

- **Fruit size and weight requirements**: Verify the process and/or equipment used to sort the fruit by measuring or weighing the fruit that is to be treated. Weigh and measure the largest fruit per treatment lot. If fruit are found that do **not** meet the size and weight requirements, evaluate the sorting process and/or equipment and resort the fruit.
- **Fruit pulp temperature**: There are no specific pretreatment fruit pulp temperature requirements. However, the temperature of the fruit pulps within the treatment lot should **not** vary by more than 3.0 °C (5.0 °F). The PPQ official verifies that the pulp temperatures meet this requirement prior to treatment.
- **Pest inspection**: The PPQ official conducts pest inspections required by the workplan and/or compliance agreement.

Loading

Load the fruit into containers (crates, lugs, or bins) according to the requirements in the certification conditions or workplan. Generally, these requirements will indicate whether or **not** the fruit must be sorted and the volume of fruit allowed in each container.

Load the containers onto pallets or into cabinets according to the requirements in the certification conditions or workplan. These requirements may specify that containers with larger fruit must be located in the colder areas of the stack or that certain layers of containers are left empty when partial loads are treated.

The sensors are placed in the largest fruit in the treatment lot as it is being loaded into the containers. Insert the tip of the sensor into an area of the fruit pulp that will take the longest to reach treatment temperature. The PPQ official or APHIS designated representative monitors the placement of the sensors and verifies that the probes are placed in the locations required by the certification conditions.

Conducting the Treatment

After all the fruit is loaded into the containers and onto the pallets, and the sensors are properly installed into the heaviest fruit, load the fruit into the chamber. Close and lock the chamber doors to prevent accidental openings. The PPQ official or APHIS designated representative (and the NPPO official, if required by the work plan or compliance agreement) must initial the treatment temperature record and the chamber operator can then initiate the treatment.

During the treatment, the official must monitor the sensor data to ensure the treatment is proceeding in the approved manner. The PPQ official must also check the chamber for leaks or other problems during the treatment.

Verifying the Treatment

The PPQ official or APHIS designated representative must review the treatment temperature record after the treatment is complete. The official must ensure that the temperature and recording interval requirements have been met. Additionally, the official must verify that the requirements for the duration of the run up and dwell times are conducted according to the treatment schedule. Time requirements for the run up and dwell time are continuous. Once the official determines that all the treatment requirements are met, the official must sign and date the treatment record.

Important Treatment Terminology

The following terms are referred to in the treatment schedules:

- **Heat up time:** the minimum time allowed for all the temperature probes to reach the prescribed minimum pulp temperature (may also be referred to as the approach or run-up time)
- **Heat up recording interval:** the time interval required for recording temperatures during the heat up time
- **Minimum air temperature:** the minimum temperature required for the air in the chamber
- **Minimum pulp temperature at end of heat up:** the minimum temperature required for all fruit pulp temperature probes
- **Dwell time:** the length of time all pulp temperature probes must maintain the minimum pulp temperature
- **Dwell recording interval:** the time interval required for recording temperatures during the dwell time
- **Cooling method:** optional and may be either hydrocooled or air cooled

Table 3-5-1 Example of a Treatment Schedule

Heat Up Time:	4 hours
Heat Up Recording Interval:	5 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	47.2 °C/117.0 °F
Dwell Time:	5 minutes
Dwell Recording Interval:	5 minutes
Cooling Method:	Forced air or Hydrocooled

NOTICE

"N/A" in any of the requirements in the Treatment Schedule indicates that PPQ has no requirement.

Post-Treatment Handling

After the treatment is complete, move the fruit from the chamber into the quarantine area. Cool the fruit according to the requirements listed in the treatment schedule.

Record Keeping

Keep all treatment records at the treatment facility for one year after treatment. The facility must also maintain a record of all problems and/or breakdowns and any maintenance performed on the chamber. All the records listed above must be made available to the PPQ official upon request.

Common Problems and Failure Points

If the temperature recording intervals and minimum temperature requirements are **not** met, the treatment fails. The only exception to this is that a sensor may record no data for a single recording interval during the treatment. (Note: This does **not** mean the temperature may be out of range, only that the data may be missing). After reviewing the treatment data, the official should sign and date the data.

If a problem arises during treatment, such as a sensor stops recording data, records above other sensors, appears to be broken, or if the temperature drops below the required temperature, the following actions **must** be taken:

- After the treatment is complete, test the sensor according to calibration procedures.
  - If the sensor **passes** calibration, then there was a problem with the treatment. FAIL the treatment.
  - If the sensor **fails** calibration, then there was a problem with the sensor. PASS the treatment. If there is more than one failed sensor, then fail the treatment.

The facility manager must determine if the fruit will be re-treated or will be removed from the chamber into the non-quarantine area.

3 Nonchemical Treatments

Treatment Manual

Heat • Forced Hot Air • Niger Seed

Contents

Heat Treatment of Niger Seed (*Guizotia abyssinica*)

Niger seed is imported into the United States for bird feed and is frequently contaminated with federal noxious weed seeds. In order to devitalize the weed seeds, the Niger seed is required to undergo heat treatment in accordance with T412 treatment schedule. Conduct the heat treatment in a foreign or domestic APHIS-certified treatment facility.

Minimum Requirements for Heat Treatment Facilities

If the facility is located in the United States, it must be constructed near the port environs (10 miles or less). The facility and equipment must adhere to the following requirements:

- All facilities must comply with treatment schedule T412-a in this Treatment Manual (Refer to ***Certification of Niger seed Treatment Facilities* on page 6-6-1** for certification guidelines)
- All facilities must possess a current work plan or compliance agreement.
- Facility operators or managers must record the following information on each treatment recorder printout:
  - Date
  - Lot number
  - Operator signature

Treatment Requirements

The Niger seed heat treatment schedule requires the seed be treated for a minimum of 15 minutes at 248 °F/120 °C. Determine if the treatment standards are met using the following guidance:

- Examine treatment recorder printout for completion of treatment and verify that the Niger seed was kept at the target temperature for the required time.
- If records indicate that any temperature reading fell below 248 °F/120 °C for 15 minutes, nullify the treatment for that specific lot, correct the reason for the faulty treatment, and retreat the seed.

Documentation Requirements

- Maintain a logbook of all Niger seed treatments.
- Maintain records of equipment breakdowns and repairs, changes, or modifications to the treatment process, facility, and/or equipment

Sanitation and Pest Control

The Plant and Warehouse Premises

Require the facility manager to ensure that there is a cleaning and control program in the plant and/or warehouse and that there are no potential breeding grounds for pests on the premises.

Containers and Packaging

Require the facility manager to ensure that seed containers and/or packaging, whether used or new, is checked and cleaned for pests so that the packages are **not** a source of pests and contamination.

Waste Disposal

To minimize contamination risk and eliminate pest breeding sites, require the facility manager to implement a regular waste program for waste and nonconforming or infested produce.

Post Treatment Requirements

After treatment and cooling, immediately place the Niger seed in new bags or in a storage area only for treated seed. Dispose of the original bags in a manner that will eliminate regulated pests.

- PPQ will sample treated seeds for actionable contaminants according to guidelines in the work plan or compliance agreement or by conducting random inspections and TZ (tetrazolium) tests as needed at the port of entry.

- Label each treated sample with the following information:
  - Bill of lading number
  - Container and lot number
  - Date the sample was taken
  - Date the seeds were treated
  - Origin of seed
  - Vessel name and nationality
- Send the sample to an APHIS-approved testing facility.

When the laboratory results are available, send laboratory results with the above information to the address identified on the work plan or compliance agreement.

3

Treatment Manual

Nonchemical Treatments

Cold Treatment (CT)

Contents

Intransit Cold Treatment in Conventional Vessels, Self-Refrigerated (Integral) Containers, and Warehouses

The use of sustained cold temperatures as a means of insect control has been employed for many years. Rigid adherence to specified temperatures and time periods effectively eliminates certain insect infestations. Treatments may be conducted in warehouses, refrigerated compartments of transporting vessels (Conventional Vessels), containers cooled by the ship's refrigeration system (Container Vessels) or by individually refrigerated containers (Self-Refrigerated/Integral Containers). Information concerning conventional vessels, self-refrigerated containers, and warehouses is found in this chapter.

Only certified USDA representatives have permission to conduct warehouse, vessel and/or container approval tests under the general guidance of CPHST-AQI. The following website provides information for the testing of specific vessels and/or containers:

https://treatments.cphst.org/vessels

Precooling Procedures

Experience with in-transit cold treatments and Computational Fluid Dynamics (CFD) modeling of refrigerated vessel compartments show that the fruit must be precooled at or below the prescribed cold treatment temperature before loading. Otherwise, a large quantity of fruit in the middle of large pallet groups may require a week or more to reach the cold treatment temperature.

Fruit intended for intransit cold treatment must be precooled to the temperature at which the fruit will be treated prior to beginning treatment.

The precooling process cannot be conducted in the in-transit cold treatment conveyance unless authorized by the Executive Director of USDA APHIS PPQ Plant Health Programs.

Conduct random fruit pulp sampling in the precooling location prior to loading in order to verify that the commodity has completed precooling.

Use the following general guidelines for fruit pulp sampling in the precooling location:

- Pulp temperatures will be taken by personnel authorized by APHIS, which includes industry representatives

- Take pulp temperatures by probing the fruit on the periphery of the pallet
  - If pulp temperatures are 0.28 °C (0.5 °F) or more above the temperature at which the fruit will be treated, the pallet will remain in the precooling location for further precooling

Also, sample fruit pulp temperatures **immediately** before the fruit is loaded on the intransit cold treatment conveyance. Take fruit pulp temperatures by probing fruit in the **top** of the pallet. An official authorized by APHIS will sample the fruit pulp temperatures in all sections of the load to verify temperatures have **not** risen appreciably. If the pulp temperatures for the sample are 0.28 °C (0.5 °F) or more above the temperature at which the fruit will be treated, the pallet will be rejected and returned to the precooling location for further precooling until the fruit reaches the treatment temperature.

Initiating Intransit Cold Treatment in Vessels and Containers

For cold treatments conducted in approved vessels and containers, the ship's officers will have already received instructions on the APHIS requirements from their owners. However, a discussion by the authorized APHIS official with these individuals will provide for better understanding and cooperation. Such a discussion should include:

- General treatment procedures in accordance with 7CFR 305.15
- Stowage arrangement
- Temperature sensor and instrument calibration testing
- Treatment conditions

Ensure that there is an adequate communication system in place between personnel in the compartments and the recording room.

Verification of Temperature Recording Equipment

Approved vessels and containers must be capable of maintaining fruit pulp temperatures within the specified CT schedules. To monitor these treatments, they must be equipped with a temperature recording device which meets the approval of **USDA-APHIS-PPQ-S&T-CPHST-AQI**. All approved temperature recording devices must be password protected and tamper-proof and have the ability to record the date, time, sensor number, and temperature during all calibrations and actual treatments.

If APHIS determines that the records and calibrations can be manipulated, the vessel and/or container will be suspended from conducting cold treatments until proper equipment is installed. Submit any changes to the temperature recording and monitoring equipment to

USDA-APHIS-PPQ-S&T-CPHST-AQI for approval before installation in the vessel or container. Compare the existing equipment with the equipment listed at http://treatments.cphst.org/vessels/ to determine if new equipment has been installed that was **not** approved by CPHST-AQI.

Specifications for temperature recording installations and other requirements for approval are discussed in ***Certification of Cold Treatment* on page 6-4-1**. Refer to ***Reference Guide to Commercial Suppliers of Treatment and Related Safety Equipment* on page E-1-1** for a list of approved temperature recorders.

Strip Chart Recorder

Important

Since December 31, 2005, strip chart recorders were no longer acceptable temperature recording devices. Consequently, by December 31, 2008, there should be no strip chart recorders in use for APHIS cold treatment.

Contact CPHST-AQI for approved temperature recording instrumentation.

Data Logger

A sufficient supply of log sheets must be available to provide a continuous record of calibration and treatment temperatures. The instrument should be in operation for at least 30 minutes prior to calibration tests. Examine a completed log sheet printout and the functioning of the visual scanner, the printer, and the high limit setting. Check the log sheets for proper format and serialization. Activate the temperature set-point for an alarm printout to verify that this function is operational.

Important

Data logger installations are utilized to record various components of the vessel's operating systems. Temperature recording is only a part of the record produced. Under CPHST-AQI approval requirements, the log sheets upon which the intransit cold treatment is recorded are generally more detailed in design than the standard commercial log sheet. They are prepared and serialized to facilitate scanning and to provide a level of security against fraudulent records. The USDA log should be printed on separate sheets with no other ship data interspersed. Data loggers are programmed to print out the temperatures above a set limit in a contrasting color. Some instruments print a symbol to indicate this. The limit is set at the time of loading to a temperature level that coincides with the projected treatment schedule.

Calibration of Temperature Sensors

Calibrate all air and pulp temperature sensors in a clean ice water slurry mixture that is at 0 ºC (32 ºF), the freezing/melting point of freshwater.

1. Check individual sensors to verify that they are properly labeled and correctly connected to the temperature recorder. This can be accomplished by hand warming each sensor when its' number appears on the visual display panel of the recording instrument. A temperature change, which can be observed on the instrument, should occur. If the instrument fails to react, the sensor is incorrectly connected or malfunctioning and should be corrected by the instrument representative.

2. Prepare a mixture of clean ice and fresh water in a clean insulated container.
3. Crush or chip the ice to completely fill the container.
4. Add enough water to stir the mixture.
5. Stir the ice and water for a minimum of 2 minutes to ensure the water is completely cooled and good mixing has occurred.
   - ❖ Generally, the ice will occupy approximately 85 percent of the total volume of the container, with the water occupying the remaining space.
6. Add more ice as the ice melts.
7. Stir the ice water slurry to maintain a temperature of 0 °C (32 °F).
8. Submerge the sensors in the ice water slurry without touching the sides or bottom of the container.
9. Stir the slurry mixture again.
10. Continue testing of each sensor in the ice water slurry until the temperature reading stabilizes.
11. Allow at least a 1 minute interval between two consecutive readings for any one sensor; however, the interval **cannot** exceed 5 minutes.
    - ❖ The difference between the two readings **cannot** exceed 0.1°C.
12. Record at least two consecutive readings on a written calibration report. If the two readings are different, test the sensors again and record the temperature.
13. Contact an instrument company representative immediately if the time interval exceeds the normal amount of time required to verify the reading and accuracy of the sensor and recorder system.
    - ❖ The recorder used with the sensors must be capable of printing or displaying on demand and **not** just at hourly intervals.
14. Have the instrument company representative correct any deficiencies in the equipment before certification.
15. Replace any sensor that reads more than plus or minus 0.3 °C (0.5 °F) from the standard 0 ºC (32 ºF).
16. Replace and recalibrate any sensors that malfunction.
17. Determine the calibration factors to the nearest tenth of one degree Celsius.
18. If the temperature recorder microprocessor can be zeroed, tared, or if the calibration factors can be otherwise entered into the recorder microprocessor for automatic adjustment this **must** be done. In this case,

verify that the adjustment factors have been entered or that the recorder was zeroed or tared by the instrument company representative. Enter zero as the calibration factor for each individual probe in the Online 556 database (if the database is **not** used, then enter zero for each individual probe in the written calibration report that is submitted with the shipment.)

19. If the temperature recorder microprocessor cannot be zeroed, tared, or if the calibration factors cannot be entered into the recorder microprocessor memory (so that they are sustained in memory and can be viewed again after all the factors are entered), the calibration factors for each individual probe must be recorded in the online 556 database (if the database is **not** used, then enter the calibration factors for each individual probe on the written calibration report that is submitted with the shipment.)

20. After the calibration factors have been accounted for, no other changes should be made to the temperature recorder microprocessor.

21. Refer to the section on ***Clearance of Cold Treated Shipments* on page 3-7-14** for complete instructions on entering data into the Form 556 or preparing written calibration reports.

Loading of Commodity in Conventional Vessels and Self-Refrigerated (Integral) Containers—General

Important

In countries with which USDA-APHIS has a cooperative agreement, these activities can be conducted by qualified officials from that country. Contact the **USDA-APHIS-PPQ-S&T-CPHST-AQI** for a list of qualified officials.

1. Each compartment or container must contain only one type of fruit loaded in one type of carton.
2. Load fruit directly from the precooling area so fruit temperatures do **not** rise significantly after loading and during the transfer of the container to the vessel.
3. Open the cartons in which the sensors will be located and insert the sensors well into the fruit (**Figure 3-7-1**). The tip of the sensor must **not** extend through the fruit.

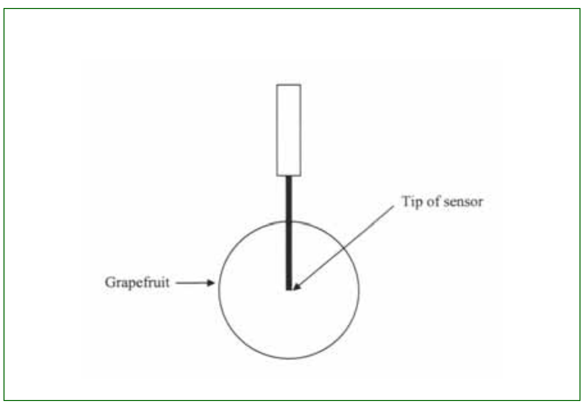


Figure 3-7-1 Proper Placement of Pulp Sensor within Larger Fruit

In the case of small fruit, cover a minimum of two thirds of the tip of the sensor using multiple fruit. If, for example, the fruit is grapes, insert the sensor directly into the grapes in a shis-ka-bob fashion (**Figure 3-7-2**). Completely cover the probe with the top layer of fruit in the top of the box or carton located in the middle of the pallet.

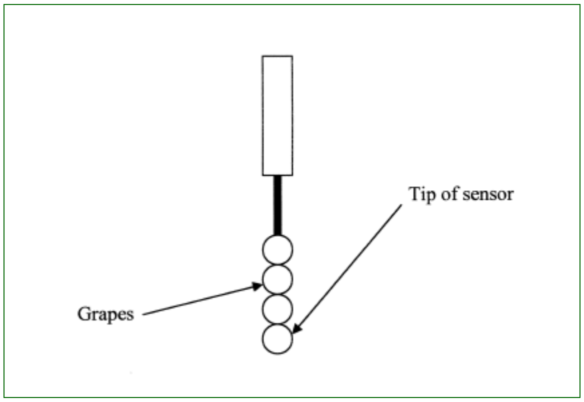


Figure 3-7-2 Proper Placement of Pulp Sensor within Smaller Fruit

4. Securely close the cartons following insertion of the sensors. If the fruit is palletized, it may be necessary to insert the sensor into the fruit from the side of the carton. If the side of the carton or box is opened to insert a sensor, reseal the opened side of the carton or box using tape.

Conventional Vessels

Important

Hanging decks, hatch coamings within vessels and double-stacking of pallets are not approved for intransit cold treatment. The treatment will **not** begin until all double-stacked pallets are reconfigured into a single-stack pallet arrangement and any pallets located in hanging decks or hatch coamings are removed.

Contact **USDA-APHIS-PPQ-S&T-CPHST-AQI** for more information regarding hatch coamings or hanging decks for particular vessels.

There are two sensor types used for the compartments during cold treatment.

- Ambient air sensors—the cables which are attached to the ceiling of the compartment, should be long enough to extend from the ceiling to the floor. Place the sensors on the center line of the vessel approximately 30 centimeters from the ceiling. Attach the sensors in such a way that they do **not** touch the bulkhead and are protected from damage from the cargo. One sensor must be located on the fore and aft bulkheads of each compartment.

  In the case of twin deck compartments, two sensors are required in the upper compartment plus one sensor in the lower compartment. Place the lower sensor on the bulkhead furthest from the cooling unit. Ensure that all sensors are readily detachable and stowed in compartments to protect from damage when **not** in use.

- Fruit pulp sensors—the cables which are attached to the side walls of the compartment must be distributed throughout the compartment so that all areas of the compartment can be reached. The cables should be long enough to extend from the hold walls to three meters beyond the center line of the ship hold.

Placement of Temperature Sensors

All of the sensors for conventional vessels must be located at the mid level of the pallets as depicted in **Figure 3-7-3**. The black circles represent pulp sensors.

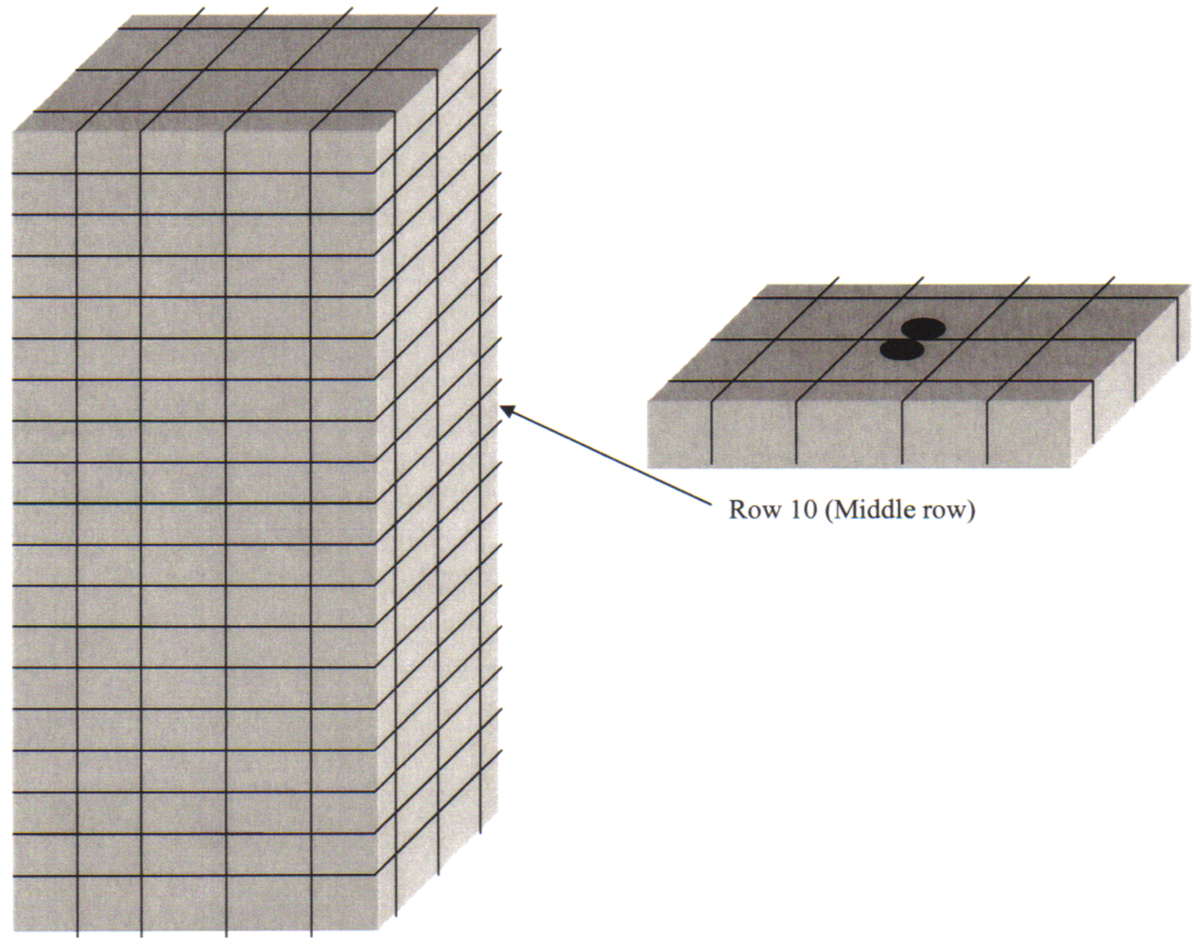


Figure 3-7-3 Fruit stack with middle row temperature probe placement

.

NOTICE

It is highly recommended that more temperature sensors be installed than the minimum number required for each refrigerated compartment. If a sensor malfunctions during a treatment, the certified USDA representative has the option of disregarding it, providing that an additional working sensor is present, and the functional sensors were appropriately placed, certified, and calibrated. Otherwise, the entire treatment must be repeated for the fruit in that compartment.

Self-Refrigerated (Integral) Containers

When loading refrigerated containers, place the warmest fruit in the last quarter of the load (near the back doors of the container), completely cover the floor and ensure that the load is of uniform height.

Place a numbered seal on the loaded container. This must **not** be removed until the load has been cleared at the port of destination.

Use a minimum of three pulp sensors. Place all sensors as far into a box of fruit as possible. Use **Figure 3-7-4** as a general guideline for sensor placement.

- Place the first sensor, labeled USDA1, in a box at the top of the stack of fruit nearest to the air return intake.
- Place the second sensor, labeled USDA2, slightly aft of the middle of the container, halfway between the top and bottom of the stack.
- Place the third sensor, labeled USDA3, one pallet stack in from the doors of the container, halfway between the top and bottom of the stack.

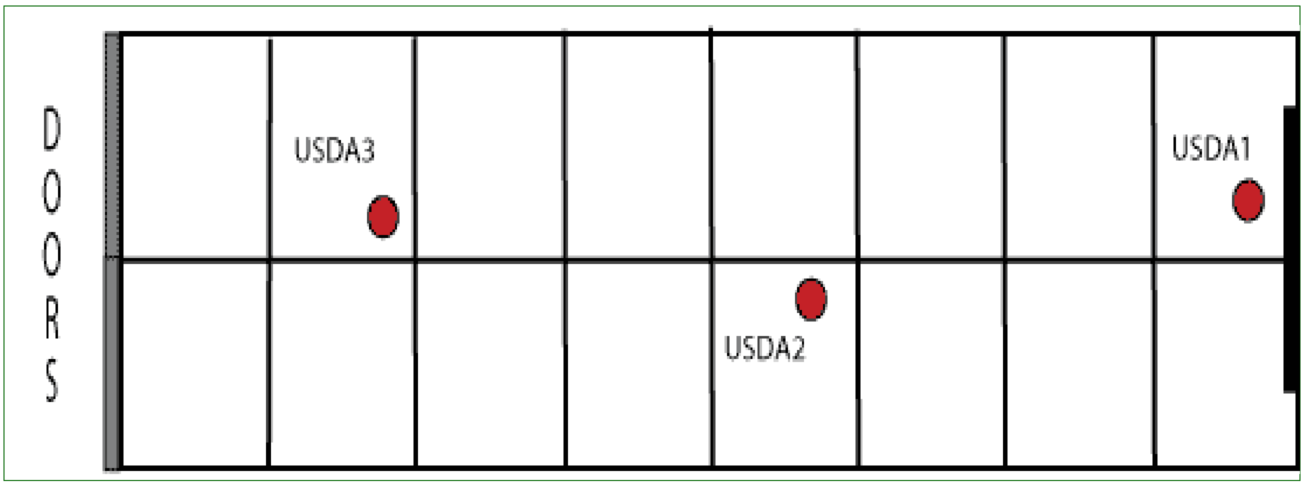


Figure 3-7-4 40 foot Refrigerated Container with 18 Pallets of Fruit (not drawn to scale)

Secure the Load

Place a piece of cardboard that extends from the front edge of the second-to-last pallet row to the back doors on the container floor before the last pallet row is loaded. Once the cardboard is installed properly, load the last pallet row so the pallets rest on top of the cardboard. Place a second piece of cardboard perpendicular to the first piece of cardboard and staple to the cartons in the last pallet row (**Figure 3-7-5**). The placement of the cardboard between the back doors of the container and the last row of pallets aids in maximizing air flow through the pallets. Complete this procedure for all pallets in the last pallet row of the container.

Figure 3-7-5 Proper placement of cardboard between the last pallet row of fruit and the back doors of the container

Treatment Requirements

Temperatures must be recorded at intervals no longer than 1 hour apart. Gaps of longer than 1 hour may invalidate the treatment or cause treatment failure.

Fruit pulp temperatures must be maintained at the temperature specified in the treatment schedule with no more than **0.39 °C (0.7 °F)** variation in temperature between two consecutive hourly readings. Failure to comply with this requirement may result in treatment failure.

The time required to complete the treatment begins when all temperature probes reach the prescribed treatment schedule temperature.

Prepare Documents

Complete the following PPQ forms and worksheets:

- "Calibration of Temperature Probes" record showing the temperature readings as taken from the temperature chart or log sheet during the calibration testing. Record readings to the nearest tenth of one degree. When the loading of each compartment has been completed, obtain the temperature reading of each fruit probe from the temperature recorder and record on this form.
- "Instructions to Captain" form letter.
- "Location of Temperature Sensors" record to show the actual position of each fruit temperature sensor. (See sample form in Appendix A.) This can be accomplished by a written description or by a diagrammatic sketch. Include compartment loading start and end times and dates on the form.
- PPQ Form 203, Foreign Site Certificate (for APHIS pre-inspected fruit)
- Shipper's manifest containing the quantity and kind of commodity.

Distribution of Documents

Conventional Vessels and Self Refrigerated (Integral) Containers

Place the following documents in a sealed envelope and give to the Captain for presentation to the clearance official at the port of arrival.

- Original "Calibration of Temperature Probes"
- Original "Location of Temperature Sensors"
- Copy of the "Instructions to Captain"

For reference purposes, present the Captain with the following documents:

- Original "Instructions to Captain"
- Copy of the "Calibration of Temperature Probes"
- Copy of the "Location of Temperature Sensors"

Send copies of all documents to the clearance official at the port of arrival and to **USDA-APHIS-PPQ-S&T-CPHST-AQI**.

Clearance of Cold Treated Shipments

The CPHST-AQI is in the process of designing electronic versions of all required cold treatment documentation. In the future the forms that are filled out overseas (excluding the preclearance forms) will be entered on-line through a secured website so that the port of arrival will be able to view all required documentation before the certified vessel or container undergoing intransit cold treatment arrives at a U.S. port of entry. Until the new database and electronic forms are finished, continue following the instructions listed below.

Off-loading of self-refrigerated containerized fruit that is under treatment must be accomplished rapidly. Containers must be off-loaded and treatment reconvened within 2 or 3 hours from the time the container was disconnected from the refrigerating unit. The pulp sensors should never exceed the maximum allowable treatment temperature.

Observe the stacking pattern. Double stacking is **not** permitted. Do **not** release the shipment if the pallets have been double stacked.

Conventional Vessels

The “Calibration of Temperature Sensors” and “Location of Portable Sensors” documents from the country of origin should have been received at the port of entry prior to the arrival of the carrying vessel.

The document, “Calibration of Temperature Sensors”, is required for all shipments and includes information regarding the loading date and location of temperature sensors within the commodity, as well as calibration correction factors for every sensor.

Check the CPHST-AQI web site (http://treatments.cphst.org/vessels/) to familiarize yourself with the compartment layout.

Check the documents, and any accompanying correspondence for comments relating to deficiencies noted at origin. The documents must bear the signature of an APHIS-approved official or of an authorized official of the exporting country. A list of authorized names and signatures for each country is on file at CPHST-AQI and is available upon request.

Inform shipping line officials and pier supervisors of the quarantine safeguards to be observed pending clearance. The authorized APHIS official boarding the vessel must have several calibrated thermometers.

PPQ Form 556, In Transit Cold Treatment Report

Complete PPQ Form 556, In Transit Cold Treatment Report. Record the date and time of completion of each compartment and the officer's signature on the temperature chart or log sheet. Do **not** add fruit to the compartment after loading has been completed.

Complete the entries on the PPQ Form 556 during the actual performance of each step of the clearance procedure. The PPQ Form 556 instructions provide for a progressive clearance in the event that treatments are **not** completed before a vessel sails for a second U.S. port.

The Officer responsible for a U.S. vessel is typically the Chief Engineer or Reefer Engineer. The Officer responsible for a Foreign Flag vessel is typically the Chief Officer or Captain.

Inform the ship's officer to withhold discharging the treated commodity until clearance has been completed.

Obtain the clearance officer's copy of the calibration documents from ship's officer (Record in blocks 1-6, and 10).

Proceed to the data logger with the ship's officer and retrieve a temperature printout.

Review the temperature chart.

NOTICE

If the initial treatment period is broken because of excessive temperatures, failure of the recorder, or improper procedure, and the treatment is later restarted, enter the date and time of restart on the second line of item 28. Air temperatures may occasionally exceed treatment temperatures during defrost cycles; however, fruit temperatures should **not** rise appreciably during this time and must **not** exceed the temperature listed in the schedule. During non defrost times, the temperatures of the air sensors should never exceed the maximum allowable treatment temperature. For each compartment of a hold, the hourly sensor printouts will be examined by a PPQ Officer at the port of entry. Based on these records, the PPQ Official will make a determination as to whether to accept the treatment as satisfactory. In case of dispute, the ultimate decision will be made by the Officer in Charge (PPQ), who will take all factors into consideration. Occasionally, for example, there are cases in which one or two sensors in a compartment mechanically malfunctioned during the voyage, due to situations beyond the ship's control (e.g., rough seas). This is generally excusable, as long as the other sensors in the same compartment showed no readings higher than the cold treatment schedule allows. If, however, the ship stopped at another port while in route to the discharge destination in the U.S., but failed to have the facility sensor(s) repaired and recalibrated, it may be considered negligence on the part of the shipping line. The fruit from such refrigerated compartments would have to be retreated (in a cold warehouse) to be eligible for entry.

If a sensor is reading consistently high, it should be tested by using the ice-water bath technique. If this sensor proves to be accurate (i.e, readings within plus or minus 0.3 ºC from zero) then it must be assumed that the high readings obtained in the fruit were indeed accurate, which would be sufficient grounds for rejection. For additional evidence, the PPQ Official can also obtain independent fruit pulp readings from a hand-held portable temperature-sensing instrument in the area of the load where high readings were obtained form the ship's sensor(s).

The vessel is permitted to store logged temperatures on magnetic media instead of printed on paper. However, the stored data must be printed in the presence of the authorized APHIS official.

Assemble log sheets so that a review can be made starting at the beginning of the temperature record. Check the calibration record; compare the actual calibration readings on log sheets with the calibration data on the calibration document (Record in block 23).

NOTICE

Many data logger installations are programmed to record temperature variations to one-hundredth of a degree centigrade (0.01°C). With this high resolution of temperature readings, a deviation of up to three-hundredths of a degree can be expected from consecutive readings in a standard ice water test. Accordingly, calibration certifications that are acceptable under our accuracy requirements show either the average of two consecutive calibration readings or two consecutive readings that are within three-hundredths of a degree centigrade of each other. Report deviations beyond this standard.

Review the log sheets up to when the loading of the compartment was complete. Determine the maximum and minimum fruit temperature at the time the sensors were inserted (Record in blocks 24, 25, and 26).

Continue reviewing the log sheets through the precooling period to the time when treatment commenced. Note abnormalities in the temperature readings that could indicate an irregularity in the treatment process (Record in block 27).

Review the treatment portion of the log sheets for irregularities and excessive temperatures (Record in block 28).

NOTICE

If the initial treatment period is broken because of excessive temperatures, failure of the data logger, or improper procedure, and the treatment is later restarted, enter the date and time of restart on the second line of item 28.

Clearance Action by Authorized APHIS Official

The authorized APHIS official will:

- Release shipment for discharge if all requirements have been met and notify ship's officers, pier superintendents, and Customs and Border Protection Agriculture Inspector(s).
- Hold shipment pending further evaluation if total effects of irregularities are **not** consistent with treatment requirements (Contact the supervisor regarding the reasons for holding the shipment).
- Record all exceptions in narrative form and attach to the clearance report.

Inspection of Load and Compartments

Time permitting, examine the load and compartments during and after unloading. Observe sensor locations, labeling, and physical condition and report irregularities.

Distribution of Clearance Documents

After final clearance, the completed PPQ Form 556 with supporting documents are to be distributed as follows:

- Keep copies of the PPQ Form 556 and the chart printouts at the port of arrival.
- Send copies of the PPQ Form 556 to **USDA-APHIS-PPQ-S&T-CPHST-AQI**.

Self-Refrigerated (Integral) Containers

Obtain the temperature printout and match it with the corresponding "Location of Temperature Sensors" and "Calibration of Temperature Probes" documents by using the container or recorder number. Check the documents and any accompanying correspondence for comments relating to deficiencies noted at origin. They must bear the signature of a PPQ Official or of an authorized official of the exporting country.

Compare the printout with the loading document to ensure the calibration factors, recorder start time, recorder serial number and recorder start date are the same. If the information is **not** the same, there must be proof that the equipment was exchanged and calibrated at the country of origin. Undocumented discrepancies will be cause for treatment failure.

Using PPQ Form 556, complete blocks 1-6 and 10. Record the container number in block 24. Six containers can be cleared per form.

Record the maximum and minimum fruit temperatures from the printout at time of loading (Blocks 25 and 26).

Review the temperatures and mark the printout where treatment commences at each temperature according to the appropriate treatment schedule. Determine date and time each treatment commenced (Block 27).

Review the treatment portion of the printout for irregularities and excessive temperatures (Block 28). If necessary, subtract or add correction factors to obtain the true temperature.

NOTICE

If the initial treatment period is broken because of excessive temperatures, failure of the data logger, or improper procedure, and the treatment is restarted, enter the date and time of restart on the second line of Block 27.

Determine the amount of time needed to complete the treatment if the treatment has **not** been completed, and report this to the persons responsible for the container. Check the temperature recordings to determine if the treatment has been completed at the end of the predicted completion period.

Record the last readings of the printout in Block 30. Investigate discrepancies. Submit documentation even if the treatment was negated.

Cold Treatment in Refrigerated Warehouses

The warehouse must be approved by PPQ (see Certifying Facilities).

The shipment must move directly from the port of entry to the cold storage warehouse with no diversion or delay.

The warehouse must provide the necessary security for safeguarding each shipment.

The unloading of containers which arrive at the warehouse under seal must be conducted under PPQ supervision.

Initiating the Cold Treatment

The procedures for the verification of recording equipment and calibration of temperature sensors are the same as those outlined for vessels in ***Intransit Cold Treatment in Conventional Vessels, Self-Refrigerated (Integral) Containers, and Warehouses* on page 3-7-2**, ***Initiating Intransit Cold Treatment in Vessels and Containers* on page 3-7-3**, ***Verification of Temperature Recording Equipment* on page 3-7-3** and ***Calibration of Temperature Sensors* on page 3-7-4**. These activities must be performed under the direction of an authorized APHIS official.

Arrange stowage to provide for adequate air distribution throughout the shipment, and to allow for the sampling of pulp temperatures in any desired location. To accomplish this, leave aisles between rows of pallets, with the aisles parallel to the air flow. Allow space between pallets. Double stacking of pallets is **not** allowed; therefore treatments will **not** begin until pallets are reconfigured to a single stacked pallet arrangement. However, rack systems are acceptable provided they have been approved by CPHST-AQI.

Placement of Temperature Sensors:

After loading is completed, take fruit temperatures at various locations throughout the load to determine the location of the warmest fruit. Place temperature sensors throughout the load, being sure to place sensors in the warmest areas. Under some conditions, additional air circulation will be required to cool the shipment uniformly. The use of additional fans or blowers will depend on the particular circumstances at the time of treatment.

Placement of sensors should be under the direction of an authorized APHIS official. Insert the sensor well into the fruit. The tip of the sensor must **not** extend through the fruit (**Figure 3-7-1 on page-3-7-7**). If necessary (in the case of small fruit), the sensor should penetrate multiple fruit (**Figure 3-7-2 on page-3-7-8**). The number and location of the temperature sensors are determined during warehouse certification (**Figure 3-7-6**).

Cubic Feet	Cubic Meters	Number of Pallets	Number of Air Sensors	Number of Pulp Sensors	Total Number of Sensors
0 to 10,000	0 to 283	1 - 100	1	2	3
10,001 to 20,000	284 to 566	101 - 200	1	3	4
20,001 to 30,000	567 to 849	201 - 300	1	4	5
30,001 to 40,000	850 to 1132	301 - 400	1	5	6
40,001 to 50,000	1133 to 1415	401 - 500	1	6	7
50,001 to 60,000	1416 to 1698	501 - 600	1	7	8
60,001 to 70,000	1699 to 1981	601 - 700	1	8	9
70,001 to 80,000	1982 to 2264	701 - 800	1	9	10
80,001 to 90,000	2265 to 2547	801 - 900	1	10	11
90,001 to 100,000	2548 to 2830	901 - 1000	1	11	12
Over 100,000	>2830	1000 +	Must be approved by CPHST AQI		

Figure 3-7-6 Number of Sensors in a Warehouse

Quick Freeze Guidelines

Freezing will ruin the market quality of most fresh fruits and vegetables, except for thick-skinned items such as durian and coconut. Generally, this treatment is used on fruits and vegetables that will be processed into another form (e.g. for puree, juice, or mashed vegetables).

Freezing is an acceptable method of mitigating the pests listed in the schedule. Treatment may result in commodity destruction. APHIS is not liable for damage to the commodity. Importers that choose freezing as a treatment do so at their own risk.

Operational procedures and equipment specifications are under development.

Contact Information

USDA-APHIS-PPQ-S&T-CPHST-AQI

1730 Varsity Drive, Suite 300
Raleigh, NC 27606-5202
Email: CPHST.TQAU@aphis.usda.gov

Phone: 919-855-7450
Fax: 919-855-7493

Nonchemical Treatments

Irradiation

Contents

Introduction

This chapter provides background and general information for the use of irradiation as a phytosanitary treatment of plant pests. Irradiation was first approved by APHIS in 1997 for use on papayas from Hawaii for export to the U.S. mainland, Guam, Puerto Rico, and the U.S. Virgin Islands. In 2002, irradiation was approved as a phytosanitary treatment for all admissible fresh fruits and vegetables from all countries.

Authorities and Other Responsible Parties

- 7CFR 305.31 through 305.9
- Food and Drug Administration (FDA)

  The FDA is responsible for determining the labeling requirements for irradiated food.
- National nuclear regulatory authority of the country where the facility is located
- International Standard for Phytosanitary Measures #18 (ISPM)

  This International Standard provides technical guidance on the specific procedures for the application of ionizing radiation as a phytosanitary treatment for regulated pests or articles.

Treatment Objectives

The objective of phytosanitary treatments is to prevent the introduction or spread of regulated pests. As a phytosanitary treatment, irradiation may reduce the risk of introduction by achieving certain responses, known as “endpoints,” in the targeted pest(s). These endpoints are:

- Inability to emerge or fly
- Inactivation or devitalization (seeds may germinate but seedlings do not grow; or tubers, bulbs or cuttings do not sprout)
- Mortality
- Sterility (inability to reproduce)

Efficacy

Unlike the Probit 9 mortality required for many chemical and nonchemical quarantine treatments, the use of irradiation as a phytosanitary measure presents a new paradigm to PPQ. The officer inspecting the treated consignment upon arrival in the U.S. may encounter living insects. However, this is to be expected since the treatment endpoint may not necessarily be mortality.

Treatment

There are three types of ionizing radiation:

- Electrons generated from machine sources up to 10 MeV (eBeam)
- Radioactive isotopes (gamma rays from cobalt-60 or cesium-137)
- X-rays (up to 5 MeV)

The unit of measure for absorbed dose from any type of radiation is gray (Gy).

Modified atmospheres, such as low oxygen, may reduce treatment efficacy at a prescribed dose. Do **not** treat commodities that are in an oxygen-deficient environment.

Treatment procedures should also ensure that the minimum absorbed dose (Dmin) is fully attained throughout the commodity to provide the prescribed level of efficacy. Owing to the differences in the configuration of lots being treated, higher doses than the Dmin may be received by some of the commodities to ensure that the Dmin is achieved throughout the configured commodity. All treatments must be certified by verifying Dmin with approved dosimetry systems.

The minimum absorbed dose for the most-tolerant unmitigated pest is required if more than one pest is present. Refer to ***Table 5-2-2*** on **page 5-2-70** to determine the required minimum absorbed dose. For example, if a shipment of grapes is infested with both Mediterranean fruit fly and codling moth, the commodity would be irradiated using a minimum dose of 200 Gy.

Dosimetry

Dosimetry is the system used by the facility to determine absorbed dose. The absorbed dose is a quantity of radiation energy (measured in Gray (Gy)) absorbed per unit of mass of the commodity.

The dosimetry system should be calibrated in accordance with international standards or appropriate national standards (e.g. Standard ISO/ASTM 51261 *Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing*).

Dose Mapping

Prior to routine treatments, the region(s) of lowest and highest dose absorbance must be mapped for each treatment configuration. Configurations may be defined by a variety of criteria which may vary by facility. Factors that affect dose mapping commonly include:

- Density and composition of the material treated
- Orientation of the product, stacking, volume and packaging
- Shape and/or size

Dose mapping of the product in each geometric packing configuration, arrangement and product density that will be used during routine treatments should be required by APHIS prior to the approval of a facility for the treatment application. Only the configurations approved by the APHIS should be used for actual treatments.

The data obtained from the dose mapping is used to determine the proper number and placement of dosimeters during routine operations.

Facility Approval

Chapter 6-8 of this manual covers the requirements for Irradiation facility approval (***Certifying Irradiation Treatment Facilities*** on **page 6-8-1**).

Documentation

The tracking and reporting of an irradiation treatment is critical to the integrity of the entire irradiation process. Treatment failure is linked to non-compliance, not pest detection. Consequently, an electronic database is being developed to standardize data entry, accurately and quickly produce data summaries and analysis, and allow access to a geographically diverse group of people.

Until this electronic database is fully operational, documentation requirements for precleared articles include the completion of the PPQ Form 203, Foreign Site Certificate of Inspection and/or Treatment.

Important

The Irradiation Reporting and Accountability Database (IRAD) is a component of the Commodity Treatment Information System (CTIS) developed by USDA-APHIS-PPQ-CPHST-AQI. Access to this web-based system will be permitted depending on the user's specific role or function in the irradiation process. CPHST-AQI will assign individual usernames and passwords.

Terminology

absorbed dose—Quantity of radiation energy (in gray) absorbed per unit of mass of a specified target [ISPM No. 18]

dose mapping—Measurement of the absorbed dose distribution within a process load through the use of dosimeters placed at specific locations within the process load [ISPM No. 18]

dosimeter—A device that, when irradiated, exhibits a quantifiable change in some property of the device which can be related to absorbed dose in a given material using appropriate analytical instrumentation and techniques [ISPM No. 18]

dosimetry—A system used for determining absorbed dose, consisting of dosimeters, measurement instruments and their associated reference standards, and procedures for the system's use [ISPM No. 18]

gray (Gy)—Unit of absorbed dose where 1 Gy is equivalent to the absorption of 1 joule per kilogram (1 Gy = 1 J.kg-1) [ISPM No. 18]

ionizing radiation—Charged particles and electromagnetic waves that as a result of physical interaction create ions by either primary or secondary processes [ISPM No. 18]

irradiation—Treatment with any type of ionizing radiation [ISPM No. 18]

minimum absorbed dose—The localized minimum absorbed dose within the process load [ISPM No. 18] (Dmin)

radura—internationally recognized symbol used to indicate when a food product has been irradiated

4

Treatment Manual

Residue Monitoring

Overview

Contents

Overview

Methyl bromide fumigants, except those with “Q” labels, are subject to requirements of the FIFRA Section 18 Quarantine Exemption. When commodities intended for food or feed are fumigated with methyl bromide under the FIFRA Section 18 Quarantine Exemption, one additional EPA requirement must be met: PPQ must monitor aeration by sampling the gas concentration to determine when a commodity may be released.

NOTICE

Currently, Plant Protection and Quarantine (PPQ) is **not** taking samples of commodities for residue monitoring. However, if residue monitoring becomes necessary, this section provides guidelines for taking samples that will be used for monitoring fumigant residues.

In the past, PPQ used residue monitoring to comply with the Environmental Protection Agency’s (EPA’s) guidelines for fumigation of edible food or feed products conducted under a Section 18 Quarantine Exemption. PPQ took and analyzed samples of fumigated commodities, and they reported the resulting data yearly to EPA. When a fumigation was conducted under a Section 18 Quarantine Exemption, samples were taken only when the commodity would be eaten by people or fed to animals. When the commodity would **not** be used for food or feed, PPQ did **not** take samples.

For example, if thyme would be used as an herb and fumigated under the schedule (T101-n-2), PPQ would sample the commodity because it would be eaten. On the other hand, if that same thyme were treated but imported as a cut flower, sampling would be unnecessary because it would be used for decoration—**not** eating.

4

Treatment Manual

Residue Monitoring

Instructions for Collecting, Packaging, and Shipping Residue Monitoring Samples

Contents

Important Information

Currently, Plant Protection and Quarantine (PPQ) is **not** taking samples of commodities for residue monitoring. However, if residue monitoring becomes necessary, this section provides guidelines for taking samples that will be used for monitoring fumigant residues.

Safety

Pretreatment samples will be shipped with dry ice. Be sure to store dry ice in well-ventilated areas and to transport dry ice and samples packed in dry ice in well-ventilated containers. Wear gloves when handling dry ice. For detailed information, see ***Hazard Communication Standard* on page 7-1-1**.

The Department of Transportation (DOT) considers dry ice a hazardous material and requires that aircraft record the amount of dry ice carried in the cargo hold. Amounts of 5 pounds or less are **not** stringently regulated; however, include the weight of dry ice on the shipping label. In addition, some overnight delivery companies have restrictions on shipping dry ice. Equip shipping containers with loose-fitting lids to prevent an explosive release of sublimating carbon dioxide. Identify dry ice as ORM-A on the shipping label. Also indicate on the label that the package contains diagnostic specimens.

Collecting the Sample

You must take a sample prior to treatment (pretreatment) and after aeration is completed (post-treatment). To avoid contaminating the sample, handle it as little as possible. Take pretreatment and post-treatment samples from the same general location within a given lot (i.e., the same bags, boxes, or other containers).

Some ports receive commodities several times a month. For example, the port of Ft. Lauderdale received 20 shipments of chayote in October 1992. These shipments need **not** be sampled each time. For frequently received commodities, ports should develop a routine sample collection plan, such as one sample collected per week. However, when a new commodity is received or a commodity is received infrequently (once a week or less), collect a sample each time the commodity is treated.

Pretreatment Sample

1. Collect a minimum of 450g (approximately 1 lb.) except for herbs of which you need to collect 150 grams (approximately one-third pound). If you are collecting fruits or vegetables that are heavy (for example grapefruit or yams), be sure to collect at least two pieces of produce that weigh 450g.
2. Place these samples in containers with dry ice.
3. Ship the pretreatment samples separately from post-treatment samples.

Post-Treatment Samples

1. Collect a minimum of 450g (approximately 1 lb.) except for herbs of which you need to collect 150g (approximately one-third pound). If you are collecting fruits or vegetables that are heavy (for example grapefruit or yams), be sure to collect at least two pieces of produce that weigh 450g.
2. Ship the post-treatment samples separately from the pretreatment samples and in accordance with standard shipping practices. If the samples require refrigeration, then ship the samples with wet ice or ice packs. If the samples are normally shipped at ambient temperature (e.g., yams), ship them without ice.

Labeling the Sample

Label each sample container with the State, county, date, and name of contents and whether the sample is “pre” or “post” treatment. For this label, use waterproof ink on a strip of masking tape or other label material. Be sure to attach the label before leaving the sampling site. Securely fasten a plastic envelope containing the yellow copy of the APHIS Form 2061 to the side of the sampling container. Label this envelope with the same information that you placed on the sample container (State, county, date, and name of contents and whether sample was “pre” or “post” treatment).

Storing the Sample

Immediately place the samples in a freezer or refrigerator until ready to package the samples for shipping.

Shipping Samples

Quarantine Requirements

Contact the State Plant Health Director to determine where to ship the samples. Ship all samples in leakproof, double sealed containers. Ensure the pretreatment sample is secure since it does **not** meet entry requirements for the United States.

Ship samples in coolers with dry ice packed above the samples. The lid of the cooler should be loose fitting to allow gasses to escape. Ship the samples using the contract overnight delivery service or the U.S. Postal Service Overnight Delivery.

5

Treatment Manual

Treatment Schedules

Index to Schedules

Contents

5

Treatment Manual

Treatment Schedules

T100 - Schedules for Fruit, Nuts, and Vegetables

Contents

Reporting Commodity Injury

Record any new or unusual observations relating to injury of commodity and report them to Quarantine Policy, Analysis and Support (QPAS) in Riverdale. Give pertinent details of the treatment and conditions regarding its application. In appraising the effect of a particular treatment, take care to distinguish between the actual or apparent effects directly attributable to the treatment and those relating to factors or conditions not subject to PPQ control.

Commodities in the T100 series are intended for consumption as food or feed. These commodities may have to be treated with methyl bromide to control a pest.

FIFRA Section 18 Exemption

Methyl bromide fumigants, except those with “Q” labels, are subject to requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Section 18 Quarantine Exemption. When commodities intended for food or feed are fumigated with methyl bromide under the FIFRA Section 18 Quarantine Exemption, one additional EPA requirement must be met: PPQ must monitor aeration by sampling the gas concentration to determine when a commodity may be released.

In this manual, fumigation schedules under the FIFRA Section 18 Quarantine Exemption are identified by the following note:

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

Determine the Correct Label for Fumigation

Always use the label of the fumigant to determine if the commodity can be treated. Fumigation schedules in this publication are intended to clarify and expand commercial labels for methyl bromide. The EPA only authorizes fumigation for commodities that are listed on the label of the gas being used for the fumigation. Also, to comply with State regulations, a fumigant must be registered in the State where it is being used.

Although the EPA only authorizes the use of a pesticide on a crop, animal, or site that is listed on the label of a pesticide, specific pests do not have to be listed on the label to use the pesticide. An amendment to FIFRA in 1978 permits the use of a pesticide to control a pest not on the label if the application is to a crop, animal, or site specified on the label, unless mentioned otherwise.

How Fruits and Vegetables Are Listed

Fruits and vegetables that are to be fumigated with methyl bromide (T101s) will be listed in alphabetical order. Each schedule will have an assigned letter, e.g., Apples T101-a-1, Zucchini T101-h-3. For fruits and vegetables that require treatment as a condition of entry, refer to the Fruits and Vegetables Import Requirement database for the specific treatment.

T101—Methyl Bromide Fumigation

T101-a-1 Apple and Pear[1]

Pest: External feeders

Treatment: **T101-a-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

T101-a-3 Apricot[2], Peach, Plum, Nectarine

Pest: External feeders

Treatment: **T101-a-3** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

1 Fumigation may cause **severe** damage to Chinese, Japanese, Asian and Sand Pears. Obtain the importer's consent before fumigation.

2 Pluots and plumcots are considered hybrids of apricots and plums and can be treated using T101-a-3 provided they are treated as a **Section 18 Crisis Exemption**.

T101-b-1 Asparagus

Pest: External feeders such as Noctuidae spp., *Thrips* spp. (except *Scirtothrips dorsalis* from Thailand), *Copitarsia* spp.

Treatment: **T101-b-1** MB (“Q” label only) at NAP—tarpaulin or chamber..

NOTICE

Fumigation may cause damage and a reduction in shelf life. Obtain the importers consent before fumigation.

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2.5 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2.0 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3.0 lbs	38	29
40-49 °F	4.0 lbs	48	38

Important

Asparagus can be fumigated with T101-b-1 in those states listed in the PPQ 2ee recommendation: California, Florida, Georgia, Illinois, New Jersey, New York, and Texas. In these states, aeration is the fumigator’s responsibility.

If asparagus is to be fumigated in states other than CA, FL, GA, IL, NJ, NY, and TX, contact USDA-APHIS-PPQ at (301)851-2312 or (301)851-2243.

T101-b-1-1 Asparagus from Thailand, Australia, and New Zealand

Pest: *Scirtothrips dorsalis* (Thailand), *Halotydeus destructor* (Australia) (New Zealand)

Treatment: **T101-b-1-1** MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	2.5 lbs	32	24
70-79 °F	3 lbs	38	29
60-69 °F	4 lbs	48	38

T101-c-1 Avocado (from Hawaii, Israel, or the Philippines)

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: **T101-c-1** MB at NAP—tarpaulin or chamber

This treatment is marginal as to host tolerance and shipper should be warned of possible injury. Treatment approved for issuance of 318.13-4e certification.

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	4 hrs
70 °F or above	2 lbs	26	16	14

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

Alternate Treatment—Fumigation plus refrigeration T108

T101-d-1 Banana

Pest: External feeders such as Noctuidae, *Thrips* spp., *Copitarsia* spp.

Treatment: **T101-d-1** MB at NAP—tarpaulin or chamber

This treatment is marginal as to host tolerance and shipper should be warned of possible injury.

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-e-1

Bean (except for faba bean), dry

Pest: Bruchidae (seed beetles)

Treatment: **T101-e-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs	4 hrs
70 °F or above	3 lbs	38	—	24	—	—	—
60-69 °F	3 lbs	38	29	—	24	—	—
50-59 °F	3 lbs	38	29	—	—	24	—
40-49 °F	3 lbs	38	29	—	—	—	24

see also T101-k-2 or T101-k-2-1 for fresh beans

T101-g-1

Beet

Pest: Internal feeders

Treatment: **T101-g-1** MB chamber, 15" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90 °F or above	2 lbs	2 hrs
80-89 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	3.5 hrs

NOTICE

As of October 2008, **no commercial** chambers in the United States are approved for the vacuum fumigation of imported commodities. If vacuum treatment is required as a **condition of entry**, the consignment must be destroyed, reexported or returned to country of origin.

Beet

T101-g-1-1

Pest: External feeders

Treatment: **T101-g-1-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	3 hrs	3.5 hrs	4 hrs
90 °F and above	2 lbs	26	19	19	—	—
80-89 °F	2.5 lbs	32	24	24	—	—
70-79 °F	3 lbs	38	29	24	—	—
60-69 °F	3 lbs	38	29	—	24	—
50-59 °F	3 lbs	38	29	—	—	24

T101-h-1

Blackberry

Pest: External feeders such as Noctuidae, *Thrips* spp., *Copitarsia* spp., Pentatomidae, and *Tarsonemus* spp.

Treatment: **T101-h-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-i-1

Blueberry

Pest: External feeders

Treatment: **T101-i-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19

T101-i-1-1

Blueberry

Important

Lobesia botrana (European grapevine moth) has been added to this treatment schedule as the result of an emergency action required by PPQ in order to mitigate the pest risk. The emergency action is an interim measure and is pending final regulatory approval. (Federal Order DA-2013-56)

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Anastrepha fraterculus* (South American fruit fly), and *Lobesia botrana* (European grapevine moth)

Treatment: **T101-i-1-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	3.5 hrs
70 °F or above	2 lbs	26	22	21

T101-i-1-2

Blueberry

Important

Lobesia botrana (European grapevine moth) has been added to this treatment schedule as the result of an emergency action required by PPQ in order to mitigate the pest risk. The emergency action is an interim measure and is pending final regulatory approval. (Federal Order DA-2013-56)

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Anastrepha fraterculus* (South American fruit fly), and *Lobesia botrana* (European grapevine moth)

Treatment: **T101-i-1-2** MB at NAP—chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Exposure Period
60 °F or above	2.0 lbs	3.5

T101-i-1-3 Blueberry

Pest: *Lobesia botrana* (European grapevine moth)

Treatment: **T101-i-1-3** MB at NAP—tarpaulin
The yellow and black colors of this schedule indicates that the authority to conduct the treatment comes from an emergency action required by PPQ in order to mitigate the pest risk. (Federal Order DA-2014-03) The emergency action is an interim measure and is pending final regulatory approval.

Fumigate after cold storage (34 °F or lower) for a minimum of 10 days.The cold storage is not subject to verification by PPQ nor CBP and is not a quarantine treatment.

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	3 hrs
40–69 °F	4.0	55	45

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

CAUTION

Phytoxicity is unknown. Obtain the importer’s consent before fumigation.

T101-i-1-4 Blueberry

Pest: *Lobesia botrana* (European grapevine moth)

Treatment: **T101-i-1-4** MB at NAP—chamber
The yellow and black colors of this schedule indicates that the authority to conduct the treatment comes from an emergency action required by PPQ in order to mitigate the pest risk. (Federal Order DA-29014-03) The emergency action is an interim measure and is pending final regulatory approval.

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period (hours)
50–59 °F	3.5 lbs	3.0
40–49 °F	4.0 lbs	3.0

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

CAUTION

Phytoxicity is unknown. Obtain the importer’s consent before fumigation.

T101-n-2 Broccoli (*Brassica oleracea* var. *botrytis*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-n-2 Broccoli, Chinese (gai lon) (*Brassica albogiabra*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-n-2 Broccoli raap (rapini) (*Brassica campestris*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-n-2

Brussels sprouts (*Brassica oleracea* var. *gemmifera*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-j-1

Cabbage

Includes both European and Chinese cabbage

Pest: External feeders

Treatment: **T101-j-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

For other *Brassica* spp., use the leafy vegetable schedule, T101-n-2

T101-n-2

Cabbage (*Brassica oleracea*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-n-2

Cabbage, Chinese (bok choy) (*Brassica chinensis*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-n-2

Cabbage, Chinese (napa) (*Brassica pekinensis*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-n-2

Cabbage, Chinese mustard (gai choy) (*Brassica campestris*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-k-1

Cantaloupe

Pest: External feeders

Treatment: **T101-k-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above*	1.5 lbs	19	14
70-79 °F*	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

* Use “MB 100” at 70 °F or above, use MB “Q” label at 40 °F or above.

For other melons, see T101-o-2

T101-l-1

Carrot

Pest: External feeders

Treatment: **T101-l-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	3 hrs	3.5 hrs	4 hrs
90 °F and above	2 lbs	26	19	19	—	—
80-89 °F	2.5 lbs	32	24	24	—	—
70-79 °F	3 lbs	38	29	24	—	—
60-69 °F	3 lbs	38	29	—	24	—
50-59 °F	3 lbs	38	29	—	—	24

T101-m-1

Carrot

Pest: Internal feeders

Treatment: **T101-m-1** MB, chamber, 15" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90 °F or above	2 lbs	2 hrs
80-89 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	3.5 hrs

NOTICE

As of October 2008, **no commercial** chambers in the United States are approved for the vacuum fumigation of imported commodities. If vacuum treatment is required as a **condition of entry**, the consignment must be destroyed, reexported or returned to country of origin.

T101-n-1 Cassava (manihot and yuca)

Pest: External feeders and hitchhikers[3]

Treatment: **T101-n-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate ($lb/1,000\ ft^3$)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	3 hrs	3.5 hrs
90 °F or above	2 lbs	26	19	19	—
80-89 °F	2.5 lbs	32	24	24	—
70-79 °F	3 lbs	38	29	24	—
60-69 °F	3 lbs	38	29	—	24

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-n-2 Cauliflower (*Brassica oleracea* var. *botrytis*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate ($lb/1,000\ ft^3$)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

3 T101-n-1 should NOT be used for snails, but can be used for slugs.

T101-n-2 Cavalo broccolo (*Brassica oleracea* var. *botrytis*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-n-1 Celeriac (celery root)

Pest: External feeders

Treatment: **T101-n-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	3 hrs	3.5 hrs
90 °F or above	2 lbs	26	19	19	—
80-89 °F	2.5 lbs	32	24	24	—
70-79 °F	3 lbs	38	29	24	—
60-69 °F	3 lbs	38	29	—	24

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-o-1 Celery (above-ground parts)

Pest: External feeders

Treatment: **T101-o-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/ 1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

For below ground parts, use T101-n-1

T101-p-1 Chayote (fruit only)

Pest: External feeders

Treatment: **T101-p-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

For below ground parts, use T101-a-2 (Dasheen)

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-r-1

Cherry

Pest: Insects other than fruit flies

Treatment: **T101-r-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

T101-s-1

Cherry

Pest: *Rhagoletis indifferens* (Western cherry fruit fly) and *Cydia pomonella* (codling moth)

Treatment: **T101-s-1** MB at NAP—chamber only

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	2 lbs	2 hrs
60-69 °F	2.5 lbs	2 hrs
50-59 °F	3 lbs	2 hrs
40-49 °F	4 lbs	2 hrs

T101-s-1-1

Cherry from Australia

Pest: *Ceratitis capitata* (Mediterranean fruit fly)

Treatment: **T101-s-1-1** MB at NAP—chamber only

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
63 °F or above	2.5 lbs	2 hrs

NOTICE

Run the circulation fans continuously during the entire fumigation.

Do not exceed a 21% (by volume) load factor in the chamber.

T101-t-1

Chestnut

Pest: *Cydia splendana* (nut fruit tortrix) and *Curculio* spp.

Treatment: **T101-t-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs
90 °F and above	4 lbs	58	34	34	—	—	—
80-89 °F	4 lbs	58	32	—	32	—	—
70-79 °F	5 lbs	72	42	—	42	—	—
60-69 °F	5 lbs	72	40	—	—	40	—
50-59 °F	6 lbs	85	50	—	—	50	—
40-49 °F	6 lbs	85	48	—	—	—	48

see also T101-u-1

Does **not** include water chestnut

T101-u-1

Chestnut

Pest: *Cydia splendana* (nut fruit tortrix) and *Curculio* spp.

Treatment: **T101-u-1** MB in 26" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80 °F or above	3 lbs	2 hrs
70-79 °F	4 lbs	2 hrs
60-69 °F	4 lbs	3 hrs
50-59 °F	4 lbs	4 hrs
40-49 °F	4 lbs	5 hrs

Does **not** include water chestnut

T101-v-1

Chicory (above-ground parts)

Pest: External feeders

Treatment: **T101-v-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

see T101-n-1 for below-ground parts

see T101-z-1 for below-ground parts

see T101-a-2 for below-ground parts

T101-n-1 Chicory root

Pest: External feeders

Treatment: **T101-n-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	3 hrs	3.5 hrs
90 °F or above	2 lbs	26	19	19	—
80-89 °F	2.5 lbs	32	24	24	—
70-79 °F	3 lbs	38	29	24	—
60-69 °F	3 lbs	38	29	—	24

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-w-1 Cipollini (bulbs)

Pest: *Exosoma lusitanica* (chrysomelid beetle)

Treatment: **T101-w-1** MB in 15" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80 °F or above	2 lbs.	2 hrs
70-79 °F	3 lbs.	2 hrs
60-69 °F	4 lbs.	2 hrs
50-59 °F	4 lbs.	3 hrs
40-49 °F	4 lbs.	4 hrs

NOTICE

As of October 2008, **no commercial** chambers in the United States are approved for the vacuum fumigation of imported commodities. If vacuum treatment is required as a **condition of entry**, the consignment must be destroyed, reexported or returned to country of origin.

T101-w-1-2 Citrus from U.S. (interstate movement)

Pest: *Ceratitis capitata* (Mediterranean fruit fly)

Treatment: **T101-w-1-2** MB at NAP—tarpaulin or chamber

See "Ceratitis capitata (Mediterranean fruit fly) D301.32-10(c)" on page-5-8-5.

T101-n-2-1 Clementine, Grapefruit, Lemon, Lime, Orange, Mandarin, and Tangerine from Chile

Pest: External feeders and *Brevipalpus chilensis* (Chilean False Red Mite)

Treatment: **T101-n-2-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29

T101-j-2-1 Clementine (Tangerine), Grapefruit, Orange from Mexico and quarantine areas of the U.S.

Pest: *Anastrepha* spp.

Treatment: **T101-j-2-1** MB at NAP—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80 °F or above[1]	2.5 lbs	2 hrs

1 The temperature was changed from a minimum of 70 °F to 80 °F administratively in October 2005 due to interceptions of live *Anastrepha* larvae.

Load limit **not** to exceed 80 percent of chamber capacity.

Inspect a representative sample of the fruit. If the level of infestation with fruit flies is more than 0.5 percent for the lot, then the fruit is ineligible for fumigation.

T101-n-2 Coles (Brassica spp.)*

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

Important

*Coles (Brassica spp.), EPA Crop Group 5, are restricted to broccoli (Brassica oleracea var. botrytis); broccoli, Chinese (gai lon) (Brassica albogiabra); broccoli raap (rapini) (Brassica campestris); brussels sprouts (Brassica oleracea var. gemmifera); cabbage (Brassica oleracea); Cabbage, Chinese (bok choy) (Brassica chinensis); Cabbage, Chinese (napa) (Brassica pekinensis); cabbage, Chinese mustard (gai choy) (Brassica campestris); cauliflower (Brassica oleracea var. botrytis); cavalo broccolo (Brassica oleracea var. botrytis); collards (Brassica oleracea var. acephala); kale (Brassica oleracea var. acephala); kohlrabi (Brassica oleracea var. gongyiodes); mizuna (Brassica rapa Japonica Group); mustard greens (Brassica juncea); mustard spinach (Brassica rapa Perviridis Group); rape greens (Brassica napus)

Of these, cabbage (Brassica oleracea) (labeled treatment T101-j-1) is the only vegetable in this group **not** covered by a FIFRA Section 18 Exemption.

T101-n-2

Collard Greens (*Brassica oleracea* var. *acephala*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-x-1

Copra

(Dried coconuts and whole coconuts without the husk)

Pest: External feeders

Treatment: **T101-x-1** MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24

T101-x-1-1

Corn-on-the-cob

(Green corn, sweet corn)

Pest: *Ostrinia nubilalis* (European corn borer)

Treatment: **T101-x-1-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2.5 hrs
70 °F or above	2.5 lbs	32	24

T101-y-1

Cucumber

Pest: External feeders

Treatment: **T101-y-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29

T101-z-1

Dasheen

(Eddoe, malanga, tannia, tanya, taro, and yautia)

Pest: External feeders

Treatment: **T101-z-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	3 hrs	3.5 hrs	4 hrs
90 °F or above	2 lbs	26	19	19	—	—
80-89 °F	2.5 lbs	32	24	24	—	—
70-79 °F	3 lbs	38	29	24	—	—
60-69 °F	3 lbs	38	29	—	24	—
50-59 °F	3 lbs	38	29	—	—	24
40-49 °F	4 lbs	48	40	—	—	32


Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-a-2 Dasheen

Pest: Internal feeders

Treatment: **T101-a-2** MB chamber, 15" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90 °F or above	2 lbs	2 hrs
80-89 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	3.5 hrs

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

NOTICE

As of October 2008, **no commercial** chambers in the United States are approved for the vacuum fumigation of imported commodities. If vacuum treatment is required as a **condition of entry**, the consignment must be destroyed, reexported or returned to country of origin.

T101-b-2 Endive

Pest: External feeders

Treatment: **T101-b-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-c-2 Faba (Fava) bean (dried)

Pest: Bruchidae (seed beetles)

Treatment: **T101-c-2** MB in 26" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	3 lbs	3.5 hrs
60-69 °F	3 lbs	4 hrs
50-59 °F	3 lbs	4.5 hrs
40-49 °F	3 lbs	5 hrs

T101-d-2 Faba (Fava) bean (dried)

Pest: Bruchidae (seed beetles)

Treatment: **T101-d-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	11 hrs	12hrs	13 hrs	14 hrs
70 °F and above	3.5 lbs	46	28	27	—	—	—
60-69 °F	3.5 lbs	46	28		27		
50-59 °F	3.5 lbs	46	28			27	
40-49 °F	3.5 lbs	46	28				27

If fresh, see Green Pod Vegetables

T101-e-2 Garlic

Pest: *Brachycerus* spp. (garlic beetles) and *Dyspessa ulula* (garlic carpenterworm)

Treatment: **T101-e-2** MB in 15" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90 °F or above	2 lbs	1.5 hrs
80-89 °F	2 lbs	2 hrs
70-79 °F	2.5 lbs	2 hrs
60-69 °F	3 lbs	2 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	4 hrs

NOTICE

As of October 2008, **no commercial** chambers in the United States are approved for the vacuum fumigation of imported commodities. If vacuum treatment is required as a **condition of entry**, the consignment must be destroyed, reexported or returned to country of origin.

Load limit **not** to exceed 80 percent of chamber capacity

T101-f-2 Ginger (rhizome)

Pest: Internal feeders

Treatment: **T101-f-2** MB in 15" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90 °F or above	2 lbs	3 hrs
80-89 °F	2.5 lbs	3 hrs
70-79 °F	3 lbs	3 hrs
60-69 °F	3 lbs	3.5 hrs

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

NOTICE

As of October 2008, **no commercial** chambers in the United States are approved for the vacuum fumigation of imported commodities. If vacuum treatment is required as a **condition of entry**, the consignment must be destroyed, reexported or returned to country of origin.

T101-g-2 Ginger (rhizome)

Pest: External feeders

Treatment: **T101-g-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	3 hrs	3.5 hrs
90 °F or above	2 lbs	26	19	19	—
80-89 °F	2.5 lbs	32	24	24	—
70-79 °F	3 lbs	38	29	24	—
60-69 °F	3 lbs	38	29	—	24

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-h-2

Grape

Pest: *Lobesia botrana* (European grapevine moth)

Treatment: **T101-h-2** MB at NAP—tarpaulin (4 lbs.) or chamber (3.5 lbs.) The yellow color of this treatment indicates that the authority to conduct the treatment comes from an emergency action required by PPQ in order to mitigate the pest risk. The emergency action is an interim measure and is pending final regulatory approval.

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	3 hrs
50 °F and above	3.5 lbs[1]	50	40
40 °F and above	**4.0 lbs[2]**	**55**	**45**

1 3.5 lb. dosage: must be conducted in a chamber with a commodity load not to exceed 50%.

2 4.0 lb. dosage: must be used in conjunction with cold storage (34 °F or lower for a minimum of 10 days). The fumigation may be conducted under tarp.

T101-h-2-1

Grape

Pest: *Ceratitis capitata* (Mediterranean fruit fly) [4]

Treatment: **T101-h-2-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs	4 hrs
70 °F or above	2 lbs	26	22	22	—	21	—
65-69 °F	2 lbs	26	22	22	—	—	19

T101-i-2

Grape

Pest: External feeders and insects other than *Ceratitis capitata* (Mediterranean fruit fly) and mealybugs[4]

Treatment: **T101-i-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

4 Effective November 19, 2010, PPQ suspended the use of T101-h-2-1 and T101-i-2 against *Lobesia botrana*. Use T101-h-2 if *Lobesia botrana* is detected.

T101-i-2-1 Grape, Baby kiwi (*Actinidia arguta*), and Pomegranate

Pest: *Brevipalpus chilensis* (Chilean false red mite)

Treatment: **T101-i-2-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb./1000 ft3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	3 hrs[1]
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3.0 lbs	38	29
40-49 °F	4.0 lbs	48	38

1 If the treatment is conducted in a chamber, decrease the total fumigation time to 2.5 hours.

Important

Baby kiwi and pomegranate must be treated as FIFRA Section 18 treatments. Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-i-2-2 Fig (*Ficus carica*)

Pest: *Brevipalpus chilensis* (Chilean false red mite)

Treatment: **T101-i-2-2** MB at NAP—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period (hours)
70°F and above	2.5 lbs	3
60-69 °F	3.0 lbs	3
50-59 °F	3.5 lbs	3

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-j-2 Grapefruit and other kinds of citrus

Pest: *Aleurocanthus woglumi* (citrus blackfly)

Treatment: **T101-j-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	16	12
70-79 °F	1.5 lbs	19	15
65-69 °F	1.75 lbs	23	17

T101-k-2

Green pod vegetables

Snap, string, yard-long beans, peas, pigeon peas, and lablab beans

Two alternative treatments, T101-k-2 or T101-k-2-1

Pest: *Cydia fabivora*, *Crocidosema aporema*, *Maruca vitrata* (exotic legume pod borers), *Melanagromyza obtusa* (pigeon pea pod fly), and leaf miners

Treatment: **T101-k-2** MB in 15" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90 °F or above	0.5 lb	1.5 hrs
80-89 °F	1 lb	1.5 hrs
70-79 °F	1.5 lbs	1.5 hrs
60-69 °F	2 lbs	1.5 hrs
50-59 °F	2.5 lbs	1.5 hrs
40-49 °F	3 lbs	1.5 hrs

T101-k-2-1

Green pod vegetables

Snap, string, yard-long beans, peas, pigeon peas,and lablab beans

Two alternative treatments, T101-k-2 or T101-k-2-1

Pest: *Cydia fabivora*, *Crocidosema aporema*, *Maruca vitrata* (exotic legume pod borers), *Melanagromyza obtusa* (pigeon pea pod fly), and leaf miners

Alternative treatment: **T101-k-2-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29

The term “green pod vegetables” refers to legumes, **not** peppers nor okra.

T101-n-2-1-1 Dried Herbs, Spices, and Mint (*Mentha* spp.[5]) (all plant parts and seeds)

Pest: Various stored product pests, **not** including khapra beetle[6]

Treatment: T101-n-2-1-1 MB ("Q" label only) at NAP-tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	4 hrs	16 hrs	24 hrs
70 °F or above	2 lbs	24	16	10	—
60-69 °F	2 lbs	24	16	—	10
50-59 °F	3 lbs	36	24	15	—
40-49 °F	3 lbs	36	24	—	15

Important

Dried herbs and spices are restricted to Allspice, (*Pimenta dioica*), Angelica (*Angelica archangelica*), Anise (Anise seed) (*Pimpinella anisum*), Anise star (*Illicium verum*), Annatto (seed), Balm (Lemon balm) (*Melissa officinalis*), Basil (*Ocimum basilicum*), Borage (*Borago officinalis*), Bumet (*Sanguisorba minor*), Camomile (*Anthemis nobilis*), Caper buds (*Capparis spinosa*), Caraway (*Carum carvi*), Curaway, black (*Nigelia sativa*), Cardamom (*Elettaria cardamomum*), Cassia bark (*Cinnamomum aromaticum*), Cassia buds (*Cinnamomum aromaticum*), Catnip (*Nepeta cataria*), Celery seed (*Apium graveolens*), Chervil (dried) (*Anthriscus cerefolium*), Chive (*Allium schoenoprasum*), Chive, Chinese (*Allium tuberosum*), Cinnamon (*Cinnamomum verum*), Clary (*Salvia sciarea*), Clove buds (*Eugenia caryophyllata*), Coriander (cilantro or Chinese parsley) (leaf) (*Coriandrum sativum*), Coriandor (cilantro) (seed) (*Coriandrum sativum*), Costmary (*Chyrsanthemum balsamita*), Culantro (leaf) (*Eryngium foetidum*), Culantro (seed) (*Eryngium foetidum*), Cumin (*Cuminum cyminum*), Curry (leaf) (*Murrya koenigii*), Dill (dillweed) (*Anthemum graveolens*), Dill (seed) (*Anthmum graveolens*), Fennel (common) (*Foeniculum vulgare*), Fennel, Floronce (seed) (*Foeniculum vulgare Azoricum* group), Fenugreek (*Trigonella foenumgraecum*), Grains of paradise (*Afromomum melgueta*), Horehound (*Marribium vulgare*), Hyssop (*Hyssopus officinalis*), Juniper berry (*Juniperus communis*), Lavender (*Lavendula offinalis*), Lemongrass (*Cymbopogon citratus*), Lovage (leaf) (*Levisticum officinale*), Lovage (seed) (*Levisticum officinale*),Mace (*Myristica fragrans*), Marigold (*Calendula officinalis*), Marjoram (*Origanum* spp.) (includes sweet or annual marjoram, wild marjoram, or oregano, and pot marjoram), Mustard (seed) (*Brassica junceca, B. hirta, B. nigra*), Nasturtium (*Tropaeolum majus*), Nutmeg (*Myristica fragrans*) Parsley (dried) (*Pestroselinum crispum*), Pennyroyal (*Mentha pulegium*),Pepper, black (*Piper nigrum*), Poppy (seed) (*Papaver somniferum*), Rosemary (*Rosemarinus officinalis*), Rue (*Ruta graveolens*), Saffron (*Crocus sativus*), Sage (*Salvia officinalis*), Savory summer and winter (*Saturega* spp.), Sweet bay (bay leaf) (*Laurus nobilis*), Tansy (*Tanacetum vulgare*),Tarragon (*Artemisia dracunculus*), Thyme (*Thymus* spp.), Vanilla (*Vanillia planifolia*), Wintergreen (*Gaultheria procumbens*), Woodruff (*Galium odorata*), Wormwood (*Artemisia absinthium*).

5 Mint (*Mentha* spp.) **must** be fumigated as a Section 18 exemption.
6 If khapra beetle is intercepted on herbs and spices (dried), do **not** use this schedule. Contact USDA-APHIS-PPQ-S&T-CPHST-AQI, tel: 1-919-855-7450.

T101-n-2 Fresh Herbs, Spices, and Mint (*Mentha* spp.) (all plant parts except seeds)

Pest: External feeders and leaf miners

Treatment: T101-n-2 MB at NAP-tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 ° F	3.5 lbs	43	34
40-44 ° F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

Important

Fresh herbs and spices are restricted to Allspice, (*Pimenta dioica*), Angelica (*Angelica archangelica*), Anise (Anise seed) (*Pimpinella anisum*), Anise star (*Illicium verum*), Annatto (seed), Balm (Lemon balm) (*Melissa officinalis*), Basil (*Ocimum basilicum*), Borage (*Borago officinalis*), Burnet (*Sanguisorba minor*), Camomile (*Anthemis nobilis*), Caper buds (*Capparis spinosa*), Caraway (*Carum carvi*), Curaway, black (*Nigelia sativa*), Cardamom (*Elettaria cardamomum*), Cassia bark and buds (*Cinnamomum aromaticum*), Catnip (*Nepeta cataria*), Celery seed (*Apium graveolens*), Chervil (dried) (*Anthriscus cerefolium*), Chive (*Allium schoenoprasum*), Chive, Chinese (*Allium tuberosum*), Cinnamon (*Cinnamomum verum*), Clary (*Salvia sciarea*), Clove buds (*Eugenia caryophyllata*), Coriander (cilantro or Chinese parsley) (leaf, seed) (*Coriandrum sativum*), Costmary (*Chyrsanthemum balsamita*), Culantro (leaf, seed) (*Eryngium foetidum*), Cumin (*Cuminum cyminum*), Curry (leaf) (*Murrya koenigii*), Dill (dillweed, dill seed) (*Anthemum graveolens*), Fennel (common) (*Foeniculum vulgare*), Fennel, Floronce (seed) (*Foeniculum vulgare Azoricum* group), Fenugreek (*Trigonella foenumgraecum*), Grains of paradise (*Afromomum melgueta*), Horehound (*Marribium vulgare*), Hyssop (*Hyssopus officinalis*), Juniper berry (*Juniperus communis*), Kaffir lime leaves (*Citrus hystrix*), Lavender (*Lavendula offinalis*), Lemongrass (*Cymbopogon citratus*), Lovage (leaf, seed) (*Levisticum officinale*), Mace (*Myristica fragrans*), Marigold (*Calendula officinalis*), Marjoram (*Origanum* spp.) (includes sweet or annual marjoram, wild marjoram, or oregano, and pot marjoram), Mustard (seed) (*Brassica junceca, B. hirta, B. nigra*), Nasturtium (*Tropaeolum majus*), Nutmeg (*Myristica fragrans*), Parsley (dried) (*Pestroselinum crispum*), Pennyroyal (*Mentha pulegium*),Pepper, black (*Piper nigrum*), Poppy (seed) (*Papaver somniferum*), Rosemary (*Rosemarinus officinalis*), Rue (*Ruta graveolens*), Saffron (*Crocus sativus*), Sage (*Salvia officinalis*), Savory summer and winter (*Saturega* spp.), Sweet bay (bay leaf) (*Laurus nobilis*), Tansy (*Tanacetum vulgare*),Tarragon (*Artemisia dracunculus*), Thyme (*Thymus* spp.), Vanilla (*Vanillia planifolia*), Wintergreen (*Gaultheria procumbens*), Woodruff (*Galium odorata*), Wormwood (*Artemisia absinthium*).

T101-l-2

Horseradish

Pest: *Baris lepidii* (imported crucifer weevil)

Treatment: **T101-l-2** MB in 15" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90 °F or above	2 lbs	2 hrs
80-89 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs

NOTICE

As of October 2008, **no commercial** chambers in the United States are approved for the vacuum fumigation of imported commodities. If vacuum treatment is required as a **condition of entry**, the consignment must be destroyed, reexported or returned to country of origin.

T101-n-2

Kale (*Brassica oleracea* var. *acephala*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-m-2

Kiwi

Three alternative treatments, depending on the pest.

Pest: External feeders (except *Brevipalpus chilensis)*, *Nysius huttoni* (wheat bug)

Treatment: **T101-m-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-m-2-1

Kiwi

Pest: *Ceratitis capitata* (Mediterranean fruit fly)

Treatment: **T101-m-2-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	3.5 hrs	4 hrs
70 °F or above	2 lbs	26	22	21	—
65-69 °F	2 lbs	26	22	—	19

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-m-2-2 Kiwi

The yellow color of this treatment indicates that the authority to conduct the treatment comes from an emergency action required by PPQ in order to mitigate the pest risk. The emergency action is pending final regulatory approval.

Pest: *Brevipalpus chilensis* (Chilean false red mite)

Treatment: **T101-m-2-2** MB at NAP—tarpaulin or chamber[7]

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	3 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	**2 lbs**	**26**	**19**
60-69 °F	2.5 lbs	32	24
50-59 °F	**3 lbs**	**38**	**29**
40-49 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-n-2 Kohlrabi (*Brassica oleracea* var. *gongyiodes*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

7 If the treatment is conducted in a chamber, decrease the total fumigation time to 2.5 hours.

T101-n-3

Kumquat (*Fortunella japonica*)

Pest: *Ceratitis capitata* (Wiedemann) and *Anastrepha fracterculus* (Wiedemann)

Treatment: **T101-n-3** MB at NAP—chamber

Temperature	Dosage Rate (lb/1,0000 ft^3)	Exposure Period
80 °F or above	3 lbs	2 hours

T101-n-2

Leafy vegetables

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

Important

Leafy vegetables, EPA Crop Group 4, (Except *Brassica* Vegetables) are restricted to amaranth (leafy amaranth, Chinese spinach, tampala) (*Amaranthus* spp.); arugula (Roquette) (*Eruca sativa*); cardoon (*Cynara cardunculus*); celery (*Apium graveolens* var. *dulcea*); celery, Chinese (*Apium graveolens* var. *secalinum*); celtuce (*Lactuca sativa* var. *angustana*); chervil (*Anthriscus cerefolium*); chrysanthemum, edible-leaved (*Chrysanthemum coronanium* var. *coronanium*); chrysanthemum, garland (*Chrysanthemum coronarium* var. *spatiosum*); corn salad (*Valerianella locusta*); cress garden (*Lepidium sativum*); cress upland (yellow rocket, winter cress) (*Barbarea vulgaris*); dandelion (*Taraxacum offincinale*); dock (sorrel) (*Rumex* spp.); endive (escarole) (*Cichorium endivia*); fennel, Florence (finochio) (*Foeniculum vulgare Azoricum* Group); lettuce, head and leaf *(Lactuca sativa*); Orach (*Atriplex hortensis*); parsley (*Petroselinum crispum*); purslane, garden (*Portulaca oleracea*); purslane, winter (*Montia perfoliata*); radicchio (red chicory) (*Cichorium intybus*); rhubarb (*Rheum rhabarbarum*); spinach (*Spinacia oleracea*); spinach, New Zealand (*Tetragonia tetragonioides, T. expansa*); spinach, vine (Malabar spinach, Indian spinach) (*Basella alba*); swiss chard (*Beta vulgaris* var. *cicia*). Reference 40 CFR 180.34 (f)(a)(iv)(A)

T101-q-2 Leeks

Pest: Internal feeders (including leafminers)

Treatment: **T101-q-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs
90 °F or above	2 lbs	26	19	—	—	—
80-89 °F	2.5 lbs	32	24	—	—	—
70-79 °F	3 lbs	38	29	—	—	—
60-69 °F	3 lbs	38	26	26	—	—
50-59 °F	3 lbs	38	26	—	26	—
40-49 °F	3 lbs	38	26	—	—	26

T101-e-1 Lentils (Dry)

Pest: Bruchidae (seed beetles)

Treatment: **T101-e-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs	4 hrs
70 °F or above	3 lbs	38	—	24	—	—	—
60-69 °F	3 lbs	38	29	—	24	—	—
50-59 °F	3 lbs	38	29	—	—	24	—
40-49 °F	3 lbs	38	29	—	—	—	24

T101-n-2 Lettuce from Spain

Pest: *Autographa gamma*, *Helicoverpa armigera*, *Mamestra brassicae*, *Spodoptera littoralis*

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber (see **Leafy vegetables** for treatment schedule)

T101-b-1-1

Lychee (Litchi)

Pest: Mealybugs (Pseudococcidae)

Treatment: **T101-b-1-1** MB ("Q" label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	2.5 lbs	32	24
70-79 °F	3 lbs	38	29
60-69 °F	4 lbs	48	38

Important

T101-b-1-1 is **not** a substitute for the mandatory cold treatment of lychee from China and Taiwan, T107-h, which targets the pests *Bactrocera dorsalis* (Oriental fruit fly), *Bactrocera curubitae* (melon fly) and ***Conopomorpha sinensis*** (lychee fruit borer). Because mealybugs are **not** controlled by T107-h, T101-b-1-1 can be used as a follow-up treatment if mealybugs are found.

T101-o-2

Melons

(Including honeydew, muskmelon, and watermelon)

Pest: External feeders such as Noctuidae spp., *Thrips* spp., *Copitarsia* spp.

Treatment: **T101-o-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above*	1.5 lbs	19	14
70-79 °F*	2 lbs	26	19
60-69 °F*	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

* Use "MB 100" at 60 °F or above, use MB "Q" label at 40 °F or above

For cantaloupe, see T101-k-1

T101-n-2 Mizuna (*Brassica rapa Japonica* Group)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-n-2 Mustard greens (*Brassica juncea*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-n-2 Mustard spinach (*Brassica rapa Perviridis* Group)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-a-3 Nectarine

Pest: External feeders

Treatment: **T101-a-3** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

T101-p-2 Okra*

Pest: *Pectinophora gossypiella* (pink bollworm)

Treatment: **T101-p-2** MB at NAP—chamber only

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90 °F or above	1 lb	2 hrs
80-89 °F	1.5 lbs	2 hrs
70-79 °F	2 lbs	2 hrs
60-69 °F	2.5 lbs	2 hrs
50-59 °F	3 lbs	2 hrs
40-49 °F	3.5 lbs	2 hrs

*Okra may be injured by fumigation if moisture is present. The term “okra” does **not** include Chinese okra (*Luffa* spp.), which is a cucurbit.

T101-p-2-1 Okra*

Pest: *Pectinophora gossypiella* (pink bollworm)

Treatment: T101-p-2-1 MB at NAP—tarpaulin

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
90 °F or above	1.5 lbs	19	14
80-89 °F	2 lbs	26	19
70-79 °F	2.5 lbs	32	24
60-69 °F	3 lbs	38	29
50-59 °F	3.5 lbs	48	38

*Okra may be injured by fumigation if moisture is present or if it is fumigated at temperatures greater than 90°F. The term “okra” does **not** include Chinese okra (*Luffa* spp.), which is a cucurbit.

T101-q-2 Onion*

Pest: Internal feeders (and leaf miners)

Treatment: **T101-q-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs
90 °F or above	2 lbs	26	19	—	—	—
80-89 °F	2.5 lbs	32	24	—	—	—
70-79 °F	3 lbs	38	29	—	—	—
60-69 °F	3 lbs	38	26	26	—	—
50-59 °F	3 lbs	38	26	—	26	—
40-49 °F	3 lbs	38	26	—	—	26

*The term “onion” includes dry bulbs. It also includes leeks, shallots and chives for both above ground and below ground parts.

T101-g-1 Parsnip

Pest: Internal feeders

Treatment: **T101-g-1** MB chamber, 15" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90 °F or above	2 lbs	2 hrs
80-89 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	3.5 hrs

NOTICE

As of October 2008, **no commercial** chambers in the United States are approved for the vacuum fumigation of imported commodities. If vacuum treatment is required as a **condition of entry**, the consignment must be destroyed, reexported or returned to country of origin.

T101-a-3

Peach

Pest: External feeders

Treatment: **T101-a-3** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

T101-a-1

Pear[8]

Pest: External feeders

Treatment: T101-a-1 MB at NAP-tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

T101-e-1

Peas (Dry)

Pest: Bruchidae (seed beetles)

Treatment: **T101-e-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs	4 hrs
70 °F or above	3 lbs	38	—	24	—	—	—
60-69 °F	3 lbs	38	29	—	24	—	—
50-59 °F	3 lbs	38	29	—	—	24	—
40-49 °F	3 lbs	38	29	—	—	—	24

see T101-k-1 or T101-k-2 for fresh peas

8 Fumigation may cause **severe** damage to Chinese, Japanese, Asian and Sand Pears. Obtain the importer's consent before fumigation.

T101-a-3 Peppers

Pest: Internal pests (except fruit flies) and External pests (except mealy bugs)

Treatment: T101-a-3 MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

Important

This treatment is **not** effective against fruit flies or mealy bugs. For fruit flies, use T106-b (vapor heat). For mealy bugs, use T104-a-2 (fumigation). Certain varieties of peppers are sensitive to methyl bromide and may develop darkening of the seed cavity.

T101-r-2 Pineapple

Pest: Internal feeders

Treatment: **T101-r-2** MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	6 hrs
70 °F or above	2 lbs	26	22	16

T101-s-2 Pineapple

Pest: External feeders

Treatment: **T101-s-2** MB (“Q” label only if under 70 °F (21.1 °C)) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above*	1.5 lbs	19	14
70-79 °F*	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F**	4 lbs	48	38

* Use “MB 100” at 70 °F or above, use MB “Q” label at 40 °F or above

** 40–49°F temperature range may cause pineapple core to turn purple.

T101-t-2 Plantain

Pest: External feeders such as Noctuidae spp., *Thrips* spp., *Copitarsia* spp.

Treatment: **T101-t-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-a-3 Plum

Pest: External feeders

Treatment: **T101-a-3** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

T101-u-2 Potato (white or Irish)

Pest: *Graphognathus* spp. (white fringed beetles)

Treatment: **T101-u-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	2.5 lbs	30	20
70-79 °F	3 lbs	36	24

T101-v-2 Potato (white or Irish)

Pest: *Ostrinia nubilalis* (European corn borer) and *Phthorimaea operculela* (potato tuberworm)

Treatment: **T101-v-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2.75 lbs	33	22

T101-e-1 Pulses, dried

Pest: Bruchidae (seed beetles)

Treatment: **T101-e-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs	4 hrs
70 °F or above	3 lbs	38	—	24	—	—	—
60-69 °F	3 lbs	38	29	—	24	—	—
50-59 °F	3 lbs	38	29	—	—	24	—
40-49 °F	3 lbs	38	29	—	—	—	24

T101-w-2 Pumpkin

Pest: External feeders

Treatment: **T101-w-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24

T101-g-1 Radish

Pest: Internal feeders

Treatment: **T101-g-1** MB chamber, 15" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90 °F or above	2 lbs	2 hrs
80-89 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	3.5 hrs

NOTICE

As of October 2008, **no commercial** chambers in the United States are approved for the vacuum fumigation of imported commodities. If vacuum treatment is required as a **condition of entry**, the consignment must be destroyed, reexported or returned to country of origin.

T101-n-2 Rape greens (*Brassica napus*)

Pest: External feeders and leaf miners

Treatment: **T101-n-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	2 lbs	26	14
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
45-49 °F	3.5 lbs	43	34
40-44 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

Of these, cabbage (Brassica oleracea) (labeled treatment T101-j-1) is the only vegetable in this group **not** covered by a FIFRA Section 18 Exemption.

T101-x-2 Raspberry

Pest: External feeders such as Noctuidae spp., *Thrips* spp., *Copitarsia* spp., Pentatomidae spp.

Treatment: **T101-x-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-q-2 Shallots

Pest: Internal feeders (including leaf miners)

Treatment: **T101-q-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs
90 °F or above	2 lbs	26	19	—	—	—
80-89 °F	2.5 lbs	32	24	—	—	—
70-79 °F	3 lbs	38	29	—	—	—
60-69 °F	3 lbs	38	26	26	—	—
50-59 °F	3 lbs	38	26	—	26	—
40-49 °F	3 lbs	38	26	—	—	26

T101-y-2 Squash* (winter, summer, and chayote**)

Pest: External feeders

Treatment: **T101-y-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

* If zucchini, see **T101-h-3**. If pumpkin, see **T101-w-2**.

** Chayote is not covered on any MB label and must be treated as a FIFRA crisis exemption. (see **T101-p-1**)

T101-z-2 Strawberry

Pest: External feeders

Treatment: **T101-z-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29

T101-b-3-1 Sweet Potato *(Ipomoea)*

Pest: External and internal feeders

Treatment: **T101-b-3-1** MB at NAP—tarpaulin or chamber

This treatment is also required for the interstate movement from Hawaii.

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	4.0 hrs
90 °F or above*	2.5 lbs	32	20	20
80-89 °F*	3 lbs	38	24	24
70-79 °F*	3.5 lbs	44	28	28
60-69 °F	4 lbs	50	32	32

* Use “MB 100” at 70ºF or above, use MB “Q” label at 60 °F or above

NOTICE

Temperatures below 70 °F may cause injury to sweet potatoes. Fumigation below 70 °F is to be made only on specific request from the importer.

NOTICE

Sweet potatoes should be cured, free from surface moisture, and held at the fumigation temperature for 24 hours following treatment. This is **not** mandatory; however, following this advise will help maintain the quality of the fumigated product.

T101-c-3 Tomato (from quarantine areas in the United States)

Pest: *Ceratitis capitata* (Mediterranean fruit fly)

Treatment: **T101-c-3** MB at NAP—tarpaulin or chamber
See “Ceratitis capitata (Mediterranean fruit fly) D301.32-10(c)” on page-5-8-5.

T101-c-3-1 Tomato (from Chile)

Pest: *Tuta absoluta* (tomato fruit moth) and *Rhagoletis tomatis* (tomato fruit fly)

Treatment: **T101-c-3-1** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F or above	3 lbs	43	33

T101-d-3

Tuna (Opuntia) and all other fruits from cacti (prickly pear, pitahaya, pitaya, dragon fruit)

Pest: *Ceratitis capitata* (Mediterranean fruit fly)

Treatment: **T101-d-3** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	3.5 hrs
70 °F or above	2 lbs	26	21	21

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-e-3

Tuna (Opuntia) and all other fruits from cacti (prickly pear, pitahaya, pitaya, dragon fruit)

Pest: External feeders and leaf miners

Treatment: **T101-e-3** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

Important

Do **not** use this treatment schedule if its FIFRA Section 18 Exemption has expired. For the current exemption status, call your local State Plant Health Director (SPHD).

T101-g-1 Turnip

Pest: Internal feeders

Treatment: **T101-g-1** MB chamber, 15" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90 °F or above	2 lbs	2 hrs
80-89 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	3.5 hrs

NOTICE

As of October 2008, **no commercial** chambers in the United States are approved for the vacuum fumigation of imported commodities. If vacuum treatment is required as a **condition of entry**, the consignment must be destroyed, reexported or returned to country of origin.

T101-f-3 Yam (*Dioscorea* spp.)

Pest: Internal and external feeders

Treatment: **T101-f-3** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	4 hrs
90 °F or above	2.5 lbs	32	20	20
80-89 °F	3 lbs	38	24	24
70-79 °F	3.5 lbs	44	28	28
60-69 °F	4 lbs	50	32	32

NOTICE

Temperatures below 70 °F may cause injury to yams. Fumigation below 70 °F is to be made only on specific request from the importer.

NOTICE

Sweet potatoes and yams should be cured, free from surface moisture, and held at the fumigation temperature for 24 hours following treatment. This is **not** mandatory; however, following this advise will help maintain the quality of the fumigated product.

T101-h-3 Zucchini

Pest: External feeders

Treatment: **T101-h-3** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft’)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24

If another variety of squash, see T101-y-2

T102—Water Treatment

Important

Whenever water comes into contact with fresh produce, the water's quality dictates the potential for pathogen contamination. To reduce the risk of food-borne illnesses, the water used for washing, treatments, and cooling must be fortified with sodium hypochlorite (household bleach), and constantly maintained at a chlorine level **not** to exceed 200 ppm.

T102-b

Cherimoya from Chile

Pest: *Brevipalpus chilensis* (Chilean false red mite)

Treatment: **T102-b** Soapy water and wax

1. Immerse fruit for 20 seconds in soapy water bath of one part soap solution (such as Deterfruit) to 3,000 parts water.
2. Follow the soapy bath with a pressure shower rinse to remove all the soapy excess.
3. Immerse fruit for 20 seconds in an undiluted wax coating (such as Johnson's Wax Primafresh 31 Kosher fruit coating). The wax coating should cover the entire surface of the fruit.

Important

At the port of entry, the PPQ Officer should check to make sure the wax coating covers the entire surface of the fruit.

T102-c

Durian and other large fruits such as breadfruit

Pest: External Feeders

Treatment: **T102-c** Warm, soapy water and brushing

1. Add detergent (such as Deterfruit) to warm water (110° to 120 °F) at the rate of one part detergent or soap to 3,000 parts water.
2. Immerse the fruit for at least 1 minute in the warm detergent water.
3. Using a brush with stiff bristles, have the importer or the importer's agent scrub each fruit to remove any insects.
4. Using a pressure shower, have the importer or the importer's agent rinse the fruit free from residue (detergent and dead insects).
5. Inspect each brushed and cleaned fruit. Pay particular attention to external feeders such as mealybugs and scales. If any insects remain, have the fruit retreated or have it destroyed.

T102-e

Limes

Pest: Mealybugs (Pseudococcidae) and other surface pests

Treatment: **T102-e** Hot water immersion

1. Fruit must be treated in a certified hot water immersion treatment tank, and the treatment must be monitored by an inspector.
   - **A.** Fruit must be submerged at least 4 inches below the water's surface.
   - **B.** Water must circulate continually and be kept at 120.2 °F (or above) for 20 minutes. Treatment time begins when the water temperature reaches at least 120.2 °F in all locations of the tank.
2. Cooling and waxing the fruit are both optional, and are the sole responsibility of the processor.

NOTICE

Phytotoxic damage (increased yellowing) may occur if the temperature reaches 125.6 °F or if the treatment duration significantly exceeds 20 minutes.

T102-b-1

Limes from Chile

Pest: *Brevipalpus chilensis* (Chilean false red mite)

Treatment: **T102-b-1** Soapy water and wax

1. Immerse fruit for 20 seconds in soapy water bath of one part soap solution (such as Deterfruit) to 3,000 parts water.
2. Follow the soapy bath with a pressure shower rinse to remove all the soapy excess.
3. Immerse fruit for 20 seconds in an undiluted wax coating (such as Johnson's Wax Primafresh 31 Kosher fruit coating). The wax coating should cover the entire surface of the fruit.

Important

At the port of entry, the PPQ Officer should check to make sure the wax coating covers the entire surface of the fruit.

T102-d-1

Longan fruit from Hawaii

Pest: *Ceratitis capitata* (Mediterranean fruit fly) and
Bactrocera dorsalis (Oriental fruit fly)

Treatment: **T102-d-1** Hot water immersion

Important

Fruit must be at ambient temperature before the treatment begins

1. Submerge the fruit at least 4 inches below the water's surface in a hot water immersion treatment tank certified by APHIS.
2. Keep the fruit submerged for 20 minutes after the water temperature reaches at least 120.2 °F in all locations of the tank. The water must circulate continually and be kept at 120.2 °F (or above) for the duration of the treatment.

NOTICE

Phytotoxic damage (increased yellowing) may occur if the temperature exceeds 121.1 °F.

3. Cool the fruit to ambient temperature. Hydrocooling for 20 minutes at 75.2 °F is recommended, though **not** required, to prevent injury to the fruit from the hot water immersion treatment.

T102-d

Lychee (litchi) fruit from Hawaii

Pest: *Ceratitis capitata* (Mediterranean fruit fly) and *Bactrocera dorsalis* (Oriental fruit fly)

Treatment: T102-d Hot water immersion

1. Lychees must be thoroughly examined at the packinghouse by an inspector and found free of ***Cryptophlebia spp.*** (Lychee fruit moth) and other plant pests[9]
2. Fruit must be grown and treated in Hawaii, under monitoring of an inspector, in a certified hot water immersion treatment tank.[10]
   A. Fruit must be submerged at least 4 inches below the water's surface.

9 Because ***Eriophyes litchii*** (lychee mite) cannot be effectively detected by inspection, and would **not** be effectively eliminated by hot water immersion, the lychees may **not** be shipped into Florida. Each carton must be stamped "**Not** for importation into or distribution in Florida."

10 Use of Treatment T102-d is at the risk of the shipper. Limited research on fruit quality after treatment application indicated that fruit quality varies among cultivars. 'Kaimana' and 'Kwai Mi' ('Tai So') tolerate the treatment better than 'Brewster' and 'Groff'; no other cultivars were tested.

B. Water must circulate constantly, and be kept at 120.2 °F (or above) for 20 minutes. Treatment time begins when the water temperature reaches at least 120.2 °F in all locations throughout the tank.[11]

Temperatures exceeding 121.1 °F can cause phytotoxic damage.

3. Hydrocooling for 20 minutes at 75.2 °F is recommended, though **not** required, to prevent injury to the fruit from the hot water treatment.

T102-a

Mango

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Anastrepha spp*., *Anastrepha ludens* (Mexican fruit fly)

Treatment: **T102-a** Hot water immersion

Treat the fruit in the country of origin at a certified facility under the monitoring of APHIS personnel.

1. Pre-sort mangoes by weight class. Treatment of mixed loads is **not** allowed.
2. Pulp temperature must be 70 °F or above before start of treatment.
3. Submerge fruit at least 4 inches below the water's surface.
4. Water must circulate constantly and be kept at least 115 °F throughout the treatment with the following tolerances:

- ***During the first 5 minutes of a treatment***—Adjusted Tank Temperatures from ***Figure 6-5-1*** on **page 6-5-3** that are below 113.7 °F are allowed during the first 5 minutes of a treatment only if the temperature is at least 115 °F at the end of the 5 minute period.
- ***For treatments lasting 65 to 75 minutes***—Adjusted Tank Temperatures from ***Figure 6-5-1*** on **page 6-5-3** may fall as low as 113.7 °F for no more than 10 minutes under emergency conditions.
- ***For treatments lasting 90 to 110 minutes***—Adjusted Tank Temperatures from ***Figure 6-5-1*** on **page 6-5-3** may fall as low as 113.7 °F for no more than 15 minutes under emergency conditions.

11 Treatment does **not** begin until after the fruit is immersed and the water temperature recovers to 120.2 °F (or above). Therefore, before the start of the treatment, fruit pulp temperatures of 70 °F (or above) are recommended to minimize water temperature recovery time and the overall time fruit are immersed in heated water. Fruit quality of treated lychees with initial pulp temperatures below 68 °F has **not** been studied.

5. Determine the dip time from **Table 5-2-1**.

Important

Dip times for T102-a are valid if the fruit is **not** hydrocooled within 30 minutes of removal from the hot water immersion tank.

However, if hydrocooling starts immediately after the hot water immersion treatment, then the original dip time must be extended for an additional 10 minutes.

(Hydrocooling is optional and may be done only at temperatures of 70ºF or above, for any length of time, or **not** at all.)

Table 5-2-1 Hot Water Dip Time Based on Weight of Fruit[1]

If the weight of the mango (in grams) is:	Then the dip time (in minutes) is:
Up to 375	65
376 to 500	75
501 to 700	90
701 to 900	110

1 Valid if the fruit is **not** hydrocooled within 30 minutes of removal from the hot water immersion tank.

T102-b-2

Passion Fruit from Chile

Pest: *Brevipalpus chilensis* (Chilean false red mite)

Treatment: **T102-b-2** Soapy water and wax

1. Immerse fruit for 20 seconds in soapy water bath of one part soap solution (such as Deterfruit) to 3,000 parts water.
2. Follow the soapy bath with a pressure shower rinse to remove all the soapy excess.
3. Immerse fruit for 20 seconds in an undiluted wax coating (such as Johnson's Wax Primafresh 31 Kosher fruit coating). The wax coating should cover the entire surface of the fruit.

Important

At the port of entry, the PPQ Officer should check to make sure the wax coating covers the entire surface of the fruit.

T103—High Temperature Forced Air

T103-a-1 Citrus from Mexico and infested areas in the United States

Pest: *Anastrepha* spp.

Treatment: T103-a-1 High temperature forced air

Heat Up Time:	90 minutes
Heat Up Recording Interval:	2 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	44 °C/111.2 °F
Dwell Time:	100 minutes
Dwell Recording Interval:	2 minutes
Cooling Method:	Hydrocooling optional

Size Restrictions	Standard Count	Max. Weight/Fruit		Max. Diameter
	bushel	grams	ounces	inches
Navel Orange	100 per 1 2/5	450	15.9	3 3/16
Orange (other than Navel)	100 per 1 2/5	468	16.4	3 13/16
Tangerine	120 per 4/5	245	8.6	—
Grapefruit	70 per 1 2/5	536	18.8	4 5/16

T103-b-1 Citrus from Hawaii

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T103-b-1 High temperature forced air

Heat Up Time:	4 hours
Heat Up Recording Interval:	5 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	47.2 °C/117.0 °F
Dwell Time:	5 minutes
Dwell Recording Interval:	5 minutes
Cooling Method:	Forced air or Hydrocooling

NOTICE

Tolerance of Citrus to Treatment—Users of this treatment for citrus should test the specific cultivar to determine how well it will tolerate the required heat treatment. Of all citrus species tested to date, grapefruit showed the highest tolerance to this treatment. The tolerance of citrus treated in excess of 7 hours has **not** been determined. Although the method of cooling fruit after treatment is optional, research indicated that forced air cooling using ambient air temperature produced the least fruit injury.

T103-c-1 Mango from Mexico

Pest: *Anastrepha ludens* (Mexican fruit fly), *Anastrepha obliqua* (West Indian fruit fly), and *Anastrepha serpentina* (black fruit fly)

Treatment: T103-c-1 High temperature forced air

Heat Up Time:	N/A
Heat Up Recording Interval:	2 minutes
Minimum Air Temperature:	50.0 °C/122.0 °F
Minimum Pulp Temperature at End of Heat Up:	48.0 °C/118.0 °F
Dwell Time:	2 minutes
Dwell Recording Interval:	2 minutes
Cooling Method:	Forced air or Hydrocooling
Size Restrictions:	Fruit weight must **not** exceed 1 1/2 lbs. (700 grams)

T103-d

Mountain Papaya from Chile (T103-d-1) and Papaya from Belize and Hawaii (T103-d-2)

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T103-d-1 High temperature forced air

Heat Up Time:	4 hours
Heat Up Recording Interval:	5 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	47.2 °C/117.0 °F
Dwell Time:	5 minutes
Dwell Recording Interval:	5 minutes
Cooling Method:	Forced air or Hydrocooling (If papayas are hydrocooled with water lower than 54.5 °F (12.5° C), the fruit may be damaged.)

NOTICE

Tolerance of Papayas to Treatment—To enable the papayas to tolerate the treatment, the fruit may first have to be conditioned. Such conditioning is the responsibility of the shipper and at the shipper's risk.

T103-e

Rambutan from Hawaii

Pest: *Ceratitis capitata* (Mediterranean fruit fly), and *Bactrocera dorsalis* (Oriental fruit fly)

Treatment: T103-e-1 High temperature forced air

Heat Up Time:	1 hour
Heat Up Recording Interval:	5 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	47.2 °C/117.0 °F
Dwell Time:	20 minutes
Dwell Recording Interval:	5 minutes
Cooling Method:	Optional

T104—Pest Specific/Host Variable

For the treatments that follow, never exceed the labeled or Section 18 dosage and time for the specific commodity at the given temperature. Moreover, the specific commodity being treated determines if the schedule is a labeled treatment or one authorized under a Section 18 exemption. For example, oranges cannot be treated for hitchhikers using T104-a-1 at 40-49 °F because this schedule requires 4 lbs. of methyl bromide/1,000 ft^3. Whereas, the methyl bromide “Q” label allows a maximum of only 3 lbs. at this temperature range. Therefore, the oranges would have to be heated to at least 50 °F before fumigation because at 50 °F a dosage of only 3 lbs./1,000 ft^3 is required.

Although the following treatments are pest specific, the treatment schedule for the associated host will determine if and when a pest specific treatment can be used. Always check the schedule for the host before selecting the proper treatment schedule. Also, consult the methyl bromide labeling brochure, and do **not** exceed the restrictions on dosage and exposure time.

T104-a-1 Various Commodities

Pest: Hitchhikers and surface pests such as: thrips, aphids, scale insects, leaf miners, spider mites (*Tetranychidae*)[12], lygaeid bugs, ants, earwigs, surface-feeding caterpillars and slugs[13]

Treatment: **T104-a-1** MB at NAP—tarpaulin or chamber.

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5	19	14
70-79 °F	2	26	19
60-69 °F	2.5	32	24
50-59 °F	3	38	29
40-49 °F	4	48	38

To comply with dosage and temperature restrictions on methyl bromide labels, ONLY the fruits and vegetables listed may be fumigated with T104-a-1. If you have a commodity that is not in the list, it may be listed elsewhere in the T100 schedules for a different pest complex. Refer to the Index for a complete list of commodities for which there are approved treatment schedules. Refer to **Appendix F** (or 40 CFR 180.41) for a list of EPA crop groups and commodities.

The **bolded** commodities in the list are under FIFRA Section 18 Exemption.

NOTICE

Do not use T104-a-1 if the FIFRA Section 18 exemption has expired. For any questions concerning the exemption status, call your State Plant Health Director or Regional Treatment Program Manager.

The commodities that are **not bold** are covered on the label. There may be some commodities that are on the label at one dosage and duration, and are also covered in the Section 18 at a different dosage and duration.

EXAMPLE: Coffee bean (roasted) is on the Chemtura MB-Q label and can be treated up to 3.0 lbs. for 24 hours. However, the Section 18 allows for coffee bean (unroasted) to be treated up to 9 lbs. for 12 hours.

12 DO NOT use T104-a-1 for Chilean False Red Mite (*Brevipalpus chilensis*).

13 Quarantine-significant slugs of the families Agriolimacidae, Arionidae, Limacidae, Milacidae, Philomycidae, and Veronicellidae, including the following genera: *Agriolimax, Arion,Colosius, Deroceras, Diplosolenodese, Leidyula, Limax, Meghimatium, Milax, Pallifera, Pseudoveronicella, Sarasinula, Semperula, Vaginulus,Veronicella*. **Treat slugs at 60 F (2.5 lbs.) or above .**

List of Commodities Approved for Fumigation With T104-a-1:

CAUTION

Fumigation may cause damage to some commodities and is at the risk of the importer.

- 70 °F or above (maximum dosage 2 lbs./1000 ft^3): **avocado,** beet (root), blueberry, cocoa bean
- 60 °F or above (maximum dosage 2.5 lbs./1000 ft^3): **coconut (unprocessed without husk)**, pimento, pumpkin, zucchini squash
- 50 °F or above (maximum dosage 3 lbs./1000 ft^3): clementine, coffee bean (roasted), copra (coconut), corn-on-the-cob (sweet corn), edible podded legumes, grapefruit, kumquat, lemon, lime, mandarin, **Malvaceae seeds for food use, including kenaf and hibiscus, mint (dried),** okra, onion, orange, parsnip, potato, radish, **root and tuber crop group,** rutabaga, salsify root, strawberry, sugar beet, tangelo, tangerine, tomato, turnip root
- 40 °F or above (maximum dosage 4 lbs./1000 ft^3): apple, apricot, asparagus, **banana (fruit and leaf),** beans (fresh), **blueberry**, cabbage, **cactus fruit (tuna)**, cantaloupe, carrot, **chayote**, cherry, chestnut, citron, **coffee bean (unroasted)**, **cottonseed**, cucumber, **cucurbit seed (unprocessed), dasheen**, **edible podded legumes,** eggplant, fava (faba) bean (dried), **fresh figs, genip,** grapes, herbs (dried), honeydew melon, **ivy gourd**, Jerusalem artichoke, **kaffir lime leaves, kola nuts, longan, lorocco flower, lychee**, **mint (fresh)**, **mango**, muskmelon, nectarine, **okra, opuntia,** peach, pear**,** peas and beans (dried), pepper, **persimmon**, pineapple, **pitaya/pitahaya/dragon fruit**, **plantain,** plum, **pomegranate, pointed gourd,** prune, quince, **rambutan, snow peas,** squash (summer, winter), **squash flower,** sweet potato, watermelon, yam
  - ANY OTHER UNLABELED commodities from the following crop groups[14] are treated under **FIFRA exemption**: **berry and small fruits, Brassica leafy vegetables, bulb vegetables, cucurbit vegetables, fresh herbs and spices, fruiting vegetables, leafy vegetables, leaves of legumes, leaves of roots and tubers, oilseed, stalk/stem/leaf petiole fruit, stone fruits including their hybrids, tropical and subtropical fruit (edible and inedible peels)**

14 Crop groups are defined by the Environmental Protection Agency (EPA) in 40CFR 180.41 and are provided for quick reference in **Appendix F** in this manual.

T104-a-2 Various Commodities

Pest: Mealybugs (Pseudococcidae)

Treatment: **T104-a-2** MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	2.5	32	24
70-79 °F	3	38	29
60-69 °F	4	48	38

To comply with dosage and temperature restrictions on methyl bromide labels, ONLY the fruits and vegetables listed may be fumigated with T104-a-2. If you have a commodity that is not listed, it may be elsewhere in the T100 schedules for a different pest complex. Refer to the Index for a complete list of commodities for which there are approved treatment schedules. Refer to **Appendix F** (or 40 CFR 180.41) for a list of EPA crop groups and commodities.

The **bolded** items are under FIFRA Section 18 Exemption.

NOTICE

Do not use T104-a-2 if the FIFRA Section 18 quarantine exemption has expired. For any questions concerning the exemption status, call your State Plant Health Director or Regional Treatment Program Manager.

The commodities that are **not bold** are covered on the label. There may be some commodities that are on the label at one dosage and duration, and are also covered in the Section 18 at a different dosage and duration.

EXAMPLE: Coffee bean (roasted) is on the Chemtura MB-Q label and can be treated up to 3.0 lbs. for 24 hours. However, the Section 18 allows for coffee bean (unroasted) to be treated up to 9 lbs. for 12 hours.

List of Commodities Approved for Fumigation With T104-a-2:

CAUTION

Fumigation may cause damage to some commodities and is at the risk of the importer.

- 80 °F or above (maximum dosage 2.5 lbs./1000 ft3): **coconut (unprocessed without husk),** pimento, pumpkin, zucchini squash
- 70 °F or above (maximum dosage 3.0 lbs./1000 ft3): **avocado,** bean, carrot, clementine, coffee bean (roasted), copra (coconut), corn-on-the-cob (sweet corn), edible podded legumes, eggplant, grapefruit, kumquat, lemon, lime, mandarin, **Malvaceae seeds for food use including kenaf and hibiscus**, **dried mint**, okra, onion, orange, parsnip, potato, radish, **root and tuber crop group**, rutabaga, salsify, strawberry, sugar beet, tangelo, tangerine, tomato, turnip root
- 60 °F or above (maximum dosage 4.0 lbs./1000 ft3): apple, apricot, asparagus, **banana (fruit and leaf)**, **blueberry**, cabbage, **cactus fruit (tuna)**, cantaloupe, carrot, **chayote**, cherry, chestnut, citron (ethrog), **coffee bean (unroasted), cottonseed,** cucumber, **cucurbit seed (unprocessed)**, **dasheen**, **edible podded legumes**, fava bean (dried), **fresh figs**, **genip**, grapes, herbs (dried), honeydew melon, **ivy gourd,** Jerusalem artichoke, **kaffir lime leaves, kola nuts**, **longan**, **lorocco flower**, **lychee fruit**, **mango**, **mint (fresh),** muskmelon, nectarine, **opuntia, okra**, peach, pear, peas and beans (dried), pepper, **persimmon**, pineapple, **pitaya/pitahaya/dragon fruit**, **plantain**, plum, **pomegranate**, **pointed gourd**, prune, quince, **rambutan**, **snow peas**, squash (summer, winter), **squash flower**, sweet potato, watermelon, yam
    - ANY OTHER UNLABELED commodities from the following crop groups[15] are treated under FIFRA exemption: **berry and small fruits, Brassica leafy vegetables, bulb vegetables, cucurbit vegetables, fresh herbs and spices, fruiting vegetables, leafy vegetables, leaves of legumes, leaves of roots and tubers, oilseed, stalk/stem/leaf petiole fruit, stone fruits including their hybrids, tropical and subtropical fruit (edible and inedible peels)**

15 Crop groups are defined by the Environmental Protection Agency (EPA) in 40CFR 180.41 and are provided for quick reference in **Appendix F** in this manual.

T105—Irradiation

Irradiation (IR) is an approved treatment for all imported fruits and vegetables and for fruits and vegetables moved interstate from Hawaii, Puerto Rico, and the U.S. Virgin Islands. In addition, irradiation can be used against particular pests of cut flowers and foliage, however, some damage may occur. Refer to ***Table 5-2-2*** on **page 5-2-70** for a list of pest-specific doses.

Treatment must be conducted at approved facilities in a foreign country, Hawaii, Puerto Rico, US Virgin Islands or any area in the US mainland that does **not** support fruit flies (any state except AL, AZ, CA, FL, GA[16], KY, LA, MS[16], NV, NM, NC [16], SC, TN, TX, or VA).

Refer to chapter ***Certifying Irradiation Treatment Facilities*** on **page 6-8-1** of this manual for facility certification requirements.

Commodities that are currently admissible with a treatment or systems approach could also use irradiation as an alternative treatment, provided all the pests targeted by the treatment or systems approach are neutralized by the irradiation dose. Use of irradiation in place of a systems approach or another treatment must be approved and appear in the this manual and FAVIR prior to use.

Important

When designing the facility’s dosimetry system and procedures for its operation, the facility operator must address guidance and principles from American Society for Testing Materials (ASTM) standards or an equivalent standard recognized by the Administrator of APHIS.

(The American Society for Testing and Materials (ASTM) publication, ISO/ ASTM 51261-2002 (E), “**Standard Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing”** is available from: ASTM, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania, USA 19428-2959).

16 IR facilities may be located at the airport of Atlanta, GA, maritime ports of Gulfport, MS, and Wilmington, NC, provided the conditions listed in CFR 305.31(b) are met.

The minimum absorbed doses (MAD) listed in **Table 5-2-2** can be applied ONLY when **all** pests of concern can be mitigated. For example, if a country has Mexican fruit fly, West Indian fruit fly, and Sapote fruit fly, the MAD would have to be 100 Gy, not 70 Gy.

Table 5-2-2 Pest-Specific Minimum absorbed dose (Gy) For Any Approved Imported Fruits, Vegetables and Cut Flowers, and Fruits, Vegetables, and Cut Flowers Moved Interstate from Hawaii, Puerto Rico, and the U.S. Virgin Islands

Scientific Name	Common Name	Minimum Absorbed Dose (Gy) Not To Exceed 1000 Gy
Rhagoletis pomonella	Apple maggot	60
Anastrepha ludens	Mexican fruit fly	70
Anastrepha obliqua	West Indian fruit fly	
Anastrepha suspensa	Caribbean fruit fly	
Conotrachelus nenuphar	Plum curculio	92
Anastrepha serpentina	Sapote fruit fly	100
Bactrocera jarvisi	Jarvis fruit fly	
Bactrocera tryoni	Queensland fruit fly	
Ceratitis capitata	Mediterranean fruit fly	
Copitarsia declora[1]		
Aspidiotus destructor	Coconut scale	150
Bactrocera cucurbitae	Melon fruit fly	
Bactrocera dorsalis	Oriental fruit fly	
Cylas formicarius elegantulus	Sweet potato weevil	
Euscepes postfasciatus	West Indian sweet potato weevil	
Omphisa anastomosalis	Sweet potato vine borer	
Pseudaulacaspis pentagona	White peach scale	
	All other fruit flies of the family Tephritidae which are **not** listed	
Sternochetus frigidus (Fabr.)	Mango pulp weevil	165
Cydia pomonella	Codling moth[1]	200
Epiphyas postvittana	Light Brown Apple Moth[1]	
Grapholita molesta	Oriental fruit moth[1]	
Cryptophlebia ombrodelta	Litchi fruit moth[1]	250
Cryptophlebia illepida	Koa seedworm	
	Eggs and larvae of the family Tortricidae **not** listed	290
Brevipalpus chilensis	Chilean false red mite	300
Sternochetus mangiferae	Mango seed weevil	
	Plant pests of the class Insecta **not** listed **except** pupae and adults of the order Lepidoptera	400

1 Eggs and larvae **only**

T105-a-1 Approved imported fruits, vegetables and cut flowers, and fruits, vegetables, and cut flowers moved interstate from Hawaii, Puerto Rico, and the U.S. Virgin Islands

Refer to https://www.aphis.usda.gov/aphis/ourfocus/planthealth/import-information/sa_quarantine_treatments/ct_irradiation_treatment for detailed information regarding the use of irradiation as a quarantine treatment.

Treatment: T105-a-1 (IR @ 150 Gy)

Pests: All fruit flies from the family Tephritidae
(Refer to **Table 5-2-2** for other pests that can be treated at 150 Gy or less.) Treat using a minimum absorbed dose of 150 Gy, **not** to exceed 1000 Gy.

Important

Refer to the **Hawaii Manual** for detailed inspection procedures and additional entry requirements for pests **not** managed by 150 Gy or when a 400 Gy dose may be used instead.

Table 5-2-3 lists all **currently** approved countries and commodities. The irradiation facilities in each country have been approved and certified by USDA and dose mapping has occurred for each commodity. Countries and commodities can be added (or removed) from this table based on facility certification, compliance agreements, and/or work plans.

Table 5-2-3 Origin and Approved Commodity List for 150 Gy

Origin	Commodity
Grenada	Ambarella *(Spondias dulcis),* Yellow Mombin (*S. mombin),* Purple Mombin (*S. purpurea)*
Hawaii	Abiu, Atemoya, Banana, Breadfruit, *Capsicum* spp., Carambola, Citrus, *Cucurbita* spp., Dragon fruit (pitahaya. pitaya), Eggplant, Jackfruit, Litchi, Longan, Mangosteen, Melon, Moringa pods (Drumstick), Papaya, Pineapple, Rambutan, Sapodilla, Sweet Potato, and Tomato
Jamaica	Mango
Mexico	Carambola, Clementine/Mandarin/Tangerine (*Citrus reticulata*), Fig, Grapefruit (*Citrus paradisi*), Mango, Manzano Pepper (*Capsicum pubescens*), Pitahaya (Pitaya, Dragon fruit), Pomegranate, Sweet lime (*Citrus limettoides*), Sweet Orange (*Citrus sinensis*), Tangelo (*Citrus tangelo*)
Peru	Blueberry, Fig, Pomegranate
Philippines	Mango

T105-a-2 Approved imported fruits, vegetables and cut flowers, and fruits, vegetables, and cut flowers moved interstate from Hawaii, Puerto Rico, and the U.S. Virgin Islands

Refer to https://www.aphis.usda.gov/aphis/ourfocus/planthealth/import-information/sa_quarantine_treatments/ct_irradiation_treatment for detailed information regarding the use of irradiation as a quarantine treatment.

Treatment: T105-a-2 (IR @ 400 Gy)

Pests: Fruit flies from the family Tephritidae and all insect pests **except** adults and pupae of the order Lepidoptera

Treat using a minimum absorbed dose of 400 Gy, **not** to exceed 1000 Gy.

Table 5-2-4 lists all **currently** approved countries and commodities. The irradiation facilities in each country have been approved and certified by USDA and dose mapping has occurred for each commodity. Countries and commodities can be added (or removed) from this table based on facility certification, compliance agreements, and/or work plans.

Table 5-2-4 Origin and Approved Commodity List for 400 Gy

Origin	Commodity
Australia	Litchi
Dominican Republic	Mango
Ghana	Eggplant, Okra, Pepper
Hawaii	Banana, Breadfruit, Cowpea (pod), Curry Leaf, Dragon fruit (pitahaya, pitaya), Guava, Jackfruit, Mangosteen, Melon, Moringa pods (Drumstick), and Sweet Potato Cut flowers and leis
India	Mango, Pomegranate
Malaysia	Carambola (Star fruit), Jackfruit, Papaya, Pineapple, Rambutan
Mexico	Guava
Pakistan	Mango
Philippines	Litchi, Longan, Rambutan
South Africa	Grape, Litchi, Persimmon
Thailand	Dragon Fruit (pitahaya, pitaya), Litchi, Longan, Mango, Mangosteen, Pineapple, Rambutan
Viet Nam	Dragon Fruit (pitahaya, pitaya), Litchi, Longan, Mango, Rambutan, Star Apple

T105-a-3 Approved imported fruits, vegetables and cut flowers, and fruits, vegetables, and cut flowers moved interstate from Hawaii, Puerto Rico, and the U.S. Virgin Islands

Refer to https://www.aphis.usda.gov/aphis/ourfocus/planthealth/import-information/sa_quarantine_treatments/ct_irradiation_treatment for detailed information regarding the use of irradiation as a quarantine treatment.

Treatment: T105-a-3 (IR @ 300 Gy)

Pests: *Sternochetus mangiferae* (Mango seed weevil), and all fruit flies from the family Tephritidae

Treat using a minimum absorbed dose of 300 Gy, **not** to exceed 1000 Gy.

Table 5-2-5 lists all **currently** approved countries and commodities. The irradiation facilities in each country have been approved and certified by USDA and dose mapping has occurred for each commodity. Countries and commodities can be added (or removed) from this table based on facility certification, compliance agreements, and/or work plans.

Table 5-2-5 Origin and Approved Commodity List for 300 Gy

Origin	Commodity
Australia	Mango
Hawaii	Mango
Philippines	Mango

T105-a-4 Mango

Refer to https://www.aphis.usda.gov/aphis/ourfocus/planthealth/import-information/sa_quarantine_treatments/ct_irradiation_treatment for detailed information regarding the use of irradiation as a quarantine treatment.

Treatment: T105-a-4 (IR @ 165 Gy)

Pests: *Sternochetus frigidus* (Mango pulp weevil)

Treat using a minimum absorbed dose of 165 Gy, **not** to exceed 1000 Gy.

Table 5-2-6 lists all **currently** approved countries and commodities. The irradiation facilities in each country have been approved and certified by USDA and dose mapping has occurred for each commodity. Countries and commodities can be added (or removed) from this table based on facility certification, compliance agreements, and/or work plans.

Table 5-2-6 Origin and Approved Commodity List for 165 Gy

Origin	Commodity
Philippines	Mango

T106—Vapor Heat

T106-a Various Commodities from Mexico: Clementine (T106-a-1), Grapefruit (T106-a-2), Mango (Manilla variety only; T106-a-3), Orange (T106-a-4)

Pest: *Anastrepha* spp. (includes Mexican fruit fly, *A. ludens*)

Treatment: T106-a Vapor heat

Heat Up Time:	8 hours
Heat Up Recording Interval:	5 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	43.3 °C/110.0 °F
Dwell Time:	6 hours
Dwell Recording Interval:	5 minutes
Cooling Method:	N/A

T106-b Bell Pepper (T106-b-1), Eggplant (T106-b-2), Mountain papaya (T106-b-3), Papaya (T106-b-4), Pineapple (T106-b-5), Squash (T106-b-6), Tomato (T106-b-7), Zucchini (T106-b-8)

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T106-b Vapor heat

Heat Up Time:	N/A
Heat Up Recording Interval:	N/A
Minimum Air Temperature:	112.0 F
Minimum Pulp Temperature at End of Heat Up:	44.4 °C/112.0 °F
Dwell Time:	8.75 hours
Dwell Recording Interval:	5 minutes
Cooling Method:	Optional

Important

Commodities should be exposed at 112 °F to determine tolerance to the treatment before commercial shipments are attempted.

T106-a-1-1 Clementine or Orange from Mexico

Treatment: T106-a-1-1 Vapor heat

Heat Up Time:	6 hours[1]
Heat Up Recording Interval:	5 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	43.3 °C/110.0 °F
Dwell Time:	4 hours
Dwell Recording Interval:	5 minutes
Cooling Method:	N/A

1 During the initial raising of fruit temperature, the temperature should be raised rapidly in the first 2 hours; the increase over the next 4 hours should be gradual.

T106-f Litchi and Longan from Hawaii

Pest: *Ceratitis capitata* (Mediterranean fruit fly), and *Bactrocera dorsalis* (Oriental fruit fly)

Treatment: T106-f Vapor heat

Heat Up Time:	1 hour
Heat Up Recording Interval:	5 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	47.2 °C/117.0 °F
Dwell Time:	20 minutes
Dwell Recording Interval:	5 minutes
Cooling Method:	Cool water spray

T106-d-1 Mango from the Philippines (the island of Guimaras only)

Pest: *Bactrocera occipitalis, Bactrocera cucurbitae,* and *Bactrocera philippinensis*

Treatment: T106-d-1 Vapor heat

Heat Up Time:	4 hours
Heat Up Recording Interval:	5 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	46.0 °C/114.8 °F
Dwell Time:	10 minutes
Dwell Recording Interval:	1 minute
Cooling Method:	Hydrocooling optional

T106-d Mango from Taiwan

Pest: *Bactrocera dorsalis* (Oriental fruit fly) and *Bactrocera cucurbitae*

Treatment: T106-d Vapor heat

Heat Up Time:	N/A
Heat Up Recording Interval:	N/A
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	47.5 °C/115.7 °F
Dwell Time:	30 minutes
Dwell Recording Interval:	5 minute
Cooling Method:	Cooling required

T106-c Papaya

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T106-c Vapor heat

Heat Up Time:	4 hours
Heat Up Recording Interval:	5 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	47.2 °C/117.0 °F
Dwell Time:	N/A
Dwell Recording Interval:	N/A
Cooling Method:	Optional

T106-e Yellow Pitaya (*Hylocereus megalanthus*) from Colombia

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Anastrepha fraterculus* (South American fruit fly)

Treatment: T106-e Vapor heat

Heat Up Time:	4 hours
Heat Up Recording Interval:	5 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	46.0 °C/114.8 °F
Dwell Time:	20 minutes
Dwell Recording Interval:	5 minutes
Cooling Method:	Hydrocooling optional[1]

1 If post-treatment cooling is conducted, wait 30 minutes after the treatment to start the forced cooling process.

T106-g Rambutan from Hawaii

Pest: *Ceratitis capitata* (Mediterranean fruit fly), and *Bactrocera dorsalis* (Oriental fruit fly)

Treatment: T106-g Vapor heat

Heat Up Time:	1 hour
Heat Up Recording Interval:	5 minutes
Minimum Air Temperature:	N/A
Minimum Pulp Temperature at End of Heat Up:	47.2 °C/117.0 °F
Dwell Time:	20 minutes
Dwell Recording Interval:	5 minutes
Cooling Method:	Optional

T106-h Sweet Potato from Hawaii

Pest: *Cylas formicarius* (Sweet potato weevil), *Euscepes postfasciatus* (West Indian sweet potato weevil), and *Omphisa anastomosalis* (Sweet potato vine borer)

Treatment: T106-h Vapor heat

Heat Up Time:	240 minutes
Heat Up Recording Interval:	N/A
Minimum Air Temperature at Start of Heat Up:	31 °C
Minimum Air Temperature at End of Heat Up:	44 °C
Dwell Time:	190 minutes
Dwell Recording Interval:	5 minutes
Minimum Dwell Time Air Temperature:	48 °C
Minimum Dwell Time Pulp Temperature:	47 °C
Cooling Method:	N/A

Important

The relative humidity in the chamber should be 95% or greater during the heat up interval (from 31 °C to 44 °C). Relative humidity requirements are for commodity quality. Failure to reach 95% relative humidity may decrease the quality of the commodity, but does not result in a treatment failure.

T107—Cold Treatment

Pulp of the Fruit

The pulp of the fruit must be at or below the indicated temperature at time of beginning treatment for all cold treatments.

Fruits for Which Cold Treatment Is Authorized

The following cold treatment schedules are authorized by Plant Protection and Quarantine (PPQ) for the control of specific pests associated with shipments of fruit. The cold treatment schedule that must be used for a specific commodity from a specific country is listed in the Fruits and Vegetables Import Requirement database (FAVIR). These cold treatment schedules indicate the specific pests for which they are designed to control.

Treatment upon arrival may be accomplished at authorized ports as named in the permits.

Treatment in transit may be authorized for specifically equipped and approved vessels or containers and from approved countries, for entry at ports named in the permits. Intransit cold treatment authorization must be preceded by a visit to the country of origin by a PPQ Official to explain loading, inspection, and certification procedures to designated certifying officials of country of origin. Refrigerated compartments on carrying vessels and cold storage warehouse must have prior certification by PPQ. Authorization of cold treatments from countries with direct sailing time less than the number of days prescribed for intransit refrigeration treatment must be contingent on importer understanding that prescribed intransit refrigeration period must be met before arrival of vessel at the approved U.S. port.

Gaps in the cold treatment data print-out for pulp sensors and air sensors shall be allowed or disallowed on a case-by-case basis, taking into account the number of gaps, the length of each gap, and the temperatures before and after. Air temperatures may occasionally exceed treatment temperatures during defrost cycles; however, fruit temperatures should **not** rise appreciably during this time. During non-defrost times, the temperatures of the air sensors should never exceed the maximum allowable treatment temperature.

Important

The fruit must be precooled at or below the target treatment temperature prior to loading. A certified USDA representative must sample the fruit pulp temperatures during loading in all sections of the lot until precooling has been accomplished.

T107-a

Apple, Apricot[17], Avocado, Blueberry, Cape Gooseberry, Cherry, Citrus[18], Ethrog, Grape, Kiwi, Loquat, Litchi (Lychee), Nectarine, Orange, Ortanique, Peach, Pear, Persimmon, Plum, Plumcot, Pomegranate, Pummelo, Quince, Sand Pear,

Pest: *Ceratitis capitata* (Mediterranean fruit fly) and *Ceratitis rosa* (Natal fruit fly)

Treatment: T107-a Cold treatment

Temperature	Exposure Period
34 °F (1.11 °C) or below	14 days
35 °F (1.67 °C) or below	16 days
36 °F (2.22 °C) or below	18 days

Important

Pretreatment conditioning for avocado (heat shock or 100.4 °F (38 °C) for 10 to 12 hours) is optional and is the responsibility of the shipper. The pretreatment conditioning, which may improve fruit quality, is described in HortScence 29 (10): 1166-1168. 1994. and 30(5): 1052-1053 (1995)

T107-a-1

Apple, Apricot[17], Blueberry, Cherry, Grape, Grapefruit, Kiwi, Mandarin, Nectarine, Orange, Peach, Pear, Plum, Pomegranate, Quince, Sweet Orange, Tangelo, Tangerine (includes Clementine)

Pest: *Ceratitis capitata* (Mediterranean fruit fly) and species of *Anastrepha* (other than *Anastrepha ludens)*

Treatment: T107-a-1 Cold treatment

Temperature	Exposure Period
34 °F (1.11 °C) or below	15 days
35 °F (1.67 °C) or below	17 days

T107-a-2

Orange (*Citrus sinensis)* and Tangor *(Citrus nobilis)* from Australia

Pest: *Ceratitis capitata* (Mediterranean fruit fly)

Treatment: T107-a-2 Cold treatment

Temperature	Exposure Period
37.4 °F (3.0 °C) or below	20 days

17 Pluots and plumcots are considered hybrids of plums and apricots and can be treated using T107-a.

18 Citrus includes clementine, grapefruit, lime, lemon, mandarin, orange, satsuma, tangor, tangerine, and other fruits grown from *Citrus reticulata* or its hybrids.

T107-a-3 Lemon (*Citrus limon)* from Australia

Pest: *Ceratitis capitata* (Mediterranean fruit fly)

Treatment: T107-a-3 Cold treatment

Temperature	Exposure Period
35.6 °F (2.0 °C) or below	16 days
37.4 °F (3.0 °C) or below	18 days

T107-b Apple, Apricot[19], Cherry, Ethrog, Grapefruit, Litchi, Longan, Orange, Peach, Persimmon, Plum, Pomegranate, Tangerine (includes Clementine), White Zapote

Pest: *Anastrepha ludens* (Mexican fruit fly)

Treatment: **T107-b** Cold treatment

Temperature	Exposure Period
33 °F (0.56 °C) or below	18 days
34 °F (1.11 °C) or below	20 days
35 °F (1.67 °C) or below	22 days

T107-c Apple, Apricot[20], Carambola, Cherry, Grape, Grapefruit, Orange, Pomegranate, Tangerine (includes Clementine)

Pest: Species of *Anastrepha* (other than *Anastrepha ludens)*

Treatment: **T107-c** Cold treatment

Temperature	Exposure Period
32 °F (0 °C) or below	11 days
33 °F (0.56 °C) or below	13 days
34 °F (1.11 °C) or below	15 days
35 °F (1.67 °C) or below	17 days

19 **Pluots** and **plumcots** are considered hybrids of plums and apricots and can be treated using T107-b.

20 **Pluots** and **plumcots** are considered hybrids of plums and apricots and can be treated using T107-c.

T107-d Apple, Citrus[21], Kiwi, Pear

Pest: *Bactrocera tryoni* (Queensland fruit fly)

Treatment: **T107-d** Cold treatment

Temperature	Exposure Period
32 °F (0 °C) or below	13 days
33 °F (0.56 °C) or below	14 days
34 °F (1.11 °C) or below	18 days
35 °F (1.67 °C) or below	20 days
36 °F (2.22 °C) or below	22 days

T107-d-1 Cherry from Australia

Pest: *Bactrocera tryoni* (Queensland fruit fly)

Treatment: **T107-d-1** Cold treatment

Temperature	Exposure Period
33.8 °F (1 °C) or below	14 days
37.4 °F (3 °C) or below	15 days

T107-d-2 Orange (*Citrus sinensis)*, Tangerine/Clementine/Mandarin (*C. reticulata*), Tangelo (*C. paradisi* x *C. reticulata*) and Tangor *(C. nobilis)* from Australia

Pest: *Bactrocera tryoni* (Queensland fruit fly) and *B. neohumeralis* (lesser Queensland fruit fly)

Treatment: **T107-d-2** Cold treatment

Temperature	Exposure Period
32 °F (0 °C) or below	13 days
33 °F (0.56 °C) or below	14 days
37.4 °F (3.0 °C) or below	16 days

T107-d-3 Lemon (*Citrus limon)* and Grapefruit from Australia

Pest: *Bactrocera tryoni* (Queensland fruit fly) and *B. neohumeralis* (lesser Queensland fruit fly)

Treatment: T107-d-3 Cold treatment

Temperature	Exposure Period
37.4 °F (3.0 °C) or below	14 days

21 Citrus includes clementine, grapefruit, lime, lemon, mandarin, orange, satsuma, tangor, tangerine, and other fruits grown from *Citrus reticulata* or its hybrids.

T107-e

Apricot[22], Citrus[23], Grape, Nectarine, Peach, Plum

Pest: *Thaumatotibia leucotreta* (false codling moth), *Ceratitis capitata* (Mediterranean fruit fly), *C. quinaria* (five-spotted, Rhodesian, or Zimbabwean fruit fly), *C. rosa* (Natal fruit fly), and *Bactrocera invadens*[24]

Treatment: **T107-e** Cold treatment

Temperature	Exposure Period
31 °F (-0.55 °C) or below[1]	22 days

1 The treatment shall **not** commence until all sensors are reading 31 °F (-0.55 °C) or below. If the temperature exceeds 31.5 °F (-0.27 °C), the treatment shall be extended one-third of a day for each day or part of a day the temperature is above 31.5 °F (-0.27 °C). If the exposure period is extended, the temperature during the extension period must be 34° F (1.11 °C) or below. If the temperature exceeds 34 °F (1.11 °C) at any time, the treatment is nullified. Also, some freeze damage to the fruit may occur if the pulp temperature is allowed to drop below approximately 29.5 °F (-1.38 °C) (This varies with the commodity.)

T107-h

Carambola, Litchi (Lychee), Longan, Sand Pear

Pest: *Bactrocera dorsalis* (Oriental fruit fly), *Bactrocera curcubitae* (melon fly) and *Conopomorpha sinensis* (lychee fruit borer)

Treatment: **T107-h** Cold treatment

Temperature	Exposure Period
33.8 °F (0.99 °C) or below	17 days
34.5 °F (1.38 °C) or below	20 days

T107-j

Carambola, Litchi (Lychee), Longan, Sand Pear

Pest: *Bactrocera dorsalis* (Oriental fruit fly)

Treatment: **T107-j** Cold treatment

Temperature	Exposure Period
33.8 °F (0.99 °C) or below	15 days
34.5 °F (1.38 °C) or below	18 days

NOTICE

Use T107-j when *Bactrocera dorsalis is* the **ONLY** pest of concern that is identified by APHIS PPQ import requirements.

22 Pluots and plumcots are considered hybrids of plums and apricots and can be treated using T107-e.
23 Consignments that received treatment T107-e may **only** arrive at Houston, TX, Newark, NJ, Philadelphia, PA, or Wilmington, DE.
24 The addition of this pest is pending regulatory approval.

T107-g

Pecans and Hickory Nuts

Pest: *Curculio caryae* (Pecan weevil)

Treatment: **T107-g** Cold treatment

Temperature	Exposure Period
0 °F (-17.78 °C) or below	7 days

T107-f

Ya Pear from China

Treatment: **T107-f** Cold treatment

Temperature	Exposure Period
32 °F (0 °C) or below	10 days
33 °F (0.56 °C) or below	11 days
34 °F (1.11 °C) or below	12 days
35 °F (1.67 °C) or below	14 days

T107-i

Barhi Date (*Phoenix dactylifera* L.'Barhi')

Pest: *Ceratitis capitata* (Mediterranean fruit fly)

Treatment: **T107-i** Cold treatment

Temperature	Exposure Period
34 °F (1.11 °C) or below	14 days
35 °F (1.67 °C) or below	16 days
36 °F (2.22 °C) or below	18 days

T107-L

Orange (*Citrus sinensis*) and Tangerine/Clementine/Mandarin (*C. reticulata*)

Pest: *Bactrocera zonata* (Peach fruit fly), *Ceratitis capitata* (Mediterranean fruit fly), *C. rosa* (Natal fruit fly), and *Anastrepha* spp. (other than *A. ludens*)

Treatment: **T107-L** Cold treatment

Temperature	Exposure Period
35.0 °F (1.67 °C) or below	18 days

T108—Fumigation Plus Refrigeration of Fruits

Fruits for Which Fumigation Followed by Cold Treatment Is Authorized

The following treatment schedules (fumigation followed by cold treatment) are authorized by Plant Protection and Quarantine (PPQ) for the control of specific pests associated with shipments of fruit. The treatment schedule that must be used for a specific commodity from a specific country is listed in the Fruits and Vegetables Import Requirement database (FAVIR). These treatment schedules indicate the specific pests for which they are designed to control.

Important

For Hawaiian-grown avocados, research has shown that, during the process of cold treatment (T108-a), a single transient heat spike of no greater than 39.6 °F (4.2 °C) and no longer than 2 hours, during or after 6 days of cold treatment, does **not** affect the efficacy of the treatment. However, in the absence of supporting research, such a tolerance for heat spikes shall **not** be extended to other fruits.

NOTICE

Some varieties of fruit may be injured by exposure to MB. Importers should be encouraged to treat small samples of fruit to determine tolerance levels before shipping commercial quantities. The USDA is **not** liable for damages caused by quarantine.

T108-a Apple, Apricot[25], Avocado, Cherry, Grape, Kiwi, Nectarine, Peach, Pear[26], Plum, Quince

Pest: *Bactrocera cucurbitae* (melon fly), *Bactrocera dorsalis* (Oriental fruit fly), *Bactrocera tryoni* (Queensland fruit fly), *Brevipalpus chiliensis* (Chilean false red mite), *Ceratitis capitata* (Mediterranean fruit fly)

Treatment: **T108-a** Fumigation plus Cold treatment
Three alternative schedules based upon the fumigation exposure time

Important

Pretreatment conditioning for avocado (heat shock or 100.4 °F (38 °C) for 10 to 12 hours) is optional and is the responsibility of the shipper. The pretreatment conditioning, which may improve fruit quality, is described in HortScence 29 (10): 1166-1168. 1994. and 30(5): 1052-1053 (1995)

NOTICE

Check the Fruits and Vegetables Import Requirement database (FAVIR) to determine the required treatments for a commodity from a specific country.

Important

Some varieties of fruit may be injured by the 3-hour exposure. Importers should be encouraged to test treat small quantities to determine tolerance before shipping commercial quantities

Important

Time lapse between fumigation and start of cooling **not** to exceed 24 hours.

25 **Plumcot** and **pluot** are considered hybrids of plums and apricots and may also be treated using T108-a provided they are treated under **Section 18 Crisis exemption.**

26 Fumigation may cause **severe** damage to Chinese, Japanese, Asian and Sand Pears. Obtain the importer's consent before fumigation.

T108-a-1

Treatment: **T108-a-1**[27] MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F (21.11 °C) or above	2 lbs	25	18
Followed by cold treatment			

Refrigeration	
Temperature	Exposure Period
33 to 37 °F (0.56 to 2.77 °C)	4 days
OR 38 to 47 °F (3.33 to 8.33 °C)	11 days

T108-a-2

Treatment: **T108-a-2**[28] MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	2.5 hrs
70 °F (21.11 °C) or above	2 lbs	25	18	18
Followed by cold treatment				

Refrigeration	
Temperature	Exposure Period
34 to 40 °F (1.11 to 4.44 °C)	4 days
OR 41 to 47 °F (5.0 to 8.33 °C)	6 days
OR 48 to 56 °F (8.88 to 13.33 °C)	10 days

27 **DO NOT** use T108-a-1 for Chilean False Red Mite (*Brevipalpus chilensis*). Use T108-a-3.
28 **DO NOT** use T108-a-2 for Chilean False Red Mite (*Brevipalpus chilensis*). Use T108-a-3.

T108-a-3

Treatment: **T108-a-3** MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs*	2.5 hrs	3 hrs
70 °F (21.11 °C) or above	2 lbs	25	18	18	17
Followed by cold treatment					

Refrigeration	
Temperature	**Exposure Period**
43 °F to 47 °F (6.11 to 8.33 °C)	3 days
OR 48 °F to 56 °F (8.88 to 13.33 °C)	6 days

T108-b

Apple, Grape, and Pear[29]

Pest: *Austrotortrix* spp. and *Epiphyas* spp. (light brown apple moth complex), *Bactrocera tryoni* (Queensland fruit fly), *Ceratitis capitata* (Mediterranean fruit fly) and other fruit flies

Treatment: T108-b MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
50 °F (10 °C) or above	1.5 lbs	23	20
40-49 °F (4.44 to 9.44 °C)	2 lbs	30	25
Followed by cold treatment			

Temperature	Exposure Period
33 °F (0.56 °C) or below	21 days

Important

Load **not** to exceed 80 percent of chamber capacity. Time lapse between fumigation and start of cooling **not** to exceed 24 hours.

29 Fumigation may cause **severe** damage to Chinese, Japanese, Asian and Sand Pears. Obtain the importer's consent before fumigation.

T109—Cold Treatment Plus Fumigation of Fruits

T109-d-1 Apple, Grape, and Pear[30] from Australia

Pest: *Austrotortrix* spp. and *Epiphyas* spp. (light brown apple moth complex), *Bactrocera tryoni* (Queensland fruit fly), *Ceratitis capitata* (Mediterranean fruit fly) and other fruit flies

Treatment: T109-d-1 Cold treatment followed by MB at NAP—tarpaulin or chamber

Temperature	Exposure Period
33 °F (0.56 °C) or below	21 days
Followed by MB at NAP—tarpaulin or chamber	

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F (21.11 °C) or above	2 lbs	30	25
60 to 69 °F (15.55 to 20.55 °C)	2.5 lbs	36	28
40 to 59 °F (4.44 to 15 °C)	3 lbs	44	36

Alternate treatment for *Austrotortrix* and *Epiphyas* is fumigation plus refrigeration (***T108-b*** on **page 5-2-88**).

Alternate treatment for grapes from Australia as a fruit fly precautionary treatment for *Bactrocera tryoni* and *Ceratitis capitata* is fumigation plus refrigeration (***T108-a*** on **page 5-2-86** and ***T108-b*** on **page 5-2-88**).

NOTICE

Load **not** to exceed 80 percent of capacity.

30 Fumigation may cause **severe** damage to Chinese, Japanese, Asian and Sand Pears. Obtain the importer's consent before fumigation.

T109-a

Apple (‘Fuji’ Apple from Japan and Korea)

Pest: *Carposina niponensis* (peach fruit moth), *Conogethes punctiferalis* (yellow peach moth), *Tetranychus viennensis* (fruit tree spider mite), *Tetranychus kanzawai* (Kanzawa mite)

Two alternative schedules based on type of container

T109-a-1

Treatment: **T109-a-1** (apples in plastic field bins at maximum load factor 50 percent or less) Cold treatment followed by MB at NAP—tarpaulin or chamber

Temperature	Exposure Period
34 °F (1.11 °C) or below	40 days
Followed by MB at NAP—tarpaulin or chamber	

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
50 °F or (10 °C) above	3 lbs	44	36

T109-a-2

Treatment: **T109-a-2** (apples in only cardboard cartons at maximum load factor 40 percent or less) Cold treatment followed by MB at NAP—tarpaulin or chamber

Temperature	Exposure Period
34 °F (1.11 °C) or below	40 days
Followed by MB at NAP—tarpaulin or chamber	

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
59 °F (15 °C) above	2 lbs 6 oz	35	29

T110—Quick Freeze

Under Development: **See "Quick Freeze Guidelines" on page-3-7-21** for operational guidelines and equipment specifications.

Important

Never use this treatment for the control of bruchid beetles in dried beans. Research has shown that a treatment of -18.0 °C (-0.4 °F) for 14 days would be needed to be efficacious.

T110-a

Treatment: T110-a — Quick Freeze

1. Initially, lower the commodity's temperature to 0 °F (-17.77 °C) or below.
2. Hold the commodity's temperature at 20 °F (-6.66 °C)or below for at least 48 hours.

   The commodity may be transported during the 48-hour treatment period, but at no time may the commodity's temperature rise above 20 °F (-6.66 °C) prior to release.

Certain fruits and vegetables are admissible from all foreign countries after receiving this treatment in accordance with 7CFR 319.56-12. Also, interstate movement of all fruits and vegetables from offshore areas of the United States (except mango from Hawaii) is authorized in the frozen state after being quick frozen.

T110-b

Treatment: T110-b — Quick Freeze for Destruction

Important

T110-b may ONLY be used with permission from CPHST-AQI.

Contact 919-855-7450 for official approval.

1. Initially, lower the commodity's temperature to 0 °F (-17.77 °C) or below.
2. Hold the commodity's temperature at 20 °F (-6.66 °C)or below for at least 48 hours.

   The commodity may be transported during the 48-hour treatment period, but at no time may the commodity's temperature rise above 20 °F (-6.66 °C) prior to release.
3. After treatment, transport the commodity to a landfill for deep burial.

T110-c Miscellaneous Food/Feed Commodities

Important

Historically these treatments have been used on nonfood/nonfeed commodities. Be aware that the treatment may result in severe damage to food or feed commodities.
T110-c schedules may ONLY be used with permission from CPHST-AQI. Contact 919-855-7450 for official approval.

T110-c-1

Pest: Quarantine-significant snails of the families Bradybaenidae, Geomitridae, Helicidae, Helicellidae, Hygromiidae, and Succineidae, including the following genera:

Bradybaena *Cochlicella* *Trochoidea*
Candidula *Helicella* *Xerolenta*
Cepaea *Helicostyla* *Xeropicta*
Cathaica *Theba* *Xerosecta*
Cernuella *Trishoplita* *Xerotricha*

Treatment: T110-c-1—Cold Treatment

Temperature	Exposure Period
0 °F	48 hrs

T110-c-2

Pest: Quarantine-significant snails of the family Helicidae, including the following genera:
Helix, Otala

Treatment: T110-c-2—Cold Treatment

Temperature	Exposure Period
0 °F	32 hrs
10 °F	48 hrs

T110-c-3

Pest: Quarantine-significant snails of the family Achatinidae, including the following genera:

Achatina *Lignus*
Archachatina *Limicolaria*

Treatment: T110-c-3—Cold Treatment

Temperature	Exposure Period
0 °F	8 hrs
10 °F	16 hrs
20 °F	24 hrs

5

Treatment Manual

Treatment Schedules

T200 - Schedules for Propagative Plant Material

Contents

The following schedules of the T200 series are arranged by category such as a specifically named plant, type of plant, character of growth, or pest.

Important

> Plant and plant parts treated under the T200 series schedules are **not** to be used for food or feed purposes.

T201—Plants

T202—Bulbs, Corms, Tubers, Rhizomes, and Roots

T203—Seeds

The condition of the plants at the time of treatment may have a bearing on reaction to treatment.

Any new or unusual observations relating to treatment tolerance of treated material should be recorded and reported to the USDA-APHIS-PPQ-S&T-CPHST-AQI, giving details of the treatment and the conditions of application. In appraising the effects of a particular treatment, take care to distinguish between the actual or apparent effects attributable to the treatment and those **not** related to the treatment.

NOTICE

Containers. Give boxes, crates, and other propagative containers the same treatment as the propagative material with which they are associated. Exceptions are necessary, however, when significant pests are found infesting containers or packing materials that would not be controlled by the treatment required for the contents.

T201—Plants

NOTICE

Plant Tolerance. In general, nursery stock should be fumigated in a normal atmospheric pressure (NAP) chamber. Damage may occur when treatment is performed under a tarpaulin. When selecting a treatment for a particular pest, consider the tolerance of the plant material to the treatment. Refer to the "Handbook of Plant Tolerances to Quarantine Treatments" to determine if a genus or species is tolerant to treatment.

T201-q Aquatic plants infested with freshwater snails

Pest: Snails of the following families: Amphulariidae, Bulinidae, Limnaeidae, Planorbidae, Viviparidae

Treatment: T201-q—Hot water treatment 112 °F for 10 minutes. *Elodea densa* and *Cabomba caroliniana* plants not tolerant to this treatment. Inspection stations should refer to their reference report guide for host tolerances to the hot water treatment.

T201-e-1 Bromeliads

Pest: External feeders

Treatment: T201-e-1 MB ("Q" label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2 lbs	1.5 hrs
80-89 °F	2 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs

T201-e-2 Bromeliads

Pest: Internal feeders such as borers and miners

Treatment: T201-e-2 MB (“Q” label only) at 15" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2 lbs	1.5 hrs
80-89 °F	2 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs

T201-f-1 Cacti and other succulents

Two schedules based on type of pest

Pest: External feeders (other than soft scales) infesting collected dormant and nondormant plant material

Treatment: T201-f-1 MB (“Q” label only) at NAP—tarpaulin or chamber)

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period:	
		Brachyrhinus larvae	All others
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

T201-f-2 Cacti and other succulents

Two schedules based on type of pest

Pest: Borers and soft scales

Treatment: T201-f-2 MB (“Q” label only) in 15" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period:	
		Brachyrhinus larvae	All others
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

Important

Vacuum fumigation requires prior consent of the importer. If consent is denied, entry should be refused unless hand removal plus 100 percent inspection is feasible.

NOTICE

Obtain consent of the importer prior to treatment of the following plants since some damage may occur:

- Bromeliads, see ***T201-e-3-1*** on **page 5-3-15**
- Kalenchoe synsepala, see ***T201-p*** on **page 5-3-19**
- Sedum adolphi, see ***T201-p*** on **page 5-3-19**

T201-g-1 *Chrysanthemum* spp., rooted and unrooted cuttings

NOTICE

Obtain consent of the importer prior to fumigation since some damage may occur.

Pest: Aphids

Treatment: T201-g-1 MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate ($lb/1,000 ft^3$)	Exposure Period
70 °F or above	0.75 lb	2 hrs

T201-g-2 *Chrysanthemum* spp., rooted and unrooted cuttings

DO NOT USE this treatment schedule. The schedule is not authorized for use and will be removed or revised following a Federal Register notice according to 7 CFR 305.3.

May 01, 2012

Pest: External feeders

Treatment: T201-g-2 Malathion-carbaryl chemical dip—Hand removal of pests of infested parts *plus* a malathion-carbaryl chemical dip. Solution prepared by adding 3 level tablespoons of 25 percent malathion wettable powder and 3 level tablespoons of 50 percent carbaryl wettable powder to each gallon of water. The addition of a sticker-spreader formulation may be required for hard to wet plants. Use fresh chemicals and prepare dip for the same day use. Plants, including the roots, should be entirely submerged in the chemical dip for 30 seconds.

T201-g-3 *Chrysanthemum* spp., rooted and unrooted cuttings

Pest: Leafminers, aphids, mites, etc.*

Treatment: T201-g-3—Hot water at 110-111 °F for 20 minutes

*This treatment is marginal as to host tolerance.

Important

Chrysanthemum spp. from the Dominican Republic and Colombia when infested with Agromyzid leaf miners requires no treatment unless destined to Florida.

T201-l Commodities infested with quarantine-significant slugs

Pest: Quarantine significant slugs of the families Agriolimacidae, Arionidae, Limacidae, Milacidae, Philomycidae, and Veronicellidae, including the following genera:

Agriolimax	***Leidyula***	***Pseudoveronicella***
Arion	***Limax***	***Sarasinula***
Colosius	***Meghimatium***	***Semperula***
Deroceras	***Milax***	***Vaginulus***
Diplosolenodes	***Pallifera***	***Veronicella***

Treatment: T201-l MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
90-96 °F	1 lb	12	9
80-89 °F	1.25 lbs	15	12
70-79 °F	1.5 lbs	18	15
60-69 °F	1.75 lbs	22	19

T201-h-1 Cycads—excluding *Dioon edule* (chestnut dioon)

Pest: External feeders

Treatment: T201-h-1 MB (“Q” label only) in 15" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2 lbs	2 hrs
80-89 °F	2.5 lbs	2 hrs
60-79 °F	3 lbs	2 hrs
40-59 °F	3 lbs	2.5 hrs

T201-a-1

Deciduous woody plants (dormant)

Pest: External feeders

Treatment: T201-a-1 MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period: *Brachyrhinus* larvae	All others
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

For gypsy moth egg masses, use ***T313-a*** on **page 5-4-38** or ***T313-b*** on **page 5-4-38**.

Important

If treating for mealybugs, use ***T305-c*** on **page 5-4-19**.

NOTICE

This schedule is not entirely satisfactory for use against egg masses of *Yponomeuta malinellus* (apple ermine moth).

T201-a-2

Deciduous woody plants (dormant)

root cuttings, scion wood cuttings, and nonfoliated citrus whitefly host—such as *Acer, Berberis, Fraxinus, Philadelphus, Rosa, Spiraea,* and *Syringa*

Pest: Borers

Treatment: T201-a-2 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period: *Brachyrhinus* larvae	All others
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

Important

Citrus whitefly hosts, see ***T201-k-1*** on **page 5-3-10** Evergreens* broadleaved genera

T201-h-2 Dioon edule (chestnut dioon)

For other cycads see cycads

Pest: External feeders

Treatment: T201-h-2 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2 lbs	2 hrs
80-89 °F	2.5 lbs	2 hrs
60-79 °F	3 lbs	2 hrs
40-59 °F	3 lbs	2.5 hrs

T201-i-1 *Dieffenbachia* spp., *Dracaena* spp., *Philodendron* spp. (plants and cuttings)

Pest: External feeders

Treatment: T201-i-1 MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	1.5 hrs	2 hrs	2.5 hrs	3 hrs
90-96 °F	2 lb	24	16	—	—	—
80-89 °F	2 lbs	24	—	16	—	—
70-79 °F	3 lbs	36	—	24	—	—
60-69 °F	3 lbs	36	—	—	24	—
50-59 °F	3 lbs	36	—	—	—	24

Important

This treatment may cause leaf tip burn in *Dieffenbachia* (dumbcane).

T201-i-2 *Dieffenbachia* spp., *Dracaena* spp., *Philodendron* spp. (plants and cuttings)

Pest: Internal feeders

Treatment: T201-i-2 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2 lbs	1.5 hrs
80-89 °F	2 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs

Immature and tender plants and cuttings, and species and varieties known or considered to be affected by MB, should **not** be fumigated without consent of the importer. Without such consent, REFUSE entry.

NOTICE

This schedule may cause leaf tip burn in *Dieffenbachia* (dumbcane).

T201-b-1 Evergreens*, (Broadleaved genera, such as *Azalea*, *Berberis*, *Camellia*, *Ilex*, and *Photinia*)

(Coniferous genera, such as *Cedrus*, *Cupressus*, *Juniperus*, *Podocarpus*, *Thuja*, and *Taxus)*

Pest: External feeder

Treatment: T201-b-1 MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate ($lb/1,000 ft^3$):		Exposure Period:	
	Brachyrhinus larvae	All others	*Brachyrhinus* larvae	All others
90-96 °F	2 lbs	1.5 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	2.5 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	2.5 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	2.5 lbs	4 hrs	3.5 hrs

Important

*If treating for mealybugs, fumigate at 60 °F or above.

Exceptions:

Araucaria spp., see *T201-c-1* on **page 5-3-10**
Azalea indica, see *T201-c-2* on **page 5-3-11**
Cycads, see *T201-l* on **page 5-3-6**
Citrus whitefly hosts, see *T201-k-1* on **page 5-3-10**
Daphne spp., see *T201-c-1* on **page 5-3-10**
Lavandula spp., see *T201-p-1* on **page 5-3-19**
Osmanthus americanus, see *T201-p-2* on **page 5-3-20**
Pinus from Canada to certain States, see *T201-j* on **page 5-3-16**
Peanuts with gypsy moth egg masses, see *T313-a* on **page 5-4-38**

NOTICE

Some species and varieties of evergreens, particularly in *Azalea* and *Juniperus* have low tolerances and should be fumigated as in schedule T201-c; those known or believed to be intolerant should be handled under T201-p. For tolerance data, see Handbook of Plant Tolerances to Quarantine Treatments.

T201-k-1 Foliated hosts plants of *Dialeurodes citri* (citrus whitefly), excluding *Osmanthus americanus*

For Osmathus americanus, see T201-p

Pest: *Dialeurodes citri* (citrus whitefly)

Treatment: T201-k-1 MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3):		Exposure Period:
	Brachyrhinus larvae	All others	
85-96 °F	1.5 lbs	1 lb	4 hrs
80-84 °F	2.5 lbs	2 lbs	2.5 hrs
70-79 °F	2 lbs	2 lbs	3.5 hrs

T201-c-1 Greenhouse-grown plants, herbaceous plants and cuttings, and greenwood cuttings of woody plants

For cut flowers and greenery, use T305-a, which is identical to this schedule).

Pest: External feeders*, leaf miners, thrips

Treatment: T201-c-1 MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80-90 °F	1.5 lbs	19	12
70-79 °F	2 lbs	24	16
60-69 °F	2.5 lbs	30	20
50-59 °F	3 lbs	36	24
40-49 F	3.5 lbs	41	27

Important

*If treating for mealybugs, fumigate with 2.5 lbs. at 60 °F or above.

T201-c-2 Greenhouse-grown plants, herbaceous plants and cuttings, and greenwood cuttings of woody plants

Pest: Borers, soft scales

Important

For cut flowers and greenery, use ***T305-b*** on **page 5-4-18**, which is identical to this schedule.

Treatment: T201-c-2 MB ("Q" label only) in 15" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-90 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	3.5 hrs

Vacuum fumigation requires prior consent of the importer. If consent is denied, refuse entry unless T201-c-1, plus hand removal of these pests is feasible. For shipments of a size to permit 100 percent inspection, plants with these pests may be handled separately. Vacuum fumigation is **not** required for soft scales known to be widely distributed in the United States.

Important

Exceptions to Schedules T201-c-1 and 2

- Bromeliads, see ***T201-e-3-1*** on **page 5-3-15**
- Cacti and other succulents, see ***T201-f-2*** on **page 5-3-4**
- *Chrysanthemum* spp., see***T201-g-1*** on **page 5-3-5**
- Cycads, see ***T201-l*** on **page 5-3-6**
- Cyclamen mites, ***T201-a-2*** on **page 5-3-7**
- *Dieffenbachia* spp., *Dracaena* spp., and *Philodendron* spp., see ***T201-i-1*** on **page 5-3-8**
- *Kalanchoe synsepala*, see ***T201-p-1*** on **page 5-3-19**
- *Lavandula* spp., see ***T201-p-2*** on **page 5-3-20**
- Orchids, see ***T201-d-1*** on **page 5-3-14**
- *Osmanthus americanus*, see ***T201-p*** on **page 5-3-19**
- *Pelargonium* spp., see ***T201-p*** on **page 5-3-19**
- *Sedum adolphi*, see ***T201-p*** on **page 5-3-19**
- Plants infested with *Succinea horticola*, see ***T201-o-1*** on **page 5-3-12**
- Plants infested with *Veronicella* or other slugs, see ***T201-l*** on **page 5-3-6**

T201-n Host plants of *Aleurocanthus woglumi* (citrus blackfly)

Pest: *Aleurocanthus woglumi* (citrus blackfly)

Treatment: T201-n MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
85 °F or above	1 lb	13	9
80-85 °F	1.25 lbs	16	12
70-79 °F	1.5 lbs	19	15
65-69 °F	1.75 lbs	23	17

Precautions within citrus blackfly quarantine areas:

- Conduct tarpaulin fumigations in shaded areas, if possible, to prevent the development of high space temperatures within the tarpaulin enclosure.
- Fumigate 4 to 5 days after plants are dug, balled, and burlapped, if possible.
- Roots and soil should be moist prior to fumigation. Watering should be deferred for 12 hours after fumigation unless there is wilting, in which case, water as needed.
- Avoid excessive air circulation during fumigation or during the post-treatment aeration period.
- Avoid placing plants in direct sunlight after fumigation.

T201-o-1 Host plants of *Omalonyx unguis* and *Succinea spp.* (snails)

Important

These treatments are for use on plants that may **not** tolerate fumigation. Use either of the following treatments.

Pest: *Omalomyx unguis* and *Succinea spp.* (snails)

Treatment: T201-o-1 Water Spray—Use a high-pressure water spray on the foliage to flush snails from the plants. Care should be taken **not** to spray the root systems of conifers since they will be damaged. The run-off drain must be screened to catch snails before drainage into the sewer system. Reinspect plants after wash.

T201-o-2

Host plants of *Omalonyx unguis* and Succinea spp. (snails)

DO NOT USE this treatment schedule. The schedule is not authorized for use and will be removed or revised following a Federal Register notice according to 7 CFR 305.3.

May 01, 2012

Treatment: **T201-o-2** Chemical Dip—Dip plants with a Malathion-carbaryl chemical dip. Solution prepared by adding 3 level tablespoons of 25 percent Malathion wettable powder and 6 level teaspoons of 50 percent carbaryl wettable powder per gallon of water with a sticker-spreader formulation.

T201-k-2

Nonfoliated hosts plants of *Dialeurodes citri* (citrus whitefly), excluding *Osmanthus americanus*

Pest: *Dialeurodes citri* (citrus whitefly)

Treatment: T201-k-2 MB (“Q” label) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period:	
		Brachyrhinus larvae	All others
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

T201-d-1 Orchids, plants, and cuttings

Pest: External feeders, other than soft scales

Collected: Dormant or nondormant

Treatment: T201-d-1 MB (“Q” label only) at NAP tarpaulin or chamber,

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period:	
		Brachyrhinus larvae	All others
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

NOTICE

Some varieties of Orchids may be sensitive to methyl bromide (MB) treatments. These varieties include *Cymbidium, Cypripedium,* and *Phalaenopsis.* For alternatives, see ***T201-p*** on **page 5-3-19.**

Important

If treating for mealybugs, use ***T305-c*** on **page 5-4-19**.

T201-d-2 Orchids, plants, and cuttings

Pest: External feeders (other than soft scales) infesting greenhouse-grown plant material

Treatment: T201-d-2 MB (“Q” label only) at NAP tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	1 lb	2 hrs
80-89 °F	1.5 lbs	2 hrs
70-79 °F	2 lbs	2 hrs
60-69 °F	2.5 lbs	2 hrs
50-59 °F	3 lbs	2 hrs
40-49 °F	3.5 lbs	2 hrs

T201-d-3 Orchids, plants, and cuttings

Pest: Borers, cattleya fly, *Mordellistena* spp., soft scales, *Vinsonia* spp.

Treatment: T201-d-3 MB (“Q” label only) in 15" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	3 lbs	1 hr
80-89 °F	3 lbs	1.5 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	3.5 hrs

For nondormant plants, collected or greenhouse grown, vacuum fumigation requires prior consent of the importer. If consent is denied, REFUSE entry unless T201-a-1 plus hand removal of these pests is feasible. Plant shipments of a size to permit 100 percent inspection and pest removal may be handled separately.

T201-d-4 Orchids, plants, and cuttings

Pest: Cecidomyid galls

Treatment: **T201-d-4** Excised in all cases

T201-d-5 Orchids, plants, and cuttings

Pest: Leaf miner, *Eurytoma* spp., infesting *Rhynchostylis*

Treatment: T201-d-5 Hot water—118 °F for 0.5 hour followed by a cool water bath

T201-e-3-1 Pineapple slips

Two alternative schedules

Pest: Various

Treatment: T201-e-3-1 MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	1.5 lbs	2 hrs
80-89 °F	2 lbs	2 hrs
70-79 °F	2.5 lbs	2 hrs
60-69 °F	3 lbs	2 hrs

T201-e-3-2

Pineapple slips

Alternative schedule

Treatment: T201-e-3-2 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate| (lb/1,000 ft^3)	Exposure Period
90-96 °F	1.5 lbs	1.5 hrs
80-89 °F	2 lbs	1.5 hrs
70-79 °F	2.5 lbs	1.5 hrs
60-69 °F	3 lbs	1.5 hrs

NOTICE

Some varieties of bromeliads may be sensitive to methyl bromide (MB) treatments. These varieties include *Aechmea* spp., *Billbergia* spp., *Guzmania* spp., *Nidularium* spp., *Vriesia* spp., and other broad shiny-leafed types, and thin-leafed types. For alternatives, see ***T201-p*** on **page 5-3-19.**

T201-j

Pines (*Pinus* spp.) from Canada

Destined to California, Idaho, Oregon, and Utah

Pest: *Rhyacionia buoliana* (European pine shoot moth)

Treatment: T201-j MB (“Q” label only) at NAP

Dosage rate for all schedules is 4 lbs MB (51 oz. minimum concentration)

Temperature	Exposure Period	Temperature	Exposure Period
75 °F	2 hrs	59 °F	2 hrs 41 min
74 °F	2 hrs 1 min	58 °F	2 hrs 43 min
73 °F	2 hrs 2 min	57 °F	2 hrs 46 min
72 °F	2 hrs 4 min	56 °F	2 hrs 49 min
71 °F	2 hrs 7 min	55 °F	2 hrs 52 min
70 °F	2 hrs 9 min	54 °F	2 hrs 55 min
69 °F	2 hrs 11 min	53 °F	2 hrs 58 min
68 °F	2 hrs 14 min	52 °F	3 hrs 1 min
67 °F	2 hrs 16 min	51 °F	3 hrs 5 min
66 °F	2 hrs 19 min	50 °F	3 hrs 8 min
65 °F	2 hrs 22 min	49 °F	3 hrs 12 min
64 °F	2 hrs 25 min	48 °F	3 hrs 15 min
63 °F	2 hrs 28 min	47 °F	3 hrs 19 min
62 °F	2 hrs 31 min	46 °F	3 hrs 24 min
61 °F	2 hrs 35 min	45 °F	3 hrs 28 min
60 °F	2 hrs 38 min		

Important

This is a precautionary treatment for pine trees with or without roots and twigs and branches of all *Pinus* species. Christmas trees and other pine decorative materials are exempt from the fumigation requirement during the period November 1 through December 31.

Prior consent of the importer is required for fumigation at temperatures above 65 °F or below 50 °F and also for all bare-rooted pines, since some damage may occur.

T201-m-1 Plant cuttings (Scion wood)*

Pest: External feeders

Treatment: T201-m-1 MB (“Q” label only) at NAP—tarpaulin or chamber

Important

*See exceptions to plant cuttings.

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period:	
		Brachyrhinus larvae	All others
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

T201-m-2

Plant cuttings (greenwood cuttings of woody plants and herbaceous plant cuttings)*

Pest: External feeders

Treatment: T201-m-2 MB (“Q” label only) at NAP—tarpaulin or chamber

Important

*See exceptions to plant cuttings.

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80-90 °F	1.5 lbs	19	12
70-79 °F	2 lbs	24	16
60-69 °F	2.5 lbs	30	20
50-59 °F	3 lbs	36	24
40-49 °F	3.5 lbs	41	27

T201-m-3

Plant cuttings (root cuttings)*

Pest: External feeders

Treatment: T201-m-3 MB (“Q” label only) at NAP—chamber

Important

*See exceptions to plant cuttings.

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period:	
		Brachyrhinus larvae	All others
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

T201-m-4

Plant cuttings (root cuttings)*

Pest: External feeders

Treatment: T201-m-4 MB (“Q” label only) at NAP—tarpaulin

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2.5 hrs	3 hrs	3.5 hrs	4 hrs
90-96 °F	2 lbs	24	16	—	—	—
80-89 °F	2.5 lbs	30	20	—	—	—
70-79 °F	3 lbs	36	24	—	—	—
60-69 °F	3 lbs	36	—	24	—	—
50-59 °F	3 lbs	36	—	—	24	—
40-49 °F	3 lbs	36	—	—	—	24

Important

*See exceptions to plant cuttings.

Important

Exceptions to Plant Cutting Commodities Treated with T201-m-1, T201-m-2, T201-m-3, and T201-m-4:

- Avocado, see *T201-p* on **page 5-3-19**
- *Chrysanthemum*, see *T201-g-1* on **page 5-3-5**
- *Dieffenbachia*, see *T201-i-1* on **page 5-3-8**
- *Dracaena*, see *T201-i-2* on **page 5-3-8**
- *Lavandula*, see *T201-p* on **page 5-3-19**
- Orchids, see *T201-d-1* on **page 5-3-14**
- *Philodendron*, see *T201-i-1* on **page 5-3-8**

T201-p

Plant material not tolerant to fumigation

Three treatments based on pest

Propagative material known to be sensitive to fumigation (see Handbook of Plant Tolerance to Quarantine Treatments) should be handled by the following methods for “quarantine action” pests. The selection of the method will depend upon the character of the plant material and the type of pests that may be found.

T201-p-1

Plant material not tolerant to fumigation

Pest: Actionable Pests Excluding Scale Insects

Treatment: **T201-p-1** Hand removal—With the exception of scale insects, hand removal of pests or infested parts and detailed inspection to ensure plants are pest free. If the characteristics of the plant growth, volume, or the type of pest are such that hand removal plus inspection may **not** provide a pest free shipment, then see *T201-p-2* on **page 5-3-20** or *T201-p-3* on **page 5-3-20**.

T201-p-2 Plant material not tolerant to fumigation

DO NOT USE this treatment schedule. The schedule is not authorized for use and will be removed or revised following a Federal Register notice according to 7 CFR 305.3.

May 01, 2012

Pest: Actionable Pests

Treatment: **T201-p-2** Hand removal plus chemical dip—Hand removal of pests of infested parts *plus* a malathion-carbaryl chemical dip. Solution prepared by adding 3 level tablespoons of 25 percent malathion wettable powder and 3 level tablespoons of 50 percent carbaryl wettable powder to each gallon of water. The addition of a sticker-spreader formulation may be required for hard to wet plants. Use fresh chemicals and prepare dip for the same day use. Plants, including the roots, should be entirely submerged in the chemical dip for 30 seconds.

Important

When the actionable pests are scale insects or their immature crawlers, prepare the solution by adding 4 level tablespoons of 25 percent malathion wettable powder (if the label allows) and 3 level tablespoons of 50 percent carbaryl wettable power to each gallon of water. Labels registered for this concentration are currently available from the following companies:

Micro-Flo Company LLC
Memphis, TN
Product: Malathion 25-WP
EPA Registration No. 051036-00033
(Tel 901-432-5131)

Cheminova Inc.
Oak Hill Park
1700 Route 23, Suite 210
Wayne, NJ 07470
Product Fyfanon 25 WP
EPA Registration No. 067760-00016
(Tel 201-305-6600)

T201-p-3 Deleted (Docket APHIS-13-009-2, July 21, 2015)

T201-p-4 Plant material not tolerant to fumigation

Pest: **Insects** (Aphidae, Thripidae, Formicidae, Coccidae, Pseudococcidae, Diaspididae, Pyralidae, Tortricidae, Syrphidae, Scarabaeidae, Cucurlionidae, Tenebrionidae)

Snails (Ampullariidae, Planorbidae)

Mites (Acaridae, Tarsonemidae, Tetranychidae, Tydeidae)

Nematodes (*Pratylenchus* (genus only))

Treatment: T201-p-4 Hand removal plus hot water treatment—Hot water at 52 °C/125 °F for 30 minutes

If hand removal is **not** feasible, allow the importer to fumigate at their own risk or return the commodity to the country of origin.

Under Development: **See "Plant Material Not Tolerant to Fumigation" on page-3-3-15** for operational guidance and equipment specifications.

T202—Bulbs, Corms, Tubers, Rhizomes, and Roots

T202-b Astilbe roots

Pest: *Brachyrhinus* larvae

Treatment: T202-b MB ("Q" label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70-96 °F	4 lbs	2 hrs
60-69 °F	4 lbs	2.5 hrs
50-59 °F	4 lbs	3 hrs
40-49 °F	4 lbs	4 hrs

For roots received in large cases packed in peat moss, temperatures apply to packing materials, if lower than root temperatures.

T202-c Banana roots

Pest: External feeders

Treatment: T202-c Hot water 110 °F for 30 minutes as pretreatment followed by 120 °F for 60 minutes. Requires consent of importer. Deny entry without consent unless 100 percent inspection plus pest removal is feasible.

T202-j Garlic

Pest: *Brachycerus* spp. (garlic beetles) and *Dyspessa ulula* (Bkh.) (onion/garlic carpenterworm)

Treatment: T202-j MB ("Q" label only) in 15" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2 lbs	1.5 hrs
80-89 °F	2 lbs	2 hrs
70-79 °F	2.5 lbs	2 hrs
60-69 °F	3 lbs	2 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	4 hrs

Important

Load limit **not** to exceed 80 percent of chamber.

T202-j-1 Garlic

Pest: *Brachycerus* spp. (garlic beetles) and *Dyspessa ulula* (Bkh.) (onion/garlic carpenterworm)

Treatment: T202-j-1 MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs
90 °F or above	2 lbs	26	19	—	—	—
80-89 °F	2.5 lbs	32	24	—	—	—
70-79 °F	3 lbs	38	29	—	—	—
60-69 °F	3 lbs	38	26	26	—	—
50-59 °F	3 lbs	38	26	—	26	—
40-49 °F	3 lbs	38	26	—	—	26

Important

This treatment is a precautionary requirement for *Brachycerus* spp. (garlic beetles) and *Dyspessa ulula* (Bkh.) (onion/garlic carpenterworm).

T202-e-1

Gladiolus spp.

Two alternative schedules

Pest: *Taeniothrips simplex* (gladiolus thrips)

Treatment: T202-e-1 MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2 lbs	3 hrs
80-89 °F	2.5 lbs	3 hrs
70-79 °F	3 lbs	3 hrs
60-69 °F	3 lbs	3.5 hrs
50-59 °F	3 lbs	4 hrs
40-49 °F	3 lbs	4.5 hrs

T202-e-2

Gladiolus spp.

Pest: *Taeniothrips simplex* (gladiolus thrips)

Treatment: T202-e-2 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2 lbs	2 hrs
80-89 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	3.5 hrs

T202-f

Horseradish roots

Pest: External feeders

Treatment: T202-f MB in 15" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period:	
		Brachyrhinus larvae	All others
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

T202-g Lily bulbs packed in subsoil

Pest: Internal feeders

Treatment: T202-g MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2 lbs	3 hrs
80-89 °F	2.5 lbs	3 hrs
70-79 °F	3 lbs	3 hrs
60-69 °F	3 lbs	3.5 hrs
50-59 °F	3 lbs	4 hrs
40-49 °F	3 lbs	4.5 hrs

Load limit 50 percent of chamber volume. Remove all wooden case covers. Overnight or longer aeration advisable.

T202-h Lycoris

Pest: *Taeniothrips eucharii*

Treatment: T202-h MB in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period:	
		Brachyrhinus larvae	All others
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

T202-i-1 Narcissus

Pest: *Steneotarsonemus laticeps* (bulb scale mite)

Treatment: T202-i-1 MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	3 lbs	2 hrs
80-89 °F	3.5 lbs	2 hrs
70-79 °F	4 lbs	2 hrs
60-69 °F	4 lbs	2.5 hrs
50-59 °F	4 lbs	3 hrs
40-49 °F	4 lbs	3.5 hrs

T202-i-2

Narcissus

Pest: *Steneotarsonemus laticeps* (bulb scale mite)

Treatment: T202-i-2 MB (“Q” label only) in 26" vacuum chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2 lbs	2 hrs
80-89 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	3.5 hrs

T202-i-3

Narcissus

Pest: *Steneotarsonemus laticeps* (bulb scale mite)

Treatment: T202-i-3 Hot water, 110-111 °F for 1 hour

Important

Exposure measured from time bulbs reach 110 °F pulp temperature. Hot water should be applied *within 1 month after normal harvest,* or flower bud injury may develop.

T202-a-1

Selaginella spp. (Resurrection plants)

Pest: External feeders

Treatment: T202-a-1 MB (“Q” label only) at NAP—Chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period:	
		***Brachyrhinus* larvae**	**All others**
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

T202-a-2 *Selaginella* spp. (Resurrection plants)

Pest: External feeders

Treatment: T202-a-2 MB ("Q" label only) at NAP—Tarpaulin

Temperature	Dosage Rate ($lb/1000\ ft^3$)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2.5 hrs	3 hrs	3.5 hrs	4 hrs
90-96 °F	2 lbs	24	16	—	—	—
80-89 °F	2.5 lbs	30	20	—	—	—
70-79 °F	3 lbs	36	24	—	—	—
60-69 °F	3 lbs	36	—	24	—	—
50-59 °F	3 lbs	36	—	—	24	—
40-49 °F	3 lbs	36	—	—	—	24

T202-a-3 *Selaginella* spp. (Resurrection plants)

Pest: Internal feeders

Treatment: T202-a-3 MB ("Q" label only) in 26" vacuum—chamber

Temperature	Dosage Rate ($lb/1,000\ ft^3$)	Exposure Period:	
		Brachyrhinus larvae	All others
90-96 °F	2 lbs	2.5 hrs	2 hrs
80-89 °F	2.5 lbs	2.5 hrs	2 hrs
70-79 °F	3 lbs	2.5 hrs	2 hrs
60-69 °F	3 lbs	3 hrs	2.5 hrs
50-59 °F	3 lbs	3.5 hrs	3 hrs
40-49 °F	3 lbs	4 hrs	3.5 hrs

T202-d Yams (*Dioscorea* spp.) and Sweet Potatoes (*Ipomoea* spp.)

Pest: Internal and external feeders

Treatment: T202-d MB ("Q" label only) at NAP—Tarpaulin

Temperature	Dosage Rate ($lb/1,000\ ft^3$)	Minimum Concentration Readings (ounces) At:		
		0.5 hr.	2.0 hrs	4 hrs
90 and above °F	2.5 lbs	32	20	20
80-89 °F	3 lbs	38	24	24
70-79 °F	3.5 lbs	44	28	28
60-69 °F	4 lbs	50	32	32

NOTICE

Temperatures below 70 °F may cause injury to yams. Fumigations below 70 °F should only be made with consent of importer. The tuberous roots should be cured, free from surface moisture, and held at fumigation temperatures for 24 hours following treatment. Mandatory for yams for all foreign countries except Japan, Dominican Republic into Puerto Rico, and all of the West Indies into the U.S. Virgin Islands. Also, for interstate movement of sweet potatoes from Hawaii.

T203—Seeds

NOTICE

Seeds for Propagation. Precautionary treatment for small lots of seeds (1 lb or less) is **not** required if you can inspect 100 percent of the seeds and you do **not** find any pests.

CAUTION

Methyl bromide fumigation of seeds for propagation may effect germination. Obtain the importers consent prior to fumigation.

T203-m Avocado (seeds only, without pulp)

Pest: Avocado seed weevils (*Conotrachelus* spp., *Heilipus lauri*, and *Caulophilus latinasus*); avocado stem weevil (*Copturus aguacatae*), and avocado seed moth (*Stenoma catenifer*)

Treatment: T203-m MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2 lbs	2 hrs
80-89 °F	3 lbs	2 hrs
70-79 °F	4 lbs	2 hrs
60-69 °F	4 lbs	3 hrs
50-59 °F	4 lbs	4 hrs
40-49 °F	4 lbs	5 hrs

T203-e Chestnuts (does not include water chestnuts) and Acorns

From all countries except Canada and Mexico

Pest: Internal feeders

Treatment: T203-e MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-96 °F	3 lbs	2 hrs
70-79 °F	4 lbs	2 hrs
60-69 °F	4 lbs	3 hrs
50-59 °F	4 lbs	4 hrs
40-49 °F	4 lbs	5 hrs

T203-e-1

Chestnut (does not include water chestnuts) and Acorns*

Pest: *Cydia splendana* (nut fruit tortrix) and *Curculio* spp.

Treatment: T203-e-1 MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs
90 °F and above	4 lbs	58	34	34	—	—	—
80-89 °F	4 lbs	58	32	—	32	—	—
70-79 °F	5 lbs	72	42	—	42	—	—
60-69 °F	5 lbs	72	40	—	—	40	—
50-59 °F	6 lbs	85	50	—	—	50	—
40-49 °F	6 lbs	85	48	—	—	—	48

Important

*It is a label violation to treat acorns at dosage rates greater than 4 lbs. Treat acorns only at 80 °F or above.

T203-i-1

Conifer seeds (species with small seeds, such as *Picea* spp., *Pinus sylvestris*, and *Pinus mugo*)

For species with small seeds, such as *Picea* spp., *Pinus sylvestris*, and *Pinus mugo*, in bags containing 75 lbs. draw an initial vacuum of at least 24 inches. Once the MB is introduced, then reduce the vacuum to NAP. This procedure is necessary for efficient penetration and distribution of the fumigant. Conifer seeds in bags of more than 75 lbs. each should be aerated in a well ventilated area for 24 hours, small seeds should be aerated for 48 hours.

Pest: External feeders

Treatment: T203-i-1 MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-96 °F	2.5 lbs	2.5 hrs
70-79 °F	3 lbs	2.5 hrs
60-69 °F	3 lbs	3 hrs
50-59 °F	3 lbs	3.5 hrs
40-49 °F	3 lbs	4 hrs

Important

Load limit is 30 percent of chamber space. Moisture should **not** be added in fumigation of dry seeds.

T203-i-2

Conifer seeds (species with small seeds, such as *Picea* spp., *Pinus sylvestris*, and *Pinus mugo*)

Pest: Internal feeders, nutlike seeds, or when seeds are tightly packed so as to make fumigant penetration questionable.

Treatment: T203-i-2 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-96 °F	2.5 lbs	2.5 hrs
70-79 °F	3 lbs	2.5 hrs
60-69 °F	3 lbs	3 hrs
50-59 °F	3 lbs	3.5 hrs
40-49 °F	3 lbs	4 hrs

Important

Load limit is 50 percent of chamber space. Plastic or impermeable liners should be removed or well perforated. This schedule is **not** entirely effective against some species of Chalcid wasps.

T203-i-3

Conifer seeds (species with small seeds, such as *Picea* spp., *Pinus sylvestris*, and *Pinus mugo*)

Pest: External feeders

Treatment: T203-i-3 MB (“Q” label only) tarpaulin
The yellow color of this treatment indicates that the authority to conduct the treatment comes from an emergency action required by PPQ in order to mitigate the pest risk. The emergency action is an interim measure and is pending final regulatory approval.

Temperature (°F)	Dosage Rate (lbs./1000 ft^3)	Minimum Concentration Readings (ounces) At (x) hrs.:						
		0.5	2	4	5	6	8	10
80-96	2.5	30	25	25	–	–	–	–
70-79	3	36	30	25	18	–	–	–
60-69	3	36	30	25	–	17	–	–
50-59	3	36	30	25	–	17	17	–
40-49	3	36	30	25	–	17	17	17

NOTICE

The commodity must not exceed 30 percent of the entire tarped enclosure. Refer to Fumigants • Methyl Bromide • Tarpaulin Fumigation for instructions on calculating the enclosure size. Moisture should **not** be added in fumigation of dry seeds. Normally, dry seed shipments arriving in wet or damp condition may be injured.

T203-f-1

Cottonseed—bagged, packaged, or in bulk

Four alternative schedules

Pest: External feeders

Treatment: T203-f-1 MB (“Q” label only) at NAP—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	6 lbs	12 hrs
OR	3 lbs	24 hrs
40-59 °F	7 lbs	12 hrs
OR	4 lbs	24 hrs

Important

Load limit is 50 percent of chamber volume.

T203-f-2

Cottonseed—bagged, packaged, or in bulk

Pest: External feeders

Treatment: T203-f-2 MB (“Q” label only) at NAP—tarpaulin

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	12 hrs	24 hrs
60 °F or above	7 lbs	54	56	27	—
OR	5 lbs	40	40	—	20
40-59 °F	8 lbs	64	64	32	—
OR	6 lbs	48	48	—	24

T203-f-3

Cottonseed—bagged, packaged, or in bulk

Pest: External feeders

Treatment: T203-f-3 MB (“Q” label only) in 26" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	4 lbs	2 hrs

Important

Load limit is 50 percent of chamber volume.

T203-f-4 Cottonseed—bagged, packaged, or in bulk

Pest: External feeders

Treatment: T203-f-4 Phosphine at NAP

Temperature	Dosage Rate (gms/1000 ft^3)	Minimum Concentration Readings (ppm) At:	
		72 hrs	120 hrs
50 °F or above	60[1] g	225[2]	50 or above

1 60 g/1000 ft^3 (28.3 m^3) is equivalent to 2.1 g/m^3.

2 An average reading with no reading less than 50 ppm.

Relative humidity must be 40 percent or higher when commodity enclosed.

Aerate minimum of 24 hours.

T203-g-1 Pods and seed of Kenaf, Hibiscus, and Okra

Three alternative schedules

Pest: Internal feeders

Treatment: T203-g-1 MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	12 hrs	24 hrs
60-96 °F	2 lbs	24	12	—
OR	1 lb	12	—	5
40-59 °F	3 lbs	36	17	—
OR	2 lbs	24	—	10

T203-g-2 Pods and seeds of Kenaf, Hibiscus,and Okra

Pest: Internal feeders

Treatment: T203-g-2 MB (“Q” label only) in 26" vacuum—chamber (kenaf and okra seed only)

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	4 lbs	2 hrs

Important

Load limit is 50 percent of chamber volume.

T203-g-3 Pods and seed of Kenaf, Hibiscus, and Okra

Pest: Internal feeders

Treatment: T203-g-3 Phosphine at NAP

Temperature	Dosage Rate ($gms/1000\ ft^3$)	Minimum Concentration Readings (ppm) At:	
		72 hrs	120 hrs
50 °F or above	60[1] g	225[2]	50

1 60 $g/1000\ ft^3$ ($28.3\ m^3$) is equivalent to 2.1 g/m^3.

2 An average reading with no reading less than 50 ppm.

Relative humidity must be 40 percent or higher when commodity enclosed.

Aerate minimum of 24 hours.

T203-k Macadamia nuts (as seeds)

Pest: *Cryptophlebia illepida* (koa seedworm)

Treatment: T203-k MB (“Q” label only) at NAP

Temperature	Dosage Rate ($lb/1,000\ ft^3$)	Exposure Period
70 °F or above	2 lbs	2 hrs
60-69 °F	2.5 lbs	2 hrs
50-59 °F	3 lbs	2 hrs
40-49 °F	3.5 lbs	2 hrs

T203-k-1 Macadamia nuts (as seeds)

Pest: *Cryptophlebia illepida* (koa seedworm)

Treatment: T203-k-1 MB ("Q" label only) tarpaulin

The yellow color of this treatment indicates that the authority to conduct the treatment comes from an emergency action required by PPQ in order to mitigate the pest risk. The emergency action is an interim measure and is pending final regulatory approval.

Temperature (°F)	Dosage Rate (lbs./ 1000 ft^3)	Minimum Concentration Readings (ounces) At (x) hrs.:		
		0.5	2	4
70-79	2	24	16	16
60-69	2.5	30	20	20
50-59	3	36	24	24
40-49	3.5	42	28	28

NOTICE

The commodity must not exceed 30 percent of the entire tarped enclosure. Refer to Fumigants • Methyl Bromide • Tarpaulin Fumigation for instructions on calculating the enclosure size.

Moisture should **not** be added in fumigation of dry seeds. Normally, dry seed shipments arriving in wet or damp conditions may be injured.

T203-h *Rosmarinus* seeds

Pest: Juvenile *Helicella* spp. (snails) or Internal Feeders

Treatment: T203-h MB ("Q" label only) at 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	4 lbs	4 hrs

T203-l Seeds

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T203-l MB ("Q" label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	4 hrs	12 hrs
90 °F or above	2.5 lbs	30	20	20	15
80-89 °F	3.5 lbs	42	30	30	20

T203-b Seeds excluding seeds of *Vicia* spp.

Pest: Bruchidae (seed beetles)

Treatment: T203-b MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3):		Exposure Period:	
	Caryedon spp.	All others	*Caryedon* spp.	All others
70-96 °F	5 lbs	3 lbs	2 hrs	2.5 hrs
60-69 °F	—	3 lbs	—	3 hrs
50-59 °F	—	3 lbs	—	3.5 hrs
40-49 °F	—	3 lbs	—	4 hrs

T203-o

(deleted)

T203-a-1 Seeds not specifically listed in the T203 Schedules

Pest: External feeders

Treatment: T203-a-1 MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-96 °F	2.5 lbs	2.5 hrs
70-79 °F	3 lbs	2.5 hrs
60-69 °F	3 lbs	3 hrs
50-59 °F	3 lbs	3.5 hrs
40-49 °F	3 lbs	4 hrs

NOTICE

Load limit is 30 percent of chamber space. Moisture should **not** be added in fumigation of dry seeds. Normally, dry seed shipments arriving in wet or damp condition may be injured. This schedule may scald coconut husks. (Some tropical or nutlike seeds are usually shipped damp.)

T203-a-2 Seeds not specifically listed in the T203 Schedules

Pest: Internal feeders, except *Megastigmus* spp.

Treatment: T203-a-2 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-96 °F	2.5 lbs	2.5 hrs
70-79 °F	3 lbs	2.5 hrs
60-69 °F	3 lbs	3 hrs
50-59 °F	3 lbs	3.5 hrs
40-49 °F	3 lbs	4 hrs

Important

Load limit is 50 percent of chamber space. Plastic or impermeable liners should be removed or well perforated.

T203-a-3

Seeds not specifically listed in the 203 Schedules

Pest: External feeders

Treatment: T203-a-3 MB ("Q" label only) tarpaulin

The yellow color of this treatment indicates that the authority to conduct the treatment comes from an emergency action required by PPQ in order to mitigate the pest risk. The emergency action is an interim measure and is pending final regulatory approval.

Temperature (°F)	Dosage Rate (lbs./ 1000 ft^3)	Minimum Concentration Readings (ounces) At (x) hrs.:							
		0.5	2	4	5	6	7	8	10
80-96	2.5	30	20	20	15	–	–	–	–
70-79	3	36	24	24	18	–	–	–	–
60-69	3	36	24	24	–	–	17	–	–
50-59	3	36	24	24	–	17	–	17	–
40-49	3	36	24	24	–	17	–	17	17

NOTICE

The commodity must not exceed 30 percent of the entire tarped enclosure. Refer to Fumigants • Methyl Bromide • Tarpaulin Fumigation for instructions on calculating the enclosure size.

Moisture should **not** be added in fumigation of dry seeds. Normally, dry seed shipments arriving in wet or damp conditions may be injured. This schedule may scald coconut husks. (Some tropical or nutlike seeds are usually shipped damp.)

T203-o-1

Seeds of *Casuarina*

Pest: *Bootanomyia* spp. (in *Casuarina*)

Treatment: T203-o-1 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	3.5 lbs	6 hrs

T203-j

Seeds of *Hevea brasiliensis* (rubber tree)

Pest: Seed-boring insects

Treatment: T203-j MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-96 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs

T203-j-1

Seeds of *Hevea brasiliensis* (rubber tree)

Pest: Seed-boring insects

Treatment: T203-j-1 MB (“Q” label only) tarpaulin

The yellow color of this treatment indicates that the authority to conduct the treatment comes from an emergency action required by PPQ in order to mitigate the pest risk. The emergency action is an interim measure and is pending final regulatory approval.

Temperature (°F)	Dosage Rate (lbs./1000 ft^3)	Minimum Concentration Readings (ounces) At (x) hrs.:			
		0.5	2	4	6
80-96	2.5	30	20	20	–
70-79	3	36	24	24	–
60-69	3	36	24	24	17

NOTICE

The commodity must not exceed 30 percent of the entire tarped enclosure. Refer to Fumigants • Methyl Bromide • Tarpaulin Fumigation for instructions on calculating the enclosure size.

Moisture should **not** be added in fumigation of dry seeds. Normally, dry seed shipments arriving in wet or damp conditions may be injured.

T203-o-3

Seeds of Leguminosae (Fabaceae)

Pest: *Bruchophagus* spp., *Eurytoma* spp.

Treatment: T203-o-3 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	4 lbs	4 hrs

T203-c

Seeds of Leguminosae (Fabaceae)

Pest: *Caryedon* spp.

Treatment: T203-c MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
50 °F or above	2 lbs	24 hrs

T203-o-4-1

Seeds of Leguminosae (Fabaceae)

Pest: *Caryedon* spp. (in or with, etc.)

Treatment: T203-o-4-1 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
50 °F or above	2 lbs	24 hrs

T203-o-4-2

Seeds of Leguminosae (Fabaceae)

Pest: *Caryedon* spp. (in or with, etc.)

Treatment: T203-o-4-2 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	3.5 lbs*	3 hrs

T203-d-1

Seeds of Leguminosae (Fabaceae), excluding *Vicia faba*

Pest: Bruchidae (seed beetles) excluding the beetles of *Caryedon* spp.

Treatment: T203-d-1 MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs	4 hrs
70 °F or above	3 lbs	38	—	24	—	—	—
60-69 °F	3 lbs	38	29	—	24	—	—
50-59 °F	3 lbs	38	29	—	—	24	—
40-49 °F	3 lbs	38	29	—	—	—	24

Use T203-c-1 or T203-d-2 for seeds of *Vicia faba*.

T203-o-5

Seeds of *Lonicera* and Other seeds

Pest: *Rhagoletis cerasi* (European cherry fruit fly) pupae (Diptera: Tephritidae)

Treatment: T203-o-5 MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	4 lbs*	8 hrs

NOTICE

*If seed is intended for propagation, the dosage rate may damage seed by sterilization.

T203-p

Seeds of Citrus (Rutaceae family)

Pest: Citrus Canker (*Xanthomonas axonopodis*)

Treatment: T203-p Hot water plus Chemical Dip

1. Wash the seed if any mucilaginous material, such as pulp, is adhering to the seed.
2. Immerse the seed in water heated to 125 °F (51.6 °C) or higher for 10 minutes.
3. Then, immerse the seed in a solution containing 200 parts per million sodium hypochlorite at a pH of 6.0 to 7.5 for at least 2 minutes.

T203-o-2

Seeds of *Umbelliferae*

Pest: *Systole* spp. (in Umbelliferae)

Treatment: T203-o-2 MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-86 °F	2.5 lbs	3.5 hrs
70-79 °F	3 lbs	3.5 hrs
60-69 °F	3 lbs	4 hrs
50-59 °F	3 lbs	4.5 hrs
40-49 °F	3 lbs	5 hrs

T203-c-1 Seeds of *Vicia* spp. (vetch seeds) including seeds of *Vicia faba* (Faba or Fava bean)

Pest: Bruchidae (seed beetles)

Treatment: T203-c-1 MB ("Q" label only) tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	11 hrs	12 hrs	13 hrs	14 hrs
70 °F or above	3.5 lbs	46	28	27	—	—	—
60-69 °F	3.5 lbs	46	28	—	27	—	—
50-59 °F	3.5 lbs	46	28	—	—	27	—
40-49 °F	3.5 lbs	46	28	—	—	—	27

T203-d-2 Seeds of *Vicia* spp. (vetch seeds) including seeds of *Vicia faba* (Faba or Fava bean)

Pest: Bruchidae (seed beetles)

Treatment: T203-d-2 MB ("Q" label only) in 26" vacuum

Temperature	Dosage Rate (lb/ 1,000 ft^3)	Exposure Period:	
		Vicia faba	All others
70-96 °F	3 lbs	3.5 hrs	2.5 hrs
60-69 °F	3 lbs	4 hrs	3 hrs
50-59 °F	3 lbs	4.5 hrs	3.5 hrs
40-49 °F	3 lbs	5 hrs	4 hrs

NOTICE

Seed shipments arriving wet or damp may be injured.

T203-n Seeds with infested pulp

Pest: Fruit flies and other pulp-infesting insects

Treatment: T203-n Depulping

1. Place seed in wire basket.
2. Immerse in water at 118-125 °F for 25 minutes.
3. Remove pulp from seed under running tap water.

Important

This treatment is effective only for fruit flies, as well as some other pulp infesting insects. Fumigation may also be required for seed weevils and other internal and external feeding insects.

5

Treatment Manual

Treatment Schedules

T300 - Schedules for Miscellaneous Plant Products

Contents

The following schedules are listed by product.

Important

Exposure period may be extended for any commodity which cannot be used for food or propagation. This extension is only a matter of convenience for the importer and is intended only for the purpose of reducing treatment costs. The request for extension must come from the importer or his authorized representative and should be confirmed in writing. A letter is not required for each treatment. A single blanket request should be considered as acceptable and renewed each year as required.

During the extended exposure period, the concentrations must remain stable and the prescribed minimums be met at the end of the extension. Otherwise, the treatment may be voided and retreatment required. Examples of commodities for which extended exposure periods may be approved include: cotton piece goods, baled cotton, bagging, wood, marble, soil as such, etc. Examples of commodities for which *no* extension may be approved include: cottonseed, grain, tobacco, etc. An extension of exposure period for other purposes is not permitted except as may be prescribed in various schedules for concentration readings below minimum.

Additional safety precautions, including additional aeration, may be required because of the extended exposure period. The PPQ officer or the commercial fumigator will specify any needed precautions.

T301—Cotton and Cotton Products

T301-a-3 Baled lint or linters

Pest: *Pectinophora* spp.

Treatment: T301-a-3—MB (“Q” label only) at NAP—tarpaulin

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	12 hrs	24 hrs
40 °F or above	7 lbs	84	60	30	—
OR	4 lbs	60	40	—	20

T301-b-1-1 Baled lint, linters, waste, piece goods, gin trash

Two alternative treatments

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T301-b-1-1—MB (“Q” label only) at NAP—tarpaulin

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	24 hrs*
60 °F or above	8 lbs	96	64	35
40-59 °F	11 lbs	132	88	50

*In addition to the space concentration readings, you must take a commodity concentration reading. The minimum concentration reading for commodity reading is as follows: For 60 °F or above—25 oz.; for 40-59 °F—30 oz.

Important

Load limit is 50 percent of chamber volume. Concentration readings may be omitted for chamber fumigations.

T301-b-1-2 Baled lint, linters, waste, piece goods, gin trash

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T301-b-1-2—MB (“Q” label only) at NAP—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	8 lbs	3 hrs
40-59 °F	9 lbs	3 hrs

T301-a-7 Cottonseed (samples and bulk)

Pest: *Pectinophora* spp.

Treatment: T301-a-7—Acid delinting and heat treatment (alternative treatment)

Cottonseed delinting is primarily intended for the elimination of surface-borne disease organisms. It is also effective against insects. To be completely effective against insects, this treatment must be carried out at approximately 145 °F (by the application of sufficient heat to the seed, or acid, or both) or by raising the temperature of the delinted seed during the subsequent drying process to 145 °F for a period of not less than 45 seconds or at least 140 °F for a period of not less than 8 minutes.

T301-b-2 Cottonseed, cottonseed products, or samples

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T301-b-2—MB (“Q” label only) at NAP—tarpaulin

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	12 hrs
90 °F or above	2.5 lbs	30	20	15
80-89 °F	3.5 lbs	42	30	20

The sorptive rates of commodities vary. When a commodity is known or suspected to be sorptive, take more gas readings than normal. Additional fumigant is added as prescribed on ***Special Procedures for Adding Gas and Extending Exposure Period*** on **page 2-4-30**.

Important

Items known to be sorptive or items whose sorptive properties are unknown are **not** to be fumigated in chambers at NAP unless gas readings are taken.

When both woodborers and khapra beetles are involved, use schedule ***T404-d*** on **page 5-5-20**.

T301-b-3 Cottonseed meal (not for food or feed)

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T301-b-3—MB (“Q” label only) at NAP

Important

Cottonseed meal treated under this schedule is **not** to be used for food or feed.

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	24* hrs	28* hrs	32* hrs
90 °F or above	4 lbs	48	32	25	—	—
80-89 °F	6 lbs	72	48	30	—	—
70-79 °F	8 lbs	96	64	35	—	—

*In addition to the space concentration readings, you must take a commodity concentration reading. The minimum concentration reading for commodity reading is as follows: For 90-96 °F—10 oz.; for 80-89 °F—15 oz.; and for 70-79 °F—20 oz.

**Optional

Important

Concentration readings should be obtained within the commodity.
Concentration readings **not** required for chamber fumigations.

T301-c

Cotton and cotton products

Pest: *Globodera rostochiensis* (golden nematode)

Treatment: T301-c—MB (“Q” label) at NAP—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	8 lbs	16 hrs
	10.5 lbs	12 hrs

T301-d-1-1

Cotton and cotton products

Two alternative treatments

Pest: *Anthonomus grandis* (boll weevil)

Treatment: T301-d-1-1—MB (“Q” label only) at NAP—tarpaulin

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	3 hrs	4 hrs	8 hrs
90 °F or above	2.5 lbs	30	20	—	—	—
80-89 °F	3 lbs	36	28	—	—	—
70-79 °F	4 lbs	48	36	—	—	—
60-69 °F	4 lbs	50	—	34	—	—
55-59 °F	5 lbs	64	—	48	—	—
50-54 °F	5.5 lbs	70	—	—	50	—
40-49 °F	6 lbs	80	—	—	54	40

T301-d-1-2

Cotton and cotton products

Pest: *Anthonomus grandis* (boll weevil)

Treatment: T301-d-1-2—Phosphine at NAP—tarpaulin or chamber

Temperature	Dosage Rate (g/1,000 ft^3)	Minimum Concentration Readings (ppm) At 72 hours:
50 °F or above	36 g*	225**

*36g/1,000ft^3 (28.3m^3) is equivalent to 1.27 g/m^3.
**An average reading with no reading less than 50 ppm.

Important

Refer to the Equipment Section for a description of the MityVac® pump and the Port-a-sens phosphine detector.

Important

Refer to ***Table 5-4-4*** on **page 5-4-41** for data on amount of phosphine liberated by various products.

T301-a-1-1 Lint, linters, cottonseed meal and hulls, gin trash, waste, or other baled or bulk commodities (except samples)

Pest: *Pectinophora* spp.

Treatment: T301-a-1-1—MB (“Q” label only) at NAP—chamber

Temperature	Dosage Rate (lb/1,000 ft^3) for:		Exposure Period
	Bulk shipments	Other than bulk shipments	
60 °F or above	6 lbs	6 lbs	12 hrs
OR	4 lbs	3 lbs	24 hrs
40-59 °F	7 lbs	7 lbs	12 hrs
OR	5 lbs	4 lbs	24 hrs

T301-a-1-2 Lint, linters, cottonseed meal and hulls, gin trash, waste, or other baled or bulk commodities (except samples)

Pest: *Pectinophora* spp.

Treatment: T301-a-1-2—MB (“Q” label only) in 26" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	8 lbs	3 hrs
40-59 °F	9 lbs	3 hrs

NOTICE

For propagative seed cotton, refer to ***T203-i-3*** on **page 5-3-30** through ***T203-f-4*** on **page 5-3-32**.

T301-a-6 Lint, linters, and cottonseed (bulk, sacked, or packaged cottonseed, lint or linters, cottonseed hulls, gin trash, and all other baled or bulk cotton commodities)

Pest: *Pectinophora* spp.

Treatment: T301-a-6—Phosphine at NAP

Temperature	Dosage Rate (g/1,000 ft^3)	Minimum Concentration Readings (ppm) At:	
		72 hrs	120 hrs
50 °F or above	60 g*	225**	50***

* 60 g/1,000ft^3 (28.3m^3) is equivalent to 2.1g/m^3.
** An average reading with no reading less than 50 ppm.
***An average of 50 PPM or more.

Aerate commodity 24 hours and/or make appropriate tests for presence of gas.

Important

Refer to ***Table 5-4-4*** on **page 5-4-41** for data on amount of phosphine liberated by various products.
Refer to ***Equipment*** on **page 8-1-1** for a description of the MityVac® pump and the Port-a-sens phosphine detector.

T301-a-2 Lint (except baled lint or linters), cottonseed hulls and meal, gin trash, waste, or other baled or bulk commodities (excluding samples)

Pest: *Pectinophora* spp.

Treatment: T301-a-2—MB (“Q” label only) at NAP—tarpaulin

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	12 hrs	24 hrs
40 °F or above	7 lbs	84	60	30	—
OR	5 lbs	60	40	—	20

T301-a-4 Packaged cottonseed

Pest: *Pectinophora* spp.

Treatment: T301-a-4—MB (“Q” label only) at NAP—tarpaulin

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	12 hrs	24 hrs
40 °F or above	7 lbs	84	60	30	—
OR	5 lbs	60	40	—	20

T301-a-5-1 Samples of cotton and cotton products

Two alternative treatments

Pest: *Pectinophora* spp.

Treatment: T301-a-5-1—MB at NAP—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	3 lbs	24 hrs

T301-a-5-2 Samples of cotton and cotton products

Pest: *Pectinophora* spp.

Treatment: T301-a-5-2—MB in 26" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	4 lbs	2 hrs

T301-e

Cottonseed for Food or Feed

Pest: *Fusarium oxysporum* f. sp. *vasinfectum* strains VCG 01111 and VCG 01112

Treatment: T301-e—MB at NAP—tarpaulin

Temperature	Dosage Rate (lb/ 1,000 ft^3)	Minimum Concentration Readings (ounces) At:						
		2 hrs	4 hrs	6 hrs	12 hrs	24 hrs	36 hrs	48 hrs
40 °F or above	7 lbs	60	50	50	35	20	—	—
	5 lbs	20	—	20	20	15	15	15

T302—Grains and Seeds Not Intended for Propagation

Important

If grain and seeds **are for propagation**, use appropriate treatment in T203 schedules

T302-g-1

Acorns not intended for propagation

Two alternative treatments

Pest: *Cydia splendana* (nut fruit tortrix) and *Curculio* spp. (weevils)

Treatment: T302-g-1—MB at NAP—tarpaulin, chamber, or van container

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs
90-95 °F	4 lbs	58	32	34	—	—	—
80-89 °F	4 lbs	58	32	—	34	—	—
70-79 °F	5 lbs	72	40	—	42	—	—
60-69 °F	5 lbs	72	40	—	—	40	—
50-59 °F	6 lbs	85	48	—	—	50	—
40-49 °F	6 lbs	85	48	—	—	—	48

T302-g-2

Acorns not intended for propagation

Pest: *Cydia splendana* (nut fruit tortrix) and *Curculio* spp. (weevils)

Treatment: T302-g-2—MB in 26" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-96 °F	3 lbs	2 hrs
70-79 °F	4 lbs	2 hrs
60-69 °F	4 lbs	3 hrs
50-59 °F	4 lbs	4 hrs
40-49 °F	4 lbs	5 hrs

Important

Either T302-g-1 or T302-g-2 required from all countries except Canada and Mexico. Treated commodity **not** to be used for food or feed.

T302-a-1-1

Ear corn

Two alternative treatments

Pest: Borers

Treatment: T302-a-1-1—MB at NAP—chamber only

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	2 lbs	6 hrs

T302-a-1-2

Ear corn

Pest: Borers

Treatment: T302-a-1-2—Dry heat

168 °F minimum air temperature for not less than 2 hours; ears spread in single layers on slats or wire shelves.

T302-c-1 Grains and seeds not intended for propagation, and plant gums[1]

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T302-c-1—MB (“Q” gas only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	12 hrs
90 °F or above	2.5 lbs	30	20	15
80-89 °F	3.5 lbs	42	30	20
70-79 °F	4.5 lbs	54	40	25
60-69 °F	6 lbs	72	50	30
50-59 °F	7.5 lbs	90	60	35
40-49 °F	9 lbs	108	70	40

The following commodities are considered as "grains and seeds not for propagation" and are on the MB labels at the rates in the bulleted list:

- 40 °F and above: barley, corn, oats, popcorn, processed food and grains, rice, rye, sorghum (milo), wheat
- 80 °F and above: dried beans and peas, dried faba beans, peanuts and tree nuts (almonds, Brazil nuts, bushnuts, butternuts, cashews, filberts, hickory nuts, macadamia nuts, pecans, pistachios, walnuts)
- 90 °F and above: seeds of dried herbs and spices (refer to T101-n-2-1-1)

FIFRA Section 18:

- 40 °F and above: unprocessed cucurbit seed, coffee bean (green unroasted), and oilseeds (**See “Appendix F” on page-F-1-1**: Crop Group 20 for a list of commodities included in the oilseed group)

The sorptive rates of commodities vary. When a commodity is known or suspected to be sorptive, see the list of sorptive commodities in Chapter 2-3 Section **Sorption** and take more gas readings than normal. Additional fumigant is added as prescribed on ***Special Procedures for Adding Gas and Extending Exposure Period*** on **page 2-4-30**.

When both woodborers and khapra beetles are involved, use schedule ***T404-d*** on **page 5-5-20**.

1 Plant gums are defined as "Any of numerous polysaccharide substances of plant origin that are gelatinous when moist but harden on drying. Plant gums include but are not limited to acacia gum, guar gum, gum arabic, locust gum, and tragacanth gum." [7 CFR 319.75-1]

T302-c-2 Grains and seeds not intended for propagation, and plant gums

NOTE: Load limit is 75 percent of chamber volume.

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T302-c-2—MB (“Q” label gas) in 26” vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	8 lbs	3 hrs
40-59 °F	9 lbs	3 hrs

The following commodities are considered as "grains and seeds not for propagation" and are on the MB labels at the rates in the bulleted list:

- 40 °F and above: barley, buckwheat, corn, oats, popcorn, processed food and grains, rice, rye, sorghum (milo), wheat

T302-c-3 Grains and seeds not intended for propagation (e.g., guar “gum”)

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T302-c-3—MB (“Q” gas only) in NAP—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2.5 lbs	12 hrs
80-89 °F	3.5 lbs	12 hrs
70-79 °F	4.5 lbs	12 hrs
60-69 °F	6 lbs	12 hrs
50-59 °F	10 lbs	12 hrs
40-49 °F	12 lbs	12 hrs

60 °F and above: barley, buckwheat, corn, oats, popcorn, processed food and grains, rice, rye, sorghum (milo), wheat.

The sorptive rates of commodities vary. When a commodity is known or suspected to be sorptive, see the list of sorptive commodities in Chapter 2-3 Section **Sorption** and take more gas readings than normal. Additional fumigant is added as prescribed on ***Special Procedures for Adding Gas and Extending Exposure Period*** on **page 2-4-30**.

Important

Items known to be sorptive or items whose sorptive properties are unknown are **not** to be fumigated in chambers at NAP unless gas readings are taken.

When both woodborers and khapra beetles are involved, use schedule T404-d.

T302-d

Grains and seeds not intended for propagation and contaminated with cottonseed

Pest: *Pectinophora* spp.

Treatment: See Cotton and Cotton Products, ***T301-a-1-1*** on **page 5-4-6** or ***T301-a-1-2*** on **page 5-4-6**.

Important

Alternate method—screening for removal of cotton seed contamination.

T302-e-1

Grains and seeds not intended for propagation

The following commodities are considered as "grains and seeds not for propagation" and are on the MB labels at the rates in the bulleted list:

- 40 °F and above: barley, corn, oats, popcorn, processed food and grains, rice, rye, sorghum (milo), wheat, dried beans and peas, dried faba beans, peanuts and tree nuts (almonds, Brazil nuts, bushnuts, butternuts, cashews, filberts, hickory nuts, macadamia nuts, pecans, pistachios, walnuts), seeds of dried herbs and spices (refer to T101-n-2-1-1)

FIFRA Section 18:

- 40 °F and above: unprocessed cucurbit seed, coffee bean (green unroasted), and oilseeds (**See "Appendix F" on page-F-1-1**: Crop Group 20 for a list of commodities included in the oilseed group)

Three alternative treatments

Pest: Insects other than *Trogoderma granarium* (khapra beetle)

Treatment: T302-e-1—MB ("Q" label only) at NAP—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-96 °F	2.5 lbs	2.5 hrs
70-79 °F	3 lbs	2.5 hrs
60-69 °F	3 lbs	3 hrs
50-59 °F	3 lbs	3.5 hrs
40-49 °F	3 lbs	4 hrs

T302-e-2

Grains and seeds not intended for propagation

Pest: Insects other than *Trogoderma granarium* (khapra beetle)

Treatment: T302-e-2—MB ("Q" label only) at 26" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-96 °F	2.5 lbs	2.5 hrs
70-79 °F	3 lbs	2.5 hrs
60-69 °F	3 lbs	3 hrs
50-59 °F	3 lbs	3.5 hrs
40-49 °F	3 lbs	4 hrs

Important

Load limit is 50 percent of chamber volume. This vacuum treatment primarily for material so packed or packaged as to make fumigant penetration questionable.

T302-e-3

Grains and seeds not intended for propagation

Pest: Insects other than *Trogoderma granarium* (khapra beetle)

Treatment: T302-e-3—MB ("Q" gas only) at NAP—tarpaulin or chamber

The yellow color of this treatment indicates that the authority to conduct the treatment comes from an emergency action required by PPQ in order to mitigate the pest risk. The emergency action is an interim measure and is pending final regulatory approval.

Temperature (°F)	Dosage Rate (lb/ 1,000 ft^3)	Minimum Concentration Readings (ounces) At:							
		0.5 hr	2 hrs	4 hrs	5 hrs	6 hrs	7 hrs	8 hrs	10 hrs
80-96 °F	2.5 lbs	30	20	20	15				
70-79 °F	3 lbs	36	24	24	18				
60-69 °F	3 lbs	36	24	24	–	–	17		
50-59 °F	3 lbs	36	24	24	–	17	–	17	
40-49 °F	3 lbs	36	24	24	–	17	–	17	17

NOTICE

The commodity must not exceed 30 percent of the entire tarped enclosure. Refer to **Fumigants • Methyl Bromide • Tarpaulin Fumigation** for instructions on calculating the enclosure size.

Moisture should **not** be added in fumigation of dry seeds. Normally, dry seed shipments arriving in wet or damp conditions may be injured.

T302-f Grains and seeds (excluding Rosmarinus seed) not intended for propagation

Pest: Snails

Treatment: T302-f—Mechanical separation by screening or hand removal. If **not** feasible, entry should be denied when snails are of agricultural or public health significance, or treat using appropriate schedule as listed in T403-a.

Important

For *Rosmarinus* seed use ***T203-h*** on **page 5-3-34**

T302-b-1-1 Shelled corn

Treatment: T302-b-1-1 ***Reserved***

T302-b-1-2 Shelled corn contaminated with cottonseed

Pest: *Pectinophora* spp.

Treatment: T302-b-1-2

Important

See ***T301-a-1-1*** on **page 5-4-6** or ***T301-a-1-2*** on **page 5-4-6**

Important

Shelled corn treated with T301 is **not** to be used for food or feed.

T303—Rice

T303-a

T303-a-1 through T303-a-3 have been removed

Effective November 1 2011, APHIS reclassified Panicle Rice Mite (*Steneotarsonemus spinki*, PRM) to a non-quarantine pest.

T303-d-1

Articles made with rice straw

Two alternative treatments

Pest: Fungous diseases of rice or internal feeders

Treatment: T303-d-1—Dry heat at 180-200 °F for 2 hours

T303-d-2

Articles made with rice straw

Pest: Fungous diseases of rice or internal feeders

Treatment: T303-d-2—Steam sterilization

Temperature	Pressure	Exposure Period
260 °F	20 lbs	15 minutes
250 °F	15 lbs	20 minutes

T303-d-2-1

Articles made with rice straw

Pest: Fungous diseases of rice or internal feeders

Treatment: T303-d-2-1—Steam sterilization, use ***T303-b-1*** on **page 5-4-16**

T303-d-2-3

Articles made with rice straw for indoor use only

Pest: Internal feeders

Treatment: T303-d-2-3—MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	4 hrs	24 hrs
60 °F or above	2.5 lbs	30	20	20	15
50-59 °F	3 lbs	36	25	24	20
40-49 °F	4 lbs	48	35	32	25

T303-d-2-2 Articles made with rice straw for indoor use only

Pest: Internal feeders

Treatment: T303-d-2-2—MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	2.5 lbs	2.5 hrs
50-59 °F	3.5 lbs	2.5 hrs
40-49 °F	5 lbs	2.5 hrs

T303-b-1 Rice straw and hulls imported for purposes other than approved processing

Two alternative treatments based on how commodity is packed

Pest: Fungous diseases of rice

Treatment: T303-b-1—Steam sterilization, for closely packed commodity

Introduce the live steam into a 28" vacuum until pressure reaches 10 lbs and hold for 20 minutes. (Steam sterilization is **not** practical for the treatment of bales having a density greater than 30 lbs. per cubic foot.)

T303-b-2 Rice straw and hulls imported for purposes other than approved processing

Pest: Fungous diseases of rice

Treatment: T303-b-2—Steam sterilization, for commodity packed as loose masses

Use ***T303-b-1*** on **page 5-4-16** or, if without initial vacuum, bleed air until steam vapor escapes.

T303-c-1 Rice straw and hulls imported in small lots of 25 lbs. or less

Important

T303-c-1 is suspended until further notice. (01-14-08)

Pest: Fungous diseases of rice

Treatment: T303-c-1—Dry heat at 212 °F for 1 hour

T304—Alpha (alfa) Grass and Handicrafts (*Stipa tenacissima, Ampelodesma mauritanicus*)

T304-a

Alpha (alfa) grass and handicrafts (*Stipa tenacissima, Ampelodesma mauritanicus*)

Two alternative treatments

Pest: Infested with *Harmolita* spp. (jointworms)

Treatment: T304-a—MB at NAP—chamber only

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	2.5 lbs	32 hrs
50-59 °F	3.5 lbs	32 hrs
40-49 °F	4.5 lbs	32 hrs

T304-b

Alpha (alfa) grass and handicrafts (*Stipa tenacissima, Ampelodesma mauritanicus*)

Treatment: T304-b—MB in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	2.5 lbs	2.5 hrs
50-59 °F	3.5 lbs	2.5 hrs
40-49 °F	5 lbs	2.5 hrs

T305—Cut Flowers and Greenery

T305-a Cut flowers and greenery

Important

The “external pests” controlled by this schedule do **not** include dormant snails. Refer to ***T201-o-1*** on **page 5-3-12** or ***T201-p*** on **page 5-3-19**.

Pest: External feeders, leafminers, hitchhikers, surface pests, and slugs[2]

Treatment: T305-a—MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80-89 °F	1.5 lbs	19	12
70-79 °F	2 lbs	24	16
60-69 °F	2.5 lbs	30	20
50-59 °F	3 lbs	36	24
40-49 °F*	3.5 lbs	41	27

* For leafminers, use the initial dosage rate of 4 lbs/1,000 ft^3.

T305-b Cut flowers and greenery

Pest: Borers or soft scales

Treatment: T305-b—MB (“Q” label only) in 15" vacuum

Important

Vacuum fumigation requires prior consent of the importer. If consent denied, refuse entry unless T305-a plus hand removal of these pests is feasible. Vacuum fumigation is **not** required for soft scales known to be widely distributed in the U.S.

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80-90 °F	2.5 lbs	2 hrs
70-79 °F	3 lbs	2 hrs
60-69 °F	3 lbs	2.5 hrs
50-59 °F	3 lbs	3 hrs
40-49 °F	3 lbs	3.5 hrs

2 Quarantine-significant slugs of the families Agriolimacidae, Arionidae, Limacidae, Milacidae, Philomycidae, and Veronicellidae, including the following genera: *Agriolimax, Arion,Colosius, Deroceras, Diplosolenodese, Leidyula, Limax, Meghimatium, Milax, Pallifera, Pseudoveronicella, Sarasinula, Semperula, Vaginulus,Veronicella*. **Treat slugs at 60 F (2.5 lbs.) or above .**

T305-c Cut flowers and greenery

Pest: Mealybugs

Treatment: T305-c—MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	2.5 lbs	32	24
70-79 °F	3 lbs	38	29
60-69 °F	4 lbs	48	38

T306—Bags and Bagging Material, Covers

T306-a Bags and bagging material or covers used to contain root crops

Pest: *Globodera rostochiensis* (golden nematode)

Treatment: T306-a—MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	8 lbs	16 hrs
	10.5 lbs	12 hrs
	16 lbs	8 hrs

T306-b Bags and bagging material or covers used for cotton only

Pest: *Pectinophora* spp.

Treatment: T306-b—MB at NAP—chamber

Temperature	Dosage Rate (lb/1,000 ft^3) for:		Exposure Period
	Bulk shipments	Other than bulk shipments	
60 °F or above	6 lbs	6 lbs	12 hrs
60 °F or above	4 lbs	3 lbs	24 hrs
40-59 °F	7 lbs	7 lbs	12 hrs
40-59 °F	5 lbs	4 lbs	24 hrs

T306-c-1

Bags and bagging material or covers

Two alternative treatments

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T306-c-1—MB (“Q” label only) at NAP

Important

Concentration readings should be obtained within the commodity.
Concentration readings **not** required for chamber fumigations.

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	24[1] hrs	28[1] hrs	32[1] hrs
90 °F or above	4 lbs	48	32	25	—	—
80-89 °F	6 lbs	72	48	30	—	—
70-79 °F	8 lbs	96	64	35	—	—
60-69 °F	12 lbs	144	96	50	—	—
50-59 °F	12 lbs	144	96	50	50	—
40-49 °F	12 lbs	144	96	50	50[2]	50

1 In addition to the space concentration readings,commodity concentration reading must be taken. The minimum concentration reading for commodity reading is as follows: For 90-96 °F—10 oz.; for 80-89 °F—15 oz.; and for 70-79 °F—20 oz.

2 Optional

T306-c-2

Bags and bagging material or covers

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T306-c-2—MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	8 lbs	3 hrs
40-59 °F	9 lbs	3 hrs

T306-d-1

Bagging from unroasted coffee beans

Two alternative treatments

Pest: Various

Treatment: T306-d-1—MB ("Q" label only) at NAP

Important

Concentration readings should be obtained within the commodity. Concentration readings **not** required for chamber fumigations.

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	24* hrs	28* hrs	32* hrs
90 °F or above	4 lbs	48	32	25	—	—
80-89 °F	6 lbs	72	48	30	—	—
70-79 °F	8 lbs	96	64	35	—	—
60-69 °F	12 lbs	144	96	50	—	—
50-59 °F	12 lbs	144	96	50	50	—
40-49 °F	12 lbs	144	96	50	50	50

*In addition to the space concentration readings, you must take a commodity concentration reading. The minimum concentration reading for commodity reading is as follows: For 90-96 °F—10 oz.; for 80-89 °F—15 oz.; and for 70-79 °F—20 oz.

T306-d-2

Bagging from unroasted coffee beans

Two alternative treatments

Pest: Various

Treatment: T306-d-2—MB ("Q" label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	8 lbs	3 hrs
40-59 °F	9 lbs	3 hrs

Important

Load limit maximum 75 percent of chamber volume.

T307—Khapra Beetle Infested Material

T307-a Feeds and milled products heated as a part of the processing procedure, or other commodities that can be subjected to heat

Pest: Khapra beetle

Treatment: T307-a—Heat treatment

Important

This treatment should **not** be used except when specifically authorized in each case by the Quarantine Policy, Analysis and Support (QPAS), Riverdale, MD, office.

180 °F in any part of a processing procedure or at 150 °F for a total of 7 minutes, the commodity being moved through or manipulated in the heated area in a manner to ensure that all parts meet the time and temperature requirements.

Miscellaneous products infested with Khapra beetle

Pest: Khapra beetle

Treatment: Summary of fumigation treatments for infested material

Important

Bags and bagging, see***T306-c-1*** on **page 5-4-20**
Cotton products, see ***T301-b-1-1*** on **page 5-4-2**
Finely ground oily meals, see***T306-c-1*** on **page 5-4-20**
Grains and seeds, see***T302-c-1*** on **page 5-4-10**
Flour, see ***T306-c-1*** on **page 5-4-20**
Sorptive materials, see ***T302-g-1*** on **page 5-4-8**.
Goatskins, lambskins, sheepskins (skins and hides), see “T416” on ***T416—Goatskins, Lambskins, Sheepskins (Skins and Hides)*** on **page 5-5-51**

Important

The following commodities have shown relatively high sorption:
Carpet backing, Cinnamon quill, Cocoa mats, Cocoa powder, Lumber, Myrobalan, Pistachio nuts, Polymide waste, Potato starch, Rubber (crepe or crude) Vermiculite, Wool (raw, except pulled)

All other commodities, see ***T302-g-1*** on **page 5-4-8**

T308—Tobacco

T308-e Blended strip tobacco

Pest: *Lasioderma serricorne* (Cigarette beetle) and *Ephestia elutella* (Tobacco moth)

Treatment: T308-e—Vacuum-steam flow method

1. Evacuate the chamber to the wet bulb temperature of 35 °F (0.2 in. Hg. absolute or 29.8 in. Hg. vacuum) to remove air from the tobacco mass and facilitate steam penetration.
2. Introduce steam until 160 °F is reached while maintaining vacuum to evacuate gases pushed ahead of the steam. Hold at 160 °F for 3 minutes to allow the steam to condense within the tobacco mass for the temperature to equilibrate.
3. Re-evacuate to 110 °F.
4. Introduce steam to 135 °F for 3 minutes to allow the steam to condense within the tobacco mass and for the temperature to equilibrate.

T308-c Leaf tobacco

Pest: *Lasioderma serricorne* (cigarette beetle) and *Ephestia elutella* (tobacco moth)

Treatment: T308-c—Vacuum-steam flow process followed by reconditioning

For leaf tobacco—flowing steam at 170 °F for 15 minutes in 23" vacuum. Followed by reconditioning of the tobacco to 12 to 13 percent moisture content.

T308-d Stored tobacco

Pest: *Lasioderma serricorne* (cigarette beetle) and *Ephestia elutella* (tobacco moth)

Treatment: T308-d—Kabat® (active ingredient—methoprene) is an insect growth regulator applied at the rate of 0.2 lbs. (3.9 fluid oz.) per 1,000 lbs. of tobacco.

Application should be made directly to tobacco immediately prior to compaction in hogsheads. Assure complete coverage by using multi-directional sprays and tumbling. Kabat® may be applied by use of a proportional dilution apparatus or by preparation of a dilute spray solution. Follow mixing and application instructions on the label. Zoecon Corporation will be responsible for ensuring that receivers in foreign countries will accept this treatment in lieu of fumigation.

In most cases, indication of Kabat® treatment need not be shown on the phytosanitary certificate. PPQ prefers that tobacco exporting firms utilize the letterhead certification of treatment rather than relying on the phytosanitary certificate to convey this information to foreign receivers. However, if requested, an additional declaration may be made showing application rates as supplied by the exporter if it has been determined through periodic inspection of a firm's facilities that application of the protectant is an integral part of the processing procedure.

T308-a-1 Tobacco (flue-cured and burley in hogshead and cases; turkish in bales; cigar filler/binder in cases or bales; and cigar wrappers in bales)

Four alternative treatments

Pest: *Lasioderma serricorne* (cigarette beetle) and *Ephestia elutella* (tobacco moth)

Treatment: T308-a-1—MB in 28" vacuum

Flue-cured and burley in hogshead and cases; Turkish in bales; cigar filler/ binder in cases or bales; and cigar wrappers in bales

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	4 lbs	4 hrs

T308-a-2 Tobacco (flue-cured and burley in hogshead and cases; turkish in bales; cigar filler/binder in cases or bales; and cigar wrappers in bales)

Treatment: T308-a-2—MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	1.25 lbs	72 hours
45-69 °F	2 lbs	72 hrs

T308-b-1 Tobacco (flue-cured and burley in hogshead and cases; turkish in bales; cigar filler/binder in cases or bales; and cigar wrappers in bales)

Treatment: T308-b-1—Phosphine at NAP—Tarpaulin or freight containers

Temperature	Dosage Rate ($g/1,000\ ft^3$)	Minimum Concentration Readings (ppm) At:	
		96 hrs	144 hours
Greater than 68 °F	33 g*	200	—
61-68 °F	33 g*	—	300

* $33g/1,000\ ft^3$ is equivalent to $1.17\ g/m^3$.

Important

The tobacco industry's Sanitation Committee considers “starting time” as the time when the minimum concentration reading is reached. It is recommended that concentration monitoring be done every 6 hours leading up to “starting time,” then again at completion (96 or 120 hours later). [Note that this concept differs from the “starting time” in other phosphine fumigation schedules. In those cases, “starting time” starts when the aluminum phosphide or magnesium phosphide are first introduced.]

NOTICE

Gas concentration readings and temperature readings must be taken in the middle of a tightly packed bale.The fumigation does **not** begin until the gas concentration readings reach minimum required levels.

Important

Refer to the Equipment Section of this manual for a discussion of the MityVac® hand-operated gas sampling pump and the Port-a-sens phosphine monitor. See ***Table 5-4-4*** on **page 5-4-41** for data on amount of phosphine liberated by various products.

T308-b-2 Tobacco (flue-cured and burley in hogshead and cases; turkish in bales; cigar filler/binder in cases or bales; and cigar wrappers in bales)

Treatment: T308-b-2—Phosphine at NAP—Warehouses

Temperature	Dosage Rate ($g/1,000\ ft^3$)	Minimum Concentration Readings (ppm) At:	
		96 hrs	144 hours
Greater than 68 °F	20 g*	200	—
61-68 °F	20 g*	—	300

* $20g/1,000\ ft^3$ is equivalent to $0.71\ g/m^3$.

Important

The tobacco industry's Sanitation Committee considers "starting time" as the time when the minimum concentration reading is reached. It is recommended that concentration monitoring be done every 6 hours leading up to "starting time," then again at completion (96 or 120 hours later). [Note that this concept differs from the "starting time" in other phosphine fumigation schedules. In those cases, "starting time" starts when the aluminum phosphide or magnesium phosphide are first introduced.].

NOTICE

Gas concentration readings and temperature readings must be taken in the middle of a tightly packed bale.The fumigation does **not** begin until the gas concentration readings reach minimum required levels.

Important

Refer to ***Table 5-4-4*** on **page 5-4-41** for the amount of phosphine liberated by various products

T309—Broomcorn and Broomcorn Articles

T309-a Broomcorn and broomcorn articles

Four alternative schedules

Pest: *Ostrinia nubilalis* (European corn borers), ticks, and saw flies

Treatment: T309-a—MB in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period for: Sawflies	Exposure Period for: Other than sawflies
60 °F or above	2.5 lbs	5 hrs	2.5 hrs
50-59 °F	3.5 lbs	5 hrs	2.5 hrs
40-49 °F	5 lbs	5 hrs	2.5 hrs

T309-b-1 Broomcorn and broomcorn articles

Pest: *Ostrinia nubilalis* (European corn borers), ticks, and saw flies

Treatment: T309-b-1—MB at NAP—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	2.5 lbs	16 hrs
50-59 °F	3.5 lbs	16 hrs
40-49 °F	4.5 lbs	16 hrs

T309-b-2 Broomcorn and broomcorn articles

Pest: *Ostrinia nubilalis* (European corn borers), ticks, and saw flies

Treatment: T309-b-2—MB at NAP—Railroad car, reefer, highway van, tarpaulin

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	4 hrs	24 hrs
60 °F or above	3 lbs	36	24	20	15
50-59 °F	5 lbs	60	40	30	20
40-49 °F	7 lbs	84	56	40	25

T309-c Broomcorn and broomcorn articles

Pest: *Ostrinia nubilalis* (European corn borers), ticks, and saw flies

Treatment: T309-c—Steam sterilization (alternate treatment)

Introduce live steam into 25" vacuum until pressure reaches 10 psi and 240 °F, then hold for 20 minutes.

T310—Tick-Infested Materials (Nonfood)

T310-a Nonfood materials

Three alternative treatments

Pest: Ticks

Treatment: T310-a—MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:							
		0.5 hr	2 hrs	3 hrs	4 hrs	5 hrs	7 hrs	8 hrs	16 hrs
90 °F or above	4 lbs	55	45	45	—	—	—	—	—
80-89 °F	5 lbs	65	52	52	—	—	—	—	—
70-79 °F	6 lbs	75	50	—	50	—	—	—	—
60-69 °F	7 lbs	88	60	—	—	60	—	—	—
50-59 °F	8 lbs	100	70	—	—	—	70	—	—
40-49°F	8 lbs	100	65	—	—	—	—	65	50

NOTICE

Always check the fumigant label for the proper dosage used on the commodity being treated.

T310-b Nonfood materials

Treatment: T310-b—MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
80 °F or above	3 lbs	2.5 hrs
70-79 °F	3 lbs	3.5 hrs
60-69 °F	4 lbs	4 hrs
50-59 °F	5.5 lbs	5 hrs

Important

For all fumigations with MB, if commodity temperature is known or considered to have been below the temperature range during the previous 48 hours, use the next lower range to calculate dosage.

T310-c Nonfood materials

Treatment: T310-c ***(Vacant)***

T310-d Nonfood materials

Treatment: T310-d—Sulfuryl fluoride at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	24 hrs
70 °F or above	2 lbs	25	16	20
50-69 °F	2.5 lbs	32	20	24
40-49 °F	3 lbs	40	24	28

Important

Fumigations below 50 °F to be used only on an emergency basis and specifically authorized by Quarantine Policy, Analysis and Support (QPAS) in Riverdale MD.

T311—Hay, Baled

T311

Baled hay

Pest: *Mayetiola destructor* (Hessian fly), *Oulema melanopus* (cereal leaf beetle)

Treatment: T311 Phosphine at NAP

Temperature	Dosage Rate (g/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	24 hrs	168 hrs
50 °F or above	60	45	30	15	15

Aerate 24 hours or until a level at or below 0.3 ppm is determined.

See ***Table 5-4-4*** on **page 5-4-41** for data on amount of phosphine liberated by various products.

T312—Oak Logs and Lumber

There are two alternative treatments for the MB fumigation of Oak logs, T312-a and T312-a-Alternative. Do **not** combine the schedules.

***Special Procedures for Adding Gas to Oak Logs Using T312 or T312-a-Alternative* on page 5-4-32** provides specific instructions for the correct actions to take at each gas concentration reading. Refer to **Table 5-4-2 on page-5-4-33** and **Table 5-4-3 on page-5-4-36** for every reading.

The following is a list of IMPORTANT items to remember when conducting either of these treatments:

- Take gas concentration readings 30 minutes after adding gas and record the readings in the CPHST-AQI electronic 429 Fumigation database.
  - To access the 429 database go to: https://treatments.cphst.org/tqau/
- Run the fans for 30 minutes and take gas concentration readings whenever additional gas is added.
- Ensure that the gas concentration readings **do not differ more than 4 ounces among the sampling lines**. If they do, run the fans for 30 more minutes to equalize the gas.
- Use DrieRite® and Ascarite® during the fumigation. Replace the DrieRite® when it changes color from blue to pink. Replace the Ascarite® when the granules become hard or moist.
- Aerate the logs for a minimum of 48 hours. Follow aeration procedures under sections ***Aerating Sorptive Commodities in Containers—Indoors and Outdoors*** on **page 2-4-44** and ***Aerating Sorptive, Noncontainerized Cargo—Indoors and Outdoors*** on **page 2-4-42**.
- Add additional time onto the <u>end</u> of the fumigation and record the gas concentration reading in the electronic 429 database. Explain the reason the treatment was extended in the Remarks section of the PPQ Form 429.

Important

The 72 hour reading MUST be taken even if the fumigation has been extended. Take the 72 hour reading and then take the extra reading as required by **Table 5-4-2 on page-5-4-33** or **Table 5-4-3 on page-5-4-36** in the section ***Special Procedures for Adding Gas to Oak Logs Using T312 or T312-a-Alternative* on page 5-4-32**.

Refer to **Table 5-4-1** for metric equivalents for T312-a.

Table 5-4-1 Metric Equivalents for T312-a

Temperature (°F)	Dosage Rate (lb/1000 ft^3)	Temperature (°C)	Dosage Rate (g/m^3)
40 or above	15	4.4 or above	240

T312-a

Oak logs

Pest: Oak Wilt Disease

Treatment T312-a—MB ("Q" label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At[1]:						
		0.5 hr[2]	2 hrs[3]	12 hrs	24[4] hrs	36 hrs	48 hrs	72 hrs
40 °F or above	15 lbs	240	240	200	240	160	120	80

1 Refer to **Table 5-4-2** for adding gas at each reading.

2 If the fumigation is conducted in a closed-door container, take the first reading at 1 hour instead of 0.5 hours.

3 If the fumigation is conducted in a closed-door container, take the second reading at 2.5 hour instead of 2 hours.

4 After 24 hours, add enough fumigant to bring the concentration up to 240 oz.

T312-a-Alternative

Oak logs-Alternative

Pest: Oak Wilt Disease

Treatment T312-a-Alternative—MB ("Q" label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At[1]:				
		0.5 hr[2]	2 hrs[3]	24 hrs[4]	48 hrs	72 hrs
40 °F or above	15 lbs	240	240	240	140	100

1 Refer to **Table 5-4-3** for adding gas at each reading.

2 If the fumigation is conducted in a closed-door container, take the first reading at 1 hour in-stead of 0.5 hours.

3 If the fumigation is conducted in a closed-door container, take the second reading at 2.5 hour instead of 2 hours.

4 After 24 hours, add enough fumigant to bring the concentration up to 240 oz.

T312-b

Oak lumber

Pest: Oak Wilt Disease

Treatment T312-b—MB ("Q" label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr[1]	2 hrs[2]	12 hrs	24[3] hrs	36 hrs	48 hrs
40 °F or above	15 lbs	240	160	100	40	120	80

1 If the fumigation is conducted in a closed-door container, take the first reading at 1 hour instead of 0.5 hours.

2 If the fumigation is conducted in a closed-door container, take the second reading at 2.5 hour instead of 2 hours.

3 After 24 hours, add enough fumigant to bring the concentration up to 240 oz.

Special Procedures for Adding Gas to Oak Logs Using T312 or T312-a-Alternative

There are two alternative treatments for the MB fumigation of Oak logs. Refer to **Table 5-4-2** and **Table 5-4-3** for actions to take during the fumigation of Oak Logs using T312-a or T312-a-Alternative.

Use the following formula to calculate the amount of gas to add to the enclosure:

$1.6 \times$ (number of oz. below the required minimum) $\times$ (volume in ft^3)/1,000 ft^3 = oz. of gas to add.

After adding gas, run the fans for 30 minutes and take additional gas concentration readings.

Refer to **Table 5-4-2** if using T312-a and **Table 5-4-3** if using T312-a-Alternative to determine how much additional time must be added to the fumigation to compensate for the low gas concentrations.

EXAMPLE: The treatment schedule is T312-a-Alternative. The size of the enclosure is 2400 ft^3. The required reading at 48 hours must be a minimum of 140 ounces. The actual lowest reading is 132 ounces. Calculate the amount of gas to add to the enclosure using the formula:
1.6 x (the number of ounces below 140) x (volume in ft^3)/1000 ft^3
ANSWER:
140-132=8
1.6 x 8 x 2400=30,720/1000 = 30.72 ounces of gas to add
30.72/16 = 1.92 pounds of gas to add

Determine the amount of time to add by referring to **Table 5-4-3**. In this example, 1 hour will be added to the total fumigation time.
Take the regularly scheduled reading at 72 hours (the minimum should be 100 ounces.)
Take another reading at 73 hours (the minimum should be 100 ounces.)
If the minimum is **not** 100 ounces, add more gas and time according to **Table 5-4-3**.

Instructions for Adding Gas and Time to Schedule T312-a

Do **not** combine Schedules T312-a and T312-a-Alternative. The treatment must be aborted if any individual gas concentration reading is 50 percent or more below the minimum required concentration.

Table 5-4-2 Determine Gas Concentration Values and Corrections for Oak Log Fumigations using Schedule T312-a

0.5 hour[1]	121-239	1. ADD gas, and 2. EXTEND exposure by 0.5 hour
	0-120	ABORT
2 hours[2]	160-239	1. ADD gas, and 2. EXTEND exposure by 0.5 hour
	121-159	1. ADD gas, and 2. EXTEND exposure by 1.0 hour
	0-120	ABORT
12 hours	190-199	1. ADD gas, and 2. EXTEND exposure by 0.5 hour
	180-189	1. ADD gas, and 2. EXTEND exposure by 1.0 hour
	170-179	1. ADD gas, and 2. EXTEND exposure by 1.5 hours
	160-169	1. ADD gas, and 2. EXTEND exposure by 2.0 hours
	150-159	1. ADD gas, and 2. EXTEND exposure by 2.5 hours
	140-149	1. ADD gas, and 2. EXTEND exposure by 3.0 hours
	130-139	1. ADD gas, and 2. EXTEND exposure by 3.5 hours
	120-129	1. ADD gas, and 2. EXTEND exposure by 4.0 hours
	110-119	1. ADD gas, and 2. EXTEND exposure by 4.5 hours
	101-109	1. ADD gas, and 2. EXTEND exposure by 5.0 hours
	0-100	ABORT

Table 5-4-2 Determine Gas Concentration Values and Corrections for Oak Log Fumigations using Schedule T312-a (continued)

24 hours	120-239	1. Add gas to bring the total concentration to 240 ounces. 2. DO **NOT** ADD TIME.
	110-119	1. ADD gas, and 2. EXTEND exposure by 1.0 hour
	100-109	1. ADD gas, and 2. EXTEND exposure by 2.0 hours
	90-99	1. ADD gas, and 2. EXTEND exposure by 3.0 hours
	80-89	1. ADD gas, and 2. EXTEND exposure by 4.0 hours
	70-79	1. ADD gas, and 2. EXTEND exposure by 5.0 hours
	61-69	1. ADD gas, and 2. EXTEND exposure by 6.0 hours
	0-60	ABORT
36 hours	150-159	1. ADD gas, and 2. EXTEND exposure by 1.0 hour
	140-149	1. ADD gas, and 2. EXTEND exposure by 1.5 hours
	130-139	1. ADD gas, and 2. EXTEND exposure by 2.5 hours
	120-129	1. ADD gas, and 2. EXTEND exposure by 3.0 hours
	110-119	1. ADD gas, and 2. EXTEND exposure by 4.0 hours
	100-109	1. ADD gas, and 2. EXTEND exposure by 4.5 hours
	90-99	1. ADD gas, and 2. EXTEND exposure by 5.5 hours
	81-89	1. ADD gas, and 2. EXTEND exposure by 6.0 hours
	0-80	ABORT

Table 5-4-2 Determine Gas Concentration Values and Corrections for Oak Log Fumigations using Schedule T312-a (continued)

48 hours	110-119	1. ADD gas, and 2. EXTEND exposure by 1.0 hour
	100-109	1. ADD gas, and 2. EXTEND exposure by 2.0 hours
	90-99	1. ADD gas, and 2. EXTEND exposure by 3.0 hours
	80-89	1. ADD gas, and 2. EXTEND exposure by 4.0 hours
	70-79	1. ADD gas, and 2. EXTEND exposure by 5.0 hours
	61-69	1. ADD gas, and 2. EXTEND exposure by 6.0 hours
	0-60	ABORT
72 hours	70-79	1. ADD gas, and 2. EXTEND exposure by 3.0 hours
	60-69	1. ADD gas, and 2. EXTEND exposure by 6.0 hours
	50-59	1. ADD gas, and 2. EXTEND exposure by 9.0 hours
	41-49	1. ADD gas, and 2. EXTEND exposure by 12.0 hours
	0-40	ABORT

Important

If additional time has been added to the treatment, the 72 hour reading AND the extended time reading MUST be taken. If the minimum of 80 ounces is **not** met, time and gas MUST be added according to this Table.

1 If the fumigation is conducted in a closed-door container, take the first reading at 1 hour instead of 0.5 hours.

2 If the fumigation is conducted in a closed-door container, take the second reading at 2.5 hour instead of 2 hours.

Instructions for Adding Gas and Time to Schedule T312-a-Alternative

Do **not** combine schedules T312-a and T312-a-Alternative.

Table 5-4-3 Determine Gas Concentration Values and Corrections for Oak Log Fumigations using schedule T312-a-Alternative

0.5 hours[1]	121-239	1. ADD gas, and 2. DO **NOT** EXTEND exposure.
	0-120	ABORT
2 hours[2]	160-239	1. ADD gas, and 2. DO **NOT** EXTEND exposure
	121-159	1. ADD gas, and 2. EXTEND exposure by 1.0 hour
	0-120	ABORT
24 hours	140-239	1. Add gas to bring the total concentration to 240 ounces. 2. DO **NOT** ADD TIME.
	130-139	1. ADD gas, and 2. EXTEND exposure by 1.0 hour
	120-129	1. ADD gas, and 2. EXTEND exposure by 2.5 hours
	110-119	1. ADD gas, and 2. EXTEND exposure by 4.0 hours
	100-109	1. ADD gas, and 2. EXTEND exposure by 5.5 hours
	90-99	1. ADD gas, and 2. EXTEND exposure by 7.0 hours
	80-89	1. ADD gas, and 2. EXTEND exposure by 8.5 hours
	71-79	1. ADD gas, and 2. EXTEND exposure by 10.0 hours
	0-70	ABORT

Table 5-4-3 Determine Gas Concentration Values and Corrections for Oak Log Fumigations using schedule T312-a-Alternative (continued)

48 hours	130-139	1. ADD gas, and 2. EXTEND exposure by 1.0 hour
	120-129	1. ADD gas, and 2. EXTEND exposure by 2.5 hours
	110-119	1. ADD gas, and 2. EXTEND exposure by 4.5 hours
	100-109	1. ADD gas, and 2. EXTEND exposure by 6.0 hours
	90-99	1. ADD gas, and 2. EXTEND exposure by 8.5 hours
	80-89	1. ADD gas, and 2. EXTEND exposure by 9.5 hours
	71-79	1. ADD gas, and 2. EXTEND exposure by 11 hours
	0-70	ABORT
72 hours	90-99	1. ADD gas, and 2. EXTEND exposure by 1.5 hours
	80-89	1. ADD gas, and 2. EXTEND exposure by 4.0 hours
	70-79	1. ADD gas, and 2. EXTEND exposure by 7.5 hours
	60-69	1. ADD gas, and 2. EXTEND exposure by 8.5 hours
	51-59	1. ADD gas, and 2. EXTEND exposure by 11.0 hours
	0-50	ABORT

Important

If additional time has been added to the treatment, the 72 hour reading AND the extended time reading MUST be taken. If the minimum of 100 ounces is **not** met, time and gas MUST be added according to this Table.

1 If the fumigation is conducted in a closed-door container, take the first reading at 1 hour instead of 0.5 hours.

2 If the fumigation is conducted in a closed-door container, take the second reading at 2.5 hour instead of 2 hours.

T313—Christmas Trees

NOTICE

Cut trees at least 2 weeks prior to treatment in order to reduce possible damage by the fumigant to the trees.

T313-a

Cut conifer Christmas trees

Pest: *Lymantria dispar* (gypsy moth) egg masses

Treatment: T313-a—MB ("Q" label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2.5 hrs	3 hrs	4 hrs	4.5 hrs
75 °F or above	1.5 lbs	18	12	—	—	—
70-74 °F	2 lbs	24	16	—	—	—
60-69 °F	2.5 lbs	30	—	24	—	—
60-69 °F	3 lbs	36	24	—	—	—
50-59 °F	3 lbs	36	—	—	24	—
50-59 °F	4 lbs	48	32	—	—	—
40-49 °F	3.5 lbs	42	—	—	—	28
40-49 °F	5 lbs	60	40	—	—	—

T313-b

Cut pine Christmas trees and pine logs

Pest: *Tomicus piniperda* (pine shoot beetle)

Treatment: T313-b—MB ("Q" label only) at NAP—chamber or tarpaulin

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		2 hrs	3 hrs	3.5 hrs	4 hrs
60 °F or above	3 lbs	43	—	—	36
60 °F or above	4 lbs	57	48	—	—
50-59 °F	3.5 lbs	50	—	—	42
50-59 °F	4 lbs	57	—	48	—
40-49 °F	4 lbs	57	—	—	48

Important

If treating pine Christmas trees for both gypsy moth egg masses and the pine shoot beetle, use the schedule for the pine shoot beetle since it is more potent.

T314—Logs and Firewood

These heat treatment procedures may employ steam, hot water, kilns, or any other method that raises the temperature of the **center** of the log to the minium required temperature for the time specified. Procedures for obtaining internal log temperature can be found in the chapter "Methyl Bromide-Tarpaulin", section ***Logs and Lumber* on page 2-4-21**.

The heat treatment must be performed at an approved facility that maintains a current compliance agreement. The PPQ official will review facility treatment records to ensure the treatment temperature and duration requirements have been met.

Contact USDA-APHIS-CPHST-PPQ Pest Survey Detection and Exclusion Laboratory at 508-563-9303 ext. 259 for a list of approved facilities, temperature monitoring equipment and operational guidelines.

Important

For annual facility certification guidelines, follow the procedures in “***Certifying Facilities for the Heat Treatment of Firewood* on page 6-9-1**.

T314-a

Regulated Wood Articles[3], including *Fraxinus* (Ash Logs and firewood) and all Hardwood Firewood from Emerald Ash Borer quarantine areas

Pest: *Agrilus planipennis* (Emerald Ash Borer)

Treatment: T314-a—Heat treatment

Unit	Temperature	Time (minutes)
°F	140.0	60
°C	60.0	60

T314-b

All logs (including firewood) from Gypsy Moth quarantine areas[4]

Pest: *Lymantria dispar* (Gypsy Moth egg masses)

Treatment: T314-b—Heat treatment

Unit	Temperature	Time (minutes)
°F	132.8	30
°C	56.0	30

3 Emerald Ash Borer regulated articles include: firewood of all hardwood (non-coniferous) species; nursery stock, green lumber, and other material living, dead, cut, or fallen, including logs, stumps, roots, branches, and composted and uncomposted chips of the genus *Fraxinus*.(7 CFR 301.53-2)

T314-c Regulated Wood Articles[5]

Pest: Various Wood Pests

Treatment: T314-c—Heat treatment

Unit	Temperature	Time (minutes)
°F	160.0	75
°C	71.1	75

4 If the regulated article originates from areas quarantine for BOTH gypsy moth and emerald ash borer, use T314-a.

5 Regulated wood articles are considered to be unprocessed logs; lumber; any whole tree; any cut tree or any portion of a tree not solely consisting of leaves, flowers, fruits, buds, or seeds; bark; cork; laths; hog fuel; sawdust; painted raw wood products; wood mulch; wood shavings; pickets; stakes; shingles; solid wood packing materials; humus; compost; and litter. (7 CFR 319.40-1)

Table 5-4-4 Amount of Phosphine Liberated by various Products. Calculate amount of product needed by using the amount of phosphine released as shown in the right column.

Product	Type	Unit and weight in grams	Grams of phosphine[1]
Degesch Fumi-Cel®	MP	1 plate; 117.0	33.0
Degesch Fumi-Strip®	MP	16 plates; 1872.0	528.0
Degesch Phostoxin®	AP	1 tablet; 3.0	1.0
Degesch Phostoxin® Tablet Prepac Rope	AP	1 prepac; 99.0 (strip or rope of 33 tablets)	33.0
Detia	AP	1 tablet; 3.0	1.0
Detia Rotox AP	AP	1 pellet; 0.6	0.2
Detia Gas EX-B	AP	1 bag or sachet; 34.0	11.4
Fumiphos tablets	AP	1 tablet; 3.0	1.0
Fumiphos pellets	AP	1 pellet; 0.6	0.2
Fumiphos bags	AP	1 bag; 34.0	11.0
Fumitoxin	AP	1 tablet; 3.0	1.0
Fumitoxin	AP	1 pellet; 0.6	0.2
Fumitoxin	AP	1 bag; 34.0	11.0
Gastoxin	AP	1 tablet; 3.0	1.0
Gastoxin	AP	1 pellet; 0.6	0.2
“L” Fume	AP AP	1 pellet; 0.5 1 pellet; 0.6	0.18 0.22
Phos-Kill	AP	1 tablet; 3.0	1.1
Phos-Kill	AP	1 pellet; 0.6	0.22
Phos-Kill	AP	1 bag; 34.0	12.0

1 Reacts with moisture in the air to yield grams of phosphine.

5

Treatment Manual

Treatment Schedules

T400 - Schedules for Miscellaneous Products

Contents

Commodities treated with the following schedules are **not** to be used for food or feed.

Important

Exposure period may be extended for any commodity which cannot be used for food or propagation. This extension is only a matter of convenience for the importer and is intended only for the purpose of reducing treatment costs. The request for extension must come from the importer or his authorized representative and should be confirmed in writing. A letter is not required for each treatment. A single blanket request should be considered as acceptable and renewed each year as required.

During the extended exposure period, the concentrations must remain stable and the prescribed minimums be met at the end of the extension. Otherwise, the treatment may be voided and retreatment required. Examples of commodities for which extended exposure periods may be approved include cotton piece goods, baled cotton, bagging, wood, marble, soil as such, etc. Examples of commodities for which *no* extension may be approved include cottonseed, grain, tobacco, etc. An extension of exposure period for other purposes is **not** permitted except as may be prescribed in various schedules for concentration readings below minimum.

Additional safety precautions, including additional aeration, may be required because of the extended exposure period. The PPQ officer or the commercial fumigator will specify any needed safety precautions.

T401—Railroad Cars (Empty)

T401-a Railroad cars (empty)

Pest: *Pectinophora gossypiella* (pink bollworm) and fruit flies

Treatment: T401-a—MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	4 lbs	12 hrs
OR	8 lbs	3 hrs

T401-b Railroad cars (empty)

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T401-b—MB (“Q” label only) at NAP—tarpaulin covered car

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	12 hrs
90 °F or above	2.5 lbs	30	20	15
80-89 °F	3.5 lbs	42	30	20
70-79 °F	4.5 lbs	54	40	25
60-69 °F	6 lbs	72	50	30
50-59 °F	7.5 lbs	90	60	35
40-49 °F	9 lbs	108	70	40

T401-c Railroad cars (empty)

Pest: For nematode cysts

Treatment: T401-c—High pressure steam cleaning. The debris and/or runoff from the cleaning procedure must be handled in a manner approved by local and port authority guidelines.

T402—Miscellaneous Areas Where Fumigation is Not Possible

DANGER

These schedules use insecticides that may be toxic to fish, aquatic invertebrates, small mammals, birds, and bees. Do **not** apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Do **not** apply where runoff is likely to occur. Do **not** apply these insecticides or allow them to drift to blooming crops or weeds if bees are visiting the treatment area. ALWAYS refer to the labels for specific environmental, physical and chemical hazards, mixing and application instructions.

Apply these insecticides according to the manufacturer's labels and all state and local restrictions. Direct the spray to areas where the insects congregate, with special attention to corners, cracks, and crevices. Before using any insecticide, verify that it is registered for use in YOUR city, state, or county.

T402-b-3-2 Deleted

T402-b-3-1

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T402-b-3-1—General surface, perimeter, spot, mist, or crack and crevice treatment

Refer to **Table 5-5-4** for a partial site list. Always refer to the manufacturer's label for specific areas of use.

Active Ingredient[1]	Examples of Trade Names and EPA Registration Numbers (list not all inclusive) [2]
Deltamethrin 4.75% a.i.	Suspend SC, K-Othrine® SC (#432-763) D-FENSE SC, Delta SC (#53883-276)
Malathion 57% EC	Clean Crop Malathion (#34704-108)

1 Apply at the highest rate allowed for the site on the label. (active ingredient = a.i.)

2 No endorsement is intended of the particular items listed and no discrimination is intended toward those products or companies that may not be listed. Use other formulations as long as the application method, site, and rate are listed on the label.

T402-d

Pests: Miscellaneous hitchhiking insects (e.g., crickets, scarab beetles, ants, Africanized honeybee swarms)

Treatment: T402-d—General surface, perimeter, spot, mist, or crack and crevice treatment

Refer to **Table 5-5-4** for a partial site list. Always refer to the manufacturer's label for specific areas of use.

Active Ingredient[1]	Examples of Trade Names and EPA Registration Numbers (list not all inclusive) [2]
Chlorpyrifos	Whitmire PT®, Duraguard ME (#499-367)
β-Cyfluthrin 11.8 % a.i.	Tempo Ultra® SC (#432-1363)
Cyfluthrin 6% a.i.	Cy-Kick® CS, OPTEM® (#499-304)
Cypermethrin 25.3% a.i.	Demon® EC (#100-1004)
Deltamethrin 4.75% a.i.	Suspend SC, K-Othrine® (#432-763) D-FENSE™ SC, Delta SC (#53883-276)
Lambda-Cyhalo- thrin 9.7% a.i.	Cyonara™ 9.7, Cyzmic™ CS, Demand® CS (#100-1066)
Malathion 57% EC	Clean Crop Malathion (#34704-108)

1 Apply at the highest rate allowed for the site on the label. (active ingredient = a.i.)

2 No endorsement is intended of the particular items listed and no discrimination is intended toward those products or companies that may not be listed. Use other formulations as long as the application method, site, and rate are listed on the label.

T402-c Empty holds (precautionary treatment for grain exports)

Pest: Without khapra beetle infestation

Treatment: T402-b—MB at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	1 lb	10 hrs
50-59 °F	1 lb	12 hrs
40-59 °F	1.5 lbs	12 hrs

Important

Operate fans during gas introduction and for 30 minutes thereafter. During exposure period, operate fans for 30 minutes every 3 hours.

Important

If khapra beetle is present, see *T401-b* on **page 5-5-2.**

T402-a-1 Ship holds and any nonplant cargo material within holds

Pest: Quarantine-significant snails of the family Achatinidea, including the following genera:

Achatina	*Lignus*
Archachatina	*Limicolaria*

Treatment: T402-a-1—MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	24 hrs
55 °F or above	8 lbs	96	65	35

T402-a-2 Ship holds and any nonplant cargo material within holds

Pest: Quarantine-significant snails of the families Geomitridae and Hygromiidae, including the following genera:

Candidula	*Monacha*	*Xeropicta*
Cernuella	*Platytheba*	*Xerosecta*
Cochlicella	*Pseudotrichia*	*Xerotricha*
Helicella	*Trochoidea*	
Helicopsis	*Xerolenta*	

Treatment: T402-a-2—MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	24 hrs	48 hrs	72 hrs
55 °F or above	8 lbs	95	64	62	60	40

T402-a-3 Ship holds and any nonplant cargo material within holds

Pest: Quarantine-significant snails of the families Helicidae and Succineidae, including the following genera:

Caracollina	*Omalonyx*
Cepaea	*Otala*
Cryptomphalus	*Succinea*
Helix	*Theba*

Treatment: T402-a-3—MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	10 hrs	12 hrs	16 hrs	24 hrs
80 °F or above	6 lbs	70	48	40	—	—	—
55-79 °F	6 lbs	70	48	—	—	40	—
40-54 °F	8 lbs	96	64	—	—	—	39

T402-b-1 Ship holds and storerooms that do not contain finely milled products such as flour or appreciable quantities of tightly packed cargo such as baled materials

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T402-b-1—MB (“Q” label only) at NAP–tarpaulin covered car

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	12 hrs
90 °F or above	2.5 lbs	30	20	15
80-89 °F	3.5 lbs	42	30	20
70-79 °F	4.5 lbs	54	40	25
60-69 °F	6 lbs	72	50	30
50-59 °F	7.5 lbs	90	60	35
40-49 °F	9 lbs	108	70	40

T402-b-2 Ship holds and storerooms that contain milled products, or with appreciable quantities of tightly packed or baled material

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T402-b-2—MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	4 hrs	24* hrs
90-96 °F	4 lbs	48	35	25
80-89 °F	6 lbs	72	50	30
70-79 °F	8 lbs	96	65	35

*In addition to the space concentration readings, you must take a commodity concentration reading. The minimum concentration reading for commodity reading is as follows: For 90-96 °F—10 oz.; for 80-89 °F—15 oz.; for 70-79 °F—20 oz.;

Important

Concentration readings not required for chamber fumigation.

Important

Some ships’ masters or agents prefer to abandon flour or other finely milled products to qualify for the 12 hours schedule (*T401-b* on **page 5-5-2**). This practice should not be discouraged if PPQ approved incineration or steam sterilization facilities are available within the port city. Small quantities may be burned or boiled on board the vessel, but in no case should the material be removed from treatment in PPQ facilities. Such articles must be left in the storeroom during the 12-hour fumigation and then removed under PPQ safeguards. This will serve to reduce the possibility of pest dispersal when the articles are removed under PPQ supervision.

T403—Miscellaneous Cargo (Nonfood, Nonfeed Commodities)

T403-a-1

Miscellaneous cargo (nonfood, nonfeed commodities)

Pest: Quarantine-significant snails of the family Achatinidae, including the following genera:

Achatina *Lignus*
Archachatina *Limicolaria*

Treatment: T403-a-1—use T402-a-1 for temperatures of 55 °F and above, use T403-a-6 for temperatures below 55 °F

Important

Commodity or product temperature must reach treatment temperature before exposure time begins.

T403-a-2-1

Miscellaneous cargo (nonfood, nonfeed commodities)

Three alternative treatments

Pest: Quarantine-significant snails of the families Geomitridae and Hygromiidae, including the following genera:

Candidula *Monacha* *Xeropicta*
Cernuella *Platytheba* *Xerosecta*
Cochlicella *Pseudotrichia* *Xerotricha*
Helicella *Trochoidea*
Helicopsis *Xerolenta*

Treatment: T403-a-2-1—MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	24 hrs	48 hrs	72 hrs
55 °F or above	8 lbs	95	64	60	60	40

T403-a-2-2

Miscellaneous cargo (nonfood, nonfeed commodities)

Treatment: T403-a-2-2—MB in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	8 lbs	16 hrs

T403-a-2-3

Miscellaneous cargo (nonfood, nonfeed commodities)

Treatment: T403-a-2-3—Cold treatment (for temperatures below 55 °F)

Temperature	Exposure Period
0 °F	48 hrs

T403-a-3 Miscellaneous cargo (nonfood, nonfeed commodities)

Pest: Quarantine-significant slugs of the families Agriolimacidae, Arionidae, Limacidae, Milacidae, Philomycidae, and Veronicellidae, including the following genera:

Agriolimax	*Leidyula*	*Pseudoveronicella*
Arion	*Limax*	*Sarasinula*
Colosius	*Meghimatium*	*Semperula*
Deroceras	*Milax*	*Vaginulus*
Diplosolenodes	*Pallifera*	*Veronicella*

Treatment: T403-a-3—MB at NAP

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
90-96 °F	1 lb	12	9
80-89 °F	1.25 lbs	15	12
70-79 °F	1.5 lbs	18	15
60-69 °F	1.75 lbs	22	19

T403-a-4-1 Miscellaneous cargo (nonfood, nonfeed commodities)

Three alternative schedules

Pest: Quarantine-significant snails of the family Helicidae, including the following genera:

Caracollina	*Helix*
Cepaea	*Otala*
Cryptomphalus	*Theba*

Treatment: T403-a-4-1—MB at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:					
		0.5 hr	2 hrs	10 hrs	12 hrs	16 hrs	24 hrs
80 °F or above	6 lbs	70	48	40	—	—	—
55-79 °F	6 lbs	70	48	—	—	40	—
40-54 °F	8 lbs	96	64	—	—	—	39

Important

If the fumigation is done at a temperature range of 40 to 54°F, use Methyl Bromide Q gas only.

T403-a-4-2 Miscellaneous cargo (nonfood, nonfeed commodities)

Treatment: T403-a-4-2—MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	6 lbs	6 hrs

T403-a-4-3 Miscellaneous cargo (nonfood, nonfeed commodities)

Treatment: T403-a-4-3—Cold treatment, use ***T403-a-6-1*** on **page 5-5-10** for temperatures below 55 °F

T403-a-5-1 Miscellaneous cargo (nonfood, nonfeed commodities)

Three alternative treatments

Pest: Quarantine-significant snails of the families Bradybaenidae and Succineidae, including the following genera:

Bradybaena *Omalonyx*
Cathaica *Succinea*
Helicostyla *Trishoplita*

Treatment: T403-a-5-1—MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	10 hrs	16 hrs
80 °F or above	6 lbs	72	48	40	—
40-79 °F	6 lbs	70	48	—	40

T403-a-5-2 Miscellaneous cargo (nonfood, nonfeed commodities)

Treatment: T403-a-5-2—MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	6 lbs	6 hrs

T403-a-5-3 Miscellaneous cargo (nonfood, nonfeed commodities)

Treatment: T403-a-5-3—Cold Treatment, use ***T403-a-6-1*** on **page 5-5-10** for temperatures below 40 °F

Important

Commodity or product must reach treatment temperature before exposure time begins.

T403-a-6-1 Miscellaneous cargo (nonfood, nonfeed commodities)

Three alternative treatments

Pest: Quarantine-significant snails sensitive to Cold Treatment, members of the families Bradybaenidae, Geomitridae, Helicidae, Helicellidae, Hygromiidae, and Succineidae, including the following genera:

Bradybaena	*Cochlicella*	*Trochoidea*
Candidula	*Helicella*	*Xerolenta*
Cepaea	*Helicostyla*	*Xeropicta*
Cathaica	*Theba*	*Xerosecta*
Cernuella	*Trishoplita*	*Xerotricha*

Treatment: T403-a-6-1—Cold Treatment

Temperature	Exposure Period
0 °F	48 hrs

T403-a-6-2 Miscellaneous cargo (nonfood, nonfeed commodities)

Pest: Quarantine-significant snails sensitive to Cold Treatment, certain members of the family Helicidae, including the following genera:

Helix	*Otala*

Treatment: T403-a-6-2—Cold Treatment

Temperature	Exposure Period
0 °F	32 hrs
10 °F	48 hrs

T403-a-6-3 Miscellaneous cargo (nonfood, nonfeed commodities)

Pest: Quarantine-significant snails sensitive to Cold Treatment, of the family Achatinidae, including the following genera:

Achatina	*Lignus*
Archachatina	*Limicolaria*

Treatment: T403-a-6-3—Cold Treatment

Temperature	Exposure Period
0 °F	8 hrs
10 °F	16 hrs
20 °F	24 hrs

T403-b Miscellaneous cargo (nonfood, nonfeed commodities)

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T403-b—MB at NAP, use T401-b or T402-b-2

T403-c Miscellaneous cargo (nonfood, nonfeed commodities)

Pest: *Globodera rostochiensis* (golden nematode)

Treatment: T403-c—MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	8 lbs	16 hrs
	10.5 lbs	12 hrs
	16 lbs	8 hrs

T403-d Miscellaneous cargo (nonfood, nonfeed commodities)

Pest: Wood Borers or termites

Treatment: T403-d see T404 schedules

T403-e-1-1 Miscellaneous cargo (nonfood, nonfeed commodities) that is not sorptive or difficult to penetrate

Pest: Quarantine-significant insects not specifically provided for elsewhere in nonfood or nonfeed commodities

Treatment: T403-e-1-1—MB (“Q” label only) at NAP—tarpaulin

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	12 hrs
90 °F or above	2.5 lbs	30	20	15
80-89 °F	3.5 lbs	42	30	20
70-79 °F	4.5 lbs	54	40	25
60-69 °F	6 lbs	72	50	30
50-59 °F	7.5 lbs	90	60	35
40-49 °F	9 lbs	108	70	40

T403-e-1-2 Miscellaneous cargo (nonfood, nonfeed commodities) that is sorptive or difficult to penetrate

Pest: Quarantine-significant insects not specifically provided for elsewhere in nonfood or nonfeed commodities

Treatment: T403-e-1-2—MB (“Q” label only) at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	4 hrs	24 hrs	28 hrs	32 hrs
90-96 °F	4 lbs	48	35	25*	—	—
80-89 °F	6 lbs	72	50	30*	—	—
70-79 °F	8 lbs	96	65	35*	—	—
60-69 °F	12 lbs	144	95	50*	—	—
50-59 °F	12 lbs	144	95	—	50*	—
40-49 °F	12 lbs	144	95	—	—	50*

*In addition to the space concentration readings, you must take a commodity concentration reading. The minimum concentration reading for commodity reading is as follows: For 90-96 °F—10 oz.; for 80-89 °F—15 oz.; for 70-79 °F—20 oz.; for 60-69 °F—30 oz; for 50-59 °F—30 oz; and 40-49 °F—30 oz.

This fumigation schedule may be used, for example, on finely miled products and on material that is tightly packed or baled.

T403-e-2 Miscellaneous cargo (nonfood, nonfeed commodities) that is not sorptive or difficult to penetrate

Pest: Quarantine-significant pests other than insects

Important

This would include quarantine-significant snails of the families Helicarionidae, Streptacidae, Subulinidae, and Zonitidae, as well as other noninsect pests.

Treatment: T403-e-2—MB (“Q” label only) at NAP tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	24 hrs	48 hrs
40 °F or above	10 lbs	140	130	120	80

T403-f

Miscellaneous cargo (nonfood, nonfeed commodities)

Pest: *Pieris* spp. (cabbageworms—all life stages) and all other *Lepidoptera**. Also hitchiking insects, including non-*Lepidoptera*.

Treatment: T403-f—MB at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	3 hrs
70 °F or above	3 lbs	36	16
60-69 °F	3.5 lbs	40	19
50-59 °F	4 lbs	45	21
45-49 °F	4.5 lbs	49	24
40-44 °F	5 lbs	54	27

Important

*A 3-hour exposure easily kills all Lepidopterous hitchhikers, including gypsy moth, and is preferred over using the much longer schedules that are aimed more at khapra beetles (T404-b-1 and T402-b-2). This schedule should not be used for mollusks (snails and slugs) or for any insect with cryptic habits (e.g., ants or borers), or for insects in diapause.

T404—Wood Products Including Containers[1]

T404-b-5-1

Surface spray for the following pests: Borers (wood wasps, Anobiidae, Bostrichiadae, Cerambycidae, and Lyctidae), carpenter ants, and other wood infesting ants, carpenter bees and termites

Treatment: T404-b-5-1—Surface application

Refer to **Table 5-5-4** for a partial list of label-approved surfaces. Always refer to the manufacturer's label for specific areas of use.

Active Ingredient[1]	Examples of Trade Names and EPA Registration Numbers (list not all inclusive) [2]
Chlorpyrifos	Whitmire PT, Duraguard ME (#499-367)
Cypermethrin 25.3% a.i.	Demon® EC (#100-1004)

1 Apply at the highest rate allowed for the site and the pest on the label. (active ingredient = a.i.)

2 No endorsement is intended of the particular items listed and no discrimination is intended toward those products or companies that may not be listed. Use other formulations as long as the application method, site, and rate are listed on the label.

1 **Use Treatment Schedule *T404-d* on page 5-5-20 for the fumigation of any bamboo products.**

T404-a Wood products including containers

Pest: *Globodera rostochiensis* (golden nematode)

Treatment: T404-a—MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	8 lbs	16 hrs
	10.5 lbs	12 hrs
	16 lbs	8 hrs

T404-b-2 Wood products including containers

Pest: Borers (wood wasps, carpenter ants, carpenter bees, and termites)

Treatment: T404-b-2—SF at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:						
		0.5 hr	2 hrs	4 hrs	12 hrs	16 hrs	24 hrs	32 hrs
70 °F or above	4 lbs	48	45	40	—	32	—	—
60-69 °F	4 lbs	48	45	40	36	—	32	—
50-59 °F	5 lbs	60	56	52	48	—	40	—
40-49 °F	6.5 lbs	76	71	66	60	—	52	—
OR	5 lbs	60	57	53	49	—	44	40

Important

Do not use a filter containing sodium hydroxide (Ascarite®) with this fumigant.

Sulfuryl Fluoride (SF) is **NOT** an approved quarantine treatment for wood-boring beetles because SF has difficulty in penetrating insect eggs; therefore, many eggs will still hatch following fumigation. SF treatment of wood should be authorized only for brood-tending species of insects such as termites, bees, wasps, and ants. Even if all eggs are not killed, the hatching larvae will die of starvation, due to lack of care.

T404-b-1-1 Wood products including containers

WARNING

An Ascarite® filter must be mounted on the T/C Analyzer when taking concentration readings for T404-b-1-1 treatment.

Three alternative treatments

Pest: See the pest list in **Table 5-5-2**

Treatment: T404-b-1-1—MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr[1]	2 hrs[2]	4 hrs	16 hrs[3]
70 °F or above	3 lbs	36	30	27	25
40-69 °F	5 lbs	60	51	46	42

1 If the fumigation is conducted in a closed-door container, take the first reading at 1 hour instead of 0.5 hours.

2 If the fumigation is conducted in a closed-door container, take the second reading at 2.5 hours instead of 2 hours.

3 If the 4- and 16-hour readings would occur outside of normal working hours, then the fumigation may be extended to a total of 24 hours, instead of 16. In that case, the 24-hr minimum concentration reading would be 25 (for the initial 3-lb dosage), or 42 (for the initial 5-lb dosage).

Refer to **Table 5-5-1** for metric equivalents for T404-b-1-1.

Table 5-5-1 Metric Equivalents for T404-b-1-1

Temperature (°F)	Dosage Rate (lb/1000 ft^3)	Temperature (°C)	Dosage Rate (g/m^3)
70 or above	3	21 or above	48
40-69	5	5-20	80

T404-b-1-2 Wood products including containers

Pest: See the pest list in **Table 5-5-2**

Treatment: T404-b-1-2—MB in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	4 lbs	4 hrs
40-69 °F	4 lbs	5 hrs

T404-b-4 Wood products including containers

Pest: See the pest list in **Table 5-5-2**

Treatment: T404-b-4—Kiln Sterilization

Dry bulb temperature (°F)	Wet bulb depression (°F)	Relative humidity (%)	Moisture content (%)	Thickness of lumber (inches)	Treatment Time After Kiln Reaches Conditions (hours)
140	7	82	13.8	1 i 2 3	3 5 7
130	16	60	9.4	1 2 3	10 12 14
125	15	61	9.7	1 2 3	46 48 50

Table 5-5-2 Pest list for T404-b-1-1, T404-b-1-2, and T404-b-4

Coleoptera (beetles): ◆ Bostrichidae (branch and twig borers) ◆ Buprestidae (metallic or flat-headed borers) ◆ Cerambycidae (long-horned or round-headed borers) ◆ Curculionidae (wood-boring and root-feeding weevils) ◆ Lyctidae (powder-post beetles) ◆ Lymexylonidae (ship timber beetles) ◆ Passalidae (bess beetles) ◆ Platypodidae (pin-hole borers) ◆ Rhyzophagidae (root-eating beetles) ◆ Salpingidae (narrow-wasted bark beetles) ◆ Scolytidae (bark/engraver beetles; also ambrosia/timber beetles) ◆ Trogositidae (bark-gnawing beetles)
Hymenoptera (bees, wasps, and ants): ◆ Formicidae (carpenter ants) ◆ Orussidae (parasitic wood wasps) ◆ Siricidae (wood wasps) ◆ Syntexicae (incense-cedar wood wasps) ◆ Xylocopidae (carpenter bees) ◆ Xyphydriidae (wood wasps)
Isoptera (termites)
Lepidoptera (moths): ◆ Cossidae (carpenter worms) ◆ Sesiidae (clear-winged moths)

Important

1. Minimum concentration must be met in chamber fumigations of sorptive materials. (Refer to ***Sorption* on page 2-3-10**.)
2. For fumigating of hardboard (Masonite), an initial dosage of 10 lb/1,000 ft^3 is recommended. Inspector should be prepared to provide extra attention to maintaining minimum concentrations when fumigating this commodity.
3. If both termites and borers are present at 40-69 °F, use the schedule for borers with exposure extended to 20 hours. Use same minimum concentrations.
4. Use an Ascarite filter (in addition to a Drierite filter) if any of the following conditions apply:
   The wood is uncured (“green”).
   The wood is manifested as guatamba wood.
   In the two cases above, water vapor or other gases may be evolved during the fumigation, which give false (additive) readings on the gas analyzer.
5. If the 4- and 16-hour readings would occur outside of normal working hours, then the fumigation may be extended to a total of 24 hours, instead of 16. In that case, the 24-hr minimum concentration reading would be 25 (for the initial 3-lb dosage), or 42 (for the initial 5-lb dosage).
6. When conducting the fumigation with the container doors **open,** resume use of fans anytime a difference of **4 oz.** or more occurs between the highest and lowest reading.
7. When conducting the fumigation with the container doors **closed**, resume use of fans anytime a difference of **10 oz.** or more occurs between the highest and lowest reading.
8. Readings more than 5 oz. below minimum at end of exposure negates treatment. For readings less than 5 oz. below minimum at the end of exposure period, add 2 oz/1,000 ft^3 for each ounce below minimum and extend exposure for 4 hours.
9. A reduction in dosage is allowed when fumigating nonsorptive commodities such as marble, shells, metal containers, etc., which have infested crating associated with them providing the following additional conditions are met:
   Use only new 4-mil or 6-mil tarpaulins.
   No truck trailer, van, or railroad car fumigations are permitted unless the carrier is covered with a 6-mil tarpaulin which is then sealed to the ground.
   Use five or more sampling leads to determine minimum concentrations.
10. When fumigating wood commodities (e.g., dunnage, crating, logs) the proper fumigation temperature may be determined by inserting the tip of a dial thermometer or other temperature probe in a hole in the wood. A hole can be made with an electric or hand-powered drill or an awl. The hole diameter should be just large enough to insert the probe shaft (to lessen the influence of surrounding air). The depth should be 2 inches or half the thickness of the wood. Different areas of the load should be probed and the lowest temperature used in determining fumigation temperature. Determine the wood temperature 5 to 10 minutes after drilling the hole to allow the heat generated during drilling to dissipate.

T404-c-1-1

Wood products including containers

WARNING

If using a T/C analyzer, an Ascarite® filter must be mounted when taking concentration readings for T404-c-1-1.

Pest: Termites

Three alternative treatments:

Treatment: T404-c-1-1—MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	4 hrs	16 hrs	24 hrs
40 °F or above	3 lbs	36	30	27	25	24

Important

- Minimum concentration must be met in NAP chamber fumigations of sorptive materials. (see ***Sorption*** on **page 2-3-10** for a list of sorptive materials.)
- If both **termites** and **borers** are present at 40 °F–60 °F, use the schedule for borers with exposure extended to 20 hours. Use same minimum concentrations.

T404-c-1-2

Wood products including containers

Pest: Termites

Treatment: T404-c-1-2—MB in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	4 lbs	3 hrs
40-69 °F	4 lbs	4 hrs

T404-c-2

Wood products including containers

Pest: Termites

Treatment: T404-c-2—SF at NAP (Do not use filters containing Ascarite with this fumigant.)

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	16 hrs	24 hrs
70 °F or above	1 lb	12	8	8	—
60-69 °F	1.5 lbs	18	12	—	8
50-59 °F	2.5 lbs	32	20	—	20

T404-d

Wood products including containers

WARNING

If using a T/C Analyzer, an Ascarite® filter must be mounted when taking concentration readings for the following MB-NAP treatments.

Pest: Borers and *Trogoderma granarium* (khapra beetle)

Treatment: T404-d—MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr[1]	2 hrs[2]	4 hrs	16 hrs[3]	24 hrs
80 °F or above	3.5 lbs	36	33	30	25	17
70-79 °F	4.5 lbs	50	45	40	25	22
60-69 °F[4]	6 lbs	65	55	50	42	29
50-59 °F	7.5 lbs	80	70	60	42	36
40-49 °F[5]	9 lbs	85	76	70	42	42

1 If the fumigation is conducted in a closed-door container, take the first reading at 1 hour instead of 0.5 hours.

2 If the fumigation is conducted in a closed-door container, take the second reading at 2.5 hour instead of 2 hours.

3 If the 16-hour reading is **not** performed, the 24-hour reading **must** have the following minumum concentrations: For 80 °F or above—25 oz.; for 70-79 °F—25 oz.; for 60-69 °F—42 oz; for 50-59 °F—42 oz; and 40-49 °F—42 oz.

4 Due to label restrictions, MB-100 gas may not be used at 60 °F or below.

5 MB Q-gas may be used at any temperature above 40 °F.

Refer to **Table 5-5-3** for metric equivalents for T404-d.

Table 5-5-3 Metric Equivalents for T404-d

Temperature (°F)	Dosage Rate (lb/1000 ft^3)	Temperature (°C)	Dosage Rate (g/m^3)
80 or above	3.5	27 or above	56
70-79	4.5	21-26	72
60-69	6	16-20	96
50-59	7.5	10-15	120
40-49	9	5-9	144

When fumigating containerized bamboo:

- If the bamboo is packaged, the packaging must be permeable to methyl bromide. If it is not permeable, require the fumigator to remove or puncture the packaging.

- Bamboo **must be on pallets** or have at least 2 inches (") of clearance at the bottom of the container. If the bamboo is being fumigated in a refrigerated container, the 2" clearance **cannot** be created by the I-beam floor of the container, the bamboo bundles, or by steel poles.

Photo Courtesy of USDA APHIS PPQ

Figure 5-5-1 Example of Inadequate Spacing Under Bamboo Bundles

Photo Courtesy of USDA APHIS PPQ

Figure 5-5-2 Example of Inadequate Spacing Under Bamboo Bundles

- There must be at least 18" of clearance on the top of the commodity to allow for gas circulation and introduction fans.

Photo Courtesy of USDA APHIS PPQ

Figure 5-5-3 Example of Adequate Space Above the Bamboo Bundles

Partial Site List for Chemical Treatments

Always refer to the manufacturer's label for specific areas of use. **Table 5-5-4** is **not** all-inclusive and is intended as a quick reference for PPQ officials. The label of the chemical you are using must list the site you want to treat.

Table 5-5-4 Partial Site List

Active Ingredient	Partial Site List
Deltamethrin	Food/feed and non-food/non-feed areas of: aircraft (cargo only), apartment buildings, bakeries, bottling facilities, breweries, buses, cafeterias, candy plants, canneries, dairy product processing plants, food manufacturing plants, food processing plants, food service establishments, granaries and grain mills, hospitals, hotels, houses, industrial buildings, installations, kitchens, laboratories, mausoleums, meat, poultry, and egg processing and packaging plants, mobile and motor homes, nursing homes, offices, railcars, restaurants, schools, ships and vessels, trailers, trucks, warehouses, wineries
Chlorpyrifos	Indoors,pet kennels, general surface application, barrier application,spot or crack and crevice applications, general outdoor treatment, perimeter treatments, turf grass,ornamentals, commercial ornamentals, greenhouses, and nurseries
β-Cyfluthrin	Food/feed and non-food/non-feed areas of: aircraft (cargo only), apartment buildings, bakeries, bottling facilities, breweries, buses, cafeterias, candy plants, canneries, dairy product processing plants, food manufacturing plants, food processing plants, food service establishments, granaries and grain mills, hospitals, hotels, houses, industrial buildings, installations, kitchens, laboratories, mausoleums, meat, poultry, and egg processing and packaging plants, mobile and motor homes, nursing homes, offices, outdoor pest control, perimeter spray, railcars, restaurants, schools, ships and vessels, trailers, trucks, warehouses, wineries
Cyfluthrin	In and around buildings and structures; on residential, commercial and recreational areas of turf; on ornamentals in landscapes and interior plantscapes; modes of transport; wood infesting pests; apartments, calf hutches, calving pens and parlors, campgrounds, empty chicken houses, dairy areas, dog kennels, food storage areas, grain mills, granaries, hog barns, homes, horse barns, hospitals, hotels, meat packing plants, food processing plants, milkrooms, motels, nursing homes, rabbit hutches, resorts, restaurants and other food handling establishments, schools, supermarkets, transportation equipment (buses, boats, ships, trains, trucks, planes-cargo area only), utilities, warehouses, commercial and industrial buildings
Cypermethrin	Buildings and structures and immediate surroundings, modes of transport, industrial buildings, houses, apartment buildings, laboratories, buses, greenhouses, and nonfood/feed areas of stores, warehouses, vessels, railcars, trucks,trailers, aircraft (cargo areas only), schools, nursing homes, hospitals(non patient areas), restaurants, hotels and food manufacturing, processing, and servicing establishments, outdoor surfaces, barrier treatment, treatment of preconstruction lumber and logs
Lambda-Cyhalothrin	Perimeter treatments, indoor and outdoor treatments, aircraft (cargo and other noncabin areas only), apartment buildings, boiler rooms, buses, closets, correctional facilities, decks, entries, factories, fencing, floor drains (that lead to sewers), food granaries, food grain mills, food manufacturing, processing and serving establishments; furniture, garages, garbage rooms, greenhouses (non-commercial), hospitals, hotels and motels; houses, industrial buildings, laboratories, livestock/poultry housing, landscape vegetation, locker rooms, machine rooms, mausoleums, mobile homes, mop closets, mulch, nursing homes, offices, patios, pet kennels, porches, railcars, restaurants, storage rooms, schools, sewers (dry), stores, trailers, trees, trucks, utility passages, vessels, vestibules, warehouses, wineries and yards
Malathion	Perimeter barrier treatments, outdoor surfaces, ornamentals, turf, mushroom houses, grain elevators and silos being prepared to store barley, corn, oats, rye, or wheat

T404-e—Approved marking for regulated wood packing material

The wood packing material[2] must be stamped in a visible location on each article, with a legible and permanent mark that indicates the article has met the treatment required. The mark must be approved by the International Plant Protection Convention (IPPC). The currently approved mark is shown in **Figure 5-5-4**. XX would be replaced by the country code, 000 by the producer number, and YY by the treatment type (HT or MB).

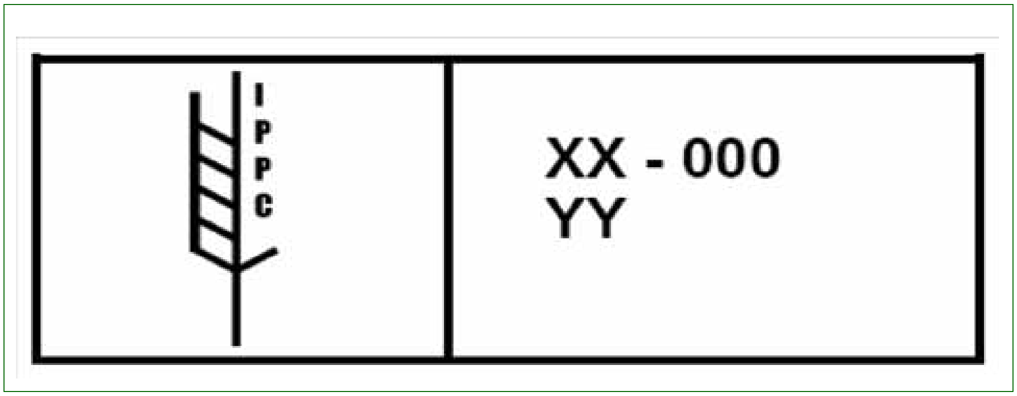


Figure 5-5-4 Example of International Plant Protection Convention Marking

T404-e-1 Regulated wood packing material (WPM)

Two alternative treatments

Pest: Various

Treatment: T404-e-1—MB at NAP—tarpaulin

Temperature	Dosage Rate ($lb/1,000\ ft^3$)	Minimum Concentration Readings (ounces) At:				
		0.5 hr[1]	2 hrs[2]	4 hrs	16 hrs	24 hrs
69.8 °F or above	3 lbs	36	36	31	28	24
61°-69.8 °F	3.5 lbs	42	42	36	32	28
51.8°-61 °F	4 lbs	48	48	42	36	32

1 If the fumigation is conducted in a closed-door container, take the first reading at 1.0 hour instead of 0.5 hours.

2 If the fumigation is conducted in a closed-door container, take the second reading at 2.5 hour instead of 2 hours.

2 Regulated wood packing material is defined as all types of wood packaging materials used for or for use with cargo to prevent damage, including, but not limited to, dunnage, crating, pallets, packing blocks, drums, cases, and skids. Excluded from the definition of wood packaging materials are:
- Pieces of wood that are less than 6mm or 0.24 inches in any dimension
- Loose wood packing materials, such as wood shavings, excelsior, etc.
- Processed wood packing materials that have received more than primary processing, such as plywood, corrugated board, fiberboard, veneer, whiskey and wine barrels, oriented strand boards, etc.

Refer to **Table 5-5-5** for metric equivalents for T404-e-1.

Table 5-5-5 Metric Equivalents for T404-e-1

Temperature (°F)	Dosage Rate (lb/1000 ft^3)	Temperature (°C)	Dosage Rate (g/m^3)
69.8 or above	3	21 or above	48
61-69.8	3.5	16-20.9	56
51.8-61	4	11-15.9	64

T404-e-2 Regulated wood packing material (WPM)

Pest: Various

Treatment: T404-e-2

Heat treatment to achieve a minimum core temperature of 56 °C (132.8 °F)for a minimum of 30 minutes. Treatments must be conducted in USDA-approved facilities. Contact CPHST-AQI in Raleigh, NC for facility specifications.

T404-f *Pinus radiata* wood chips from Chile and *Eucalyptus* wood chips from South America

Treatment: T404-f—Surface Pesticide

Refer to **Table 5-5-6** for the chemical name and percentage of active ingredients. Spray the wood chips with the pesticide mixture so that all the chips are completely exposed to the chemicals. To prevent against infestation by plant pests, safeguard the wood chips during the interval between treatment and export.

Table 5-5-6 Pesticide Treatment for *Pinus radiata* and *Eucalyptus* Wood Chips

Percentage of Active Ingredient (a.i.)	Pesticide
64.8	didecyl dimethyl ammonium chloride
7.6	3-iodo-2-propynl butylcarbamate
44.9	chlorpyrifos phosphorothioate

T405—Bags and Bagging Material

See T306 schedules

T406—Golden Nematode Contaminations

T406-a Miscellaneous cargo (nonfood, nonfeed commodities)

Pest: *Globodera rostochiensis* (golden nematode)

Treatment: T406-a—MB in 26" vacuum, use T403-c

T406-c Piers, barges, railroad cars, automobiles, used farm equipment, etc.

Pest: *Globodera rostochiensis* (golden nematode)

Treatment: T406-c—Steam Cleaning

Steam at high pressure until all soil is removed. Treated surfaces should be thoroughly wet and heated. The debris and/or runoff from the cleaning procedure must be handled in a manner approved by local and port authority guidelines.

T406-b Used farm equipment, construction equipment, containers, etc.

Pest: *Globodera rostochiensis* (golden nematode)

Treatment: T406-b—MB (“Q” label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/ 1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	24 hrs
60 °F or above	15 lbs	180	120	120

NOTICE

Soil should be easily crumbled but not wet. The soil should not exceed 12 inches in the smallest dimension.

T406-d

Used farm equipment (without cabs), construction equipment (without cabs), and used containers

Pest: *Globodera rostochiensis* (golden nematode)

Treatment: T406-d—Steam at NAP—tarpaulin, or tent

Steam heat for 60 minutes after all temperature sensors reach 140ºF (60ºC). (see sensor placement and other requirements below)

Important

This treatment must be conducted under the following minimum ambient air temperatures, which will vary with the volume of the treatment enclosure:

- For treatment enclosures of 4,000 ft^3 or less, the minimum air temperature is 40 °F.
- For treatment enclosures greater than 4,000 ft^3 and less than or equal to 6,000 ft^3, the minimum air temperature is 60 °F.

This treatment is not recommended for treatment enclosures greater than 6,000 ft^3.

Step 1—Determine if the temperature and volume requirements can be met

If you cannot meet the temperature and enclosure volume requirements, do not use this treatment.

Step 2—Assemble articles to be treated

Articles to be treated should be placed as close together as possible. Arrange articles to allow space for placement of the steam distribution manifold.

Step 3—Place the steam distribution manifold pipe beneath articles to be treated

The steam distribution manifold should be assembled and placed beneath the articles to be treated in order to facilitate steam distribution. A flexible steam introduction hose, approximately 20 feet in length, connects the steam generator to a 10 foot long U-shaped pipe capped at the ends, with 0.5 inch holes every 12 inches. This pipe serves as the steam distribution manifold.

Step 4—Place temperature recording sensors on the article to be treated

Enclosures of 4,000 ft^3 or less

When the treatment is being conducted in enclosures 4,000 ft^3 or less, use at least four temperature recording sensors in addition to the sensor on the steam generator. Place sensors in hard-to-treat cracks or crevices on the equipment or containers. Position sensors in the following locations:

1. Front high—near the top of the front of the equipment or load

2. Center middle—midway from the top and bottom of the center of the equipment or load
3. Center bottom—bottom of the center of the equipment or load, but at least 3 inches above the floor if the equipment is flush with the floor
4. Rear bottom—bottom of the rear of the equipment, but at least 3 inches above the floor if the equipment is flush with the floor

Enclosures greater than 4,000 ft^3 and less than or equal to 6,000 ft^3

When the treatment is being conducted in enclosures greater than 4,000 ft^3 and less than or equal to 6,000 ft^3, use at least eight temperature recording sensors in addition to the sensor on the steam generator. Again, place sensors in hard-to-treat cracks or crevices on the equipment or containers. Position probes in the following locations:

1. Front high—near the top of the left side of the front of the equipment or load
2. Front low—bottom of the right side of the front of the equipment or load, but at least 3 inches above the floor if the equipment is flush with the floor
3. Center high—near the top of the center of the equipment or load on the right side
4. Center middle—midway from the top and bottom of the center of the equipment or load
5. Center low—bottom of the center of the equipment or load on the left side, but at least 3 inches above the floor if the equipment is flush with the floor
6. Rear high—near the top of the rear of the equipment on the right side
7. Rear middle—midway from the top and bottom of the rear of the equipment
8. Rear low—bottom of the rear of the equipment or load on the left side, but at least 3 inches above the floor if the equipment is flush with the floor.

Step 5—Enclose the article to be treated with a trapaulin or tent

If a tarpaulin (6 mil plastic) is used instead of a tent, pad sharp edges of the equipment or containers before covering with the tarp.

If the equipment or containers will be moved into an enclosure, such as a tent, it may be more practical to place the temperature sensors after this step. In either case, the front of the equipment or load and the front of the enclosure should face in the same direction.

Step 6—Place the steam generator at an open end of the enclosure and seal the enclosure

The steam generator is placed approximately 20 feet from the front of the enclosure and connected to a steam introduction line (hose.) The steam introduction line is connected to the steam distribution manifold pipe which is situated under the articles to be treated. The enclosure is sealed at the base including the point at which the introduction line enters the enclosure. An airtight seal is not essential for steam treatment; therefore small pinholes are acceptable.

Step 7—Steam heat the enclosure for 60 minutes after all temperature sensors reach a minimum 140°F (60°C)

Important

Use only a steam generator approved by APHIS.

The maximum temperature in the enclosure should not exceed 160°F (71°C).

The temperature should be recorded once every 2 minutes during the treatment.

T407—Mechanical Cotton Pickers and Other Cotton Equipment

T407

Mechanical cotton pickers and other cotton equipment

Pest: *Pectinophora gossypiella* (pink bollworm)

Treatment: T407—MB (“Q” label only) at NAP—tarpaulin, chamber, railroad car, or van

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2 hrs	3 hrs	4 hrs	12 hrs
40 °F or above	4 lbs	48	—	—	—	21
	8 lbs	96	—	64	—	—

Important

This treatment is designed to kill exposed larvae, larvae within green cotton bolls or single locks of seed cotton, or loose trash. Any materials such as sacked or bulked seed, cotton waste, lint, linters, or any packaged commodity shall be treated in accordance with T301.

T408—Soil as Such and Soil Contaminating Durable Commodities

T408-e-1 Herbarium specimens of mosses and liverworts in soil and originating in golden nematode-free countries

Pest: (Precautionary)

Treatment: T408-e-1—MB (“Q” label only) in 26" vacuum (Precautionary fumigation)

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
70 °F or above	2 lbs	3.5 hrs

T408-e-2 Herbarium specimens of mosses and liverworts in soil and originating in golden nematode-free countries

Pest: *Globodera rostochiensis* (golden nematode)

Treatment: T408-e-2—MB (“Q” label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	8 lbs	16 hrs
	10.5 lbs	12 hrs
	16 lbs	8 hrs

T408-a

Soil as such

Two alternative treatments

Pest: Various pests and pathogens found in soil (including striga)

Treatment: T408-a—Dry heat

Temperature	Exposure Period
230 °F to 249 °F	16 hours
250 °F to 309 °F	2 hours
310 °F to 379 °F	30 minutes
380 °F to 429 °F	4 minutes
430 °F to 450 °F	2 minutes

Spread soil evenly throughout the treatment chamber. Soil depth **must not** exceed 6 inches. Take temperature readings using a calibrated temperature probe at various locations throughout the entire mass. The exposure period does not begin until the entire mass reaches treatment temperature, as verified by a calibrated temperature probe.

Important

Contact CPHST AQI Raleigh for information regarding placement and number of temperature probes.

T408-b

Soil as such

Pest: Various pest and pathogens found in soil

Treatment: T408-b—Steam—250 °F at 15 lbs pressure (p.s.i.) for 0.5 hour

Preheat laboratory autoclaves. Restrict soil depth to 2 inches when treating quantities of soil in trays. Restrict each package weight to 5 lbs. or less when treating individual packages. Load with adequate spacing. Large commercial steam facilities which operate at pressures up to 60 lbs. psi will permit treatment of greater soil depth.

T408-b-1

Soil contaminating durable commodities (e.g., equipment, cobblestone, marble)

Pest: Various pests and pathogens found in soil

Treatment: Steam Cleaning

Steam at high pressure until all soil is removed. Treated surfaces should be thoroughly wet and heated. The debris and/or runoff from the cleaning procedure must be handled in a manner approved by local and port authority guidelines.

T408-c-1

Soil as such

Two alternative treatments

Pest: *Globodera rostochiensis* (golden nematode)

Treatment: T408-c-1—MB ("Q" label only) in 26" vacuum, see ***T403-c*** on **page 5-5-11** for loose and friable material only.

Soil to be fumigated in containers—no dimensions of which can exceed 24 inches.

T408-c-2

Soil as such

Pest: *Globodera rostochiensis* (golden nematode)

Treatment: T408-c-2—MB ("Q" label only) at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/ 1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	24 hrs
60 °F or above	15 lbs	180	120	72

Important

Soil should be friable, moist, but not wet. Soil must not be more than 12 inches in depth. If stacked in containers, 12 inches of space must be left between levels.

T408-d-1

Soil as such

Two alternative treatments

Pest: Insects

Treatment: T408-d-1—Screening through 16 mesh screens will remove most larvae and pupae, except smaller types.

T408-d-2

Treatment: T408-d-2—Freezing—0 °F for 5 days

T408-f

Soil contaminated durable commodities (e.g., equipment, cobblestone, marble)(precautionary treatment)

Pest: Soil fungi, nematodes, and certain soil insects

Treatment: T408-f—Steam Cleaning

Steam at high pressure until all soil is removed. Treated surfaces should be thoroughly wet and heated.

The debris and/or runoff from the cleaning procedure must be handled in a manner approved by local and port authority guidelines.

T408-g-1

Soil contaminated nonfood or nonfeed commodities

Two alternative treatments

Pest: *Striga* spp. (witchweed)

Treatment: T408-g-1—MB (“Q” label only) (tarpaulin)

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	10 lbs	24 hrs
	20 lbs	15.5 hrs

T408-g-2

Soil contaminated nonfood or nonfeed commodities

Pest: *Striga* spp. (witchweed)

Treatment: T408-g-2—MB (“Q” label only) (tarpaulin)

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	24 hrs
60 °F or above	15 lbs	164	120	72

Important

Soil must be friable, moist, but not wet. The soil shall not exceed 12 inches in least dimension.

T409—Aircraft

Refer to the Chemical Treatments section for ***Aerosols* on page 2-12-1** for application information.

The aircraft volumes in ***Table 5-5-7*** on **page 5-5-36** through ***Table 5-5-29*** on **page 5-5-46** represent standard configurations of aircraft. Check with the captain or contact the following manufacturers to determine if the aircraft has been modified from the standard configuration and determine the actual volume.

Airbus Industries of North America, Inc.

Website: http://www.airbus.com/aircraft.html

Boeing (includes McDonald Douglas aircraft)

Website: http://www.boeing.com

European Aeronautic Defense and Space Company-EADS (merger of Aerospatiale, Daimler Chrysler Aerospace, and Casa)

Web site: http://www.eads.com

T409-a

Aircraft

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T409-a—General surface, perimeter, spot, mist, or crack and crevice using Deltamethrin 4.75% a.i.

Active Ingredient[1]	Examples of Trade Names and EPA Registration Numbers (list not all inclusive)[2]
Deltamethrin 4.75% a.i.	Suspend SC, K-Othrine® SC (#432-763) D-FENSE SC, Delta SC (#53883-276)

1 Apply at the highest rate allowed for the site on the label. (active ingredient = a.i.) Follow application instructions on the label.

2 No endorsement is intended of the particular items listed and no discrimination is intended toward those products or companies that may not be listed. Use other formulations provided the application method, site, and rate are listed on the label.

T409-b

Aircraft

Pest: Hitchhiking insect pests, except khapra beetle

Two alternative treatments—T409-b-1 and T409-b-3.

Important

No endorsement is intended of the particular items listed and no discrimination is intended toward those products or companies that may not be listed. Use other formulations provided the application method, site, and rate are listed on the label.

CAUTION

Do not subject these chemicals to extreme temperatures.

Refer to **Table 5-5-7** through **Table 5-5-29** for spray times of a variety of commercial aircraft. If the aircraft you are treating is not listed, refer to the formula in **Figure 2-12-1 on page-2-12-2** to calculate the spray time.

T409-b-1

Treatment: T409-b-1—d-phenothrin aerosol (10 percent) (EPA reg# 10308-21)

NOTICE

10% d-phenothrin is **not** approved for use in California, **except** in Federal installations such as military airports.

Application Rate (g/1000 ft^3)	Spray Rate (g/sec)	Turn off ventilation system and seal the cargo space for (x) minutes	Ventilate the space for (x) minutes
8	5[1]	15 minutes	15 - 30

1 To control the spray time within smaller spaces, use the red extender tube on the nozzle of the aerosol can. When the extender tube is used, the spray rate is 2.5 grams per second.

Important

Aerosol disinfestation of U.S. military aircraft must conform to requirements in the "DEPARTMENT OF DEFENSE CUSTOMS AND BORDER CLEARANCE POLICIES AND PROCEDURES" DoD 4500.9-R (Defense Transportation Regulation Part V).

T409-b-2

This is a placeholder for a future treatment.

T409-b-3

Treatment: T409-b-3—2% d-phenothrin + 2% permethrin (EPA reg# 83795-1—Callington 1-Shot™)

CAUTION

Do **not** apply in the passenger cabin area of the aircraft or when passengers or crew are present.

Application Rate (g/1000 ft^3)	Spray Rate (g/sec)	Turn off ventilation system and seal the cargo space for (x) minutes	Ventilate the space for (x) minutes
40	2	15 minutes	30

Table 5-5-7 Airbus Industries

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
A300	Cabin Pit-#1 Pit-#2 Pit-#3	27,100 3,722 1,265 565	27.1 3.7 1.3 0.6	43.5 6.0 2.0 1.0	7 cans + 17 sec 1 can 26 sec 12 sec
A300-600R (passenger) (long-range)	Cabin Forward Aft Bulk	? 1,134 1,134 400	? 1.1 1.1 0.4	? 2.0 2.0 0.5	? 22 sec 22 sec 8 sec
A300-600 (freighter)	Main Pit-Fwd Pit-Aft	9,950 1,900 2,250	10.0 1.9 2.2	16.0 3.0 3.5	2 cans + 50 sec 38 sec 44 sec
A300-600 (FEDEX)	Main Pit-Fwd Pit-Aft Pit-Back	19,069 2,684 2,154 742	19.1 2.7 2.2 0.7	30.5 4.5 3.5 1.0	5 cans + 7 sec 54 sec 44 sec 14 sec
A300 (convertible)	Main	11,943	11.9	19.0	3 cans + 13 sec
A300B4 (freighter)	Main Pit-Fwd Pit-Aft	9,950 1,900 1,850	10.0 1.9 1.9	16.0 3.0 3.0	2 cans + 50 sec 38 sec 38 sec
A310 (freighter)	Main Pit-Fwd Pit-Aft	7,950 1,260 1,550	8.0 1.3 1.6	13.0 2.0 2.5	2 cans + 10 sec 26 sec 32 sec
A310 (FEDEX)	Main Pit-Fwd Pit-Aft Pit-Back	14,650 1,942 1,271 742	14.7 1.9 1.3 0.7	23.5 3.0 2.0 1.0	3 cans + 69 sec 38 sec 26 sec 14 sec
A320-200 (passenger)	N/A	982	0.9	1.5	18 sec

Table 5-5-8 Antonov

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
AN 124 and 126	N/A	26,485	26.5	42.5	7 cans + 5 sec

Table 5-5-9 ATR

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
ATR 42 (CTO) (Container Transport Option)	Bulk	890	0.9	1.5	18 sec
ATR 72 (CTO)	Bulk	1,285	1.3	2.0	26 sec

Table 5-5-10 BAC (British Aircraft Corp)

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
111-200, 300, and 400	Cabin Pit-Fwd Pit-Aft	4,056 380 154	4.1 0.4 0.2	6.5 0.5 0.5	1 can + 7 sec 8 sec 4 sec
111-500	Cabin Pit-Fwd Pit-Aft	5,094 451 260	5.1 0.5 0.3	8.0 1.0 0.5	1 can + 27 sec 10 sec 6 sec
VC 10	Cabin Pit-Fwd Pit-Aft	6,750 744 820	6.8 0.7 0.8	11.0 1.0 1.5	1 can + 61 sec 14 sec 16 sec
Super VC 10	Cabin Pit-Fwd Pit-Aft	7,850 744 820	7.9 0.7 0.8	12.5 1.0 1.5	2 cans + 8 sec 14 sec 16 sec

Table 5-5-11 BAC (Aerospatiale)

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
Concorde	Cabin Pit-Fwd Pit-Aft	5,100 241 468	5.1 0.2 0.5	8.0 0.5 1.0	1 can + 27 sec 10 sec 20 sec

Table 5-5-12 Boeing

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
707-120, 120B, and 220	Cabin Pit-Fwd Pit-Aft Fl.Deck	7,484 755 910 451	7.5 0.8 0.9 0.5	12.0 1.5 1.5 1.0	2 cans 16 sec 18 sec 10 sec
707-320C	Bulk	7,548	7.5	12.0	2 cans
707-320, 420	Cabin Pit-Fwd Pit-Aft Fl. Deck	8,074 870 905 451	8.0 0.9 0.9 0.5	13.0 1.5 1.5 1.0	10 sec 18 sec 18 sec 10 sec
720	Cabin Pit-Fwd Pit-Aft Fl. Deck	6,860 688 690 451	6.9 0.7 0.7 0.5	11.0 1.0 1.0 1.0	1 can + 63 sec 14 sec 14 sec 10 sec
727-100C	Bulk	4,168	4.2	7.0	1 can + 9 sec
727-100 (passenger)	Cabin Pit-Fwd Pit-Aft Fl. Deck	4,560 900 425 451	4.6 0.9 0.4 0.5	7.5 1.5 0.5 1.0	1 can + 17 sec 17 sec 18 sec 10 sec
727-200C	Bulk	8,032	8.0	13.0	2 cans + 10 sec
727-200 (passenger)	Cabin Pit-Fwd Pit-Aft Fl. Deck	6,561 690 760 451	6.6 0.7 0.8 0.5	10.5 1.0 1.5 1.0	1 can + 57 sec 14 sec 16 sec 10 sec
737-100	Cabin Pit-Fwd Pit-Aft	4,636 280 406	4.6 0.3 0.4	7.5 0.5 0.5	1 can + 17 sec 6 sec 8 sec
737-200 (passenger)	Cabin Pit-Fwd Pit-Aft	4,636 370 505	4.6 0.4 0.5	7.5 0.5 1.0	1 can + 17 sec 8 sec 10 sec
737-200C	Bulk	3,602	3.6	6.0	1 can
737-300	Cabin Pit-Fwd Pit-Aft Fl. Deck	4,900 425 650 225	4.9 0.4 0.7 0.3	8.0 1.0 1.0 0.5	1 can + 23 sec 8 sec 14 sec 6 sec
737-400	Cabin Pit-Fwd Pit-Aft Fl. Deck	5,600 600 770 225	5.6 0.6 0.8 0.2	9.0 1.0 1.5 0.5	1 can + 37 sec 12 sec 16 sec 4 sec
737-500	Cabin Pit-Fwd Pit-Aft Fl. Deck	4,340 290 535 255	4.3 0.3 0.5 0.3	7.0 0.5 1.0 0.5	1 can + 11 sec 6 sec 10 sec 6 sec
747 Combi	—	6,886	6.9	11.0	1 can + 63 sec
747F	—	22,952	23.0	37.0	6 cans + 10 sec

Table 5-5-12 Boeing (continued)

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
747-100, 200	Cabin	27,650	27.7	44.5	7 cans + 29 sec
	Pit-Fwd	3,485	3.5	6.0	70 sec
	Pit-Aft	3,015	3.0	5.0	60 sec
	Fl. Deck	920	0.9	1.5	18 sec
	U. Deck	1,370	1.4	2.0	28 sec
	Belly	1,000	1.0	1.5	20 sec
747-300,400	Cabin	27,650	27.7	44.5	7 cans + 29 sec
	Pit-Fwd	3,485	3.5	5.5	70 sec
	Pit-Aft	3,015	3.0	5.0	60 sec
	Fl. Deck	920	0.9	1.5	18 sec
	U. Deck	2,800	2.8	4.5	56 sec
	Belly	1,000	1.0	1.5	20 sec
757-200 (passenger)	Pit-Fwd	652	0.6	1.0	12 sec
	Pit-Aft	1,086	1.1	2.0	22 sec
757-200PF	Bulk	8,405	8.4	13.5	2 cans + 18 sec
767-200	Main	14,255	14.3	23.0	3 cans + 61 sec
	Pit-Fwd	1,470	1.5	2.5	30 sec
	Pit-Aft	1,470	1.5	2.5	30 sec
767-300 (passenger)	Cabin	10,497	10.5	17.0	2 cans + 60 sec
	Pit-Fwd	1,920	1.9	3.0	38 sec
	Pit-Aft	1,680	1.7	2.5	34 sec
	Aft+Bulk	430	0.4	0.5	8 sec
777-200	Cabin	20,700	20.7	33.0	5 cans + 39 sec
	Pit-Fwd	280	0.3	0.5	6 sec
	Pit-Aft	4,630	4.6	7.5	1 can + 17 sec
	Aft+Bulk	4,220	4.2	6.5	1 can + 9 sec

Table 5-5-13 Canadair

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
CL-44	Bulk	6,235	6.2	10.0	1 can + 49 sec
CL-440	Bulk	13,798	13.8	22.0	3 cans + 51 sec

Table 5-5-14 Casa

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
C-212	N/A	777	0.8	1.5	16 sec
ATR 72 (CTO)	N/A	1,528	1.5	2.5	30 sec

Table 5-5-15 Cessna

				Aerosol Calculations	
Aircraft, model, and series	Area	Volume ft^3	1,000 ft_3 Units	T409-b-1 Spray Time in Seconds	T409-b-3 Cans/ Spray Time in Seconds
Caravan	N/A	452	0.5	1.0	10 sec

Table 5-5-16 Convair

				Aerosol Calculations	
Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	T409-b-1 Spray Time in Seconds	T409-b-3 Cans/ Spray Time in Seconds
240	Cabin Pit-Fwd Belly	1,650 193 88	1.7 .2 .1	2.5 0.5 ---[1]	34 sec 4 sec 2 sec
340 & 44-	Cabin Pit-Fwd Pit-Aft Belly	1,816 158 193 78	1.8 0.2 0.2 0.1	3.0 0.5 0.5 ---[1]	36 sec 4 sec 4 sec 2 sec
880 & 800M	Cabin Pit-Fwd Pit-Aft	5,802 415 488	5.8 0.4 0.5	9.5 0.5 1.0	1 can + 41 sec 8 sec 10 sec
990	Cabin Pit-Fwd Pit-Aft	6,336 488 497	6.3 0.5 0.5	10.0 1.0 1.0	1 can + 51 sec 10 sec 10 sec

1 In these small volume spaces, use the extender and calulate the application time using a rate of 2.5 grams per second. At a rate of 2.5 grams per second, the following table will give the spray time:

1,000 ft^3 UnitsSpray TIme in Seconds

0.10.5
0.20.5
0.31.0
0.41.5

Table 5-5-17 de Havilland

				Aerosol Calculations	
Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	T409-b-1 Spray Time in Seconds	T409-b-3 Cans/ Spray Time in Seconds
Dash 7, Series 100 (all cargo)	N/A	240	0.2	0.5	4 sec
DHC-6 Twin Otter, Series 300 (cargo version)	Fwd Aft Bulk	38 88 384	0.1 0.1 0.4	---[1] ---[1] 0.5	2 sec 2 sec 8 sec
Dash 7, Series 100, Combi (50 passengers)	N/A	240	0.2	0.5	4 sec

Table 5-5-17 de Havilland (continued)

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
Dash 7, Series 100, Combi (18 passengers)	N/A	240	0.2	0.5	4 sec
Dash 8, Series 300, Combi (49 passengers)	N/A	400	0.4	0.5	8 sec
Dash 8, Series 100, Combi (37 passengers)	N/A	300	0.3	0.5	6 sec
Dash 8, Series 100, Combi (20 passengers)	N/A	775	0.8	1.5	16 sec

1 In these small volume spaces, use the extender and calulate the application time using a rate of 2.5 grams per second. At a rate of 2.5 grams per second, the following table will give the spray time:

1,000 ft^3 UnitsSpray TIme in Seconds

0.10.5
0.20.5
0.31.0
0.41.5

Table 5-5-18 Dornier

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
228-212	N/A	642	0.6	1.0	12 sec

Table 5-5-19 Embraer

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
EMB-120 Brasilia	N/A	1,193	1.2	2.0	24 sec
EMB-110 Brasilia	N/A	523	0.5	1.0	10 sec

Table 5-5-20 Fairchild

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
Expediter	NA	580	0.6	1.0	12 sec
Metro II & IIA	NA	580	0.6	1.0	12 sec
F27	Cabin Pit	2,900 192	2.9 0.2	4.5 0.5	58 sec 4 sec
FH11227	Cabin Pit	3,200 192	3.2 0.2	5.0 0.5	64 sec 4 sec

Table 5-5-21 Fokker

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
F27	N/A	198	0.2	0.5	4 sec
F28	N/A	290	0.3	0.5	6 sec
F100C	Bulk	2,070	2.0	3.0	40 sec

Table 5-5-22 Lockheed

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
Electra	Cabin Pit-Fwd Pit-Aft	5,160 254 274	5.2 0.3 0.3	8.5 0.5 0.5	1 can + 29 sec 6 sec 6 sec
L1011 (100) (200) (250)	Cabin Pit-Fwd Pit-Ctr Pit-Aft Galley	23,100 1,600 1,600 700 1,380	23.1 1.6 1.6 0.7 1.4	37.0 2.5 2.5 1.0 2.0	6 cans + 12 sec 32 sec 32 sec 14 sec 28 sec
L-1011-1	Cargo Holds	3,900	3.9	6.0	1 can + 3 sec
L-100-30	N/A	6,057	6.1	10.0	1 can + 47 sec

Table 5-5-23 McDonnel-Douglas

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
DC-3	Bulk	1,300	1.3	2.0	26 sec
DC-6 (cargo)	Bulk	3,354	3.4	5.5	68 sec

Table 5-5-23 McDonnel-Douglas (continued)

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
DC-6 (passengers)	Cabin Pit-Fwd Pit-Aft	4,332 200 173	1.3 0.2 0.2	7.0 0.5 0.5	26 sec 4 sec 4 sec
DC-6A	Cabin Pit-Fwd Pit-Aft	4,375 267 300	4.4 0.3 0.3	7.0 0.5 0.5	1 can + 13 sec 6 sec 6 sec
DC-6B	Cabin Pit-Fwd Pit-Aft	4,375 276 242	4.4 0.3 0.2	7.0 0.5 0.5	1 can + 13 sec 6 sec 4 sec
DC-7B	Cabin Pit-Fwd Pit-Aft	4,612 267 364	4.6 0.3 0.4	7.0 0.5 0.5	1 can + 17 sec 6 sec 8 sec
DC-7C	Cabin Pit-Fwd Pit-Aft	4,778 312 339	4.8 0.3 0.3	7.5 0.5 0.5	1 can + 21 sec 6 sec 6 sec
DC-8-50	Cabin Pit-Fwd Pit-Aft	12,911 690 700	12.9 0.7 0.7	20.5 1.0 1.0	3 cans + 33 sec 14 sec 14 sec
DC-8-54F	Main Pit-Fwd Pit-Aft	5,984 690 700	6.0 0.7 0.7	9.5 1.0 1.0	1 can + 45 sec 14 sec 14 sec
DC-8-55F	Main Pit-Fwd Pit-Aft	5,878 690 700	5.9 0.7 0.7	9.5 1.0 1.0	1 can + 43 sec 14 sec 14 sec
DC-8-61 & 63	Cabin Pit-Fwd Pit-Aft	15,955 1,290 1,210	16.0 1.3 1.2	25.5 2.0 2.0	4 cans + 20 sec 26 sec 24 sec
DC-8-62	Cabin Pit-Fwd Pit-Aft	13,739 799 816	13.7 0.8 0.8	22.0 1.5 1.5	3 cans + 49 sec 16 sec 16 sec
DC-8-62CF	Main Pit-Fwd Pit-Aft	6,442 800 815	6.4 0.8 0.8	10.0 1.5 1.5	1 can + 53 sec 16 sec 16 sec
DC-8-63F and DC-8-73F	Main Pit-Fwd Pit-Aft	10,350 1,290 1,210	10.4 1.3 1.2	16.5 2.0 2.0	2 cans + 58 sec 26 sec 24 sec
DC-8-71CF	Main Pit-Fwd Pit-Aft	8,148 1,290 1,210	8.1 1.3 1.2	13.0 2.0 2.0	2 cans + 12 sec 26 sec 24 sec
DC-8-61CF & 71CF	Main Pit-Fwd Pit-Aft	15,472 1,290 1,210	15.5 1.3 1.2	25.0 2.0 2.0	4 cans + 10 sec 26 sec 24 sec
DC-9-10	Cabin Pit-Fwd Pit-Aft	4,056 1,000 619	4.1 1.0 0.6	6.5 1.5 1.0	1 can + 7 sec 20 sec 12 sec

Table 5-5-23 McDonnel-Douglas (continued)

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
DC-9-10AF	Main Pit-Fwd Pit-Aft	2,386 373 327	2.4 0.4 0.3	4.0 0.5 0.5	48 sec 8 sec 6 sec
DC-9-30	Cabin Pit-Fwd Pit-Aft	5,094 1,386 832	5.1 1.4 0.8	8.0 2.0 1.5	1 can + 27 sec 28 sec 16 sec
DC-9-32AF	Main Pit-Fwd Pit-Aft	3,300 562 333	3.3 0.6 0.3	5.5 1.0 0.5	66 sec 12 sec 6 sec
DC-9-33CF	Main Pit-Fwd Pit-Aft	2,944 562 333	2.9 0.6 0.3	4.5 1.0 0.5	58 sec 12 sec 6 sec
DC-40	Cabin Pit-Fwd Pit-Aft	5,535 1,290 1,040	5.5 1.3 1.0	9.0 2.0 1.5	1 can + 35 sec 26 sec 20 sec
DC-10-10CF & 10F, also DC-10-30CF & 30F	Main Pit-Fwd Pit-Ctr Pit-Aft Fl. Deck	12,236 3,020 1,935 510 400	12.2 3.0 1.9 0.5 0.4	19.5 5.0 3.0 1.0 0.5	3 cans + 19 sec 60 sec 38 sec 10 sec 8 sec
MD 8-61/63	Main Pit-Fwd Pit-Aft	11,173 1,290 1,210	11.2 1.3 1.2	18.0 2.0 2.0	3 cans 26 sec 24 sec
MD8-62	Main Pit-Fwd Pit-Aft	8,862 800 815	8.9 0.8 0.8	14.0 1.5 1.5	2 cans + 28 sec 16 sec 16 sec
MD9-10	Main Pit-Fwd Pit-Aft	3,582 393 254	3.6 0.4 0.3	6.0 0.5 0.5	1 can 8 sec 6 sec
MD9-30	Main Pit-Fwd Pit-Aft	4,525 562 333	4.5 0.6 0.3	7.0 1.0 0.5	1 can + 15 sec 12 sec 6 sec
MD9-40	Main Pit-Fwd Pit-Aft	4,926 618 350	4.9 0.6 0.4	8.0 1.0 0.5	1 can + 23 sec 12 sec 8 sec
MD-11F	Main Deck Lower Deck	15,530 4,976	15.5 5.0	25.0 8.0	4 cans + 10 sec 1 can + 25 sec
MD-11 Combi	Main Pit-Fwd Pit-Ctr Pit-Aft	5,822 3,655 2,685 510	5.8 3.7 2.7 0.5	9.5 6.0 4.5 1.0	1 can + 41 sec 1 can 54 sec 10 sec
MD-80 JT8D-217	Lower Hold	1,253	1.3	2.0	26 sec
MD-80 JT8D-219	Lower Hold	1,013	1.0	1.5	20 sec
MD 81 & 82	Cargo	1,253	1.3	2.0	26 sec
MD-83	Cargo	1,013	1.0	1.5	20 sec

Table 5-5-23 McDonnel-Douglas (continued)

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
MD-87	Cargo	938 or 697	0.9 0.7	1.5 1.0	18 sec 14 sec
MD-88	Cargo	1,013 or 1,253	1.0 1.3	1.5 2.0	20 sec 26 sec

Table 5-5-24 SAAB

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
340 B/QC	N/A	1,303	1.3	2.0	26 sec

Table 5-5-25 Shorts

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
330	N/A	1,230	1.2	2.0	24 sec
360 and 360-F	N/A	1,450	1.5	2.5	30 sec

Table 5-5-26 Sidely

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
Carvelle	Cabin Pit-Fwd Pit-Aft	5,600 258 116	5.6 0.3 0.1	9.0 0.5 ---[1]	1 can + 37 sec 6 sec 2 sec

1 In these small volume spaces, use the extender and calulate the application time using a rate of 2.5 grams per second. At a rate of 2.5 grams per second, the following table will give the spray time:

1,000 ft^3 UnitsSpray TIme in Seconds

0.10.5
0.20.5
0.31.0
0.41.5

Table 5-5-27 Tupolev

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
TU-154	Bulk	5,000	5.0	8.0	25 sec

Table 5-5-28 Vickers

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
Merchantman	Bulk	5,040	5.0	8.0	1 can + 25 sec
Viscount	Bulk	3,000	3.0	5.0	60 sec

Table 5-5-29 Military Aircraft

Aircraft, model, and series	Area	Volume ft^3	1,000 ft^3 Units	Aerosol Calculations: T409-b-1 Spray Time in Seconds	Aerosol Calculations: T409-b-3 Cans/ Spray Time in Seconds
C-5A	Main U. Deck Fwd. & Fl. Deck U. Floor	46,651 6,147 5,147 6,294	46.7 6.1 5.1 6.3	74.5 10.0 8.0 10.0	12 cans + 34 sec 1 can + 47 sec 1 can + 27 sec 1 can + 51 sec
C-17	Main	20,875	20.9	33.5	5 cans + 43 sec
C-26	Cabin Pit	500 198	0.5 0.2	1.0 0.5	10 sec 4 sec
C-130	Main	8,340	8.3	13.5	2 cans + 16 sec
C-130 LG382		4,737	4.7	7.5	1 can + 19 sec
C-130 LG385-G		6,057	6.1	10.0	1 can + 47 sec
C-135	Cabin	6,000	6.0	9.5	1 can + 45 sec
C-141	Main	12,000	12.0	19.0	3 cans + 15 sec
C-141B	Main	13,701	13.7	22.0	3 cans + 49 sec
KC-10	Cabin Pit-Fwd Pit-Aft	4,056 1,000 619	4.1 1.0 0.6	6.5 1.5 1.0	1 can + 7 sec 20 sec 12 sec

T410—Tick Infestations

T410 Nonplant articles (i.e., bat guano, fence posts, etc.)

Pest: Ticks

Treatment: Use T310 schedules, Tick-infested materials (nonfood)

T411—Ant Infestations—Nonplant Products

T411

Pest: Ants

Treatment: T411—MB at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	2.5 hrs	3 hrs	3.5 hrs	4 hrs
90-96 °F	2 lbs	24	16	—	—	—
80-89 °F	2.5 lbs	30	24	—	—	—
70-79 °F	3 lbs	36	24	—	—	—
60-69 °F	3 lbs	36	—	24	—	—
50-59 °F	3 lbs	36	—	—	24	—
40-49 °F	3 lbs	36	—	—	—	24

T412—Noxious Weed Seeds (Devitalization Treatment)

T412-a *Guizotia abyssinica* (niger seed)

Pest: Weed seeds of the following genera:
Asphodelus fistulosus (onionweed)
Digitaria spp. (includes African couchgrass)
Oryza spp. (red rice)
Paspalum scrobiculatum (Kodo-millet)
Prosopis spp. (includes mesquites)
Solanum viarum (tropical soda apple)
Striga spp. (witchweed)
Urochloa panicoides (liver-seed grass)

Treatment: T412-a—Dry Heat Treatment at 248ºF (120ºC) for 15 minutes

Important

Do not start counting time until the entire mass reaches the required temperature.

T412-b-1 Noxious weed seeds (devitalization treatment)

Pest: *Cuscuta* spp.

Two alternative treatments

Treatment: T412-b-1—Dry heat—commodity heated to 212ºF (100ºC) for 15 minutes

T412-b-2 Noxious weed seeds (devitalization treatment)

Pest: *Cuscuta* spp.

Treatment: T412-b-2—Steam heat—commodity heated to 212ºF (100ºC) for 15 minutes

T412-b-3

Deleted

T413—Brassware from Mumbai (Bombay), India

T413-a Brassware from Mumbai (Bombay), India

Two alternative treatments

Pest: *Trogoderma granarium* (khapra beetle)

Treatment: T413-a—MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	12 hrs
90 °F or above	2.5 lbs	30	20	15
80-89 °F	3.5 lbs	42	30	20
70-79 °F	4.5 lbs	54	40	25
60-69 °F[1]	6 lbs	72	50	30
50-59 °F	7.5 lbs	90	60	35
40-49 °F[2]	9 lbs	108	70	40

1 Use MB 100 gas at 60 °F or above.

2 Use MB “Q” gas at 40 °F or above.

Important

When both woodborers and khapra beetles are involved, use schedule *T404-d* on **page 5-5-20**.

T413-b Brassware from Mumbai (Bombay), India

Treatment: T413-b—MB in 26" vacuum

Temperature	Dosage Rate ($lb/1,000\ ft^3$)	Exposure Period
60 °F or above[1]	8 lbs	3 hrs
40-59 °F[2]	9 lbs	3 hrs

1 Use MB 100 gas at 60 °F or above.

2 Use MB “Q” gas at 40 °F or above.

NOTICE

Load limit is 75 percent of chamber volume.

T414—Inanimate, Nonfood Articles with Gypsy Moth Egg Masses

T414 Inanimate, nonfood articles with Gypsy Moth egg masses

Pest: Gypsy Moth egg masses

Treatment: T414—MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate ($lb/1,000\ ft^3$)	Minimum Concentration Readings (ounces) At:				
		0.5 hr	4 hrs	8 hrs	12 hrs	16 hrs
50 °F or above	3.5 lbs	42	28	—	—	—
	2.5 lbs	30	20	14	—	—
	2 lbs	24	16	12	12	10
40-49 °F	4.5 lbs	54	36	—	—	—
	3.25 lbs	38	26	18	—	—
	2.25 lbs	30	20	14	14	12

Important

For *Lymantria dispar* (gypsy moth) egg masses on such items as outdoor household articles, quarry products, lumber, logs, and timber products.

T415—Garbage

Three alternative treatments are approved. The treatments can be used for commodity destruction.

T415-a Garbage

Pest: Insect pest and pathogens

Treatment: T415-a—Heat Treatment- Incinerate to ash.

Important

Caterers under compliance agreement using an incinerator for garbage must comply with the following conditions:

- Incinerator must be capable of reducing garbage to ash
- Incinerator must be maintained adequately to assure continued operation

T415-b Garbage

Pest: Insect pest and pathogens

Treatment: T415-b—Dry heat or Steam- commonly heated to internal temperature of 212 °F (100 °C) for 30 minutes folllowed by burial in a landfill.

Important

Caterers under compliance agreement using a sterilizer must comply with the following conditions:

The sterilizer must be capable of heating garbage to an internal temperature of 212° F and maintaining it at that temperature for a minimum of 30 minutes.

Reevaluate and adjust the sterilization cycle twice a year using a thermocouple to recalibrate the temperature recording device. Adjusting the sterilization cycle semiannually will assure that all garbage processed is heated to a minimum internal temperature of 212° F for at least 30 minutes, and that the temperature recording device accurately reflects the internal temperature of the sterilizer.

NOTICE

Observe all reevaluations and adjustments.

The operator is to date and initial time/temperature records for each batch of garbage sterilized. The supervisor is to review and sign each time/temperature record. The facility must retain records for 6 months for review by PPQ.

Clean the drain in the bottom of the sterilizer between each cycle to assure proper heat circulation

T415-c Garbage

Pest: Insect pest and pathogens

Treatment: T415-c—Grinding and discharge into an approved sewage system

Important

Grinding and discharging is allowed into an approved sewage system. An approved sewage system is designed and operated in such a way as to preclude the discharge of sewage effluents onto land surfaces or into lagoons or other stationary waters, is adequate to prevent the dissemination of plant pests and livestock or poultry diseases, and is certified by an appropriate government official as currently complying with the applicable laws for environmental protection.

T416—Goatskins, Lambskins, Sheepskins (Skins and Hides)

Three alternative treatments

Important

Fur, horsehair articles, and leather goods (skins and hides), may cause off-odors that may be unacceptable when exposed to methyl bromide (MB).

Important

Items known to be sorptive or items whose sorptive properties are unknown are not to be fumigated in chambers at NAP unless gas concentration readings are taken.

T416-a-1 Goatskins, lambskins, sheepskins (skins and hides)

Pest *Trogoderma granarium* (khapra beetle)

Treatment MB (“Q” gas only) at NAP—tarpaulin

Temperature	Dosage Rate (lb/ 1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	12 hrs
90 °F or above	2.5 lbs	30	20	15
80-89 °F	3.5 lbs	42	30	20
70-79 °F	4.5 lbs	54	40	25
60-69 °F	6 lbs	72	50	30
50-59 °F	7.5 lbs	90	60	35
40-49 °F	9 lbs	108	70	40

The sorptive rates of commodities vary. When a commodity is known or suspected to be sorptive (see ***Sorption*** on **page 2-3-10**), take more gas readings than normal. Additional fumigant is added as prescribed in ***Additional Readings*** on **page 2-4-29**.

When both woodborers and khapra beetles are involved, use schedule ***T404-d*** on **page 5-5-20**.

T416-a-2 Goatskins, lambskins, sheepskins (skins and hides)

NOTICE

Load limit is 75 percent of chamber volume.

Pest *Trogoderma granarium* (khapra beetle)

Treatment MB (“Q” label gas) in 26” vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
60 °F or above	8 lbs	3 hrs
40-59 °F	9 lbs	3 hrs

T416-a-3 Goatskins, lambskins, sheepskins (skins and hides)

Pest *Trogoderma granarium* (khapra beetle)

Treatment MB (“Q” gas only) in 26" vacuum—chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
90-96 °F	2.5 lbs	12 hrs
80-89 °F	3.5 lbs	12 hrs
70-79 °F	4.5 lbs	12 hrs
60-69 °F	6 lbs	12 hrs
50-59 °F	10 lbs	12 hrs
40-49 °F	12 lbs	12 hrs

Amount of Phosphine liberated by various products

Calculate amount of product needed by using the amount of phosphine released as shown in the right column.

Table 5-5-30 Amount of Phosphine Liberated by Various Products

Product	Type	Unit and weight in grams	Grams of phosphine*
Degesch Fumi-Cel®	MP	1 plate; 117.0	33.0
Degesch Fumi-Strip®	MP	16 plates; 1872.0	528.0
Degesch Phostoxin®	AP	1 tablet; 3.0	1.0
Degesch Phostoxin® Tablet Prepac Rope	AP	1 prepac; 99.0 (strip or rope of 33 tablets)	33.0
Detia	AP	1 tablet; 3.0	1.0
Detia Rotox AP	AP	1 pellet; 0.6	0.2
Detia Gas EX-B	AP	1 bag or sachet; 34.0	11.4
Fumiphos tablets	AP	1 tablet; 3.0	1.0
Fumiphos pellets	AP	1 pellet; 0.6	0.2
Fumiphos bags	AP	1 bag; 34.0	11.0
Fumitoxin	AP	1 tablet; 3.0	1.0
Fumitoxin	AP	1 pellet; 0.6	0.2
Fumitoxin	AP	1 bag; 34.0	11.0
Gastoxin	AP	1 tablet; 3.0	1.0
Gastoxin	AP	1 pellet; 0.6	0.2
“L” Fume	AP AP	1 pellet; 0.5 1 pellet; 0.6	0.18 0.22
Phos-Kill	AP	1 tablet; 3.0	1.1
Phos-Kill	AP	1 pellet; 0.6	0.22
Phos-Kill	AP	1 bag; 34.0	12.0

*Reacts with moisture in the air to yield grams of phosphine.

5

Treatment Manual

Treatment Schedules

T500 - Schedules for Plant Pests or Pathogens

Contents

The following Schedules are listed by plant pest or pathogen

General Schedules

Hot Water Treatments

The following section lists the recommended treatments or actions to be applied to items or commodities found infected with various diseases, or infested with various plant pests including nematodes. Commodities may include cut flowers and greenery, propagative plant materials, as well as entire plants. Due to recent restrictions and prohibitions on the use of certain chemicals, every effort has been made to substitute the best alternative treatment available to us. The diseases and commodities for which these treatments are recommended are listed in the Index to Schedules and with the following treatment schedules. Ports should endeavor to make post-treatment examinations or arrange to have the consignee or importer submit data concerning the material following the treatment. Ports should forward any information of this nature to:

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

T501—Treatment for infestation of *Chrysomyxa* spp., *Cercospora* spp., and *Phoma chrysanthemi* on various commodities

T501-1 Azalea

Pest: *Chrysomyxa* spp.

Treatment: T501-1 Remove infected parts and treat all plants of same species in shipment with 4-4-50 Bordeaux dip or spray.

Important: See alternative treatment **T505-1** for *Chrysomyxa* spp.

T501-2 Azaleodendron

Pest: *Chrysomyxa* spp.

Treatment: T501-2 Remove infected parts and treat all plants of same species in shipment with 4-4-50 Bordeaux dip or spray.

Important: see alternative treatment **T505-1** for *Chrysomyxa* spp.

T501-4 Chrysanthemum

Pest: *Phoma chrysanthemi*

Treatment: T501-4 Remove infected parts and treat all plants of same species in shipment with 4-4-50 Bordeaux dip or spray.

T501-5 Christmas trees

Pest: *Phoma chrysanthemi*

Treatment: T501-5 Remove infected parts and treat all plants of same species in shipment with 4-4-50 Bordeaux dip or spray.

T501-3 Orchid

Pest: *Cercospora* spp.

Treatment: T501-3 Remove infected parts and treat all plants of same species in shipment with 4-4-50 Bordeaux dip or spray.

T501-6 Rhododendron

Pest: *Chrysomyxa* spp.

Treatment: T501-6 Remove infected parts and treat all plants of same species in shipment with 4-4-50 Bordeaux dip or spray.

Important

see alternative treatment **T501-2** for *Chrysomyxa* spp.

T502—Treatment for infestation of Potato cyst nematode on various commodities

T502-1 Bags and bagging used for commodities grown in soil

Pest: Potato cyst nematode

Treatment: T502-1 Methyl bromide—8 lbs/1,000 ft^3 for 16 hours in 26" vacuum at 40 °F or above.

T502-2 Covers used for commodities grown in soil

Pest: Potato cyst nematode

Treatment: T502-2 Methyl bromide—8 lbs/1,000 ft^3 for 16 hours in 26" vacuum at 40 °F or above.

T502-3 Soil

Pest: Potato cyst nematode

Treatment: T502-3 Methyl bromide—8 lbs/1,000 ft^3 for 16 hours in 26" vacuum at 40 °F or above.

T503—Treatments for Infestations of Downy Mildews and *Physoderma* diseases of Maize

T503-1 Bags and bagging (used) for small grains

Pest: Diseases listed in 7CFR 319.24: Downy Mildews and *Physoderma* diseases of Maize

Alternative treatments:

Treatment: T503-1-2 Hot water treatment—soak in water slightly below boiling (212 °F) for 1 hour.

Treatment: T503-1-3 Live steam for 10 minutes at 240 °F, NAP. For baled material, live steam at 10 pounds pressure for 20 minutes.

Treatment: T503-1-4 Dry heat at 212 °F for 1 hour. Treat small bales only.

T503-2 Covers used for small grains

Pest: Diseases listed in 7CFR 319.24: Downy Mildews and *Physoderma* diseases of Maize

Alternative treatments:

Treatment: T503-2-2 Hot water treatment—soak in water slightly below boiling (212 °F) for 1 hour.

Treatment: T503-2-3 Live steam for 10 minutes at 240 °F, NAP. For baled material, live steam at 10 pounds pressure for 20 minutes.

Treatment: T503-2-4 Dry heat at 212 °F for 1 hour. Treat small bales only.

T504—Treatment for Infestation of Flag Smut on various commodities

T504-1 Bags and bagging (used) for small grains

Pest: Flag smut

Alternative treatments:

Treatment: T504-1-1 Dry heat at 212 °F for 1 hour. Treat small bales only.

Treatment: T504-1-2 Steam at 10 pounds pressure at 242 °F (114 °C) for 20 minutes.

T504-2 Covers used for wheat

Pest: Flag smut
Alternative treatments:

Treatment: T504-2-1 Dry heat at 212 °F for 1 hour. Treat small bales only.

Treatment: T504-2-2 Steam at 10 pounds pressure at 242 °F (114 °C) for 20 minutes.

T505—Treatment for Infestation of *Chrysomyxa* spp. on various commodities

T505-1 Azaleodendron

Pest: *Chrysomyxa* spp.
Alternative treatments:

Treatment: T505-1-1 Treat with mancozeb or other approved fungicide of equal effectiveness. (Use label instructions for treatment.)

Treatment: T505-1-2 see alternative treatment T501

T505-2 Rhododendron

Pest: *Chrysomyxa* spp.
Alternative treatments:

Treatment: T505-2-1 Treat with mancozeb or other approved fungicide of equal effectiveness. (Use label instructions for treatment.)

Treatment: T505-2-2 see alternative treatment T501-1

T506—Treatment for Infestation of Potato Cyst Nematode on various commodities

T506-1 Containers

Pest: Potato cyst nematode
Alternative treatments:

Treatment: T506-1-1 MB ("Q" label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	8 lbs	16 hrs
OR	10.5 lbs	12 hrs
OR	16 lbs	8 hrs

Treatment: T506-1-3 High pressure steam. See T506-2-3.

T506-2 Nonplant articles

Pest: Potato cyst nematode
Alternative treatments:

Treatment: T506-2-1 MB ("Q" label only) in 26" vacuum

Temperature	Dosage Rate (lb/1,000 ft^3)	Exposure Period
40 °F or above	8 lbs	16 hrs
OR	10.5 lbs	12 hrs
OR	16 lbs	8 hrs

Treatment: T506-2-3 High pressure steam

Live steam is introduced into a closed chamber containing the material to be treated until the required temperature and pressure are indicated. The temperature/pressure relationship is maintained at or above this point for the required exposure period. The exposure period will depend on the nature of the material, quantity, and its penetrable condition.

For loosely packed material which permit rapid and complete penetration of steam to all parts of the mass, no initial vacuum is needed but air must be released until steam vapor escapes, and exposure at 20 pounds pressure for 10 minutes, 15 pounds for 15 minutes, or 10 pounds for 20 minutes is sufficient.

For tightly packed material, such as soil, special measures are needed to ensure rapid heat penetration to all parts of the material. Soil, if in large containers, will not allow adequate treatment under normal sterilization exposure periods.

Quicker penetration of the steam is obtained by first exhausting the air in the chamber to a high vacuum and then introducing live steam until the required positive pressure is reached.

T507—Treatment for Infestation of *Phyllosticta bromeliae*, *Uredo* and *Septoria gentianae* on various commodities

T507-1 Bromeliads

Pest: *Phyllosticta bromeliae, Uredo* spp. (when destined to Florida, refuse entry)

Treatment: T507-1 Remove infected leaves and treat all plants of same species in shipment with Captan following label directions.

Important

Advise importer or consignee that treatment may cause commodity damage.

T507-2 *Gentiana*

Pest: *Septoria gentianae*

Treatment: T507-2 Remove infected leaves and treat all plants of same species in shipment with Captan following label directions.

Important

Advise importer or consignee that treatment may cause commodity damage.

T508—Treatment for Infestation of Rusts on various commodities

T508-1 Orchids (to Florida)

Pest: Rusts

Treatment: T508-1 ***For rust-infected shipments to Florida:*** Refuse entry to all infected plants and all other plants of the same species or variety in the shipment. Treat other orchid species in the shipment (which may have become contaminated) with Captan. Repackage treated orchids in clean shipping containers. For rusts on orchids to States other than Florida, follow the procedures in T509.

T509—Treatment for Infestation of Various Plant Pests of Camellia and Orchids

T509-1 Camellia

Pest: *Cylindrosporium camelliae*

Alternative treatments:

Treatment: T509-1-1 ***Light infection:*** Remove infected leaves and dip or spray plant with 4-4-50 Bordeaux. Dry quickly and thoroughly before release.

Treatment: T509-1-2 ***Heavy infection:*** Refuse entry.

T509-2 Orchids

Pest: *Hemileia* spp.
Leptosphaeria spp.
Mycosphaerella spp.
Opiodothella orchidearum
Phomopsis orchidophilia
Phyllachora spp.
Phyllosticta spp.
Sphenospora spp.
Sphaerodothis spp.
Uredo spp. (except *U. scabies*)

Alternative treatments:

Treatment: T509-2-1 ***Light infection:*** Remove infected leaves and dip or spray plant with 4-4-50 Bordeaux. Dry quickly and thoroughly before release.

Treatment: T509-2-2 ***Heavy infection:*** Refuse entry.

T510—Treatment for Infestation of Various Corn-Related diseases

T510-1 Corn (seed) (Commercial lots (not for propagation))

Pest: Various corn-related diseases

Treatment: T510-1 Live steam from jet or nozzle into loose masses of material until all parts reach 212 °F.

T510-2 Corn (seed) (Small lots for propagation but not for food, feed, or oil purposes)

Pest: Various corn-related diseases

Treatment: T510-2 Treat seeds with a dry application of Mancozeb in combination with Captan. Disinfect bags by: 1) Dry heat at 212 °F for 1 hour. Treat small bales only; or 2) Steam at 10 pounds pressure at 40 °F for 20 minutes.

T511—Precautionary treatment for Citrus Canker (*Xanthomonas axonopodis*)

T511-1 Seeds of *Citrus* spp., *Fortunella* spp., *Clausena lansium*, and *Poncirus trifoliata* (and all cultivars, varieties, and hybrids)

Pest: Citrus Canker (*Xanthomonas axonopodis* pv. *citri*)

Treatment: T511-1

Treat seeds for possible infection with citrus canker bacteria by first washing the seeds to remove the pulp. Next, immerse the seeds in water at 125 degree F or higher for 10 minutes. Then immerse seed for a period of at least 2 minutes in a 0.525 percent sodium hypochlorite solution at a pH of 6.0 to 7.5. Drain, dry and repack near original moisture content.

T511-2 Fruit of *Citrus* spp., *Fortunella* spp., *Clausena lansium*, and *Poncirus trifoliata* (and all cultivars, varieties, and hybrids)

Pest: Citrus Canker (*Xanthomonas axonopodis*)

Treatment: T511-2

There are three chemical treatments approved for use **as part of a systems approach at an approved packing house in the exporting country**.

Table 5-6-1 Citrus Canker Chemical Treatments

Chemical Name	Concentration
Sodium hypochlorite	200 ppm (pH = 6.0 - 7.5)
Sodium o-phenyl phenate	1.86 - 2.0% of the total solution
Peroxyacetic acid	85 ppm

T512—(Deleted)

T513—Treatment for Infestations of *Ascochyta* on various commodities

T513-1 Orchids

Pest: *Ascochyta* spp.

Treatment: T513-1 Defoliate if leaf-borne only; refuse entry if pseudo-bulbs infected.

T514—Treatment for Infestations of *Xanthomonas albilineans* and *X. vasculorum*

T514-1 Saccharum (sugarcane) (seed pieces)

Pest: *Xanthomonas albilineans and X. vasculorum*

Treatment: T514-1 Presoak in water at room temperature for 24 hours then immerse in water at 122 °F for 3 hours.

This treatment may damage sprouted cane.

T514-2 Saccharum (sugarcane) (True seed (fuzz))

Pest: *Xanthomonas albilineans and X. vasculorum*

Treatment: T514-2 Immerse in 0.525 percent sodium hypochlorite solution for 30 minutes followed by at least 8 hours air drying before packaging. (Dilute 1 part Clorox or similar solution containing 5.25 percent sodium hypochlorite in 9 parts of water. If using “ultra strength” chlorine bleach, use only 3/4 as much bleach).

T514-3 Saccharum (sugarcane) (Bagasse)

Pest: *Xanthomonas albilineans and X. vasculorum*

Treatment: T514-3 Dry heat treatment for 2 hours at 158 °F.

T514-4 Saccharum (sugarcane) (Field and processing equipment)

Pest: *Xanthomonas albilineans and X. vasculorum*

Treatment: T514-4 Remove all debris and soil from equipment with water at high pressure (300 pounds per square inch minimum) or with steam.

T515—Treatment for Infestations of various Sugarcane-Related diseases

T515-1

Sugarcane (Baled)

Pest: Various sugarcane-related diseases

Alternative treatments:

Treatment: T515-1 Introduce live steam into 25" vacuum until pressure reaches 15 to 20 pounds. Hold until center of bale is 220 °F–230 °F and maintain for 30 minutes.

T515-2-1

Sugarcane (Loose Sugarcane)

Treatment: T515-2-1 Introduce steam into 25" vacuum (or if with initial vacuum, “bleed” air until steam vapor fills chamber).

T515-2-3

Sugarcane (Loose Sugarcane)

Treatment: T515-2-3 Dry heat—212 °F for 1 hour.

T515-2-4

Sugarcane (Loose Sugarcane)

Treatment: T515-2-4 Remove the pulp in water at 190 °F–205 °F, followed by drying at 212 °F for 1 hour.

T515-2-5

Sugarcane (Loose Sugarcane)

Treatment: T515-2-5 Flash heated to 1,000 °F (Arnold dryer).

T516 (Deleted)

T517 (Deleted)

T518—Treatment for Infestations of Various Rice-Related diseases

T518-1

Brooms made of rice straw

Pest: Various rice-related diseases

Treatment: T518-1 Dry heat at 170 °F for 4.5 hours—may take 2 hours to reach this temperature.

T518-2-1

Novelties made of rice straw

Two alternative treatments

Pest: Various rice-related diseases

Treatment: T518-2-1 Dry heat at 180 °F–200 °F for 2 hours

T518-2-2 Novelties made with rice straw

Pest: Various rice-related diseases

Treatment: T518-2-2 Steam sterilization

Temperature	Pressure	Exposure Period
260 °F	20 lbs	15 minutes
250 °F	15 lbs	20 minutes

T519—Treatment for Infestations of Various Rice-Related diseases

T519-1 Closely packed rice straw and hulls

Pest: Various rice-related diseases

Treatment: T519-1 Introduce steam into 28" vacuum until pressure reaches 10 pounds and hold for 20 minutes.

T519-2 Loose rice straw and hulls

Pest: Various rice-related diseases

Treatment: T519-2 Introduce steam into 28" vacuum (or if without initial vacuum, “bleed” air until steam vapor escapes) until pressure reaches 20 pounds AND temperature 259 °F and hold for 10 minutes (OR 10 pounds and 240 °F for 20 minutes).

Important

see also **T518-1**.

T520—Treatment for Infestation of Verticillium albo-atrum on various commodities

T520-1 Seeds of alfalfa (*Medicago falcata, M. gaetula, M. glutinosa, M. media, and M. sativa*) from Europe

Pest: *Verticillium albo-atrum*
Alternative treatments:

Treatment: T520-1-1 Dust with 75 percent Thiram at the rate of 166 grams per 50 kilograms of seed (3.3g/kg).

Treatment: T520-1-2 Treat with a slurry of Thiram 75 WP at a rate of 166 grams per 360 milliliters of water per 50 kilograms of seed (3.3g pesticide/7.2ml water/kg seed).

T521—Treatment for Infestation of Plant Pathogenic Fungi and Bacteria on Articles Made with Dried Plant Material

T521

Pest: Various Plant Pathogenic Fungi and Bacteria

Dried plant material includes, but is not limited to, lemon grass, bamboo leaf decorations, grass arrangements, bundles, and baskets..

Conditions	Temperature	Time (hours)
Moist heat (air with high levels of water vapor, as from steam)	80 °C (176 °F)	1
Dry heat (air free of water vapor)	80 °C (176 °F)	2

Treatment time does not start until the entire commodity has reached treatment temperature. Warn the importer of the possibility of damage to the commodity prior to treatment. Ensure that the commodity does not come in contact with heating elements or open flame. The treatment facility must be approved by USDA-APHIS-PPQ-S&T-CPHST-AQI, certified on an annual basis by PPQ, and have a Compliance Agreement with PPQ.

Under Development: **See "Heat • Steam Treatments" on page-3-4-1** for operational procedures and equipment guidelines.

T551—Treatment for Infestation of *Globodera rostochiensis* and *G. pallida* (Nematodes) on *Convallaria* (pips)

T551-1

Convallaria (pips)

Pest: *Globodera rostochiensis, G. pallida*

Treatment: T551-1 Keep pips frozen until time for treatment, then thaw enough to separate bundles one from another just before treatment begins. Without preliminary warm-up, immerse in hot water at 118 °F for 30 minutes, following with a 5 minute drain, finishing with 5 minutes cooling dip or hosing with tap water.

T552—Treatment for Infestation of *Ditylenchus dipsaci and D. destructor*

T552-1

Allium, Amaryllis, and Bulbs (NSPF)

Pest: Bulb nematodes: *Ditylenchus dipsaci*, *D. destructor*

Treatment: T552-1 Presoak bulbs in water at 75 °F for 2 hours, then at 110 °F–111 °F for 4 hours.

T553—Treatment for Infestations of Nematodes on various plant commodities

T553-1

Achimenes, Actinidia, *Agapanthus, Aloe, Amorphophallus* (bulbs), *Ampelopsis, Anchuse, Anemone, Astilbe, Begonia* (tubers), *Bletilla hyacinthina* (bulbs) (NSPF), Cactus, Calliopsis, *Campanula, Cestrum*, *Cimicifuga, Cissus, Clematis, Convolvulus japonicus*, Corytholoma, *Curcuma* (turmuric), *Cyclamen, Cytisus*, Dahlia (tubers), *Dracaena*, *Epimendium pinnatum* (only; other spp. not tolerant), *Euonymus alata* (only), *Eupatorium, Euphorbia, Fragaria* (strawberry), Gardenia, *Gentiana*, *Gerbera*, Gesneria, *Geum, Gladiolus*, *Heliopsis, Helleborus, Hibiscus, Hosta, Hoya, Iris, Jasminum*, Kaempferia, Kohleria, Naegelia, Orchid, *Ornithogalum, Paeonia, Passiflora*, Polyanthes (tuberose),

***Primula*, Reichsteineria, *Sansevieria, Scabiosa*, *Sedum,* Senecio (Lingularis), *Thompsonia nepalensis*, Tydaea, *Verbena, Vitis* (grape), *Weigela, Zantedeschia*, Zingiberaceae**

Pest: Root-knot nematodes (*Meloidogyne* spp.)

Treatment: T553-1 Hot water at 118 °F for 30 minutes.

T553-2 ***Anchusa, Astilbe, Clematis, Dicentra, Gardenia, Helleborus, Hibiscus, Kniphofia, Primula***

Pest: Lesion nematodes (*Pratylenchus* spp.)

Treatment: T553-2 Hot water at 118 °F for 30 minutes.

T553-3 **Armoracea (horseradish roots), bulbs (NSPF)**

Pest: Golden nematodes (*Globodera rostochiensis* and *G. pallida*)

Treatment: T553-3 Hot water at 118 °F for 30 minutes.

T553-4 ***Bletilla hyacinthina* (alternate treatment: T564)**

Pest: Foliar nematodes (*Aphelenchoides fragariae*)

Treatment: T553-4 Hot water at 118 °F for 30 minutes.

T553-5 **Humulus**

Pest: Cyst nematodes (*Heterodera humuli*)

Treatment: T553-5 Hot water at 118 °F for 30 minutes.

T554—Treatment for Infestations of *Ditylenchus dipsaci* and *D. destructor* on Hyacinthus

T554-1 ***Hyacinthus* (bulbs), *Iris* (bulbs and rhizomes), *Tigridia***

Pest: Bulb nematodes—*Ditylenchus dipsaci* and *D. destructor*
Alternative treatments

Treatment: T554-1-1 Presoak in water at 70 °F–80 °F for 2.5 hours, followed by hot water immersion at 110 °F–111 °F for 1 hour.

Treatment: T554-1-2 Hot water immersion at 110 °F–111 °F for 3 hours with no presoaking.

T555—Treatment for Infestations of *Ditylenchus dipsaci* on *Narcissus*

T555-1 ***Narcissus* (bulbs)**

Pest: Bulb nematodes—*Ditylenchus dipsaci*

Treatment: T555-1 Presoak in water at 70 °F–80 °F for 2 hours, then at 110 °F–111 °F until all bulbs reach that temperature and hold for 4 hours.

T556—Treatment for Infestations of Root-Knot Nematodes (*Meloidogyne* spp.) on *Calla*

T556-1 ***Calla* (rhizomes)**

Pest: Root-knot nematodes (*Meloidogyne* spp.)

Treatment: T556-1 Dip in hot water at 122 °F for 30 minutes.

T557—Treatment for Infestations of *Meloidogyne* spp. and *Pratylenchus* spp. on *Chrysanthemum* (not including *Pyrethrum*)

T557-1 ***Chrysanthemum* (not including *Pyrethrum*)**

Pest: *Meloidogyne* spp. and *Pratylenchus* spp.

Treatment: T557-1 Dip in hot water at 118 °F for 25 minutes.

T558—Treatment for Infestations of *Pratylenchus* surface diseases on *Fragaria* (strawberry)

T558-1 ***Fragaria* (strawberry)**

Pest: *Pratylenchus* spp. (surface diseases)

Treatment: T558-1 Dip in hot water at 127 °F for 2 minutes.

T559—Treatment for Infestations of Foliar Nematodes on *Begonia* and *Oryza* (paddy rice)

T559-1 *Begonia*

Pest: White tip nematode (*Aphelenchoides besseyi)*

Treatment: T559-1 Dip in hot water at 118 °F for 5 minutes.

T559-2 *Oryza* (paddy rice)

Pest: White tip nematode (*Aphelenchoides besseyi)*

Treatment: T559-2 Dip in hot water at 132.8 °F (56 °C) for 15 minutes.

T560—Treatment for Infestations of *Meloidogyne* spp. on *Rosa*

T560-1 *Rosa* spp. (except *multiflora*, which is not tolerant)

Pest: *Meloidogyne* spp.

Treatment: T560-1 Dip in hot water at 123 °F for 10 minutes.

T561—Treatment for Infestations of *Cercospora mamaonis* and *Phomopsis carica-papayae* on Papayas

T561 Papayas

Pest: *Cercospora mamaonis* and *Phomopsis carica-papayae*

Treatment: T561-1 Dip in hot water at 120.2 °F (49 °C) for 20 minutes.

T562—(deleted)

T563—(deleted)

T564—Treatment for Infestations of Foliar Nematodes on various commodities

T564-1

Astilbe, *Bletilla hyacinthina, Cimicifuga, Epimendium pinnatum* (only; other spp. not tolerant), *Hosta, Paeonia*

Pest: Foliar nematode (*Aphelenchoides besseyi*)

Treatment: T564-1 Presoak in water at 68 °F for 1 hour followed by hot water soak at 110 °F for 1 hour. Then dip in cold water and let dry.

Important

see Alternative treatment for **Bletilla hyacinthina**: **T553-1**

T565—Treatment for Infestations of Nematodes on various commodities

T565-1

Amaryllis

Pest: *Ditylenchus destructor*

Treatment: T565-1 Hot water at 110 °F for 4 hours (should be done immediately after digging)

T565-2

Crocus

Pest: *Aphelenchoides subtenuis, Ditylenchus destructor*

Treatment: T565-2 Hot water at 110 °F for 4 hours (should be done immediately after digging)

T565-3

Gladiolus

Pest: *Ditylenchus destructor*

Treatment: T565-3 Hot water at 110 °F for 4 hours (should be done immediately after digging)

T565-4 Scilla

Pest: *Ditylenchus dipsaci*

Treatment: T565-4 Hot water at 110 °F for 4 hours (should be done immediately after digging)

T565-5 *Solanum* (potato tubers)

(see Restricted Entry Orders, Part 321)

Pest: *Globodera rostochiensis, G. pallida*

Treatment: T565-5 Hot water at 110 °F for 4 hours (should be done immediately after digging)

T566—Treatment for Infestations of various diseases on Broomcorn, Broomcorn Articles, and Lilium (bulbs)

T566-1 Broomcorn

Pest: Precautionary treatment for corn-related diseases

Treatment: T566-1 Hot water at 102 °F.

T566-2 Broomcorn Articles

Pest: Precautionary treatment for corn-related diseases

Treatment: T566-2 Hot water at 102 °F.

T566-3 Lilium (bulbs)

Pest: *Aphelenchoides fragariae*

Treatment: T566-3 Hot water at 102 °F.

T567—Treatment for Infestations of Bulb nematodes on various commodities

T567-1 *Muscari, Ornithogalum, Polyanthes* (tuberose)

Pest: Bulb nematodes (*Ditylenchus dipsaci*)

Treatment: T567-1 Dip in hot water at 113 °F for 4 hours.

T568—Treatment for Infestations of Foliar nematodes on Senecio

T568-1 Senecio (Lingularis)

Pest: Foliar nematodes (*Aphelenchoides fragariae*)

Treatment: T568-1 Treat with hot water at 110 °F for 1 hour.

T569—Treatment for Infestations of Foliar nematodes on *Fragaria* (strawberry)

T569-1 *Fragaria* (strawberry)

Pest: Foliar nematodes (*Aphelenchoides fragariae*)

Treatment: T569-1 Hot water at 121 °F for 7 minutes. (National Plant Board Conference, Tennessee, 1968)

T570—Treatment for Infestations of various diseases Acalypha and Aconitum

T570-1 Acalypha

Pest: *Pratylenchus* spp.

Treatment: T570-1 Hot water dip at 110 °F for 50 minutes. (Tolerance **not** established.)

T570-2 Aconitum

Pest: *Aphelenchoides fragariae* spp.

Treatment: T570-2 Hot water dip at 110 °F for 50 minutes. (Tolerance **not** established.)

T571—(Deleted)

5

Treatment Manual

Treatment Schedules

T600-Controlled Atmosphere Temperature Treatment System

This information in this chapter has been removed.

This information in this chapter has been removed.

Treatment Manual

Domestic Treatments

Contents

Introduction

The treatments listed in this section are to be used ONLY for domestic movement of regulated articles and are conducted in conjunction with a systems approach. State and local guidelines may apply.

D301.32-10—Fruit Fly Treatments

The fruit fly treatments are organized by family or genus and species, and then by approved site or commodity.

NOTICE

Several treatments in this section are equivalent to treatments for imported commodities found in **T100 - Schedules for Fruit, Nuts, and Vegetables**.

In these cases, click on the hyperlink provided to go to the appropriate treatment.

Fruit Fly Family Tephritidae D301.32-10(a)

Soil in Containerized Nursery Stock

Important

Refer to the appropriate EPA-approved document that gives PPQ the authority to treat at the rates described in the treatment schedules. Examples of documents include chemical manufacturer labels, special local need registration (24c or SLN), and Section 18 quarantine exemptions.

Contact the National Fruit Fly Coordinator to find out if the chemicals in the treatment schedules are registered for use in your state.

Treatment: D301.32-10(a-1) — Chemical treatment Diazinon

Application Instructions

Apply to nursery stock using equipment that generates a coarse, low-pressure spray. Soak the entire contents of the nursery stock container. Do not drench to the point of runoff. Do not allow the solution to enter sewers, drains, bodies of water, or aquatic habitats.

Table 5-8-1 Diazinon Dosages for Nursery Stock

Insecticide	Dosage Rate (lb. a.i. per acre)
Diazinon	5.0

Treatment: D301.32-10(a-2) — Chemical treatment Lambda-Cyhalothrin

The yellow and black colors of this schedule indicates that the authority to conduct the treatment comes from an emergency action required by PPQ in order to mitigate the pest risk. The emergency action is an interim measure and is pending final regulatory approval.

Table 5-8-2 Lambda-Cyhalothrin Dosages for Nursery Stock

Insecticide	Dosage Rate (lb. a.i per acre)
Lambda-Cyhalothrin	0.4

Application Instructions

Apply to nursery stock using equipment that generates a coarse, low-pressure spray. Soak the entire contents of the nursery stock container. Do not drench to the point of runoff. Do not allow the solution to enter sewers, drains, bodies of water, or aquatic habitats.

Fruit Fly Family Tephritidae D301.32-10(a)

Fruits, Vegetables, Cut Flowers, Foliage

Treatment: D301.32-10 (a-3) — Irradiation using 70–150 Gy (not to exceed 1,000 Gy)

Refer to **Table 5-8-3** for a list of fruit flies that can be irradiated. Treat using the minimum absorbed dose.

Treatments **must** be approved in advance by PPQ Field Operations. Facilities located in AL, AZ, CA, FL, GA, KY, LA, MS, NV, NM, NC, SC, TN, TX, or VA will require additional safeguarding measures described in 7 CFR 305.9(a).

Table 5-8-3 Pest-Specific Minimum Absorbed Dose (Gy) for Fruit Fly Irradiation

Scientific Name	Common Name	Minimum Absorbed Dose (Gy)
Anastrepha ludens	Mexican fruit fly	70
Anastrepha obliqua	West Indian fruit fly	70
Anastrepha serpentina	Sapote fruit fly	100
Anastrepha suspensa	Caribbean fruit fly	70
Bactrocera cucurbitae	Melon fruit fly	150
Bactrocera dorsalis	Oriental fruit fly	150
Bactrocera jarvisi	Jarvis fruit fly	100
Bactrocera tryoni	Queensland fruit fly	100
Ceratitis capitata	Mediterranean fruit fly	100
	All other fruit flies of the family Tephritidae which are **not** listed above	150

Anastrepha ludens **(Mexican fruit fly) D301.32-10(b)**

White Sapote (*Casimiroa edulis*)

Treatment: D301.32-10(b-1) — Cold treatment (equivalent to **T107-b**)

Citrus

Treatment: D301.32-10(b-2) — High temperature forced air treatment (equivalent to **T103-a-1**)

Pear, Quince, Citron

Treatment: D301.32-10(b-3) — Cold treatment

Temperature	Exposure Period
33 °F (0.56 °C) or below	18 days
34 °F (1.11 °C) or below	20 days
35 °F (1.67 °C) or below	22 days

***Ceratitis capitata* (Mediterranean fruit fly) D301.32-10(c)**

Tomato

Treatment: D301.32-10(c-1) — MB at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	3.5 hrs	4 hrs
70 °F or above	2 lbs	26	21	21	—
65-69 °F	2 lbs	26	21	—	19

WARNING

Host tolerance is marginal. Warn the shipper of possible injury.

Treatment: D301.32-10(c-2) — Vapor heat
(equivalent to **T106-b**)

Citrus

Treatment: D301.32-10(c-3) — MB at NAP—tarpaulin or chamber

Temperature	Dosage Rate (lb/1000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	3.5[1] hrs
70 °F or above	2 lbs	26	22

1 This treatment is currently NOT AUTHORIZED pending EPA-approval to increase the duration to 3.5 hours.

Treatment: D301.32-10(c-4) — Cold treatment
(equivalent to **T107-a**)

Treatment: D301.32-10(c-5) — MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F (21.11 °C) or above	2 lbs	25	18
Followed by cold treatment			

Refrigeration	
Temperature	Exposure Period
33 to 37 °F (0.56 to 2.77 °C)	4 days
OR 38 to 47 °F (3.33 to 8.33 °C)	11 days

Treatment:D301.32-10(c-6) — MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	2.5 hrs
70 °F (21.11 °C) or above	2 lbs	25	18	18
Followed by cold treatment				

Refrigeration	
Temperature	**Exposure Period**
34 to 40 °F (1.11 to 4.44 °C)	4 days
OR 41 to 47 °F (5.0 to 8.33 °C)	6 days
OR 48 to 56 °F (8.88 to 13.33 °C)	10 days

Treatment: D301.32-10(c-7) — MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs*	2.5 hrs	3 hrs
70 °F (21.11 °C) or above	2 lbs	25	18	18	17
Followed by cold treatment					

Refrigeration	
Temperature	**Exposure Period**
43 °F to 47 °F (6.11 to 8.33 °C)	3 days
OR 48 °F to 56 °F (8.88 to 13.33 °C)	6 days

Bell pepper

Treatment: D301.32-10(c-8) — Vapor heat
(equivalent to **T106-b**)

Bactrocera dorsalis **(Oriental fruit fly) D301.32-10(d)**

Tomato

Treatment: D301.32-10(d-1) — MB at NAP

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	3.5 hrs
70 °F or above	2 lbs	26	21	21

WARNING

Host tolerance is marginal. Warn the shipper of possible injury.

Treatment: D301.32-10(d-2) — Vapor heat
(equivalent to **T106-b**)

Citrus and Grape

Treatment: D301.32-10(d-3) — MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F (21.11 °C) or above	2 lbs	25	18
Followed by cold treatment			

Refrigeration	
Temperature	**Exposure Period**
33 to 37 °F (0.56 to 2.77 °C)	4 days
OR 38 to 47 °F (3.33 to 8.33 °C)	11 days

Treatment:D301.32-10(d-4) — MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:		
		0.5 hr	2 hrs	2.5 hrs
70 °F (21.11 °C) or above	2 lbs	25	18	18
Followed by cold treatment				

Refrigeration	
Temperature	**Exposure Period**
34 to 40 °F (1.11 to 4.44 °C)	4 days
OR 41 to 47 °F (5.0 to 8.33 °C)	6 days
OR 48 to 56 °F (8.88 to 13.33 °C)	10 days

Treatment: D301.32-10(d-5) — MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs*	2.5 hrs	3 hrs
70 °F (21.11 °C) or above	2 lbs	25	18	18	17
Followed by cold treatment					

Refrigeration	
Temperature	**Exposure Period**
43 °F to 47 °F (6.11 to 8.33 °C)	3 days
OR 48 °F to 56 °F (8.88 to 13.33 °C)	6 days

Treatment: D301.32-10(d-6) — Cold treatment followed by MB at NAP—tarpaulin or chamber

Temperature	Exposure Period
33 °F (0.56 °C) or below	21 days
Followed by MB at NAP—tarpaulin or chamber	

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
70 °F (21.11 °C) or above	2 lbs	30	25
60 to 69 °F (15.55 to 20.55 °C)	2.5 lbs	36	28
40 to 59 °F (4.44 to 15 °C)	3 lbs	44	36

Bell pepper

Treatment: D301.32-10(d-7) — Vapor heat
(equivalent to **T106-b**)

***Anastrepha serpentina* (Sapote fruit fly) D301.32-10(e)**

Citrus

Treatment: D301.32-10(e-1) — Methyl bromide
(equivalent to **T101-j-2-1**)

D301.50-10 Pine Shoot Beetle (*Tomicus piniperda*)

NOTICE

Cut trees at least 2 weeks prior to treatment in order to reduce possible damage by the fumigant to the trees. APHIS assumes no responsibility for damage due to the phytotoxic effects of these treatments.

D301.50-10(a) Pine logs and pine lumber with bark attached, pine bark products, and pine stumps

Treatment: D301.50-10(a)—MB at NAP tarp or chamber
(equivalent to **T404-b-1-1**)

Temperature	Dosage Rate (lb/1,000 ft3)	Minimum Concentration Readings (ounces) At:			
		0.5 hr	2 hrs	4 hrs	16 hrs
70 °F or above	3	36	30	27	25
40 - 69 °F	5	60	51	46	42

D301.50-10(b) Christmas trees, pine nursery stock, raw pine materials for pine wreaths and garlands

Treatment: D301.50-10(b)—Cold Treatment

Temperature	Exposure Period
-0.5 °F (-20.6 °C)	1 hour

Load the commodity into an APHIS-approved refrigeration unit. Do not start the treatment time until the refrigeration unit reaches the treatment temperature.

D301.50-10(c) Christmas trees, raw pine materials for pine wreaths and garlands

Treatment: D301.50-10(c)—MB at NAP tarp or chamber (equivalent to **T313-b**)

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:			
		2 hrs	3 hrs	3.5 hrs	4 hrs
60°F or above	3 lbs	43	—	—	36
60°F or above	4 lbs	57	48	—	—
50-59°F	3.5 lbs	50	—	—	42
50-59°F	4 lbs	57	—	48	—
40-49°F	4 lbs	57	—	—	48

D301.75-11 Citrus Canker (*Xanthomonas axonopodis*)

Conduct treatments at a commercial packinghouse operating under a compliance agreement.

Important

All personnel using these treatments must clean their hands using one of the following disinfectants:

- Gallex 1027 Antimicrobial Soap
- Hibiclens
- Hibistat
- Sani Clean Hand Soap
- Seventy Percent Isopropyl Alcohol

WARNING

Sodium hypochlorite , peroxyacetic acid, and soduim 0-phenyl phenate (SOPP) must be applied in accordance with label directions.

Regulated Fruit[1]

D301.75-11 (a-1)

Treatment: D301.75-11(a-1) — Chemical Treatment

Thoroughly wet the fruit for at least 2 minutes with a solution containing 200 parts per million sodium hypochlorite. Maintain the solution at a pH of 6.0 to 7.5.

D301.75-11 (a-2)

Treatment: D301.75-11(a-2)— Chemical Treatment

Thoroughly wet the fruit with a solution containing sodium o-phenyl phenate (SOPP) at a concentration of 1.86 to 2.0 percent of the total solution. If the solution has sufficient soap or detergent to cause a visible foaming action, wet for 45 seconds. If the solution does not contain sufficient soap to cause a visible foaming action. wet for 1 minute.

D301.75-11 (a-3)

Treatment: D301.75-11(a-3) — Chemical Treatment

Thoroughly wet the fruit with a solution of 85 parts per million peroxyacetic acid for at least 1 minute.

Regulated Seed[2]

D301.75-11(b)

Treatment: D301.75-11(b) — Chemical and Heat Treatment
(equivalent to **T511-1**)

Following extraction from fruit treated as described in D301.75-11(a-1,2,3), the seed must be:

1. Cleaned free of pulp
2. Immersed for 10 minutes in water heated to 125 °F (51.6 °C) or higher

1 Regulated fruit is defined as any fruit, seed, plant, plant part, grass, or tree in all species, clones, cultivars, strains, varieties, and hybrids of the genera *Citrus* and *Fortunella*, and all clones, cultivars, strains, varieties, and hybrids of the species *Clausena lansium* and *Poncirus trifoliata*. The most common of these are: lemon, pummelo, grapefruit, key lime, persian lime, tangerine, satsuma, tangor, citron, sweet orange, sour orange, mandarin, tangelo, ethrog, kumquat, limequat, calamondin, trifoliate orange, and wampi.

2 Regulated seed is defined as any seed in all species, clones, cultivars, strains, varieties, and hybrids of the genera *Citrus* and *Fortunella*, and all clones, cultivars, strains, varieties, and hybrids of the species *Clausena lansium* and *Poncirus trifoliata*.

3. Immersed for at least 2 minutes in a solution containing 200 parts per million sodium hypochlorite (0.525 percent), with the solution maintained at a pH of 6.0 to 7.5.

Important

Prepare the sodium hypochlorite solution by diluting 1 part Clorox (containing 5.25 percent sodium hypochlorite) in 9 parts of water. If using "Ultra strength" bleach, use only three-fourths as much bleach.

Adjust the pH using acetic acid (vinegar or any dilute acid) under a fume hood or in a well ventilated area.

Vehicles, equipment, and other inanimate articles

D301.75-11(d)

Treatment: D301.75-11(d) — Chemical or Heat Treatment

All vehicles, equipment, and other articles for which treatment is required must be cleaned and disinfected by removing all plants, leaves, twigs, fruit, and other plant parts from all areas of the equipment or vehicles, including in cracks, under chrome strips, and on the undercarriage of vehicles, by wetting all surfaces (including the inside of boxes and trailers), to the point of runoff, with one of the following disinfectants:

- 200-ppm solution of sodium hypochlorite with a pH of 6.0 to 7.5
- 0.2-percent solution of a quaternary ammonium chloride (QAC) compound
- Solution of hot water and detergent, under high pressure (at least 30 pounds per square inch), at a minimum temperature of 160 °F
- Steam, at a minimum temperature of 160 °F at the point of contact
- Solution containing 85 parts per million peroxyacetic acid (indoor use only)

D301.76 Asian Citrus Psyllid (*Diaphorina citri* Kuwayama)

D301.76 (a-1) Curryleaf *(Bergera (=Murraya) koenigii*) and other regulated articles for consumption, apparel or similar personal accessory, or decorative use

Origin: Areas without citrus greening (Citrus huanglongbing (HLB))[3]

Treatment: D301.76 (a-1) — MB at NAP tarp or chamber
(equivalent to **T101-n-2**)

NOTICE

Curry leaf and kaffir lime leaf must be treated as a Section 18 crisis exemption. In addition, clementine, tangerine, mandarin, lemon, lime, orange, tangelo and citron must be treated using 3 pounds at 50 °F. The label does not allow fumigation of these citrus commodities at dosages greater than 3 pounds.

D301.76 (a-2)

Treatment: D301.76 (a-2) — Irradiation at 400 Gy
(equivalent to **T105-a-2**)

Treat using a minimum absorbed dose of 400 Gy, **not** to exceed 1000 Gy

D301.76(a-3) Curryleaf *(Bergera (=Murraya) koenigii*), Kaffir lime leaf (*Citrus hystrix*), and Bael leaf (*Aegle marmelos*) for consumption

Treatment: D301.76 (a-3) — Processing

NOTICE

The processing protocol has been added under the authority of Federal Order DA-2015-04, published January 01, 2015 and is pending final regulatory approval. The treatment is subject to change or removal based on public comment. (7 CFR 305.3(b)(2))

Processing includes specific harvesting, washing, rinsing, drying, and packaging requirements. Refer to the Protocol for Interstate Movement of Fresh, Mature Leaves of Kaffir Lime, Curry, and Bael for detailed instructions. The approved washing products are listed in **Table 5-8-4**.

Table 5-8-4 Food Grade Washing Products for Leaf Washing for ACP

Product	Rate Per Gallon
Environne	1/4 cup
Rebel Green	1/4 cup
Veggie Wash	1/4 cup

D301.76 (b) Citrus nursery stock and related hosts[4]

Origin: Areas with ACP[5]

Treatment: D301.76(b)—Chemical Treatment

3 Refer to the USDA Citrus Greening web site for a current list of areas without citrus greening.

Treat plants with an APHIS-approved soil drench or in-ground granular systemic insecticide, followed by a foliar spray at specified time periods prior to shipment. (Refer to **Table 5-8-5**.) The treatments will be followed by a visual inspection for living psyllids according to the requirements listed in 7 CFR 301.76 and the Citrus Nursery Stock Protocol.

Table 5-8-5 APHIS-approved Insecticides for Control of Psyllids on Citrus

USDA Approved Soil Drench or In-ground Granular Chemicals:	USDA Approved Foliar Chemicals:
Dinotefuran	Bifenthrin
Imidacloprid	Chlorpyrifos
	Deltamethrin
	Fenpropathrin
	Imidacloprid/Cyfluthrin

Important

Apply the SOIL DRENCH or IN-GROUND GRANULAR chemicals no more than 90 days but no less than 30 days prior to interstate movement. All treatments must be applied according to their EPA label, including application directions, restrictions on place of application, and any other precautions and statements pertaining to Worker Protection Standards.

Apply the FOLIAR chemicals no more than 10 days prior to interstate movement. All treatments must be applied according to their EPA label, including application directions, restrictions on place of application, and any other precautions and statements pertaining to Worker Protection Standards.

D301-81-10 Imported Fire Ant (*Solenopsis invicta* and *S.richteri*)

Used Soil Moving Equipment

D301.81-10(1) Treatment: D301.81-10(1) — Cleaning Treatment

Used soil moving equipment is eligible for movement when an inspector determines that **one** of the following procedures has been done:

4 Regulated articles for Asian Citrus Psyllid (ACP) and Citrus Greening (CG) (hosts within the plant family Rutaceae) may be intended for consumption, as apparel or similar personal accessory, or decorative use:
All plants and plant parts (including leaves), except fruit, of the following species: *Aegle marmelos, Aeglopsis chevalieri, Afraegle gabonensis, A. paniculata, Amyris madrensis, Atalantia* spp. (including *Atalantia monophylla*), *Balsamocitris dawei, Bergera (=Murraya) koenigii, Calodendrum capense, Choisya ternate, C. arizonica, X Citroncirus webberi, Citropsis articulata, Citropsis gilletiana, Citurs madurensis (=X Citrofortunella microcarpa), Citrus spp., Clausena anisum-olens, C. excavate, C. indica, C. lansium, Eremocitrus glauca, Eremocitrus hybrid, Esenbeckia berlandieri, Fortunella spp., Limonia acidissima, Merrillia caloxylon, Microcitrus australasica, M. australis, M. papuana, X Microcitronella spp., Murraya spp., Naringi crenulata, Pamburus missionis, Poncirus trifoliata, Severinia buxifolia, Swinglea glutinosa, Tetradium ruticarpum, Toddalia asiatica, Triphasia trifolia, Vepris (=Toddalia) lanceolata, and Zanthoxylum fagara*.

5 Refer to the USDA Citrus Greening web site for a current list of areas with ACP.

- It has been brushed free of noncompacted soil
- It has been washed free of noncompacted soil
- Noncompacted soil has been removed with air pressure equipment using compressors designed specifically for this purpose. Such compressors must provide free air delivery of no less than 30 ft^3 per minute at 200 pounds per in^2.

Certification Period: The certification will be valid as long as the equipment remains free of noncompacted soil.

Limitations: Regardless of the type of cleaning equipment used, all debris and noncompacted soil must be removed unless it is steam-heated by a “steam jenny” to disinfest the articles. Used soil-moving equipment, such as bulldozers, dirt pans, motor graders, and draglines, are difficult to clean sufficiently to eliminate pest risk.

CAUTION

Steam may remove loose paint and usually is not recommended for use on equipment with conveyor belts and rubber parts.

D301.81-10(2) Hay and Straw

Baled hay and straw stored in direct contact with the ground is ineligible for movement from the quarantined area to an area outside the quarantine, unless inspected, found free of IFA, and issued a certificate.

D301.81-10(3) Nursery Stock—Balled or in Containers

There are four application methods for plants in containers or balled and burlaped. The methods are:

- Method A-Immersion
- Method B-Drench
- Method C-Topical
- Method D-Granular Incorporation

Method A—Immersion

Equipment*:* You will need an open-top, watertight container sufficiently large to accommodate the treating solution and plants

Procedure*:* Follow these steps to treat the plants:

Step 1 Choose an appropriate site.

Locate the immersion tank in a well-ventilated place. The location should be covered if possible. Do not remove burlap wrap or plastic containers with drain holes before immersion.

Step 2 Immerse the plants.

Immerse the soil balls and containers, singly or in groups, so that the soil is completely covered by the insecticidal solution. Allow the plants to remain in the solution until bubbling ceases.

Important

Thorough saturation of the plant balls or containers with the insecticide solution is essential!

Step 3 Remove the plants from the dip.

After removal from the dip, set the plants on a drainboard until adequately drained.

Step 4 Add treating mixture.

As treating progresses, add freshly prepared insecticide mixture to maintain the liquid at immersion depth.

Step 5 Dispose of solution.

Dispose of tank contents 8 hours after mixing. Disposal must comply with state and local regulations.

Important

Do not permit runoff of the solution from the treatment area! Dispose of excess and unused solution in accordance with state and local regulations.

CAUTION

Wear rubber gloves, boots, and apron during this operation.

Insecticides, Dosages, and Certification Periods

Refer to **Table 5-8-6** for dosages and certification periods for approved insecticides.

Table 5-8-6 Insecticides for Immersion Treatment of Balled or Containerized Plants

Insecticide (liquid)	Dosage (lb. active ingredient per 100 gallons water)	Certification period (days)
Chlorpyrifos	0.125	30
Bifenthrin	0.115	180
	0.05	120
	0.025	60

Exposure Period: Plants certifiable immediately upon completion of treatment.

Important

Environmental factors significantly affect phytotoxicity. Dwarf yaupon, some varieties of azaleas, camellias, poinsettias, rose bushes, and variegated ivy may show phytotoxicity to chlorpyrifos.
It is recommended that a small group of plants be treated at the recommended rate under the anticipated growing conditions and observed for phytotoxic symptoms for at least seven days before a large number of plants are treated.

Important

The professional user assumes responsibility for determining if bifenthrin is safe to treat plants under commercial growing conditions.

Method B—Drench

Equipment: You will need the following pieces of equipment to drench the plants:

- A large-capacity bulk mixing tank, either pressurized or gravity-flow for mixing and holding the insecticide solution
- Properly equipped hoses and watering nozzles that can be attached to the mixing tank and used to thoroughly saturate the plant balls with insecticide solution

Containerized Plants

Step 1 Prepare the solution

The volume of the treating solution must be at least 20 percent (1/5) of the volume of the container.

Insecticides and Dosages

Table 5-8-7 Insecticides and Dosages for Drenching Plants in Containers

Insecticide (liquid)	Dosage
Chlorpyrifos (4EC)	4 fl. oz. per 100 gal water
Chlorpyrifos (2EC)	8 fl.oz. per 100 gal water
Bifenthrin	25 parts per million (ppm)[1]

1 Dose rate for bifenthrin is 25 ppm based on dry weight bulk density of the potting media. Refer to **Table 5-8-8** for bulk density calculations.

Table 5-8-8 Bifenthrin calculations based on Bulk Density

Potting Media Bulk Density (lb/yd^3)	Oz. bifenthrin/100 gal water
200	2.4
400	4.8
600	7.2
800	9.6
1,000	12.0
1,200	14.4
1,400	16.8

Step 2 Apply the solution

Apply solution to the point of saturation one time only. The volume of the solution should be one-fifth the volume of the container.

Important

Thorough saturation of the plant balls or containers with the insecticide solution is essential. Do not permit runoff of the solution from the treatment area! Dispose of excess and unused solution in accordance with state and local regulations.

Exposure Period: Plants are certifiable immediately upon completion of treatment.

Certification period

Table 5-8-9 Certification period for Plants in Containers

Insecticide	Certification Period (days)
Chlorpyrifos	30
Bifenthrin	180

Balled and Burlapped (B&B) Plants

Step 1 Select a site for the treatment

Move the plants to a well-ventilated place normally used to maintain plants prior to shipment. The treatment locations should be covered, if possible. The treatment will be enhanced by adding any agricultural wetting agent or surfactant.

Step 2 Apply the solution

Do not remove burlap wrap or baskets from plants prior to treatment. The total volume of the treating solution must be 20 percent (1/5) the volume of the root ball. Treat plants singly or in groups with the chlorpyrifos solution twice in one day. Apply one-half the total drench solution, wait at least 30 minutes, then rotate the root ball and apply the second one-half drench solution. Rotating or flipping the root ball between drench applications is required to insure all sides of the root ball are sufficiently treated.

NOTICE

Changes to the method for application have been added under the authority of SPRO-DA-2015-15, published March 31, 2015. The revision is subject to change or removal based on public comment. (7 CFR 305.3(b)(2))

CAUTION

Wear rubber gloves, boots, and apron during this operation.

***Dosage*:**

Table 5-8-10 Emulsifiable Chlorpyrifos Dosage for Balled Plants

Chlorpyrifos formulation	Amount of formulation to make 100 gallons of treating solution
1 EC	16 fl. oz. (472 ml)
2 EC	8 fl. oz. (236 ml)
4 EC	4 fl. oz. (118 ml)

Exposure Period: Plants are certifiable immediately upon completion of treatment.

Certification period: 30 days.

Method C—Topical Application

Bifenthrin liquid is the only insecticide and formulation registered for topical application. Use this method only with nursery stock in 3- and 4-quart containers. Penetration of the insecticide in larger containers does not provide sufficient residual activity. Prepare a mix with the appropriate amount of bifenthrin in 1,000 oz. of water based on the container size and the bulk density of potting media. Refer to **Table 5-8-11** for calculations based on bulk density and container size.

Table 5-8-11 Potting Media Bulk Density

	Oz. Bifenthrin liquid/1,000 fl. oz. water	
Potting Media Bulk Density (lb/yd^3)	3-quart Pots	4-quart Pots
200	3.6	5.2
400	7.2	10.4
600	10.8	15.6
800	14.4	20.8
1,000	18.0	26.0
1,200	21.6	31.2
1,400	25.2	36.4

Apply 1 fluid ounce of the mix to each container evenly distributed over the surface of the potting media.

Irrigate all treated containers with 1.5 inches of water following application.

Important

Do not permit runoff of the solution from the treatment area! Dispose of excess and unused solution in accordance with state and local regulations.

Certification period: 180 days.

Method D—Granular Incorporation

There are three granular insecticides registered and approved for incorporation into potting media:

- Granular bifenthrin
- Granular tefluthrin
- Granular fipronil

Use soil mixing equipment that will adequately mix and thoroughly blend the required dosage of insecticide throughout the potting media.

Dosage is based on the bulk density of the potting media and the desired certification period. Dosage is expressed as parts per million (ppm) and calculated by the following formula:

$$\frac{\text{Bulk density of media} \times \text{desired ppm}}{\text{concentration of pesticide}} = \text{lbs. insecticide needed per cubic yard of media}$$

Figure 5-8-1 Formula for Calculating Granular Insecticide for Treating Potting Media for IFA

Table 5-8-12 Application Rates for Incorporation of Granular Insecticides into Potting Media

Insecticide	Dosage (ppm)	Certification period (months after treatment)
Bifenthrin	10	0–6 months
	12	0–12 months
	15	0–24 months
	25	Continuous[1]
Tefluthrin	10	0-18
	25	Continuous[1]
Fipronil	10	0–6 months
	12	0–12 months
	15	0–24 months
	25	Continuous[1]

1 Continuous certification with 25 ppm dosage when all other provisions of the Imported Fire Ant detection, control, exclusion, and enforcement program for nurseries producing containerized plants are met (7 CFR 301.81-11)

D301.81-10(5)

In-Field Treatment For B&B Stock Prior to Harvest

This in-field treatment is based on a sequential application of abamectin, fenoxycarb, hydramethylnon, metaflumizone, methoprene, or pyriproxyfen bait followed by a broadcast application of chlorpyrifos. The combination treatment is necessary since broadcast application of chlorpyrifos (or other short-term residual insecticides) usually does not eliminate large, mature IFA colonies, and baits are not capable of providing a residual barrier against reinfestation by new queens. Therefore, the approved bait application will drastically reduce the IFA population while chlorpyrifos, applied approximately five days later, will destroy any remaining weakened colonies and also leave a residual barrier against reinfestation by new queens for at least 12 weeks.

NOTICE

Abamectin and metaflumizone have been added under the authority of SPRO-DA-2015-15, published March 31, 2015. The treatment is subject to change or removal based on public comment. (7 CFR 305.3(b)(2))

Method: Apply approved bait only when ants are actively foraging using a granular applicator capable of applying the labeled rates (1.0–1.5 lb (0.45–0.68 kg)) of bait per acre. Three to five days after the approved bait application, apply chlorpyrifos broadcast at 6.0 lb (2.7 kg) active ingredient (a.i.) per acre. Treatment area must extend at least 10 feet beyond the base of all plants that are to be certified.

Dosage: Apply approved baits at 1.0–1.5 lb (0.45–0.68 kg) bait/acre. Apply granular chlorpyrifos at 6.0 lb (2.7 kg) a.i./acre.

Exposure Period: 30 days. Plants are certifiable 30 days after treatment.

Certification Period: 12 weeks; an additional 12 weeks of certification can be obtained with a second application of granular chlorpyrifos.

D301.81-10(6) Blueberries and Other Fruit and Nut Nursery Stocks

Certain states have special local need labeling in accordance with section 24(c) of FIFRA for D-z-n Diazinon AG-500 and D-z-n Diazinon 50W, which APHIS will recognize as a regulatory treatment for containerized nonbearing blueberries and fruit and nut plants. Follow the label directions for use.

D301.81-10(7) Greenhouse Grown Plants

Greenhouse grown plants are certifiable without treatment if the inspector determines that the greenhouse is constructed of fiberglass, glass, or plastic in such a way that IFA is physically excluded and cannot become established within the enclosure. No other treatment of the plants will be necessary if they are not exposed to infestation.

D301.81-10(8)

Grass—Sod

***Method*:**

Step 1 Apply the insecticide.

- Chlorpyrifos: apply a single broadcast application of chlorpyrifos with ground equipment
- Fipronil or bifenthrin: apply two sequential broadcast applications one week apart of granular fipronil or liquid bifenthrin

Table 5-8-13 Pesticide Dosages for Grass Sod

Material	Dosage (lb. a.i. per acre)	Exposure Period	Certification period (after exposure period)
Chlorpyrifos	8.0	48 hours	6 weeks
Fipronil-granular	Apply 0.0125 two times, one week apart for a total dosage of 0.0250.	30 days	20 weeks
Bifenthrin-liquid	Apply a dosage of 0.2 two times, one week apart for a total dosage of 0.4. Apply the first dosage of 0.2 and then 7 days later apply a second dosage of 0.2 (total dosage of 0.4)	4 weeks (28 days)	16 weeks

EXAMPLE: You are applying liquid bifenthrin to 1 acre of fire ant infested grass sod. Using a broadcast applicator, apply 0.2 lb. a.i. per acre and then 7 days later, apply a second dosage of 0.2 lb. a.i. per acre. After 28 days exposure period, you may harvest and ship sod for 16 weeks. After that time to continue harvesting from the same area, you would need to re-treat.

Step 2 Water the treated areas.

Immediately after treatment, water the treated areas with at least ½ inch of water.

D301.81-10(9)

Soil—Bulk

Method: Bulk soil is eligible for movement when heated either by dry or steam heat after all parts of the mass have been brought to the required temperature.

Temperature: 150°F (65.5°C).

Certification Period: As long as protected from recontamination.

D301.81-10(10) Soil Samples

Soil samples are eligible for movement when heated or frozen as follows:

Method: Soil samples are heated either by dry heat or steam heat. All parts of the mass must be brought to the required temperature.

Temperature: 150°F (65.5°C).

Certification Period: As long as protected from recontamination.

Method: Soil samples are frozen in any commercial cold storage, frozen food locker, or home freezer capable of rapidly reducing to and maintaining required temperature. Soil samples will be placed in containers, such as plastic bags—one sample per bag. The containers will be arranged in the freezer in a manner to allow the soil samples to freeze in the fastest possible time. If desired, the frozen samples may be shipped in one carton.

Temperature: -10° to -20°F (-23° to -29°C) for at least 24 hours.

Certification Period: As long as protected from recontamination.

D301.87-10 Sugarcane Leaf Scald and Gummosis disease (*Xanthomonas albilineans* and *X.vasculorum)*

Seed pieces

D301.87-10(a)

Treatment: D301.87-10(a) Hot water
(equivalent to **T514-1**)

Presoak in water at room temperature for 24 hours then immerse in water at 122 °F for 3 hours.

True seed (fuzz)

D301.87-10(b)

Treatment: D301.87-10(b) Chemical Treatment
(equivalent to**T514-2**)

Immerse in 0.525 percent sodium hypochlorite solution for 30 minutes followed by at least 8 hours air drying before packaging. (Dilute 1 part Clorox or similar solution containing 5.25 percent sodium hypochlorite; if using “ultra strength” chlorine bleach, use only 3/4 as much bleach).

Bagasse

D301.87-10(c) Treatment: D301.87-10(c)—Dry heat treatment (equivalent to **T514-3**)

Apply dry heat for 2 hours at 158 °F.

Field and processing equipment

D301.87-10(d) Treatment: D301.87-10(d)—High Pressure Wash (equivalent to **T514-4**)

Remove all debris and soil from equipment with water at high pressure (300 pounds per square inch minimum) or with steam.

Juice

D301.87-10(e) Treatment: D301.87-10(e)—Heat

Heat at 212 °F (100 °C) for 10 minutes or more.

D301.89 Karnal Bunt (*Tilletia indica*)

Equipment, grain elevators, conveyances, and other structures used for storing and handling wheat, durum wheat, or triticale

D301.89-13(a) Treatment: D301.89-13(a)—Chemical Treatment

1. Wet all surfaces to the point of runoff with **one** of the following 1.5 percent sodium hypochlorite solutions:
   - One part Ultra Clorox brand regular bleach (6 percent sodium hypochlorite; EPA Reg. No. 5813-50) in 3 parts water
   - One part CPPC Ultra Bleach 2 (6.15 percent sodium hypochlorite; EPA Reg. No. 67619-8) in 3.1 parts water
2. Let stand for 15 minutes.
3. Thoroughly wash down all surfaces after 15 minutes to minimize corrosion.

D301.89-13(b) Treatment: D301.89-13(b)—Steam

Apply steam to all surfaces until the point of runoff, and so that a temperature of 170 °F is reached at the point of contact.

D301.89-13(c)

Treatment: D301.89-13(c)—Hot water and high pressure

Clean with a solution of detergent and water at a minimum temperature of 170 °F. Apply under pressure of at least 30 pounds per square inch.

D301.92

Phytophthora ramorum

Soil

D301.92-10(a)

Treatment: D301.92-10(a)—Heat Treatment

Heat to a temperature of at least 180 °F at the center of the load for 30 minutes in the presence of an inspector.

Wreaths, garlands, and greenery of host material

D301.92-10(b)

Treatment: D301.92-10(b)—Hot water

Dip for 1 hour in water that is held at a temperature of at least 160 °F.

Bay leaves

D301.92-10(c)

Treatment: D301.92-10(c)—Vacuum heat
(formerly T111-a-1)

1. Place bay leaves in a vacuum chamber.
2. Starting at 0 hour, gradually reduce to 0.133 Kpa vacuum at 8 hours.
3. Maintain the vacuum until the end of the treatment, 22 hours.
4. Gradually increase the temperature in the vacuum chamber from ambient temperature at 0 hour to 60C at 5 hours.
5. After 5 hours,gradually lower the temperature to 30C at 22 hours.

The total length of the treatment is 22 hours.

DA-2013-13
(04/02/2013)

Sweet Orange Scab (SOS), *Elsinoë australis* (Federal Order DA-2013-13)

Regulated Articles[6]

Conduct treatments at a commercial packinghouse operating under a compliance agreement. Regulated fruit can move interstate with a certificate to all States. For interstate movement under a limited permit, refer to the APHIS-Approved Packing House Procedures.

Chemicals and fungicides **must** be applied in accordance with label directions.

Step 1: Wash

Step 2: Brush

Step 3: Surface disinfect using at least one of the chemicals in DA-2013-13.

DA-2013-13
(a-1)

Treatment: DA-2013-13 (a-1) — Chemical Treatment

Thoroughly wet the fruit for at least 2 minutes with a solution containing 200 parts per million sodium hypochlorite. Maintain the solution at a pH of 6.0 to 7.5.

DA-2013-13
(a-2)

Treatment: DA-2013-13 (a-2)— Chemical Treatment

Thoroughly wet the fruit with a solution containing sodium o-phenyl phenate (SOPP) at a concentration of 1.86 to 2.0 percent of the total solution. If the solution has sufficient soap or detergent to cause a visible foaming action, wet for 45 seconds. If the solution does not contain sufficient soap to cause a visible foaming action. wet for 1 minute.

DA-2013-13
(a-3)

Treatment: DA-2013-13(a-3) — Chemical Treatment

Thoroughly wet the fruit with a solution of 85 parts per million peroxyacetic acid for at least 1 minute.

6 Regulated articles include fruit, plants, plant products (except seeds) of *Citrus* spp. and *Fortunella* spp. Regulated fruit must be free of leaves, stems that are 1-inch or less in length, or other regulated material.

Step 4: Treat with at least one of the fungicides in Table 5-8-14.

Table 5-8-14 Sweet Orange Scab Approved Fungicides

Chemical Name
Imazalil
Thiabendazole
Combination of fludioxonil plus azoxystrobin

Step 5: Wax.

DA-2012-09 (03/16/2012)

Guignardia citricarpa, fungal pathogen causing the disease Citrus Black Spot (CBS) (Federal Order DA-2012-09)

Regulated Articles[7]

Conduct treatments at a commercial packinghouse operating under a compliance agreement. Regulated fruit can move interstate with a certificate to all States. For interstate movement under a limited permit, refer to the APHIS-Approved Packing House Procedures.

WARNING

Chemicals and fungicides **must** be applied in accordance with label directions.

Step 1: Wash

Step 2: Brush

Step 3: Surface disinfect using at least one of the chemicals in DA-2012-09

DA-2012-09 (a-1)

Treatment: DA-2012-09(a-1) — Chemical Treatment

Thoroughly wet the fruit for at least 2 minutes with a solution containing 200 parts per million sodium hypochlorite. Maintain the solution at a pH of 6.0 to 7.5.

DA-2012-09 (a-2)

Treatment: DA-2012-09(a-2)— Chemical Treatment

Thoroughly wet the fruit with a solution containing sodium o-phenyl phenate (SOPP) at a concentration of 1.86 to 2.0 percent of the total solution. If the solution has sufficient soap or detergent to cause a visible foaming action, wet for 45 seconds. If the solution does not contain sufficient soap to cause a visible foaming action. wet for 1 minute.

DA-2012-09 (a-3)

Treatment: DA-2012-09(a-3) — Chemical Treatment

Thoroughly wet the fruit with a solution of 85 parts per million peroxyacetic acid for at least 1 minute.

7 Regulated articles include fruit, plants, plant products of *Citrus* spp.

Step 4: Treat with at least one of the fungicides in Table 5-8-15.

Table 5-8-15 Citrus Black Spot Approved Fungicides

Chemical Name
Imazalil
Thiabendazole

Step 5: Wax.

6

Treatment Manual

Certifying Facilities

Overview

Contents

The Certification of Facilities section of this manual is organized by the following categories:

- Vacuum Fumigation Chambers
- Atmospheric Fumigation Chambers
- Cold Treatment Facilities
- Hot Water Immersion Facilities
- Niger seed Treatment Facilities
- Forced Hot Air and Vapor Heat Treatment Facilities
- Irradiation Treatment Facilities
- Firewood Heat Treatment Facilities

Domestic and foreign treatment facilities must be certified by APHIS before they can perform treatments to meet United States quarantine requirements. Specific requirements for each type of facility are included in this section.

After USDA-APHIS-PPQ-S&T-CPHST-AQI has approved blueprints or drawings of a treatment facility, the treatment facility can request certification from Plant Protection and Quarantine at local ports or State Plant Health Directors.

Important

Send blueprints or drawings of **domestic** treatment facilities to:

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606
tel: 919-855-7450

Request for certification can be sent to State Plant Directors listed on this web site.

https://www.aphis.usda.gov/aphis/ourfocus/planthealth/ppq-program-overview/ct_sphd

Important

Send blueprints or drawings and request for certification of **foreign** treatment facilities to:

Director, Preclearance Programs
USDA, APHIS, PPQ
4700 River Road, Unit 60
Riverdale, MD 20737
tel: 301-851-2312

For foreign treatment facilities, the company requesting certification is responsible for paying money into a trust fund account to pay the salary, travel costs, and per diem of a PPQ Officer to be sent on temporary duty.

Sea-going vessels that participate in the APHIS cold treatment program for fresh fruit may be certified at a port in the USA or at a foreign port. Also, if the certification is to be carried out overseas, a trust fund account will be needed to cover the costs. (For details call PPQ Quarantine Policy, Analysis and Support (QPAS), tel: 301-851-2312.)

6

Treatment Manual

Certifying Facilities

Certification of Vacuum Fumigation Chambers

Contents

Construction and Performance Standards

Vacuum fumigation consists of placing the commodity in a gastight metal chamber, removing most of the air, and replacing a small portion of it with a gas which is lethal to insects and other pests. Vacuum fumigation provides a more rapid penetration of commodities undergoing treatment than is obtained in normal atmospheric fumigations.

Vacuum Chamber

Vacuum chambers are usually of welded steel construction. A rectangular chamber might be preferred for more effective use of space. Reinforcement of the chamber body by means of steel ribs, or other supports, is usually required to enable the chamber to withstand the difference in pressures when the vacuum is drawn. Doors can be provided at one or both ends of the chamber. In cylindrical chambers, the doors can be either concave or convex, but in rectangular chambers flat doors are commonly used with suitable reinforcements. The doors can be hinged at the side, or at the top and counterbalanced. Many doors are fitted with special mechanisms for rapid closing. Door gaskets should be durable and at the same time provide gastight seal. To a large extent, the efficiency of a chamber depends upon the tightness with which the door or doors will seal. All other chamber openings must be equally tight to sustain the prescribed vacuum over a specified period of time.

To permit circulation beneath the load, the chamber must be designed to enable the stacking of commodities on pallets, skids, or small trucks. Small chambers that are usually hand loaded have removable floors.

Vacuum Pump

Each installation requires a high quality, high capacity vacuum pump. The vacuum pump should have the capacity to reduce the chamber pressure to 1 to 2 inches (25 to 51 millimeters) of mercury (28 to 29 inches or 711 to 737 millimeters vacuum) in 15 minutes or less.

Fumigant Introduction Systems

The size of the chamber will determine the introduction system needed. For small chambers and for introducing fumigants in small quantities, measure the fumigant by volume using a graduated dispenser. For larger chambers place the gas supply cylinder on a platform scale and measure the amount of fumigant by weight.

For methyl bromide, a volatilizing unit is required to ensure fumigant introduction in a gaseous state. The volatilizer is located outside of the chamber between the gas cylinder or dispenser and the introduction port of the chamber. Essentially, the volatilizer consists of a metal coil submerged in water hot enough to vaporize the fumigant. The volatilizer must maintain the water temperature to at least 150 °F throughout the entire gas introduction period.

Within the chamber the gas introduction system should consist of tubing with multiple, graduated openings that will provide uniform distribution of the fumigant throughout the length of the chamber. Ensure that the fumigant enters the chamber from multiple points along the ceiling.

Circulation and Exhaust System

Adequate gas distribution is often hindered by the cargo placed in the chamber. To overcome this, equip vacuum chambers with a circulation system. If fans are employed, the number of fans required would depend upon the chamber design, volume, and loading arrangements. A minimum of 2 fans is normally required for chambers of over 1,000 cubic feet capacity (28.31 m^3). Place the fans at opposite ends of the chamber facing each other—one high, one low. Additional fans might be required for larger chambers. The fans should be capable of circulating air at the rate of at least one-third the volume of the chamber per minute. Some fumigants require nonsparking, explosion-proof-type circulation systems.

In most installations, the vacuum pump is used to remove the fumigant following the exposure period. The air-gas mixture is pumped out of the chamber through exhaust ducts or stacks installed for that purpose. The actual height of these stacks will vary with the location of the chamber, and may be regulated by local, state or federal safety ordinances.

Accessories

Equip chambers with a vacuum gauge and an instrument for measuring and recording the vacuum drawn and maintained during the exposure period.

Install a temperature recording system in chambers used for quarantine treatments that are 6 or more hours in length. Combination temperature and vacuum recorders are available.

Temperature sensors are usually attached to the outside of the chamber with a remote sensing unit attached to the inside wall or inserted into the product. Specifications for the temperature recording system are as follows:

- Accurate to within ± 0.6 °C or ±1.0 °F in the treatment temperature range of 4.4 °C to 26.7 °C (40 °F to 80 °F)
- Calibrated annually by the National Institute of Standards and Technology (NIST) or by the manufacturer
    - The calibration certificate will list a correction factor, if needed, and the correction factor would be applied to the actual temperature reading to obtain the true temperature.
- Capable of printing all temperature readings or downloading data to a secure source **once per hour** throughout the entire treatment (all temperature data must be accessible at a safe distance during the fumigation)
- Tamper-proof

If one or more of the temperature readings go below 40 °F the fumigation will be considered a failed treatment. The commodity must be re-treated, returned to the country of origin, reexported, or destroyed.

CAUTION

Commodities used for food or feed may not be re-treated. If commodities fall into this category, the only options are the following:

- Return to the country of origin
- Reexported to another country if they will accept the shipment
- Destroy by incineration

Certification Standards

To qualify for program approval, vacuum chambers must be able to meet or exceed specified vacuum leakage tests. There are four classification levels in which a chamber may be certified. The tests are listed in **Table 6-2-1** and determine the classification under which the chamber qualifies.

Important

There should be no commodity in the chamber during the certification procedure.

Table 6-2-1 Vacuum Chamber Classification Table

Classification	Initial vacuum (inches)	Allowable vacuum loss			
		4 hr	**6 hr**	**16 hr**	**24 hr**
Superior	28 1/2	—	1/2”	—	1"
A	28 1/2	1/2”	—	1"	2"
B	28 1/2	1"	—	2 1/2”	3"
C	26	1"	—	2 1/2”	3"

In addition to the classification tests in **Table 6-2-1**, ***ALL*** chambers must be capable of meeting the following requirement: A vacuum equivalent to 26 inches (660 mm) of mercury is drawn. The vacuum is then reduced to 5 inches (127 mm) and held for a period of 4 hours. A vacuum of 2 inches (55 mm) or more after 4 hours is considered adequate for this test.

- Chambers classified “Superior” or “A” are approved for all vacuum treatments. These chambers are to be tested annually.
- Chambers classified “B” are approved for all vacuum schedules up to and including 28-inch (711 mm) sustained vacuum. These chambers are to be tested semiannually.
- Chambers classified “C” are approved for all vacuum schedules up to and including 26-inch (711 mm) sustained vacuum. These chambers are to be tested semiannually.

During each certification, conduct a preventative maintenance inspection. The maintenance inspection will ensure the merit of each unit and correct any deficiencies prior to certification. Refer to **Table 6-2-2** for an inspection checklist.

CAUTION

Never use methyl bromide to check for leaks in the chamber. Use compressed air to check for leaks.

Once the chamber has met the requirements in **Table 6-2-1** and passes the preventative maintenance check, the approving APHIS official must complete PPQ Form 480, Treatment Facility Construction, Operation and Test Data, and PPQ Form 482, Certificate of Approval. A copy of each of the forms should be given to the owner/operator of the chamber and also mailed to:

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

Approving a chamber for vacuum fumigation does **not** include approving atmospheric (NAP) fumigations. If the vacuum chamber will also be used as a normal atmospheric pressure chamber, it must also pass a pressure leakage test (see **page 6-3-9**).

Actual detailed instructions for constructing a vacuum chamber are **not** included in this discussion. The information presented is designed to list the component parts needed and the function of each. Instructions and additional information can be obtained from the following list of vacuum chamber manufacturers. In furnishing the names of these dealers, no discrimination is intended against any firm whose name may have been omitted. Neither does this program endorse the firms mentioned nor guarantee the reliability of their products. The list is furnished solely for information and convenience.

Table 6-2-2 Chamber Checklist

Chamber and Volatilizer	Yes	No
Has chamber been measured and total volume calculated?		
Has chamber been checked for integrity?		
◆ Smoke test		
◆ Pressure test		
Have fans been tested to recirculate at least one third of the total volume per minute?		
Is gas monitoring required (by the workplan)?		
◆ If yes, are sampling leads properly placed (in commodity, if required)?		
◆ Are sampling leads one quarter inch inner diameter and free from blockage?		
Will a scale be used to apply fumigant?		
◆ If yes, has the scale been calibrated and certified this year?		
◆ Is the graduated dispenser in good condition?		
Are the door seals and gaskets in good condition?		
Is the copper tubing in the volatilizer intact? (check for holes)		
Are the vacuum and temperature gages accurate?		
Required Equipment		
Tape measure or electronic measuring device		
Calculator		
Stop watch		
Air (leaf) blower with appropriate fittings and adapters		
Manometer (including tubing and appropriate liquid)		
Digital anemometer		
Gas detection device (calibrated within one year)		
Dessicant (Drierite®) and Ascarite®		
Auxiliary pump (for large chambers)		
Digital thermometer (accuracy 0.1 F) with probe		
Required Safety Equipment		
Gas leak detection device		
Self contained breathing apparatus		
First aid kit, including eye wash		
Emergency medical treatment facility map and phone number		
Required Documentation		
PPQ Form 480, Treatment Facility		
PPQ Form 482, Certificate of Approval		
Material safety data sheet		
Warning placard (English and Spanish)		
Special local need label and permit (if applicable)		

6

Treatment Manual

Certifying Facilities

Certifying Atmospheric Fumigation Chambers

Contents

Construction and Performance Standards

The primary purpose of a program fumigation is to obtain quarantine control of the pests in all stages of development in, on, or with the product being fumigated. A fumigation chamber is defined as a stationary enclosure into which the product can be loaded and where the fumigant will be maintained at the prescribed concentration for the required exposure period.

When constructing an atmospheric fumigation chamber, the primary consideration is making it as gastight as possible. In addition, companies must install circulation equipment in chambers that are to be used for methyl bromide (MB) fumigations to ensure proper distribution of the fumigant throughout the chamber. The chamber must retain these qualities of tightness and fumigant circulation during every fumigation.

Although chamber sizes are not restricted to specific dimensions, companies should size chambers according to the volume of material to be fumigated. Experience has shown that two moderately sized chambers are preferable to one large chamber.

Chamber manufacturers should select the construction material according to the type of product to be fumigated and the method of operation involved. Wood frame construction with light metal sheathing or plywood can be used if the products to be fumigated are lightweight and are to be hand loaded. Heavy products, often loaded by machinery or handtrucks, require heavy-gauge sheet metal, masonry, or metal plate construction. It is advisable to construct the chamber in the most durable manner consistent with its intended use.

Auxiliary equipment is required to measure, vaporize, circulate, and exhaust the fumigant. Chamber manufacturers should size such equipment according to the volume of the chamber. When relatively small amounts of MB are to be used, they are often measured by volume in graduated dispensers. When larger amounts are to be used, the fumigant is most often measured by weight with the use of an approved and calibrated measuring scale.

Chambers can be equipped with heating or refrigeration units depending on the climatic environment and the products to be fumigated. Product injury or an ineffective fumigation can occur within certain temperature ranges. Although provisions for temperature control are not generally mandatory, in certain fumigation operations, temperature control is necessary and therefore must be considered in the design and construction of fumigation chambers.

While complete construction details for an atmospheric fumigation chamber are not contained in this chapter, sufficient information is available to develop specifications for a proposed structure. Firms considering chambers for approval by the USDA must submit a completed fumigation chamber approval application and other required information (e.g., manuals, technical sheets) to their local APHIS-PPQ contact. Local APHIS-PPQ personnel will determine the feasibility of constructing the proposed chamber with regards to PPQ resources and requirements. If these are permitted, local personnel will review the submitted application for completeness and forward to the National Operations Manager for Import and Exclusion Treatments.

National Operations Manager, Import and Exclusion Treatments
USDA-APHIS-PPQ
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

The National Operations Manager will subsequently forward the application to the following office:

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

Basic Elements for Design and Construction of Chambers

- Gastight and remains so during every use

- Provides an efficient system for circulating and exhausting the fumigant
- Provides an efficient system of dispensing the fumigant
- Provides heating or refrigeration units when required for fumigation efficiency, to prevent product injury, or to meet label temperature requirements
- Provides a temperature recording system when treatments are six hours or longer in duration
- Provides suitable fittings to facilitate a pressure-leakage test and gas concentration sampling

The criteria listed above deal primarily with the efficiency of the fumigation chamber itself. In determining the ultimate design and construction, it is essential to give consideration to the safe and practical operation of the facility.

All requirements outlined in this chapter apply to all USDA-approved fumigation chambers that use MB and phosphine, unless specifically noted. **See "Phosphine Chambers" on page-6-3-11** for additional information specific to phosphine.

Pallets and Bins

All material placed in the chamber must be on pallets or bins. Load pallets and bins in the chamber so that there is at least two inches of space under the commodity and between each pallet or bin. Fumigation of double-stacked commodities has been conducted in some locations, and approval for this practice is granted on an individual basis. The proposed double-stacked configuration must be designed to ensure that safe and effective fumigations are conducted. Prior to chamber certification, take gas concentration readings throughout the fumigated load to demonstrate that even readings can be achieved with the proposed configuration.

Do not fumigate items or combinations of items (e.g., commodity, packaging) that are sorptive or whose sorptive capacities are unknown unless gas readings are taken by an APHIS representative. Take gas readings for each chamber certification and anytime there is a change in commodity, packaging material, increase in chamber load capacity, or changes to the chamber itself (unless the effect of the change is known and will not decrease gas concentrations below required levels.) Refer to ***Fumigants • Methyl Bromide* on page 2-3-1** for additional information on sorption, sorptive materials, and packaging.

Gastight Construction

Interior surfaces must be impervious to the fumigant and can be constructed of metal, cement, concrete block, tile, or plywood. Any other material that is to be used on the interior surface of the chamber must be approved by PPQ prior to installation. Sorbent materials (e.g., foam, insulation) cannot be installed on the interior surfaces of the chamber, although they can be used in areas that will **not** be exposed to the fumigant. PPQ does allow the use of foam to seal joints in a phosphine chamber.

Introduction lines, fittings, pipes, exhaust stacks, and other structures that could come into contact with MB should be constructed of the following materials that are compatible with this gas:

- Brass
- Copper
- Carbon steel
- Stainless steel
- Polyethylene
- Polypropylene
- Polytetrafluoroethylene (PTFE; Teflon®)

Aluminum and galvanized metal are also acceptable if no liquid MB could come into contact with these materials, although there may be possible reactivity problems with long-term use.

Do not use the following materials for introduction lines, fittings, pipes, or other structures that could come into contact with MB:

- Natural rubber
- Nylon
- Polyvinyl chloride (PVC)
- Tygon® tubing should not be used as gas sampling or introduction lines

Seal joints with appropriate compound, solders, or welds for the construction materials used. When wood or a combination of wood and sheet metal are used, seal all joints and seams with a nonhardening material. This makes a gastight seal and allows for expansion and contraction without leakage. Use mastic tape to seal the seams between wall joints in plywood chambers. In masonry construction, joint (strike) the mortar between all courses of cement blocks to produce a smooth, compact surface. Poured concrete structures should also have smooth, compact surfaces. Weld all metal joints.

Fit all doors and vents with proper gaskets. PPQ recommends that chamber operators replace all door and vent door gaskets (regardless of construction material) once per season in chambers that receive moderate use. In chambers that receive heavier use (e.g., fumigations performed several times per week for an entire season), it is recommended that the gaskets be replaced more frequently.

The following list of materials are compatible with MB and can be used as construction material for gaskets:

- Fluoroelastomer (FKM) (for example, Dupont™ Viton®))
- Ethylene Propylene Diene Monomer (EPDM) (acceptable even though chemical compatibility charts indicate that it should not be exposed to MB; inspect regularly for damage and replace when needed)
- Neoprene (acceptable even though chemical compatibility charts indicate that it should not be exposed to MB; inspect regularly for damage and replace when needed)
- Nitrile (Buna-N)
- Silicone
- Polytetrafluoroethylene (PTFE; Teflon®)

Ensure that all openings for wiring, thermometers, tubing, and ports for pressure-leakage tests, etc. are gastight. PPQ requires a minimum of three fittings to be installed in each chamber for measuring gas concentration. Additional fittings may be required in certain circumstances, such as large chambers or chambers in which the commodity will be double-stacked.

Paint interior surfaces (except for metal) with epoxy resin, vinyl plastic, or asphalt base paints. Additional paint types may be approved if the manufacturer's specifications show compatibility of the paint with the fumigant to be used. Such paint coverings make the surfaces less sorptive, an important factor in maintaining gas concentrations. Although not mandatory, many fumigation chamber operators install concrete bumpers on the floor around the sides of the chamber to prevent forklift damage to the walls.

Important

Aluminum base paints are **not** acceptable because of the corrosive effect caused by a reaction between such paints and the fumigant.

The construction and fastening of chamber doors is most critical to the chamber's ability to hold the gas. Chamber doors can be mounted using hinges, sliding rails, cantilevers, etc., and can be tightened against the associated gasket with turnscrews, hydraulic rams, clamps, etc. Approval will be based on review of the individual system. PPQ does note that small guillotine-style doors are less likely to leak than many other door types and chamber doors that are hinged at the top are less likely to sag than those hinged at the side.

Heavy-duty or industrial hinges are required for doors that are hinged at the side. Regardless of the method used to mount and fasten the doors, it is important that a high-quality gasket is installed around the entire perimeter of the chamber opening. To obtain the maximum seal possible, uniformly and tightly compress the doors against the gaskets.

Circulation and Exhaust Systems

Fans or blowers delivering the prescribed minimum air movement are essential to proper fumigant distribution.

Various methods can be used to circulate the fumigant within the chamber. Equipment should be capable of circulating air at the rate of at least one-third the volume of the chamber per minute. A minimum of two fans is required for chambers greater than 1,000 cubic feet, although this requirement may be waived by local APHIS-PPQ personnel on an individual basis, i.e., when one fan can be shown to achieve adequate and uniform gas concentrations throughout the fumigated load. Position the fans in one of these three configurations:

- at opposite ends of the chamber, facing each other–one high and one low
- all mounted high on one wall of the chamber
- one fan is placed at the top and one at the bottom of a duct or enclosed space

Local APHIS-PPQ personnel may also approve chamber setups resembling precoolers. In this arrangement, two rows of pallets are positioned with approximately a two-foot tunnel in between them and a large fan (that meets minimum air flow requirements) at the front that pulls the fumigant through the pallets and redistributes it above the pallets into the room. In some cases, this setup may utilize a second fan which can both facilitate the circulation of the air/gas mixture and serve as the exhaust fan during aeration.

Ductwork is recommended for larger chambers, especially those that are long and narrow. It serves to pick up the air/gas mixture near the floor and blow it across the top of the load.

Additional fans might be required in certain cases (e.g., larger chambers, chambers in which the commodities are double-stacked, chambers without ductwork or return fans.) A blower located outside the chamber can also be used, but this method increases the possibility of leakage considerably.

NOTICE

Deviations from these guidelines may be permissible but will require additional testing to ensure efficacy.

Size exhaust blowers according to the volume of the chamber. Volume of enclosure (in cubic feet) divided by the sum of cubic feet per minute (cfm) of the exhaust fan(s) or exhaust blower equals the number of minutes required per complete gas volume exchange. Sixty minutes divided by the number of minutes per gas volume exchange equals the number of complete gas exchanges per hour.

APHIS PPQ requires a minimum of four gas exchanges per hour during aeration, although fifteen or higher is preferable, especially for perishable commodities. The quality of perishable commodities may be impacted even at or around the minimum required aeration rate of four gas exchanges per hour. If the exhaust flow is connected to a MB recovery system, it must **not** impede the flow rate to less than four volumes per hour. Frequently, circulation and exhaust systems are designed to utilize the same blower. Extend the exhaust stack at least 15 feet above all nearby structures. Local air quality control agencies may require more stringent measures. It is essential that the air/gas mixture is vented to the outside, with all local safety ordinances being followed.

Fumigant Dispensing System

The dispensing system needed will vary with the type of fumigant being used. The fumigant MB is usually introduced into the chamber through an introduction line extending from the volatilizer to the air stream in front of the introduction fan. Within the chamber, this tube should contain properly spaced openings through which the fumigant is dispersed.

Ensure that no liquid MB comes into contact with the commodity by one of the following methods:

- Placing a piece of impermeable sheeting (e.g., plastic or rubberized canvas) over the commodity below and to the front of each gas introduction line
- Placing a drip pan wherever the gas is introduced into the chamber
- Using a gas introduction line with holes in the sides but solid on the bottom

Graduated dispensers are used to measure small quantities of MB by volume and generally should not be used to introduce fumigant into chambers larger than 2,000 cubic feet. Place the dispenser in the introduction line between the supply cylinder and the volatilizer. For larger quantities of fumigant, place the supply cylinder on a platform scale and weigh the fumigant used. The measured amount of fumigant must pass through a volatilizer where it is converted from a liquid to a vapor.

The volatilizer consists of a metal coil submerged in heated water. When 5 pounds or less of MB are used, a simple volatilizer can be made with a 25-foot coil of 3/8 inch outer diameter coiled copper tubing immersed in a container of hot water. When amounts greater than 5 pounds are to be used, the copper tubing used in the volatilizer must consist of a minimum of 50 feet of 1/2 inch outer diameter coiled copper tubing. Volatilizers constructed as sealed metal units, in which there is no way to verify the amount or type of tubing inside, should be replaced at the discretion of local APHIS-PPQ personnel. The water in the volatilizer must reach 200 °F or above with a minimum temperature of 150 °F during gas introduction. The fumigator must provide local PPQ personnel with a record of the temperature of the water in the volatilizer both at the beginning and the end of gas introduction.

Important

You are **not** required to record the temperature of the water in the volatilizer in the electronic 429 database.

The line that runs from the methyl bromide cylinder to the copper tubing in the volatilizer must be a 3000 PSI hydraulic high pressure hose (preferably steel-braided) with a 3/8 inch or larger inner diameter. The line that exits the volatilizer and runs into the enclosure must be a 350 PSI tubing with a ½ inch or greater inner diameter. The chamber operator may wish to install either a pressure release trap (i.e., burp tube) or pull a slight vacuum in the chamber prior to dispensing the fumigant to mitigate against the increased pressure accompanying gas introduction, although neither of these recommendations is mandatory.

The maximum rate of fumigant introduction from a gas introduction line is 4 pounds of gas per minute, unless the fumigator can demonstrate that a faster rate of introduction would not result in the temperature of the water in the volatilizer falling below 150 ºF anytime during the entire gas introduction process. This temperature requirement is necessary to ensure that no MB can be introduced as a liquid into the chamber. Purge all gas introduction lines with either compressed air or nitrogen after gas introduction.

Calibrate both the scale and the thermometer on the volatilizer annually, although the latter may instead be replaced annually with a thermometer that comes with a certificate of calibration. Written documentation of calibration must be present at the time of fumigation. All calibrations must be performed by the appropriate state governmental department of weights and measures, the National Institute of Standards and Technology (NIST), or an approved calibration company.

Pressure-Leakage Test for NAP Fumigation Chambers

Before a chamber is used for fumigation, it must be checked for tightness using a pressure-leakage test. The chamber must pass this test to be certified. The certifier may also perform a smoke candle test to identify the location of any leaks which could pose safety hazards during fumigation, especially if the retention time is low during the pressure-leakage test or the certifier suspects leakage. This will allow the operator the opportunity to correct these spots before any MB is introduced into the chamber, thus minimizing the likelihood of human exposure to the fumigant.

Conduct the pressure-leakage test using an open-arm or electronic manometer. **See "Open-Arm Manometer" on page-8-1-20** for a detailed description of this type of manometer. Refer to ***Manometer (used in pressure leakage test)* on page E-1-34** for a list of approved manometers.

The procedure for conducting a pressure-leakage test is as follows:

1. Install an opening (usually 2-inches in diameter) in the chamber to which a blower or other device for introducing air can be attached.
2. Attach a 2-inch ball-valve between the opening (pipe fitting) and the blower. This will stop the flow of air when the chamber has reached pressure and prevent the air from venting out of that opening.
3. Install an additional opening, such as a gas sampling line opening, for the manometer. This opening should be located within 15 inches of the hole for the blower. Both openings should be situated approximately 4 to 5 feet from the floor, so readings can easily be taken.
4. Close chamber as for fumigation.
5. Attach one end of the manometer to the chamber opening.
6. Pressurize the chamber using a blower (or other device that blows high volumes of air) to a total pressure of 25 mm (12.5mm in each arm of the manometer) for chambers constructed partially or entirely of plywood or 50 mm for chambers constructed of materials such as cement or cinder blocks.
7. Discontinue blower and close its opening.
8. Observe time for pressure to recede.

   For a chamber constructed of materials such as cement or cinder blocks, the time lapse for the chamber pressure to recede from 25 mm to 2.5 mm in **each** arm of the manometer must be:

   - 22 to 29 seconds; reinspect chambers every 6 months
   - 30 seconds or longer; reinspect chambers annually

For plywood chambers, the time lapse for the chamber pressure to recede from 12.5 mm to 1.25 mm in **each** arm must be:

- 60 seconds or longer; reinspect chambers annually

During each certification, PPQ personnel must conduct a preventative maintenance inspection. The maintenance inspection will ensure the merit of each unit and correct any deficiencies prior to certification. Refer to **Table 6-3-1** for an inspection checklist.

Once the chamber has passed the pressure-leakage test and the preventative maintenance check, the approving APHIS official must complete PPQ Form 480, Treatment Facility Construction, Operation and Test Data, and PPQ Form 482, Certificate of Approval. A copy of each of the forms should be given to the owner/operator of the chamber and also mailed to:

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

Other Auxiliary Equipment

For chambers located inside a building, USDA requires that low-level gas monitoring devices be installed in the same room as the fumigation chamber. Multiple monitors may be necessary depending on the configuration of the facility.

According to the needs of the operation, other auxiliary equipment may be necessary. When heat is required, steam pipes or low-temperature electric strip heaters are generally recommended. Do **not** use open flame or exposed electric coils as they tend to break down the gas and form undesirable compounds. Size refrigeration units to the volume of the chamber and the type and amount of commodity involved.

Install a temperature monitoring device in chambers used for quarantine treatments that are 6 hours or more in duration. Temperature recording thermometers are usually attached to the outside of the chamber with a remote sensing unit attached to the inside wall or inserted into the product. Specifications for the temperature recording system are as follows:

- Accurate to within ± 0.6 °C or ±1.0 °F in the treatment temperature range of 4.4 °C to 26.7 °C (40 °F to 80 °F)
- Calibrated annually by the National Institute of Standards and Technology (NIST) or by the manufacturer
    - The calibration certificate will list a correction factor, if needed, and the correction factor would be applied to the actual temperature reading to obtain the true temperature.

- Capable of printing all temperature readings or downloading data to a secure source **once per hour** throughout the entire treatment (all temperature data must be accessible at a safe distance during the fumigation)
- Tamper-proof

Phosphine Chambers

Phosphine can react with certain metals (e.g., gold, silver, copper, brass, and other copper alloys) and cause corrosion, especially at higher temperatures and relative humidities. Fans, blowers, and tubing should not be constructed from these or any other materials, such as urethane or other rubber, that are not resistant to phosphine. It is recommended that all wiring be external to the chamber, but is required (at a minimum) that all wiring, electrical and exhaust systems be non-sparking and explosion proof.

All gas dispensing equipment used with cylinderized formulations of phosphine must be approved by the registrant. VAPORPH3OS can only be introduced via Cytec-approved blending equipment. ECO2FUME must be introduced via stainless steel or hydraulic dispensing lines of suitable pressure rating and materials of construction, as determined by Cytec. Heat sources are generally not used or necessary in phosphine introduction, although some methods of cylinderized phosphine introduction may use electric vaporizers. Contact the registrant for additional information on this issue. Circulation fans are not needed in phosphine chambers.

Checklist

Use the checklist in **Table 6-3-1** as a guide during chamber certification.

Table 6-3-1 Chamber Checklist

Chamber and Volatilizer	Yes	No
Has chamber been measured and total volume calculated, including all areas where the fumigant penetrates (e.g., ductwork)?		
Has chamber been checked for integrity?		
◆ Smoke test		
◆ Pressure test		
Have fans been tested to recirculate at least one third of the total volume per minute?		
Can gas monitoring be adequately performed?		
◆ Are sampling leads properly placed?		
◆ Are sampling leads one quarter inch inner diameter polyethylene or polypropylene and free from blockage?		
Will a scale be used to apply fumigant?		
◆ If yes, has the scale been calibrated and certified this year?		
◆ If no, is the graduated dispenser in good condition?		
Are the door seals and gaskets in good condition?		
Is the copper tubing in the volatilizer intact? (check for holes, if possible)		
Is the temperature gauge accurate and has it been calibrated within one year?		
Required Equipment and Documentation		
Tape measure or electronic measuring device		
Calculator		
Stop watch		
Air (leaf) blower with appropriate fittings and adapters		
Manometer (including tubing and appropriate liquid)		
Digital anemometer		
Gas detection device (calibrated within one year)		
Dessicant (Drierite®) and Ascarite®		
Auxiliary pump (for large chambers)		
Digital thermometer (resolution 0.1 °F) with probe		
Smoke candles		
Gas leak detection device		
Self contained breathing apparatus		
First aid kit, including eye wash		
Emergency medical treatment facility map and phone number		
PPQ Form 480, Treatment Facility Construction, Operation, and Test Data		
PPQ Form 482, Certificate of Approval		
Material safety data sheet		
Warning placard (English and Spanish)		
Special local need label and permit (if applicable)		

6 Certifying Facilities

Treatment Manual

Certification of Cold Treatment

Contents

Introduction

Since the early 1900s, sustained cold temperature has been employed as an effective post-harvest method for the control of the Mediterranean and certain other tropical fruit flies. Exposing infested fruit to temperatures of 2.2 °C (36 °F) or below for specific periods of time results in the mortality of the various life stages of this group of notoriously injurious insects. Procedures were developed to effectively apply cold treatment (CT) to fruit while in transport in refrigerated holds of ships, in refrigerated containers, and in warehouses located in the country of origin or in the United States.

Self-refrigerated (Integral) containers, conventional vessels, and warehouses utilized for regulatory cold treatment are subject to approval by the USDA. Approval is needed only when treating fruit under USDA regulations and does **not** constitute an endorsement for the carrying or storage of refrigerated cargo.

Only officials authorized by APHIS have permission to conduct warehouse, vessel or container certification under the general guidance of CPHST-AQI. Refer to the following web site for a complete list of USDA-certified vessels and containers for intransit cold treatment:

https://treatments.cphst.org/vessels/

Standards for Temperature Recording Systems

Temperature recording systems may consist of various electronic components such as temperature sensors, computers, printers, and cables and are required for temperature recording installations in cold treatment vessels, refrigerated containers, or warehouses. Submit plans and specifications of the temperature recording system to **USDA-APHIS-PPQ-CPHST-AQI-Raleigh** for review and approval before installation.

Temperature Recording System

- **Accuracy**—The accuracy of the system must be within plus or minus 0.3 °C (0.5 °F) of the true temperature in the range of minus 3 °C (27 °F) to plus 3 °C (37 °F.)
    - Ensure the instrument is capable of repeatability in the range of minus 3 °C to plus 3 °C (27 °F to 37 °F.)
- **Automatic Operation**—The system must be capable of automatic operation whenever the treatment system is activated.
- **Long-Term Recording**—The system must be capable of continuous recording of date, time, sensor number, and temperature during all calibrations and for the duration of a voyage and/or treatment period.
- **Password Protection**—All approved temperature recording devices must be password protected and tamper-proof.
- **Recording Frequency**—The time interval between prints will be no less than **once every hour**. For each sensor, the temperature value, location/identification, time and date must print **once per hour.**
- **Repeatability**—When used under treatment conditions over an extended period of time, the system must be capable of repeatability in the range of minus 3 °C to plus 3 °C (27 °F to 37 °F.) The design, construction and materials must be such that the typical environmental conditions (including vibration) will **not** affect performance.

- **Range**—The recorder must be programmed to cover the entire range between minus 3 °C to plus 3 °C (27 °F to 37 °F), with a resolution of 0.1 (°C or °F.)
- **Visual Display**—The system must have a visual display so the temperature can be reviewed manually during the treatment and calibrations.

Temperature Sensors

- **Construction Standards**—Sensors should have an outer sheath diameter of 0.25 inches (6.4 millimeters) or less. The sensing unit must be in the first inch of the sensor.
- **Identification**—Identify all sensors to distinguish the sensors in one compartment from those in other compartments.
  - Place an identifying number on the box where the sensor originates and on a permanent tag where the cable joins the sensor.
  - Identify the sensors for each compartment so the air sensors are numbered first (e.g., A1, A2—air; A3, A4,..., etc.,—fruit pulp.)
- **Location**—Post a diagram next to the recording instrument that shows the location and identification of each sensor by compartment.
  - Air sensors—Place sensors on the center line of the vessel, fore and aft, approximately 30 centimeters from the ceiling and connected to cables at least 3 meters in length
  - Fruit sensors—Distribute fruit sensors throughout the compartment so all areas of the compartment can be reached (5- to 15-meter cable lengths are usually sufficient.) The number and location is dependent upon cubic capacity of the compartment. Refer to **Figure 6-4-1 on page-6-4-6** for guidance for vessels and **Figure 6-4-6 on page-6-4-15** for guidance for warehouses. Three temperature sensors are required for refrigerated containers. These are labeled USDA1, USDA2, and USDA3.

Contact **USDA-APHIS-PPQ-CPHST-AQI-Raleigh** for a complete list of approved temperature recording systems.

Certification of Vessels Used for Intransit Cold Treatment

Vessels used in cold treatment must be certified by a qualified APHIS-PPQ employee or a designated representative before treating fruit under USDA regulations. Refrigeration (reefer) vessels presented for approval must be classified under the rules of the American Bureau of Shipping or a comparable internationally recognized ship classification society.

Submit plans, drawings and specifications to **USDA-APHIS-PPQ-CPHST-AQI-Raleigh** prior to the first vessel certification. Conduct certification tests prior to the vessel receiving final approval to conduct a cold treatment. Certification will be performed every **three** years or sooner if APHIS determines that a malfunction or alteration of the system warrants a recertification.

Plan and Specification Approval

Prior to the start of vessel construction, an application for vessel approval, detailed drawings of the vessel's physical characteristics and a written description of the all the equipment related to treatment must be reviewed and approved by **USDA-APHIS-PPQ-CPHST-AQI-Raleigh** (all plans and supporting materials must be submitted in Standard English.)

Plans and specifications must include the following information:

- Completed Application for Vessel Approval (an example of a completed Application is provided on **page 6-4-9**)
- Drawings showing the dimensions of the refrigerated compartments
- Example of an hourly printout from the recording system (must include date, time, temperature unit, vessel name)
- Number and location of air and pulp sensors in each compartment (see **Figure 6-4-1 on page-6-4-6**)
- Specifications of the recording system
- Specifications of refrigeration equipment (including air circulation)

The review of plans and process descriptions may take up to sixty days and subsequent requests for additional information may further extend this time.

Vessel owners will receive a letter granting plan approval or describing plan deficiencies and necessary remedial measures.

Following plan approval, the vessel should be built according to the plans.

If deviations from the plans are necessary, **USDA-APHIS-PPQ-CPHST-AQI-Raleigh** must approve the changes (changes should be submitted in a manner similar to that described in "Plan and Specification Approval".)

Certification Testing

Make the vessel available for an on-site certification visit by a PPQ official when all documents and a completed Application have been submitted and approved by the **USDA-APHIS-PPQ-CPHST-AQI-Raleigh**.

Important

> Do **not** conduct vessel certification if temperatures in the vessel holds are lower than -1.0 °C (plus or minus 0.3 °C) or 30.2 °F (plus or minus 0.5 °F).

Contact the State Plant Health Director or Officer-In-Charge at the port of call to arrange vessel certification at a US port.

Establish a cooperative agreement and other arrangements as needed with USDA for vessel certification inspections made at a foreign location. This will require a 60-day notification before the inspection can be scheduled. For specific information on the required procedure, contact:

USDA-APHIS-PPQ
Preclearance and Offshore Programs
4700 River Road, Unit 67
Riverdale, MD 20737
Phone: 301-851-2162

A representative from the temperature recorder company who is familiar with the installation, should be on hand to correct any deficiencies in the system.

Before requesting final inspection, the vessel's owner must complete all arrangements. Calibration and identification tests will be made during the inspection. Clean containers filled with crushed ice and fresh water must be made available for the immersion of the temperature sensors.

Determining the Number of Temperature Sensors

The number and location of temperature sensors is based on the cubic capacity of the compartment. Refer to **Figure 6-4-1** to determine the number and location of sensors. Always place the **air** sensors on the fore and aft bulkheads. Always distribute the **pulp** sensors throughout the compartment so that all areas can be reached.

Cubic Feet	Cubic Meters	Number of Air Sensors[1]	Number of Pulp Sensors	Total Number of Sensors
0 to 10,000	0 to 283	2 or 3	2	4 or 5
10,001 to 15,000	284 to 425	2 or 3	3	5 or 6
15,001 to 25,000	426 to 708	2 or 3	4	6 or 7
25,001 to 45,000	709 to 1,274	2 or 3	5	7 or 8
45,001 to 70,000	1,275 to 1,980	2 or 3	6	8 or 9
70,001 to 100,000	1,981 to 2,830	2 or 3	8	10 or 11
> 100,000	> 2,830	Contact CPHST-AQI		

Figure 6-4-1 Number of Temperature Sensors per compartment

1 In the case of twin deck compartments, two air sensors are required in the upper deck plus one air sensor in the lower compartment. This sensor should be located on the bulkhead farthest from the cooling unit.

Important

It is highly recommended that more temperature sensors be installed than the minimum number required for each refrigerated compartment. If a sensor malfunctions during a treatment, the Port Director has the option of disregarding it, providing that an additional working sensor is present, and the functional sensors were uniformly distributed. Otherwise, the entire treatment must be repeated for the fruit in that compartment.

Designate two of the sensors as air sensors, and the others as pulp sensors. Any sensors above the required minimum may be either pulp or air sensors.

For compartments exceeding 100,000 cubic feet, contact the **USDA-APHIS-PPQ-CPHST-AQI-Raleigh** for the minimum number of required sensors.

Calibration of Temperature Sensors

Calibrate all temperature sensors using a clean ice water slurry at 0 ºC (32 ºF).

NOTICE

It is APHIS policy to use the standard "rounding rule". In determining calibration factors, if the reading is .05 or higher, round to the next higher number in tenths. If it is .04 or lower, round to the lower number. For example: If the calibration factor was .15, round to .2. If it was .32, round to .3. Similar rounding can be used in actual treatment readings. If an actual reading was 34.04, round to 34.0, add or subtract the calibration factor, if necessary. If it was 34.07, round to 34.1, add or subtract the calibration factor, if necessary.

Use the following steps to make the ice water slurry:

1. Check individual sensors to verify that they are properly labeled and correctly connected to the temperature recorder. This can be accomplished by hand warming each sensor when its' number appears on the visual display panel of the recording instrument. A temperature change, which can be observed on the instrument, should occur. If the instrument fails to react, the sensor is incorrectly connected or malfunctioning and should be corrected by the instrument representative.

2. Prepare a mixture of clean ice and fresh water in a clean insulated container.

3. Crush or chip the ice and completely fill the container.

4. Add enough water to stir the mixture.

5. Stir the ice and water for a minimum of 2 minutes to ensure the water is completely cooled and good mixing has occurred.

- ❖ The percentage of ice is estimated at 80 to 85 percent while the water fills the air voids (15 to 20 percent).

6. Add more ice as the ice melts.

7. Prepare and stir the ice water slurry to maintain a temperature of 0 °C (32 °F).

8. Submerge the sensors in the ice water slurry without touching the sides or bottom of the container.

9. Stir the mixture.

10. Continue testing of each sensor in the ice water slurry until the temperature reading stabilizes.

11. Record two consecutive readings of the stabilized temperature on the temperature chart or logsheet.

- ❖ The temperature recording device should be in manual mode to provide an instantaneous readout.

12. Allow at least a 1 minute interval between two consecutive readings for any one sensor; however, the interval should **not** exceed 5 minutes.

- ❖ The variance between the two readings should **not** exceed 0.1°.

13. Contact an instrument company representative immediately if the time interval exceeds the normal amount of time required to verify the reading and accuracy of the sensor and recorder system

- ❖ The recorder used with the sensors must be capable of printing or displaying on demand and **not** just at hourly intervals.

14. Correct any deficiencies in the equipment before certification.

15. Replace any sensor that reads more than plus or minus 0.3 °C (0.5 °F) from the standard 0 ºC (32 ºF).
16. Replace and recalibrate any sensors that malfunction.
17. Document the recalibration and replacement of the sensor(s).
18. Determine the calibrations to the nearest tenth of one degree.

Frequency of Certification Testing

A certification test is required every three years. No extensions to this three year requirement will be granted. Make requests for renewal at least 60 days before expiration to the CPHST-AQI or USDA PPQ Preclearance programs. Certification testing is also required anytime a malfunction, breakdown or other failure occurs (excluding temperature sensors) that requires modifications to the recording and monitoring system(s).

Documentation

The APHIS official will document all tests during certification. Send a copy of the signed PPQ Form 449-R, Temperature Recording Calibration Report, copies of all charts and/or printouts, and any other pertinent addenda or appendices to the **USDA-APHIS-PPQ-CPHST-AQI-Raleigh** for final approval.

Certificate of Approval

Upon meeting all requirements, the vessel will be designated as approved to conduct intransit cold treatments under the provisions of the PPQ's Fruit and Vegetable Quarantine 56. A PPQ Form 482, Certificate of Approval, listing the approved refrigerated compartments will be issued to the vessel. This approval is for equipment only, and each shipment of fruit must satisfy all requirements as described in Section 319.56 and 305.15 of the Code of Federal Regulations as a condition of entry into the United States.

Application for USDA Vessel Approval

Visit the Commodity Treatment Information System web site or contact **USDA-APHIS-PPQ-CPHST-AQI-Raleigh** for a fillable, electronic Vessel Approval Application.

APPLICATION FOR USDA VESSEL APPROVAL

FOR USE IN CONDUCTING QUARANTINE COLD TREATMENTS UNDER USDA REGULATIONS

Instructions:

(1) Use one application for each vessel.

(2) Review the regulatory requirements in Chapter 6 of the Plant Protection and Quarantine (PPQ) Treatment Manual. An electronic PDF document of the manual is available at the following website: http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf

(3) A list of approved and certified vessels can be found at: https://treatments.cphst.org/vessels/

(4) Each application must include technical documents that support the information supplied.

(5) Fill in each field of the application completely. Review of the application will not begin until all information is received. If a field is not applicable, please put "N/A" in the space provided. In the column labeled "Reference", indicate the page number(s) or specific location where the information can be found in the supporting technical documents.

(6) Send the completed application and required additional information (manuals, technical sheets) to the following office:

USDA-APHIS-PPQ-CPHST AQI Raleigh
1730 Varsity Drive, Suite 300
Raleigh, North Carolina 27606 USA
Fax: (919) 855-7493

1. Contact Information (Please type or print)	
Requestor Information: This information will be used by USDA as the official contact information for this vessel.	
Name of Company Golden Management	
Name and Title of Requestor Ben Charles, Owner	
Address of Requestor: 111 Executive Drive Washington, DC 30943	
Telephone: 444-123-1234	FAX: 444-123-1235
E-Mail Address: bcharles@goldenmanagement.com	
Agent Responsible for the Vessel (if different from Requestor)	
Name of Agent N/A	
Address of Agent:	
Telephone:	Fax:
E-Mail Address:	
2. Vessel Information	
Shipyard: Shikoku	Hull number: 3456
IMO number: 99991111	Vessel name: Golden Swan

Form T-CT-V-A-124 Approved on Revision: 02 Page 1 of 2

The USDA is an equal opportunity provider and employer.

Figure 6-4-2 Example of a Completed Application for USDA Vessel Approval, page 1 of 2

Attach vessel schematic(s) to include the following:
All information must be clearly referenced in supporting technical documents.

Requirement	Reference Page or Section
(a) Sensor location	Page 6
(b) Sensor number	Page 2
(c) Sensor type (air or pulp)	Page 3
(d) Compartment identifiers	Page 4
(e) Airflow direction	Page 6
(f) Refrigeration Unit locations	Page 6
(g) Recorder location	Page 6

Ensure that a list of compartment identifiers with corresponding cubic capacity is attached to this application.

3. Refrigeration Unit

Make of Refrigeration Unit: Saab	Model of Refrigeration Unit: 687Vn123
Location of Refrigeration Unit: Power Plant	Model Year: 2001
Airflow maximum rate (cfm): 3000	Airflow direction: aft

4. Temperature Recorder

Manufacturer: Mycom	Model: Marcs	Model Year: 2003
Serial number(s): 5549876, 9875665	Quantity of recorders: 2	Is this a USDA approved recorder: Yes: ☑ No: ☐

Accuracy:
Recorder (Must be accurate to within +/- 0.15 C in the range of +/- 3.0 C): yes
Recorder plus Sensor (Must be accurate to within +/- 0.30 C in the range of +/- 3.0 C): yes

5. Temperature Sensors

Accuracy (Must be accurate to within +/- 0.15 C in the range of +/- 3.0 C): yes

Are these USDA approved temperature sensors: Yes: ☑ No: ☐

Do sensors numbers match the numbers on the recorder: Yes: ☑ No: ☐

Description	Air Sensors	Pulp Sensors
Manufacturer	Mycon	Mycom
Model	RM105	RM115
Length of sensor cable	3 meters (Must extend from ceiling to floor)	15 meters (Must extend beyond centerline of the vessel compartment)

X ______________________ Requestor's Signature

______________________ Date *(mm-dd-yyyy)*

Form T-CT-V-A-124 Approved on Revision: 02 Page 2 of 2

The USDA is an equal opportunity provider and employer.

Figure 6-4-3 Example of a Completed Application for USDA Vessel Approval, page 2 of 2

Certification of Self Refrigerated Containers Used for Intransit Cold Treatment

Certify refrigerated containers used as cold treatment facilities before carrying treated fruit under USDA regulations. Classify refrigerated containers under the rules of the American Bureau of Shipping or a comparable internationally recognized classification society.

Certification Requirements

Complete an Application for Container Certification and submit to **USDA-APHIS-PPQ-CPHST-AQI-Raleigh**. All plans and supporting materials must be submitted in Standard English. Refer to **Figure 6-4-4 on page-6-4-12** for an example of a completed Application for Container Certification.

Include the following specifications in the application:

- Air flow rate
- Container size
- Make and model of refrigeration unit
- Make and model of temperature recorder/control unit
- Type of sensor
    - At least 3 sensors are necessary for each container and must be labeled USDA1, USDA2 and USDA3

Letter of Certification

Upon meeting all requirements, the container(s) will be certified to conduct intransit cold treatments under the provisions of the PPQ Fruit and Vegetable Quarantine 56. A Letter of Certification listing the refrigerated container(s) will be issued to the owner. This certification is for container(s) only, and each shipment of fruit must satisfy all requirements as described in Section 319.56 and 305.15 of the Code of Federal Regulations as a condition of entry for importation into the United States.

Application for USDA Container Certification

Visit the Commodity Treatment Information System web site or contact **USDA-APHIS-PPQ-CPHST-AQI-Raleigh** for a fillable, electronic Vessel Approval Application.

APPLICATION FOR USDA CONTAINER CERTIFICATION
TO CONDUCT COLD TREATMENT UNDER USDA REGULATIONS

Instructions:
(1) Prior to submitting your Application for USDA Container Certification please verify that the containers are **not** already approved by going to the USDA Certified Containers Website:
https://treatments.cphst.org/vessels/containers.cfm
(2) Review the regulatory requirements in Chapters 3-7 and 6-4 of the PPQ Treatment Manual. An electronic PDF document of the manual is available at the following website:
http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf
(3) Fill in each field on the application completely. Review for certification will not begin until all information is received. If a field is not applicable, please put "N/A" in the space provided.
(4) Send the completed application via electronic mail, fax, or postal mail to the following office:

USDA-APHIS-PPQ-CPHST AQI Raleigh
1730 Varsity Drive, Suite 300
Raleigh, North Carolina 27606 USA
Fax: (919) 855-7493

1. Name and Address of Requestor (Please type or print)	
(First) (Last) John Johnson	Company Name: Cold World
Job Title: Manager	
Company Address: 1234 Westshore Drive, Miami, Florida 60188	
Country: USA	E-Mail Address: jjohnson@coldworld.com
Telephone: 901-565-5555	FAX: 901-565-5556
2. Name and Address of Container Series Owner (Different from Leasing Company)	
Container Series Owner: Maersk LTD	
Owner Address: Kiel, New Jersey	
Country: USA	E-Mail Address: manage@maersk.com
Telephone: 605-545-8974	FAX: 605-545-8965
3. Name and Address of Container Manufacturer (Fill out ONLY if different from 1)	
Container Manufacturer: Belding Reefer Company	
Manufacturer Address: 2565 East River Drive, New York NY	
Country: USA	E-Mail Address: bdrcompany@belding.com
Telephone: 565-509-5698	FAX: 565-509-5699

The USDA is an equal opportunity provider and employer.

Form T-CT-C-C-107 | Approved 4/9/2009 | Revision: 02 Page 1 of 2

Figure 6-4-4 Example of a Completed Application for USDA Container Certification, page 1 of 2

4. Container Information			
Container Code and Numbers:	BIC: APRU	Begin: 904954	End: 905154
Total Number of Containers in Series: 299		Date of Construction (mm/yyyy): 06/2009	
External Dimensions (feet):	Length: 40	Width: 8'	Height: 9.6'

5. Refrigeration Unit	
Make: Carrier	Model: 69NT40-551-509
Year of Manufacture: 2008	Location of the Unit: Inside the container ☑ Outside the container ☐
Airflow Maximum Rate (cubic feet per minute): 1400	Bottom Air Delivery? Yes ☑ No ☐

6. Temperature Controller	
Make: Carrier	Model: MicroLink 2
Year of Manufacture: 2008	
Is a modem connected to the controller / recorder? Yes ☐ No ☑	If Yes, specify model:

7. Temperature Sensors: Indicate which approved sensors will be used with the temperature monitoring and control system:			
Thermistor ☑	ST9702 ☐	PT100 ☐	NTC ☐

X John Johnson
Requestor's Name/Signature ____________ Date (mm/dd/yyyy)

***************DO NOT WRITE BELOW – FOR USDA PURPOSES ONLY – DO NOT WRITE BELOW***************

Reviewer________________________________

Date Application Received________________________

Approved______ **Not Approved**______ **Date**______________

Reviewer's Signature________________________________

Container ID # ______________**Document File Name** ________________________________

Comments:

The USDA is an equal opportunity provider and employer.

Form T-CT-C-C-107 Approved 4/9/2009 Revision: 02 Page 2 of 2

Figure 6-4-5 Example of a Completed Application for USDA Container Certification, page 2 of 2

Certification of Warehouses Used for Cold Treatment

The local APHIS-PPQ inspector will certify refrigerated warehouses for use as cold treatment facilities before treating fruit under USDA regulations. In addition to the general requirements, warehouse approval is subject to specific geographical pest-risk considerations as outlined in Title 7, Section 305.6 of the Code of Federal Regulations.

USDA-APHIS-PPQ-CPHST-AQI-Raleigh will approve plans and specifications prior to the initial warehouse certification. Conduct a performance survey prior to the warehouse receiving approval to conduct cold treatments under USDA regulations.

Plan and Specification Approval

Prior to the start of warehouse construction, submit a completed Application for Warehouse Approval, detailed drawings of the physical characteristics, and a written description of the all the treatment related equipment to **USDA-APHIS-PPQ-CPHST-AQI-Raleigh**. All plans and supporting materials must be submitted in Standard English. An example of a completed Application is provided in **Figure 6-4-7 on page-6-4-18**.

Include the following information in the Application:

- Address of the warehouse location
- Drawings showing the dimensions, cubic capacity and door locations

Important

> Drawings may be hand-drawn, but must clearly show location of refrigeration units, circulation fans, temperature recorder, and sensors.

- Make and model of the refrigeration equipment
- Name and address of the firm owning the warehouse chamber
- Number and location of sensors (**Figure 6-4-6 on page-6-4-15**)
- Method for segregating fruit under treatment and securing it from other foreign or domestic articles
- Specification of the air circulation system; must indicate the number of air changes and direction of air flow
- Specifications of the recording system

Certification Testing

When all documents and a completed Application have been submitted and approved by the **USDA-APHIS-PPQ-CPHST-AQI-Raleigh**, the warehouse owner should make the warehouse available for an on-site certification visit by a local PPQ official. To arrange warehouse certification, contact the State Plant Health Director or Officer-In-Charge for the port. Before requesting final inspection, the warehouse owner must complete all arrangements as directed by the PPQ officer. The PPQ official will conduct calibration and identification tests during the inspection.

Determining the Number of Temperature Sensors

The number and location of temperature sensors is based on the cubic capacity. Refer to **Figure 6-4-6** to determine the number and location of sensors. The minimum requirement is three sensors—one air sensor and two pulp sensors. Sensor cables must be long enough to reach all areas of the load.

Cubic Feet	Cubic Meters	Number of Pallets	Number of Air Sensors	Number of Pulp Sensors	Total Number of Sensors
0 to 10,000	0 to 283	1 - 100	1	2	3
10,001 to 20,000	284 to 566	101 - 200	1	3	4
20,001 to 30,000	567 to 849	201 - 300	1	4	5
30,001 to 40,000	850 to 1132	301 - 400	1	5	6
40,001 to 50,000	1133 to 1415	401 - 500	1	6	7
50,001 to 60,000	1416 to 1698	501 - 600	1	7	8
60,001 to 70,000	1699 to 1981	601 - 700	1	8	9
70,001 to 80,000	1982 to 2264	701 - 800	1	9	10
80,001 to 90,000	2265 to 2547	801 - 900	1	10	11
90,001 to 100,000	2548 to 2830	901 - 1000	1	11	12
Over 100,000	>2830	1000 +	Must be approved by CPHST-AQI		

Figure 6-4-6 Number of Sensors in a Warehouse

Important

If a refrigerated room is equipped according to the cubic capacity of the storage area (rather than of the load itself), the same criteria apply.

It is highly recommended that additional sensors beyond the required minimum be installed.

Calibration of Temperature Sensors

Calibrate all temperature sensors using a freshwater ice water slurry at 0 ºC (32 ºF).

NOTICE

It is APHIS policy to use the standard "rounding rule". In determining calibration factors, if the reading is .05 or higher, round to the next higher number in tenths. If it is .04 or lower, round to the lower number. For example: If the calibration factor was .15, round to .2. If it was .32, round to .3. Similar rounding can be used in actual treatment readings. If an actual reading was 34.04, round to 34.0, add or subtract the calibration factor, if necessary. If it was 34.07, round to 34.1, add or subtract the calibration factor, if necessary.

Use the following steps to make the ice water slurry:

1. Prepare a mixture of clean ice and fresh water in a clean insulated container.
2. Crush or chip the ice and completely fill the container.
3. Add enough water to stir the mixture.
4. Stir the ice and water for a minimum of 2 minutes to ensure the water is completely cooled and good mixing has occurred.
   - ❖ The percentage of ice is estimated at 80 to 85 percent while the water fills the air voids (15 to 20 percent).
5. Add more ice as the ice melts.
6. Prepare and stir the ice water slurry to maintain a temperature of 32 °F. (0 °C)
7. Submerge the sensors in the ice water slurry without touching the sides or bottom of the container.
8. Stir the mixture.
9. Continue testing of each sensor in the ice water slurry until the temperature reading stabilizes.
10. Record two consecutive readings of the stabilized temperature on the temperature chart or logsheet.
    - ❖ The temperature recording device should be in manual mode to provide an instantaneous readout.
11. Allow at least a 1 minute interval between two consecutive readings for any one sensor; however, the interval should **not** exceed 5 minutes.
    - ❖ The variance between the two readings should **not** exceed 0.1°.
12. Contact an instrument company representative immediately if the time interval exceeds the normal amount of time required to verify the reading and accuracy of the sensor and recorder system
    - ❖ The recorder used with the sensors must be capable of printing or displaying on demand and **not** just at hourly intervals.
13. Correct any deficiencies in the equipment before certification.
14. Replace any sensor that reads more than plus or minus 0.3 °C (0.5 °F) from the standard 0 ºC (32 ºF).
15. Replace and recalibrate any sensors that malfunction.
16. Document the recalibration and replacement of the sensor(s) on the PPQ Form 449-R, Temperature Recording Calibration Report.
17. Determine the calibrations to the nearest tenth of one degree.

Frequency of Certification Testing

A certification test is required every year. Sumit requests for recertification to the local PPQ office at least 60 days before expiration. Certification testing is also required anytime a malfunction, breakdown or other failure occurs (excluding temperature sensors) that requires modifications to the recording and monitoring system(s).

Application for USDA Warehouse Approval

Visit the Commodity Treatment Information System web site or contact **USDA-APHIS-PPQ-CPHST-AQI-Raleigh** for a fillable, electronic Vessel Approval Application.

APPLICATION FOR USDA WAREHOUSE APPROVAL
FOR USE IN CONDUCTING QUARANTINE COLD TREATMENTS UNDER USDA REGULATIONS

Instructions:
(1) Use one application for each warehouse.
(2) Review the regulatory requirements in Chapter 6 of the Plant Protection and Quarantine (PPQ) Treatment Manual. An electronic PDF document of the manual is available at the following website: http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf
(3) Each application must include technical documents that support the information supplied.
(4) Fill in each field of the application completely. Review of the application will not begin until all information is received. If a field is not applicable, please put "N/A" in the space provided. In the column labeled "Reference", indicate the page number(s) or specific location where the information can be found in the supporting technical documents.
(5) Send the completed application and required additional information (manuals, technical sheets) to the following office:

USDA-APHIS-PPQ-CPHST AQI Raleigh
1730 Varsity Drive, Suite 300
Raleigh, North Carolina 27606 USA
Fax: (919) 855-7493

1. Contact Information	
Requestor Information: This information will be used by USDA as the official contact information for this warehouse.	
Name of Company: John Smith	Name and Title of Requestor: Bilco Cold Products
Address of Requestor: 1700 Dock Street, Philadelphia PA 12345	
Telephone: 800-555-5555	FAX: 800-555-5556
E-Mail Address:	
Agent Responsible for the Warehouse (if different from Requestor)	
Name of Agent	
Address of Agent:	
Telephone:	Fax:
E-Mail Address:	
2. Warehouse Information	
Name of Warehouse: Bilco Building 14	
Address: 123 Harbour Street, Gloucester City, NJ 14567	
Telephone: 800-565-1234	FAX: 800-565-1235
E-Mail Address: jsmith@bcp.com	Company Website: www.bcp.com

Form T-CT-W-A-123 Approved on 3/23/2009 Revision: 01 Page 1 of 3

The USDA is an equal opportunity provider and employer.

Figure 6-4-7 Example of a Completed Application for USDA Warehouse Approval, page 1 of 3

Attach a warehouse schematic(s) that includes the following: *All information must be clearly referenced in supporting technical documents.*	
Requirement	**Reference Page or Section**
(a) Delineations of treatment areas to be certified	See page 5
(b) Cubic capacity of each treatment area to be certified	See page 3
(c) Total cubic capacity of warehouse	See page 2
(d) Sensor location	See page 4
(e) Sensor number	See page 4
(f) Sensor type (air or pulp)	See page 1
(g) Treatment area identifiers	See page 2
(h) Airflow direction	See page 1
(i) Refrigeration unit location	See page 1
(j) Recorder location	See page 1
Also attach a description of the method used to segregate fruit under PPQ treatment from other foreign or domestic articles.	

3. Refrigeration Unit

Make of Refrigeration Unit: Carrier	Model of Refrigeration Unit: GSE
Location of Refrigeration Unit: Equipment Room 1	Model Year: 1998
Airflow maximum rate (cfm): 1250	Airflow direction: East to West

4. Temperature Recorder

Manufacturer: ACR	Model: Smart Recorder	Model Year: 2005
Serial number(s): 123545647899, 1234564789, 123789456		Quantity of recorders:
Location of unit(s): Portable		

Accuracy:
Recorder (Must be accurate to within +/- 0.15 C in the range of +/- 3.0 C): 0.1
Recorder plus Sensor (Must be accurate to within +/- 0.30 C in the range of +/- 3.0 C): 0.3

Is this a USDA approved recorder?: Yes

5. Temperature Sensors

Manufacturer: ACR	Model: 105	Model Year: 2005
Accuracy (Must be accurate to within +/- 0.15 C in the range of +/- 3.0 C): 0.1		

Length of sensor cable (must be long enough to reach fruit in all parts of the stack): 15 meters

Do sensor numbers matches the numbers on the recorder: Yes ☑ **No** ☐

X ______________________ ______________________
Requestor's Signature **Date *(mm-dd-yyyy)***

Form T-CT-W-A-123 Approved on 3/23/2009 Revision: 01
Page 2 of 3

The USDA is an equal opportunity provider and employer.

Figure 6-4-8 Example of a Completed Application for USDA Warehouse Approval, page 2 of 3

****************DO NOT WRITE BELOW – FOR USDA PURPOSES ONLY – DO NOT WRITE BELOW***************

Date Application Received_______________________________

Reviewer____

Approved______ Not Approved______ Date________________

Reviewer's Signature____________________________________

Comments:

Form T-CT-W-A-123 Approved on 3/23/2009 Revision: 01
Page 3 of 3

The USDA is an equal opportunity provider and employer.

Figure 6-4-9 Example of a Completed Application for USDA Warehouse Approval, page 3 of 3

Contact Information

USDA-APHIS-PPQ-CPHST-AQI-Raleigh
1730 Varsity Drive
Suite 300
Raleigh, NC 27606
Phone: 919-855-7450
FAX: 919-855-7493
Email: cphst.tqau@aphis.usda.gov

6

Treatment Manual

Certifying Facilities

Certification of Hot Water Immersion Facilities

Contents

Introduction

Quarantine treatment by immersion in hot water is used primarily for fruits that are hosts of tropical fruit flies. Exposing the fruit to a temperature of at least 115 °F (46.1 °C) for specific periods of time (depending upon the specific pest, type of fruit, and size of fruit) constitutes a quarantine treatment. The U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) incorporates this principle of insect control into its regulations to facilitate the importation or interstate movement of certain fruits from areas where tropical fruit flies are the significant pests of concern.

Commercial facilities using hot water immersion treatment are subject to USDA-APHIS, certification on an annual basis. More frequent tests may be required at the option of APHIS. APHIS certification is given solely in conjunction with quarantine treatment requirements.

Important

The certifying official shall check with the manager of the facility to be sure that he is aware of the requirement for using potable water. Whenever water comes into contact with fresh produce, the water's quality dictates the potential for pathogen contamination. To reduce the risk of food- borne illnesses, the water used for washing, treatments, and cooling must be fortified with sodium hypochlorite (household bleach), and constantly maintained at a chlorine level not to exceed 200 ppm.

Preliminary Performance Testing

If the facility has **not** been previously certified by APHIS, the operators should conduct preliminary, informal performance tests on their own (together with an engineer, if needed), to assure themselves that their equipment is in good working order.

By trial and error, the manager of the facility should decide on a tentative temperature set point for their tanks. This should be done by immersing one or more full baskets of fruit into each tank, to be certain that the water temperature (nearest the fruit) reaches at least 115.0 °F (46.1 °C) within 5 minutes. A thermostatic set point for each tank is typically in the range of 115.8 °F to 116.9 °F (46.6 °C to 47.2 °C).

As an option, some hot water immersion systems use an initial higher set point for the first several minutes, then automatically drop to a lower set point for the remainder of the treatment. (If this programming option is used, the change to the second set point must be done automatically, **not** manually.)

Data from the preliminary tests need **not** be recorded on official forms. These data, however, must be presented to APHIS, as evidence that the facility is ready for the official performance test.

Once the facility has been officially certified, APHIS does **not** require the facility to present preliminary performance test data in subsequent years, except when there have been major engineering changes to the equipment.

New Procedures for Hot Water Facility Certification and Commercial Testing

These guidelines have been issued to provide a more accurate reflection of the tank's coldest temperatures. They are **not** intended to replace existing procedures, but to be used in conjunction with the current operational framework. These guidelines are only needed for facilities **not** capturing interior probe temperatures with actual sensors and are **only** in place until each facility begins capturing interior temperatures with actual sensors. Futhermore, these guidelines will be in effect until each facility develops a procedure for placing probes in the coldest locations of the tank. Facilities already using temporary probes as a routine part of commercial testing can disregard the procedures outlined below. All new equipment and procedures must be approved by the **USDA-APHIS-PPQ-S&T-CPHST-AQI** before implementation.

Refer to **Figure 6-5-1** for information regarding adjusted temperatures and set points:

1 Tank Sensor (Lowest) (°F)	2 Portable Sensor (Lowest) (°F)	3 Adjusted Tank Sensor Temperature[1] (°F)	4 Set Point (°F)	5 Treatment Interval (minutes)	6 Pulp Temperature (°F)
116.0	115.9	115.1	117.0	5	78
115.5	115.4	115.1	116.0	6 - 30	78
115.3	115.2	115.1	115.5	31 - 60	78
115.1	115.0	115.1	115.3	61 - 75	78
115.0	115.0	115.0	115.0	76 - 90	78

Figure 6-5-1 Hypothetical Certification Results: Treatment Tank with Multiple Set Points

1 Adjusted Tank Sensor Temperature Equation:

Take the amount of temperature exceeding 115.0 from Portable Sensor (Lowest) in column 2, and subtract it from Tank Sensor (Lowest) in column 1 (116.0 - 0.9 = 115.1).

1. Average minimum pulp temperatures must be taken from a minimum of 5 fruit extracted from the coldest fruit before treatment. On certification day, this average pulp temperature becomes the minimum commercial treatment pulp temperature permitted. All fruit must be at or above 70 °F to be hot water treated.
2. The "adjusted tank sensor temperature" is determined by taking the amount of temperature exceeding 115.0 from Portable Sensor (Lowest) in column 2, and subtract it from Tank Sensor (Lowest) in column 1.
3. During certification, establish the set point with its lowest corresponding charted temperature. Document these values on the PPQ Form 482, Certificate of Approval and an attachment in the format of **Figure 6-5-1**.
4. The **Figure 6-5-1** attachment and PPQ Form 482 must be displayed in a prominent location at the facility.
5. During commercial treatments, the "Adjusted Tank Sensor Temperature" is used as the lowest treatment temperature. The commercial treatment fails if the tank temperature is below the "Adjusted Tank Sensor Temperature"

Mango temperatures prior to treatment

During certification, determine and record an average pulp temperature (prior to treatment). Calculate this averaged pulp temperature by averaging pulp temperatures from the 5 "coldest" mangoes before treatment (mangoes extracted from the coldest locations). This temperature becomes the minimum pretreatment pulp temperature allowable for commercial treatments.

Therefore, during subsequent commercial treatments, mangoes must be at or above this minimum temperature before beginning treatment. (Any fruit below 70 °F cannot be treated per manual requirements).

Permanent probe temperatures

During certification, record from the printout/chart each set point with its lowest corresponding charted (permanent probe) temperature. A treatment tank may have one set point or multiple set points. If the tank has multiple set points, these set points are for a fixed length of treatment time. Refer to **Figure 6-5-1** for a detailed explanation. This "adjusted tank temperature sensor" (always above 115.0 °F) becomes the lowest temperature permitted for that set point, or the "standard" at that set point. Commercial temperatures (permanent probe temperatures from the chart/printout) must be equal to or greater than the set point standard for each length of time. Document each "adjusted tank sensor temperature" determined during certification, on the PPQ Form 482, Certificate of Approval and on the attachment to the Certificate.

Procedures for Conducting the Annual APHIS Performance Test

To approve the facility, the APHIS officer (or designated representative) shall take the following steps:

1. If the facility has **not** been previously certified, or if modifications have been made since the last performance test, compare the plans and drawings with the actual installation.

   Clearly show dimensions, water circulation, temperature sensing and recording systems, and safeguarding precautions in the plans and specifications.

2. Conduct a performance test (at least annually), during an actual treatment (as described below), to determine (or verify) a temperature “set point” for the system, and to determine the minimum duration of time required between the immersion of successive baskets of fruit within the same tank.
3. Inspect the heating, water circulation, and alarm systems, and check to see that all necessary safeguards (including screens, fans, locks, and air curtains) are secure and operational.
4. Calibrate the portable sensors, recording the results on APHIS form 205 (or a plain sheet of paper).
   - **A.** Using a factory-calibrated, mercury, non-mercury or digital thermometer as the standard, compare the reading of each portable sensor to the standard, and record any deviation.

   B. To facilitate this process, a specially designed, portable temperature calibrator may be used, which uses either hot air or a swirling hot water bath, set at approximately the temperature at which treatments will take place; a treatment tank can also be used for this purpose, provided that the water is kept in motion.

5. Examine the calibration of the tank's permanent RTD sensors, and record the results on APHIS form 206.

6. Tape the cords of three or four portable "water temperature sensors" to the skins of three or four selected fruits in each basket. (Do **not** cover the end of the sensor with tape.)

7. Insert a portable "pulp temperature sensor" approximately one centimeter into the flesh of one or more fruits in the tank.

   A. Hold the sensor in place with tape.

   B. It is **not** necessary to have a pulp temperature sensor in each basket.

8. Set the fruit at ambient temperature (70 °F or above) immediately prior to the performance test.

   If the fruit is pre-warmed by artificial means, note this routine as a condition of approval that should be followed for each commercial treatment.

9. On the location diagram (APHIS form 207), show the relative position of each portable sensor used in the test, and indicate whether it is a "water" or a "pulp" sensor. Number each sensor.

10. While the fruit are immersed in water, use an electronic thermometer to monitor the temperatures of each portable sensor at various times throughout the test. (record this information on APHIS form 208 for each tank.)

   As a second option, a portable, automatic recording instrument can be used; it must, however, operate independently from the temperature recording system installed at the facility.

11. During the performance test, lower the baskets of fruit into the hot water immersion tank.

   A. Closely monitor the "water temperature sensors" during the first five minutes of treatment.

   APHIS requires that the temperatures of all "water temperature sensors" must reach at least 115 °F (46.1 °C) within 5 minutes; if **not**, in order to achieve the 5-minute temperature recovery requirement, repeat the test using other fruit, using a slightly higher water temperature set point, and/or a slightly longer time interval between subsequent basket immersions.

B. Run the test for the full duration (up to 90 minutes, depending upon fruit size).

During that time, all “water temperature sensors” must read at least 115 °F (46.1 °C) at the 5 minute point and beyond; in addition, the “pulp temperature sensor” (or sensors) must read at least 113 °F (45 °C) *by the end of the test.*

Important

It should be noted that APHIS standards for passing the official performance test are higher than the standards accepted for commercial treatments. This is intentional. *During commercial treatments* of mangoes, the water in the tank is allowed up to 5 minutes to reach the minimum treatment temperature of 115 °F after the fruit have been submerged.

Important

The mango hot water schedules also have a built-in tolerance for subnormal temperatures in the range of 113.7 °F to 114.9 °F for up to 10 minutes (in the case of 65 or 75-minute treatments), or 15 minutes (in the case of 90-minute treatments). This tolerance was designed to “save” an ongoing treatment during an emergency situation such as an electrical power outage. However, *for purposes of the official performance test*, all water temperature sensors are required to read at least 115.0 °F within the first 5 minutes, and to maintain temperatures at or above that threshold during the remainder of the treatment.

12. For issuance of a Certificate of Approval (PPQ form 482), submit all supporting documents to the APHIS-Regional Office (or to another APHIS office delegated by the Region).

13. APHIS will certify the facility only when all requirements are met, including *two* successful hot water immersion treatments in each tank, using standard fruit loads.

For annual recertification, however, only *one* successful performance test is required per tank, unless the Work Plan requires additional tests Submit a copy of PPQ Form 482, the corresponding attachment (**Figure 6-5-1**), all forms used in the certification or recertification and printouts from the temperature recorder to **USDA-APHIS-PPQ-S&T-CPHST-AQI**.

Protocols for Foreign Treatment Facilities

Contact the USDA APHIS PPQ Preclearance and Offshore Programs Unit in Riverdale, MD, to obtain protocols for foreign treatment facilities.

Address for Technical Contact

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

Tel: 919-855-7450
Fax: 919-855-7493

6

Treatment Manual

Certifying Facilities

Certification of Niger seed Treatment Facilities

Contents

PPQ Regulation for the Entry of Niger Seeds into the United States

In accordance with the guidance provided in this manual, heat treat Niger seeds (*Guizotia abyssinica*) from any foreign place for possible infestation with noxious weeds seeds or prohibited pathogens at or before the time of arrival into the United States. Conduct the heat treatment in a foreign or domestic APHIS-certified treatment facility.

The Certification Process

Certification of Niger seed treatment facilities includes the following steps:

“Step 1—Submission and Approval of Engineering Construction Plan and Facility Requirements” on **page-6-6-1**

“Step 2—Request Certification for a Treatment Facility” on **page-6-6-2**

“Step 3—Conduct the Certification Test” on **page-6-6-2**

“Step 4—Certification of the Treatment Facility” on **page-6-6-4**

Step 1—Submission and Approval of Engineering Construction Plan and Facility Requirements

The facility submits an engineering construction plan and facility requirements to the appropriate State and country officials and to USDA-APHIS-PPQ-S&T-CPHST-AQI for approval. The plans must include facility dimensions, capacity, heating unit specifications, and temperature/time recording system specifications.

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

Facilities must comply with state, local, and country requirements. Design the equipment in a manner that will maintain the temperature at or above temperatures prescribed in the treatment schedule, T412-a. When the plans and requirements are approved, construct the treatment facility accordingly. Advanced written approval from CPHST-AQI is required for any modification of the original plans.

Step 2—Request Certification for a Treatment Facility

The facility must submit a written request to APHIS-PPQ to request certification of a Niger seed treatment facility. The request should include the following:

- Names, addresses, and phone numbers of the facility, facility manager or supervisor, and plant construction engineer
- Assurance that the facility manager accepts responsibility for facility operations
- Assurance that the required equipment is on-site
- Data from at least two preliminary performance tests indicating the facility meets performance requirements for certification, including copies of completed recorder printouts

Step 3—Conduct the Certification Test

Initial **certification** testing will be conducted by CPHST-AQI in conjunction with PPQ. For the purpose of **recertification**, CPHST-AQI can delegate this responsibility to others.

Equipment and Materials

The treatment facility must supply the following equipment and materials in order to conduct a performance test for certification:

- Copy of plans and specifications showing dimensions and other details of heating and temperature recording systems
- Certified calibrated thermometer (temperature range to at least 270 °F (132.2 °C))
- Stopwatch and tape measure
- Temperature recording system to record temperature and treatment time

Facility Standards and Specifications

To qualify for certification/recertification, the treatment facility must conform to the following minimum standards and specifications:

- An action plan to address any pests that may be associated with the storage, treatment, and shipment of Niger seeds
- Audible alarm or highly visible light on burners or other equipment to indicate that the treatment equipment is **not** operating properly
- Automatic and continuous heating controls throughout the treatment process (manual adjustments are allowed but must not negate the PPQ Form 480 guidelines)
- Gear systems used to control the Niger seed conveyor (if applicable) capable of being adjusted as needed to meet treatment requirements (the speed of the treatment conveyor cannot exceed the speed recorded on the PPQ Form 480)
- Permanent temperature sensors (minimum of 2) placed at the beginning and end of treatment area in the seeds at commercial treatment depth
    - Accuracy of the temperature recording system and permanent sensors must be within plus or minus 0.5 °F (0.3 °C) of true temperature
- Portable temperature sensors (provided by facility or certifier) accurate to plus or minus 0.1 °C and calibrated at least once a year. The sensor must come with a calibration sheet containing correction factors not to exceed plus or minus 0.1 °C. Apply the calibration factors to the portable senor readings.
- Proper sanitation measures to ensure there are no potential breeding grounds for pests on the premises and therefore, little risk of reinfestation or cross-contamination
- Recording system capable of recording temperature readings on a recorder printout in time intervals not exceeding 4 minutes between reading
- Secure valves and controls that affect heat flow to the treatment system to avoid manipulation during the treatment process by unauthorized personnel
- Seed processing equipment with the ability to divert for retreatment any untreated or treated seeds that do **not** meet treatment standards
- Speed indicator located on the conveyor for continuous treatment areas
- System to divert any untreated seeds away from the treated seeds (DO NOT mix treated and untreated seed)

- Treated seeds stored in a location separate from the untreated seeds. The treated and untreated seeds must be handled in a manner to prevent cross-contamination.

Important

The appropriate permits and approval to import Niger seeds must be approved by PPQ Permit Unit prior to shipping the commodity to the United States.

Step 4—Certification of the Treatment Facility

Use the following steps to obtain certification:

1. Record the speed of the belt before Niger seeds are in the treatment area. Place an object at beginning of belt. Use a stop watch or digital watch to record the time for the object to go from the beginning to end of treatment area. The speed must be 15 minutes or greater.
2. Attach approved portable temperature sensors (minimum of 2) to the facility permanent sensors to duplicate the same angle and depth as the permanent sensors (the sensors are located at the beginning and end of the treatment area.)
3. Niger seeds must be at maximum depth during the certification.
4. Treat the seed at 248 °F/120 °C for four or more hours. Seed that passes the certification is considered a positive treatment. The treated seed must pass TZ (tetrazolium) testing as stated in the work plan or compliance agreement.
5. Record the hertz or RPM of the treatment conveyor belt speed during certification. Verify that the speed indicator has been calibrated during the past year. Record the speed of the treatment conveyor belt on the PPQ Form 482.
6. Record the time that the treatment started and stopped on the portable sensor printout and facility recorder printout.
7. Check the system to verify that no cross-contamination has occurred.
8. Place the treated seed in new bags or store in silos designated for treated seed.
9. Verify that all portable sensors recorded 248 °F/121 °C or higher during the 4 or more hour treatment.
10. Ensure compliance with the latest work plan or compliance agreement.
11. Repeat treatment if the certification fails.

If treatment standards are **not** met during performance testing, APHIS will not certify the facility. Provide a copy of the data sheet with explanation as to why the test was **not** acceptable to the facility operator for corrective action.

Certification of the Niger facility and equipment will be given after a successful treatment has been recorded (4 or more hours at 248 °F/120 °C). Upon certification, APHIS will issue a Certificate of Approval (PPQ Form 482). The conditions of approval must contain the following:

- Must operate under the latest work plan or compliance agreement
- Treat the seed for at least 15 minutes at a temperature of at least 248 °F/120 °C. Temperatures below 248 °F/120 °C will nullify the treatment.
- Treatment conveyor belt must operate at a speed not to exceed (x)Hertz or (x) RPM (x= speed of treatment conveyor belt)

6

Treatment Manual

Certifying Facilities

Certification of Forced Hot Air and Vapor Heat Treatment Facilities

Contents

Introduction

Forced hot air (FHA) and vapor heat (VH) treatment facilities must be certified by a qualified APHIS inspector. For brevity, “certification” and “re-certification” will both be referred to as “certification” in this chapter.

For foreign treatment facilities, the physical location of the facility must be approved by the USDA APHIS PPQ Preclearance and Offshore Programs (POP). Domestic treatment facilities are approved by PPQ Field Operations or other entity defined in the workplan. After PPQ or POP approves the facility location and prior to the first facility certification, **USDA-APHIS-PPQ-S&T-CPHST-AQI** must approve the plan and process description. Facilities must conduct tests prior to APHIS certification to ensure that the chamber meets treatment requirements. Certification tests must be carried out prior to treatment at the beginning of the shipping season once per year or whenever APHIS determines that a malfunction or alteration in the system warrants a certification test.

Certification will be granted on the basis of the ability of the chamber to meet treatment requirements, extent and condition of phytosanitary safeguards, sanitary (human health) conditions, and safety conditions. Facilities must be certified for each species (in some cases each variety or subspecies) of fruit, each chamber load configuration (half full, quarter full, etc.…), and, for some species, each size class of fruit treated. For example, mango and papaya are separate species and must be certified separately.

Facilities should be aware that certification may **not** be the only condition under which they may treat fruit for shipment to or within the United States. In addition to certification, there are other requirements such as operational workplans, compliance agreements, and import permits that must be satisfied prior to treatment. Treatment facility managers outside the United States should contact POP. Managers of facilities in the United States or its territories should contact their local PPQ office for a complete list of requirements.

Plan and Process Approval

Prior to the start of facility construction, a detailed plan of the facility's physical characteristics and a written, step by step, description of the all the processes related to treatment must be approved by **USDA-APHIS-PPQ-S&T-CPHST-AQI** (all plans and supporting materials must be submitted in Standard English). Plans and process descriptions for facilities within the United States and its territories must be submitted through the local PPQ office. Facilities outside the United States should consult POP for the appropriate plan submission procedure.

At a minimum, plans must include the following information as diagrams and/or written descriptions:

- Areas designated for fruit arrival
- Areas designated for loading of treated fruit
- Areas for storage of untreated fruit
- Crates, lugs, bins, etc., that will be used to hold fruit during treatment, including total volume and projected fruit capacity
- Delineations of area(s) for storage of treated and untreated fruit
- Description of all processes related to treatment of fruit. These descriptions should reference diagrams with numbers where appropriate
- Hot water bath used for sensor calibration must have an accuracy of ±0.3 °C (0.5 °F)
- Physical location of facility
- Post-treatment cooling system
- Post-treatment packing
- Pre-treatment sorting and grading areas

- Reference thermometer must be approved by **USDA-APHIS-PPQ-S&T-CPHST-AQI** or listed in **Appendix E** of this manual. Calibrate reference thermometers once per year using an approved company listed in **Appendix E** of this manual.
- Systems designed to ensure phytosanitary security of the treated fruit
- Systems designed to ensure water which comes into contact with fruit is free of microbial or any other contaminants that may adversely affect human health
- Temperature recording system requirements
  - Permanent and portable sensors and the temperature recorder must have an accuracy of ±0.3 °C (0.5 °F) and must be approved by **USDA-APHIS-PPQ-S&T-CPHST-AQI** or listed in **Appendix E**.
  - Permanent sensors issued by the chamber manufacturer (not portable sensors) must be platinum 100-ohm resistive thermal detectors (RTD). The sensor unit must be within the distal 1 inch (2.54 cm) of the sensor. The sensor must have an outer sheath of 0.25 inches (6.4 mm) or less in diameter.
  - Recorder must be capable of printing the date, time, temperature (°F or °C), and alarms.
- Treatment chamber including heating system, crate arrangement within the chamber, and air flow

The number of permanent sensors is determined by the facility manufacturer. The APHIS official is responsible for facility approval and has the option to increase the number of permanent sensors as determined during chamber certification.

The process of reviewing the plans and process descriptions may take as long as sixty days and subsequent requests for additional information may further extend this time. Facilities should take this time constraint into account when developing a project timeline. Facilities will receive a letter granting plan approval or describing plan deficiencies. Plan approvals expire one year from the approval date if the facility has **not** been certified.

Preliminary Performance Testing

Following plan approval, the facility should be built according to the facility engineered plans. If deviations from the plans (including changes to the heating and temperature recording systems) are necessary, **USDA-APHIS-PPQ-S&T-CPHST-AQI** must approve these changes. Submit changes in a manner similar to that described in **Plan and Process Approval**.

After construction is completed, the facility must be tested to be sure it can meet all treatment requirements. These trials should test the ability of the treatment chambers to heat a full (maximum) load of fruit to according the treatment guidelines. Any problems or deficiencies found in the facility must be corrected and the preliminary tests must be re-run until all treatment requirements are met. After the facility representative is satisfied that the treatment system is running properly and can fully meet treatment requirements, they must submit results of the test to **Preclearance and Offshore Programs** or the local APHIS office for review.

Facilities will be provided with specific requirements as part of the plan approval letter. General requirements for test result submission are as follows:

- Amount, type, and size of fruit in load and in each crate
- A diagram of chamber that shows location of each permanent sensor
- Time and temperature data from the test run(s)

After POP reviews the results from the preliminary performance test, they will issue an approval or rejection letter. If approval is granted, the facility representative can then schedule an official certification test.

Official Certification Testing

The official certification test has two main components:

1. Calibrating the portable and permanent sensors
2. Thermal mapping (cold spot mapping)

These steps are discussed below in detail. Complete a certification test for each combination of fruit species, chamber load configuration, and, in some cases, fruit size class.

Calibrating the Sensors

If the facility is outside the United States, it is the responsibility of the exporter to provide sensors for the certification procedure. Temperature sensors can be either permanent or portable.

NOTICE

Use only sensors approved by **USDA-APHIS-PPQ-S&T-CPHST-AQI**. Refer to **Appendix E** for a list of approved sensors.

The number of portable and permanent sensors is determined by the APHIS certifying official. The APHIS official has the option to increase the number of sensors required.

Calibrate temperature sensors in a swirling hot water bath with a factory calibrated certified reference mercury, non-mercury, or digital thermometer with 0.1 °C (0.2 °F) graduations as a standard. The temperature of the swirling hot water bath must consistently read the treatment temperature on the certified reference thermometer. Place temperature sensors into the hot water bath and keep them there until the certified reference thermometer reads the treatment temperature for 10 consecutive minutes. After the temperature stabilizes, remove the sensors and read the data. Do **not** use any sensor that deviates by more than ±0.3 °C (0.5 °F) from the treatment temperature. Record the greatest deviation for each sensor as the correction factor for that sensor. Any sensor that cannot be calibrated or repaired may not be used.

Important

Refer to **Appendix E** for a list of approved digital thermometers.

Thermal Mapping

Thermal mapping determines the placement of sensors in the chamber. Because the sensors will be placed in the coldest areas of the chamber, this process is also referred to as “cold spot mapping” or “cold spot testing”. The sensors are placed throughout the chamber and the treatment is conducted. The sensors that took the longest time to record treatment temperature represent colder areas of the chamber. The thermal mapping procedure is as follows:

1. Based on basic thermodynamics and data from the preliminary performance test, develop hypotheses about which regions of the chamber are most likely to have cold spots. This will be based primarily on the direction of the air flow in the chamber. Chambers in which air flows in a single vertical direction will generally have cold regions in portions of the load that come into contact with the heated air last. For example, if the chamber delivers hot air from the bottom, the top of the load is likely to take longer to heat up because the fruit at the bottom absorbs heat first. In chambers where the air flow changes direction or the air delivery is horizontal, it may be more difficult to form these types of hypotheses.
2. The fruits selected for the test must be similar in size, ripeness, and variety. Sort the fruit and select a subset totaling the number of sensors plus 20 percent. The difference between the heaviest and lightest fruit must not be more than 5 percent or higher (at the discretion of the certifying official) of the heaviest fruit’s weight.
3. Place one sensor in each of the largest fruit collected. Place the most sensitive portion of the sensor in the area of the fruit pulp most resistant to temperature change, usually the center of the fruit or close to the pit.

4. Based on the hypotheses formed in #1 above, place the majority of the sensors in the areas thought to be cold regions. In order to verify the hypothesis, place a portion of the sensors in the areas thought to be warmer. If no hypotheses were formed in #1 above, sensors must be placed in a systematic pattern that can provide a complete thermal map of the entire load.

NOTICE

Each chamber may require a different number of sensors depending on factors such as the chamber size, chamber dimensions, air flow patterns, and size and species of the fruit. Typically, a chamber approximately the size of a standard 40 ft. shipping container will require about 60 sensors.

5. Create a map of the chamber that shows the relative horizontal and vertical location of each sensor.
6. Conduct the treatment.
7. Remove the sensors and read their data.
8. Determine the amount of time each sensor took to reach treatment temperature. The sensors which required the longest time to reach treatment temperature indicate cold spots.

NOTICE

All sensors must reach treatment temperature.

9. Create a map of the cold spots based on the map created in step #5 and the analysis completed in step #8.
10. Repeat this process for each load/volume configuration to ensure that correct and consistent cold spots are found. Results from the two consecutive tests must be similar.
11. Based on the conclusion of two consecutive tests, create a map showing the location of each permanent temperature sensor for each load/ volume configuration.

Important

If thermal mapping shows that difference in the time required to reach treatment temperature between any two sensors is greater than 2 hours, the chamber will **not** be certified.

A facility cannot perform a commercial treatment between recertification tests.

Conducting a Test Treatment

Conduct a test treatment in order to verify that the chamber is capable of meeting treatment requirements and for any of the following situations:

- A new facility is approved

- The heating system is changed
- The recording system is changed

Test treatments are only required for the maximum load/volume configuration that the facility will be certified for and may be done in conjunction with the thermal mapping. The procedure for conducting a test treatment is as follows:

1. Place sensors in areas of the load that are thought to be cold spots (based on thermal mapping data).
2. Conduct the treatment.
3. During treatment, inspect the outside of the chamber to ensure it is free of leaks, is operating smoothly, and generally is in good working order.
4. After treatment is completed, review the temperature logs. All sensors must have reached the treatment temperature.
5. After a successful test treatment, continue to **Certification** section.

Certification

Upon successful completion of the facility certification test (as indicated by completion of the APHIS Form 482), the commercial treatments can begin.

A certification test is required once a year, usually at the beginning of the shipping season, if a new heating or recording system is approved, or whenever the system has a malfunction, breakdown, or other failure (excluding malfunction of temperature sensors.)

Verification of Sensor Calibration

Verify the integrity of the temperature sensors daily using the process described in ***Calibrating the Sensors* on page 6-7-4**.

Calibration can also occur whenever any part of the permanent temperature recording system fails or is replaced, or at the discretion of the APHIS inspector.

Documentation

All tests performed during certification must be documented by the APHIS official. A copy of the signed APHIS Form 482, copies of all thermal maps, description of load size limitations, description of any other special limitations placed on the treatment, and any other pertinent addenda or appendices, must be sent to **USDA-APHIS-PPQ-S&T-CPHST-AQI** for final approval.

Contact Information

USDA-APHIS-PPQ-S&T-CPHST-AQI

1730 Varsity Drive, Suite 300
Raleigh, NC 27606

Tel: 919-855-7450
Fax: 919-855-7493

Preclearance and Offshore Programs

Director, Preclearance and Offshore Programs
USDA, APHIS, PPQ, POP
4700 River Road, 4th Floor
Rivderdale, MD 20737

Tel: 301-851-2281

6

Treatment Manual

Certifying Facilities

Certifying Irradiation Treatment Facilities

Contents

Introduction

Certification of irradiation facilities ensures that each facility's equipment and personnel are able to safely, accurately, and consistently administer the required minimum absorbed dose (MAD) to all components of the commodity. This chapter describes the process and requirements for certification of facilities that irradiate agricultural products for import into or movement within the United States.

Facilities, exporters, and others interested in the administrative and operational processes for establishing irradiation programs, applying for permits, and signing compliance agreements can find more information on this USDA APHIS PPQ web site.

PPQ officials reviewing plan approval applications or conducting certification and recertification activities must follow the guidelines in this chapter. If a PPQ official finds that a deviation from these guidelines is necessary, or if a facility requests a deviation, the PPQ official will direct the facility to develop a detailed proposal outlining the need for the deviation. The proposal will be forwarded to **USDA APHIS PPQ S&T CPHST AQI** for review. Following review, CPHST will make a recommendation to the Treatment Cross Functional Working Group (TCFWG) for a decision. The TCFWG will make the final decision on the proposal and the operational unit will communicate the decision to the facility. The process of reviewing a proposal may take as long as 60 days.

Pre-Certification Requirements

Prior to starting any certification work, facilities located in the United States should contact **USDA APHIS PPQ Field Operations** to discuss the certification process and requirements. This discussion will help facilitate the certification process and processes associated with the establishment of an operational program.

Facilities located in countries **other than** the Unites States should contact the National Plant Protection Organization (NPPO) in their country to request information and certification to PPQ via official channels. Foreign facilities should **not** contact PPQ without first consulting with their NPPO.

Plan Approval Application

The first step in the certification process is a review of the “Plan Approval Application for Irradiation Facilities”. Contact **USDA APHIS PPQ Field Operations** for the Application. The Application collects information about the facility, including radiation source type and strength, standard operating procedures, facility diagram, and other information that helps PPQ understand how the facility operates.

Facilities located in the United States should send the completed Application to PPQ Field Operations. Facilities located in countries **other than** the United States must submit their Applications through their NPPO, which will then forward the Application to **USDA APHIS International Services (IS)**. The Application will then be forwarded to PPQ Phytosanitary Issues Management (PIM), and Preclearance and Offshore Programs (POP) (**Figure 6-8-1**).

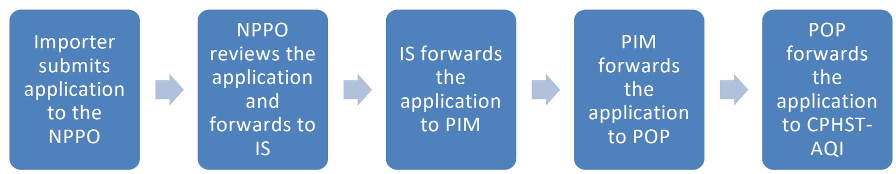


Figure 6-8-1 Flow Diagram for Plan Approval Application for Irradiation Facilities in Countries Other Than the United States

The CPHST review may take as long as 60 days. Facilities are encouraged to submit their Applications well in advance of the desired certification date. Following review, CPHST will communicate the results of the review through the appropriate operational unit, including Field Operations and POP. The results may be approval of the Application or a request for additional information or clarification.

Once the Application is approved by CPHST, an onsite certification inspection can be scheduled. The appropriate operational unit will work with the facility to schedule a date for the certification inspection. CPHST will provide a copy of the Application, along with any notes or relevant information to the certifying official. This information will help prepare the certifying official.

Certification Requirements

Certification will include a review of the following:

- Dosimetry system
- Phytosanitary safeguards
- Standard operating procedures and documentation
- The facility structure

- Treatment and certification records
- Other processes, procedures, equipment or infrastructure that may affect treatment or safeguarding

Prior to conducting the certification activities, the certifying official must:

- Carefully review the Plan Approval Application to gain a full understanding of the processes, procedures, and systems used at the facility
- Develop an agenda with the facility to ensure that the official is able to observe or examine all the necessary minimum processes, procedures, and/or systems required for certification
- Familiarize themselves with the American Society for Testing and Materials (ASTM) standards that apply to the facility. **See "ASTM Standards" on page-6-8-13**.
- Review the standards for selection and calibration of dosimetry systems, estimating uncertainty, processing standards, and the standards specific to the routine dosimetry system

Certification by the National Nuclear Regulatory Authority

For facilities using radioactive isotopes, certification by the National Nuclear Regulatory Authority (NNRA) of the country in which the facility is located is one of the most important things to verify during certification. This certification is important because it indicates that the facility meets national and international standards for safety, security, and monitoring. In the United States, some States have agreements with the U.S. Nuclear Regulatory Commission (NRC) that allow agencies in those states to issue the certifications. Certifying officials who certify facilities must verify that the certificate issued by the NNRA is current.

Approved Source

Three sources of radiation are approved by APHIS for phytosanitary treatments:

- Electrons generated from machine sources up to 10 MeV (eBeam)
- Radioactive isotopes (gamma rays from cobalt-60)
- X-rays (up to 5 MeV)

The certifying official must verify that the facility is using one of these sources by examining the facility's records and/or verifying that standard operating procedures (SOPs) are in place that ensure delivery of radiation at the appropriate energy level.

Dosimetry System

The routine dosimetry system is critical for accurate and precise measurement of dose. Measurements of dose may not provide assurance that the proper treatment was delivered if the dosimetry system is not properly configured, calibrated, operated by qualified individuals, and precise in the appropriate dose range. The certifying official must ensure that the dosimetry system, and the management and operation of that system, meet the requirements in this chapter.

The facility's routine dosimetry system must follow guidance in ISO/ASTM standard 51261 "*Standard Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing*" and other ASTM standards that specifically address the routine dosimetry system in use. Facility staff should be well-versed in the applicable standards and have copies on hand for reference. **See "ASTM Standards" on page-6-8-13**.

Absorbed Dose Range

The facility's routine dosimetry system must be accurate and precise in the dose range required for PPQ treatments. When selecting a routine dosimetry system, facilities must follow guidance from dosimetry system-specific ASTM standards to determine which systems meet PPQ's dose range requirements. For example, ISO/ASTM 51310 "*Standard Practice for Use of a Radiochromic Optical Waveguide Dosimetry System*" provides guidance that "The absorbed dose range is from 1 to 10,000 Gy for photons.". Because this range includes the PPQ irradiation treatments, this is an acceptable dosimetry system. **See "ASTM Standards" on page-6-8-13**.

Calibration

Calibration of the routine dosimetry system is critical to measuring absorbed dose during routine treatments. Descriptions of calibration techniques and procedures can be found in ISO/ASTM standard 51261 "*Standard Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing*". Facilities must follow guidance in the procedures and techniques described in these standards or in equivalent standards recognized by the APHIS Administrator. The certifying official should review calibration procedures and documentation with the facility staff to verify that the routine dosimetry system has been calibrated using guidance from and adherence to the applicable ASTM standards.

All routine dosimetry system calibration must be traceable to the U.S National Institute of Standards and Technology (NIST). Facilities must keep records that show traceability of calibration to NIST, including certificates of calibration from NIST.

Uncertainty Estimates

Facilities must develop estimates of measurement uncertainty associated with routine dosimetry systems. Uncertainty parameters describe variability in measurement estimates and measurement correction factors can be calculated from these estimates. Each facility must follow guidance in ISO/ASTM 51707

"*Standard Guide for Estimating Uncertainties in Dosimetry for Radiation Processing*". Certifying officials should review uncertainty estimates and related correction values with facility staff and verify that procedures used to develop the estimates and correction values follow guidance in the relevant ASTM standards. **See "ASTM Standards" on page-6-8-13**.

Influence Factors

Dosimetry systems can be influenced by factors that introduce error into estimates of absorbed dose. The influencing factors may include heat, humidity, or light, and the magnitude of the effects of these factors vary between dosimetry systems. Influencing factors are described in ASTM standards for specific dosimetry systems, such as ISO/ASTM 51310 "*Standard Practice for Use of a Radiochromic Optical Waveguide Dosimetry System*". Facilities must follow guidance in these standards when developing procedures to mitigate the effect of influence factors on dose estimates. Certifying officials should verify that facilities are aware of the influencing factors with the potential to affect their dosimetry systems and have taken steps to minimize these effects and/or account for the effect in measurement estimates.

Dosimetry Procedures

The facility dosimetry staff should demonstrate important dosimetry procedures to the certifying official. These procedures should include, but are not limited to:

- Archiving dosimeters
- Calculating estimates of absorbed dose and applying correction factors
- Preparing and reading dosimeters
- Storage and handling of dosimeters
- Tracking dosimeters
- Verification of calibration

The certifying official should verify that these procedures match those in the facility's SOPs and follow the guidance in the applicable ASTM standards.

Standard Operating Procedures

Irradiation facilities must have SOPs that fully describe processes related to treatment of APHIS regulated articles. Additionally, these SOPs must include documentation of important data and events. The SOPs and documentation are critical for ensuring that well designed processes are executed and that records show that the processes were followed. The certifying official should carefully examine the SOPs and documentation to ensure that they are being implemented. Additionally, the facility should demonstrate to the certifying official the procedures related to:

- Analyzing routine dosimeters and reporting results

- Certification of treatment, releasing articles for shipping, loading articles into conveyances
- Creating configurations and placing routine dosimeters on configurations prior to treatment
- Emergency shutdown and natural disaster preparedness
- Inspection of conveyances
- Managing pest detections and disposal or destruction of infested and/or untreated articles (information on disposal and destruction for facilities in the United States can be found in the *Manual for Agricultural Clearance*)
- Maps of agricultural production areas within a four-square mile area (for U.S. facilities in AL, AZ, CA, FL, GA, KY, LA, MS, NV, NC, SC, TN, TX, VA)
- Pest trapping, monitoring, and control
- Post-treatment handling of articles and collection of routine dosimeters
- Receiving articles and preparing them for treatment
- Safeguarding or protecting articles from potential pest infestation pre- and post-treatment
- Verifying article, package condition, and package weights and labeling
- Other procedures the PPQ official deems appropriate

Change Control

All facilities **must** maintain a change control system for managing changes to SOPs and documentation. The change control system should be designed to capture information about changes to the SOPs and documentation. This system should collect information about:

- Details about the change to the SOP or document
- The person, or people, who authorized the change to the SOP or document
- The reason the change was made to the SOP or document
- When the SOP or document was changed

Additionally, the change control system **must** include processes for ensuring that old SOPs and documents are retired or no longer available for use.

The certifying official **must** review this system with the facility staff to ensure that the change control system is properly implemented.

PPQ Specific Data Collection and Storage Requirements

PPQ has program specific data storage requirements that all facilities must meet. All facilities **must** store the following general records:

- Configuration and dose mapping records for each commodity that is treated
- Dosimetry system calibration records
- Ionizing energy source
- Operational Workplan(s) for the commodities treated at the facility
- PPQ Form 482, Certificate of Approval
- PPQ Treatment Schedule(s)
- PPQ Compliance Agreement
- Record(s) of training and credentials of facility employees
- Written agreements with participating packing houses (for facilities located outside the United States only)

Additionally, each facility **must** have a system for collecting and storing information related to each treatment. The following information **must** be stored for at least one year:

- Date of irradiation treatment
- Dosimetry data for each PPQ treatment
- Evidence of compliance with the prescribed treatment
- Irradiation processor's certificate of treatment
- Lot number (except for interstate movement)
- Name and quantity of article treated
- Packinghouse code (PHC) assigned by the NPPO of the exporting country to the packinghouse where the articles were packed (except for interstate movement)
- Prescribed treatment
- Production unit code (PUC) assigned by the NPPO of the exporting country to the area where the articles were produced (except for interstate movement)
- Treatment identification number (TIN)

Staff Training

All facility personnel with treatment-related responsibilities **must** have received training in applicable standards, PPQ treatment requirements, applicable operational workplans, and facility SOPs and documentation systems. Training should be documented and available for review by the inspecting official. Additionally, the inspecting official should evaluate the knowledge of facility staff by requesting that they demonstrate operations, as described in the **Standard Operating Procedures** section.

Infrastructure

Facilities may be designed and built to meet the needs of the operator and must meet international safety and security requirements. However, there are several PPQ specific requirements that **must** be met:

- Inspection area
  - The facility must have an area for inspection of articles and packages. Facilities located in the United States must have scales for verification of box and load weights. Facilities located outside the United States must be equipped with cutting boards, knives, magnifying glass, and scales for use by PPQ officials.
- Internet connection
  - The facility must have a high speed Internet connection that allows uninterrupted connection to the Irradiation Reporting and Accountability Database (IRADS).
- Physical barrier between treated and untreated articles
  - The facility must have a sturdy physical barrier that separates the areas where untreated and treated articles are present. The barrier may have a door for personnel or equipment to pass through. However, this door must remain closed when not in use.
- PPQ workspace
  - The facility must set aside an area for the PPQ official to work. This area should include a desk, chair, and access to high speed Internet.

The certifying official must verify that the infrastructure is in place and functional.

Safeguarding

Facilities **must** have phytosanitary safeguards in place to prevent pest infestation and movement of pests. Safeguarding requirements may vary depending on the location of the facility, the proximity of host crops, and the risk of pests associated with commodities treated at the facility. PPQ operational staff will develop safeguarding requirements for each facility based on the unique circumstances at each facility. However, safeguarding requirements frequently include measures such as:

- Air curtains
- Cold storage areas

- Double doors
- Screens on windows
- Sealed cracks or holes that insects might move through

Process Configurations

During the certification activity, each facility **must** test at least one process configuration. This test must be observed by the certifying official. This initial test helps ensure that the facility fully understands the PPQ process configuration, testing, and approval process, and can successfully conduct the testing. Additionally, the configuration test also serves to provide evidence that the facility can deliver a dose in the required range.

Contact **USDA APHIS PPQ Field Operations** for more information on process configurations.

Facility Compliance Agreement

Each PPQ certified facility must have a compliance agreement (or equivalent) in place prior to certification. There are three standard compliance agreements, one each for:

- Facilities in the United States that treat articles imported from foreign countries
- Facilities in the United States that treat articles for interstate movement
- Facilities located outside the United States

These standard compliance agreements may be modified to include information specific to a facility or specific risks associated with the articles that may be treated at the facility. Operational managers must review and approve modifications to the compliance agreements.

NOTICE

Compliance agreements will be reviewed annually by PPQ.

Important

The compliance agreement between PPQ and the irradiation facility is different from the compliance agreement between PPQ and importers. Refer to the USDA APHIS PPQ Irradiation web site for more information on compliance agreements with importers.

PPQ Form 482 Certificate of Approval

When the certification activity is complete and the certifying official is satisfied that all requirements are met, the certifying official will issue a PPQ Form 482 Certificate of Approval. This form is the official certificate, and once the facility receives the Form 482 it may begin routine treatments, provided it has a current compliance agreement.

The certifying official should send electronic copies of the PPQ 482 to **USDA APHIS PPQ S&T CPHST AQI** and **USDA APHIS PPQ Field Operations**.

Recertification

Periodic certification of irradiation facilities is **not** required. However, facilities will be recertified under the following conditions:

- Changes to operations or infrastructure
  - Examples include but are not limited to altering the manner in which articles are exposed to the source or changing dosimetry systems
- Change to the source
  - Examples include but are not limited to changes to the equipment that delivers radiation, changing the cobalt configuration, or increasing or reducing source strength not due to natural decay
- Management change
  - Change in management that results in new processes or procedures that change operations at the facility
- Problems with the facility
  - Examples include but are not limited to the inability to accurately measure dose or the failure or inability to follow SOPs or document processes

Facilities that are unsure if they require recertification should contact the appropriate operational unit.

Certified facilities must provide at least 90 days’ notice prior to making changes to the radiation source or changes to operations or infrastructure. Notice of change in management or problems at a certified facility must be made within 14 days. All information related to changes in source, occurrence of problems, change in management, and/or changes to operations or infrastructure should be detailed and specific, and clearly describe the situation and the steps the facility is proposing to address any issues.

Facilities located in the United States should send recertification notifications to **USDA APHIS PPQ Field Operations**. Facilities located in other countries must submit their recertification notifications through their NPPO, which will in turn forward it to APHIS IS. The information will then be forwarded to PIM and POP.

In some cases, recertification will not require an onsite recertification inspection. Operational staff will review requests for recertification and decide whether an onsite or remote recertification is appropriate.

Adding Cobalt 60

One of the most common reasons for recertification is the addition of new cobalt 60 to increase total source strength. When cobalt 60 is added to an irradiator, the facility must characterize the dose distribution of the new source configuration. Facilities must follow the source characterization as described in ISO/ASTM standard 51702 "*Standard Practice for Dosimetry in a Gamma Irradiation Facility for Radiation Processing*". Generally, the goal of this characterization will be to describe the dose distribution of the new source and its affects, if any, on the dose delivered to articles during treatment.

Facilities should send the written results of the source characterization to PPQ operational units when the characterization is complete. These results should include the following:

- A detailed and specific narrative that describes the characterization process that was followed
- Analysis of the characterization data along with a detailed and specific explanation of the analysis
- Proposed course of action, including proposed actions for changing existing process configurations
- The data from the characterization study

PPQ will review the characterization information and determine if the facility's proposed course of action is appropriate and if the facility can be recertified.

Audits

Onsite audits of facilities may be performed from time to time by PPQ. These audits may cover a wide range of processes, procedures, and documentation at a facility. Facilities should be prepared to demonstrate operational procedures and have records available for review by the PPQ auditor. Audits will be conducted when operational units determine that they are necessary.

Electronic audits may also be performed by PPQ. These electronic audits will generally utilize data from the IRADS system to look for anomalies or indications that treatments are not being applied correctly.

Contacts

ASTM Standards

Copies of the ISO/ASTM methods may be examined at the USDA APHIS PPQ Headquarters Library located at 4700 River Road, Riverdale, MD, 20737. Copies of ISO/ASTM Standard Methods may also be obtained from the American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

USDA APHIS International Services (IS)

A list of International Service offices is located on this web site.

USDA APHIS PPQ S&T CPHST AQI

Nichole Levang-Brilz
email: Nichole.M.Levang-Brilz@aphis.usda.gov

USDA APHIS PPQ Field Operations

Laura Jeffers
email: Laura.A.Jeffers@aphis.usda.gov

6 Certifying Facilities

Treatment Manual

Certifying Facilities for the Heat Treatment of Firewood

Contents

Introduction

Agrilus planipennis Fairmaire (Coleoptera: Buprestidae), commonly known as the Emerald Ash Borer (EAB,)is a wood-boring insect that infests firewood. This destructive beetle attacks all North American species of Ash trees and has been detected in many states across the United States and Canada. For more information on the pest and a map of current quarantine areas, visit the USDA Emerald Ash Borer web site.

The European Gypsy moth (*Lymantria dispar* L.) feeds on over 500 species of trees and shrubs. Potentially, all temperate hardwood growing areas of North America are at risk from attack by the gypsy moth. Despite all attempts to prevent its movement, the gypsy moth has been quite successful in increasing its range along the leading edge of the quarantine area. For more information on the pest and a map of current quarantine areas, visit the USDA Gypsy Moth web site.

Heat treatment is an approved treatment for these two common wood pests. The treatment must occur in a certified heat treatment facility. The purpose of this chapter is to provide guidelines for the certification of a heat treatment facility.

Heat treatment facilities must be certified by a qualified PPQ official. For brevity, “certification” and “re-certification” will both be referred to as “certification” in this chapter.

Certification tests must be carried out prior to treatment to allow movement of wood from the current quarantine areas, or whenever a malfunction or alteration in the system warrants a certification test.

Certification will be granted on the basis of the ability of the chamber to meet treatment requirements, extent and condition of phytosanitary safeguards, and safety conditions.

Facilities should be aware that certification may **not** be the only condition under which firewood for shipment can be moved from quarantine areas. In addition to certification, there are other requirements that must be satisfied prior to treatment:

- An operational workplan
- A compliance agreement
- Appropriate federal, state or local permits

Treatment facility managers should contact their local PPQ office and/or local state departments of agriculture for state-specific requirements.

Plan and Process Approval

Prior to the start of the certification process for a new or existing facility, a detailed plan of the facility's physical characteristics and a written, step by step, description of all the processes related to treatment must be approved by USDA-APHIS. Plans and process descriptions must be submitted through the local PPQ office.

At a minimum, plans must include a description of all processes related to the heat treatment of firewood. These descriptions should reference diagrams with numbers where appropriate. Submit the following information as diagrams and/or written descriptions:

- Areas designated for:
  - Arrival and storage of untreated firewood
  - Loading of untreated and treated firewood
  - Storage of untreated and treated firewood
- Crates, bins, racks etc. used to hold firewood during treatment, including total volume and projected capacity
- Physical location of facility
- Post-treatment cooling system

- Post-treatment packaging
- Pre-treatment sorting and grading areas
- Systems to ensure phytosanitary security of the treated wood
- Treatment chamber including heating system, arrangement within the chamber, and air flow

The process of reviewing the plans and process descriptions may take as long as sixty days and subsequent requests for additional information may further extend this time. Facilities should take this time constraint into account when developing a project timeline. Facilities will receive a letter granting plan approval or describing plan deficiencies. Plan approvals expire one year from the approval date if the facility has **not** been certified.

Official Certification Testing

Following plan approval, facilities seeking certification must be tested to ensure they can meet all treatment requirements. If deviations from the plans are necessary, PPQ must approve these changes prior to testing (changes should be submitted in a manner similar to that described in “Plan and Process Approval”).

The official certification test has three main components: (i) calibrating the temperature sensors, (ii) thermal mapping (cold spot mapping), and (iii) conducting an actual test treatment. These steps are discussed below in detail. A certification test must be completed for each chamber load configuration.

Calibrating the Temperature Sensors

Important

Only temperature sensors approved by USDA-APHIS may be used. Contact the PPQ personnel listed in ***Contact Information* on page 6-9-6**.

Calibrate all temperature sensors prior to facility certification tests and a minimum of once annually thereafter. In addition, if a permanent temperature recording system is used, the system must be recalibrated when any part or portion of the system is repaired or replaced. Calibrations must be performed by the temperature sensor manufacturer or by manufacturer trained technicians. All temperature sensors must read within +/-0.5 °C (0.9 °F) of the treatment temperature.

Thermal Mapping

Thermal mapping determines the placement of permanent temperature sensors in the chamber. Because the permanent temperature sensors will be placed in the coldest areas of the chamber, this process is also referred to as cold spot mapping or cold spot testing. The process of thermal mapping is relatively simple; portable temperature sensors are placed throughout the chamber and the treatment is conducted. The sensors that took the longest time to record treatment temperature represent colder areas of the chamber.

Important

Each facility may require a different number of portable sensors depending on factors such as the chamber size, chamber dimensions, and air flow patterns. A facility that is less than or equal to 10,000 ft^3 will require about 20 sensors for thorough temperature mapping. Contact the PPQ personnel listed at the end of this chapter for help in determining the number of sensors required for a facility larger than 10,000 ft^3.

The thermal mapping procedure is as follows:

1. Drill holes a minimum of 4 inches deep into the ends of the largest pieces of wood. The diameter of the hole should be equivalent to the outer diameter of the sensor.
2. Place the sensors in the wood and in various locations throughout the entire chamber.
3. Create a diagram of the chamber that shows the relative horizontal and vertical location of each temperature sensor.
4. Conduct the treatment.
5. Remove the temperature sensors and analyze the temperature data.
6. Determine the amount of time each temperature sensor took to reach the treatment temperature. The temperature sensors that required the longest time to reach treatment temperatures indicate cold spots.
7. Create a map of the cold spots based on the map created in step #3.
8. Repeat this process for each load and volume configuration to ensure that correct and consistent cold spots are found.
9. Based on the thermal maps created in step #7, create a map to indicate where temperature sensors should be placed for each load and volume configuration during daily operational treatments.

Conducting a Test Treatment

A test treatment must be performed to verify that the chamber is capable of meeting treatment requirements. Test treatments are only required for the maximum load/volume configuration that the facility will be certified for and may be done in conjunction with the thermal mapping described above. The procedure for conducting a test treatment is as follows:

1. Place permanent temperature sensors in areas of the load that are thought to be cold spots (based on thermal mapping data).
2. Conduct the treatment.
3. After treatment is completed, review the temperature data from the temperature sensors. All temperature sensors must have reached the treatment temperature.

These trials should test the ability of the treatment chambers to heat a full (maximum) load of wood according to the treatment guidelines. Any problems or deficiencies found in the facility or with the treatment must be corrected and the tests run again until all treatment requirements are met. After the facility representative is satisfied the treatment system is running properly and can fully meet treatment requirements, test results must be submitted to USDA-APHIS for review.

The process of reviewing results from preliminary performance tests may take as long as 30 days. After USDA-APHIS-PPQ reviews the results from the preliminary performance test, a letter will be issued either approving or rejecting the results. Once the facility is approved, treatment and shipment may begin.

Frequency of Certification and Temperature Sensor Calibration

A certification test is required once a year, and/or whenever the system has a malfunction, breakdown, or other failure that requires modifications that alter the manner in which the system functions. This excludes the replacement of a faulty temperature sensor.

All temperature sensors must be calibrated at the discretion of the PPQ official, annually, or whenever any part of the temperature recording system fails or is replaced. Use the process described in the “Calibrating the Permanent Temperature Sensors” section of this chapter.

Documentation

All tests performed during certification must be documented by the PPQ official. A copy of the signed APHIS Form 482, copies of all thermal maps, description of load size limitations, description of any other special limitations placed on the treatment, and any other pertinent addenda or appendices, must be sent to USDA-APHIS-PPQ for final approval.

Contact Information

USDA-APHIS-PPQ
Federal Program Manager, Philip Bell
920 Main Campus Dr. Ste 200
Raleigh, NC 27606-5210
Phone: 919 855-7300
Philip.D.Bell@aphis.usda.gov

USDA-APHIS-PPQ
National Program Coordinator, Paul Chaloux
4700 River Road, Unit 137
Riverdale, MD 20737
Phone: 301-851-2064
Paul.Chaloux@aphis.usda.gov

USDA-APHIS-PPQ
Mitch Dykstra
2200 Garden Drive, Suite 200A
Seven Fields, PA 16046
Phone: 724-776-1270

7 Treatment Manual

Hazard Communication Standard

Safety Data Sheets

Contents

Overview

Safety data sheets (SDS) provide information about hazardous chemicals that are used in the workplace. This information is necessary to safely handle hazardous chemicals.

OSHA Requirements

The Occupational Safety and Health Administration (OSHA) requires that the hazards of all chemicals produced or imported be evaluated, and information concerning chemical hazards be communicated to employers and employees by means of a comprehensive hazard communication program. A hazard communication program should include, but **not** be limited to, the following:

- Developing and maintaining a written hazard communication program for the workplace, including lists of hazardous chemicals present at the workplace
- Developing and implementing employee training programs regarding hazards of chemicals and protective measures
- Labeling of containers of chemicals in the workplace, as well as containers of chemicals being shipped to other workplaces
- Preparation and distribution of SDS to employees and downstream employers

Employers who do **not** produce or import chemicals need only focus on those parts of 29CFR 1910.1200 that deal with establishing a workplace program and communicating information to their workers. Refer to the OSHA Hazard Communication Standard for a general guide for employers to help determine the compliance obligations under the regulation. The Hazard Communication Standard includes the following topics:

- Becoming Familiar With the Rule
- Identify Responsible Staff
- Identify Hazardous Chemicals in the Workplace
- Preparing and Implementing a Hazard Communication Program
  - Labels and Other Forms of Warning
  - Safety Data Sheets (SDS's)
  - Employee Information and Training
  - Other Requirements
- Checklist for Compliance
- Further Assistance

7

Treatment Manual

Emergency Aid and Safety

Guidelines for Managing Pesticide Spills

Contents

Introduction

This document provides instructions for dealing with pesticide spills during program operations. “Pesticide spill” refers to any unplanned spill or leakage into the environment that occurs during storage, use, transport, or disposal of pesticide. Examples include aircraft and surface vehicular crashes, jettisoning pesticide cargoes from the air, and leaks or other equipment failures. After a pesticide spill, the responsible program person should evaluate the situation and begin appropriate corrective measures. (Use **Figure 7-2-2** to identify your responsible program contact.)

The Officer-in-Charge (OIC), Contracting Officer's Representative (COR), or other responsible program official should prepare a site-specific plan based on the generic plan, **Emergency Spill Procedures**. (Refer to **Figure 7-2-1** for an abbreviated plan. Make a copy of this figure, and keep it for your pocket reference.) Prepare the plan before program operations begin by filling in the names, telephone numbers, and other required information. Specific objectives of each plan include:

- Protecting people working in the spill area.
- Preventing or minimizing the risk of further pesticide exposure to people, animals, and the environment.
- Cleanup of the area and disposal or detoxification of residual material.
- Notifying Federal, State, and local government officials of the magnitude and details of the pesticide spill.
- Evaluation of the potential impact to the environment based on chemical residues found in environmental components.

____
Responsible Program Contact (Name)

____
(Work telephone number)

____
(Home telephone number)

IF A PESTICIDE SPILLS TAKE THE FOLLOWING STEPS:

1. **Evaluate**. (Take care of people first!!!)
2. **Safety and First Aid**. The most immediate concern is for the health and well-being of persons in and around the area.
3. **Call 911** for fire/rescue squad to obtain medical assistance for injured or contaminated persons.
4. **Contamination Control**. Consult pesticide label & MSDS for appropriate protective clothing and hazards (or **CHEMTREC Emergency Hotline (800) 424-9300**).

Figure 7-2-1 Abbreviated Spill Plan, Personal Reference Card (Wallet-size)

Emergency Spill Procedures

Use this section as your guide to prepare a site-specific plan for pesticide spills. (Please, complete the blanks for your specific program.) The following is a summary of factors you must consider when a pesticide spill occurs (details follow this summary):

- Identify Contacts and Telephone Numbers

- Evaluate the Situation
- Safety and First Aid
- Crash Notification
- Contamination Control
- Notification
- Site Security
- Cleanup Techniques
- Decontamination

Identify Contacts and Telephone Numbers

You must know who to contact and where to call if a pesticide spill occurs. **Figure 7-2-2** identifies preliminary information that you will need in case of an emergency. Fill in the blanks for your site-specific plan.

____
(Program name)
____
Responsible Program Contact (Name)
____
(Work telephone number)
____
(Home telephone number)
____
Alternative Program Contact (Name)
____
(Work telephone number)
____
(Home telephone number)

Figure 7-2-2 Emergency Contacts for Pesticide Spills

Evaluate the Situation (Take care of people first!!!)

1. Injury/pesticide exposure. Refer to **Safety and First Aid**.
2. Vehicle or aircraft crash. Refer to **Crash Notification**.
3. Spill containment. Refer to **Contamination Control**.

Safety and First Aid

The most immediate concern is for the health and well-being of persons in and around the area.

1. Call **911** for fire/rescue squad to obtain medical assistance for injured or contaminated persons.
2. Evacuate the immediate area, if necessary get upwind.
3. Remove injured people from the area. (Do **not** move a seriously injured person unless absolutely essential because of the risk of further injury.)
4. Consult the pesticide label and/or MSDS for appropriate protective equipment and hazards.
5. Administer first aid as necessary. see the pesticide's MSDS or contact the nearest poison control center. **Figure 7-2-3** identifies information that you will need in case of an emergency. Fill in the blanks for your site-specific plan.

____
(Center Name)
____
(Telephone)

Figure 7-2-3 Poison Control Center

6. Remove contaminated clothing and wash affected area with soap and water. If eyes are contaminated, flush with clean water.
7. If individuals experience pesticide poisoning symptoms (blurred vision, trembling, nausea, etc.) then transport them to the nearest medical emergency facility. **Figure 7-2-4** identifies information that you will need in case of an emergency. Fill in the blanks for your site-specific plan.

____
____
(Address)
____
(How to get there)

Figure 7-2-4 Medical Emergency Facility

8. Eliminate sources of ignition (e.g., pilot lights, electric motors, gasoline engines, or smoking) to prevent the threat of fire or explosion from flammable vapors.

Crash Notification

1. If the spill involved a vehicle or aircraft crash, contact the local police (911) as soon as possible.
2. If the spill involved an aircraft crash, notify the nearest Federal Aviation Administration (FAA) office. Figure 7-2-5 identifies information that you will need in case of an emergency. Fill in the blank for your site-specific plan.

____
(Telephone number)

Figure 7-2-5 Federal Aviation Administration (FFA) Office

Contamination Control

1. Consult the pesticide label and/or MSDS for appropriate protective clothing and hazards (**or call the CHEMTREC Emergency Hotline at (800) 424-9300**).
2. Try to contain the spilled pesticide at the original site, and prevent it from entering streams, rivers, ponds, storm drains, wells, and water systems as follows:
   - **A.** If possible, reposition the pesticide container to stop further leakage.
   - **B.** Prevent the spill from spreading by trenching or encircling the area with a dike of sand, sand snakes, absorbent material, soil or rags.
   - **C.** If a liquid formulation spills, cover it with absorbent material; however, use absorbent sparingly, since it also becomes hazardous waste. Use no more than necessary.
   - **D.** If a dry formulation spills, securely cover it with polyethylene or plastic tarpaulin to prevent tracking or airborne spreading of dust.

Notification

1. Notify by telephone state officials and the PPQ regional office. Headquarters management will be notified through normal channels.
2. Contact the local Community-Right-To-Know or Emergency Planning Coordinator (often the Fire Marshall). **Figure 7-2-6** identifies information that you will need in case of an emergency. Fill in the blanks for your site-specific plan.

(Name)

(Telephone number)

Figure 7-2-6 Community-Right-To-Know or Emergency Planning Coordinator (Fire Marshall)

3. Call the CHEMTREC Emergency Hotline at **(800) 424-9300**.
4. Notify by telephone the National Monitoring and Residue Analysis Laboratory (NMRAL) in Gulfport, Mississippi, Area Code (601) 863-8124 or (601) 863-1813. NMRAL will provide any supplies needed for sampling environmental components.
5. If the spill involves a large area (4 hectares (10 acres) or more) or you judge that it could affect a large area through runoff or other movement, notify the State Fish and Game Department or equivalent through appropriate channels. **Figure 7-2-7** identifies information that you will need in case of an emergency. Fill in the blank for your site-specific plan.

(Telephone number)

Figure 7-2-7 Fish and Game Department

6. If animal poisoning may occur, notify the Regional Veterinary Services (RVS) Office. **Figure 7-2-8** identifies information that you will need in case of an emergency. Fill in the blank for your site-specific plan.

(Telephone number)

Figure 7-2-8 Regional Veterinary Services (VS) Office

7. If the spilled product is a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) classified hazardous substance or a Superfund Amendments and Reauthorization Act of 1986 (SARA) Title III classified extremely hazardous substance, spills of active ingredient exceeding the reportable quantities may be reportable (see Appendix 8 for information on determining whether to report).
8. If you are unsure as to reporting under CERCLA or SARA look at the product's MSDS or call the National Response Center **(800) 424-8802** for CERCLA, and for SARA call **(800) 535-0202**.
9. Notify your Regional Safety and Health Coordinator. **Figure 7-2-9** identifies information that you will need in case of an emergency. Fill in the blank for your site-specific plan.

____
(Telephone number)

Figure 7-2-9 Regional Safety and Health Coordinator

Site Security

Secure the spill site from unauthorized entry by roping off the area and posting warning signs. If necessary, request assistance from local police. **Figure 7-2-10** identifies information that you will need in case of an emergency. Fill in the blank for your site-specific plan.

____
(Telephone number)

Figure 7-2-10 Local Police

Cleanup Techniques

The following are general techniques. You should consult local hazardous waste officials, the pesticide's label, or its MSDS to determine specific cleanup and disposal techniques. (Refer to **State Hazardous Waste Management Agencies** for a list of local hazardous waste officials.) **Figure 7-2-11** identifies information that you will need in case of an emergency. Fill in the blanks for your site-specific plan.

____
(Name)
____
(Telephone)

Figure 7-2-11 Local Hazardous Waste Official

Adequate cleanup of spilled pesticides is essential to minimize health or environmental hazards. When cleaning pesticide spills, **NEVER WORK ALONE**. Be sure to ventilate the area and use appropriate protective equipment. Clean up dry spills (dusts, wettable powders, granular formulations) as follows:

- Immediately cover powders, dusts, or granular materials with polyethylene or plastic tarpaulin to prevent them from becoming airborne. If outside, weight the tarp ends, especially the end facing into the wind. Begin cleanup operations by rolling up the tarp while simultaneously sweeping up the spilled pesticide using a broom and shovel or dust pan. Avoid brisk movements to keep the dry pesticide from becoming airborne. When practical, lightly sprinkle the material with water to minimize dust. Always use an approved dust mask or respirator when working with dry pesticide materials.
- Collect the pesticide and place it in heavy-duty plastic bags. Secure and label the bags, properly identifying the pesticide and possible hazards. Set the bags aside in a secured area for disposal.
- Clean up liquid spills by placing an appropriate absorbent material (floor-sweeping compound, sawdust, sand, etc.) over the spilled pesticide. Work the absorbent into the spill using a broom or other tool to force the absorbent material into contact with the pesticide. Collect all spent absorbent material and place into a properly labeled metal drum for disposal.

Depending upon the pesticide, the size of the spill, and local conditions, you may need to remove the top 1-inch layer of contaminated soil with a shovel and dispose of it.

Decontamination

As soon as practical, decontaminate crashed aircraft, wrecked vehicles, and pavements. see the pesticide's MSDS or label for specific instructions. For aircraft, coordinate with investigating officials and FAA authorities. For automobile wrecks, coordinate with appropriate law enforcement agencies or investigative bodies.

Chlorine bleach, caustic soda (lye, sodium hydroxide) detergents, or burnt or hydrated lime effectively decontaminate most spill areas (see attached MSDS sheets for precautions when using these substances).

CAUTION

Use bleach or lye, but never both together since this combination may liberate poisonous chlorine gas. Lye or lime readily decomposes many pesticides, especially the organophosphates, and carbamates. Clean up and remove as much of the spilled pesticide as possible prior to applying any decontaminate. Allow 1 to 6 hours reaction with the decontaminate before using an absorbent material.

Spread decontaminates thinly and evenly over the spill area. Then, lightly sprinkle the area with water to activate the decontaminate. Repeat the cleanup procedures until all the spilled pesticide is removed.

Clean all equipment used for spill cleanup with detergent and appropriate decontaminates. Collect all used decontaminates and rinse water and place them in labeled metal drums. Place clothing and gloves that cannot be decontaminated in the drums for proper disposal.

It may also be necessary to completely remove and dispose of contaminated porous materials.

If pesticides have leaked or spilled on the soil, removal of the visibly contaminated soil (top 1-inch) may be required using a shovel. In such cases, place the contaminated soil in metal drums for disposal. Chemical analysis of monitoring samples may govern removal of additional soil.

Post-Spill Procedures

Disposal of Contaminated Material

You may contact the pesticide's manufacturers for specific instructions regarding their product. Also contact the State or Federal EPA office with jurisdiction over the pesticide spill location about disposal, and consult with the U.S. Department of Transportation (DOT) prior to shipping/transporting across state lines. Shipping by licensed transporters may be required.

In general, place contaminated materials in sealed leak-proof metal disposal drums. Label all drums properly and dispose of in an approved hazardous waste disposal facility (incinerator, landfill site, etc.) under current EPA or State permit. The pesticide's labeling and MSDS contain specific information concerning disposal.

Environmental Monitoring

After cleanup and disposal, if the pesticide spilled into the environment, collect environmental monitoring samples. see M390.1403, ***Collecting Environmental Monitoring Samples*** for specific instructions. Contact the Region and request an Environmental Monitoring Coordinator if you need help with sample collection.

Reporting

Report information regarding pesticide spills in accordance with the program's specific monitoring plan, and as required by state and federal law. In general, reports should include:

1. Detailed map with the site of the pesticide spill clearly marked.
2. Information on location, time, spill area, terrain, pesticide spilled, how spill occurred, and how managed.
3. Any other information the writer deems pertinent to the pesticide spill.

Upon completion of the chemical analyses NMRAL will report its findings to Technical and Scientific Services (TSS). TSS will include the spill residue data in its programmatic environmental monitoring report and distribute as appropriate.

Planning for Pesticide Spills

Pesticides vary in toxicity as described in the pesticide's labeling and MSDS. Actions taken following an accidental spill will depend upon the pesticide toxicity involved. Always consult the labeling and MSDS for your program's pesticides when planning for spills. Check the telephone book for the telephone number of the local poison control center and enter it on your plan.

The Environmental Protection Agency (EPA) under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); Resource Conservation and Recovery Act (RCRA); and CERCLA or Superfund assigned the primary responsibility for enforcing safe pesticide use and disposal to most States. States may therefore acquire primary responsibility for determining pesticide spill, cleanup, and disposal procedures.

Not all States will perform or react to pesticide spills in the same way. Therefore the Port Director or COR should assist with cleanup, sample collection, sample analysis, securing affected area, etc. The Port Director or COR must monitor such activities to assure PPQ that the responsible parties take proper actions during and after a spill. Keep in mind that legal actions as a result of a pesticide spill may place liability on the cooperating Federal Agency.

Program Managers should inform the PPQ Assistant Regional Director's office of procedures to follow when pesticide spills occur within their jurisdictions so they may support field operations when needed. The Port Director, COR, or Senior Staff Officer for any given PPQ operation, is responsible for implementing pesticide spill procedures. These officers must be familiar with these guidelines and should make contingency plans for such pesticide spills in advance of field operations.

Useful information for completing your spill plan is found in the appendices to these guidelines. Copies of the MSDS (obtainable from the manufacturer) for your program's pesticides should be included in your spill plan.

State Hazardous Waste Management Agencies

When a pesticide spill occurs, you should consult local hazardous waste officials, the pesticide's label, and its MSDS to determine specific cleanup and disposal techniques. The following is a list of State Hazardous Waste Management Agencies:

ALABAMA
Land Division
Alabama Department of Environmental Management
P.O. Box 301463
Montgomery, AL 36130-1463
(334) 279-3050
Email: landmail@adem.state.al.us
http://www.adem.state.al.us/LandDivision/LandDivisionPP.htm

ALASKA
Division of Environmental Health
Pesticide Control
Alaska Department of Environmental Conservation
1700 E. Bogard Avenue
Building B, Suite 202
Wasilla, AK 99654
(907) 376-1870
(800) 478-2577 (toll free in-state)
http://www.dec.alaska.gov/eh/pest/factsheets.htm

AMERICAN SAMOA
No Listing Available

ARIZONA
Office of Waste and Water Quality Management
Arizona Department of Environmental Quality
1110 W. Washington Street
Phoenix, AZ 85007
(602) 771-4673
http://www.azdeq.gov/

ARKANSAS
Hazardous Waste Division
Arkansas Department of Environmental Quality
5301 Northshore Drive
North Little Rock, AR 72118-5317
(501) 682-0565
http://www.adeq.state.ar.us/hazwaste/

CALIFORNIA
Department of Toxic Substances Control
1001 I Street
Sacramento, CA 95814-2828 or
P.O. Box 806
Sacramento, CA 95812-0806
(916) 255-3618 (if calling from outside CA)
(800) 728-6942 (if calling from within CA)
http://www.dtsc.ca.gov/

COLORADO
Hazardous Materials and Waste Management Division
Colorado Department of Public Health and Environment
HMWMD-B2
4300 Cherry Creek Drive South
Denver, Colorado 80246-1530
(303) 692-3300
(888) 569-1831
Emergency Response: (877) 518-5608
Email: comments.hmwmd@state.co.us
http://www.cdphe.state.co.us/hm/

CONNECTICUT
Hazardous Material Management Unit
Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127
(860) 424-3000
http://www.ct.gov/dep/site/default.asp

DELAWARE
Division of Air and Waste Management
Department of Natural Resources and Environmental Control
89 Kings Highway
Dover, DE 19901
(302) 739-9403
http://www.awm.delaware.gov/Pages/default.aspx

DISTRICT OF COLUMBIA
Hazardous Materials Division
District Department of the Environment
51 N Street, NE
Washington, DC 20002
(202) 535-2600
Email: ddoe@dc.gov
http://ddoe.dc.gov/service/hazardous-wast

FLORIDA
Division of Waste Management
Department of Environmental Protection
2600 Blair Stone Road, MS 4500
Tallahassee, FL 32399-2400
(850) 245-8705
http://www.dep.state.fl.us/waste/Default.htm

GEORGIA
Environmental Protection Division
Georgia Department of Natural Resources
2 Martin Luther King Jr. Drive
Suite 1152, East Tower
Atlanta, GA 30334
(404) 656-4863
(800) 241-4113
http://www.gaepd.org/

GUAM
Air and Land Programs Division
Guam Environmental Protection Agency
17-3304 Mariner Avenue
Tiyan, Guam 96913
1 - (671) 475-1658 or 1659
http://www.gepa.guam.gov/

HAWAII
Solid and Hazardous Waste Branch
Hawaii Department of Health
919 Ala Moana Boulevard, #212
Honolulu, HI 96814
(808) 586-4226
http://hawaii.gov/health/environmental/waste/index.html

IDAHO
Waste Management and Remediation
Department of Environmental Quality
1410 North Hilton
Boise, ID 83706
(208) 373-0502
http://www.deq.idaho.gov/waste-mgmt-remediation.aspx

ILLINOIS
Bureau of Land
Illinois Environmental Protection Agency
1021 North Grand Avenue East
P. O. Box 19276
Springfield, IL 62794-9276
(217) 782-3397
https://www2.illinois.gov/sites/agr/Pesticides/Pages/default.aspx

INDIANA
Indiana Department of Environmental Management
Indiana Government Center North
100 N. Senate Avenue
Indianapolis, IN 46204
(317) 232-8603
(800) 451-6027
http://www.in.gov/idem/5217.htm

IOWA
Air Quality and Solid Waste Protection
Department of Natural Resources
Henry A. Wallace Bldg.
502 East 9th Street
Des Moines, IA 50319-0034
(515) 281-5918 (customer service)
(505) 281-8694 (24-hour number *only* for environmental spills)
Email: webmaster@dnr.iowa.gov
http://www.iowadnr.gov/index.html

KANSAS
Bureau of Waste Management
Department of Health and Environment
1000 SW Jackson, Suite 320
Topeka, KS 66612-1366
(785) 296-1500
Email: info@kdheks.gov
http://www.kdheks.gov/index.html

KENTUCKY
Division of Waste Management
Department of Environmental Protection
200 Fair Oaks Lane
Frankfort, KY 40601
(502) 564-6716
Email: waste@ky.gov
http://www.waste.ky.gov/

LOUISIANA
Louisiana Department of Environmental Quality
602 N. Fifth Street
Baton Rouge, LA 70802
(866) 896-LDEQ (5337)
Email: webmaster-deq@la.gov
http://deq.louisiana.gov/resources/category/hazardous-waste

MAINE
Bureau of Remediation and Waste Management
Department of Environmental Protection
17 State House Station
Augusta, ME 04333-0017
(207) 287-7688
Spills, Toll Free: (800) 452-4664
http://www.maine.gov/dep/rwm/index.htm

MARYLAND
Land Management Administration
Maryland Department of the Environment
1800 Washington Boulevard
Baltimore, MD 21230
(410) 537-3000
Emergency Toll Free (866) 633-4686
Email: webmaster@mde.state.md.us
http://www.mde.state.md.us/

MASSACHUSETTS
Bureau of Waste Prevention
Department of Environmental Protection
One Winter Street
Boston, MA 02108
(617) 292-5500
http://www.mass.gov/dep/recycle/hazwaste.htm

MICHIGAN
Department of Environmental Quality
525 W. Allegan
Constitution Hall, 4th Floor, North
P.O. Box 30242
Lansing, MI 48909-7742
(517) 335-6010
Emergency Response:
(800) 292-4707 (within Michigan)
(517) 373-7660 (outside Michigan)
http://www.michigan.gov/deq/0,1607,7-135-3312---,00.html

MINNESOTA
Minnesota Pollution Control Agency
520 Lafayette Road
St. Paul, MN 55155-4194
(651) 296-6300
(800) 657-3864
24-hour Emergency Response:
(651) 649-5451
(800) 422-0798
http://www.pca.state.mn.us/index.php/waste/index.html

MISSISSIPPI
Office of Polution Control
Environmental Enforcement & Compliance Division
Department of Environmental Quality
515 East Amite Street
P.O. Box 2261
Jackson, MS 39225
(601) 961-5068
http://www.deq.state.ms.us/MDEQ.nsf/page/Main_Home?OpenDocument

MISSOURI
Hazardous Waste Program
Division of Environmental Quality
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, MO 65102
(573) 751-3176
(800) 361-4827
Email: hazwaste@dnr.mo.gov
http://www.dnr.mo.gov/env/hwp/index.html

MONTANA
Hazardous Waste Program
Department of Environmental Quality
Lee Metcalf Building
1520 E. Sixth Avenue
P.0. Box 200901
Helena, MT 59620-0901
(406) 444-2544
http://deq.mt.gov/Land/hazwaste

NEBRASKA
Department of Environmental Quality
1200 "N" Street, Suite 400
P.O. Box 98922
Lincoln, NE 68509
(402) 471-2186
Email: MoreInfo@NDEQ.state.NE.US
http://www.deq.state.ne.us/

NEVADA
Bureau of Waste Management
Division of Environmental Protection
901 South Stewart Street
Suite 4001
Carson City, NV 89701-5249
(775) 687-4670
https://ndep.nv.gov/land/waste/hazardous-waste-management

NEW HAMPSHIRE
Waste Management Division
Department of Environmental Services
29 Hazen Drive
P.O. Box 95
Concord, NH 03302-0095
(603) 271-3503
Hazardous Materials Emergency Numbers:
(603) 271-3899 (M-F 8:00 am - 4:00 pm)
(800) 346-4009 (evenings and weekends)
http://des.nh.gov/organization/divisions/waste/index.htm

NEW JERSEY
Chemical & Pollution Control/Waste Management
Department of Environmental Conservation
401 East State Street
P.O. Box 414
Trenton, NJ 08625
(609) 633-1418
Environmental Emergency: 1-877-WARNDEP (1-877-927-6337)
http://www.state.nj.us/dep/dshw/

NEW MEXICO
Hazardous Waste Bureau
New Mexico Environment Division
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6303
(505) 476-6000
http://www.nmenv.state.nm.us/HWB/

NEW YORK
Division of Hazardous Substance Regulation
Department of Environmental Conservation
625 Broadway
Albany, NY 12233-0001
(518) 402-8013
DEC 24-hour Spill Hotline (800) 457-7362
http://www.dec.ny.gov/chemical/292.html

NORTH CAROLINA
Division of Waste Management
Department of Environment and Natural Resources
1646 Mail Service Center
Raleigh, NC 27699-1646
(919) 508-8400
http://wastenotnc.org/

NORTH DAKOTA
Division of Waste Management
Department of Health
908 East Divide Avenue, 3rd Floor
Bismarck, ND 58501-5166
(701) 328-5166
http://www.ndhealth.gov/wm/index.htm

NORTHERN MARIANA ISLANDS, COMMONWEALTH OF
No listing available.

OHIO
Division of Hazardous Waste Management
Ohio Environmental Protection Agency
50 West Town Street, Suite 700
P.O. Box 1049
Columbus, Ohio 43215
(614) 644-2917
Emergency Response Hotline (800) 282-9378
http://www.epa.state.oh.us/Default.aspx?alias=www.epa.state.oh.us/dhwm

OKLAHOMA
Land Protection Division
Department of Environmental Quality
P.O. Box 1677
Oklahoma City, OK 73101-1677
(405) 702-5100
http://www.deq.state.ok.us/LPDnew/hwindex.html

OREGON
Land Quality/Hazardous Waste Management
Department of Environmental Quality
811 Sixth Avenue
Portland, OR 97204-1390
(503) 229-5696
Oregon Emergency Response System
Toll Free: (800) 452-0311
http://www.oregon.gov/deq/Hazards-and-Cleanup/hw/Pages/default.aspx

PENNSYLVANIA
Division of Hazardous Waste Management
Pennsylvania Department of Environmental Protection
Rachel Carson State Office Building
400 Market Street
Harrisburg, PA 17101
(717) 787-2814
http://www.depweb.state.pa.us/landrecwaste/cwp/view.asp?a=1216&Q=442095&landrecwasteNav=|

PUERTO RICO
Environmental Quality Board
P.O. Box 11488
Santurce, PR 00910-1488
(809) 725-0439
—or—
U.S. EPA Region II
290 Broadway
New York, NY 10007
(212) 637-3660
Emergency Response: (787)-729-6826
http://www.epa.gov/epahome/violations.htm

RHODE ISLAND
Office of Waste Management
Bureau of Environmental Protection
Department of Environmental Management
235 Promenade Street
Providence, RI 02908-5767
(401) 222-2797
http://www.dem.ri.gov/programs/wastemanagement/

SOUTH CAROLINA
Land and Waste Management
Department of Health and Environmental Control
2600 Bull Street
Columbia, South Carolina 29201
(803) 898-3432
Emergency Response: (888) 481-0125
http://www.scdhec.gov/environment/lwm/

SOUTH DAKOTA
Division of Environmental Regulation
Department of Environment and Natural Resources
523 East Capitol
Joe Foss Building
Pierre, SD 57501
(605) 773-3151
http://denr.sd.gov/

TENNESSEE
Division of Solid and Hazardous Waste Management
Department of Environment and Conservation
5th Floor, L&C Tower
Nashville, TN 37243
(615) 532-0780
http://tennessee.gov/environment/swm/hazardous/

TEXAS
Hazardous and Solid Waste Division
Texas Commission on Environmental Quality
P.O. Box 13087
Austin, TX 78711
(512) 463-7760
Spill Reporting (24-hr): (800) 832-8224
Email: ac@tceq.state.tx.us
https://www.tceq.texas.gov/permitting/waste_permits/ihw_permits/ihw.html

UTAH
Division of Solid and Hazardous Waste
Department of Environmental Quality
P.O. Box 144880
Salt Lake City, UT 84114-4880
(801) 538-6170
http://www.hazardouswaste.utah.gov/

VERMONT
Waste Management Division
Department of Environmental Conservation
103 South Main Street, West Office Building
Waterbury, VT 05671-0404
(802) 241-3888
Emergency: (800) 641-5005
http://www.anr.state.vt.us/dec/wmd.htm

VIRGIN ISLANDS
Department of Conservation and Cultural Affairs
P.O. Box 4399, Charlotte Amalie
St. Thomas, Virgin Islands 00801
(809) 774-6420
—or—
U.S. EPA Region II
290 Broadway
New York, NY 10007
(212) 637-3660
Emergency Response: (787)-729-6826
http://www.epa.gov/epahome/violations.htm

VIRGINIA
Waste Management
Department of Environmental Quality
P.O. Box 1105
629 E. Main Street
Richmond, VA 23218
(804) 698-4000 or
Toll free in VA: (800) 592-5482
24-hour Emergency Hotline: (800) 468-8892
http://www.deq.state.va.us/waste/homepage.html

WASHINGTON
Waste Management Programs
Department of Ecology
P.O. Box 47600
300 Desmond Drive
Olympia, WA 98504-7600
(360) 407-6700
http://www.ecy.wa.gov/waste.html

WEST VIRGINIA
Environmental Enforcement
Division of Water and Waste Management
Department of Environmental Protection
601 57th Street
Charleston, WV 25304
(304) 926-0470
24 Hour Spill Hotline: (800) 642-3074
http://www.dep.wv.gov/WWE/Programs/hazwaste/Pages/default.aspx

WISCONSIN
Waste and Materials Management
Department of Natural Resources
101 S. Webster Street
P.O. Box 7921
Madison, WI 53707-7921
(608) 266-2621
Hazardous Substances Hotline: (800) 943-0003
http://dnr.wi.gov/topic/waste/

WYOMING
Division of Solid Waste
Department of Environmental Quality
122 West 25th Street, Herschler Building
Cheyenne, WY 82002
(307) 777-7937
Emergency: (307) 777-7781
http://deq.wyoming.gov/shwd/

Accident or Spill Emergency Kit

The Port Director, COR, or their designee should have available a fully supplied pesticide emergency spill cleanup/decontamination kit with instructions for its use. The kit will have the label designation “For Use in Handling and Cleanup of Accident Pesticide Spills Only.”

Responsible officials should use their discretion as to what items will be stored in vehicles for immediate use. The following items should be immediately available for responding to a pesticide spill:

Safety

- First aid kit—bus and truck kit, (GSA #6545-00-664-5312, or equivalent)
- Fire extinguisher, 5-lb. size for class A, B, C fires

Cleanup

- One shovel, square-point, "D" handle (GSA 5120-00-224-9326, or equivalent)
- Twenty-five large, heavy-duty plastic bags with ties (GSA 8105-00-848-9631, or equivalent)
- Two pair, unlined vinyl rubber boots
- Four pair, disposable coveralls
- One 5-gallon water container
- Four pair, unlined vinyl rubber gloves
- Two approved respirators with approved pesticide canisters (Self-contained breathing apparatus must also be available in operations where methyl bromide is utilized.)
- One broom and dust pan
- One pint bottle of liquid detergent
- Two scrub brushes (GSA 7920-00-068-7903 or equivalent)
- One plastic cover or tarpaulin (to cover dry spills) (GSA 8135-00-529-6487, or equivalent)
- Twenty-five pound bag, absorbent material (GSA 7930-00-269-1272), or sweeping compound, sawdust, "kitty litter", or other absorbent materials
- One large metal or heavy duty plastic garbage can with removable cover for storing contaminated materials for later disposal

Important

Use this can to store the spill kit materials during transport.

- Several sand snakes should be kept in storage areas

Obtain many of these items through the GSA Federal Supply System or from a local hardware store.

8 Equipment

Treatment Manual

Contents

Thermal Conductivity Gas Analyzers

The thermal conductivity gas analyzer (T/C) is a portable instrument specifically designed to determine the concentration of gases under a tarpaulin or within a chamber during a fumigation. These fumigation gases include methyl bromide (MB) and sulfuryl fluoride (SF).

Instrument Description

Currently, there is one company that manufactures USDA-approved T/C instruments used during a PPQ-monitored fumigation. The Fumiscope® (**Figure 8-1-1**) Models D, 4.0, 4.2, and 5.1, are manufactured by ***Key Chemical and Equipment Co., Inc.* on page E-1-30**.

The Fumiscope® is lightweight, portable, and completely contained in a compact metal case. It contains a thermal conductivity cell, scale, gas pump, range switch, and gas flow meter. A gas drying tube is also included. For large enclosures, an auxiliary pump may be needed.

Figure 8-1-1 Fumiscope® Models D, 4.0, and 5.1

Inlet

The inlet tube connector is the gas inlet for the instrument. The sampling lines are 1/4" inner diameter (I.D.) and are connected to the inlet through the drying tube.

Flow Rate Meter

The flow rate meter indicates the gas flow rate in “simulated cubic feet per hour (SCFH).” Note: The flow rate should always be read at the middle of the ball.

Flow Rate Adjustment

The flow rate adjustment dial controls the air or gas flow rate by adjusting the pump. After connecting to the gas sampling line, adjust the flow rate upward until it reads exactly 1.0 SCFH.

Scale or Digital Display

The scale or digital display indicates the concentration of the fumigant in ounces per 1,000 cubic feet (milligrams per liter or grams per cubic meter). Record the gas concentration reading only after this meter stabilizes, which may take a minute or more (depending on the length of the tubing and whether an auxiliary pump is being used). Digital Fumiscope® models can indicate a range from 0 to 2999 ounces per 1,000 cubic feet.

Zero Adjustment Knobs

The zero adjustment knob is used to adjust the display to zero after the instrument has warmed up for at least 20 minutes. Set the Fumiscope to zero prior to taking a reading and after each reading.

The Model 5.1, has two knobs used to zero the display. The "Recenter Zero" red knob acts as a coarse zero adjustment and the "Zero Adjust" knob acts as a fine zero adjustment. (See **Figure 8-1-1**) Adjust the red "Recenter Zero" knob first to bring the display as close to zero as possible. Then adjust the "Zero Adjust" knob to set the unit on zero.

Figure 8-1-2 Fumiscope® Model 5.1

Line Switches

Line switches control the electrical supply to the pump and scale.

Fumigant Selector Switch

The fumigant selector switch changes the display to register either methyl bromide or sulfuryl fluoride (Vikane®.)

Exhaust Outlet

Always connect an exhaust line to the exhaust outlet to carry gas away from the instrument and operator. When using the T/C unit in confined or poorly ventilated areas, recirculate the exhaust gas back to the fumigation space or exhaust it to the outside.

Drying Tube

Use drying tubes (filter tube) with a prepared chemical for removing certain contaminant gases or vapors that interfere with correct fumigant concentration readings. The tubes will contain a desiccant such as Drierite® (granules of anhydrous calcium sulfate), or Ascarite® (sodium hydroxide). Both are available from scientific supply houses. **Never mix Drierite® and Ascarite® in the same tube.**

When a drying tube is used, place a thin layer of glass wool or aquarium filter wool at the bottom and top of the tube to prevent small particles from sifting into the T/C unit. Using absorbent cotton or similar materials is **not** recommended. Cotton tends to pick up moisture and to become matted, and once matted, the cotton may restrict normal air flow, thus, adversely affecting the T/C unit's operation.

Mount the drying tube *vertically* so the gas mixture moves through the drying material and does **not** pass over the top. The gas mixture will pass over the top of the drying tube when the tube is mounted horizontally (lengthwise).

Drierite®

Always use anhydrous calcium sulfate (Drierite®) to remove moisture from the gas sample. Insert the drying tubes in the gas sampling line just before the inlet connection. Drierite® should be fresh and frequently changed to ensure correct readings. Drierite®, blue in color when dry, turns pink when moisture is absorbed. Replace the Drierite® when most of it has turned pink. In extremely high moisture conditions, two Drierite® tubes can be connected in tandem. Close drying tube openings when **not** in use.

Ascarite®

T/C gas analyzers are sensitive to a number of gases other than MB. For example, CO_2 may be troublesome when fumigating fruit where kerosene heaters are placed under the tarpaulin to raise pulp temperatures, or with plant material packed in peat moss or subsoil. Correct MB gas concentration readings may be obtained if a CO_2 absorbent is used in the gas sampling line before the air-gas mixture enters the T/C unit. A CO_2 absorbent that can be used is Ascarite®. Observe the poison warning labels on the containers when using Ascarite®. **Tubes containing Ascarite® should be clearly labeled, "Warning—Avoid contact with skin, eyes, and clothing."**

WARNING

During a fumigation of living plant products, such as plants, plant material, logs, wood and wood products, use tubes containing Ascarite® to remove carbon dioxide from gas samples. Used Ascarite® should be discarded per label instructions. Connect the Ascarite® tube between the Drierite® tube and the sample inlet. **Never mix Drierite® and Ascarite® in the same tube**. Replace Ascarite® when the granules begin to aggregate or become moist.

Because a chemical reaction will occur, ***never*** use Ascarite® when taking readings of SF.

Instrument Standardization

Instrument standardization is the first and basic operation. In order to standardize the instrument, do the following:

1. Connect the instrument to an electrical outlet with proper voltage and set the pump and meter switches to “on”; if inoperable, check fuse (replacements—Little Fuse or Buss #3AG 1/2 Amp.—should be kept on hand).
2. Attach the drying tube to the inlet port.
   - **A.** Give the instrument a tightness test.
   - **B.** A tightness test can be accomplished by placing a finger over the inlet of the drying tube; if the tubing and connections are tight, the flow ball in the flow meter should then fall to zero.
3. Warm up the instrument for 20 to 30 minutes.

Important

> The manufacturer recommends that the analyzer be kept at the same temperature as the fumigated site. It may take up to two hours for the analyzer to acclimate if moved from extreme temperatures.

4. Adjust the gas flow rate to 1.0 SCFH by adjusting the flow rate knob.
   - **A.** If the flow rate knob is turned counterclockwise too far, the pump will emit noises and cease to operate properly.
   - **B.** When properly adjusted, the flow ball should float at the center mark, or slightly below it, on the calibrated glass cylinder.
   - **C.** The pump now draws dry, fresh air through the T/C cell; the air enters via the inlet on the face of the instrument, passes through the cell, and leaves through the exhaust outlet.
5. Turn the zero adjustment knob to obtain a zero reading on the meter.
   - **A.** To obtain a stable zero reading, several additional adjustments during the first few minutes may be necessary.

   If using Model 5.1, adjust the "Recenter Zero" red knob first, then adjust the "Zero Adjust" knob to zero.

Standardization is now complete and readings can be made of fumigant-air mixture drawn through the unit. At this point, it may be necessary to replace the desiccant.

The difference in the thermal conductivity of the fumigant-air mixture as compared with fresh air is measured electrically and indicated on the meter as concentration readings in ounces of gas per 1,000 cubic feet. T/C units used in

PPQ must be calibrated for MB and/or SF by the manufacturer or an approved outside contractor prior to use. When fumigations are under even a small vacuum, readings will **not** be accurate.

Operation Procedures

Because of the variety of fumigation situations, some adjustments may be necessary to meet specific needs. Nevertheless, this outline should be helpful in establishing correct operational procedures.

The proper use of the T/C unit is discussed under two headings:

- Selecting operational site
- Measuring gas concentrations

Selecting Operational Site

The T/C unit should be at least 30 feet upwind from the fumigation site to allow the operator to function without the fear of accidental exposure to gas and to allow for easy exit in an emergency. It should be close enough to the fumigation site to avoid using unreasonable lengths of sampling lines, to allow for constant surveillance of the fumigation during testing, and to avoid interference with other activities in the area. Avoid excessive wiring length. When T/C unit readings in multiple locations are necessary, see that each location is the best available.

The T/C unit should be supported on a sturdy, level surface, outside the traffic pattern, and protected from wind, rain, excessive cold, and, in hot weather, sun. In some cases, temporary shelter such as a tarpaulin cover may be adequate. The gas concentration readings indicated by the T/C unit may be inaccurate unless the unit is placed in an area that is approximately the same temperature as the gas mixture in the enclosure being fumigated. If the temperature of the gas mixture within the fumigated enclosure is approximately equal to that of the ambient air outside the enclosure, the gas concentration readings indicated by the T/C unit’s meter will be generally more accurate. If there are great differences between the two temperatures, water vapor may condense inside the gas sampling leads. Such condensation, if desiccant is saturated, can result in a lower than normal T/C meter reading, thus leading to the unnecessary addition of fumigant to compensate for the apparent shortage. Therefore, if vapor condensation appears inside the gas sampling leads, purge the line and move the T/C unit to a new location where the ambient temperature approximates that of the enclosure.

Most T/C units operate on 110 to 120 volts alternating current (AC). T/C units operating on 210 to 220 volts AC on direct current (DC) are available for overseas or other assignments as necessary. A converter is required to use DC. Keep extension wiring and gas sampling line length to a practical minimum and raise extension wiring above floor level when feasible.

Measuring Gas Concentrations

As a protection for the cell and the pump of T/C units, **use a drying tube filled with Drierite® at all times.**

When taking gas concentration readings, first warm up the unit for at least 20 to 30 minutes depending on ambient temperatures. Then turn on the pump and adjust the gas flow meter to a 1.0 SCFH flow. Turn the zero adjustment knob to obtain a zero reading on the meter. If using Model 5.1, adjust the "Recenter Zero" red knob first, then adjust the "Zero Adjust" knob to zero.

The unit is now ready to measure gas samples drawn through labeled gas sampling lines from the area being treated. The meter will indicate gas concentrations in ounces per 1,000 cubic feet (grams per cubic meter).

Important

> If monitoring lines are stored outside, water may accumulate in the leads after heavy rainfall.
>
> If you observe water or suspect that there may be water in the sampling lines, install a water trap. **See "Water Trap" on page-8-1-26** for details on obtaining and using water traps.

Connect the gas sampling line to the Drierite tube using 1/4 inch ID polyethylene tubing. Allow sufficient time to draw a true sample. With 150 to 200 feet of 1/4 inch ID tubing and a temperature of 70 °F, a sufficient amount of time will be approximately 7 minutes. Stations equipped with small, auxiliary pumps can draw a sample through the same length of tubing in 12 to 15 seconds.

Wait until the analyzer reaches the maximum reading (at least thirty seconds) and does **not** move for thirty seconds. Ensure the flow meter still reads 1.0 SCFH. This is the gas reading. Record this reading on the PPQ Form 429.

Disconnect the sampling line and allow the pump to draw uncontaminated air through the T/C cell. The instrument should return to zero, however it may be necessary to re-zero the analyzer. Again, ensure that the flow meter reads 1.0 SCFH. **Always re-zero the analyzer before taking the next reading.**

After taking the final reading at the end of the fumigation, thoroughly purge the unit by disconnecting it from the gas sampling line and allowing the pump to draw fresh air through the instrument for several minutes.

Maintenance

If it is to function properly, the T/C unit requires the same attention as any other equipment. While the instrument is designed specifically for field use, the components, particularly the meter, may be damaged easily. To maintain an instrument capable of accurate gas concentration readings, careful handling is essential. If repairs are needed and are extensive, or the parts are **not** readily available, there will be a delay in returning the instrument. Should the need for a substitute T/C unit occur, the port should be prepared to obtain one from another source.

Repair and Calibration

Under normal service, the T/C unit will hold its calibration for a considerable length of time. To ensure all units are providing accurate gas concentration readings, recalibrate T/C units at least annually; calibrate more often if use is frequent.

Send the instrument by insured delivery service (ie. Federal Express, United Parcel Service, U.S. postal priority mail) to one of the contractors listed below. To prevent damage, the unit must be well-packed and shipped in a durable, tamper-proof box.

Prepare a memorandum to accompany each instrument explaining the need for sending the unit. Ensure all instruments are shipped with a proper return address, name of a contact person, and telephone number. The T/C unit will be calibrated for MB only, unless the PPQ office requests calibration for SF. **Notify the contractor if Ascarite® will be utilized during the readings, as the T/C must be calibrated using this type of absorbent.** All port locations will be responsible for payments to contractors.

Use one of the following contractors for repair and calibration:

Key Chemical and Equipment Co. (BPA# 45-6395-3-2872)
13195 49th St. North
Unit A
Clearwater, FL 33762
tel (727) 572-1159
fax (727) 572-4595
http://www.fumiscope.com/

Cardinal Professional Products (BPA# 45-6395-3-2871)
2675 W. Woodland Drive
Anaheim, CA 92801-2628
tel (714) 761-3292
fax (714) 761-2095
www.cardinalproproducts.com

Infrared Spectroscopy Gas Monitoring Device

Infrared spectroscopy is an accurate and efficient method for measuring methyl bromide gas concentrations. There is one unit currently approved for use by PPQ. The MB-ContainIR™ is manufactured by Spectros Instruments Inc., Hopedale, MA, and will be referred to in this document as the "Spectros." The Spectros is light-weight (9 pounds; 4 kg) and battery operated.

Figure 8-1-3 Spectros Methyl Bromide Monitor

The Spectros uses a technology known as "non-dispersive infrared technology" (NDIR.) NDIR is based on Beer's Law (also known as Lambert-Beer Law or Beer-Lambert-Bouguer Law) that relates the absorption of light to the properties of the material through which the light is traveling. The Spectros is not affected by other volatile organic compounds such as carbon dioxide, eliminating the need for Ascarite™. Other benefits of the unit include:

- Audible and visible programmable alarm
- Battery powered and portable
- Measuring range for methyl bromide 0-240 oz./1000 ft^3 (g/m^3)
    - Sensitivity 0.16 oz./1000 ft^3 (g/m^3)
    - Accuracy 0.08 oz./1000 ft^3 (g/m^3)
- Operating temperature 32 °F - 122 °F (0 °C - 50 °C)
- Variable temperature compensation

The information and guidelines in this chapter are based on the Spectros Inc. Operation and Maintenance Guide. Contact **Spectros** for more detailed operating instructions or technical assistance.

Important points to remember:

Important

- Install a water trap and particulate filter in-line between the fumigation site and the monitoring unit. See “Respiratory Protection” on page-8-1-13.
- This monitor **is not** and **should not** be used as a worker safety clearance device.
- This monitor is **not** set up to evaluate, test, or determine readings for other approved fumigants that PPQ uses, such as **phosphine** or **sulfuryl fluoride.**
- Do not operate the monitor in the presence of flammable liquids, vapors, or aerosols.
- Do not use soap and water to clean the monitor; use a dry cloth to clean the monitor.
- Maintain proper care and storage of the monitor when not in use.
- Use only batteries supplied by the factory.
- Operate the monitor at all times in a horizontal position. Operating the monitor in a vertical position may cause inaccurate measurements.
- Never operate this unit at or above 6,562 feet. (2,000 meters.)
- The monitor must be maintained free of moisture or other contaminants.
- Always place supplied filter on the gas sample line between the monitor and the sampling line.
- Always ensure that the direction of flow is correct for the supplied filter before using the monitor.
- Cap the ends of the gas sample lines to prevent the possibility of mists, aerosol, oil, water, dust, or other contaminants being drawn into the monitor.
- The maximum length of the gas sample line is 1000 feet.
- The monitor does not require Drierite if the measuring range is greater than 2 oz./1000 ft^3.
- Return the monitor to the manufacturer for calibration every 6 months.

General Operation

Prior to taking gas concentration readings, follow the guidelines in Chapter 2-4 Methyl Bromide Tarpaulin Fumigation, Conducting a Fumigation, to ensure proper installation of gas sampling lines and circulation fans.

If not using direct current, ensure that the battery for the Spectros is fully charged before the fumigation begins. When using the Spectros in battery mode, press the "test" button and observe the number of LEDs that light up.

- Four green LEDs on the battery indicate that the unit is fully charged and monitoring can begin. A fully charged battery pack will power the monitor for 8-10 hours.

- A red flashing LED on the battery indicates a low battery. Recharge the battery per manufacturer instructions before using for gas monitoring. Charging time is 3-4 hours for a fully discharged battery pack.

Water Trap

Install a water trap and particulate filter in-line between the fumigation site and the monitor in order to keep water from damaging the monitor. See "Water Trap" on page-8-1-26 for more information.

Gas Sample Line

Using 1/4-inch flex tubing, connect the gas sample line to the monitor by pushing the tubing onto the gas sample port on the front of the monitor. The gas sample line can be up to 50 feet in length and should be free of kinks or obstructions. If the gas sample line is longer than 300 feet, the instrument will display "FAULT" on the display screen. Ensure that the end of the line is positioned to prevent moisture or water intake, or utilize the filter element.

Purge Air Line

Connect the purge air line to the monitor by pushing the tubing onto the purge air port on the left side of the monitor. The purge line can be up to 100 feet maximum in length and should be in an area of fresh air. Ensure that the end of the line is positioned to prevent moisture or water intake, or utilize the filter element.

Exhaust Line

Connect the exhaust line to the monitor by pushing the tubing onto the exhaust port's barbed fitting. The exhaust line can be up to 50 feet in length and should terminate outside the building. Ensure that the end of the tube is positioned to prevent moisture or water intake.

Measuring Gas Concentration

To turn on the monitor lift the shield in front of the handle and press the red power ON/OFF toggle switch. Allow the monitor to warm up for 15 minutes.

The WARM UP screen is displayed and the ON light (green) will blink. After 15 minutes the ON light will stop blinking and glows steady.

The data display screen will show:

ZONETEMP - enter temperature of the area being monitored in °C. The zone is the area where the monitor is being operated, rather than the temperature of the commodity undergoing fumigation

The factory default temperature setting is 25 °C.

NOTICE

If the monitor is turned off at any time during operation, the monitor will run through an entire 15 minute WARM UP cycle, regardless of how long the monitor has been running.

After the warm up period, the Data Display Screen will read either MEASURE or PURGE in the upper left corner of the screen.

MEASURE indicates the monitor is actively measuring gas. The measurement is shown in the lower section of the screen. The monitor measures up to 240 g/m^3 with a sensitivity of 0.16g/m^3.

The measurement (reading) should stabilize (stop) before recording the reading. This may take one or more purge cycles depending on the length of the gas sample line.

The measurement cycle will run for 4 minutes before the purge cycle begins. When the display shows "PURGE", the monitor is resetting it’s infrared detector to baseline. The PURGE cycle runs for 10 seconds.

A zero reading indicates the concentration measured is below the lower limit of detection of 0.77g/m^3 (200ppm approximately).

NOTICE

If kinks or obstructions occur in the line, the monitor may not function properly.

Check for crimped sampling lines. Make sure nothing is restricting the flow of either the inlet sample air, purge air, or the exhaust (return sample line).

Calibration and Service

Return the Spectros to the manufacturer every 6 months for a calibration check and service. Contact Spectros to obtain a Service Request Form and Return Materials Authorization Number (RMA). Ship the unit using an insured carrier.

Contact Information

Spectros

Spectros Instruments, Inc.
17D Airport Road
Hopedale, MA 01747
Phone: 508-478-1648
FAX: 508-478-1652
Website: www. spectrosinstruments.com
Email: info@spectrosinstruments.com

CPHST-AQI-Raleigh

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive
Suite 300
Raleigh, NC 27606
Phone: 919-855-7450
FAX: 919-855-7493
Email: cphst.tqau@aphis.usda.gov

Respiratory Protection

Fumigation or other treatments conducted under the monitored conditions stated in this manual and other program manuals, are safe operations. The Occupational Safety and Health Administration (OSHA) has ruled that employees with possible exposure to pesticides (including fumigants) must be provided adequate respiratory protection from such exposure. Refer to **Appendix G** for detailed respiratory protection information. USDA employees may also refer to Chapter 11 in the *APHIS Safety and Health Manual* on the APHIS myportal web site for additional respiratory information.

Detector Kits or Gas Samples

Although thermal conductivity (T/C) units such as the Gow-Mac® and the Fumiscope® are used to measure concentrations of MB and SF in ounces per 1,000 cubic feet (milligrams per liter), concentrations of phosphine and some other fumigants cannot be measured with a T/C unit. However, they may be measured with detector tubes. Residual gas concentrations during commodities or enclosures aeration can also be determined for most fumigants with detector tubes.

Principles of Operations

Special pumps are used to draw a measured sample (usually 100 milliliters) of an air-gas mixture. The sample is drawn through 1 or 2 detector tubes where a chemical reaction with the tube reagent takes place, creating a stain. The length of the stain is proportional to the concentration of the gas. Measure the length of the stain by using a calibrated chart or by simply reading the number from a scale printed on the glass tube.

Gas detector tubes are manufactured with a constant reagent weight with corrections for variations in the diameter of each tube. Detailed operational instructions accompany the equipment.

The detector tubes are specific for each fumigant and are usually available from several manufacturers. However, it is advisable to use the pump supplied by the manufacturer of the tube used. In an emergency, detector tubes available under the trade names Auer, Draeger, Gastec, Kitagawa, and Mine Safety Appliances can be used with pumps manufactured by any of these companies provided they draw 100 milliliters. Because of the different diameters of the tubes sold by each manufacturer, adapters may be necessary. The Kitagawa pump uses a removable, stainless-steel micro-orifice to reduce the rate of air flow through many of its detector tubes. This provides greater accuracy in the chemical reaction within the tube. Remove the orifice when using tubes manufactured by other companies.

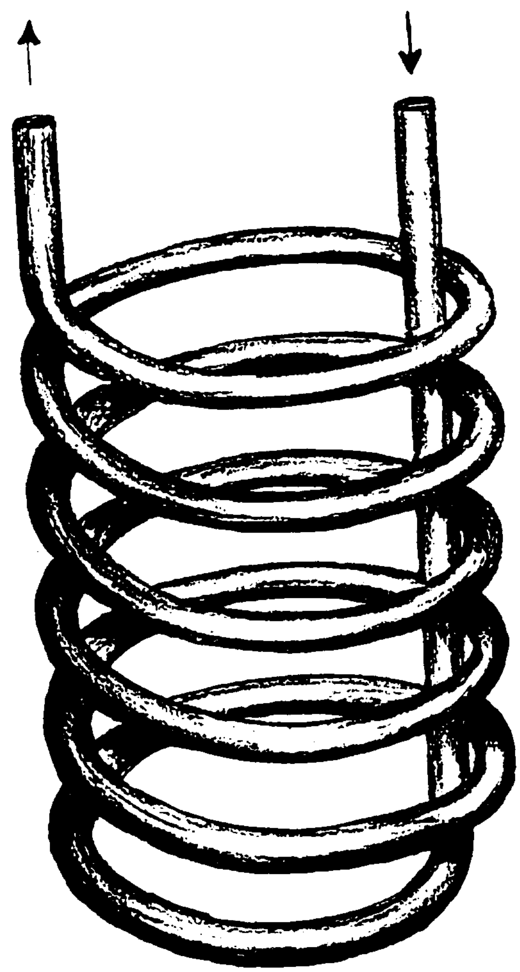
To increase shelf life, store tubes under refrigeration. Before each day's use, test pumps as provided by instructions with each kit and make repairs as necessary. Keep spare parts and operational instructions with each kit for use as needed.

When many samples must be drawn to a common point during a large fumigation, an auxiliary pump can be used. If only one sample lead is involved, it may be necessary to pull the fumigant through the line by pumping several times. A used tube can be inserted in the pump to determine when the fumigant has reached the pump.

Volatilizer

Methyl bromide must pass through a volatilizer (vaporizer) to ensure adequate conversion of liquid MB to gaseous MB. The volatilized fumigant should be introduced into or near to the air flow of the gas introduction fan. When 5 pounds or less of MB are used, a simple volatilizer can be made with a 25-foot coil of 3/8 inch O.D. (outer diameter) coiled copper tubing immersed in a container of hot water.

When amounts greater than 5 pounds are to be used, the copper tubing used in the volatilizer must consist of a minimum of 50 feet of 1/2 inch O.D. coiled copper tubing immersed in a container of hot water.



The volatilizer should be made of semihard copper tubing. It is important that gas be introduced and discharged as shown by arrows. If applied in reverse order, it may move so rapidly that some liquid will pass into the chamber.

Figure 8-1-4 Methyl Bromide Volatilizer Coil

The water in all sizes of volatilizers must be heated to temperatures of 200 °F or above with a minimum of 150 °F during the gas introduction process. A calibrated thermometer must be inserted into the water to determine the water temperature. The thermometer must be calibrated once per year by an approved calibration company. Written documentation of calibration must be present at the time of fumigation.

The line that runs from the from MB cylinder to the copper tubing in the volatilizer must be a 3000 PSI hydraulic high pressure hose with a 3/8 inch diameter ID (inner diameter) or larger. The line that exits the volatizer and runs into the enclosure must be a 350 PSI tubing with a 1/2 inch diameter ID or greater.

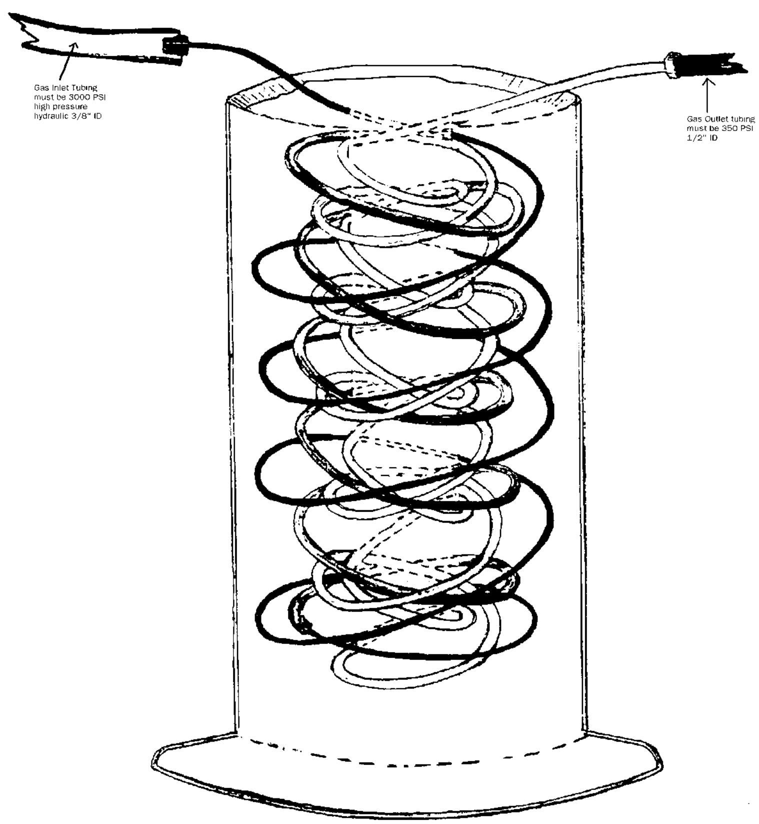


Figure 8-1-5 Tubing Specifications

The fumigant should be introduced through the tubing at the rate of 3 to 4 pounds of gas per minute. The gas introduction tube should feel hot to the touch as a good measure of satisfactory vaporization.

Air Velocity Measuring Instruments

Anemometer

Anemometers (wind meters) are used for measuring the air velocity of circulation fans and air curtains. Wind meters must be approved by the USDA-APHIS-PPQ-S&T-CPHST-AQI. Submit specifications of unapproved wind meters to CPHST-AQI for approval. Refer to ***Air Velocity Measuring (Anemometer)* on page E-1-11** for a list of approved models.

Fan Velocity

The cubic feet per minute (cfm) of a fan can be measured by placing the anemometer 12 inches from the face of the fan to be tested. Take a minimum of three readings; one from the center and the others from points toward the outside of the fan. Average the readings. If an anemometer is used, each measurement should be for 1 minute, thereby giving the result in feet per minute. If a wind speed indicator is used, the reading in miles per hour should be converted to feet per minute by multiplying the miles per hour by 5,280 and dividing by 60.

Area of the fan is calculated by first measuring the radius (R)—distance from the center of the fan to the end of a blade. Formula for area is Pi* R^2 where Pi is equivalent to 3.14. The final answer should be given in cfm. Therefore, if the radius of the blade is given in inches and **not** feet, the factor 1/144 must be multiplied in to convert square inches to square feet. The full formula would be: Feet per minute × R^2 (in inches) × 3.14 × 1/144 = cfm.

EXAMPLE: If average air movement is 1,600 feet for 1 minute from a fan having a 7 inch radius (14 inch diameter), the calculations are as follows:

$$1{,}600 \times 7^2 \times 3.14 \times 1/144 = 1{,}700 \text{ cfm (approximate)}$$

Air Curtain Velocity

The velocity of air curtains is also measured with an anemometer. Anemometers used in this capacity must meet the following specifications:

- Hand held
- Digital
- +/- 3 percent accuracy

- Record in at least one of the following units with the resolution in parenthesis:
  - m/s (0.1)
  - ft/min (1)
  - km/h (0.1)
  - mph (1)
  - knots (0.1)
  - Beaufort (0.1)
- CE certified with a certificate of conformity
- Tested to NIST-Traceable standards with a written certificate of tests
- Calibrated once a year to NIST calibration and certification

Auxiliary Pump

During large-enclosure fumigations, it is necessary to take numerous gas concentration readings from various locations throughout the enclosure. Thus, some sample leads may be over 200 feet long. Pump the fumigant to the sampling point before making an accurate concentration reading using an auxiliary pump. If the inspector must rely on the pump provided with the gas sampler or T/C unit to pull the fumigant, a great deal of time will be needed between readings.

Because it pumps the fumigant from many areas and keeps a constant pull, the auxiliary pump will reduce sampling time to only the reading time. Constructing a unit is relatively simple. Petcocks capable of accepting sample leads are tapped and soldered to a short length of pipe. This pipe is connected to the suction side of the pump. The pipe acts as a manifold. Opening or closing the petcocks allows the gas samples to be drawn as required. Connect an exhaust line of sufficient length to the pump to ensure the fumigant is removed from the sample area.

It is important that all soldering be done in such a manner as to provide gastight construction of the petcocks. The pump should be of sufficient size to pull one cubic foot per minute through all of the leads on the manifold. Therefore, the more leads, the higher the required capacity of the pump. Mount the whole unit on a board large enough to keep vibration to a minimum. Keep the unit weight down to allow easy transport.

Disconnect each sampling line from the auxiliary pump in turn, and close the petcock. Attach the line to the T/C unit or gas detector. Obtain a reading and reconnect the line to the auxiliary pump and open the petcock.

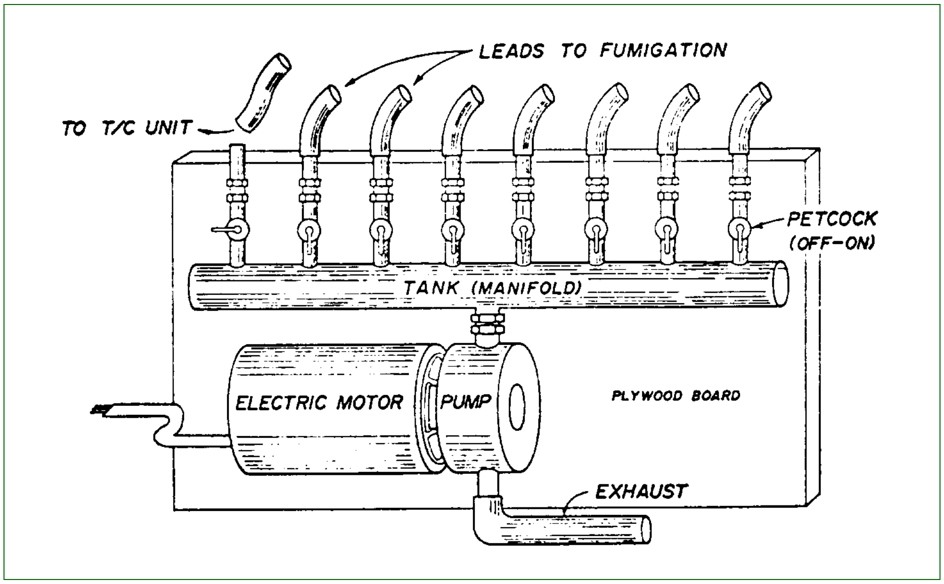


Figure 8-1-6 Auxiliary Pump

Open-Arm Manometer

The information included in this section has been extracted from the following web site http://www.dwyer-inst.com/Products/ManometerIntroduction.cfm

Manometers are devices that can be used to measure pressure during a pressure-leakage test in a fumigation chamber. Pressure is defined as a force per unit area.

Open-Arm Manometer

The most accurate way to measure low air pressure is to balance a column of liquid of known weight against it and measure the height of the liquid column so balanced. The units of measure commonly used are inches of mercury (in. Hg), using mercury as the fluid and inches of water (in. w.c.), using water or oil as the fluid.

An open-arm manometer is typically a U-shaped tube partially filled with liquid. The tube may be of glass or transparent plastic tubing. A ruler calibrated in millimeter (mm) divisions or carefully measured lines on a background is used to measure the difference in level of the liquid in the two arms (or the level in one arm).

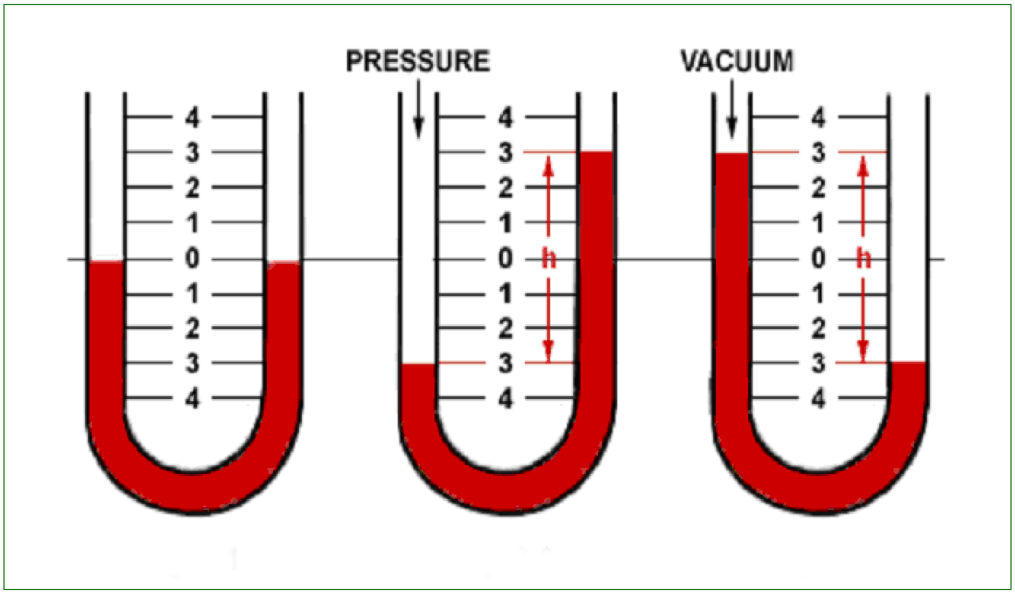


Figure 8-1-7 Example of Pressure Measurement in an Open-arm Manometer

As displayed by the middle picture in **Figure 8-1-7**, when positive pressure is applied to one arm, the liquid is forced down in that arm and up in the other. The difference in height, "h," which is the sum of the readings above and below zero, indicates the pressure.

The picture of the manometer on the right in **Figure 8-1-7** shows that when a vacuum is applied to one arm, the liquid rises in that arm and falls in the other. The difference in height, "h," which is the sum of the readings above and below zero, indicates the amount of vacuum.

No manometer can be read more accurately than the accuracy with which the specific gravity of the liquid inside the manometer is known. The liquid must also have good "wetting" characteristics and be capable of forming a consistent, well shaped meniscus in the indicating tube to facilitate accurate, repeatable readings.

The liquid used also affects the operating range of the manometer. Mercury being 13.6 times the weight of water will move 1/13.6th the distance water will move in response to a given pressure. Red gage oil, having a specific gravity of 0.826. which is lighter than water, will move about 1.2 times farther than water in response to a given pressure. This, obviously, expands the scale for easier, more precise reading.

Red gage oil is a stable petroleum base oil with carefully controlled specific gravity which gives an excellent, consistent high visibility meniscus. Manometers for use with water are furnished with a fluorescent green concentrate which when added to water serves as a setting agent and a dye to improve the consistency and visibility of the meniscus for easier more accurate readability. Because of increased accuracy and consistency, CPHST-AQI recommends the use of red gage oil manometers.

Electronic Manometer

Refer to ***Manometer (used in pressure leakage test)* on page E-1-34** for a list of commercial suppliers of electronic manometers. Select a model that encompasses the pressure range needed for pressure-leakage testing and that displays the results in the required units of measurement. Consult the operation manual of the specific manometer to be used for complete information on operation and maintenance of the device. Contact CPHST-AQI Raleigh[1] for approval of electronic manometers not listed in **Appendix E**. Note that all restrictions on instrument approval are included in conjunction with the appropriate supplier in **Appendix E**. PPQ personnel should select the appropriate device for their situation within the guidelines outlined in this section and the restrictions included in **Appendix E**.

1 USDA-APHIS-PPQ-S&T-CPHST-AQI Raleigh, 1730 Varsity Drive, Suite 300, Raleigh, NC 27606

Operating Procedures

When a fumigant is volatilized in a chamber at atmospheric pressure, a positive pressure is created, which may then be continuously reduced by leakage of the air-fumigant mixture. PPQ-approved chambers must be sufficiently tight to retain the fumigant during the exposure period. An open-arm or electronic manometer is used during the pressure leakage test for NAP chamber certification and the vacuum leakage test for vacuum chamber certification. (**See "Pressure-Leakage Test for NAP Fumigation Chambers" on page-6-3-9** and ***Certification Standards* on page 6-2-4** for detailed descriptions of the certification processes.) Use the following example for the most accurate way to determine the pressure measurement from a manometer.

EXAMPLE: Referencing **Figure 8-1-8**, the left arm of the open-arm manometer measures 8 mm below zero. The right arm measures 7 above zero. The sum of the two measurements equals 15 mm. Therefore, in this example, 15 mm is the actual reading.

Photo by PPQ Specialist John Loyd

Figure 8-1-8   Example of U Tube Manometer

MityVac® Hand-held Vacuum Pump

Detect detect blocked monitoring leads by using a MityVac® hand-held vacuum pump (for supplier, see ***Air Pump, Auxiliary* on page E-1-10**).

Usage

1. Prior to introducing fumigant, connect the MityVac® hand-held vacuum pump to a monitoring lead.
2. Squeeze the handle on the MityVac® Unit; if the lead is blocked, a vacuum will be indicated on the vacuum gauge of the MityVac® unit (squeeze the handle 2 or 3 times for monitoring leads longer than 25 feet; the MityVac® hand-held pump has the capacity to attain and hold 25 inches of Hg vacuum and a minimum of 7 psi pressure).
3. Disconnect the MityVac® hand-held pump from the monitoring lead, and repeat this procedure for each monitoring lead (connect monitoring leads to the gas analyzer prior to fumigant introduction).

Phosphine Detector

PortaSens Phosphine Detector

Description

Historically, measuring phosphine has been done using detector tubes specific for phosphine (see ***Detector Kits or Gas Samples* on page 8-1-13**). The high cost associated with these tubes has been a deterrent for many ports.

A more accurate, portable unit has been recommended for use during phosphine fumigations. The Series B16 PortaSens is a portable, battery-operated instrument for measuring various gas concentrations in ambient air. The instrument can be ordered specifically for phosphine in the 0 to 1,000 ppm range. Ranges from 0 to 1 ppm are available also, along with other configurations. The PortaSens is a complete measuring instrument containing an electrochemical sensor, sampling pump, flow cell assembly, microprocessor electronics, and a two-line, backlit LCD display. The unit is powered by a rechargeable NiCad battery located in the handle, with the charger connection located at the bottom of the handle.

Operation

The PortaSens needs to be calibrated by USDA-APHIS-PPQ-S&T-CPHST-AQI before use. After calibration, the instrument is ready to use directly out of the box. Simply remove the instrument from the storage case and press and release the button (instrument switch) on the front of the handle. The LCD display on the front will immediately be activated and the internal pump will begin to pull sample into the flow cell.

The unit comes with a flexible extension wand that screws into the standard inlet fitting. Connect the extension wand and a length of flexible tubing that will reach safely from the item(s) being fumigated to the PortaSens.

Response Time

Response time will vary depending on the gas concentration and ambient temperature. The LCD readout will stabilize when maximum concentration is reached. Readings will be more timely when the monitoring leads are purged using the MityVac® hand-held vacuum pump (refer to ***MityVac® Hand-held Vacuum Pump* on page 8-1-23**).

Alarm Function

The PortaSens contains both visual and audible gas concentration alarm functions that are preset at the factory. Refer to B16 PortaSens Operation and Maintenance Manual for specific instructions. For instruments in the 0 to 1,000 ppm range, the alarm has been disabled to allow for more efficient use.

Battery Power Supply

The instrument is powered by a rechargeable NiCad battery. With a fully charged battery, the unit will continuously operate for 12 hours at 20 °C. Battery capacity will drop with decreasing temperature. Should the battery become weak during operation, the lower line of the LCD display will indicate "LOW BATT." An audible beeper will begin to sound. At this point, there will be 1 hour of operating time left. When the voltage reaches a level where reliable measurements are no longer possible, the unit will turn itself off. If emergency use is anticipated, it is good practice to leave the instrument on charge at all times.

Flow Verification

Verify proper flow before using the PortaSens for leak detection. When the unit is turned on, a pump continuously delivers an air sample to the flow cell. In normal operation, the flow rate is approximately 300 cc/min. In order to allow quick verification of proper flow, a flowmeter is included in the PortaSens kit. Turn the instrument on and connect the sampling wand. Place the tip of the sampling wand into the tubing adapter attached to the flowmeter. Hold the flowmeter in the vertical position and verify that the flow rate is above 150 cc/min.

Power Down

In order to turn the unit off, press and hold the switch for approximately three seconds, until the "POWER DOWN" message appears on the display and then release.

Photo Ionization Detector

The Photo Ionization Detector (PID) is a portable vapor and gas detector that detects a variety of organic compounds. For methyl bromide, the PID has been used both as a leak detector to locate fumigant leakage around chambers, application equipment, temporary enclosures, and as a safety device around fumigation sites.

Principles of Operations

The PID is used to indicate the presence and approximate concentration of methyl bromide or other volatile organic compounds (VOCs) present. This is accomplished by photo ionization that occurs when an atom or molecule absorbs light of sufficient energy to cause an electron to leave and create a positive ion. Because PIDs measure all VOCs, careful attention must be paid to the presence of other VOCs in the air. Other VOCs include but are **not** limited to cigarette smoke, perfume, soap, and exhaust fumes from vehicles.

Description

All PIDs have the same basic construction, differing only in detail by the various manufacturers. Each has an ultraviolet lamp that emits photons that are absorbed by the compound in an ionization chamber. Electrodes collect the ions that are produced. The current that is generated provides a measure of the concentration.

Calibration

PIDs are typically calibrated using isobutylene, a stable gas with a slightly pungent odor. This gas is easy to handle and can be stored at high pressure, allowing calibration bottles to be used for calibrations many times. The PID manufacturer supplies a reference manual that describes calibration procedures and provides a list of correction factors.

For a partial list of manufacturers refer to ***Reference Guide to Commercial Suppliers of Treatment and Related Safety Equipment*** **on page E-1-1**.

Certified Precision Thermometers: Calibration Guidelines

Before a thermometer can be used as a calibration standard, it must meet the following requirements from an approved facilities. All calibration facilities must be approved by USDA-APHIS-PPQ-S&T-AQI, 1730 Varsity Drive, Suite 300, Raleigh, NC 27606 USA.

A list of current approved facilities can be accessed in ***Thermometers, Certified Precision, Approved Calibration Companies*** **on page E-1-67**.

- Accuracy must be 0.1 °C or less for Centigrade thermometer or 0.1 °F or less for Fahrenheit thermometer.
- Thermometer must be calibrated against standards that are approved by National Institute of Standards and Technology (NIST).

- The calibration certificate issued by calibration facility lists one to five calibration points, tabulated corrections for each calibration point, serial and test identification number of the NIST standard, and explanatory notes defining the conditions under which the test results were made.
- The thermometer must be calibrated annually or as designated by CPHST-AQI. Thermometers with expired calibration certificates cannot be used in quarantine treatments.
- ASTM thermometers must have 5 or more calibration points. Non-ASTM (precision thermometers must have calibration points at the treatment temperature.

Water Trap

When there is a large difference in temperature between the fumigation and monitoring locations, water vapor may condense inside the gas monitoring leads. Additionally, if monitoring leads are stored outside, water may accumulate in the leads after heavy rainfall. If water is observed or suspected in the monitoring leads, use forced air to remove water from the leads. If water is observed in the water trap, remove the water from the trap and use forced air to remove water from the leads.

Install a water trap in-line between the fumigation site and the monitor in order to keep water from damaging the monitor. If using an infrared spectroscopy analyzer to monitor gas concentrations, also install a particulate filter. A particulate filter is **not** needed if monitoring gas concentrations with a T/C. Refer to **Figure 8-1-9 on page-8-1-27** for an example of a water trap.

Contact your Regional Treatment Program Manager to obtain information about acquiring a water trap.

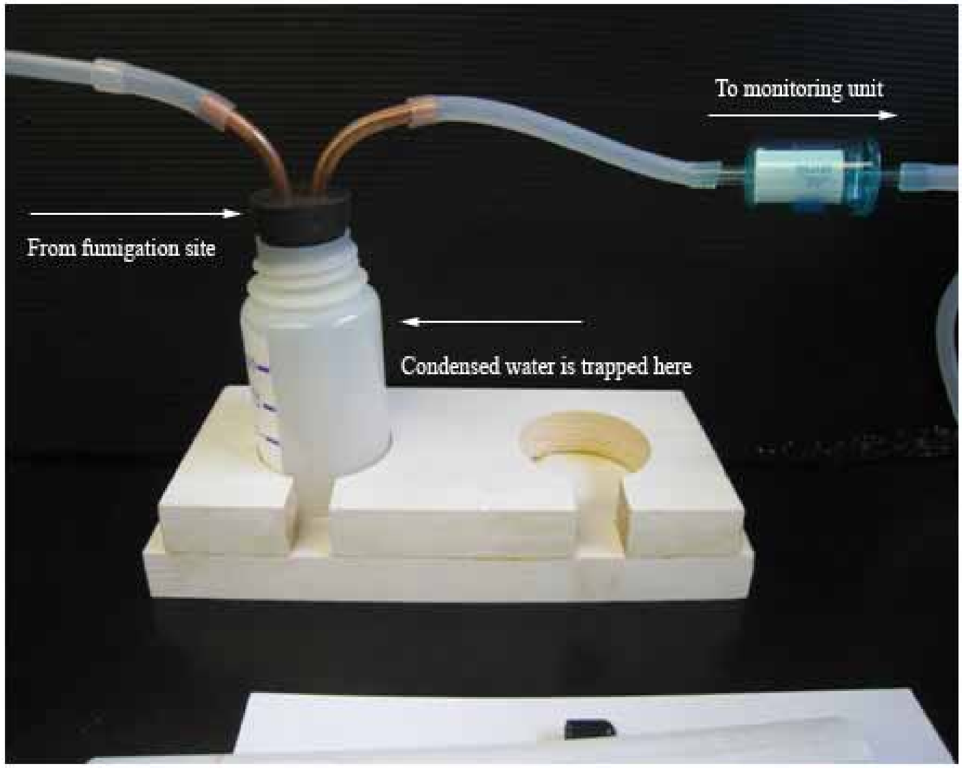


Figure 8-1-9   Example of a water trap

Dupont™ Tyvec® Air Cargo Covers

Tyvek® air cargo covers containing the label and Dupont™ hologram shown in **Figure 8-1-10** through **Figure 8-1-12** are approved as pallet covers during methyl bromide fumigations. Since these covers are permeable to methyl bromide, they do **not** need to be cut or removed prior to fumigation. They may be cut or removed as needed to take commodity temperatures. However, these covers should be taped or replaced on the pallet as quickly as possible following any cutting or removal. This cover is **not** approved for use with any other fumigant besides methyl bromide.

PMC Size Cover

Source: Photograph courtesy of E.I. du Pont de Nemours and Company

Figure 8-1-10 Tyvek® Cover

UK/USA Size Cover

Source: Photograph courtesy of E.I. du Pont de Nemours and Company

Figure 8-1-11 Tyvek® Cover with Safety Label (outlined in red and magnified in Figure 8-1-12)

Source: Photograph courtesy of E.I. du Pont de Nemours and Company

Figure 8-1-12 SKU Safety Label with Hologram

Electrochemical Gas Sensor and Pyrolyzer

Pyrolyzer technology combined with a renewable electrochemical sensor cell provides sensitive and specific methyl bromide monitoring. Currently, there is one unit approved for use during PPQ fumigations. The Air Check Advantage methyl bromide monitor is manufactured by PureAire Monitoring Systems, Inc.[2]

The Air Check system may be permanently installed in a fumigation facility and can continuously and remotely sample over distances of up to 100 feet. The system has the following features:

- Accuracy: ±10% or reading
- Dimensions: 10" W x 7.0" H x 7.0" D
- Operating Temperatures: -4 to 122 °F (-20 to +50 °C)
- Power requirements: 24 VDC 2.0 amp
- Repeatability: ±10% of full scale
- Response time: within 60 seconds
- Sensor range: 0-10 ppm (other ranges are available)
- Sensor type: renewable electrochemical cell that is field rechargeable
- User selectable alarms
- Weight: 10 pounds (4.5 kg)

Initial Startup

Refer to the Air Check Advantage Manual for more detailed operating instructions.

Allow at least a 2 hour warm up period. The sensor's zero will stabilize during this warm up period.

Important

The monitor is designed for continuous 24/7 operation. Do not power down unless the monitor will be stored for a long period of time.

If, after the 2 hour warm up period, the LED display is reading a positive PPM, then adjust the LED display to zero.

2 PureAire Monitoring Systems, Inc., 557 Capital Drive, Lake Zürich, IL 60047. PH: 888-788-8050. www.pureairemonitoring.com

Connect a gas sampling tube to the monitor and begin gas sampling readings. The MB gas is drawn through a pyrolyzer where it is heated and converted into bromine that is detected by the electrochemical sensor.

Maintenance and Calibration

Ensure that the fumigator replaces the electrochemical cell every 6 months and replaces the pyrolizer and O-rings when damaged. Ensure that the fumigator calibrates the sensor every 3 months under continuous MB exposure or every 6 months under normal use.

Fans — Introduction and Aeration

When fumigating with methyl bromide, fans **must** be operational during gas introduction and for at least 30 minutes after the gas has been introduced. Fans are also required for aeration. Do **not** use plastic fans.

Fans must be:

- Constructed of steel
- Capable of circulating the equivalent cubic feet per minute (cfm) of the total volume of the enclosure, but a minimum of 2,500 cfm
- Minimum of 18 inches in diameter

Require the fumigator to turn on all fans before gas introduction to ensure they are functioning properly. Refer to **Figure 8-1-13** for an example of an approved fan.

Figure 8-1-13 Example of an Approved Fan

9

Treatment Manual

Glossary

Acronyms, Abbreviations, and Terms

a.i.	active ingredient
APHIS	Animal and Plant Health Inspection Service
CA	Controlled Atmosphere
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHEMTREC	24-hour emergency telephone service for spills
COR	Contracting Officer's Representative
DOT	U.S. Department of Transportation
EPA	Environmental Protection Agency
External Feeder	A pest that normally inhabits the outside or outer part of its host. Contrast with hitchhiker and internal feeder.
FAA	Federal Aviation Administration
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FOH	Federal Occupational Health
g	grams
Hitchhiker	A pest transported by chance and **not** found inhabiting its host. Contrast with external feeder.
IDLH	Immediately Dangerous to Life or Health
Internal Feeder	A pest that normally inhabits the inside or inner part of its host. Contrast with external feeder.
kg	kilogram
m	meter
MB	methyl bromide
MCL	medical clearance letter
MED	minimum effective dose
mg	milligram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mmHg	millimeters of mercury; a measure of pressure
NAP	normal atmospheric pressure
NIOSH	National Institute for Occupational Safety and Health
OIC	Officer-in-Charge

OMMP	Occupational Medical Monitoring Program
OSHA	U.S. Occupational Safety and Health Administration
PH	phosphine
PEL	permissible exposure limit
PLHCP	physician or other licensed health care professional
ppb	parts per billion
ppm	parts per million
PPQ	Plant Protection and Quarantine
SDS	safety data sheet
SHEP	Safety and Health Environmental Programs
STEL	short-term exposure limit
TLV	threshold limit value
TWA	time-weighted average
ug	microgram
ug/cu.	micrograms per cubic meter
ug/L	micrograms per liter
USDA	United States Department of Agriculture

A

Treatment Manual

Appendix A

Forms

Contents

This Appendix contains example forms and instructions for completing the forms you may need when conducting or monitoring a fumigation.

APHIS Form 2061 (Residue Sample for Food or Feed Product)

The APHIS Form 2061 has been removed from this manual. Contact the Manuals Unit to obtain a copy and instructions for use.

APHIS Form 205-R, Instructions and Worksheet for Calibrating Portable Temperature Sensors

INSTRUCTIONS AND WORKSHEET FOR CALIBRATING PORTABLE TEMPERATURE SENSORS — USDA - APHIS — 1. DATE

2. NAME OF FACILITY	3. SIGNATURE OF PERSON CALIBRATING SENSORS	4. NAME OF PERSON CALIBRATING SENSORS *(Type or Print)*

INSTRUCTIONS

These instructions are for calibrating the portable temperature sensors that will be used in performance tests of hot water tanks.

(A) Assign each portable sensor a number. *(Write sensor numbers on pieces of duct tape or tag, and attach them near the "dry" end of each sensor.)*

(B) Submerge the "wet" end of the sensors into a circulating hot water bath in a temperature range of 115° to 120°F *(46.1° to 48.9°C)*, in close proximity to the bulb of a submersible certified glass mercury thermometer. Both must be submerged to the same depth. The mercury thermometer *(with demarcations readable to the nearest tenth of a degree)* shall be used as the standard against which the portable sensors are to be compared.

(C) Record the temperatures obtained from each portable sensor and the mercury thermometer, in succession. Compute the difference in the two temperatures, if any, and record this also.

(D) If the temperature shown by the portable sensor falls within five-tenths of a degree *(F) (or +/- 0.3°C)* of the true temperature shown on the certified mercury thermometer, then this sensor is considered to be within the tolerance, and may be used in the performance test. Any sensors reading outside of this range do not meet APHIS standards for accuracy, and should not be used. Recommend that they be destroyed.

5. PORTABLE SENSOR NO.	TEMPERATURE *(Specify °C or °F)* 6. SENSOR READING	7. MERCURY READING	8. DIFFERENCE *(Add/Subtract)*	9. REMARKS

RETURN COMPLETED FORM TO THE METHODS DEVELOPMENT CENTER THAT WILL ISSUE A CERTIFICATE.

APHIS FORM 205-R
(NOV 93)

Figure A-1 APHIS Form 205-R, Instructions and Worksheet for Calibrating Portable Temperature Sensors

APHIS Form 206-R, Test of the Accuracy of the Permanent RTD Sensors Installed in Hot Water Tanks

TEST OF THE ACCURACY OF THE PERMANENT RTD SENSORS INSTALLED IN HOT WATER TANKS

USDA - APHIS

1. DATE

2. NAME OF FACILITY	3. SIGNATURE OF PERSON TESTING SENSORS	4. NAME OF PERSON TESTING SENSORS *(Type or Print)*

INSTRUCTIONS

These instructions describe the procedure for testing the accuracy of the permanent RTD temperature sensors installed in the hot water tanks, which are wired to a recorder located in the Control Room.

(A) First, calibrate all available portable sensors against the certified glass mercury thermometer standard. *(See separate instructions and worksheet for performing this procedure - APHIS FORM 205.)*

(B) Select the portable sensor that shows the least deviation from the certified mercury standard. This particular sensor will now be used as a tool for testing the accuracy of each of the permanent RTD sensors installed on the tanks.

(C) Using a 6-foot rod *(such as a broom handle or PVC pipe)* and duct tape, fasten the "wet" end of the portable sensor wire to one end of the rod, being careful not to cover the metal sensor tip with tape. *(The use of a metal rod should be avoided because if it comes in direct contact with the portable sensor, it may cause false readings.)* Tape the sensor wire also to the center, and to the opposite end of the rod, to remove the slack.

(D) Raise the water temperature in the tanks to 115°F to 120°F *(46.1° to 48.9°C)*, and run the pump to ensure uniform distribution of heat. Inspect the sides of the tank to locate the exact position of each permanent RTD sensor. Using the portable sensor and rod assembly, dip it into the hot water until the portable sensor comes in close proximity to the tank's sensor. *(NOTE: Each basket position should have its own sensor.)* Plug the portable sensor into a hand-held digital thermometer, and read the display. Compare this number with the display on the data logger or strip chart recorder in the control room. *(You may need an assistant for this purpose.)* Record the results from the chart on this form. Repeat the procedure for each permanent sensor in the tank.

(E) Decision: If the temperature shown on the display in the control room matches the temperature shown on the hand-held digital thermometer *(as calibrated)*, then the permanent sensor in the tank is acceptable. If the two temperatures do not match exactly, but are within five-tenths of a degree *(F)* of each other *(+/- 0.3°C)*, then this small amount of deviation is considered to be within tolerance. Any permanent sensors that fail this standard must be repaired or replaced.

5. HAND-HELD DIGITAL THERMOMETER USED FOR THE STANDARD *(Portable Sensor Number Used: ____________.)*	6. MAKE & MODEL OF THE RECORDER USED IN CONTROL ROOM FOR TEMPERATURE DISPLAY

7. TANK NO. AND PERMANENT RTD SENSOR NO. *(Basket Position)*	8. READING OBTAINED *(°F or °C)* *(Hand-held)*	9. CORRECTION FACTOR *(Determined Previously)* (+/-)	10. TRUE READING (°F or °C)	11. READING OBTAINED *(°F or °C)* *(In Control Room)*	12. DIFFERENCE BETWEEN COLUMN 10. AND COLUMN 11. (°F or °C)	13. REMARKS

RETURN COMPLETED FORM TO THE METHODS DEVELOPMENT CENTER THAT WILL ISSUE A CERTIFICATE.

APHIS FORM 206-R (NOV 93)

Figure A-2 APHIS Form 206-R, Test of the Accuracy of the Permanent RTD Sensors Installed in Hot Water Tanks

APHIS Form 207-R, Sensor Location Diagram Fruit Weights and Pulp Temperatures

SENSOR LOCATION DIAGRAM FRUIT WEIGHTS AND PULP TEMPERATURES	USDA-APHIS	1. DATE
2. NAME OF FACILITY	3. TANK NUMBER	4. TEST NUMBER

INSTRUCTIONS

Show sensor numbers, and their approximate location within each basket. *(Use three or four sensors per basket.)* Place an asterisk (*) beside fruit pulp sensors. *(Use one or two per test.)* Indicate, by arrow, the direction of water flow in the tank. *(If the tank is of an unusual shape (e.g., round) please use the reverse side of this form to draw a diagram, showing position of baskets and sensors.)*

BASKET NO. 1	BASKET NO. 2	BASKET NO. 3	BASKET NO. 4	BASKET NO. 5

5. WEIGHT (g) OF 10 FRUITS SELECTED AT RANDOM		6. WEIGHT (g) OF 5 LARGEST FRUITS	7. FRUIT PULP TEMPERATURES (Taken at random)	8. NET WEIGHT OF A TYPICAL FIELD CRATE OF MANGOES
				9. NUMBER OF FIELD CRATES PER LOADED BASKET
MEAN WT. = (g)		MEAN WT. =	MEAN TEMP. =	

10. REMARKS

APHIS FORM 207-R (OCT 95) (Previous edition is obsolete)

Figure A-3 APHIS Form 207-R, Sensor Location Diagram Fruit Weights and Pulp Temperatures

APHIS Form 208, Performance Test for Mango Hot Water Immersion Tank

PERFORMANCE TEST FOR MANGO HOT WATER IMMERSION TANK USDA-APHIS	1. DATE OF TEST
2. NAME OF FACILITY	3. LOCATION
4. NAME OF FACILITY MANAGER (Type or print)	
5. TELEPHONE NUMBER ( )	6. FAX NUMBER ( )
7. FRUIT VARIETY	8. STAGE OF RIPENESS

9. TEMPERATURES AT START OF TEST

9A. THERMOSTATIC SET POINT	9B. WATER IN THE TANK	9C. FRUIT PULP (Average)	9D. AMBIENT AIR

10. SIGNATURE OF INSPECTOR	11. NAME OF INSPECTOR (Type or print)

12. NOTES

BASKET NO.: ______ TANK NO.: ______ TEST NO.: ______

Readings taken at specific times (minutes) before calibration adjustment (if any). Use 1 or 2 pulp sensors per tank. Indicate pulp sensors with an asterisk (*)

PORTABLE SENSOR NO. (Use at least 3)	CALLIBRATION ADJUSTMENT	[illegible]	0-1	1-2	2-3	3-4	5	30	60	75	90
		TIME									
		TEMP.									
		TIME									
		TIME									
		TIME									
		TEMP.									
		TIME									
		TEMP.									

APHIS FORM 208 (OCT 95) (Previous edition is obsolete) Page 1 of 2

Calibration of Temperature Probes (Cold Treatment)

CALIBRATION OF TEMPERATURE PROBES

Vessel: ______________________________

Date of Calibration: ______________ Date Loaded: ______________

Hatch & Compartment	Temperature Probe No.	Calibration at 0.0°C			Probe Temperature of Fruit at Completion of Loading
		Test #1	Test #2	Correction °C/°F	

Signature: ______________________________

Figure A-4 Calibration of Temperature Probes (Cold Treatment)

Location of Temperature Sensors in Containerized Cargo (Cold Treatment)

LOCATION OF TEMPERATURE SENSORS IN CONTAINERIZED CARGO

NAME OF VESSEL ______________________

CONTAINER NUMBER ____________________

PROBE 1 ________________________________

____

____

PROBE 2 ________________________________

____

____

PROBE 3 ________________________________

____

____

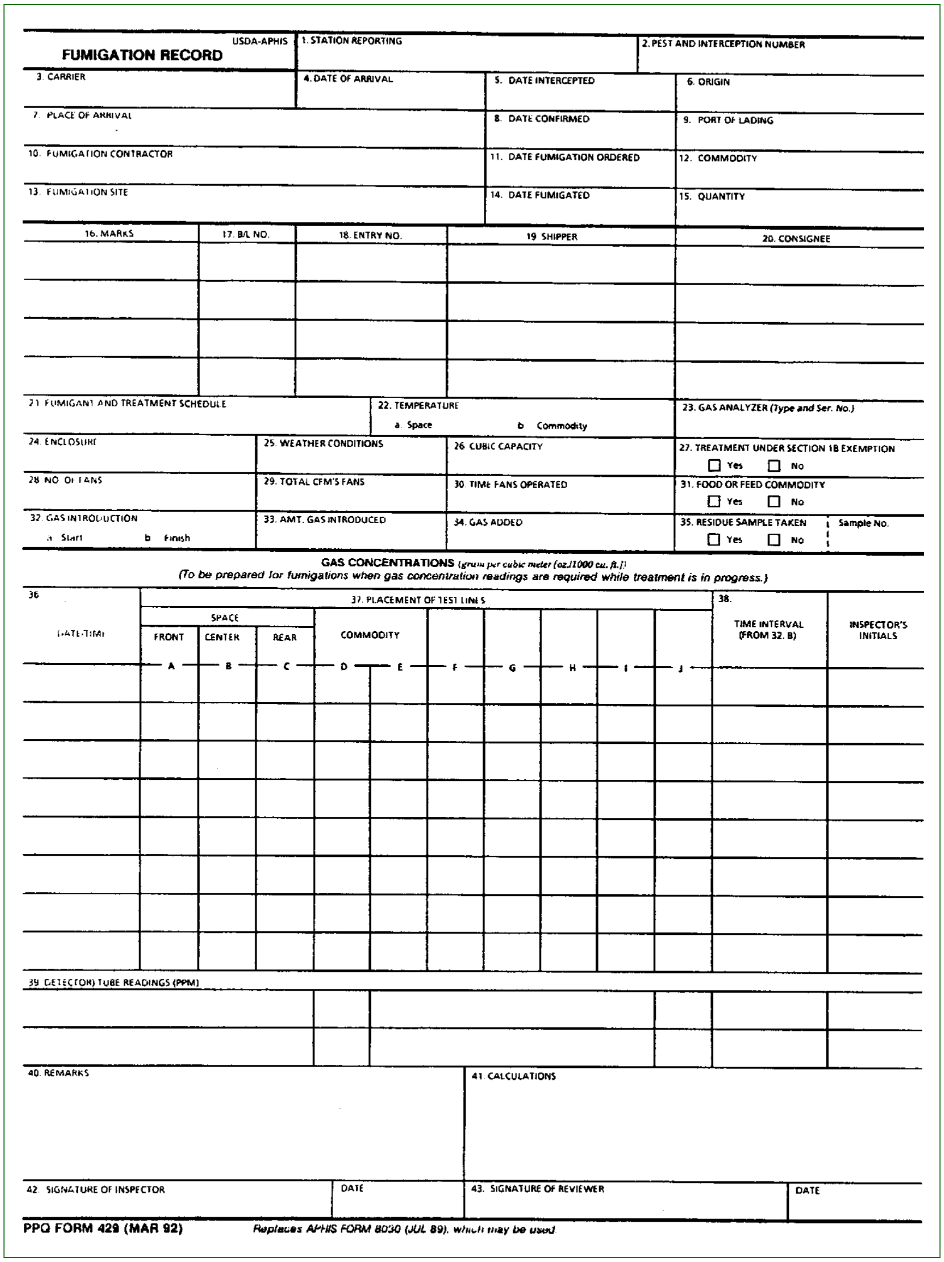
SIGNATURE: __________________ DATE: _____________

TITLE: _______________________

Figure A-5 Location of Temperature Sensors in Containerized Cargo (Cold Treatment)

PPQ Form 429, Fumigation Record

The PPQ Form 429 is to be used as a station record for all treatments conducted in approved chambers or in temporary enclosures (tarpaulin, in containers, truck vans, railroad cars, ships, warehouses, or other enclosures). Treatments conducted under temporary enclosures require minimum gas concentration readings be reported. CPHST-AQI tracks MB fumigant usage in an electronic 429 database. Contact CPHST-AQI for username and password.



USDA-APHIS
FUMIGATION RECORD
1. STATION REPORTING
2. PEST AND INTERCEPTION NUMBER
3. CARRIER
4. DATE OF ARRIVAL
5. DATE INTERCEPTED
6. ORIGIN
7. PLACE OF ARRIVAL
8. DATE CONFIRMED
9. PORT OF LADING
10. FUMIGATION CONTRACTOR
11. DATE FUMIGATION ORDERED
12. COMMODITY
13. FUMIGATION SITE
14. DATE FUMIGATED
15. QUANTITY
16. MARKS
17. B/L NO.
18. ENTRY NO.
19. SHIPPER
20. CONSIGNEE
21. FUMIGANT AND TREATMENT SCHEDULE
22. TEMPERATURE a. Space b. Commodity
23. GAS ANALYZER *(Type and Ser. No.)*
24. ENCLOSURE
25. WEATHER CONDITIONS
26. CUBIC CAPACITY
27. TREATMENT UNDER SECTION 18 EXEMPTION ☐ Yes ☐ No
28. NO. OF FANS
29. TOTAL CFM'S FANS
30. TIME FANS OPERATED
31. FOOD OR FEED COMMODITY ☐ Yes ☐ No
32. GAS INTRODUCTION a. Start b. Finish
33. AMT. GAS INTRODUCED
34. GAS ADDED
35. RESIDUE SAMPLE TAKEN ☐ Yes ☐ No
Sample No.
GAS CONCENTRATIONS *(grams per cubic meter (oz./1000 cu. ft.))*
(To be prepared for fumigations when gas concentration readings are required while treatment is in progress.)
36. DATE-TIME
37. PLACEMENT OF TEST LINES
SPACE: FRONT, CENTER, REAR
COMMODITY
A B C D E F G H I J
38. TIME INTERVAL (FROM 32. B)
INSPECTOR'S INITIALS
39. DETECTOR TUBE READINGS (PPM)
40. REMARKS
41. CALCULATIONS
42. SIGNATURE OF INSPECTOR
DATE
43. SIGNATURE OF REVIEWER
DATE
PPQ FORM 429 (MAR 92)
Replaces APHIS FORM 8030 (JUL 89), which may be used.

Figure A-6 Example of PPQ Form 429, Fumigation Record (Front)

TARPAULIN FUMIGATION

NOTE: *In preparation for the fumigation and prior to site selection the officer should have determined (1) the immediate pest risk associated with the infested commodity, (2) the temperature requirements for the fumigation, and (3) the permeability of the packaging.*

CHECKLIST OF MATERIALS AND PROCEDURES *(Consider each of the listed items when performing a fumigation.)*

MATERIALS

FUMIGATOR			PPQ
Tarpaulin	Tarpaulin Supports	Volatilizer	Gas Analazer
Sand Snakes	Fans	Heat Supply	Drierite
Water Snakes	Extension Cords	Exhaust Fans	
Loose Sand	2-3 Prong Plug Adapters	Sampling Tubes	Self Contained (SCBA) Breathing Apparatus
Burlap / Padding	Fumigant	Scale	Halide Detector
Masking Tape	Gas Introduction Line	Fumigation Placards	Tape Measure
Pesticide & Spray Equipment	T/C Gas Analyzer	SCBA - Self Contained Breathing Apparatus	Thermometer
			Gas Detector Kit and Detector Tubes

PROCEDURES *(SECTION III TREATMENT MANUAL)*

PREPARATION		FUMIGATION	
1. **SITE SELECTION**	3. **TARPAULIN ENCLOSURE**	4. **TREATMENT SCHEDULE DETERMINATION**	Introduction Rate
Ventilated Area	A. **COVER**	Plant Pest	Check for Leaks
Sheltered Area	Condition	Commodity Temperature	6. **SAFETY**
Impervious Surface	Air Space, Above Load	Space Temperature	Gas Detection Tests
Non-work Area	Floor Area 30 cm (12") Space Around Load	Volume Determination	7. **CONCENTRATION READINGS**
Proximity to Electrical Source	Overlap 45 cm (18") Border	Sorptive Commodity	T/C Gas Analyzer Standardization
Proximity to Commodity	B. **SNAKES**	Amount of Fumigant	Time Intervals
2. **ARRANGEMENT OF COMMODITY & EQUIPMENT**	Contact Along Sides	5. **FUMIGANT INTRODUCTION**	Gas Distribution
Stack Size Limitation	Contact Around Corners	Area Clear of Unauthroized Personnel	Maximum / Minimum
Air Space, Below and Between Load	Overlap 15 cm (6") Minimum	Cover condition	8. **AERATION (MULTIPLE STACKS)**
Placement of Tarp. Supports	C. **SAND**	Fan Operation	Exhaust Fan(s)
Placement of Padding	Perimeter	Contaminant Gases	Exhaust Tube(s)
Placement of Fans	D. **ADHESIVE**	Fumigant Cylinder Weight	Exhausted in a Non-fumigation Area
Placement of Gas Introdution Line(s)	Perimeter	Gas Line Connections	Negligible Gas Readings Before Tarpaulin Removal
Placement of Sampling Lines		Volatilizer Heated	Halide or Other Detector Tests

PPQ FORM 429 (Reverse) ☆ U.S. GOVERNMENT PRINTING OFFICE: 1997 417-294/60024

Figure A-7 Example of PPQ Form 429, Fumigation Record (Back)

Block	Instruction
1	Fill in.
2	Fill in scientific name(s) of pest or simply “precautionary” when fumigation is mandatory as a condition of entry or movement. Include station interception number(s) if fumigation is based on pest findings.
3-20	Fill in. In completing Block 12, if the commodity is a fruit or vegetable, enter the common name. The common name is more descriptive. If available, include the variety. By using common names and names of varieties, tolerances to the fumigant can be better predicted.
21	Fill in fumigant (for example, MB, CB, PH, EO, or SF), schedule number, dosage rate, and exposure period (4 lbs/1,000 ft^3 for 12 hours).
22	Fill in beginning temperatures in space under enclosure (a) and commodity temperature (b). Specify Centigrade or Fahrenheit.
23	Fill in type of thermal conductivity unit used (Fumiscope® or Gow-Mac®) and the serial number of the conductivity unit.
24	Fill in chamber, tarpaulin, structure, or type of carrier such as truck van, railroad car, or ship. If a container was used, indicate if covered by tarpaulin. Fill in type of tarpaulin used—single or multiple-use and the thickness (4 mil or 6 mil).
25	If treatment is conducted outside, fill in the weather conditions.
26	Fill in.
27	If commodity is treated under APHIS Section 18 Exemption, check “yes.” If commodity is treated at label dosage or less, check “no.”
28-30	Fill in.
31	If food or feed, check “yes.” If nonfood/nonfeed, check “no.”
32	Record time gas introduction started (a) and finished (b). Treatment does **not** start until gas is completely introduced in the chamber or enclosure.
33	When the fumigant dosage is calculated by weight, fill in the dosage to the nearest quarter pound. If liquid measures are needed, convert from weight to volume by using the conversion table in Appendix D.
34	If additional gas is required, note under Remarks (Block 40) and show calculations (Block 41).
35	Check appropriate box. Sample number refers to Block 7 on APHIS Form 2061 (Residue Sample for Food or Feed Product).
36	Record the date and time you take concentration readings. Treatment schedules specify when to take concentration readings.
37	Fumigants such as methyl bromide may be read and recorded directly from the gas analyzer. However, readings for fumigants such as sulfuryl fluoride must be corrected to get the true concentration reading. Each gas analyzer used for fumigants other than methyl bromide is calibrated with a correction factor. The factor is multiplied times the dial reading, to give the actual concentration. Record phosphine gas concentrations as ppm as determined by detector tubes or APHIS-approved detection device. Specify where the gas sampling line was placed: space or commodity. Use at least three lines. Use additional lines as needed.
38	Fill in.
39	Fill in time as well as the reading. Refer to the section in the manual that is tabbed “Aeration” for guidelines.

Block	Instruction
40	Note any unusual events that occurred during the treatment. When it is necessary to abort a fumigation, details concerning the termination of the treatment should be reported in this block.
41	Show all calculations used in determining the volume of temporary enclosures. Also show calculations when additional gas is added.
42-43	Sign and date.
Reverse Side	Use as a check list.

Distribution

Give the original and one copy to your supervisor for review. The supervisor should keep the original for port files and send one copy to:

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

PPQ Form 519, Compliance Agreement

FORM APPROVED
OMB NUMBER 0579-0054

UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE

COMPLIANCE AGREEMENT

According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0579-0054. The time required to complete this information collection is estimated to average 1.25 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

1. NAME AND MAILING ADDRESS OF PERSON OR FIRM	2. LOCATION

3. REGULATED ARTICLE(S)

4. APPLICABLE FEDERAL QUARANTINE(S) OR REGULATIONS

5. *I/We agree to the following:*

6. SIGNATURE	7. TITLE	8. DATE SIGNED
The affixing of the signatures below will validate this agreement which shall remain in effect until canceled, but may be revised as necessary or revoked for noncompliance.		9. AGREEMENT NO.
		10. DATE OF AGREEMENT

11. PPQ OFFICIAL *(Name and Title)*	12. ADDRESS
13. SIGNATURE	
14. STATE AGENCY OFFICIAL *(Name and Title)*	15. ADDRESS
16. SIGNATURE	

PPQ FORM 519
(FEB 2002)

Figure A-8 Example of PPQ Form 519, Compliance Agreement

Purpose

The PPQ Form 519 is a form that provides a signed, written agreement with fumigators to indicate their understanding of methods, conditions, and procedures necessary for compliance with regulations.

The PPQ Form 519 is also available electronically.

Instructions

Many PPQ ports maintain Compliance Agreements with commercial pesticide applicators. PPQ may maintain compliance agreements, however if they cancel an agreement, PPQ should not ban an exterminator from doing business, or applying regulatory treatments. PPQ may however, discontinue certification of a particular treatment that did **not** meet the required time, temperature, and concentration levels indicated in the treatment schedule. Similarly, PPQ may not want to begin monitoring a fumigation if the tarp appears inadequate and excessive leakage may lead to a safety problem.

Review compliance agreements at least annually, but preferably twice a year. Amend compliance agreements as appropriate.

If the establishment fails to abide by the conditions of the agreement, then the Port Director may cancel that agreement orally or in writing.

If you make an oral cancellation, confirm it in writing as soon as possible. The establishment has 10 days to appeal the cancellation. Appeals must be made to the Deputy Administrator.

Table A-1 Instructions for Completing PPQ Form 519, Compliance Agreement

Block	Instructions
1,8,9, 10-12	Fill in.
2	Fill in the location of the specific property(s) for which the agreement is signed.
3	Fill in the specific regulated articles to which the agreement applies.
4	Fill in the titles, parts, and subparts.
5	Outline stipulations which apply to the fumigator for each quarantine or regulation affecting the fumigator. Make clear to the fumigator that stipulations in the compliance agreement do **not** preclude compliance with other sections of the quarantine or regulations. If space in Block 6 is inadequate for listing the stipulations, then write “see Attached Sheets.”
6	Have a responsible official of the fumigator’s sign.
9	Assign a compliance agreement number.
13	Have the PPQ Port Director sign.
14-16	Complete only when State is involved in cooperating with enforcing Federal quarantines.

Distribution

If:	Then:
Compliance agreement affects one work unit	GIVE original to the fumigator, and KEEP a copy for port files in the area where the fumigator is located
Compliance agreement affects more than one work unit	GIVE original to the fumigator, and GIVE copies to all work units affected by the compliance agreement, and KEEP a copy for port files in the area where the fumigator is located

PPQ Form 523, Emergency Action Notification

According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information is 0579-0102. The time required to complete this information collection is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

FORM APPROVED - OMB NO. 0579-0102

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE

EMERGENCY ACTION NOTIFICATION

SERIAL NO.

1. PPQ LOCATION
2. DATE ISSUED
3. NAME AND QUANTITY OF ARTICLE(S)
4. LOCATION OF ARTICLES
5. DESTINATION OF ARTICLES
6. SHIPPER
7. NAME OF CARRIER
8. SHIPMENT ID NO.(S)
9. OWNER/CONSIGNEE OF ARTICLES

Name:

Address:

PHONE NO. FAX NO.

SS NO. TAX ID NO.

10. PORT OF LADING
11. DATE OF ARRIVAL
12. ID OF PEST(S), NOXIOUS WEEDS, OR ARTICLE(S)

12a. PEST ID NO.
12b. DATE INTERCEPTED

13. COUNTRY OF ORIGIN
14. GROWER NO.
15. FOREIGN CERTIFICATE NO.

15a. PLACE ISSUED
15b. DATE

Under Sections 411, 412, and 414 of the Plant Protection Act (7 USC 7711, 7712, and 7714) and Sections 10404 through 10407 of the Animal Health Protection Act (7 USC 8303 through 8306), you are hereby notified, as owner or agent of the owner of said carrier, premises, and/or articles, to apply remedial measures for the pest(s), noxious weeds, and or article(s) specified in Item 12, in a manner satisfactory to and under the supervision of an Agriculture Officer. Remedial measures shall be in accordance with the action specified in Item 16 and shall be completed within the time specified in Item 17.

AFTER RECEIPT OF THIS NOTIFICATION, ARTICLES AND/OR CARRIERS HEREIN DESIGNATED MUST NOT BE MOVED EXCEPT AS DIRECTED BY AN AGRICULTURE OFFICER. THE LOCAL OFFICER MAY BE CONTACTED AT:

16. ACTION REQUIRED

☐ TREATMENT:

☐ RE-EXPORTATION:

☐ DESTRUCTION:

☐ OTHER:

Should the owner or owner's agent fail to comply with this order within the time specified below, USDA is authorized to recover from the owner or agent cost of any care, handling, application of remedial measures, disposal, or other action incurred in connection with the remedial action, destruction, or removal.

17. AFTER RECEIPT OF THIS NOTIFICATION COMPLETE SPECIFIED ACTION WITHIN (Specify No. Hours or No. Days):

18. SIGNATURE OF OFFICER:

ACKNOWLEDGMENT OF RECEIPT OF EMERGENCY ACTION NOTIFICATION

I hereby acknowledge receipt of the foregoing notification.

SIGNATURE AND TITLE:

DATE AND TIME:

19. REVOCATION OF NOTIFICATION

ACTION TAKEN:

SIGNATURE OF OFFICER:

DATE:

PPQ FORM 523 (JULY 2002) Previous editions are obsolete.

Figure A-9 Example of PPQ Form 523, Emergency Action Notification

Purpose

The Emergency Action Notification (EAN) is a document that serves purposes for APHIS regulations. When an emergency action must be taken on a shipment, this form allows Customs and Border Protection - Agriculture Inspection (CBPAI) and/or Plant Protection and Quarantine (PPQ) to communicate the need for a specific action on a shipment to the interested parties. The EAN specifies to the broker, shipper, market owner, or other stakeholder the reason(s) why the shipment is being refused and basic explanation(s) as to what action is necessary.

The document also serves other critical needs. Use of the EAN information assists in determining risks and identifying trends. Through data compilation and analysis PPQ will use the information to update regulations, inform trade partners of areas of concern in foreign countries, and help with domestic emergencies. Targeting is another use for the information. CBPAI will be better able to determine which shipments may need closer inspection.

An EAN **must be issued from the National AQAS EAN Database** every time an emergency action is ordered for an agricultural purpose in the cargo or express courier environment. Agricultural purposes would be those that relate back to a violation of a regulation within the 7 CFR or 9 CFR chapters.

Important

EANs may **not** be issued as a hand written document, typed on a manual typewriter, from any local database, or any means of issuance other than the **National** AQAS system.[1]

1 The only acceptable reason for issuing an EAN from a source other than the AQAS National EAN Database is if the AQAS system is **not** in operation. In this instance, the EAN issued in another format must be entered into the AQAS National EAN Database within 24 hours.

Issue an EAN when:

- The Agriculture Specialist finds an actionable pest, potential quarantine pest, a contaminant, or prohibited product
- The Agriculture Specialist needs to record a commercial seizure
- The shipment lacks proper documentation
- The shipment contains non-compliant WPM
- The shipment is in the express courier environment (i.e. FedEx, UPS, DHL, etc.).

Do **not** issue an EAN for the following reasons:

- Condition of Entry/Precautionary Treatments - An EAN is **not** to be issued for a shipment requiring treatment as a condition of entry.
- Holding a Shipment - An EAN is only for taking immediate action. Do **not** use an EAN as a hold or supplemental hold for a shipment for any other reason than immediate treatment.
- Quality Issues - An EAN is **not** to be issued for the quality of a shipment. If the shipment does **not** pose a pest risk do **not** write an EAN.
- No inspection - An EAN is only to be issued if a shipment has been inspected (either a physical inspection of the goods or a paperwork inspection when that is the requirement) and an agricultural problem has been found. Do **not** write an EAN in lieu of inspection.
- Mail - Do **not** issue an EAN for any USPS mail. A Mail Interception Notification (PPQ 287) must be used for these shipments.
- Selected Animal Products - EANs are **not** to be issued on shipments of live animals or live animal commodities that are regulated by Veterinary Services. Refer to the Animal Product Manual for instructions on these products.
- Other Agencies' regulations - EANs are **not** to be issued for a violation of other agencies regulations. The only regulations that may be cited on an EAN are chapters 7 CFR and 9 CFR.

Instructions

The instructions in **Table A-2** are for initiating an EAN. The electronic version of PPQ Form 523 which is located in the National Agricultural Quarantine Activity System (AQAS) at https://aqas.aphis.usda.gov is the only method by which an Emergency Action Notification may be initiated. **Emergency Action Notifications MAY NOT be issued in any other format.** Fields marked with an asterisk (*) are mandatory fields.

Table A-2 Instructions for Initiating an EAN

Block Number	Field Name	Instructions
1	Issuing Port	Select the port in which the EAN is being issued. Please note that some users will have multiple locations. If the user is assigned to multiple locations, be sure to select the correct location. If the user is **not** assigned to a port to which he/she requires access, contact the help desk.
2	Date Issued	Enter the date that the EAN was issued.

Table A-2 Instructions for Initiating an EAN (continued)

Block Number	Field Name	Instructions
3 Name and Quantity of Manifested Article	Article Category* Article Name*	This block is to determine the commodity of the shipment. **Only one commodity is allowed to be listed per EAN.** Do **not** list pallets, crates, dunnage, etc. as the Name of Article unless they are the actual **commodity** being shipped. **Article Category** - Select a category (Animal Product, Plant Product, or Miscellaneous). The user must select the appropriate category as the other fields in this block are dependent upon it. **Animal Products** Animal Classification - Select the classification of the shipment. The classification selected will determine the drop down list for the classification category in the next field. See the Animal Products Manual (APM) contents page for further clarification. Classification Category - Select the classification category. The classification category will determine if a classification subcategory is required. To decide on a classification category see the APM classification selected in the previous field. Classification Subcategory - Select the classification subcategory. This information can be found in shipment documentation. * The drop down lists in this category have come directly from the Animal Product Manual. If you need assistance with this menu, see the APM. **Plant Products** This selection is for fresh cut flowers, fresh fruits and vegetables, logs, lumber, and propagative materials only. Any processed plant products (mulch, handicrafts, potpourri, Chinese Teas, etc.) will be found in the Miscellaneous Category. **Miscellaneous Products** This category is for all products that do **not** fit into either Animal Products or Plant products as defined above. Select the category that best fits the commodity. If there is **not** a category that fits your item please contact the help desk, National Coordinator, or Regional Coordinators before continuing. If the user selects miscellaneous, a description of the article must be entered. The description should be as accurate as the information available. For example, brake pads, bolt screws, linen fabric, stuffed toys, etc. If the product is agricultural but processed, the user must give an exact description of the article. For example, wooden birdhouses with grass roofs, dried whole apricots, wood carvings with bark edging, etc. **Article Name** - This drop down list has been determined by the user's previous selections. If the user does **not** find the article name in the drop down list please contact the help desk.
	Quantity* Unit of Measure*	Enter the numerical quantity of the shipment. When determining the article quantity, use the most specific number. For example, kilograms is a better selection than box count when dealing with most produce or meat products, but square meter is a better selection for veneer. **"Boxes/Crates" may not be used if another option is available.**
	APHIS Permit Number	**APHIS Permit Number** - If the shipment has any kind of APHIS permit, enter the number here.
	Wood Packing Material*	Check the appropriate boxes. If the user selects none or non-compliant only one box may be selected, but if the wood is non-compliant the user may chose both non-compliant for timber pest and no markings. **If wood is not marked with an acceptable symbol, then it is considered unmarked.**

Table A-2 Instructions for Initiating an EAN (continued)

Block Number	Field Name	Instructions
4	Location of Articles*	The location of articles is the place where the shipment is located when it is inspected. For example, US Air Warehouse, 123 Airplane Way, Butte, MT 12345. Each port will have a local drop down list so that users will **not** have to type addresses that have already been added to the system. If using the drop down list, ensure that the correct location has been selected. If the location that the user needs to select is **not** on the default list, it may be added by port users and supervisors by selecting "Set Defaults". All locations must contain the name of the facility, the physical address, city, state, and zip code.
5 Delivery Address of Articles	Name*	Enter the name of the company/individual accepting the goods as destination of the articles (delivery address). Do **not** use the broker as destination. Do **not** automatically assume that the consignee address and delivery address is the same.
	Address where the articles will be delivered*	Enter the address where the goods are intended to be delivered including street address, city, state (within the US), country, and zip/postal code. If the shipment has multiple destinations, the officer should include the destination to which the majority of the shipment is being delivered. If the shipments will be distributed evenly then choose the location to which the product could potentially cause the greatest risk. When determining the address to select the officer should use his/her best judgment. Additional delivery addresses should be entered into the “Comments” field on page 4 of the data entry screens. Questions regarding this should be directed to the officer’s first line supervisor.
6 Shipper	Name*	Enter the name of the shipper.
	Address of Shipper*	Enter the address of the shipper including street address, city, and country. Enter state/ province and postal code if known. **This must be a foreign address.**
7 Name of Carrier	Name*	Enter the name of the carrier company. For example, Northwest Airlines, M/V Panama, Canadian Pacific, Yellow Freight. On the land borders independent trucks frequently cross. If the truck is independent use the name of the owner of the tractor. Do **not** enter vehicle numbers in this field. **Do not enter abbreviations for the name of carrier including airline codes.**
	Flight/Voyage/ Trip Number*	Enter the appropriate number based on pathway. For trucks use the trailer license number.

Table A-2 Instructions for Initiating an EAN (continued)

Block Number	Field Name	Instructions
8 Consignment Identification Numbers	Airway Bill, Bill of Lading, PAPS Code*	Enter the bill of lading number. If the cargo is border cargo and does **not** have a bill number, use the PAPS code. **This is a mandatory field. Every shipment will have this number at the time that shipment is presented for inspection.**
	Tariff Number*	Enter the 10 character tariff number as provided in ACS or ATS. This is indicated in ATS as the HTS number. Do **not** add any punctuation, numbers only. If the user cannot find the tariff number in ATS or ACS then use this link to look up the number: http://dataweb.usitc.gov/scripts/tariff_current.asp
	Customs Entry Number*	Enter the Customs Entry Number. Do **not** add any punctuation, numbers only. *If the entry has **not** yet been filed at the time of inspection, enter "**Not** Yet Filed" *If the shipment is of low value (under $2000 as of 09/2006) it is considered informal and no entry number will ever be processed, enter "Informal" **Do not enter N/A or Not Available. If the user doesn't have an entry number other than listed above, describe why.**
	Container Number	Enter the complete container number. This is usually a 4-letter code followed by 5 or 6 numbers. Include the check digit.
	ISPM Markings	Enter the complete information from the ISPM Marking (IPPC wood marking). If the officer finds a pest in **marked** wood, this is a required field.
	Other Identifying Number	This field is available to include another number that there is either **not** a field for or can be used for a number collected for port policy. Examples include invoice number, shipment number, etc. **If the pathway is air cargo, the House Airway Bill must be entered here.**
	Other Identifying Number Description	If the user enters an "Other Identifying Number" then this field must be completed. The entry should clearly identify what the "Other Identifying Number" is. Do **not** use abbreviations in the description other than HAWB for "House Airway Bill."
9 Consignee of Articles	Name*	Enter the name of the Consignee. This will be a company name most of the time. If the shipment owner is an individual, enter the name of the individual. The Consignee is the owner of the shipment. The broker is usually **not** the consignee.
	Address of Consignee*	Enter the street address of the consignee. Street address, city, and country must be entered. Enter the state/province and postal code if known.
	Phone and Fax Numbers	Enter the phone and fax numbers of consignee if known
10 Port of Lading	City*	Enter the foreign city where the shipment was last loaded onto a vessel, plane, railcar, or vehicle.
	Country*	Enter the foreign country where the shipment was last loaded onto a vessel, plane, railcar, or vehicle.
11	Date of Arrival*	Enter the date that the shipment entered the port.

Table A-2 Instructions for Initiating an EAN (continued)

Block Number	Field Name	Instructions
12	Reason for EAN*	Select the reason(s) that the EAN is being issued. The following is a guideline to help determine the reason. **Pest** - If a pest or disease is found on, in, or with a shipment. Do **not** to enter a tentative ID. A national AQAS Pest ID number will be required. **FRSMP Pest** - Identified pest is restricted under FRSMP Program. **Lacks Documentation or Certification** - Shipment is missing documentation or the documentation is **not** acceptable. Documents may include but are **not** limited to health certificates, FSIS paperwork, permits, phytosanitary certificates, etc. **Contaminant- Seed** - Shipment is found to have seed or seed heads that are contaminants, but **not** part of the manifested commodity. A national AQAS Pest ID number is required. **Contaminant-Other** - Shipment is found to have any contaminant that does **not** need to be sent to an identifier. Examples include blood, soil, manure, etc. **Lacking ISPM15 Marking** - Shipment was found to have unmarked or improperly marked WPM. **Prohibited Animal Product** - Shipment was found to be prohibited by a 9 CFR. **Prohibited Product** - Shipment was found to be prohibited by 7 CFR regulation.
12a	Pest ID Number*	Enter the Pest ID number generated by the Pest ID system. This number must be provided by the identifier or an APHIS employee acting on behalf of an identifier. If pest or seed contaminant is selected as the reason for the EAN then the user will have to enter the 17 digit Pest ID number. If the user does **not** have the Pest ID number the EAN may be saved and printed, however the EAN cannot be closed in the system until this information has been added. The system will **not** accept local pest ID numbers in any form.
12b	Date Intercept- ed*	Enter the date that the reason for writing the EAN was found. This date must match the date that is entered on the Pest ID record (309A).
13	Country of Origin	Enter country of origin. The country of origin is **not** necessarily the country from which it is being shipped. The country of origin is the location where the commodity was grown, manufactured, or produced. For example, a shipment of handicrafts might be shipped from Canada, but were made in China. China is the country of origin. Canada is the country of lading.
14	Grower/ Facility Number	Enter the number of the foreign facility in which the product was processed or the foreign grower number. This number is frequently found on the invoice. It may also be available in ATS.
15	Foreign Sanitary Certificate Status*	Select the status of the certificate. If a certificate is **not** required continue to Block 16.
15a	Foreign Sanitary Certificate Number	Enter the certificate number.
15b	Place Issued	Enter City/Country where the certificate was issued. This will be a foreign address.
	Date Issued	Enter the date on which the certificate was issued.

Table A-2 Instructions for Initiating an EAN (continued)

<table>
<tr><th>Block Number</th><th>Field Name</th><th>Instructions</th></tr>
<tr><td>Contact Number</td><td>Phone Number*</td><td>Enter the phone number at which the user issuing the EAN can be reached.</td></tr>
<tr><td>16</td><td>Treatment Schedule</td><td>Using the drop down menu, if treatment is available, select the appropriate treatment schedule. The treatment schedule MUST be provided by a PPQ Identifier or PPQ Employee acting on behalf of an Identifier. CBP AI should not select a treatment schedule that has not been approved by a PPQ Identifier or PPQ Employee acting on behalf of an Identifier.</td></tr>
<tr><td></td><td>Explanation Text*</td><td>Select the explanation text that best matches the scenario for this EAN. This explanation tells the acceptor of the EAN two things: 1) what the problem is and 2) how to correct the situation. This is where the options are given. DO NOT use the “check boxes” printed on the form.

The identifier will verify Federally Recognized State Managed Phytosanitary (FRSMP) Program status and/or FRSMP options. If the pest is a FRSMP Program pest, then movement may be restricted.

<table>
<tr><th>If the pest is:</th><th>And the commodity is:</th><th>Then:</th></tr>
<tr><td rowspan="2">A FRSMP Program pest</td><td>Arriving in a FRSMP Program State for that pest</td><td>Use one of the following options:
◆ Treat
◆ Export
◆ Destroy
◆ Other
If "Other" is selected, then follow requirements to "Re-direct and Avoid" the FRSMP Program State</td></tr>
<tr><td>Arriving in other than a FRSMP Program State for that pest</td><td>Use option "Other" and notify the broker/importer of movement restriction to "Avoid" FRSMP Program States.</td></tr>
<tr><td>Not as above</td><td>→</td><td>No FRSMP action is required.</td></tr>
</table>
</td></tr>
<tr><td></td><td>Phyto-Fumigation Disclaimer</td><td>If fumigation is an option, the phyto disclaimer must be selected.</td></tr>
</table>

Table A-2 Instructions for Initiating an EAN (continued)

Block Number	Field Name	Instructions
16 (cont.)	CFR Regulation*	Select the Code of Federal Regulations under which the shipment is being regulated. More than one CFR can be selected.
	Seal Text	If the shipment must be transferred to another location under seal, select the text that is appropriate to scenario. If the shipment is being sent for treatment by PPQ the quantity of the shipment being transferred (preferably in box count) **must** be included. **NOTE:** If the PPQ Officer supervising the treatment does **not** know the quantity to be treated the shipment will **not** be treated until that information is provided from CBP.
	Comments	If the user has any additional comments to make, they should be recorded in the Comment field. Do **not** repeat information that has previously been provided. Do **not** enter any pest name in this location. It may be helpful on a local level to enter a local ID number or broker information here. **NOTE:** These comments will print on the paper EAN.
17	After Receipt of Notification Complete Specified Action Within:	The user should select the amount of time allowed before treatment begins. For example, if the shipment is to be re-exported then the user should select the amount of time before the shipment must be on the conveyance back to country of origin.
18	Name of Inspecting Officer	Enter the name of the officer that inspected the shipment. Do **not** enter the name of the data enterer unless it is the same individual.
Acknowledgement of Receipt of Notification	Name of Recipient	Enter the first and last name of the person accepting the EAN. The user **MUST** have this person print their name next to the signature. The only acceptable entry in this field is the first and last name of the person accepting the EAN. Do **not** enter "On File."
	Title of Recipient	Enter the title of the person accepting and signing the EAN. Preferably enter name of their company as well. Example: Dispatcher, American Shipping
	Date Signed	Enter the date the EAN was signed and accepted.
19 Revocation Notification	Reason for Action Taken*	Enter the reason that the EAN was written. **This should match the data entered in block 12.**

Table A-2 Instructions for Initiating an EAN (continued)

Block Number	Field Name	Instructions
19 (cont.)	Action Taken*	Enter the action that was actually taken. **Do not enter an action unless that action was taken.** If the action was “Treatment,” select the treatment type. If the action was “Other,” enter what action was taken in the “Additional Remarks” section. Be descriptive in the narrative. If FRSMP option "Avoid" was selected, then the additional comment should read "Broker/importer has been notified."
	Was the Article Mislabeled, Misrepre-sented, or Conceal-ed?*	Select yes or no.
	Form 518 Reference Number	If the above answer is yes, then a 518 number must be entered.
	Additional Remarks	If the user has additional information that was **not** previously recorded, it should be entered here. This field is required if Action Taken-Treatment Type is equal to “Other.” This field will **not** print at any time. These are private comments visible only to system users.
	Signature of Officer*	Enter the name of the officer that completed or monitored the treatment, received confirmation of destruction, or received confirmation of re-exportation. Do **not** enter the data entry clerk’s name unless it is the same officer as described above. This may be a different user than originally opened the EAN.
	Date Action was Completed*	Enter the date that the final action was completed.

* Mandatory field

Special Instructions for Infested Vessels Sailing Foreign Without Treatment

When an infested vessel is allowed to sail foreign without treatment, type the following statement in the "Comments" field on the EAN.

> The requirements of the Emergency Action Notification are suspended upon condition that this vessel shall leave the territorial limits of the United States within *[list number]* of hours after receipt of this notice. This vessel shall **not** re-enter any port in the United States unless it has been treated in accordance with the notification and certified by the person who applied the treatment. If the certificate is **not** presented to the CBP officer when arriving at a port in the United States, or if the CBP officer for any other reason is **not** satisfied that the infestation has been eliminated, the notification shall immediately become effective and treatment required.

Distribution

Because PPQ Form 523 is now electronic, distribution as in the past, on every EAN, is unnecessary. The procedure has been that the signing party, who is responsible for the cargo, receives a hard copy of the notification. The hard copy is necessary to communicate to the consignee or shipper, and also gives the broker time to review the options and select one. The CBP contact number is listed as well.

Routinely sending the EAN to any other parties is not required. Sharing courtesy copies between PPQ and CBP should continue for local, regional or national projects. Ports may also keep their own hard copies.

PPQ Form 449-R, Temperature Recording Calibration Report

Use the PPQ Form 449-R to document the calibration of temperature sensors for intransit cold treatment in vessels.

TEMPERATURE RECORDING CALIBRATION REPORT
(IN-TRANSIT COLD TREATMENT)

1. NAME OF VESSEL Crown Emerald			
2. PPQ DUTY STATION Houston	3. DATE OF INSPECTION 8-5-2008	4. POINT OF INSPECTION Bremerhaven, Germany	5. HULL NUMBER AND DOCKYARD 164 - Imabari
6. IMO NUMBER 9128037	7. FLAG (3-LETTER CODE) PAN	8. SHIP'S OFFICER ENS Smith	9. OWNER/OPERATOR Wallem Management

10. RECORDING INSTRUMENT 1	11. RECORDING INSTRUMENT 2
10a. MAKE Mycom	11a. MAKE
10b. MODEL Marcs	11b. MODEL

Recorder(s) must match CPHST website – see instructions.

TEMPERATURE SENSORS
(If unsatisfactory, explain in item 17.)

12. LOCATIONS MATCH DIAGRAM	13. LABELING OF SENSORS/BOXES	14. CABLE LENGTH	15. REACTION TIME
Satisfactory ◉ Unsatisfactory ○	Satisfactory ◉ Unsatisfactory ○	Satisfactory ◉ Unsatisfactory ○	Satisfactory ◉ Unsatisfactory ○

16. TEMPERATURE READINGS AT 0 C (32 F)

BULB NO.	TEST I	TEST II	TEST III	BULB NO.	TEST I	TEST II	TEST III	BULB NO.	TEST I	TEST II	TEST III	BULB NO.	TEST I	TEST II	TEST III
1A1	0.1	0.1		1C3	0.0	0.0		2A4	0.1	0.1		2C4	0.1	0.1	
1A2	0.0	0.0		1C7	0.0	0.0		2A5	0.1	0.1		2C5	0.1	0.1	
1A3	0.1	0.1		1C8	0.0	0.1	0.0	2A6	0.1	0.1		2D1	0.1	0.1	
1A4	0.1	0.1		1C9	0.0	0.0		2A7	0.1	0.1		2D2	0.1	0.1	
1A5	0.1	0.1		1D1	0.1	0.1		2B3	0.1	0.1		2D3	0.1	0.1	
1A6	0.1	0.1		1D2	0.1	0.1		2B8	0.1	0.1		2D4	0.1	0.1	
1A7	0.1	0.1		1D3	0.1	0.1		2B9	0.1	0.1		2D5	0.1	0.1	
1B1	0.1	0.1		1D4	0.1	0.1		2B10	0.1	0.1		3A1	0.1	0.1	
1B2	0.1	0.1		1D5	-0.2	-0.2		2B11	0.1	0.1		3A2	0.1	0.1	
1B4	0.2	0.2		1D6	-0.1	-0.1		2C1	0.1	0.1		3A3	0.1	0.1	
1B5	0.0	0.0		2A1	0.2	0.2		2C2	0.1	0.1		3A4	0.1	0.1	
1B6	0.0	0.0		2A2	0.3	0.3		2C3	0.1	0.1		3A5	-0.1	-0.1	

17. REMARKS (List names of all USDA officials participating in the calibration.)
D. Jones, S. Wood

18. COMPANY NAME AND ADDRESS TO SEND CERTIFICATE OF APPROVAL Wallem Ship Management 1799 West Street New York, NY	19. COMPANY EMAIL WSM@gmail.com 20. COMPANY PHONE NUMBER 800-879-4659
21. SIGNATURE OF LEAD INSPECTOR	22. DATE 5-August-2008

PPQ FORM 449-R (Local Reproduction Authorized)
(JAN 2007)

Figure A-10 Example of PPQ Form 449-R, Temperature Recording Calibration Report

Instructions for Completing PPQ Form 449-R

Block	Instructions
1	Verify that the vessel name agrees with the name on the CPHST -AQI web site: https://treatments.cphst.org/vessels/.
2	PPQ officer's duty station.
3	Date of Inspection
4	Place of Inspection
5	Verify that the hull number and dockyard agrees with the CPHST-AQI web site: https://treatments.cphst.org/vessels/.
6	The IMO number is a unique identification number for every vessel engaged in commerce and provides a complete history of the vessel. Verify that the IMO number agrees with the CPHST-AQI web site: https://treatments.cphst.org/vessels/. If this information is not on the CPHST-AQI web site, collect the number from the ship's officer and record in this block.
7	Verify that the flag (country of registry) agrees with the 3-letter code on the CPHST-AQI web site: https://treatments.cphst.org/vessels/.
8	Name of Captain, Chief Engineer, Reefer Engineer, or First Officer
9	Name of the shipping line owner or agent. Verify with CPHST-AQI web site: https://treatments.cphst.org/vessels/.
10a, b	Verify the make and model agree with the information on the web site. If the information differs from that listed on the website, gather as much information as possible from the vessels crew regarding when (date) instrument was changed, and whether or not they have any documentation from CPHST -AQI approving the changes. Record this additional information in the remarks section.
11a, b	Multiple recorders may be used. Record the make and model.
12	Verify that the sensor and cable locations match the diagram on the CPHST -AQI web site.
13	Verify that the sensors and cables are labeled correctly and in accordance with the sensor diagram.
14	Confirm that air sensors are capable of reaching the floor and fruit sensors are capable of reaching all areas of the compartment from their location along the walls (each should reach past the center line of the compartment).
15	Do the sensors respond appropriately when hand-warmed?
16	TEST ALL AIR AND PULP SENSORS. If officer suspects a compartment to be a hanging deck, test any sensors located in the space and make a notation in this block and in the narrative.
17	Record names of all USDA officials participating in the inspection, indicating lead officer for the report. Include any other information deemed appropriate.
18	Include as much information as possible.
19	Company email.
20	Company phone number.
21	Signature of Lead Inspector.
22	Date the report is completed.

PPQ Form 203, Foreign Site Certificate of Inspection and/ or Treatment

According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control num ber. The valid OMB control numbers for this information collection are 0579-0190 and 017 3. The time required to complete this information collection is estimated to a verage .5 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completi ng and reviewing the collection of information.

OMB APPROVED
0579-0190 and 0173

U.S DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE

FOREIGN SITE CERTIFICATE OF INSPECTION AND/OR TREATMENT

1. CERTIFICATE NO.	2. COUNTRY OF ORIGIN
3. DATE LOADED	4. FOREIGN PORT OF EXPORT
5. CARRIER IDENTIFICATION	6. U.S. PORT OF ENTRY
7. SHIPPER (Name and Address - Include Zip Code)	8. CONSIGNEE (Name and Address - Include Zip Code)

9. COMMODITY	10. NO. CONTAINERS (Identify as box, sack, 1/2 Bruce box, flat, cardboard box, etc.)	11. CONTAINER IDENTIFICATION MARKS

12. LOCATION OF INSPECTION AND/OR TREATMENT	13. DATE

This certifies that the shipment described above has been inspected and/or treated in accordance with agricultural requirements for entry into the United States.

14. SIGNATURE OF PLANT PROTECTION AND QUARANTINE OFFICER	15. DATE ISSUED

PPQ FORM 203
(JUL 2007)

Figure A-11 PPQ Form 203, Foreign Site Certificate of Inspection and/or Treatment

Purpose

PPQ Form 203 verifies that PPQ has precleared the commodity it accompanies (either through inspection or treatment) at the foreign site.

An electronic copy of this form is available in the APHIS forms library at the USDA APHIS PPQ Forms web site.

Instructions

The Agriculture Specialist at Port of Entry (POE) examines this form when a precleared commodity arrives at the port.

The APHIS officer completes this form at the foreign site where the commodity is inspected or treated. The form may either be handwritten in ink or typed. Use **Table A-3** to decide what paperwork should be presented upon the arrival of a precleared commodity.

Table A-3 Determine Paperwork to Be Presented upon Arrival of a Precleared Commodity

If arriving from:	And by:	Then the exporter or the exporter's agent must provide the following paperwork:
Australia, Japan, Korea, or the Republic of South Africa	→	◆ Original (yellow or white) PPQ Form 203 for the commodity ◆ Copy of the master PPQ Form 203 or original Phytosanitary Certificate, specifying the number of units shipped or remaining in cold storage from the master PPQ Form 203
Chile	Vessel	◆ Original Chilean Phytosanitary Certificate ◆ E-mail notification of the cargo on board and its status from the IS Region II office to the POE **NOTE:** No PPQ Form 203 will accompany the commodity
	Air	◆ Original (yellow or white) PPQ Form 203 for the commodity ◆ Original Chilean Phytosanitary Certificate
India or Thailand	→	◆ Original (yellow or white) PPQ Form 203 for the commodity ◆ Original Indian or Thailand Phytosanitary Certificate
New Zealand	→	◆ Original (yellow or white) PPQ Form 203 for the commodity, **or** a copy of the master 203 ◆ Original New Zealand Ministry of Agriculture forms specifying the number of units shipped or remaining in cold storage from the master PPQ Form 203, Final Balances-Balance Sheet for USA-Passed Product in Coolstore and Details of Loading Certificate
Other than a country listed in the cells above	→	◆ Original (yellow or white) PPQ Form 203 for the commodity

Verify that any seals listed on the form are still intact. Also, confirm that the information and conditions described on the form agree with the cargo manifest, invoice, or other CBP entry documents. Contact QPAS at 301/851-2312 if **any** of the following occurs:

- PPQ Form 203 is missing
- Seals are broken
- Information on the PPQ Form 203 does **not** match the entry documents

Important

Refer to the Fruits and Vegetables Import Requirement database (FAVIR) for the commodity being shipped. The commodity may be undergoing in-transit cold treatment. If it is, you need to ensure that the commodity meets the time and temperature requirements.

Instructions for Issuing Officer

The APHIS Issuing Officer will complete PPQ Form 203, as follows:

1. Type the form or write in ink.
2. Number the certificate using the numbering system assigned by the Area Office with responsibility for the program.
3. If the commodity was treated, mark the form with the plant's approved stamp.
4. Fill in the remaining, self-explanatory information.

Distribution

Issuing Officer

The APHIS Issuing Officer will distribute PPQ Form 203 using **Table A-4** as a guide.

Table A-4 Distribution of PPQ Form 203, Foreign Site Certificate of Inspection and/or Treatment

If:	Then:
Original and first copy	GIVE to the exporter (the original must be presented at the first POE)
Copy	SEND to the Area Office, IS, with responsibility for the program
Copy	RETAIN by the certifying APHIS officer
Copy (through the office of cooperator)[1]	FAX a copy to the U.S. Port of Arrival
Copy	ATTACH to trip report

1 This does **not** apply to all programs. Check the technical packet or with the IS Field Office in Charge.

PPQ Form 556, Intransit Cold Treatment Clearance Report

U. S. DEPARTMENT OF AGRICULTURE
Animal and Plant Health Inspection Service
Plant Protection and Quarantine Programs
IN TRANSIT COLD TREATMENT CLEARANCE REPORT

INSTRUCTIONS: Refer to PPQ Treatment Manual Sec. III part 10 and CFR 319.56-2d.

1. NAME OF CARRIER	2. PORT OF LOADING	3. PAGE NO. of
4. PORT REPORTING	5. DATE	6. TIME
7. PORT REPORTING	8. DATE	9. TIME

10. CONTENTS OF COMPARTMENTS

COMMODITY	NO. CASES	COMMODITY	NO. CASES	COMMODITY	NO. CASES	COMMODITY	NO. CASES
Apples		Nectarines		Pears		Plums	
Cherries		Oranges		OTHER (Specify)		OTHER (Specify)	
Grapes		Peaches					

INSTRUMENT EXAMINATION		INSTRUMENT EXAMINATION	
11. INSTRUMENT NO.	12. WAS INSTRUMENT LOCKED? YES ☐ NO ☐	17. INSTRUMENT NO.	18. WAS INSTRUMENT LOCKED? YES ☐ NO ☐
13. PRINTING INTERVAL	14. CHART SPEED (in. or cm/24 hours)	19. PRINTING INTERVAL	20. CHART SPEED (in. or cm/24 hours)
15. ACTUAL LENGTH OF RECORD	16. CALCULATED LENGTH OF RECORD	21. ACTUAL LENGTH OF RECORD	22. CALCULATED LENGTH OF RECORD

23. CALIBRATION RECORD SATISFACTORY ☐	IF NOT SATISFACTORY - WHY	SIGNED BY

TEMPERATURE RECORD

24. IDENTIFY COMPARTMENTS													
25. Initial fruit temp. recorded		MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.
26. Loading completed		DATE	TIME	DATE	TIME	DATE	TIME	DATE	TIME	DATE	TIME	DATE	TIME
27. TREATMENT COMMENCED	2.2°C(36°F)												
	1.7°C(35°F)												
	1.1°C(34°F)												
	0.6°F(33°F)												
	0°C(32°F)												
28. Total No. days treatment to time of clearance		TEMP.	DAYS	TEMP.	DAYS	TEMP.	DAYS	TEMP.	DAYS	TEMP.	DAYS	TEMP.	DAYS
29. Pulp temperatures (manual check by PPQ officer)		MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.
30. Recorded temperatures		BULB NO.	TEMP.	BULB NO.	TEMP.	BULB NO.	TEMP.	BULB NO.	TEMP.	BULB NO.	TEMP.	BULB NO.	TEMP.

31. CARGO STOWAGE SATISFACTORY ☐	IF NOT, SPECIFY WHY	32. SIGNATURE OF OFFICER

PPQ FORM 556
AUG. 1977
REPLACES PPQ FORM 556(9/74) WHICH MAY BE USED

Figure A-12 PPQ Form 556, In Transit Cold Treatment Clearance Report

Worksite Specific Respiratory Protection Plan—Template

A worksite specific respiratory protection plan is mandatory. Refer to **Figure A-13** through **Figure A-20** for a generic template or go to the S&H Sharepoint site for other worksite plans. Contact your FO Safety Manager for a site specific plan.

MANDATORY WORKSITE SPECIFIC RESPIRATORY PROTECTION PLAN

TEMPLATE

APHIS /PPQ FIELD OPERATIONS

RESPIRATORY PROTECTION PROGRAM

COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

This operation instruction (OI) contains information and guidance for proper respirator selection, use, care and maintenance. Template meets OSHA 29 CFR 190.134 Respiratory Protection requirements to establish worksite specific plan.

DIRECTIONS:
1.1. Review Policy
1.2. Input your Program management position in accordance with identified *font in black*.
1.3. May edit or add specific procedures with approval of PPQ FO Safety and Health.

DOCUMENT APPROVAL:
1.4. Approval by Local Manager with signature/date
1.5. Approval by State Plant Health Director with signature/date
1.6. Approval by PPQ FO Safety Manager with signature/date

RECORDKEEPING:
1.7. Approved/signed copy (PDF file) of original must be sent to PPQ FO Safety Health Office.
1.8. Copy will be kept on Site, readily available for review.

- http://sp.we.aphis.gov/PPQ/fieldops/safehealth/SitePages/Respiratory%20Protection.aspx

Figure A-13 Worksite Specific Respiratory Protection Plan—Template (page 1 of 8)

TEMPLATE FOR SITE USE
RESPIRATORY PROTECTION PROGRAM
COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

Approved By: **NAME OF SPHD**

This operation instruction (OI) contains information and guidance for proper respirator selection, use, care and maintenance.

REFERENCES:

29 CFR 1910.134, Respiratory Protection

USDA APHIS Safety and Health Manual, Chap 11

GENERAL:

The use of respiratory protection should be a last resort. Substituting less hazardous materials or processes, eliminating hazards through engineering changes or controls, isolating hazardous operations, or providing administrative controls shall be considered before the decision is made to protect workers with respirators.

No personnel may wear a respirator unless required or recommended by Site Supervisor in conjunction with advice from Safety and Occupational Health Manager/Specialist.

CATEGORIES OF RESPIRATOR USAGE: Site Supervisor shall identify the location and use of all respirators worn by employees.

Operation/Process	Type of Respirator	Cartridge Type	Cartridge Change out Frequency	Category of Use
Fumigation Process *Methyl Bromide* *Readings > 5ppm*	*Full Face (SCBA)*	*n/a*	*n/a*	*Required*
Fumigation Process *Methyl bromide* *Reading >1- < =4 ppm*	*APR (Half Face)* *or* *APR (Full Face)*	*Organic Vapor/Acid Gas/P100 cartridges*	*-Change immediately after each use or if air is restricted when breathing*	*Required*

Medical Clearance: Medical evaluation and clearance is required before performing tasks requiring use of respirators in order to determine an employee is physically able to do the work and utilize the equipment medically (ref. APHIS Safety and Health Manual, Chap 11, Sec 11.3.4, Para F) or (new ref. APHIS Safety and Health Manual, Chap 7, Section 9, Dec. 2010). The evaluation must be performed by a physician or

Figure A-14 Worksite Specific Respiratory Protection Plan—Template (page 2 of 8)

licensed health care professional. Final evaluation approval shall be determined by an authorized APHIS medical provider. The respirator user's medical status should be reviewed every year or as certifying physician determines. The medical evaluation should include, as a minimum, an evaluation to identify pulmonary and cardiovascular impairment.

Training: All personnel will receive initial respiratory protection training prior to wearing a respirator. Periodic training will be accomplished by a work place supervisor annually. Documentation of the initial and annual training will be documented on SF form 182 or equivalent. A copy of the training plan is located in attachment 2.

Fit-Testing: After instruction, a quantitative fit-testing will be conducted. Contact Candace Robl for assistance at (941) 359-3281. Fit Test documentation will be recorded and maintained by Site Supervisor. Employees are only allowed to wear respirators for which they have been fit tested/trained. A respirator fit-test shall be carried out for each wearer of a tight-fitting respirator at least once every 12 months. A new fit test will be accomplished when a worker experiences a change in physical condition that could affect respirator fit (e.g., weight change of more than 20 pounds, facial scarring, dental changes cosmetic surgery, disfigurement, … etc.).

Program Compliance:
Site Supervisor: Supervisors will be familiar with the training/fit-testing status of all respirator wearers. SF form 182 or computerized equivalent and 429 data base shall be used to record and track the date of the most current certification. Supervisors will ensure personnel on the respirator protection program wear the correct respiratory protection for which they have been fit-tested and trained prior to utilization.

Individuals: Individuals provided respiratory protection will use it according to the instructions and training received. Report to their supervisor any change in medical status, which may impact their ability to safely wear respiratory protection. Inspect, clean, and maintain any respiratory protection device issued to them for their individual use. Wear only respiratory protection (mfg, make, model and size) for which they have received fit-testing and training, and only for the tasks specified.

User Seal Check Procedures:
Workers who use tight-fitting respirators will perform positive and negative pressure checks to ensure adequate seal is achieved each time the respirator is put on.

Positive Pressure Check: Close off exhalation valve and exhale gently into the face piece. The face fit is considered satisfactory if a slight positive pressure can be built up inside the face piece without any evidence of outward leakage of air at the seal. For most respirators this method of leak testing requires the wearer to first remove the exhalation valve cover before closing off the exhalation valve and then carefully replacing it after the test.

Negative Pressure Check: Close off inlet opening of the canister or cartridge(s) by covering with palm of the hand(s) or by replacing the filter seal(s), inhale gently so that the face piece collapses slightly, and hold breath for ten seconds. The design of the inlet opening of some cartridges cannot be effectively covered with the palm of the hand; in those circumstances, covering the inlet opening of the cartridge with a thin latex or nitrile glove can perform this test. If face piece remains in its slightly collapsed condition and no inward leakage of air is detected, tightness of the respirator is considered satisfactory.

Respirator Sealing Problems:
A head covering which passes between the sealing surface of a tight-fitting respirator face piece and the wearer's face shall not be used.

Figure A-15 Worksite Specific Respiratory Protection Plan—Template (page 3 of 8)

Wearing of protective equipment used by the wearer shall not interfere with seal of the respirator. Personnel who are not clean-shaven or on a shaving waiver will not be permitted to wear a tight fitting respirator. If personnel are on a shaving waiver they are disqualified from the tight fitting respirator program until they can shave again.

Vision:
When a respirator user must wear corrective lenses, the wearer must use protective spectacles, goggles, face shields or other eye and face protective devices such that the item shall be fitted to provide good vision and shall be worn in such a manner as not to interfere with the proper seal of the respirator.

Spectacles with straps or temple bars that pass through the sealing surface of either negative or positive pressure, tight-fitting, full-face piece respirators shall not be used.

Contact lenses will not be worn with respirators in a fuel systems repair area.

If an individual who must wear corrective lenses uses spectacle inserts with a full-face piece respirator, then the government will purchase the spectacle inserts for the respirator, using a prescription provided by the user.

Care, Inspection, and Maintenance of Respirators:
General Discussion: Each individual issued a respirator is responsible for its primary maintenance and care. **Supplied Air shall be of high purity and tested according to 29 CFR 1910.134(i)(1)(ii) . Copy of results of breathing air shall be received form vendor and kept by supervisor or designated Respiratory Program Manager.**

Care:
Cleaning and sanitizing: Respirators issued to an individual shall be cleaned and sanitized at the end of each day in which the respirator is used. Each respirator shall be cleaned and sanitized with MSA Cleaner Sanitizer II before and after each use. (See Attachment 1)

Storage: Respirators shall be stored in a manner that will protect them against chemical agents and physical agents such as vibration, shock, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals. Respirators shall be stored to prevent distortion of rubber or other elastomeric parts. Respirators shall not be stored in such places as lockers and toolboxes unless they are protected from contamination, distortion, and damage.

Inspection: The user shall inspect the respirator immediately before each use to ensure it is in proper working condition. After cleaning and sanitizing, each respirator shall be inspected to determine if it is in proper working condition, needs replacement of parts, needs repairs, or should be discarded. Air supplied respirators will be inspected each month. Respirators, which do not meet applicable inspection criteria, shall be immediately removed from service. Respirator inspection shall include a check for tightness of connections; for the condition of the respiratory inlet covering, head harness, valves, connecting tubes, harness assemblies, hoses, filters, cartridges and for the proper functioning of regulators, alarms, and other warning systems. Each rubber or other elastomeric part shall be inspected for pliability and signs of deterioration. The breathing air system shall be inspected to ensure it is fully charged prior to use according to the manufacturer's instructions.

Maintenance:
Only personnel trained in proper respirator maintenance and assembly shall do replacement of parts or repairs.

Figure A-16 Worksite Specific Respiratory Protection Plan—Template (page 4 of 8)

Replacement parts shall be used only as designated for specific respirators.

Respiratory Documentation and Respirator Recordkeeping:
Site Supervisor establish and retain written information regarding medical evaluation, fit testing, respirator training. Itemized PPE maintenance/care/cleaning and appropriate respirator cartridge/filter change-out schedule shall be documented and retained. The documentation shall include User/respirator model/cartridge type/change-out date/cleaning date/initials shall be readily available. The respirator itself shall have a change-out date incorporated on the outside of each cartridge/filter which matches the latest documentation entry.

Print Name / signature

POSITION or RESPONSIBLE SUPERVISOR

Attachments:

1. Respirator Cleaning Procedures
2. Respiratory Protection Shop Specific Training
3. Voluntary use of Respirator-Where Respirators are Not Required

Approved/Disapproved

Signature_______________________________________Date____________

Local Director/Manager

Signature_______________________________________Date____________

State Plant Health Director

Signature_______________________________________Date____________

Safety and Health Office

Figure A-17 Worksite Specific Respiratory Protection Plan—Template (page 5 of 8)

Attachment 1

RESPIRATOR CLEANING PROCEDURES

The following procedure is recommended for cleaning and disinfecting respirators:

1. Remove any filters, cartridges, canisters, or communication devices.
2. Wash face piece and breathing tube in a cleaner-disinfectant solution. Use a soft brush to facilitate dirt removal.
3. Use MSA Cleaner Sanitizer II for proper sanitizing of respirators.
4. Rinse completely in clean, warm, water, which is less than or equal to 120 degrees F.
5. Air-dry in a clean area.
6. Clean other respirator parts as recommended by the manufacturer.
7. Inspect valves, head straps, and other parts; replace defective parts with new ones.
8. Insert new filters, cartridges, or canisters periodically as specified by the manufacturer; make sure seal is tight.
9. Place in plastic bag or other closed container for storage.
10. Document cleaning date, respirator model and user for recordkeeping.

Figure A-18 Worksite Specific Respiratory Protection Plan—Template (page 6 of 8)

Attachment 2

SHOP SPECIFIC TRAINING LESSON PLAN

Respirator Requirement (Type and number of RP must be the same. Change to update for local work unit)

This work center has a requirement for the use of *XX* different respirators.

List required respirators.

Why is a respirator required?

IAW USDA, PPQ Treatment Manual dated 1 Mar 2006 respirators are required when using various fumigants during the following processes: Installing the exhaust system, opening the tarplin for aeration, removing the tarpaulin if measured levels of fumigant are above 5 ppm and any time during the aeration process when a risk of exposure to concentration above 5 ppm exists. **This includes any time the concentration is unknown.**

Confined space incinerator inspection maintenance, cleaning and inspection of propagated material shall require respirator use from possible unknown residual chemical exposure.

What are the potential acute and chronic health effects of exposure to the following material(s)?:

Headache, fatigue, skin irritation, loss of appetite, experience shortness of breath, dizziness, unconsciousness, central nervous system depression, fever and death.

Weight of Respirators:

List weight of required respirators.

List Duration of Use.

List Frequency of Use.

List Expected Physical Work Effort.

List Additional Required PPE.

List Temperature/Humidity Extremes.

Administrative Controls.

Figure A-19 Worksite Specific Respiratory Protection Plan—Template (page 7 of 8)

Attachment 3

Voluntary use of Respirator-Where Respirators are Not Required

APHIS may provide respirators at the request of employees if the Agency determines the respirator will not in itself create a hazard. APHIS has determined disposable respirators will not be used when performing PPQ plant inspection and incinerator duties. Disposable respirators do not protect against possible contamination of pesticides. Disposable respirators will only protect against particulates at a given efficiency rate and size. At a minimum, half face and or full face APR respirators with combination VOC/HEPA cartridge shall be used when suspect possible unknown contaminates.

Figure A-20 Worksite Specific Respiratory Protection Plan—Template (page 8 of 8)

Appendix B

Treatment Manual

Coast Guard Regulations

This Appendix contains information reprinted from 46CFR, October 1, 2011

Title 46—Shipping
Chapter 1—Coast Guard, Dept. of Transportation

Part 147A—Interim Regulations For Shipboard Fumigation

Authority: 46U.S.C. 5103; Department of Homeland Security Delegation, No. 0170.1.
Source: CGD 74-144, 39 FR 32998, Sept. 13, 1974, unless otherwise noted.

General

Sec. 147A.1 Purpose.

The purpose of this part is to prescribe the requirements for shipboard fumigation that are critical for the health and safety of the crew and any other person who is on board a vessel during fumigation. These are interim rules pending further study and promulgation of comprehensive regulations on shipboard fumigation.

Sec. 147A.3 Applicability.

This part prescribes the rules for shipboard fumigation on vessels to which 49 CFR parts 171-179 apply under 49 CFR 176.5.

Sec. 147A.5 General requirement.

No person may cause or authorize shipboard fumigation contrary to the rules in this part.

Sec. 147A.6 Right of Appeal.

Any person directly affected by a decision or action taken under this part, by or on behalf of the Coast Guard, may appeal therefrom in accordance with subpart 1.03 of this chapter.

Sec. 147A.7 Definitions.

As used in this part:

(a) Qualified person means a person who has experience with the particular fumigant or knowledge of its properties and is familiar with fumigant detection equipment and procedures, or an applicator who is certified by the Environmental Protection Agency if his certification covers the fumigant that is used.

(b) Fumigant means a substance or mixture of substances that is a gas or is rapidly or progressively transformed to the gaseous state though some nongaseous or particulate matter may remain in the space that is fumigated.

(c) Fumigation means the application of a fumigant on board a vessel to a specific treatment space.

Sec. 147A.9 Persons in charge of fumigation and the vessel; designation.

(a) The person, including any individual, firm, association, partnership, or corporation, that is conducting a fumigation operation shall designate a person in charge of fumigation for each operation.

(b) The operator of each vessel shall designate a person in charge of the vessel for each fumigation operation.

Sec. 147A.10 Notice to Captain of the Port.

Unless otherwise authorized by the Captain of the Port, at least 24 hours before fumigation the operator of the vessel shall notify the Coast Guard Captain of the Port, for the area where the vessel is to be fumigated, of the time and place of the fumigation, and the name of the vessel that is to be fumigated.

Before Fumigation

Sec. 147A.11 Person in charge of fumigation; before fumigation.

(a) The person in charge of fumigation shall notify the person in charge of the vessel of:

(1) The space that is to be fumigated;

(2) The name, address, and emergency telephone number of the fumigation company;

(3) The dates and times of fumigation;

(4) The characteristics of the fumigant;

(5) The spaces that are determined to be safe for occupancy paragraph (b)(1)(i) of this section;

(6) The maximum allowable concentration of fumigant in spaces, if any, that are determined to be safe for occupancy under paragraph (b)(1)(i) of this section;

(7) The symptoms of exposure to the fumigant; and

(8) Emergency first aid treatment for exposure to the fumigant.

(b) The person in charge of fumigation shall ensure that:

(1) A marine chemist or other qualified person who has knowledge of and experience in shipboard fumigation evaluates the vessel's construction and configuration and determines:

(i) Which spaces, if any, are safe for occupancy during fumigation; and

(ii) The intervals that inspections must be made under Sec. 147A.21(a)(1);

(2) No persons or domestic animals are in the space that is to be fumigated or the spaces that are designated as unsafe for occupancy under paragraph (b)(1)(i) of this section;

(3) There is proper and secure sealing to confine the fumigant to the space that is to be fumigated, including blanking off and sealing any ventilation ducts and smoke detectors;

(4) The personal protection and fumigation detection equipment for the fumigant that is to be used is on board the vessel;

(5) Warning signs are:

(i) Posted upon all gangplanks, ladders, and other points of access to the vessel;

(ii) Posted on all entrances to the spaces that are designated as unsafe for occupancy under paragraph (b)(1)(i) of this section; and

(iii) In accordance with 49 CFR 173.9(c) or section 8.10 of the General Introduction of the International Maritime Dangerous Goods Code. The word “unit" on the warning sign may be replaced with “vessel,” “barge,” “hold,” or “space,” as appropriate.

(6) Watchmen are stationed at all entrances to:

(i) Spaces that are not determined to be safe for occupancy under paragraph (b)(1)(i) of this section; or

(ii) The vessel, if no spaces are determined to be safe for occupancy under paragraph (b)(1)(i) of this section.

Sec. 147A.13 Person in charge of the vessel; before fumigation.

(a) After notice under Sec. 147A.11 (a)(5), the person in charge of the vessel shall notify the crew and all other persons on board the vessel who are **not** participating in the fumigation of the spaces that are determined to be safe for occupancy under Sec. 147A.11(b)(1)(i).

(b) If no spaces are determined to be safe for occupancy under Sec. 147A.11 (b)(1)(i), the person in charge of the vessel shall ensure that the crew and all persons who are **not** participating in the fumigation leave the vessel and remain away during fumigation.

During Fumigation

Sec. 147A.21 Person in charge of fumigation; during fumigation.

(a) Until ventilation begins, or until the vessel leaves port, the person in charge of fumigation shall ensure that a qualified person inspects the vessel as follows:

(1) He must use detection equipment for the fumigant that is used to ensure that the fumigant is confined to:

(i) The space that is fumigated, if partial occupancy is allowed under Sec. 147A.11(b)(1)(i); or

(ii) The vessel, if no space is determined to be safe for occupancy under Sec. 147A.11(b)(1)(i).

(2) He must make inspections at the intervals that are determined to be necessary by the marine chemist or qualified person under Sec. 147A.11 (b)(1)(ii).

(b) If leakage occurs, the person in charge of fumigation shall:

(1) Notify the person in charge of the vessel that there is leakage;

(2) Ensure that all necessary measures are taken for the health and safety of any person; and

(3) Notify the person in charge of the vessel when there is no danger to the health and safety of any person.

(c) After the exposure period, if the vessel is in port, the person in charge of fumigation shall ensure that fumigators or other qualified persons ventilate the space that is fumigated as follows:

(1) Hatch covers and vent seals must be removed, other routes of access to the atmosphere must be opened, and if necessary, mechanical ventilation must be used.

(2) Personal protection equipment that is appropriate for the fumigant that is used must be worn.

(d) If ventilation is completed before the vessel leaves port, the person in charge of fumigation shall:

(1) Ensure that a qualified person, who is wearing the personal protection equipment for the fumigant that is used if remote detection equipment is **not** used, tests the space that is fumigated and determines if there is any danger to the health and safety of any person, including a danger from fumigant that may be retained in bagged, baled, or other absorbent cargo;

(2) Notify the person in charge of the vessel of this determination; and

(3) If it is determined that there is a danger:

(i) Ensure that all measures are taken that are necessary for the health and safety of all persons; and

(ii) Notify the person in charge of the vessel when there is no danger to the health and safety of any person.

Sec. 147A.23 Person in charge of vessel; during fumigation.

(a) The person in charge of the vessel shall ensure that the crew and all other persons on board the vessel who are **not** participating in the fumigation restrict their movement during fumigation to the spaces that are determined to be safe for occupancy under Sec. 147A.11(b)(1)(i).

(b) The person in charge of the vessel shall ensure that the crew and all other persons who are **not** participating in the fumigation follow any instructions of the person in charge of fumigation that are issued under Sec. 147A.21(b)(2) or (d)(3)(i) and that the vessel does **not** leave port if he is notified under:

(1) Section 147A.21(b)(1) that there is leakage, unless the person in charge of fumigation notifies him under Sec. 147A.21(b)(3) of this subpart that there is no danger; or

(2) Section 147A.21(d)(2) that there is a danger after ventilation, unless the person in charge of the fumigation notifies him under Sec. 147A.21(d)(3)(ii) that there is no danger.

(c) If fumigation is **not** completed before the vessel leaves port, the person in charge of the vessel shall ensure that personal protection and fumigant detection equipment for the fumigant that is used is on board the vessel.

(d) If the vessel leaves port before fumigation is completed, the person in charge of the vessel shall ensure that a qualified person makes periodic inspections until ventilation is completed and this person shall use detection equipment for the fumigant that is used to determine if:

(1) There is leakage of fumigant; or

(2) There is a concentration of fumigant that is a danger to the health and safety of any person.

(e) If the qualified person determines under paragraph (d) of this section that there is leakage or a concentration of fumigant that is a danger to the health and safety of any person, the person in charge of the vessel shall take all measures that are, in his discretion, necessary to ensure health and safety of all persons who are on board the vessel. If the danger is due to leakage, he shall also ensure that qualified persons immediately ventilate in accordance with paragraphs (c)(1) and (2) of Sec. 147A.21.

(f) If the vessel leaves port during the exposure period, the person in charge of the vessel shall ensure that the space that is fumigated is ventilated by qualified persons after the exposure period in accordance with paragraphs (c) (1) and (2) of Sec. 147A.21.

(g) If ventilation is completed after the vessel leaves port, the person in charge of the vessel shall ensure that a qualified person, who is wearing the personal protection equipment for the fumigant that is used if remote detection equipment is **not** used, tests the space that is fumigated to determine if there is a danger to the health and safety of any person, including a danger from fumigant that may be retained in bagged, baled, or other absorbent cargo. If the qualified person determines that there is a danger, the person in charge of the vessel shall take all measures that are, in his discretion, necessary to ensure the health and safety of all persons who are on board the vessel.

Sec. 147A.25 Entry.

(a) No person may enter the spaces that immediately adjoin the space that is fumigated during fumigation unless entry is for emergency purposes or the space is tested and declared safe for human occupancy by a marine chemist or other qualified person and is inspected under Sec. 147A.21(a)(2) or Sec. 147A.23(d).

(b) If entry is made for emergency purposes:

(1) No person may enter the space that is fumigated or any adjoining spaces during fumigation unless he wears the personal protection equipment for the fumigant that is in use;

(2) No person may enter the space that is fumigated unless the entry is made by a two person team; and

(3) No person may enter the space that is fumigated unless he wears a lifeline and safety harness and each life-line is tended by a person who is outside the space and who is wearing the personal protection equipment for the fumigant that is in use.

After Ventilation

Sec. 147A.31 Removal of fumigation material and warning signs.

After ventilation is completed and a marine chemist or other qualified person determines that there is no danger to the health and safety of any person under Sec. 147A.21(d) or Sec. 147A.23(g), the person in charge of fumigation, or, if the vessel has left port, the person in charge of the vessel, shall ensure that all warning signs are removed and fumigation containers and materials are removed and disposed of in accordance with the manufacturer's recommendations.

Special Requirements for Flammable Fumigants

Sec. 147A.41 Person in charge of fumigation; flammable fumigants.

(a) The person in charge of fumigation shall ensure that:

(1) Before the space that is to be fumigated is sealed, it is thoroughly cleaned, and all refuse, oily waste, and other combustible material is removed;

(2) Before fumigation, all fire fighting equipment, including sprinklers and fire pumps, is in operating condition; and

(3) Before and during fumigation, electrical circuits that are in the space that is fumigated are de-energized.

(b) [Reserved]

Sec. 147A.43 Other sources of ignition; flammable fumigants.

While the space that is fumigated is being sealed or during fumigation, no person may use matches, smoking materials, fires, open flames, or any other source of ignition in any spaces that are **not** determined to be safe for occupancy under Sec. 147A.11(b)(1)(i).

C

Treatment Manual

Appendix C

Conversion Tables

Table C-1 Conversion Tables

To convert from:	To:	Multiply by:
Acres (a)	Hectares (ha)	0.4047
Acres (a)	Square meters (m^2)	4,047.0
Celsius	Fahrenheit	9/5 (then add 32)
Centimeters, cu. (cm^3)	Cubic inches (in^3)	0.061
Centimeters, sq. (cm^2)	Square inches (in^2)	0.155
Centimeters (cm)	Inches (in)	0.3937
Fahrenheit	Celsius	First, subtract 32, then multiply by $\frac{5}{9}$
Feet, cubic (ft^3)	Liters (L)	28.32
Feet, cubic (ft^3)	Cubic meters (m^3)	0.0283
Feet, square (ft^2)	Square meters (m^2)	0.0929
Feet, square (ft^2)	Sq. centimeters (cm^2)	929.0
Feet (ft)	Centimeters (cm)	30.48
Feet (ft)	Meters (m)	0.3048
Gallons (gal)	Liters (L)	3.785
Grams (g)	Ounces (oz)	0.0353
Hectares (ha)	Acres (a)	2.471
Inches (in)	Centimeters (cm)	2.54
Inches, square (in^2)	Sq. centimeters (cm^2)	6.4516
Inches, cubic (in^3)	Cu. centimeters (cm^3)	16.387
Kilograms (kg)	Pounds (lb)	2.205
Kilograms (kg)	Ounces (oz)	35.27
Kilometers, sq. (km^2)	Square miles (mi^2)	0.3861
Kilometers, sq. (km^2)	Acres (a)	247.1
Kilometers (km)	Miles (mi)	0.6214
Liters (L)	Gallons (gal)	0.2642
Liters (L)	Quarts (qt)	1.0567
Meters, cubic (m^3)	Cubic feet (ft^3)	35.314
Meters, cubic (m^3)	Cubic yards (yd^3)	1.308
Meters (m)	Feet (ft)	3.281
Meters (m)	Yards (yd)	1.0936
Meters, sq. (m^2)	Square inches (in^2)	1,550.00
Meters (m)	Inches (in)	39.37
Meters, sq. (m^2)	Square feet (ft^2)	10.764

Table C-1 Conversion Tables

To convert from:	To:	Multiply by:
Miles, square (mi^2)	Hectares (ha)	258.99
Miles, square (mi^2)	Sq. kilometers (km^2)	2.5899
Miles, statute (mi)	Meters (m)	1,609.347
Miles, statute (mi)	Kilometers (km)	1.609
Milliliters (ml)	Liquid ounces (lq oz)	0.0338
Nautical miles	Meters (m)	1,852.00
Ounces, fluid (fl oz)	Milliliters (ml)	29.57
Ounces (oz)	Kilograms (kg)	0.0284
Ounces (oz)	Grams (g)	28.35
Pounds (lb)	Kilograms (kg)	0.4536
Pounds (lb)	Grams (g)	453.6
Quarts (qt)	Liters (L)	0.9464
Tons, short (2000 lb)	Metric tons (t)	0.9072
Tons, Metric (t)	Tons, short	1.102
Yards, cubic (yd^3)	Liters (L)	764.6
Yards, cubic (yd^3)	Cubic meters (m^3)	0.765
Yards (yd)	Meters (m)	0.9144
Yards (yd)	Centimeters (cm)	91.44

Miscellaneous:

Pounds per acre (lb/a) × 1.1206 = kg/ha
Ounces (liquid) per acre × 73.14 = ml/ha
Gallons per acre (gal/a) × 9.3527 = liters per hectare (L/ha)
Pressure per square inch (PSI) × 6.894757 = kilopascals (kPa)
Inches mercury × 3.38 = kilopascals (kPa)
Kilogram per hectare (kg/ha) × 0.8924 = pounds per acre
Milliliters per hectare × 0.01367 = ounces (lq.) per acre
Liters per hectare (L/ha) × 0.1069 = gallons per acre
Kilopascals (kPa) × 0.145038 = pounds per square inch (PSI)
Grams per liter × 0.008345 = pounds per gallon
Kilopascals (kPa) × 0.29586 = inches mercury
Pound per cubic feet = 0.0160 grams per cubic meter

D

Treatment Manual

Appendix D

Approved Treatment Facilities and Conveyances

Refer to **Table D-1** for hyperlinks to lists of USDA APHIS PPQ approved quarantine treatment facilities, vessels, and containers.

These lists are updated semi-annually. If you have any questions regarding the status of a treatment facility, contact your local PPQ office. If you have any questions regarding the status of a self-refrigerated container or vessel, contact:

CPHST-AQI at (919) 855-7450 or fax (919) 855-7493

Table D-1 Hyperlinks to Lists of Approved Treatment Facilities, Vessels, and Containers

Type	Hyperlink
U.S. treatment facilities	http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/national_treatment_facility_list.pdf
Maritime containers and vessels	https://treatments.cphst.org/vessels/

E

Treatment Manual

Appendix E

Reference Guide to Commercial Suppliers of Treatment and Related Safety Equipment

Introduction

This list is **not** intended to be all inclusive and is intended to be a reference guide solely for the convenience of potential users, particularly PPQ plant inspection stations. No endorsement is intended of the particular items listed, and no discrimination is intended toward those products or companies that may not be listed.

Products

Aeration Duct, Flexible

(specify diameter and length)

Biesterfeld U.S. Inc.
200 Madison Avenue
New York, NY 10016
Phone: (212) 689-6610 (resmethrin)
http://www.biesterfeld.com/index.php?lang=EN&area=home&page=root

Fumigation Service & Supply, Inc.
16950 Westfield Park Road
Westfield, IN 46074
Phone: (800) 992-1991 or (317) 896-9300
FAX: (317) 867-5757
email: info@fumigationzone.com
www.fumigationzone.com

Aerosol Insecticides

Gilmore Marketing and Development, Inc.
152 Collins Street
Memphis, TN 38112
Phone: (901) 323-5870
Fax: (901) 454-0295
www.gmdinc.com
(resmethrin)

Otis Laboratory
USDA/APHIS/PPQ/CPHST
1398 W. Truck Road
Buzzards Bay, MA 02542
Phone: (508) 563-9303
Fax: (508) 564-4398
(10% d-phenothrin)

Southern Agricultural Insecticides, Inc.
P.O. Box 218
Palmetto, FL 34220
Phone: (941) 722-3285
Fax: (941) 723-2974
(resmethrin)
www.southernag.com

Air Pump, Auxiliary

Barnant
(Sold as Thermo Scientific brand)
28W092 Commercial Avenue
Barrington, IL 60010
Phone: (847) 381-7050
Fax: (847) 381-7053
www.thermo.com

Cole-Parmer
625 East Bunker Court
Vernon Hills, IL 60061
Phone: (800) 323-4340
Fax: (847) 247-2929
Email: info@coleparmer.com
www.colepalmer.com
("Air Cadet" Vacuum/Pressure Pump; Single-J7530-40; Dual J7530-60)

McMaster-Carr Supply Co.
P.O. Box 740100
Atlanta, GA 30374-0100
Phone: (404) 346-7000
Fax: (404) 349-9091
Email: atlsales@mcmaster.com
www.mcmaster.com
(Hand-held MityVac® vacuum/pressure pump, zinc alloy, cat. no. 9963K12)
Air-Purifying Respirator*

(gas masks with cartridge for organic vapors)

Thermo Scientific
81 Wyman Street
Waltham, MA 02454
Phone: (none listed)
Fax: (781) 622-1207
www.thermo.com

Air-Purifying Respirator

Air purifying respirators are available from many different companies, including but not limited to Mine Safety Appliances (MSA), ULine, Northern Safety and Industrial, Grainger, etc.
APHIS-approved air purifying respirators are:

- MSA Advantage (half face) 420 and (full face) 1000
- 3M (half face) 6100, 6200, 6300 and (full face) 6700, 6800, 6900
- North (half face) 7700 and (full face) 76008AS, 76008A
- Survivair/Sperian (half face) 250000, 260000, 270000

APHIS-approved cartridges:
Contact a PPQ Field Operations Safety and Health Manager for approved organic vapor/acid gas N95 P100 cartridges (970-494-7560 or 919-855-7308).

Air Velocity Measuring (Anemometer)

Extech Instruments®
9 Townsend West
Nashua, NH 03063
Phone: 877-439-8324
Fax: 603-324-7864
http://www.extech.com/instruments/product.asp?catid=1

(Mini Thermo-Anemometer model #45118, Mini Thermo-Anemometer with humidity model #45158)

NK Nielson-Kellerman
21 Creek Circle
Boothwyn, PA 19061
USA
Phone: 610-447 1555
Fax: 610 447 1577
Email: info@nkhome.com
http://www.nkhome.com/kestrel/index.php

(Kestrel® Pocket Wind Meters (all models))

Trutech Tools
515 Turkey Foot Lake Road
Akron, OH 44319
USA
Phone: 1-888-224-3437
Fax: 866-694-8655
Email: info@trutechtools.com
http://www.trutechtools.com/testo417?gclid=CPqD3u7z1rQCFcef4AodkA8Aaw
(Testo 417 Large Vane Anemometer)

TSI, Inc. Alnor Products
500 Cardigan Road
Shoreview, MN 55126
Phone: 651-490-2811
Toll Free: 1-800-874-2811
Fax: 651-490-3824
Email: answers@tsi.com
http://www.tsi.com/en-1033/products/13926/velometer_anemometers.aspx
(Velometer Jr.®)

Aluminum Phosphide

Degesch America, Inc.
P.O. Box 116
Weyers Cave, VA 24486
Phone: (800) 330-2525 or (540) 234-9281
Fax: (540) 234-8225
www.degeschamerica.com

Fumigation Service & Supply, Inc.
16950 Westfield Park Road
Westfield, IN 46074
Phone: (800) 992-1991 or (317) 896-9300
FAX: (317) 867-5757
Email: info@fumigationzone.com
www.fumigationzone.com

Gilmore Marketing and Development, Inc.
152 Collins Street
Memphis, TN 38112
Phone: 901-323-5870
Fax: 901-454-0295

Helena Chemical Co.
225 Schilling Blvd., Suite 300
Collierville, TN 38017
Phone: (901) 761-0050
www.helenachemical.com

ICD Group Metals, LLC
600 Madison Avenue
New York, NY 10022-1615
Phone: (212) 644-1500
Fax: (212) 644-1480
Email: info@icdmetals.com
www.icdmetals.com

INCHEMA, Inc.
180 Old Tappan Road, Building 6
Old Tappan, NJ 07675
Phone: (201) 768-1770
Fax: (201) 768-2290
Email: inchema201@inchema-usa.com
www.inchema-usa.com

Loveland Products, Inc.
7251 W. 4th Street
Greeley, CO 80634
Phone: 970-356-4400
www.lovelandproducts.com/

Pest Fog, Inc.
1424 Bonita
P.O. Box 3703
Corpus Christi, TX 78463
Phone: (361) 884-8214
Fax: (361) 884-5903
Email: info@pestfog.com
www.pestfog.com

Pestcon Systems, Inc.
1808 Firestone Parkway
Wilson, NC 27893-7991
Phone: (800) 548-2778
Fax: (252) 243-1832
Email: info@pestcon.com
www.pestcon.com

United Suppliers, Inc.
Box 538
30473 260th St.
Eldora, IA 50627
Phone: (800) 782-5123 or (641) 858-2341
Fax: (641) 858-5493
www.unitedsuppliers.com
Applicator (Dispenser) for Methyl Bromide
(sight gauges calibrated in ml, grams, or pounds)

Applicator (Dispenser) for Methyl Bromide

Pest Fog, Inc.
P.O. Box 3703
1424 Bonita
Corpus Christi, TX 78463
Phone: (361) 884-8214
Fax: (361) 884-5903
Email: info@pestfog.com
www.pestfogsales.com

Vuscamante North
(Attn.: Sr. Maurilio Plata)
307 Montemorelos
Neuvo Leon, Mexico
Phone: 82-63-33-58

Ascarite II

(Granules of sodium hydroxide-coated silica used to remove carbon dioxide from gas samples)

Sigma-Aldrich Chemical Company, Inc.
6000 North Teutonia Avenue
Milwaukee, WI 53209
Phone: (800) 771-6737 or (414) 438-3850
Fax: (800) 962-9591
www.sigmaaldrich.com

Fisher Scientific
2000 Park Lane Drive
Pittsburgh, PA 15275
Phone: (800) 766- 7000
Fax: (800) 926-1166
www.fishersci.com

Thomas Scientific
P.O. Box 99
99 High Hill Road at I 295
Swedesboro, NJ 08085-0099
Phone: (800) 345-2100 or (800) 345-2000
Fax: (800) 345-5232 or (856) 467-3087
Email: value@thomassci.com
www.thomassci.com

Balances, Portable (for weighing individual fruit)

Ohaus Corporation
19A Chapin Road
P.O. Box 2033
Pine Brook, NJ 07058
Phone: (973) 377-9000
Fax: (973) 593-0359
Email: cs@ohaus.com
www.ohaus.com
(Portable balance for weighing individual fruits, Model LS 2000)

Batch Systems (complete installations, hot water immersion treatments)

Agri Machinery and Parts, Inc.
3489 All American Boulevard
Orlando, FL 32810
Phone: (407) 299-1592
Fax: (407) 299-1489
Email: Gillian Dobes (owner) at gdobes@ouramp.com
(2-tank system with 4 baskets each, with Honeywell strip chart recorder)

Agroindustrias Integradas, S.A. de C.V.
Calle Cernicalo, No. 590
Col. Mor, S.H.C.P. 44490
Guadalajara, Jalisco
Mexico
Phone: (52) 810-7422
Fax: (52) 810-7422

Calderas Astro, S.A. de C.V.
Jose Herrera, No. 607-B
C.P. 36350
San Francisco del Rincon
Guanajuato, Guan.
Mexico
Phone: (474) 31274
Fax: (474) 32698

Construcciones Pyrsa
Depto. de Ingenieria
Anil No. 100
Col. Los Pinos
Celaya, Guanajuato
Mexico
Phone: 91-461-20946

Consultecnia
3a Calle 28-70, Zona 1
Quetzaltenango
Apartado Postal 537-1
Guatemala
Phone: (502) 02-781-496

Dica de Mexico, S.A.
Corretera - Navolato, km 8
Culiacan, Sinaloa
Mexico
Phone: (52) 4-32-23

Diseños y Maquinaria Jer, S.A. de C.V. ("Jersa")
Emiliano Zapata, No. 51-A
Cuatitlan Izcalli
Estado do Mexico, C.P. 54710
Mexico
Phone: (52) 5-873-84-09 or 77
Phone: (52) 5-873-85-22
Fax: (52) 5-871-20-02

Equipos Agroindustriales de Occidente, S.A. de C. V.
Avenida Washington, No. 1370
Guadalajara, Jalisco
Mexico
Phone: (52) 11-04-66
Fax: (52) 11-44-67

Frutico International
P.O. Box 35-A
Avenida Vallarta 2095
Culiacan, Sinaloa
Mexico
Phone: (52) 671-490-30 or (52) 671-490-80

Guiar Industrial, S.A. de C.V.
Rayon No 989
Colonia Moderna, Sector Juarez
Guadalajara, C.P. 44190, Jalisco
Mexico
Phone: (91-36) 10-10-06 or (91-36) 10-19-49
Fax: (91-36) 10-19-52
("System Model No. 63-89")

Industria de Maquinas Agricolas GB Ltda.
Via Anhanguera, Km 150
Limeira / Sao Paulo
Brazil CEP 13480-970-Cx. Pt. 385
Phone: (55-19) 451-1811
Fax: (55-19) 451-5854

Industrial Equipment & Engineering Co.
(I.E.& E.)
2045 Sprint Blvd.
Apopka, FL 32703
Phone: (407) 293-9212

NOJOXTEN S.A. de C.V.
Eduardo Velazquez
Av Santa Margarit Razoa #283
Santa Margarita
Zapopan, Jal. CP 45140
Phone (office): (33) 3833-1999
Phone (cell): (33) 3115-9429
Email: eduardo.velazquez@nojoxtn.com.mx
(NOJOXTEN-BR Automation Studio V3.09 IEC 61131-3-ST)

Produce Sorters International
7403 West Sunnyview Avenue
Visalia, CA 93291
Phone: (559) 651-7840
Fax: (559) 651-7845

Proyect Asesoria Industrial
Av. Los Diplomaticos 1318
San Salvador, El Salvador
or
8a Avenida 33-10, Zona 11
Guatemala, Guat.
Phone: (503) 701731/707217
Phone: (503) 701749/802221
Fax: (503) 701731/259145
Fax: (502-2) 767439

Pyrsa de Celaya
Calle Violeta No. 1204
Colonia Las Flores
Celaya, Guanajuato, Mexico
Phone: (52-4) 61-270-72

Silsa, S.A. de C.V.
Avenida Acueducto
597 Planta Alta
Colonia Tecoman
07330 Mexico 14, D.F.
Mexico
Fax: (52) 754-32-27

William B. Cresse, Inc.
117 Commerce Avenue
Lake Placid, FL 33852
Phone: (305) 633-0977
Fax: (863) 465-0016
Email: cressecan@aol.com
www.equip2go.com
(Batch system with 2 tanks of 3 baskets each.)

Blower

(Used in pressure leakage test; may also be used to evacuate a fumigation chamber)

W. W. Grainger, Inc.
Branch offices in various cities.
www.grainger.com

William W. Meyer & Sons, Inc.
1700 Franklin Blvd.
Libertyville, IL 60048-4407
Phone: (847) 918-0111
Fax: (847) 918-8183
www.wmwmeyer.com

Bubble Fumigation System

Inflatable tarpaulin

B&G Equipment Company
135 Region South Drive
Jackson, GA 30233
Phone: (800) 544-8811
Fax: (678) 677-5633
www.bgequip.com

Power Plastics
Station Road
Thirsk, N. Yorkshire Y07 1PZ
England
Phone: 01845-525503
Fax: 0845-525483
Email: info@powerplastics.co.uk
www.powerplastics.co.uk

Cascade Air Tank Recharging System (for SCBA)

Mine Safety Appliance Co. (MSA)
P.O. Box 426
600 Penn Center Boulevard
Pittsburgh, PA 15230
www.msanorthamerica.com/overview.html

Chain Hoist (Electronic) (For hot water immersion treatments)

Chemonics
1717 H Street, NW
Washington, DC 20006
Phone: (202) 955-3300
Fax: (202) 955-3400
Email: info@chemonics.com
www.chemonics.com
(Post-harvest advice; international consulting)

Columbus McKinnon Corp.
Industrial Products Division
140 John James Audubon Parkway
Amherst, NY 14228
Phone: (716) 689-5400
Fax: (716) 689-5644
Email: sales@cmworks.com
www.cmworks.com
(Lodestar electronic chain hoist, capacity to 3 tons)

Consultants (For hot water immersion treatments)

C.C. Coutinho Consulting
Av. Princess Leopddina, 238
Ap. 101 D
Graca - Ed Olga Pontes
Cep 40150-080 Salvador, Bahia
Brazil
Phone: (55-81) 99-98-42-84
Fax: (55-81) 8-62-29-93
Email: cosam@uol.com.br

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606
Phone: (919) 855-7450
Fax: (919) 513-1995
(APHIS technical contact; approval of plans and drawings)

Consultecnia
3a Calle 28-70, Zona 1
Quetzaltenango
Apartado Postal 537-1
Guatamala
Phone: (502) 02-781-496

Dica de Mexico, S.A.
Carretera a Navolato, Km 8
Culiacan, Sinaloa
Mexico
Phone: (52) 4-32-23

Frutico International
P.O. Box 35-A
Avenida Vallarta 2095
Culiacan, Sinaloa
Mexico
Phone: (52) 671-490-30
Phone: (52) 671-490-80

GEC Instruments
5530 NW 97th Street
Gainesville, FL 32653
Phone: (352) 373-7955
Email: info@gecinstruments.com
www.gecinstruments.com
(Engineering consulting)

Nojoxten
Sta. Martha No.276-A Col. Sta.
Margarita C.P.45140
Zapopan, Jalisco, Mexico
Phone (33)3833-1999
Fax (33)3633-9380
www.nojoxten.com.mx

North Bay Produce, Inc.
10a Calle 1-4, Zona 9
Guatemala, Guat.
Phone: (502-2) 342-295 or 6
Fax: (502-2) 344-974
Email: marketing@northbayproduce.com
www.northbayproduce.com
(Legal and technical advice)

Societe d'Entretien & d'Installation (SODEIN)
Route de Carrefour #83
(P.O. Box 995)
Port-au-Prince, Haiti
(Installation of temperature recording equipment, especially the Chessel 346)

Curtains (air, safeguarding)

W.W. Granger, Inc.
Branch offices in many cities.
www.grainger.com

Digital Thermister Instrument (hand-held for hot water immersion treatments) and Portable Sensors (used in Performance Test)

Allied Electronics
15721 NW 60th Avenue
Miami Lakes, FL 33014
Phone: (305) 558-2511
Fax: (305) 558-1130
(Additional sales outlets in other cities) (Instruments include Cooper Instrument Corp's Model TM99A, and thermistor sensors with submersible 10 or 20 ft. cord, Catalog No. 2010.)

Cooper Instrument Corp.
33 Reeds Gap Road
Middlefield, CT 06455
Phone: (860) 347-2256
Fax: (860) 347-5135
www.cooperinstrument.com
(Note: This company manufactures the Cooper instruments sold by Allied Electronics, but does **not** sell directly to retail customers.)

Oakton Instruments
P.O. Box 5136
Vernon Hills, IL 60061
Phone: (888) 462-5866
Fax: (847) 247-2984
Email: info@4oakton.com
http://www.4oakton.com/

Acorn® Temp 4, 5, 6 meter: use thermistor probe or Pt 100 RTD temperature sensors. Suggested general purpose probes are:

- Oakton air probe #WD-08491-08
- Oakton penetration probe # WD-08491-16
- Oakton general purpose probe 10, 50, or 100 feet #WD-08491-02, #WD-08491-04, #WD-08491-03
- Oakton Acorn® Temp 5 #EW-35626-10

Oakton products can be purchased at numerous distributors such as Cole-Parmer, Davis Instruments, etc.

Recommended temperature sensors for Acorn® Temp 4,5, and 6 are from **Measurement Specialties**.

Measurement Specialties
2670 Indian Ripple Road
Dayton, OH 45440
Phone: 937-490-4470
FAX: 937-427-1640
Email: phyllis.henry@meas-spec.com
http://www.meas-spec.com

Sensor Model SP20758-1, long term immersion sensor with 4-meter cable for use with Acorn® Temp 4, 5, and 6. Use Switchcraft adapter Part #364-A to connect sensor to Acorn® Temp 4, 5, and 6. Two conductor adapters from 3.5mm to phone jack mono to 6.35 phone jack mono.

Switchcraft, Inc.
555 N. Elston Ave.
Chicago, IL 60630
Phone: 773-792-2700
Fax: 773-792-2129
Email: sales@switchcraft.com

Adapter Part #364-A (to connect SP20758-1 to the Acorn® Temp 4)

Contech
Rafael G. De Avila Aceves
Miguel Galindo 2033, J. del Country
Guadalajarra, Jalisco, Mexico, C.P. 44210
Phone: 52-33-3126-0101 or 3853-1293
Email: rdeavilaa@gmail.com

SP20758-1 and adapter Part #364-A for Oakton Acorn Temp 4

Drierite® (anhydrous calcium sulfate)

Sigma-Aldrich Chemical Company, Inc.
6000 North Teutonia Avenue
Milwaukee, WI 53209
Phone: (800) 771-6737 or (414) 438-3850
Fax: (800) 962-9591
www.sigmaaldrich.com

Fisher Scientific
2000 Park Lane Drive
Pittsburgh, PA 15275
Phone: (800) 766- 7000
Fax: (800) 926-1166
www.fishersci.com

W. A. Hammond Drierite Co. (Manufacturer)
138 Dayton Avenue
Xenia, OH 45385
Phone: (937) 376-2927
Fax: (937) 376-1977
Email: drierite@aol.com
www.drierite.com

Electrochemical Gas Sensor and Pyrolyzer

PureAir Monitoring Systems, Inc.
557 Capital Drive
Lake Zürich, IL 60047
Phone: 888-788-8050
www.pureairemonitoring.com

Air Check Advantage methyl bromide monitor

Exhaust Duct (Tube), Flexible

Stock sizes available in diameters of 12, 16, and 24 inches. Available in 10 and 20 feet lengths, which may be attached by a ring coupling.

Gaskets, Inc.
301 W. Highway 16
Rio, WI 53960
Phone: (800) 558-1833 or (920) 992-3137
Fax: (920) 992-3124
Email: info@gasketsinc.com
www.gasketsinc.com

Super Vacuum Manufacturing Company, Inc.
P.O. Box 87
Loveland, CO 80539-0087
Phone: (800) 525-5224
Fax: (970) 667-4296
Email: info@supervac.com
www.supervac.com

Fans

Pest Fog, Inc.
1424 Bonita
P.O. Box 3703
Corpus Christi, TX 78463
Phone: (361) 884-8214
Fax: (361) 884-5903
Email: info@pestfog.com
www.pestfog.com
(18-inch fumigation fan)

Super Vacuum Manufacturing Company, Inc.
P.O. Box 87
Loveland, CO 80539-0087
Phone: (800) 525-5224
Fax: (970) 667-4296
Email: info@supervac.com
www.supervac.com
For use in a chamber or under tarpaulin, or during exhaust. Specify blade size, horsepower, and CFM.

Fruit Crates (Plastic for hot water immersion treatments)

No listings

Fruit Sizing Equipment (Automatic)

Hortagro International, b.v.
P.O. Box: 4050
8901 EB Leeuwarden
Holland
Phone: 31-58-21-23-795
Fax: 31-58-21-25-344
www.hortagro.nl
(Mechanical weight sizer with conveyor belt)

Kerian Machines, Inc.
1709 Highway 81 South
P.O. Box 311
Grafton, ND 58237
Phone: (701) 352-0480
Fax: (701) 352-3776
Email: sales@kerianmachines.com
www.kerianmachines.com
(Roller type of sizing equipment)

Fumigators, Commercial

See listings in local telephone directories (yellow pages) under the heading "Pest Control Services."

Fungicides

(Bordeaux Mixture (hydrated lime + copper sulfate)

Chemtura Corporation
199 Benson Road
Middlebury, CT 06749
Phone: (203) 573-2000
www.chemtura.com
(Product name: Nutra-Spray Captan)

Crystal Chemical Inter-America
6800 SW. 40th Street, Suite 499
Miami, FL 33155-3708
Phone: (305) 971-4753
(Product name: Captanex)

Drexel Chemical Co.
P.O. Box 13327
Memphis, TN 38113-0327
Phone: (901) 774-4370
Fax: (901) 774-4666
Email: mstewart@drexchem.com
www.drexchem.com
(Product name: Drexel Captan)

Syngenta
1800 Concord Pike
P.O. Box 8353
Wilmington, DE 19803
Phone: (800) 759-4500 or (302) 425-2000
www.syngenta-us.com

(Ferbam)

Cytec Industries, Inc.
5 Garrett Mountain Plaza
West Patterson, NJ 07424
Phone: (800) 652-6013 or (973) 357-3100
Email: custinfo@cytec.com
www.cytec.com
(Product names: Carbamate WDG, Ferbam 76 WDG, Ferbam, Granuflo)

FMC Agricultural Products
Chemical Group
1735 Market Street
Philadelphia, PA 19103
Phone: (800) 845-0187 or (215) 299-6000
Fax: (215) 299-5998
www.fmccrop.com
(Product Name: Carbamate. Mancozeb)

Arkema, Inc.
2000 Market Street
Philadelphia, PA 19103-3222
Phone: (215) 419-7000
www.arkema-inc.com
(Product name: Penncozeb 80 WP)

Rohm and Haas
100 Independence Mall West
Philadelphia, PA 19106
Phone: (877) 288-5881
www.rohmhaas.com
(Product name; Dithane, Thiram)

Bayer CropScience LP
P.O. Box 12014
2 T.W. Alexander Drive
Research Triangle Park, NC 27709
Phone: (919) 549-2000
Fax: (919)949-3959
www.bayercropscience.com
(Product Names: Cuprothex Super Mix)

Cytec Industries, Inc.
5 Garrett Mountain Plaza
West Patterson, NJ 07424
Phone: (800) 652-6013 or (973) 357-3100
Email: custinfo@cytec.com
www.cytec.com
(Product Names: Tech TMTD, Thianosan, THiLor, Thipel, Thiram, Granuflo, Thiram 65, Thiram 75-WDG, Zineb)

Gas Analyzers

Analytical Technology, Inc.
6 Iron Bridge Drive
Collegeville, PA 19426
Phone: (800) 959-0299 or (610) 917-0991
Fax: (610) 917-0992
Email: sales@analyticaltechnology.com
www.analyticaltechnology.com
(Porta-Sens Phosphine Detector)

EB&S Solutions
6587 66th Avenue North
Pinellas, Park, FL 33781
Phone: 727-224-5072
Email: sean@emorybrantleyandsons.com

Interscan Corporation
P.O. Box 2496
Chatsworth, CA 91313
Phone: (800) 458-6153 or (818) 882-2331
Fax: (818) 341-0642
Email: info@gasdetection.com
www.gasdetection.com
(Interscan Model GF 1900 pyrolysis unit, sensitive to SF at 0–50 ppm.)

Key Chemical and Equipment Co., Inc.
13195 49th Street North, Unit A
Clearwater, FL 33762
Phone: (727) 572-1159
Fax: (727) 572-4595
www.fumiscope.com
(Fumiscope, Models D, 4.0, 4.2, and 5.12)

Neal Systems, Inc.
122 Terry Drive
Newtown, PA 18940
Phone: (215) 968-7577
Fax: (215) 968-6480
Email: sales@nealsystems.com
www.nealsystems.com
(Porta-Sens Phosphine Detector)

Pest Fog, Inc.
1424 Bonita
P.O. Box 3703
Corpus Christi, TX 78463
Phone: (361) 884-8214
Fax: (361) 884-5903
Email: info@pestfog.com
www.pestfog.com

Rae Systems
3775 North First Street
San Jose, CA 95134
408-952-8200
http://www.raesystems.com/products

MiniRae 3000

Spectros Instruments, Inc.
17D Airport Road
Hopedale, MA 01747
Phone: (508) 478-1648
Fax: (508) 590-0262
www.spectrosinstruments.com
(methyl bromide monitor MB-Contain IR; sulfuryl fluoride monitor SF-Contain IR)

Gas Detector Tube (colorimetric) and Apparatus

APHIS/NOAA Centralized Warehouse
(**Must** order by Fedstrip procedure)
FTS: 758-6222 (Draeger tubes)

Draeger Safety, Inc.
101 Technology Drive
Pittsburgh, PA 15275-1057
Phone: (800) 858-1737 or (412) 787-8383
Fax: (412) 787-2207
Email: prodinfo@draeger.com
www.draeger.com/en-us_us/Home
(Draeger tubes in the ranges 0.2-8.0 ppm (product # 8103391) and 0.5-30.0 ppm (product # 8101671))

Lab Safety Supply
P.O. Box 1368
Janesville, WI 53547-1368
Phone: (800) 356-0783
Fax: (800) 543-9910
www.labsafety.com
(Draeger tubes)

Matheson TriGas
603 Heron Drive
Bridgeport, NJ 08014
Phone: (201) 933-2401
Fax: (856) 467-3415
www.mathesongas.com
(Matheson-Kitagawa tubes in the range 0.5-10 ppm (product # 8014-187sc))

Pest Fog, Inc.
1424 Bonita
P.O. Box 3703
Corpus Christi, TX 78463
Phone: (361) 884-8214
Fax: (361) 884-5903
Email: info@pestfog.com
www.pestfog.com

Protech Safety Equipment
37 East 21st Street
P.O. Box 455
Linden, NJ 07036
Phone: (908) 862-1550
Fax: (908) 862-4436
(Draeger tubes)

Sensidyne, LP
16333 Bay Vista Drive
Clearwater, FL 33760
Phone: (800) 451-9444 or (727) 530-3602
Fax: (727) 539-0550
Email: info@sensidyne.com
www.sensidyne.com
(Sensidyne/Gastec tubes in the range of 0.1-20 ppm (product # 157SD))

SKC, Inc.
863 Valley View Road
Eighty Four, PA 15330
Phone: (800) 752-8472 or (724) 941-9701
Fax: (724) 941-1369
Email: skcinc@skcinc.com
www.skcinc.com

Union Carbide Corp, Linde Div.
National Specialty Gases Office
40 Veronica Avenue
Somerset, NJ 08873-3498
Phone: (732) 937-4900
(Sensidyne/Gastec tubes and apparatus)

Gas Drying Tube (for Drierite®)

Wilmad-LabGlass
1172 NW Boulevard
Vineland, NJ 08360
Phone: (800) 220-5171 or (856) 691-3200
Fax: (856) 691-6206
www.wilmad-labglass.com
((glass tube) – Catalog # 301-7501)

Germicides/Disinfectants

Georgia-Pacific Corp.
300 W. Laurel Street
Bellingham, WA 98225
Phone: (360) 733-4410
Fax: (206) 676-7247
www.gp.com

Halide Gas Leak Detector (removed)

Incinerators

Whitton Technology, Inc.
Air Burners Products Div.
4390 Cargo Way
Palm City, FL 34990
Phone: (561) 220-7303
Fax: (561) 220-7302
Email: info@airburners.com
www.airburners.com
(Air Curtain Incinerators)

Magnesium Phosphide

Degesch America, Inc.
P.O. Box 116
Weyers Cave, VA 24486
Phone: (800) 330-2525 or (540) 234-9281
Fax: (540) 234-8225
www.degeschamerica.com

Fumigation Service & Supply, Inc.
16950 Westfield Park Road
Westfield, IN 46074
Phone: (800) 992-1991 or (317) 896-9300
Fax: (317) 867-5757
Email: info@fumigationzone.com
www.fumigationzone.com

Helena Chemical Co.
225 Schilling Blvd., Suite 300
Collierville, TN 38017
Phone: (901) 761-0050
www.helenachemical.com

Manometer (used in pressure leakage test)

Alnor Instruments
500 Cardigan Road
Shoreview, MN 55126
Phone: (800) 874-2811 or (651) 490-2811
Fax: (651) 490-3824
www.tsi.com/en-1033/categories/alnor_instruments.aspx
(Model 530 (1–10 inches of water) (electronic))

Davis Calibration
1946 Greenspring Drive, Suite A
Timonium, MD 21093
Phone: (410) 842-1000
Fax: (410) 842-1003
Email: tthompson@daviscalibration.com
(U-tube or electronic)

Dwyer Instruments, Inc.
102 Indiana Highway 212
Michigan City, IN 46360
Phone: (800) 872-9141 or (219) 879-8000
Fax: (219) 872-9057
www.dwyer-inst.com
(flex-tube type)

Fisher Scientific
2000 Park Lane Drive
Pittsburgh, PA 15275
Phone: (800) 766- 7000
Fax: (800) 926-1166
www.fishersci.com
(tube or electronic)

Zellweger Analytics
Neotronics Sieger Solomat Division
4331 Thurmond Tanner Road
P.O. Box 2100
Flowery Branch, GA 30542
Phone: (770) 967-2196
Fax: (770) 967-1854
www.zelana.com
Model No. 530 (0–19.99 inches of water)

Metam-sodium

Amvac Chemical Corp.
4100 East Washington Blvd.
Los Angeles, CA 90023
Phone: (888) 462-6822 or (323) 264-3910
Fax: (323) 728-7863
www.american-vanguard.com

Methyl Bromide

Biesterfeld U.S., Inc.
200 Madison Avenue
New York, NY 10016
Phone: (212) 689-6610
(resmethrin)
http://www.biesterfeld.com/index.php?lang=EN&area=home&page=root

Chemtura Corp.
1801 Hwy. 52 W.
West Lafayette, IN 47906
Phone: (800) 428-7947 or (765) 497-6100
www.chemtura.com

Table E-1 Cylinder Tare, Net, and Gross Weights

Net Weight Product Description:	Cylinder Tare Weight (lbs.):	Cylinder Net Weight (lbs.):	Cylinder Gross Weight (lbs.):	Comments:
50 lbs-short	25	50	75	
50 lbs-tall	30	50	80	Used for Meth-O-Gas Q **only**
100 lbs	35	100	135	
175 lbs	50	175	225	
200 lbs	50	200	250	
1500 lbs	350	1500	1850	

Degesch America, Inc.
Houston Division
P.O. Box 451036
Houston, TX 77245
Phone: (713) 433-4777
Fax: (713) 433-0877
www.degeschamerica.com

Fumigation Service & Supply, Inc.
16950 Westfield Park Road
Westfield, IN 46074
Phone: (800) 992-1991 or (317) 896-9300
Fax: (317) 867-5757
Email: info@fumigationzone.com
www.fumigationzone.com

Helena Chemical Co.
225 Schilling Blvd., Suite 300
Collierville, TN 38017
Phone: (901) 761-0050
www.helenachemical.com

ICD Metals Group, LLC
600 Madison Avenue
New York, NY 10022
Phone: (212) 644-1500
Fax: (212) 644-1480
Email: info@icdmetals.com
www.icdmetals.com

ICL Industrial Products (formerly Ameribrom, Inc.)
622 Emerson Road, Suite 500
St. Louis, MO 63141
Phone: (877) 661-4272
Fax: (314) 983-7610
http://icl-ip.com/

Pest Fog, Inc.
1424 Bonita
P.O. Box 3703
Corpus Christi, TX 78463
Phone: (361) 884-8214
Fax: (361) 884-5903
Email: info@pestfog.com
www.pestfog.com

Pestcon Systems, Inc.
1808 Firestone Parkway
Wilson, NC 27893-7991
Phone: (800) 548-2778
Fax: (252) 243-1832
Email: info@pestcon.com
www.pestcon.com

Southern Agricultural Insecticides Inc.
P.O. Box 218
Palmetto, FL 34220
Phone: (941) 722-3285
Fax: (941) 723-2974
Email: sales@southernag.com
www.southernag.com

Moisture Meter (for wood)

Delmhorst Instrument Company
51 Indian Lane East
Towaco, NJ 07082
Phone: (877)-DELMHORST or (973) 334-2557
Fax: (973) 334-2657
Email: info@delmhorst.com
www.delmhorst.com
Order: Moisture Meter G30
Electrode 26ES
Type 496 pin
Above comes as package in carrying case.

Lignomat USA Ltd.
14345 NE Morris Court
Portland, OR 97230
Phone: (800) 227-2105
Email: sales@lignomat.com
www.lignomat.com

Newsletters and Trade Journals

(Containing articles on fumigation)

Fumigants and Pheromones
(Free newsletter)
Fumigation Service & Supply, Inc.
16950 Westfield Park Road
Westfield, IN 46074-9374
Phone: (317) 896-9300
Email: insectslimited@aol.com
www.fumigationzone.com
www.insectslimited.com

Pest Control Technology
(Monthly for professional pest control operators)
4020 Kinross Lakes Parkway, Suite 201
Richfield, OH 44286
Phone: (800) 456-0707
Fax: (330) 659-0823
www.pctonline.com

Pest Management Professional
(Monthly for professional pest control operators)
Questex Media Group, Inc.
600 Superior Avenue East, Suite 1100
Cleveland, OH 44114
Customer Service Mailing Address:
Pest Management Monthly
P.O. Box 1268
Skokie, IL 60076-8268
Phone: (847) 763-9594
Email: pestmanagement@halldata.com
www.mypmp.net

Photo Ionization Detector

Mine Safety and Appliance
MSA World Headquarters
Customer Service Center
P.O. Box 426
Pittsburgh, PA 15230

1-800-MSA-2222
http://www.msanorthamerica.com/
Sirius Multigas Detector

Rae Systems
3775 North First Street
San Jose, CA 95134
408-952-8200
http://www.raesystems.com/products

Safety Equipment

United States Plastic Corporation
1390 Neubrecht Road
Lima, OH 45801-3196
Phone: (800) 809-4217
Fax: (800) 854-5498
Email: usp@usplastic.com
www.usplastic.com
(Safety guards for belt and chain drives; fan guards; fire extinguishers; safety equipment in general)

Scale (portable platform type)

(For weighing gas cylinders) (in addition to the following, *see also* Yellow Pages)

Arlington Scale Co., Inc.
38 Davey Street
Bloomfield, NJ 07003
Phone: (978) 748-8000
Fax: (978) 748-8035
www.arlingtonscale.com

Atlantic Scale Co., Inc.
136 Washington Avenue
Nutley, NJ 07110
Phone: (973) 661-7090
Fax: (973) 661-3651
www.atlanticscale.com
(*See* Web site for other locations in Hicksville, NY and Yonkers, NY)

Eastern Scale of NJ
1053 Pennsylvania Avenue
Linden, NJ 07036-2240
Phone: (732) 381-8007

Phifer Incorporated
P.O. Box 1700
Tuscaloosa, AL 35403-1700
Phone: (205) 345-2120
Fax: (205) 759-4450
Email: info@phifer.com
www.phifer.com
(Fiberglass insect screening of various mesh sizes and colors)

Sealing Tape

Degesch America, Inc.
Houston Division
P.O. Box 451036
Houston, TX 77245
Phone: (713) 433-4777
Fax: (713) 433-0877
www.degeschamerica.com

Fumigation Service & Supply, Inc.
16950 Westfield Park Road
Westfield, IN 46074
Phone: (800) 992-1991 or (317) 896-9300
FAX: (317) 867-5757
Email: info@fumigationzone.com
www.fumigationzone.com
(ARMAK sealing tape)

Self-Contained Breathing Apparatus (SCBA)

Mine Safety and Appliance
MSA World Headquarters
Customer Service Center
P.O. Box 426
Pittsburgh, PA 15230

1-800-MSA-2222
http://www.msanorthamerica.com/
MSA AirHawk Ultra Elite

USDA employees monitoring fumigations **must** order model ATO#A-A2LB33A00F11AA1.

The letter "F" is the size of the face mask. "F" is medium, "G" is large, and "E" is small.

Spectacle kits: center support part #493581 or sidewire part #804638

Smoking Candle

(Used in pressure leakage test. Candles of various sizes.)

Purchase **only** candles that emit white smoke. If candles that emit colored smoke are used, their residue will stain the interior walls of the fumigation chamber, skin, and clothing. Store candles in a dry cool place.

Superior Signal Co., Inc.
P.O. Box 96
Spotswood, NJ 08884
Phone: (800) 345-8378 or (732) 251-0800
Fax: (732) 251-9442
www.superiorsignal.com

Snakes (sand snakes, watersnakes)

Fumigation Service & Supply, Inc.
16950 Westfield Park Road
Westfield, IN 46074
Phone: (800) 992-1991 or (317) 896-9300
FAX: (317) 867-5757
Email: info@fumigationzone.com
www.fumigationzone.com

Pest Fog, Inc.
1424 Bonita
P.O. Box 3703
Corpus Christi, TX 78463
Phone: (361) 884-8214
Fax: (361) 884-5903
Email: info@pestfog.com
www.pestfog.com

Soil Fumigants

(Metam-sodium, Vapam, etc.)

Buckman Laboratories International Inc.
1256 North McLean Boulevard
Memphis, TN 38108-1241
Phone: (901) 278-0330
Fax: (901) 276-5343
Email: knetix@buckman.com
Product name: Busan 1020

Cytec Industries, Inc.
5 Garrett Mountain Plaza
West Patterson, NJ 07424
Phone: (800) 652-6013 or (973) 357-3100
Email: custinfo@cytec.com
www.cytec.com
Products: Metam 32.7, Metam 42, Ucetam

OR-CAL, Inc.
29454 Meadowview Road
Junction City, OR 97448
Phone: (800) 237-2367 or (541) 689-4413
Fax: (541) 689-5026
Email: orcal@orcalinc.com
www.orcalinc.com
(Product name: Sectagon)

Syngenta
1800 Concord Pike
P.O. Box 8353
Wilmington, DE 19803
Phone: (800) 759-4500 or (302) 425-2000
www.syngenta-us.com
(Product name: Vapam)

Spill Recovery Materials

(Products to absorb spills of hazardous materials)

Ansul
One Stanton Street
Marinette, WI 54143
Phone: (715) 735-7411
Fax: (800) 543-9822
www.ansul.com
(Product: Spill-X)

Fumigation Service & Supply, Inc.
16950 Westfield Park Road
Westfield, IN 46074
Phone: (800) 992-1991 or (317) 896-9300
FAX: (317) 867-5757
Email: info@fumigationzone.com
www.fumigationzone.com

New Pig Corp.
One Pork Avenue
P.O. Box 304
Tipton, PA 16684-0304
Phone: (800) 468-4647
Fax: (800) 621-7447
Email: hothogs@newpig.com
www.newpig.com

WYK Sorbents, LLC
11721 Lackland Road
St. Louis, MO 63146
Phone: (800) 248-7007
Email: wyks@wyksorbents.com
www.wyksorbents.com
(Product: absorbant pillows and socks) (Free samples available)

Steam Boilers (For hot water immersion treatment)

Fulton Boiler Works, Inc.
3981 Port Street
Pulaski, NY 13142
Phone: (315) 298-5121
Fax: (315) 298-6390
www.fulton.com
(Oil-fired, gas-fired, or combination)

Steam Generators

Sioux Corporation
One Sioux Plaza
Beresford, SD 57004
Phone: (888) 763-8833 or (605) 763-3333
Fax: (605) 763-3334
Email: email@sioux.com
www.sioux.com

Steam Sterilizers/Autoclaves

Environmental Tectonics Corporation
125 James Way
Southhampton, PA 18966
Phone: (215) 355-9100
www.etcusa.com

Sulfuryl Fluoride (Vikane)

Dow AgroSciences LLC
9330 Zionsville Road
Indianapolis, IN 46268
Phone: (800) 992-5994 or (317) 337-3000
www.dowagro.com

Pest Fog, Inc.
1424 Bonita
P.O. Box 3703
Corpus Christi, TX 78463
Phone: (361) 884-8214
Fax: (361) 884-5903
Email: info@pestfog.com
www.pestfog.com

Southern Agricultural Insecticides Inc.
P.O. Box 218
7400 Bayshore Road
Palmetto, FL 34221
Phone: (941) 722-3285
Fax: (941) 723-2974
Email: sales@southernag.com
www.southernag.com

Tarpaulins

Tarpaulins for fumigation are made by many companies. Consult the Yellow Pages.

Elastec/American Marine
1309 West Main
Carmi, IL 62821
Phone: (618) 382-2525
Fax: (618) 382-3610
also located at:
401 Shearer Blvd
Cocoa, FL 32922
Phone: (321) 636-5783
Email: elastec@elastec.com
www.elastec.com

Dupont™ Protection Technologies
Phone: 1-888-476-6827
Tyvek® Air Cargo Covers
www.aircargocovers.dupont.com

Poly-Flex, Inc.
2000 West Marshall Drive
Grand Prairie, TX 75051
Phone: (888) 765-9359
Fax: (972) 337-8269
www.poly-flex.com

Raven Industries
P.O. Box 5107
Sioux Falls, SD 57117-5107
Phone: (605) 336-2750
Email: raveninfo@ravenind.com
www.ravenind.com

Reef Industries, Inc. (Griffolyn Division)
9209 Almeda Genoa
Houston, TX 77075
Phone: (800) 231-6074 or (713) 507-4250
Fax: (713) 507-4295
Email: ri@reefindustries.com
http://www.reefindustries.com/division.php?div=1
(Inflatable tarpaulin: see “Bubble Fumigation System”)

Temperatures, Recorders, and Sensors—General Use

CAS Datalogger
12628 Chillicothe Road
Chesterland, OH 44026
Phone: 800-956-4437
Email: sales@dataloggerinc.com
www.dataloggerinc.com
(dataTaker DT-85, Delphin Expert Logger Models 100, 200, 300)

Cole-Parmer
625 East Bunker Court
Vernon Hills, IL 60061
Phone: (800) 323-4340
Fax: (847) 247-2929
Email: info@coleparmer.com
www.coleparmer.com

GEC Instruments
5530 NW 97th Street
Gainesville, FL 32653
Phone: (352) 373-7955
Email: info@gecinstruments.com
www.gecinstruments.com
(Model S16TC Type T Thermocouple, Model S4TC Type T Thermocouple)

MadgeTech, Inc.
879 Maple Street
Contoocook, NH 03229 or
P.O. Box 50
Warner, NH 03278
Phone: (603) 456-2011
Fax: (603) 456-2012
Email: info@madgetech.com
www.madgetech.com
(Model: HITEMP 150A)

Mesa Laboratories, Inc.
Data Trace Division
12100 West 6th Avenue
Lakewood, CO 80228
Phone: (800) 525-1215 or (303) 987-8000
Fax: (303) 987-8989
Email: Technical Support and Service: datatracetechnical@mesalabs.com
datatraceservice@mesalabs.com
www.mesalabs.com
(Models: Data Tracers, STO, LTO, and Micropack III)

Nanmac Corporation
9-11 Mayhew Street
Framingham, MA 01702-2400
Phone: (800) 786-4669
Fax: (508) 879-5450
www.nanmac.com

National Instruments
11500 N. Mopac Expressway
Austin, TX 78759-3504
Phone: (800) 531-5066
Fax: (512) 68-8411
www.ni.com

Nordic Sensors Industrial, Inc. (NSI)
6860 Louis-Sicard
Montreal, Quebec
Canada H1P 1T7
Phone: (888) 667-3421
Fax: (888) 867-9986
Email: info@nordicsensors.com
www.nordicsensors.com

Omega Engineering Inc.
P.O. Box 4047
One Omega Drive
Stamford, CT 06907-0047
Phone: (800) 848-4286 or (203) 359-1660
Fax: (203) 359-7700
Email: info@omega.com
www.omega.com

Temperature Recorders (Portable Type) for Cold Treatment in Self-regulated Containers

Controlyne, Inc.
14 Highpoint
Cedar Grove, NJ 07009
Phone: (800) 766-5737 or (973) 819-7816
Fax: (973) 857-3014
Email: m.degan@verizon.net
(ACR SmartReader 8 Logger)

DeltaTRAK, Inc.
P.O. Box 398
Pleasanton, CA 94566
Phone: (800) 962-6776 or (925) 249-2250
Fax: (925) 249-2251
Email: salesinfo@deltatrak.com
www.deltatrak.com
(DeltaTrak T-8, DeltaTrak CDX-100, CDX-300, CDX-22000)

GE Sensing (formerly Kaye Instruments)
1100 Technology Park Drive
Billerica, MA 01821
Phone: (978) 437-1000
Fax: (978) 437-1021
Email: sensing@ge.com
www.kayeinstruments.com
(Model DR-2B Digistrip II

International Reactor Corporation
521 Kiser Street
Dayton, OH 45404-1641
Phone: (937) 224-4444
Fax: (937) 224-4434
Email: sales@irc-reactors.com
www.ifs-frp.com/irc-web
(Grant Squirrel Meter/Logger), Squirrel 2020 series with thermistors or PT100 sensors)

Metrosonics, Inc.
1060 Corporate Center Drive
Oconomowoc, WI 53066
Phone: (800) 245-0779 or (262) 567-9157
Fax (262) 567-4047
Email: quest.mail@mmm.com
www.metrosonics.com
(DocuTemp 714A)

Remonsys Limited
The Stables, Church Hanborough
Witney, Oxfordshire OX29 8AB
United Kingdom
Phone and Fax: +44 (0)1993 886996
Email: info@remonsys.com
www.remonsys.com
(Autolog Time/Temperature Monitor, AUTOLOG 2000 Data Logger, Multilog2)

Sensitech, Inc.
800 Cummings Center, Suite 258X
Beverly, MA 01915-6197
Phone: (800) 843-8367 or (978) 927-7033
Fax: (978) 921-2112
www.sensitech.com
(Data Mentor, RTM 2000 CTU)

Wescor Environmental
P. 0. Box 361
Logan, UT 84323-0361
Phone: (435) 752-6011 ext. 1310
Fax: (435) 753-6756
Email: enviro@wescor.com
www.wescor.com
(Datapod)

Temperature Recorders (Built-in Type) for Cold Treatment in Self-Regulated Containers

Carrier Transicold Division
Carrier Corporation
United Technologies
P. 0. Box 4808, Carrier Parkway
Syracuse, NY 13221-4808
Phone: (800) 227-7437
Fax: (315) 432-6620
https://www.carrier.com/carrier/en/us/products-and-services/transport-refrigeration/
(Micro Link 2 DataCorder, Micro Link 2i Controller/DataCorder, Micro Link 3 DataCorder, 69NT40-541, 69NT40-551, and 69NT20-551)

Daikin Industries Ltd.
Umeda Center Building, 2-4-12
Nakazaki-Nishi, Kita-ku, Osaka,
530-8323, Japan
Phone: 81-6-6373-4312
Fax: 81-6-6373-4380
www.daikin.com
(Decos III Microproc. Temp Controller, Decos III A, Decos III B, Decos III C, and Decos IIID)

Klinge Corporation
4075 E. Market Street
York, PA 17402
Phone: (717) 840-4500
Fax: (717) 840-4501
Email: info@klingecorp.com
www.klingecorp.com
(ThermLogger II)

Matrix Dynamics
501 Doylestown Road
Lansdale, PA 19446
Phone: (215) 393-9780
Fax: (215) 393-9783
(Road Warrior 1, HACCP Warrior)

Mitsubishi Heavy Industries
3-1, Asahi, Nishi-biwajima-cho, kiyosu,
Aichi Prefecture, 452-8561, Japan
Phone: 81-52-503-9200
Fax: 81-52-503-3533
www.mhi.co.jp
(MMCCIII & MMCC IIIA, MMCC IIIA-47B)

Thermo King Corporation
314 West 90th Street
Minneapolis, MN 55420
Phone: (888) 887-2202 or (952) 887-2200
Fax: (952) 887-2615
www.thermoking.com
(Thermoguard PA Microprocessor Temperature Controller, MP-D Microprocessor Controller, Thermoguard PA+ Microprocessor Controllers) (MP-2000, MP-3000)

Temperature Recorders (Portable Type) for Cold Treatment in Warehouses

Computer Aided Solutions
8437 Mayfield Rd., Unit 104
Chesterland, OH 44026
Phone: (440)729-2570
Email: sales@dataloggerinc.com
https://www.dataloggerinc.com/contact/

(RTR-505-Pt Wireless Data Logger, Sensors: thermistor, Pt 100)

Evidencia LLP
505 Tennessee St., Ste. 502
Memphis, Tennessee 38103
Phone: (901)529-9163
Fax: (901)529-9197
www.evidencia.biz

(ThermAssureRF, ThermProbeRF)

Fluke Electronics Corporation
14150 SW Karl Braun Dr.
Bldg. 50-209
Beaverton, OR 97077
Phone: 800-555-6658
Email: sales@comarkusa.com
http://www.comarkusa.com/comark_wireless_monitoring.tpl
(Comark RF500, RF500A/USA, and RF500AP/USA Wireless Temperature Monitoring System)

Inteligistics, Inc.
210 William Pitt Way, A11
Pittsburgh, PA 15238
Phone: (412) 826-0379
Email: prmandava@inteligistics.com

(TES-31 (wireless recorder), USP14966 (sensor))

MicroDAQ.com LTD
879 Maple Street
Contoocook, NH 03229
Phone: (603)746-5524
www.microdaq.com/contact-microdaq

(RTR 505-Pt Wireless Data Logger; Sensors: thermistor Pt100)

Temperature Recorders for Hot Water Immersion Treatment

Agri Machinery and Parts, Inc.
3489 All American Boulevard
Orlando, FL 32810
Phone: (407) 299-1592
Fax: (407) 299-1489
Email: Gilian Dobes, Sales - gdobes@ouramp.com
(Honeywell strip chart recorders)

Conax Technologies
2300 Walden Avenue
Buffalo, NY 14225
Phone: (800) 223-2389 or (716) 684-4500
Fax: (716) 684-7433
Email: conax@conaxtechnologies.com
www.conaxtechnologies.com

Contech
Rafael G. De Avila Aceves
Miguel Galindo 2033, J. del Country
Guadalajarra, Jalisco, Mexico, C.P. 44210
Phone: 52-33-3126-0101 or 3853-1293
Email: rdeavilaa@gmail.com
(Contech data logger)

Electro Scientific Industries, Inc.
13900 Science Park Drive
Portland, OR 97229
Phone: (503) 641-4141
www.elcsci.com
(Dekabox Delade Resister instrument, Model No. DB62, which may be used in the calibration of RTD sensors)

Enterprise S.A. de C.V.
Rodriguez Saro 424
Colonia del Valle
03100 Mexico D.F.
Mexico
Phone: (905) 534-6028
Fax: (905) 524-6426
(Honeywell and Molytek 2702 temperature recorders)

Equipos Industriales Guadalajara
Aguador No. 3959-A
Int. 5 Fracc. La Calma
C.P. 45070, Zapopan, Jalisco
Mexico
Phone: (52-3) 634-52-64
Fax: (52-3) 632-35-20
(Honeywell instruments)

Eurotherm Chessell
44621 Guilford Drive
Ashburn, VA 20147
Phone: (703) 724-3000
www.eurotherm.com/chessell
(Chessell strip-unit recorder, Model 346)

Guiar Industrial, S.A. de C.V.
Rayon No. 989
Colonia Moderna
Sector Juarez
Guadalajara, C.P. 44190, Jalisco
Mexico
Phone: (91-36) 10-10-06
Phone: (91-36) 10-19-49
Fax: (91-36) 10-10-52
(Honeywell instruments)

Honeywell International, Inc.
101 Columbia Road
Morristown, NJ 07962
Phone: (800) 328-5111 or (973) 455-2000
Fax: (973) 455-4807
www51.honeywell.com/honeywell
(Honeywell instruments)

Instrumentacion y Control Industrial
Santa Martha No. 269
Zapopan, Jalisco
Mexico
Phone/Fax: (52-3) 636-5145
(National and Honeywell Instruments)

Laboratorios Jael
Automation Division
Calle 2 Norte #7
Parque Industrila Francisco I. Madero
Puerto Chiapas,Tapachula, Chiapas
Mexico
Phone: (962) 620-4147 or (962) 620-4146
Fax: (962) 620-4148
Email: fjsanchez@labjael.com
www.labjael.com
(HyThsoft v 2)

Nanmac Corporation
9-11 Mayhew Street
Framingham, MA 01702-2400
Phone: (800) 786-4669
Fax: (508) 879-5450
www.nanmac.com
(Nanmac data logger, Model H30-1)

National Instruments
11500 N. Mopac Expressway
Austin, TX 78759-3504
Phone: (800) 531-5066
Fax: (512) 68-8411
www.ni.com
(National Instruments)

Neuberger Messinstrumente Gmbh
Steinerstr 16, D-8000
Munchen, Germany
Phone: (089) 72402-0
(Neuberger strip chart recorder P1Y)

NOJOXTEN S.A. de C.V.
Eduardo Velazquez
Av Santa Margarit Razoa #283
Santa Margarita
Zapopan, Jal. CP 45140
Phone (office): (33) 3833-1999
Phone (cell): (33) 3115-9429
Email: eduardo.velazquez@nojoxtn.com.mx

(NOJOXTEN-BR Automation Studio V3.09 IEC 61131-3-ST)

NZ Automacao Ltda-ME
R. Areal
99 - Bom Retiro 01125-020
Sao Paulo SP
Phone: 0 xx 11 223-6596
Email: nz@ig.com.br
www.nzautomacao.com.br

Process Technologies, Inc.
154 Whitaker Road
Tampa, FL 33549
Phone: (800) 889-5699 or (813) 949-9553
Fax: (877) 569-0775 or (813) 949-8108
Email: info@process-technologies.com
www.process-technologies.com

Telecontrol Y Sistemas Automaticos Sac
Tacna 230 La Arena
Piura, Peru
Phone: 51 73 37 3004; 51 73 968 158 208
Email: tsa.sac@gmail.com

Vacuum Research Corp.
2419 Smallman Street
Pittsburgh, PA 15222
Phone: (800) 426-9340 or (412) 261-7630
Fax: (412) 261-7220
Email: VRC@vacuumresearch.com
www.vacuumresearchcorp.com
(Molytek temperature recorder, Model 2702)

William B. Cresse, Inc.
117 Commerce Avenue
Lake Placid, FL 33852
Phone: (305) 633-0977
Fax: (863) 465-0016
Email: cressecan@aol.com
www.equip2go.com
(Honeywell strip chart recorder, Temperature Sensors (RTD, 100 ohm))

Temperature Recorders and Sensors—High Temperature (Niger Seed)

Madge Tech Inc.
879 Maple Street
Contoocook, NH 03229 or
P.O. Box 50
Warner, NH 03278
Phone: 603-456-2011
Fax: 603-456-2012
Email: infor@madgetech.com
http://www.madgetech.com
(Model HiTemp 140)

Omega Engineering, Inc.
P.O. Box 4047
One Omega Drive
Stamford, CT 06907-0047
Phone: (800) 848-4286 or (203) 359-1660
Fax: (203) 359-7700
Email: info@omega.com
www.omega.com
(Model-OM-CP-HiTemp140)

Mesa Laboratories Inc.
Data Trace Division
12100 West 6th Avenue
Lakewood, CO 80228
Phone: 303-987-8000
Fax: 303-987-8989
Email: datatracetechnical@mesalabs.com
www.mesalabs.com
(Model Data Trace Hi Temp Micropack III)

Thermocouple Wire

Omega Engineering, Inc.
P.O. Box 4047
One Omega Drive
Stamford, CT 06907-0047
Phone: (800) 848-4286 or (203) 359-1660
Fax: (203) 359-7700
Email: info@omega.com
www.omega.com
(Type "T" thermocouple wire, Catalog No. PR-T-24)

Thermometers

Cole-Parmer
625 East Bunker Court
Vernon Hills, IL 60061
Phone: (800) 323-4340
Fax: (847) 247-2929
Email: info@coleparmer.com
www.coleparmer.com
(Digital thermometers, hand-held; EW-90080-09 Scientific Thermistor Thermometer with USB)

Cooper Atkins
33 Reeds Gap Road
Middlefield, CT 06455-0450
Phone: (860) 347-2256
Fax: (860) 347-5135
www.cooper-atkins.com
(Electro-Therm hand-held digital thermometer. Instrument model Tm-99a (Electro Therm), general purpose air/surface probes, 12 feet in length, cat # 20-10, puncture probe #1075 (no longer comes with offset adjustment to change the temperature to true temperature with the aid of a reference thermometer))

Davis Instruments
625 Bunker Court
Vernon Hills, IL 60061-1844
Phone: 800-358-1844
Fax: 800-433-9971
Email: info@Davis.com
www.davis.com/home.aspx

Oakton Instruments
P.O. Box 5136
Vernon Hills, IL 60061
Phone: (888) 462-5866
Fax: (847) 247-2984
Email: info@4oakton.com
http://www.4oakton.com/

Central and South America

Phone: 847-327-5062
Fax: 847-549-1700

(Acorn® Temp 4 Meter (use 400 series thermistor probe; suggested general purpose probes are: Oakton air probe #WD-08491-08; Oakton penetration probe # WD-08491-16; Oakton general purpose probe 10, 50, or 100 feet #WD-08491-02, #WD-08491-04, #WD-08491-03; Oakton Acron Temp 5 #EW-35626-10))

Oakton products can be purchased at numerous distributors such as Cole-Parmer, Davis Instruments, etc.

Omega Engineering, Inc.
P.O. Box 4047
One Omega Drive
Stamford, CT 06907-0047
Phone: (800) 848-4286 or (203) 359-1660
Fax: (203) 359-7700
Email: info@omega.com
www.omega.com

Thermo Electric Company, Inc.
60-A Commerce Way
Totowa, NJ 07512
Phone: (800) 766-4020 or (201) 843-5800
Fax: (201) 843-4568
Email: info@te-direct.com
www.te-direct.com
(Micromite indicator/calibrator, Model 3115-1-T-0-1-0-0, Probe for Micromite; Model T-18-G-304-0-36-4M1)

Thermometers, Glass-Mercury, Certified Precision

These thermometers are used as calibration standards in cold treatment, hot water dip treatment and hot air treatment.

Thermometers from other sources may be considered as long as they meet the specifications outlined in **Chapter 8: Certified Precision Thermometers: Calibration Guidelines**.

Request approval for thermometers from:

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

DC Scientific Glass
P.O. Box 1099
Pasadena, MD 21123
Physical Location: 510 McCormick Drive, Suite D
Hanover, Maryland 21076
Phone: (800) 379-8493 or (410) 863-1700
Fax: (410) 863-1704
Email: sales@dcglass.com
www.dcglass.com

Catalog Number:	Type:	Range:	Scale Divi-sion:	Calibration Points:	Length (mm):	Immer-sion:
210-624	Extreme Precision	30 to 124 °F	0.1 °F	Minimum of one at the treatment temperature	610	Total
210-626	Extreme Precision	30 to 124 °F	0.1 °F	Minimum of one at the treatment temperature	610	3 inches
10064F-C	ASTM	77 to 131 °F	0.2 °F	5 calibration points (32, 80, 05, 115, 130 °F)	379	Total
10064C-C	ASTM	25 to 55 °C	0.1 °C	5 calibration points (0, 25, 35, 45, 55 °C)	379	Total
67C-100MM-C	ASTM	95 to 155 °C	0.2 °C	5 calibration points (0, 100, 110, 130, 150 °C)	379	100 mm

Figure E-1 DC Scientific Glass - Approved Thermometers

Fisher Scientific
2000 Park Lane Drive
Pittsburgh, PA 15275
Phone: (800) 766- 7000
Fax: (800) 926-1166
www.fishersci.com

Catalog Number:	Type:	Range:	Scale Division:	Calibration Points:	Length (mm):	Immersion:
15-142C	ASTM Mercury	77 to 131 °F	0.2 °F	5 calibration points (32, 80, 95, 115, 130 °F)	379	Total
15-140C	ASTM Mercury	25 to 55 °C	0.1 °C	5 calibration points (0, 25, 35, 45, 55 °C)	379	Total
15-169-120	ASTM Mercury	95 to 155 °C	0.2 °C	5 calibration points (0, 100, 110, 130, 150 °C)	379	Total

Figure E-2 Fisher Scientific - Approved Thermometers

VWR
1310 Goshen Parkway
West Chester, PA 19380
Phone: (800) 932-5000
www.VWR.com

Catalog Number:	Type:	Range:	Scale Division:	Calibration Points:	Length (mm):	Immersion:
61099-068	ASTM Mercury	77 to 131 °F	0.2 °F	5 calibration points (32, 80, 95, 115, 130 °F)	379	Total
15-61099-057	ASTM Mercury	25 to 55 °C	0.1 °C	5 calibration points (0, 25, 35, 45, 55 °C)	379	Total

Figure E-3 VWR - Approved Thermometers

Thermometers, Glass Non-Mercury, Certified Precision

These thermometers are used as a calibration standard in cold treatment, hot water dip treatment and hot air treatment.

Thermometers from other sources may be considered as long as they meet the specifications outlined in ***Certified Precision Thermometers: Calibration Guidelines* on page 8-1-25**.

Request approval for thermometers from:

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

Cole-Parmer
625 East Bunker Court
Veron Hills, IL 60061
Phone: (800) 323-4340
Fax: (847) 247-2929
Email: info@coleparmer.com
www.coleparmer.com

Catalog Number:	Type:	Range:	Scale Divi-sion:	Calibration Points:	Length (mm):	Immer-sion:
K-08007-15	Thermo Scientific ERTCO®	77 to 131 °F	0.2 °F	5 calibration points (32, 80, 95, 115, 130 °F)	379	Total
K-08007-14	Thermo Scientific ERTCO®	25 to 55 °C	0.1 °C	5 calibration points (0, 25, 35, 45, 55 °C)	379	Total
EW-08007-20	Thermo Scientific ERTCO®	95 to 155 °C	0.2 °C	5 calibration points (0, 100, 110, 130, 150 °C)	379	100 mm

Figure E-4 Cole Parmer - Approved Thermometers

Thermometers, Digital, Certified Precision

These thermometers are used as a calibration standard and can be substituted for mercury and non-mercury thermometers in cold treatment, hot water dip treatment and hot air treatment.

Thermometers from other sources may be considered as long as they meet the specifications outlined in ***Certified Precision Thermometers: Calibration Guidelines* on page 8-1-25**.

Request approval for thermometers from:

USDA-APHIS-PPQ-S&T-CPHST-AQI
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

EUTECH Instruments
For Africa, Asia, Middle East and Pacific Rim:
Eutech Instruments Pte Ltd
Blk 55, Ayer Rajah Crescent, #04-16/24, Singapore 139949
Phone: (65) 6778-6876
Fax: (65) 6773-0836
Email: eutech@thermofisher.com
www.eutechinst.com

For Europe:
Eutech Instruments Europe B.V.
P.O. Box 254, 3860 AG Nijkerk
The Netherlands
Phone: (31) 033-2463887
Fax: (31) 033-2460832
Email: info@eutech.nl
www.eutech.nl/

For North and South America:
OAKTON Instruments
P.O. Box 5136, Vernon Hills, IL 60061
Phone: (888) 4OAKTON (888)-462-5866
Fax: (847) 247-2984
Email: info@4oakton.com
www.4oakton.com

Cole-Parmer
625 East Bunker Court
Vernon Hills, IL60061
Phone: (800) 323-4340
Fax: (847) 247-2929
Email: info@coleparmer.com
www.coleparmer.com

For China:
Thermo Fisher Scientific
Builsing 6, No. 27 Xin Jinqiao Rd.
Shanghai 21206, China
Phone: (86) 021 6865 4588
Fax: (86) 021 6445 7909
Email: candy.tian@thermofisher.com
http://www.thermofisher.com/global/en/about/locations.asp

For India:
Thermo Fisher Scientific
102, 104 Delphi 'C' wing
Hiranandani Business Park
Powai, Mumbai - 400 076
Phone: 022-6742 94 94 (Board No.)
Fax: 022-6742 94 95
Email: prasanna.pandit@thermofisher.com
www.eutechinst.com

Catalog # 60010-85: Digital thermometer with range -330 to 2210 °F or -201 to 1210 °C; Resolution 0.1 °C/°F at 100.0 to 999.9 C/F; Accuracy +/- 0.1 °C/°F at 100 to 999.9 °C/°F; various probe lengths; Request NIST traceable calibration with 5 temperature points or more and a certificate.

Fluke Corporation
6920 Seaway Blvd.
Everett, WA 98206, USA
Phone: (425)347-6100
Fax: (425)446-5166
www.fluke.com

Model Name 1551A -9 to 20: 1551A EX Thermometer, Fixed RTD, -50C to 160C (-58F to 320F), choice of sensor length can be 9, 12 and 20 inches; Accuracy +/- 0.05C; Includes NVLAP- accredited report of calibration;, NIST traceable, User's guide on CD-ROM, 3 AAA batteries

Model Name 1552A -9 to 20: 1552A EX Thermometer, Fixed RTD, -80 C to 300 C (-112F to 572F), Sensor length 12 inches; Accuracy +/- 0.05C; Includes NVLAP- accredited report of calibration;, NIST traceable, User's guide on CD-ROM, 3 AAA batteries

OpticsPlanet, Inc.
Phone: (800) 504-5897 or (847) 513-6201
Fax: (847) 919-3003
Email: sales@opticsplanet.com
www.opticsplanet.net/
control-company-vwr-digital-data-logger-thermometers-4000.html

Catalog # C1-LB-4000: Control Company Digital Data Logger Thermometer with Probe 4000/61220-601; Accuracy- +/-0.05 °C; Request NIST calibration and certificate with 5 or more temperature points in treatment range.

Palmer Wahl
234 Old Weaverville Road
Asheville, NC 28804-1228
Phone: 800 421 2853; 828 658 3131
Fax: 828 658 0728
Email: info@palmerwahl.com
www.palmerwahl.com

Model DST600 series: Precision handheld reference thermometer: Range;-50 to 500 °F; Accuracy +/-0.1F/ °C over 1 year period; w/certificate of calibration. Request NIST calibration and certificate with temperature points in treatment range; choice of temperature sensors.

Tech Instrumentation, Inc.
160 W. Kiowa Avenue
P.O. Box 2029
Elizabeth, CO 80107
Phone: (800) 390-0004 or (303) 841-7567
Fax: (303) 840-8568
Email: sales@techinstrument.com
www.techinstrument.com

Catalog #TL-1W: Digital thermometer with range -44 to 600 °F and -43 to 315 °C; Resolution 0.01 degrees; Accuracy -/+0.1 F below 300 °F; Various stem lengths; 4 point NIST traceable calibration included;1 year warranty.

Thermco Products, Inc.
10 Millpond Drive, Unit #2
Lafayette, NJ 07848
Phone: (973) 300-9100
Fax: (973) 255-1000
Email: info@thermcoproductsinc.com
www.thermcoproductsinc.com

Catalog #ACCD650P: High Precision Digital Pt100 Platinum Thermometer; Range- Pt100: -200 °C to +850 °C: Accuracy- Pt 100 +/- 0.03 from -50 °C to + 199.99 °C; with Certificate of calibration. Request NIST calibration and certificate with 5 or more temperature points in treatment range; ACCD1019 High Precision Probe Pt100 Platinum 12" (405mm)

Thermoprobe, Inc.
112A Jetport Drive
Pearl, MS 39208
Phone:(601) 939-1831
Fax: (601) 355-1831
Email: ronnie@thermoprobe.net
www.thermoprobe.net

Catalog #TL-1W: Digital thermometer with range -44 to 600 °F and -43 to 315 °C; Resolution 0.01 degrees; Accuracy -/+0.1 F below 300 °F; Various stem lengths; 4 point NIST traceable calibration included;1 year warranty.

ThermoWorks
165 N. 1330 W., #A1
Orem, UT 84057
Phone: (801) 756-7705
Fax: (801) 756-8948
Email: info@thermoworks.com
www.thermoworks.com

Model P600 series; Precision handheld reference thermometer: Range; -328 F to 842 F; Accuracy 0.05 F from -148 to 302 F: w/Certificate of calibration. Request NIST calibration and certificate with temperature points in treatment range; choice of temperature sensors.

Thermometers, Certified Precision, Approved Calibration Companies

Conduct thermometer calibration by USDA-approved calibration companies. Follow the procedures for calibration summarized in **Chapter 8**, **Certified Precision Thermometers: Calibration Guidelines**.

DC Scientific Glass
P.O. Box 1099
Pasadena, MD 21123
Physical Location: 510 McCormick Drive, Suite D
Hanover, MD 21076
Phone: (800) 379-8493 or (410) 863-1700
Fax: (410) 863-1704
Email: sales@dcglass.com
www.dcglass.com

Barnstead International
(sold as Thermo Scientific brand)
2555 Kerper Blvd.
P.O. Box 797
Dubuque, IA 52001
Phone: (563) 556-2241
Fax: (563) 556-0695
www.thermofisher.com

Fluke Corporation
6920 Seaway Blvd.
Everett, WA 98206, USA
Phone: (425)347-6100
Fax: (425)446-5166
www.fluke.com

ICL Calibration Laboratories, Inc.
1501 Decker Avenue, Suite 118
Stuart, FL 34994
Phone: (800) 713-6647 or (772) 286-7710
Fax: (772) 286-8737
Email: sales@iclcalibration.com
www.icllabs.com
(Calibration, repair and adjustment of the Thermoprobe TL-1-W)

INNOCAL
625 East Bunker Court M/S 14
Vernon Hills, IL 60061-1844
Phone: (866) 466-6225
Fax: (847) 247-2984
Email: info@innocalsolutions.com
www.innocalsolutions.com

Instrumentation Technical Services
20 Hagerty Blvd., Suite 1
West Chester, PA 19382
Phone: (610) 436-9703
Fax: (610) 436-9097
Email: general@calservice.net
www.calservice.net

Measurement Assurance Technology
2109 Luna Road, Suite 240
Carrollton, TX 75006
Phone: (877) 871-TEST or (972) 241-2165
Fax: (972) 241-2167
Email: sales@mattestusa.com
www.mattestusa.com

Phoenix Calibration DR
Parque Industrial de Zona Franca Excel Boca Chica
Los Tanquecitos, Boca Chica
Santo Domingo, RD
Phone: (809) 563-0457
Fax: (809) 540-2320
Email: dweil@phoenixcalibrationdr.com
www.phoenixcalibrationdr.com

Thermoprobe, Inc.
112A Jetport Drive
Pearl, MS 39208
Phone:(601) 939-1831
Fax: (601) 355-1831
Email: ronnie@thermoprobe.net
www.thermoprobe.net
(Calibration, repair and adjustment of the Thermoprobe TL-1-W)

VWR
1310 Goshen Parkway
West Chester, PA 19380
Phone: (800) 932-5000
www.VWR.com

Tubing, Gas-Sampling

(Polyethylene or polypropylene)

Cole-Parmer
625 East Bunker Court
Vernon Hills, IL 60061
Phone: (800) 323-4340
Fax: (847) 247-2929
Email: info@coleparmer.com
www.coleparmer.com

Consolidated Plastics Co. Inc.
4700 Prosper Drive
Stow, OH 44224
Phone: (800) 362-1000
Fax: (800) 858-5001
www.consolidatedplastics.com

Fisher Scientific
2000 Park Lane Drive
Pittsburgh, PA 15275
Phone: (800) 766- 7000
Fax: (800) 926-1166
www.fishersci.com

Pest Fog, Inc.
1424 Bonita
P.O. Box 3703
Corpus Christi, TX 78463
Phone: (361) 884-8214
Fax: (361) 884-5903
Email: info@pestfog.com
www.pestfog.com

Thomas Scientific
P.O. Box 99
99 High Hill Road at I 295
Swedesboro, NJ 08085-0099
Phone: (800) 345-2100 or (800) 345-2000
Fax: (800) 345-5232 or (856) 467-3087
www.thomassci.com

Vacuum Pump

Air compressor for use with vacuum fumigation chambers.

Neward Enterprises, Inc.
Distributor: McMaster-Carr
P.O. Box 740100
Atlanta, GA 30374-0100
Phone: (404) 346-7000
Fax: (404) 349-9091
Email: atlsales@mcmaster.com
www.mcmaster.com
(MityVac® hand-held vacuum pump, cost: $69 (zinc-alloy pump #9963K12)

Sargent Welch
P.O. Box 4130
Buffalo, NY 14217
Phone: (800) 727-4368
Fax: (800) 676-2540
Email: customerservice@sargentwelch.com
www.sargentwelch.com

Vapam

(*See* Metam-sodium)

Volatilizer

(For volatilizing liquid methyl bromide into a fumigant gas)

Degesch America, Inc.
Houston Division
P.O. Box 451036
Houston, TX 77245
Phone: (713) 433-4777
Fax: (713) 433-0877
www.degeschamerica.com

Pest Fog, Inc.
1424 Bonita
P.O. Box 3703
Corpus Christi, TX 78463
Phone: (361) 884-8214
Fax: (361) 884-5903
Email: info@pestfog.com
www.pestfog.com

Vacudyne, Inc.
375 East Joe Orr Road
Chicago Heights, IL 60411
Phone: (800) 459-9591 or (708) 757-5200
www.vacudyne.com

Warning Signs and Placards

Carlton Industries, L.P.
P.O. Box 280
La Grange, TX 78945
Phone: (800) 231-5934 or (979) 242-5055
Fax: (979) 242-5058
Email: sales@carltonusa.com
www.carltonusa.com

Champion America
P.O. Box 3092
Stoney Creek, CT 06405
Phone: (877) 242-6709
Fax: (800) 336-3707
www.champion-america.com

Pest Fog, Inc.
1424 Bonita
P.O. Box 3703
Corpus Christi, TX 78463
Phone: (361) 884-8214
Fax: (361) 884-5903
Email: info@pestfog.com
www.pestfog.com

F

Treatment Manual

Appendix F

EPA Crop Groups

Contents

Introduction

The EPA requires chemical tolerances for residue data on raw agricultural commodities intended for human or animal consumption.

This Appendix lists the individual commodities in each crop group and is intended as a quick reference for the reader. These tables are updated annually and may not reflect the current crop groups in CFR 40 180.41. Refer to the EPA Crop Group tables for the most recent information.

Table F-1 Crop Group 1: Root and Tuber

Arracacha (*Arracacia xanthorrhiza*)
Arrowroot (*Maranta arundinacea*)
Artichoke, Chinese (*Stachys affinis*)
Artichoke, Jerusalem (*Helianthus tuberosus*)
Beet, garden (*Beta vulgaris*)
Beet, sugar (*Beta vulgaris*)
Burdock, edible (*Arctium lappa*)
Canna, edible (Queensland arrowroot) (*Canna indica*)
Carrot (*Daucus carota*)
Cassava, bitter and sweet (*Manihot esculenta*)
Celeriac (celery root) (*Apium graveolens var. rapaceum*)
Chayote (root) (*Sechium edule*)
Chervil, turnip-rooted (*Chaerophyllum bulbosum*)
Chicory (*Cichorium intybus*)
Chufa (*Cyperus esculentus*)
Dasheen (taro) (*Colocasia esculenta*)
Ginger (*Zingiber officinale*)
Ginseng (*Panax quinquefolius*)
Horseradish (*Armoracia rusticana*)
Leren (*Calathea allouia*)
Parsley, turnip-rooted (*Petroselinum crispum var. tuberosum*)
Parsnip (*Pastinaca sativa*)
Potato (*Solanum tuberosum*)
Radish (*Raphanus sativus*)
Radish, oriental (daikon) (*Raphanus sativus subvar. longipinnatus*)
Rutabaga (*Brassica campestris var. napobrassica*)
Salsify (oyster plant) (*Tragopogon porrifolius*)
Salsify, black (*Scorzonera hispanica*)
Salsify, Spanish (*Scolymus hispanicus*)
Skirret (*Sium sisarum*)
Sweet potato (*Ipomoea batatas*)
Tanier (cocoyam) (*Xanthosoma sagittifolium*)
Turmeric (*Curcuma longa*)
Turnip (*Brassica rapa* var. *rapa*)
Yam bean (jicama, manoic pea) (*Pachyrhizus* spp.)
Yam, true (*Dioscorea* spp.)

Table F-2 Crop Group 2: Leaves of Root and Tuber Vegetables

Beet, garden (*Beta vulgaris*)
Beet, sugar (*Beta vulgaris*)
Burdock, edible (*Arctium lappa*)
Carrot (*Daucus carota*)
Cassava, bitter and sweet (*Manihot esculenta*)
Celeriac (celery root) (*Apium graveolens* var. *rapaceum*)
Chervil, turnip-rooted (*Chaerophyllum bulbosum*)
Chicory (*Cichorium intybus*)
Dasheen (taro) (*Colocasia esculenta*)
Parsnip (*Pastinaca sativa*)
Radish (*Raphanus sativus*)
Radish, oriental (daikon) (*Raphanus sativus* subvar. *longipinnatus)*
Rutabaga (*Brassica campestris* var. *napobrassica*)
Salsify, black (*Scorzonera hispanica*)

Table F-3 Crop Group 3: Bulb Vegetable (*Allium* spp.)

Garlic, bulb (*Allium sativum*)
Garlic, great headed, (elephant) (*Allium ampeloprasum* var. *ampeloprasum*)
Leek (*Allium ampeloprasum , A. porrum, A. tricoccum*)
Onion, dry bulb and green (*Allium cepa, A. fistulosum*)
Onion, Welsh, (*Allium fistulosum*)
Shallot (*Allium cepa var. cepa*)
Chive, fresh leaves (*Allium schoenoprasum* L .)
Chive, Chinese, fresh leaves (*Allium tuberosum* Rottler ex Spreng)
Daylily, bulb (*Hemerocallis fulva* (L.) L. var. *fulva*)
Elegans hosta (*Hosta Sieboldiana* (Hook.) Engl)
Fritillaria, bulb (*Fritillaria* L. *fritillary*)
Fritillaria, leaves (*Fritillaria* L. *fritillary*)
Garlic, bulb (*Allium sativum* L. var. *sativum*) (*A. sativum* Common Garlic Group)
Garlic, great headed, bulb (*Allium ampeloprasum* L. var. *ampeloprasum*) (*A. ampeloprasum* Great Headed Garlic Group)
Garlic, Serpent, bulb (*Allium sativum* var. *ophioscorodon* or *A. sativum* Ophioscorodon Group)
Kurrat (*Allium kurrat* Schweinf. Ex. K. Krause or *A. ampeloprasum* Kurrat Group)
Lady's leek (*Allium cernuum* Roth)
Leek *Allium porrum* L. (syn: *A. ampeloprasum* L . var. *porrum* (L.) J. Gay) (*A.ampeloprasum* Leek Group)
Leek, wild (*Allium tricoccum* Aiton)
Lily, bulb (Lilium spp. (*Lilium* Leichtlinii var. *maximowiczii, Lilium lancifolium*))
Onion, Beltsville bunching (*Allium* x *proliferum* (Moench) Schrad.) (syn: *Allium fistulosum* L. x *A. cepa* L.)
Onion, bulb (*Allium cepa* L. var. *cepa*) (*A. cepa* Common Onion Group)
Onion, Chinese, bulb (*Allium chinense* G. Don.) (syn: *A. bakeri* Regel)
Onion, fresh (*Allium fistulosum* L. var. *caespitosum* Makino)
Onion, green (*Allium cepa* L. var. *cepa*) (*A. cepa* Common Onion Group)
Onion, macrostem (*Allium macrostemom* Bunge)
Onion, pearl (*Allium porrum* var. *sectivum* or *A. ampeloprasum* Pearl Onion Group)
Onion, potato, bulb (*Allium cepa* L. var. *aggregatum* G. Don.) (*A. cepa* Aggregatum Group)
Onion, tree, tops (*Allium* x *proliferum* (Moench) Schrad. ex Willd.) (syn: *A. cepa* var. *proliferum* (Moench) Regel; *A. cepa* L. var. *bulbiferum* L.H. Bailey; *A. cepa* L. var. *viviparum* (Metz.) Alef.)
Onion, Welsh, tops (*Allium fistulosum* L.)
Shallot, bulb (*Allium cepa* var. *aggregatum* G. Don.)
Shallot, fresh leaves (*Allium cepa* var. *aggregatum* G. Don.)
Cultivars, varieties, and/or hybrids of these.

Table F-4 Crop Group 4: Leafy Vegetables (except Brassica vegetables)

Amaranth (leafy amaranth, Chinese spinach, tampala) (*Amaranthus* spp.)
Arugula (Roquette) (*Eruca sativa*)
Cardoon (*Cynara cardunculus*)
Celery (*Apium graveolens* var. *dulce*)
Celery, Chinese (*Apium graveolens* var. *secalinum*)
Celtuce (*Lactuca sativa* var. *angustana*)
Chervil (*Anthriscus cerefolium*)
Chrysanthemum, edible-leaved (*Chrysanthemum coronarium* var. *coronarium*)
Chrysanthemum, garland (*Chrysanthemum coronarium* var. *spatiosum*)
Corn salad (*Valerianella locusta*)
Cress, garden (*Lepidium sativum*)
Cress, upland (yellow rocket, winter cress) (*Barbarea vulgaris*)
Dandelion (*Taraxacum officinale*)
Dock (sorrel) (*Rumex* spp.)
Endive (escarole) (*Cichorium endivia*)
Fennel, Florence (finochio) (*Foeniculum vulgare* Azoricum Group)
Lettuce, head and leaf (*Lactuca sativa*)
Orach (*Atriplex hortensis*)
Parsley (*Petroselinum crispum*)
Purslane, garden (*Portulaca oleracea*)
Purslane, winter (*Montia perfoliata*)
Radicchio (red chicory) (*Cichorium intybus*)
Rhubarb (*Rheum rhabarbarum*)
Spinach (*Spinacia oleracea*)
Spinach, New Zealand (*Tetragonia tetragonioides*, *T. expansa*)
Spinach, vine (Malabar spinach, Indian spinach) (*Basella alba*)
Swiss chard (*Beta vulgaris* var. *cicla*)

Table F-5 Crop Group 5: *Brassica* (Cole) Leafy Vegetables

Broccoli (*Brassica oleracea* var. *botrytis*)
Broccoli, Chinese (gai lon) (*Brassica alboglabra*)
Broccoli raab (rapini) (*Brassica campestris*)
Brussels sprouts (*Brassica oleracea* var. *gemmifera*)
Cabbage (*Brassica oleracea*)
Cabbage, Chinese (bok choy) (*Brassica chinensis*)
Cabbage, Chinese (napa) (*Brassica pekinensis*)
Cabbage, Chinese mustard (gai choy) (*Brassica campestris*)
Cauliflower (*Brassica oleracea* var. *botrytis*)
Cavalo broccolo (*Brassica oleracea* var. *botrytis*)
Collards (*Brassica oleracea* var. *acephala*)
Kale (*Brassica oleracea* var. *acephala*)
Kohlrabi (*Brassica oleracea* var. *gongylodes*)
Mizuna (*Brassica rapa* Japonica Group)
Mustard greens (*Brassica juncea*)
Mustard spinach (*Brassica rapa* Perviridis Group)
Rape greens (*Brassica napus*)

Table F-6 Crop Group 6: Legume Vegetables (succulent or dried)

Bean (*Lupinus* spp.) (includes grain lupin, sweet lupin, white lupin, and white sweet lupin)
Bean (*Phaseolus* spp.) (includes field bean, kidney bean, lima bean, navy bean, pinto bean, runner bean, snap bean, tepary bean, wax bean)
Bean (*Vigna* spp.) (includes adzuki bean, asparagus bean, blackeyed pea, catjang, Chinese longbean, cowpea, Crowder pea, moth bean, mung bean, rice bean, southern pea, urd bean, yardlong bean)
Broad bean (fava bean) (*Vicia faba*)
Chickpea (garbanzo bean) (*Cicer arietinum*)
Guar (*Cyamopsis tetragonoloba*)
Jackbean (*Canavalia ensiformis*)
Lablab bean (hyacinth bean) (*Lablab purpureus*)
Lentil (*Lens esculenta*)
Pea (*Pisum* spp.) (includes dwarf pea, edible-pod pea, En glish pea, field pea, garden pea, green pea, snow pea, sugar snap pea)
Pigeon pea (*Cajanus cajan*)
Soybean (*Glycine max*)
Soybean (immature seed) (*Glycine max*)
Sword bean (*Canavalia gladiata*)

Table F-7 Crop Group 7: Leaves of Legume Vegetables

Any cultivar of bean (*Phaseolus* spp.) and field pea (*Pisum* spp.), and soybean (*Glycine max*) Plant parts of any legume vegetable included in the legume vegetables that will be used as animal feed.

Table F-8 Crop Group 8: Fruiting Vegetables

African eggplant *(Solanum macrocarpon* L..)
Bush tomato (*Solanum centrale* J.M. BlackCocona, *Solanum sessiliflorum* Dunal)
Currant tomato (*Lycopersicon pimpinellifolium)*
Eggplant (*Solanum melongena* L.)
Garden huckleberry (*Solanum scabrum* Mill)
Goji berry (*Lycium barbarum)*
Groundcherry (*Physalis alkekengi* L., *P. grisea* (Waterf.) M. Martinez, *P. peruviana* L., *P. pubescens)*
Martynia (*Proboscidea louisianica* (Mill.) Thell)
Naranjilla (*Solanum quitoense* Lam)
Okra (*Abelmoschus esculentus* (L.) Moench)
Pea eggplant (*Solanum torvum* Sw.)
Pepino (*Solanum muricatum* Aiton)
Pepper, bell (*Capsicum annuum* L. var. *annuum*, *Capsicum* spp.)
Pepper, nonbell (*Capsicum chinese* Jacq., *C. annuum* L. var. *annuum*, *C. frutescens* L., *C. baccatum* L., *C. pubescens* Ruiz & Pav., *Capsicum* spp.)
Roselle (*Hibiscus sabdariffa* L.)
Scarlet eggplant (*Solanum aethiopicum* L.)
Sunberry (*Solanum retroflexum* Dunal)
Tomatillo (*Physalis philadelphica* Lam)
Tomato (*Solanum lycopersicum* L., *Solanum lycopersicum* L. var. *lycopersicum)*
Tree tomato (*Solanum betaceum* Cav)
Cultivars, varieties, and/or hybrids of these

Table F-9 Crop Group 9: Cucurbit Vegetables

Chayote (fruit) (*Sechium edule)*
Chinese waxgourd (Chinese preserving melon) (*Benincasa hispida*)
Citron melon (*Citrullus lanatus* var. *citroides*)
Cucumber (*Cucumis sativus*)
Gherkin (*Cucumis anguria*)
Gourd, edible (*Lagenaria* spp.) (includes hyotan, cucuzza); (*Luffa acutangula*, *L. cylindrica*) (includes hechima, Chinese okra)
Momordica spp. (includes balsam apple, balsam pear, bitter melon, Chinese cucumber)
Muskmelon (hybrids and/or cultivars of *Cucumis melo*) (includes true cantaloupe, cantaloupe, casaba, crenshaw melon, golden pershaw melon, honeydew melon, honey balls, mango melon, Persian melon, pineapple melon, Santa Claus melon, and snake melon)
Pumpkin (*Cucurbita* spp.)
Squash, summer (*Cucurbita pepo* var. *melopepo*) (includes crookneck squash, scallop squash, straightneck squash, vegetable marrow, zucchini)
Squash, winter (*Cucurbita maxima*; *C. moschata*) (includes butternut squash, calabaza, hubbard squash); (*C. mixta*; *C. pepo*) (includes acorn squash, spaghetti squash)
Watermelon (includes hybrids and/or varieties of *Citrullus lanatus*)

Table F-10 Crop Group 10: Citrus Fruit

Australian desert lime (*Eremocitrus glauca* (Lindl.) Swingle)
Australian finger lime (*Microcitrus australasica* (F. Muell.) Swingle)
Australian round lime (*Microcitrus australis* (A. Cunn. Ex Mudie) Swingle)
Brown River finger lime (*Microcitrus papuana* Winters)
Calamondin (*Citrofortunella microcarpa* (Bunge) Wijnands)
Citron (*Citrus medica* L..)
Citrus hybrids (*Citrus* spp. *Eremocitrus* spp., *Fortunella* spp., *Microcitrus* spp., and *Poncirus* spp.)
Grapefruit (*Citrus paradisi* Macfad)
Japanese summer grapefruit (*Citrus natsudaidai* Hayata)
Kumquat (*Fortunella* spp.)
Lemon (*Citrus limon* (L.) Burm. f.)
Lime (*Citrus aurantiifolia* (Christm.) Swingle)
Mediterranean mandarin (*Citrus deliciosa* Ten)
Mount White lime (*Microcitrus garrowayae* (F.M. Bailey) Swingle)
New Guinea wild lime (*Microcitrus warburgiana* (F.M. Bailey) Tanaka)
Orange, sour (*Citrus aurantium* L.)
Orange, sweet (*Citrus sinensis* (L.) Osbeck)
Pummelo (*Citrus maxima* (Burm.) Merr)
Russell River lime (*Microcitrus inodora* (F.M. Bailey) Swingle)
Satsuma mandarin (*Citrus unshiu* Marcow)
Sweet lime (*Citrus limetta* Risso)
Tachibana orange (*Citrus tachibana* (Makino) Tanaka)
Tahiti lime (*Citrus latifolia* (Yu. Tanaka) Tanaka)
Tangelo (*Citrus* x *tangelo* J.W. Ingram & H.E. Moore)
Tangerine (Mandarin) (*Citrus reticulata* Blanco)
Tangor (*Citrus nobilis* Lour)
Trifoliate orange (*Poncirus trifoliata* (L.) Raf.)
Uniq fruit (*Citrus aurantium* Tangelo group)
Cultivars, varieties and/or hybrids of these

Table F-11 Crop Group 11: Pome Fruit

Apple (*Malus domestica* Borkh.)
Azarole (*Crataegus azarolus* L..)
Crabapple (*Malus sylvestris* (L.) Mill., *M. prunifolia* (Willd.) Borkh.)
Loquat (*Eriobotrya japonica* (Thunb.) Lindl.)
Mayhaw (*Crataegus aestivalis* (Walter) Torr. & A. Gray, *C. opaca* Hook. & Arn., and *C. rufula* Sarg.)
Medlar (*Mespilus germanica* L.)
Pear (*Pyrus communis* L.)
Pear, Asian (*Pyrus pyrifolia* (Burm. f.) Nakai var. *culta* (Makino) Nakai)
Quince (*Cydonia oblonga* Mill.)
Quince, Chinese (*Chaenomeles speciosa* (Sweet) Nakai, *Pseudocydonia sinensis* (Thouin) C.K. Schneid.)
Quince, Japanese (*Chaenomeles japonica* (Thunb.) Lindl. ex Spach)
Tejocote (*Crataegus mexicana* DC.)
Cultivars, varieties and/or hybrids of these.

Table F-12 Crop Group 12: Stone Fruit

Apricot (*Prunus armeniaca)*
Apricot, Japanese (*Prunus mume*
Capulin (*Prunus serotina*)
Cherry, black (*Prunus serotina*)
Cherry, Nanking (*Prunus tomentosa*)
Cherry, sweet (*Prunus avium*)
Cherry, tart (*Prunus cerasus*)
Jujube, Chinese (*Ziziphus jujuba*)
Nectarine (*Prunus persica*)
Peach (*Prunus persica*)
Plum (*Prunus domestica*, *Prunus* spp.)
Plum, American (*Prunus americana*)
Plum, beach (*Prunus maritima*)
Plum, Canada (Prunus nigra)
Plum, cherry (Prunus cerasifera)
Plum, Chickasaw (*Prunus angustifolia*)
Plum, Damson (*Prunus domestica* spp. *insititia*)
Plum, Japanese (*Prunus salicina*)
Plum, Klamath (Prunus subcordata)
Plum, prune (Prunus domestica L. subsp. domestica)
Plumcot (Prunus hybr.)
Sloe (Prunus spinosa L.)
Cultivars, varieties, and/or hybrids of these

Table F-13 Crop Group 13: Berries and Small Fruit

Amur river grape (*Vitis amurensis* Rupr)
Aronia berry (*Aronia* spp.)
Bayberry (*Myrica* spp.)
Bearberry (*Arctostaphylos uva-ursi*)
Bilberry (*Vaccinium myrtillus* L.)
Blackberry (*Rubus* spp.) (including Andean blackberry, arctic blackberry, bingleberry, black satin berry, boysenberry, brombeere, California blackberry, Chesterberry, Cherokee blackberry, Cheyenne blackberry, common blackberry, coryberry, darrowberry, dewberry, Dirksen thornless berry, evergreen blackberry, Himalayaberry, hullberry, lavacaberry, loganberry, lowberry, Lucretiaberry, mammoth blackberry, marionberry, mora, mures deronce, nectarberry, Northern dewberry, olallieberry, Oregon evergreen berry, phenomenalberry, rangeberry, ravenberry, rossberry, Shawnee blackberry, Southern dewberry, tayberry, youngberry, zarzamora, and cultivars, varieties and/or hybrids of these.)
Blueberry, highbush (*Vaccinium* spp.)
Blueberry, lowbush (*Vaccinium angustifolium* Aiton)
Buffalo currant (*Ribes aureum* Pursh)
Buffaloberry (*Shepherdia argentea* (Pursh) Nutt.)
Che (*Cudrania tricuspidata* Bur. Ex Lavallee)
Chilean guava (*Myrtus ugni* Mol.)
Chokecherry (*Prunus virginiana* L.)
Cloudberry (*Rubus chamaemorus* L.)
Cranberry (*Vaccinium macrocarpon* Aiton)
Currant, black (*Ribes nigrum* L..)
Currant, red (*Ribes rubrum* L.)
Elderberry (*Sambucus* spp.)
European barberry (*Berberis vulgaris* L.)
Gooseberry (*Ribes* spp.)
Grape (*Vitis* spp.)
Highbush cranberry (*Viburnum opulus* L. var. Americanum Aiton)
Honeysuckle, edible (*Lonicera caerula* L . var. *emphyllocalyx* Nakai, *Lonicera caerula* L var . *edulis* Turcz. ex herder)
Huckleberry (*Gaylussacia* spp.)
Jostaberry (*Ribes* x *nidigrolaria* Rud. Bauer and A. Bauer)
Juneberry (Saskatoon berry) (*Amelanchier* spp.)
Kiwifruit, fuzzy (*Actinidia deliciosa* A. Chev.) (C.F. Liang and A.R. Fergusons, *Actinida chinensis* Planch.)
Kiwifruit, hardy (*Actinidia arguta* (Siebold and Zucc.) Planch. ex Miq)

Lingonberry (*Vaccinium vitis-idaea* L.)
Maypop (*Passiflora incarnata* L.)
Mountain pepper berries (*Tasmannia lanceolata*)(Poir.) A.C.Sm.
Mulberry (*Morus* spp.)
Muntries (*Kunzea pomifera* F. Muell.)
Native currant (*Acrotriche depressa* R. BR.)
Partridgeberry (*Mitchella repens* L.)
Phalsa (*Grewia subinaequalis* DC.)
Pincherry (*Prunus pensylvanica* L.f.)
Raspberry, black and red (*Rubus* spp.)
Riberry (*Syzygium luehmannii*)
Salal (*Gaultheria shallon* Pursh.)
Schisandra berry (*Schisandra chinensis* (Turcz.) Baill.)
Sea buckthorn (*Hippophae rhamnoides* L.)
Serviceberry (*Sorbus* spp.)
Strawberry (*Fragaria* x *ananassa* Duchesne)
Wild raspberry (*Rubus muelleri* Lefevre ex P.J. Mull)
Cultivars, varieties, and/or hybrids of these.

Table F-14 Crop Group 14: Tree Nuts

Almond (*Prunus dulcis*)
Beech nut (*Fagus* spp.)
Brazil nut (*Bertholletia excelsa*)
Butternut (*Juglans cinerea*)
Cashew (*Anacardium occidentale*)
Chestnut (*Castanea* spp.)
Chinquapin (*Castanea pumila*)
Filbert (hazelnut) (*Corylus* spp.)
Hickory nut (*Carya* spp.)
Macadamia nut (bush nut) (*Macadamia* spp.)
Pecan (*Carya illinoensis*)
Walnut, black and English (Persian) (*Juglans* spp.)

Table F-15 Crop Group 15: Cereal Grains

Barley (*Hordeum* spp.)
Buckwheat (*Fagopyrum esculentum*)
Corn (*Zea mays*)
Millet, pearl (*Pennisetum glaucum*)
Millet, proso (*Panicum milliaceum*)
Oats (*Avena* spp.)
Popcorn (*Zea mays* var. *everta*)
Rice (*Oryza sativa*)
Rye (*Secale cereale*)
Sorghum (milo) (*Sorghum* spp.)
Teosinte (*Euchlaena mexicana*)
Triticale (T*riticum-Secale* hybrids)
Wheat (*Triticum* spp.)
Wild rice (*Zizania aquatica*)

Crop Group 16: Forage, Fodder, and Straw of Cereal Grains

The commodities included in Crop Group 16 are: forage, fodder, and straw of all commodities included in the group cereal grains group (corn, wheat and any other cereal grain crop).

Crop Group 17: Grass Forage, Fodder, and Hay

The commodities included in Crop Group 17 are: any grass, Gramineae family (either green or cured) except sugarcane and those included in the cereal grains group, that will be fed to or grazed by livestock, all pasture and range grasses and grasses grown for hay or silage.

Table F-16 Crop Group 18: Nongrass Animal Feeds (Forage, Fodder, Straw, and Hay)

Alfalfa (*Medicago sativa* subsp. *sativa*)
Bean, velvet (*Mucuna pruriens* var. *utilis*)
Clover (*Trifolium* spp., *Melilotus* spp.)
Kudzu (*Pueraria lobata*)
Lespedeza (*Lespedeza* spp.)
Lupin (*Lupinus* spp.)
Sainfoin (*Onobrychis viciifolia*)
Trefoil (*Lotus* spp.)
Vetch (*Vicia* spp.)
Vetch, crown (*Coronilla varia*)
Vetch, milk (*Astragalus* spp).

Table F-17 Crop Group 19: Herbs and Spices

Angelica (*Angelica archangelica*)
Anise (anise seed) (*Pimpinella anisum*)
Anise, star (*Illicium verum*)
Annatto (seed)
Balm (lemon balm) (*Melissa officinalis*)
Basil (*Ocimum basilicum*)
Borage (*Borago officinalis*)
Burnet (*Sanguisorba minor*)
Camomile (*Anthemis nobilis*)
Caper buds (*Capparis spinosa*)
Caraway (*Carum carvi*)
Caraway, black (*Nigella sativa*)
Cardamom (*Elettaria cardamomum*)
Cassia bark (*Cinnamomum aromaticum*)
Cassia buds (*Cinnamomum aromaticum*)
Catnip (*Nepeta cataria*)
Celery seed (*Apicum graveolens*)
Chervil (dried) (*Anthriscus cerefolium*)
Chive (*Allium schoenoprasum*)
Chive, Chinese (*Allium tuberosum*)
Cinnamon (*Cinnamomum verum*)
Clary (*Salvia sclarea*)
Clove buds (*Eugenia caryophyllata*
Coriander (cilantro or Chinese parsley) (leaf) (*Coriandrum sativum*)
Costmary (*Chrysanthemum balsamita*)
Culantro (leaf) (*Eryngium foetidum*)
Culantro (seed) (*Eryngium foetidum*)
Cumin (*Cuminum cyminum*)
Curry (leaf) (*Murraya koenigii*)
Dill (dillweed) (*Anethum graveolens*)
Dill (seed) (*Anethum graveolens*)
Fennel (common) (*Foeniculum vulgare*)
Fennel, Florence (seed) (*Foeniculum vulgare Azoricum* Group)
Fenugreek (*Trigonella foenumgraecum*)
Grains of paradise (*Aframomum melegueta*)

Horehound (*Marrubium vulgare*)

Hyssop (*Hyssopus officinalis*)

Juniper berry (*Juniperus communis*)

Lavender (*Lavandula officinalis*)

Lemongrass (*Cymbopogon citratus*)

Lovage (leaf) (*Levisticum officinale*)

Lovage (seed) (*Levisticum officinale*)

Mace (*Myristica fragrans*)

Marigold (*Calendula officinalis*)

Marjoram (*Origanum* spp.) (includes sweet or annual marjoram, wild marjoram or oregano, and pot marjoram)

Mustard (seed) (*Brassica juncea*, *B. hirta, B. nigra*)

Nasturtium (*Tropaeolum majus*)

Nutmeg (*Myristica fragrans*)

Parsley (dried) (*Petroselinum crispum*)

Pennyroyal (*Mentha pulegium*)

Pepper, black (*Piper nigrum*)

Pepper, white

Poppy (seed) (*Papaver somniferum*)

Rosemary (*Rosemarinus officinalis*)

Rue (*Ruta graveolens*)

Saffron (*Crocus sativus*)

Sage (*Salvia officinalis*)

Savory, summer and winter (*Satureja* spp.)

Sweet bay (bay leaf) (*Laurus nobilis*)

Tansy (*Tanacetum vulgare*)

Tarragon (*Artemisia dracunculus*)

Thyme (*Thymus* spp.)

Vanilla (*Vanilla planifolia*)

Wintergreen (*Gaultheria procumbens*)

Woodruff (*Galium odorata*)

Wormwood (*Artemisia absinthium*)

Table F-18 Crop Group 20: Oilseed

Borage (*Borago officinalis* L.)
Calendula (*Calendula officinalis* L.)
Castor oil plant (*Ricinus communis* L.)
Chinese tallowtree, *Triadica sebifera* (L.) Small
Cottonseed (*Gossypium hirsutum* L.; *Gossypium* spp.)
Crambe (*Crambe hispanica* L.; *C. abyssinica* Hochst. ex R.E. Fr.)
Cuphea (*Cuphea hyssopifolia* Kunth)
Echium (*Echium plantagineum* L.)
Euphorbia (*Euphorbia esula* L.)
Evening primrose (*Oenothera biennis* L.)
Flax seed (*Linum usitatissimum* L.)
Gold of pleasure (*Camelina sativa* (L.) Crantz)
Hare's ear mustard (*Conringia orientalis* (L.) Dumort)
Jojoba (*Simmondsia chinensis* (Link) C.K. Schneid.)
Lesquerella (*Lesquerella recurvata* (Engelm. ex A. Gray) S. Watson)
Lunaria (*Lunaria annua* L.)
Meadowfoam (*Limnanthes alba* Hartw. ex Benth.)
Milkweed (*Asclepias* spp.)
Mustard seed (*Brassica hirta* Moench, *Sinapis alba* L. subsp. *Alba*.)
Niger seed (*Guizotia abyssinica* (L.f.) Cass.)
Oil radish (*Raphanus sativus* L. var. *oleiformis* Pers.)
Poppy seed (*Papaver somniferu*m L. subsp. *Somniferum)*
Rapeseed (*Brassica* spp.; *B. napus* L.)
Rose hip (*Rosa rubiginosa* L.)
Safflower (*Carthamus tinctorious* L.)
Sesame (*Sesamum indicum* L., *S. radiatum* Schumach. & honn.)
Stokes aster (*Stokesia laevis* (Hill) Greene)
Sunflower (*Helianthus annuus* L.)
Sweet rocket (*Hesperis matronalis* L.)
Tallowwood (*Ximenia americana* L.)
Tea oil plant (*Camellia oleifera* C. Abel)
Vernonia (*Vernonia galamensis* (Cass.) Less)
Cultivars, varieties, and/or hybrids of these

Table F-19 Crop Group 21: Edible Fungi

Blewitt (*Lepista nuda*)
Bunashimeji (*Hypsizygus marrmoreus*)
Chinese mushroom (*Volvariella volvacea* (Bull.) Singer)
Enoki (*Flammulina velutipes* (Curt.) Singer)
Hime-Matsutake (*Agaricus blazei* Murill)
Hirmeola (*Auricularia auricular*)
Maitake (*Grifola frondosa*)
Morel (*Morchella* spp.)
Nameko (*Pholiota nameko*)
Net Bearing (*Dictyophora*)
Oyster mushroom (*Pleurotus* spp.)
Pom Pom (*Hericium erinaceus*)
Reishi mushroom (*Ganoderma lucidum* (Leyss. Fr.) Karst.)
Rodman's agaricus (*Agaricus bitorquis* (Quel.) Saccardo)
Shiitake mushroom (*Lentinula edodes* (Berk.) Pegl.)
Shimeji (*Tricholoma conglobatum*)
Stropharia (*Stropharia* spp.)
Truffle (*Tuber* spp.)
White button mushroom (*Agaricus bisporous* (Lange) Imbach)
White Jelly Fungi (*Tremella fuciformis*)

Table F-20 Crop Group 22: Stalk, Stem, and Leaf Petiole Vegetables

Agave (*Agave* spp.)
Aloe vera (*Aloe vera* (L.) Burm.f.)
Asparagus (*Asparagus officinialis* L.)
Bamboo shoots (*Arundinaria* spp., *Bambusa* spp.,*Chimonobambusa* spp.; *Dendrocalamus* spp., *Fargesia* spp.; *Gigantochloa* spp., *Nastus elatus*; *Phyllostachys* spp.; *Thyrsostachys* spp.)
Cardoon/Globe artichoke (*Cynara cardunculus* L.)
Celery (*Apium graveolens* var. *dulce* (Mill.) Pers.)
Celery, Chinese (*Apium graveolens* L. var. *secalinum* (Alef.) Mansf.)
Celtuce (*Lactuca sativa* var. *angustana* L.H. Bailey)
Fennel, Florence, fresh leaves and stalk (*Foeniculum vulgare* subsp. *vulgare* var. *azoricum* (Mill.) Thell.)
Fern, edible, fiddlehead
Fuki (*Petasites japonicus* (Siebold & Zucc.) Maxim.)
Kale, sea (*Crambe maritima* L.)
Kohlrabi (*Brassica oleracea* L. var *gongylodes* L.)
Palm hearts (various species)
Prickly pear, pads (*Opuntia ficus-indica* (L.) Mill., *Opuntia* spp.)
Prickly pear, Texas, pads (*Opuntia engelmannii* Salm-Dyck ex Engelm. var. *lindheimeri* (Engelm.) B.D. Parfitt & Pinkav)
Rhubarb (*Rheum* x *rhabarbarum* L.)
Udo (*Aralia cordata* Thunb.)
Zuiki (*Colocasia gigantea* (Blume) Hook. f.)
Cultivars, varieties, and hybrids of these commodities

Table F-21 Crop Group 23: Tropical and Subtropical Fruit, Edible Peels

Açaí (*Euterpe oleracea* Mart.)
Acerola (*Malpighia emarginata* DC.)
Achachairú (*Garcinia gardneriana* (Planch. & Triana) Zappi)
African plum (*Vitex doniana* Sweet)
Agritos (*Berberis trifoliolata* Moric.)
Almondette (*Buchanania lanzan* Spreng.)
Ambarella (*Spondias dulcis* Sol. ex Parkinson)
Apak palm (*Brahea dulcis* (Kunth) Mart.)
Appleberry (*Billardiera scandens* Sm.)
Arazá (*Eugenia stipitata* McVaugh)
Arbutus berry (*Arbutus unedo* L.)
Babaco (*Vasconcellea* x *heilbornii* (V.M. Badillo) V.M. Badillo)
Bacaba palm (*Oenocarpus bacaba* Mart.)
Bacaba-de-leque (*Oenocarpus distichus* Mart.)
Bayberry, red (*Morella rubra* Lour.)
Bignay (*Antidesma bunius* (L.) Spreng.)
Bilimbi (*Averrhoa bilimbi* L.)
Borojó (*Borojoa patinoi* Cuatrec.)
Breadnut (*Brosimum alicastrum* Sw.)
Cabeluda (*Plinia glomerata* (O. Berg) Amshoff)
Cajou, fruit (*Anacardium giganteum* Hance ex Engl.)
Cambucá (*Marlierea edulis* Nied.)
Carandas-plum (*Carissa edulis* Vahl)
Carob (*Ceratonia siliqua* L.)
Cashew apple (*Anacardium occidentale* L.)
Ceylon iron wood (*Manilkara hexandra* (Roxb.) Dubard)
Ceylon olive (*Elaeocarpus serratus* L.)
Cherry-of-the-Rio-Grande (*Eugenia aggregata* (Vell.) Kiaersk.)
Chinese olive, black (*Canarium tramdenum* C.D. Dai & Yakovlev)
Chinese olive, white (*Canarium album* (Lour.) Raeusch.)
Chirauli-nut (*Buchanania latifolia* Roxb.)
Ciruela verde (*Bunchosia armeniaca* (Cav.) DC.)
Cocoplum (*Chrysobalanus icaco* L.)
Date (*Phoenix dactylifera* L.)
Davidson's plum (*Davidsonia pruriens* F. Muell.)
Desert-date (*Balanites aegyptiacus* (L.) Delile)
Doum palm coconut (*Hyphaene thebaica* (L.) Mart.)

False sandalwood (*Ximenia americana* L.)

Feijoa (*Acca sellowiana* (O. Berg) Burret)

Fig (*Ficus carica* L.)

Fragrant manjack (*Cordia dichotoma* G. Forst.)

Gooseberry, abyssinian (*Dovyalis abyssinica* (A. Rich.) Warb.)

Gooseberry, Ceylon (*Dovyalis hebecarpa* (Gardner) Warb.)

Gooseberry, Indian (*Phyllanthus emblica* L.)

Gooseberry, otaheite (*Phyllanthus acidus* (L.) Skeels)

Governor's plum (*Flacourtia indica* (Burm. F.) Merr.)

Grumichama (*Eugenia brasiliensis* Lam)

Guabiroba (*Campomanesia* xanthocarpa O. Berg)

Guava (*Psidium guajava* L.)

Guava berry (*Myrciaria floribunda* (H. West ex Willd.) O. Berg)

Guava, Brazilian (*Psidium guineense* Sw.)

Guava, cattley (*Psidium cattleyanum* Sabine)

Guava, Costa Rican (*Psidium friedrichsthalianum* (O. Berg) Nied.)

Guava, Para (*Psidium acutangulum* DC.)

Guava, purple strawberry (*Psidium cattleyanum* Sabine var. *cattleyanum*)

Guava, strawberry (*Psidium cattleyanum* Sabine var. *littorale* (Raddi) Fosberg)

Guava, yellow strawberry (*Psidium cattleyanum* Sabine var. *cattleyanum forma lucidum* O. Deg.)

Guayabillo (*Psidium sartorianum* (O. Berg) Nied.)

Illawarra plum (*Podocarpus elatus* R. Br. Ex Endl.)

Imbé (*Garcinia livingstonei* T. Anderson)

Imbu (*Spondias tuberosa* Arruda ex Kost.)

Indian-plum (*Flacourtia jangomas* (Lour.). *basionym*)

Jaboticaba (*Myrciaria cauliflora* (Mart.) O. Berg)

Jamaica-cherry (*Muntingia calabura* L.)

Jambolan (*Syzygium cumini* (L.) Skeels)

Jelly palm (*Butia capitata* (Mart.) Becc.)

Jujube, Indian (*Ziziphus mauritiana* Lam.)

Kaffir-plum (*Harpephyllum caffrum* Bernh. Ex C. Krauss)

Kakadu plum (*Terminalia latipes* Benth. subsp. *psilocarpa* Pedley)

Kapundung (*Baccaurea racemosa* (Reinw.) Mull. Arg.)

Karanda (*Carissa carandas* L.)

Kwai muk (*Artocarpus hypargyreus* Hance ex Benth.)

Lemon aspen (*Acronychia acidula* F. Muell)

Mangaba (*Hancornia speciosa* Gomes)
Marian plum (*Bouea macrophylla* Griff.)
Mombin, malayan (*Spondias pinnata* (J. Koenig ex L. f.) Kurz)
Mombin, purple (*Spondias purpurea* L.)
Mombin, yellow (*Spondias mombin* L.)
Monkeyfruit (*Artocarpus lacucha* Buch. Ham.)
Monos plum (*Pseudanamomis umbellulifera* (Kunth) Kausel)
Mountain cherry (*Bunchosia cornifolia* Kunth)
Nance (*Byrsonima crassifolia* (L.) Kunth)
Natal plum (*Carissa macrocarpa* (Eckl.) A. DC.)
Noni (*Morinda citrifolia* L.)
Olive (*Olea europaea* L. subsp. *europaea*)
Papaya, mountain (*Vasconcellea pubescens* A. DC.)
Patauá (*Oenocarpus bataua* Mart.)
Peach palm, fruit (*Bactris gasipaes* Kunth var. *gasipaes*)
Persimmon, black (*Diospyros texana* Scheele)
Persimmon, Japanese (*Diospyros kaki* Thunb.)
Pitomba (*Eugenia luschnathiana* Klotzsch ex O. Berg)
Plum-of-Martinique (*Flacourtia inermis* Roxb.)
Pomerac (*Syzygium malaccense* (L.) Merr. & L.M. Perry)
Rambai (*Baccaurea motleyana* (Mull. Arg.) Mull. Arg.)
Rose apple (*Syzygium jambos* (L.) Alston)
Rukam (*Flacourtia rukam* Zoll. & Moritizi)
Rumberry (*Myrciaria dubia* (Kunth) McVaugh Myrtaceae)
Sea grape (*Coccoloba uvifera* (L.) L.)
Sentul (*Sandoricum koetjape* (Burm. F.) Merr.)
Sete-capotes (*Campomanesia guazumifolia* (Cambess.) O. Berg)
Silver aspen (*Acronychia wilcoxian* (F. Muell.) T.G. Hartley)
Starfruit (*Averrhoa carambola* L.)
Surinam cherry (*Eugenia uniflora* L.)
Tamarind (*Tamarindus indica* L.)
Uvalha (*Eugenia pyriformis* Cambess)
Water apple (*Syzygium aqueum* (Burm. F.) Alston)
Water pear (*Syzygium guineense* (Willd.) DC)
Water berry (*Syzygium cordatum* Hochst. Ex C. Krauss)
Wax jambu (*Syzygium samarangense* (Blume) Merr. & L.M. Perry)
Cultivars, varieties, and hybrids of these commodities

Table F-22 Crop Group 24: Tropical and Subtropical Fruit, Inedible Peels

Abiu (*Pouteria caimito* (Ruiz & Pav.) Radlk)
Aisen (*Boscia senegalensis* (Pers.) Lam.)
Akee apple (*Blighia sapida* K.D. Koenig)
Atemoya (*Annona cherimola* Mill. X A. *squamosa* L.)
Avocado (*Persea americana* Mill.)
Avocado, Guatemalan (*Persea americana* Mill. var. *guatemalensis*)
Avocado, Mexican (*Persea americana* Mill. var. *drymifolia* (Schltdl. & Cham.) S.F. Blak)
Avocado, West Indian (*Persea americana* var. *americana*)
Bacury (*Platonia insignis* Mart.)
Bael fruit (*Aegle marmelos* (L.) Corrêa)
Banana (*Musa* spp.)
Banana, dwarf (*Musa* hybrids; *Musa acuminata* Colla)
Binjai (*Mangifera caesia* Jack)
Biriba (*Annona mucosa* Jacq.)
Breadfruit (*Artocarpus altilis* (Parkinson) Fosberg)
Burmese grape (*Baccaurea ramiflora* Lour.)
Canistel (*Pouteria campechiana* (Kunth) Baehni)
Cat's-eyes (*Dimocarpus longan* Lour. subsp. *malesianus* Leenh.)
Champedak (*Artocarpus integer* (Thunb.) Merr.)
Cherimoya (*Annona cherimola* Mill.)
Cupuacú (*Theobroma grandiflorum* (Willd. Ex Spreng.) K. Schum.)
Custard apple (*Annona reticulata* L.)
Dragon fruit (*Hylocereus undatus* (Haw.) Britton & Rose)
Durian (*Durio zibethinus* L.)
Elephant-apple (*Limonia acidissima* L.)
Etambe (*Mangifera zeylanica* (Blume) Hook. F.)
Granadilla (*Passiflora ligularis* Juss.)
Granadilla, giant (*Passiflora quadrangularis* L.)
Ilama (*Annona macroprophyllata* Donn. Sm.)
Ingá (*Inga vera* Willd. subsp. *affinis* (DC.) T.D. Penn.)
Jackfruit (*Artocarpus heterophyllus* Lam.)
Jatobá (*Hymenaea courbaril* L.)
Karuka (*Pandanus julianettii* Martelli)
Kei apple (*Dovyalis caffra* (Hook. F. & Harv.) Warb.)
Langsat (*Lansium domesticum* Corrêa)

Lanjut (*Mangifera lagenifera* Griff.)
Longan (*Dimocarpus longan* Lour.)
Lucuma (*Pouteria lucuma* (Ruiz & Pav.) Kuntze)
Lychee (*Litchi chinensis* Sonn.)
Mabolo (*Diospyros blancoi* A. DC.)
Madras-thorn (*Pithecellobium dulce* (Roxb.) Benth.)
Mammy-apple (*Mammea americana* L.)
Manduro (*Balanites maughamii* Sprague)
Mango (*Mangifera indica* L.)
Mango, horse (*Mangifera foetida* Lour.)
Mango, Saipan (*Mangifera odorata* Griff.)
Mangosteen (*Garcinia mangostana* L.)
Marang (*Artocarpus odoratissimus* Blanco)
Marmaladebox (*Genipa americana* L.)
Matisia (*Matisia cordata* Humb. & Bonpl.)
Mesquite (*Prosopis juliflora* (Sw.) DC.)
Mongongo, fruit (*Schinziophyton rautanenii* (Schinz) Radcl.-Sm)
Monkey-bread-tree (*Adansonia digitata* L.)
Monstera (*Monstera deliciosa* Liebm.)
Nicobar-breadfruit (*Pandanus leram* Jones ex Fontana)
Paho (*Mangifera altissima* Blanco)
Pandanus (*Pandanus utilis* Bory)
Papaya (*Carica papaya* L.)
Passionflower, winged-stem (*Passiflora alata* Curtis)
Passionfruit (*Passiflora edulis* Sims)
Passionfruit, banana (*Passiflora tripartita* var. *mollissima* (Kunth) Holm-Niels. & P. Jorg.)
Passionfruit, purple (*Passiflora edulis* Sims *forma edulis)*
Passionfruit, yellow (*Passiflora edulis* Sims *forma flavicarpa* O. Deg.)
Pawpaw, common (*Asimina triloba* (L.) Dunal)
Pawpaw, small-flower (*Asimina parviflora* (Michx.) Dunal)
Pelipisan (*Mangifera casturi* Kosterm.)
Pequi (*Caryocar brasiliense* Cambess)
Pequia (*Caryocar villosum* (Aubl.) Pers.)
Persimmon, American (*Diospyros virginiana* L.)
Pineapple (*Ananas comosus* (L.) Merr.)
Pitahaya (*Hylocereus polyrhizus* (F.A.C. Weber) Britton & Rose)

Pitaya (*Hylocereus* sp. including *H. megalanthus* (*H. ocamponis* and *H. polychizus*)

Pitaya, amarilla (*Hylocereus triangularis* Britton & Rose)

Pitaya, roja (*Hylocereus ocamponis* (Salm-Dyck) Britton & Rose)

Pitaya, yellow (*Hylocereus megalanthus* (K. Schum. ex Vaupel) Ralf Bauer)

Plantain (*Musa paradisiaca* L.)

Pomegranate (*Punica granatum* L.)

Poshte (*Annona liebmanniana* Baill.)

Prickly pear, fruit (*Opuntia ficus-indica* (L.) Mill.)

Prickly pear, Texas, fruit (*Opuntia engelmannii* Salm-Dyck ex Engelm. var. lindheimeri (Engelm.) B.D. Parfitt & Pinkav)

Pulasan (*Nephelium ramboutan-ake* (Labill.) Leenh.)

Quandong (*Santalum acuminatum* (R. Br.) DC.)

Rambutan (*Nephelium lappaceum* L.)

Saguaro (*Carnegiea gigantea* (Engelm.) Britton & Rose)

Sapodilla (*Manilkara zapota* (L.) P. Royen)

Sapote, black (*Diospyros digyna* Jacq.)

Sapote, green (*Pouteria viridis* (Pittier) Cronquist)

Sapote, mamey (*Pouteria sapota* (Jacq.) H.E. Moore & Stearn)

Sapote, white (*Casimiroa edulis* La Llave & Lex)

Sataw (*Parkia speciosa* Hassk.)

Satinleaf (*Chrysophyllum oliviforme* L.)

Screw-pine (*Pandanus tectorius* Parkinson)

Sierra Leone-tamarind (*Dialium guineense* Willd.)

Soncoya (*Annona purpurea* Moc. & Sessé ex Dunal)

Soursop (*Annona muricata* L.)

Spanish lime (*Melicoccus bijugatus* Jacq.)

Star apple (*Chrysophyllum cainito* L.)

Sugar apple (*Annona squamosa* L.)

Sun sapote (*Licania platypus* (Hemsl.) Fritsch)

Tamarind-of-the-Indies (*Vangueria madagascariensis* J.F. Gmel.)

Velvet tamarind (*Dialium indum* L.)

Wampi (*Clausena lansium* (Lour.) Skeels)

White star apple (*Chrysophyllum albidum* G. Don)

Wild loquat (*Uapaca kirkiana* Müll. Arg.)

Cultivars, varieties, and hybrids of these commodities

Treatment Manual

Appendix G

Respirator Protection Information

Contents

Introduction

The information in this chapter has been developed from the Department of Labor, Occupational Safety and Health Administration (OSHA) standard Title 29, Code of Federal Regulations (CFR), Part 1910.134, and the APHIS *Safety and Health Manual* (under revision). These guidelines apply to all APHIS employees who must wear respiratory protection equipment. These are the minimum requirements for an effective respiratory protection program.

USDA employees should also refer to the USDA APHIS PPQ Safety and Health Sharepoint site or Chapter 11 in the *APHIS Safety and Health Manual* on the APHIS myportal web site for additional information.

Equipment Selection

USDA APHIS PPQ recommends two different types of supplied air systems to provide breathing air to employees conducting fumigation activities. These are:

- Self Contained Breathing Apparatus (SCBA)
- Cascade air supply system

Each of these systems is configured for **one** style of air mask. When methyl bromide concentrations are unknown or 5 ppm and above, employees must wear and use SCBA. There is **one** approved air mask, the MSA Airhawk Ultra Elite. (**Figure G-1-4**)

MB 2016 Label

Important

USDA APHIS PPQ approves the following half and full face air purifying respirators for use in areas where methyl bromide levels are between 1 and 5 ppm (refer to **Appendix E** for ordering information):

Half face respirators: MSA Advantage 420, 3M 6100, 6200, 6300, North 7700, Survivair/Sperian 250000, 260000, 270000

Full face respirators: MSA Advantage 1000, 3M 6700, 6800, 6900, North 76008AS/76008A

Refer to **Figure G-1-1** for approved half face respirators.

Figure G-1-1 Approved Half Face Respirators

Refer to **Figure G-1-2** for approved full face respirators.

3M 6700, 6800, 6900 | MSA Advantage 1000 | North 76008AS/76008A

Figure G-1-2 Approved Full Face Respirators

Refer to **Figure G-1-3** for approved organic vapor/acid gas/P100 cartridges for both half and full face respirators.

3M | MSA Advantage | North

Figure G-1-3 Approved Organic Vapor/Acid Gas/P100 Cartridges

Refer to **Figure G-1-4** for approved SCBA.

MSA AirHawk Ultra Elite

Figure G-1-4 Approved SCBA

If needed, employees may also order spectacle kits for the MSA AirHawk. Models available include a center-support kit and a sidewire kit.

MSA AirHawk Ultra Elite Spectacle Kit

Figure G-1-5 Approved AirHawk Ultra Elite Spectacle Kit-Sidewire

Responsibilities

APHIS Safety, Health, and Environmental Programs

APHIS Safety, Health and Environmental Programs (SHEP) is responsible for:

- ensuring that a physician or other licensed health care professional determines that an employee is physically able to wear a respirator
- establishing a medical evaluation protocol for respirator users and is the authority on medical surveillance of respirators
- establishing and conducting a respiratory protection program according to the requirements of this manual and applicable OSHA standards when respiratory protection is required and used

Managers and Supervisors

In workplaces where respiratory protection is used managers and supervisors have a direct responsibility for protecting their employees and must:

- advise all respirator wearers that they may safely leave the area at any time for relief from respirator use in the event of equipment malfunction, physical or psychological distress, procedural or communication failure, significant deterioration of operating conditions, or any other conditions that might warrant such relief
- annually review the workplace-specific written plan and provide a copy to the appropriate safety and health office with proper signature for approval

- appoint an individual to be responsible for the use, maintenance, inspection, and care of common use, emergency, or escape respirators
- contact applicable safety and health office whenever workplace operations change to schedule appropriate evaluations when new hazardous materials are introduced, processes or procedures are changed, or engineering controls are modified or added
- develop, maintain, and enforce a workplace-specific written plan according to the guidance in 29 CFR 1910.134, Appendix A
- document training on the employee safety and health record, or electronic equivalent
- ensure employees in the respiratory protection program wear the approved respiratory protection for the hazard and for which they have been fit tested and trained
- ensure employees have received the necessary medical evaluations, training, and fit testing before engaging in workplace operations requiring the use of the respirator. Supervisors receive training from the applicable safety office and should contact applicable safety office if they become a manager/supervisor of a new work place
- follow and enforce the cartridge change-out schedule developed by supervisor/manager at worksite and include the schedule in the workplace-specific written plan
- maintain applicable standards in the workplace
- notify applicable safety and health office of conflicts between respiratory protection guidance and applicable standards
- notify applicable safety office when new employees require fit testing or when current employees have a change affecting their wear of respiratory protection
- provide copies of workplace-specific written plan to employees to hand-carry to their medical evaluation when requested
- provide for quality control of respirator breathing air (if used)

Important

> Cylinders of purchased breathing air have a certificate of analysis from the supplier. Discontinue the use of compressed breathing air and contact applicable safety office if sample results are unsatisfactory and/or employees complain of taste, odor or irritation from compressed breathing air.

- provide initial and periodic (annual and as changes occur) respiratory protection training, including training to all employees in their workplace who use “voluntary” use (filtering facepieces) respirators. (Refer to 29 CFR 1910.134, Appendix D for mandatory training requirements for voluntary use respirators.)

Employee Responsibilities

Employees who wear respiratory protection will:

- complete initial respirator medical evaluation questionnaire (APHIS 29 Form, Occupational Exposures) and other physical examination requirements as needed prior to performing duties requiring respiratory protection
- ensure that no facial hair comes between the sealing surface of the facepiece and the face or interferes with valve function, if required, to wear a tight-fitting facepiece
- guard respirators against damage, do not use unsanitary, damaged or unserviceable respirators, and turn in unserviceable respirators to their supervisor
- inspect, clean, and maintain any respiratory protection device issued to them for their individual use
- maintain the integrity of the National Institute of Occupational, Safety and Health (NIOSH) certification by not mixing respirator parts from different manufacturers
- provide workplace-specific written program to the provider for the medical evaluation when requested
- receive initial and periodic training and fit testing (annual, and as changes occur)
- report to their supervisor any change in medical status which may impact their ability to safely wear respiratory protection (e.g., weight changes, facial scarring, dental changes, cosmetic surgery, disfigurement, etc.)
- use the provided respiratory protection according to the instructions and training received
- wear only that respiratory protection for which they have received fit testing and training, and only for the tasks specified

Work Unit Responsibilities

With assistance from the applicable safety office, the work unit will:

- conduct fit testing on those individuals who have been medically cleared by a physician or licensed health care provider
- conduct routine surveys in workplaces where respirators are used
- educate and train workplace supervisors, and those individuals appointed to oversee the use, maintenance, and care of common use, or escape-only respirators. Supervisor training will be repeated when a supervisor becomes a supervisor of a different workplace

- ensure fit testing is conducted according to OSHA and APHIS guidelines
- maintain or have immediate access to current copies (paper or electronic) of applicable OSHA standards (i.e., 29 CFR 1910, 29 CFR 1926), and the NIOSH Certified Equipment List
- provide guidance to workplace supervisors, as necessary, in the preparation of the workplace-specific written plan and annual training program
- review workplace-specific written plans annually to ensure respiratory protection procedures are addressed and submit to applicable safety office for approval (refer to **Figure A-13 on page-A-A-33** for a site plan template or see the USDA APHIS PPQ Safety and Health Sharepoint site for site-specific plans)

Physician or Other Licensed Health Care Professional (PLHCP)

The physician or PLHCP will:

- conduct medical evaluations of individuals identified to wear a respirator, as required
- medically clear individuals to wear a respirator
- review the respirator medical evaluation questionnaires and document as outlined in **Occupational Medical Monitoring Program (OMMP)**

Workplace Specific Respiratory Protection Program Elements

The respiratory protection program must be conducted in accordance with OHSA's standard 29 CFR 1910.134, APHIS *Safety and Health Manual*, and this *Treatment Manual.*

The program elements of a respiratory protection program will be shared among workplace supervisors, employees and the applicable safety office. Only NOISH/MSHA approved respirators can be used by employees in federal workplaces. No privately-procured respiratory protection device will be used by federal employees in workplaces

Management must develop procedures to address the following at each workplace:

- fit testing procedures for tight-fitting respirators in 29 CFR 1910.134(f)

- program evaluation procedures in 29 CFR 1910.134(l)

Important

> Management must ensure the respiratory protection program is evaluated annually. The applicable safety office should assist management during review and report the findings in writing to workplace supervisor with recommendation for correction if necessary.

- training procedures in 29 CFR 1910.134(k)

The program evaluation will review the adequacy of the following elements as a minimum:

- air supply and breathing air (review of air testing results as appropriate) and checking for breathing air outlet incompatibilities with other gas lines
- filters used for each hazard
- maintenance and storage practices (shared, emergency use, and individual respirators)
- the respirator for workplace exposures
- work practices, documentation of inspections of shared and emergency use respirators, and documentation of respirator training

The findings of these evaluations may be included in the workplace survey reports.

Medical evaluations will be conducted as outlined in **Occupational Medical Monitoring Program (OMMP)**.

Workplace-Specific Program Elements

Supervisors in workplaces where respiratory protection is used must develop a written plan as required by 29 CFR 1910.134(c). The plan must be approved by the applicable safety office. Workplace-specific written plans must include the following:

- duration and frequency of respirator use (including use for rescue and escape if applicable)
- expected physical work effort involved in the process requiring respiratory protection (see 29 CFR 1910.134 Appendix C, Part B)
- proper use of respirators in routine and emergency situations
- protective clothing and equipment to be worn while wearing the respirator
- selection criteria—describe the processes in which respirators are required

- type and weight of the respirators used by employees
- temperature and humidity extremes that may be encountered
- training procedures for required respirators (see 29 CFR 1910.134(k)(1-6))
- use, maintenance, and care procedures (describe the criteria that employees use to determine when respirator filters, cassettes, or cartridges must be changed)

Supervisors must ensure that approved respirators in their workplace are used, are used correctly, and are in good condition.

Respirator Selection, Use, and Limitations

Select respirators according to 29 CFR 1910.134 (d) and the NIOSH Certified Equipment List. Document the rationale for selection in the workplace-specific written plan.

If a more stringent standard such as a substance-specific OSHA standard exists for the contaminants, follow those guidelines and requirements for respirator selection.

Employee Activity

Consider each employee's activity and location in an inhalational hazardous area when selecting the proper respiratory protection. For example, whether the employee is in the hazardous area continuously or intermittently during the work shift and whether the work rate is light, medium, or heavy.

Respirator Use Conditions

Take into account the period of time a respirator must be worn when selecting a respirator. Consider the type of respirator application, such as for routine, non-routine, emergency, or rescue use.

Location of the Potential Hazardous Area

Consider the location of the hazardous area with respect to a safe area, which has respirable air, when selecting a respirator. This will permit planning for the escape of employees if an emergency occurs, entry of employees to perform maintenance duties, and rescue operations.

Operational Limitations

Environmental conditions and level of effort required of the respirator wearer may affect respirator service life. For example, extreme physical exertion can cause the user to deplete the air supply in a SCBA such that its service life is reduced by half or more.

Immediately Dangerous to Life or Health (IDLH) Conditions

Evaluate all possible actions, such as increasing ventilation or isolating the source of contaminants, to attain an atmosphere that is not IDLH before authorizing employees to enter areas known to have IDLH conditions. Refer to 29 CFR 1910.134 g (3) and g(4) for procedures for IDLH atmospheres.

Other Exposure Routes

Consider other exposure routes (e.g., skin absorption or external radiation) when selecting respiratory protection. Wearing the respirator could increase exposure by longer stay times in a hazardous environment such as exposures to external radiation.

Document respirator selection on the workplace-specific written respiratory protection plans.

Respirator Limitations

In addition to the following, refer to the requirements in 29 CFR 1910.134:

- Communications—consider ambient environmental noise and communication needs when specific respirators are selected. See **Verbal Communication Considerations**.
- Eye Irritation—if contaminants cause eye irritation, wear full facepiece respirators or chemical protective goggles with half facepiece respirators.
- Respirators in Low Temperature Environments—low temperatures may cause detrimental effects on the performance of respirators. Consider the effects of low temperatures in the selection and maintenance of respirators and respirable gas supplies. See **Low Temperature Environment Considerations**.
- Respirators In High Temperature Environments—high temperatures may affect the performance of the respirator, and may add undue physiological stress. Consider the effects of high temperatures in respirator selection and for medical approvals. See **High Temperature Environment Considerations**.

Corrective Lenses

PPQ will pay for corrective lenses; however, employees are required to pay for the personal doctor visit to get the prescription for the lenses.

WARNING

Wearing of contact lenses in contaminated atmospheres with a respiratory protection device is **prohibited**.

Occupational Medical Monitoring Program (OMMP)

Medical Evaluation

Potential respirator wearers must complete a respirator medical evaluation questionnaire and/or may receive a physical examination prior to initial fit testing to identify existing medical conditions that would place the employee at an increased health risk from the use of a respirator or interfere with the use or wear of a respirator. The OSHA standard 29 CFR 1910.134 (e) and Appendix C specifies the minimum mandatory requirements for medical evaluations. Supervisors will assist employees in the completion of the APHIS Form 29 Occupational Exposure and ensure that the employees required to use respirators are medically qualified and fit-tested for the appropriate respirator. Contact the applicable PPQFO safety manager with any questions regarding the medical clearance process before using a respirator.

Respirator Questionnaires and Medical Evaluations

All health care providers conducting medical evaluations and reviewing completed respirator medical evaluation questionnaires for the respiratory protection program must be a physician or other licensed health care professional (PLHCP), as defined in 29 CFR 1910.134 (b). The Federal Occupational Health (FOH) Medical Advisor meets the requirements of the PLHCP and will be referred to as such in this section.

The medical evaluation consists of the respirator medical evaluation questionnaire and a physical examination if wearing SCBA. The FOH Medical Advisor determines medical evaluation expirations.

Following review of the respirator medical evaluation questionnaire, follow-up medical evaluation may be needed. The FOH Medical Advisor will determine what is needed. The FOH Medical Advisor is the determining official for the employee's ability to use a respirator.

The FOH Medical Advisor's written recommendation will be in the form of a medical clearance letter (MCL). The MCL is sent to the employee and employer (applicable PPQFO Safety Manager). It is the employee's responsibility to provide a copy of the MCL to his/her supervisor. MCL's will be one of the following:

- MCL for respirator use **without restrictions**

- MCL for respirator use **with restrictions**. Follow all restrictions on the MCL.
    - If an employee recovers from the medical condition and the restrictions can be lifted, the employee's personal doctor must notify the FOH Medical Advisor so the recommendations and restrictions can be updated.
- MCL for no respirator use.
    - The employee will **not** be allowed to perform any work activities that require the use of a respirator. The FOH Medical Advisor will convey to the employee the reason for the failure to pass the examination and give the employee appropriate options. The reasons are personal health issues identified through the medical history and physical examination (including any testing) during the clearance process. In some cases, there may be no options available. In most cases, there are remedies that can be achieved by the employee working with his/her healthcare provider. The employee has the option to do nothing, in which case, the MCL for no respirator use will still stand.
    - The employee may elect to go to their personal physician to treat the condition. All expenses for personal health issues are the responsibility of the employee. Any documentation to support reconsideration for medical clearance by the FOH Medical Advisor, must be submitted to the FOH medical advisor by the employee or their healthcare provider. Final determination for medical clearance rests with the FOH medical advisor.

Follow-up Medical Evaluations

Based on an employee's answers on the respirator medical evaluation questionnaire, a follow-up medical evaluation may be required. The follow up medical evaluation can be in the form of a physical examination, blood work, and/or a stress test.

Workplace supervisors should be communicating with their employees and know if they may have developed medical conditions affecting respirator use since initial fit testing. Discretion is advised.

Supervisors should brief employees if there are any questions or concerns about an employee's ability to use a respirator due to a medical condition.

The supervisor will notify as soon as possible, the applicable safety and health office if a worker who uses a respirator develops a medical condition that could affect their ability to use a respirator.

When a worker reports to an annual respirator fit test, a program appointed fit-tester will formally (e.g., with written verification that is locally developed) ask if the employee has experienced any difficulty wearing a respirator and if personnel are medically cleared to wear a respirator. If the worker responds with a change in medical history, he or she will be directed back to the supervisor, and will not be fit-tested until cleared by the FOH Medical Advisor.

Fit Testing

Fit Testing Procedures

Before an employee may be required to wear a respirator with a tight-fitting facepiece, the employee must be fit tested with the same make, model, style, and size of respirator that will be used in the workplace. Current fit tests from other installations may be used if the employee will be using the same make, model and style of respirator.

Perform fit testing according to 29 CFR 1910.134 and the APHIS *Safety and Health Manual*.

Fit Test Failures

If a medically cleared employee cannot attain an adequate fit with a tight-fitting respirator the applicable safety and health office should be contacted for assistance.

Record Keeping

Records of respirator fit test results will include the information required in 29 CFR 1910.134 (m)(2)(i)(A-E). This information will be recorded on an Certificate of Respirator Fit Test, or equivalent

Copies of respirator fit test results will be given to the employee and their supervisor to be maintained and filled in personnel records

User Seal Check Procedures

Employees who use tight-fitting respirators will perform a user seal check to ensure that an adequate seal is achieved each time the respirator is donned. Employees will use either the positive and negative pressure check methods listed in 29 CFR 1910.134, Appendix B-1, or the respirator manufacturer's recommended user seal check method.

Training

Initial Training

All personnel will receive initial respiratory protection training prior to wearing a respirator. Use the USDA SF Form 182, Authorization, Agreement and Certification of Training, to document the initial and annual training.

Management will provide or arrange for the initial training of supervisors who have the responsibility of overseeing work activities of one or more persons who must wear respirators and respirator wearers. Training will include the requirements of 29 CFR 1910.134 (k).

Periodic Training

Trained workplace supervisors will provide annual instruction and retraining to respirator wearers. Training may also be conducted by applicable safety office or fit-tester during the annual fit testing. Management will provide retraining when notified by the supervisor of changes in the workplace or the type of respirator which render previous training obsolete. Management will also provide retraining when notified of or observed inadequacies in the employee's knowledge or use of the respirator indicate that the employee has not retained the requisite understanding or skills.

Supervisors must discuss respiratory protection requirements with employees during routine surveillance inspection. Supervisor training will be repeated when a supervisor is relocated to a different workplace.

Documentation

Document training in AgLearn or an electronic equivalent.

Care, Inspection, and Maintenance

Employees who are issued a respirator are responsible for its primary maintenance and care. Where respirators are used collectively or kept ready for emergencies by a workplace or operating activity, the supervisor of the activity is responsible for establishing a respirator maintenance and cleaning program as specified in 29 CFR 1910.134. This program includes care, inspection, and maintenance of respirators.

Respirators

- Cleaning and Disinfecting
    - In addition to the requirements in 29 CFR 1910.134, respirators issued to an individual must be cleaned and disinfected, at a minimum, using a respirator wipe at the end of each day in which the

respirator is used. Each respirator must be thoroughly cleaned and disinfected before being worn by a different individual. Emergency use respirators must be thoroughly cleaned and disinfected after being used. Refer to 29 CFR 1910.134, Appendix B-2.

- Storage
  - Refer to 29 CFR 1910.134.
- Respirable Air and Oxygen for SCBA and Air-line Respirators
  - Compressed gaseous air, compressed gaseous oxygen, liquid air, and liquid oxygen used for respiration must be of high purity and tested.
- Inspection
  - Inspect respirators per 29 CFR 1910.134.
  - Each air and oxygen cylinder must be inspected to ensure that it is fully charged according to the manufacturer's instructions.
  - The employee must inspect the respirator immediately before each use and during cleaning to ensure that it is in proper working condition. Inspect emergency or escape-only respirators prior to carrying it into the workplace. After cleaning and disinfecting, inspect each respirator to determine if it is in proper working condition, needs replacement of parts or repairs, or needs to be discarded. Each respirator stored for emergency or rescue use must be inspected at least monthly. Refer to 29 CFR 1910.134 (h)(3).
  - The record of inspection of emergency or rescue respirators must be maintained on Inspection/Maintenance Record. Respirators that do not meet applicable inspection criteria must be immediately removed from service and repaired or replaced.
- Maintenance
  - Refer to 29 CFR 1910.134(h) for maintenance and repair instructions.
  - Change cartridges, filters, or canisters of air-purifying respirators immediately after each use or if air is restricted when breathing.
  - If, at any time an employee detects an increase in breathing resistance, smells or tastes the contaminant, or detects the irritant properties of the contaminant the employee must immediately leave the area and replace the cartridge, filter or canister.

Breathing Air Quality and Use and Testing of Breathing Air Containers

Breathing air quality and use, testing, and breathing air containers must comply with 29 CFR 1910.134(i).

Ambient or Free-Air Pumps and Compressors

The workplace supervisor is responsible for inspecting ambient or free-air pumps and compressors used with air-line (supplied-air) systems.

- Air-line couplings must be incompatible with outlets for other gas systems to prevent inadvertent servicing of air-line respirators with other gases or oxygen.
- Inspect the air-line, compressor and respirator to ensure all three components match the air pressure and other requirements specified by the manufacturers.
- Place the pumps in a position to avoid entry of contaminated air into the system.

Verbal Communication Considerations

Verbal communication in a noisy industrial environment can be difficult. It is important to ensure that respirator wearers can comfortably communicate when necessary because an employee who is speaking very loudly or yelling may cause a facepiece seal leak, and the employee may be tempted to temporarily dislodge the device in order to communicate. Both situations are undesirable. There are several options that may be used to aid communications when wearing respirators.

Speaking Diaphragms

A speaking diaphragm consists of a resonating surface and cavity that vibrates during speech, amplifying the speaker's voice outside of the respirator. Consider the following when using speaking diaphragms:

- Not all facepiece respirators are available with a speaking diaphragm. Contact the equipment manufacturer for availability.
- There are key components in maintaining the airtight integrity of the facepiece requiring care when installing and handling.
- Use of a respirator with a speaking diaphragm during welding, cutting, burning, or grinding operations is of special concern, as flying sparks may burn a hole in the diaphragm, creating a leak. Some manufacturers have compensated for these applications by providing shrouds to cover the diaphragm or by using metal diaphragms.

Built-In Microphones

Some respirator manufacturers make small microphones that are mounted inside or connected to the respiratory inlet covering. The microphone may be connected to a radio, telephone, loudspeaker, or other means of electronic transmittal. Consider the following when using built-in microphones:

- Any component that is attached to or through the respiratory inlet covering may affect its function. In cases where the manufacturer provides components, strictly adhere to the installation instructions and leak test procedures to ensure that airtight integrity is maintained.
- Voice activated communication systems may cause continuous sound pickup of the blower, when used with powered air-purifying respirators, or air flow noise, when used with supplied air devices.

Hand or Coded Signals

A predetermined set of signals may be useful in communicating.

Cranial, Throat, or Ear Microphones

Cranial and throat microphones are held in place with a harness against the wearer's head and larynx, respectively. Ear microphones are worn in the same manner as a transistor radio earphone and function as both a microphone and speaker. Use of these devices does not require making penetrations or attachments to the respirator, and does not impact the NIOSH certification status. They may be used with radios, telephones, loudspeakers, or other means of electronic transmittal, similar to facepiece microphones. Consider the following when using cranial, throat, or ear microphones:

- Do not place cranial microphones under the head harness of facepiece respirators since their dislodgement may loosen the respirator straps.
- When connecting wires are passed underneath the bibs or neck seals of supplied-air hoods or helmets, attach them to the wearer’s body to avoid disturbing the bib positioning.

Telephone Handsets

Since a person exhales while speaking, the exhalation valve in a facepiece respirator is partially open. This is a perfect location to place a handset or hand-held microphone to obtain the clearest voice transmission. An alternative is to hold the handset or microphone to the wearer's throat while speaking.

Safety Considerations

Electronic devices shall be selected and used with caution in explosive atmospheres or Class I hazardous locations identified in Article 501 of the National Electric Code (NEC). When required, ensure all such devices comply with requirements for permissibility and intrinsically safe systems according to Article 504 of the NEC. Consider the effects of radio frequency emissions when utilizing such devices in the vicinity of sensitive electronic equipment.

Low Temperature Environment Considerations

A low temperature environment may cause lens fogging in a respiratory inlet covering and freezing or improper sealing of the valves. Coating the inside surface of the lens may inhibit fogging at temperatures approaching 0 degrees Celsius (°C) (32 degrees Fahrenheit (°F)). Full facepieces are available with nose cups that direct the warm and moist exhaled air through the exhalation valve without contacting the lens. Facepieces with nose cups may provide satisfactory vision at temperatures as low as -32 °C (-25 °F).

SCBA equipped with a full facepiece and certified for use below 32 °F shall be equipped with a nose cup or other suitable accessory or coating to maintain the device's NIOSH certification when it is used in environments below 32 °F.

Additionally, there are several other important considerations that users should be aware of when using SCBA in a low temperature environment. Users should thoroughly review the manufacturer's instructions and, if necessary, consult with the manufacturer to become thoroughly familiar with the precautions and recommendations for use of a specific SCBA in cold weather conditions. In general, consider the following:

- Storage—elastomeric components such as facepieces and breathing tubes may be prone to distortion if improperly stored in cold weather; such distortion could prevent the user from an adequate fit
- Accessory availability—cold temperature accessories and components such as special elastomeric gaskets and diaphragms may not be readily available

Respirator valves may freeze open or closed due to the presence of moisture at very low temperatures. Some air-line respirators are approved with a device called a “vortex tube” that warms the air supplied to the respiratory inlet covering of the respirator.

High Temperature Environment Considerations

Working in a high temperature environment while wearing a respirator creates additional stress on the wearer. Using a respirator that has a low weight, offers a low resistance to breathing, possesses a minimal dead air space, and, if feasible, provides a tempering of inlet air should minimize the additional stress.

Dead air volume is the volume of previously exhaled air (which is available to be inhaled) remaining in a respiratory inlet covering. Reducing the amount of dead air volume in a respirator reduces the level of carbon dioxide in the inhaled air, which is a major source of respirator usage related stress. This can be accomplished through the use of powered air-purifying respirators, continuous flow air-line respirators, use of a half facepiece respirator in lieu of a full facepiece, and use of a nose cup in full face- piece devices (regardless of the mode of operation).

Air-line respirators are recommended for use in a high temperature environment. Air-line respirators approved with a vortex tube will substantially reduce the temperature of the air supplied to the respirator. If air-purifying respirators are to be used, a half facepiece respirator, where it offers adequate protection, is preferable to the full facepiece.

Elastomeric components of respirators stored in high temperature environments may deteriorate at an accelerated rate and the facepiece may become permanently distorted. Use special care to prevent facepiece distortion.

Treatment Manual

Index

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

C

D

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

E

F

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

H

I

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

J

K

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

M

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

N

O

P

A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
Z

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

S

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

U

V

A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
Z

Attachment 8

Residential Proximity to Methyl Bromide Use and Birth Outcomes in an Agricultural Population in California

Alison Gemmill,[1] Robert B. Gunier,[2] Asa Bradman,[2] Brenda Eskenazi,[2] and Kim G. Harley[2]

[1]Department of Demography, University of California, Berkeley, Berkeley, California, USA; [2]Center for Environmental Research and Children's Health, School of Public Health, University of California, Berkeley, Berkeley, California, USA

Background: Methyl bromide, a fungicide often used in strawberry cultivation, is of concern for residents who live near agricultural applications because of its toxicity and potential for drift. Little is known about the effects of methyl bromide exposure during pregnancy.

Objective: We investigated the relationship between residential proximity to methyl bromide use and birth outcomes.

Methods: Participants were from the CHAMACOS (Center for the Health Assessment of Mothers and Children of Salinas) study (*n* = 442), a longitudinal cohort study examining the health effects of environmental exposures on pregnant women and their children in an agricultural community in northern California. Using data from the California Pesticide Use Reporting system, we employed a geographic information system to estimate the amount of methyl bromide applied within 5 km of a woman's residence during pregnancy. Multiple linear regression models were used to estimate associations between trimester-specific proximity to use and birth weight, length, head circumference, and gestational age.

Results: High methyl bromide use (vs. no use) within 5 km of the home during the second trimester was negatively associated with birth weight (β = –113.1 g; CI: –218.1, –8.1), birth length (β = –0.85 cm; CI: –1.44, –0.27), and head circumference (β = –0.33 cm; CI: –0.67, 0.01). These outcomes were also associated with moderate methyl bromide use during the second trimester. Negative associations with fetal growth parameters were stronger when larger (5 km and 8 km) versus smaller (1 km and 3 km) buffer zones were used to estimate exposure.

Conclusions: Residential proximity to methyl bromide use during the second trimester was associated with markers of restricted fetal growth in our study.

Key words: birth outcomes, birth weight, fumigants, methyl bromide, pesticides, residential proximity. *Environ Health Perspect* 121:737–743 (2013). http://dx.doi.org/10.1289/ehp.1205682 [Online 19 April 2013]

Methyl bromide is a fumigant used for pre-planting soil preparation. Because of concerns about its effect on the ozone layer, methyl bromide was banned in 2005 under the Montreal Protocol (United Nations Environment Programme 2000). Before the ban, methyl bromide was one of the most heavily used pesticides in California, with nearly 5 million kg applied in 2000 [California Department of Pesticide Regulation (DPR) 2001b]. Although methyl bromide use has declined in recent years, > 1.75 million kg was applied throughout the state in 2010 due to critical use exemptions for strawberries and other agricultural commodities (California DPR 2012c). Critical use of methyl bromide in the United States has declined markedly since 2005, but authorizations for use are still granted by the U.S. Environmental Protection Agency (U.S. EPA 2012).

Animal studies of methyl bromide exposure suggest the potential for developmental toxicity (National Research Council 2000). In an inhalation study of New Zealand white rabbits, exposure to 80 ppm methyl bromide during gestational days 7–19 resulted in decreased fetal body weights and increased rates of fetal malformations including gall bladder agenesis and fused sternebrae (National Research Council 2000). In another inhalation study, pups born to dams exposed to 20 and 70 ppm during gestation had increased rates of skull ossification defects (National Research Council 2000). A similar study of rats found dose-dependent reductions in fetal body and brain weights, as well as reduced cerebral cortex widths (National Research Council 2000). Based on this limited evidence, the California DPR lists methyl bromide as a probable developmental toxicant (National Research Council 2000).

Several human poisoning case studies indicate that high levels of acute methyl bromide exposure are associated with dermal burns, neurological impairment, and death (Breeman 2009; Langård et al. 1996; Lifshitz and Gavrilov 2000). Much less is known about the effects of chronic, low-level exposure in human populations (National Research Council 2000). In a sample of 56 male workers, long-term occupational exposure to methyl bromide was associated with chronic symptoms of dizziness, numbness, nightmares, and fatigue (Kishi et al. 1991). Other studies have investigated the health effects of residential proximity to methyl bromide use as part of larger analyses of ambient pesticide exposure. To date, one study reported evidence of an association with prostate cancer (Cockburn et al. 2011), but studies of breast cancer (Reynolds et al. 2004), childhood cancers (Reynolds et al. 2005), and autism spectrum disorders (Roberts et al. 2007) did not report associations with proximity to methyl bromide use.

Unlike most pesticides, fumigants such as methyl bromide have a high vapor pressure and are more likely to drift off-site (Woodrow and Krieger 2007). It is estimated that 30–50% of agricultural applications of methyl bromide are released into the air even when protective measures such as plastic tarps are in place (Honaganahalli and Seiber 2000; Majewski et al. 1995; Yagi et al. 1993). Because inhalation is the primary route of exposure to methyl bromide, ambient air concentrations are important for assessing exposure to nearby residents (National Research Council 2000). In agricultural areas of California, measured outdoor concentrations of methyl bromide averaged 0.1–7.7 ppb over an 8-week monitoring period in 2000 (California Air Resources Board 2001), or up to one-tenth of the levels associated with adverse outcomes in some animal studies. In addition, methyl bromide has been detected in air > 70 km away from the nearest application site (Honaganahalli and Seiber 2000).

Chronic exposure to methyl bromide is difficult to assess because there are no exposure biomarkers (Minnesota Department of Health 1999). The few studies that have assessed chronic methyl bromide exposure have done so by residential proxy or occupational history reports (Cockburn et al. 2011;

Address correspondence to K.G. Harley, Center for Environmental Research and Children's Health, School of Public Health, University of California, Berkeley, 1995 University Ave., Suite 265, Berkeley, CA 94704 USA. Telephone: (510) 643-1310. E-mail: kharley@berkeley.edu

Supplemental Material is available online (http://dx.doi.org/10.1289/ehp.1205682).

We acknowledge the CHAMACOS participants and families, without whom this study would not have been possible.

This publication was made possible by research supported by the following grants: PO1 ES009605 from the National Institute of Environmental Health Sciences, R82670901 from the U.S. Environmental Protection Agency, and HD07275 from the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development.

The authors declare they have no actual or potential competing financial interests.

Received 27 June 2012; accepted 18 April 2013.

Kishi et al. 1991; Reynolds et al. 2004, 2005; Roberts et al. 2007). Studies in California can use extensive information on the timing, location, and amount of agricultural methyl bromide applications, which must be reported to the state's Pesticide Use Reporting (PUR) system (California DPR 2012b).

In the current study we examined whether residential proximity to methyl bromide applications is associated with fetal growth and gestational length in a cohort of pregnant women living in an agricultural community in the Salinas Valley of California. We linked California PUR data with birth outcome and demographic data for pregnant women participating in the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) study, a longitudinal cohort study examining the health effects of environmental exposures on pregnant women and their children living in an agricultural community in northern California.

Methods

Participants. Women were recruited for the CHAMACOS study if they presented for prenatal care at one of six partnering community clinics located throughout the Salinas Valley between October 1999 and October 2000. Women were eligible for the study if they were at least 18 years of age, ≤ 20 weeks gestation, English or Spanish speaking, Medi-Cal eligible, and planning to deliver at the county hospital.

A total of 601 women were enrolled, and after losses due to miscarriage and loss to follow-up, birth weight information was available for 536 children. Women were excluded from the present analysis if they delivered twins (n = 5), stillbirths (n = 3), or infants born at < 500 g (n = 1), as well as women who were diagnosed with pregnancy-induced hypertension (n = 15) or diabetes (n = 26). Women were also excluded if residential proximity to methyl bromide use could not be assessed for at least 75 days during one trimester of pregnancy (n = 44). Participants who were excluded were likely to have relocated at least once during pregnancy (any residential moves: 85% vs. 41%) and tended to be less educated (high school graduate: 15% vs. 22%) and with lower parity (nulliparous: 46% vs. 31%) than participants included in the present analysis. The final sample size was 442 mothers with residential information available for at least one trimester of pregnancy. Written informed consent was provided by all women, and the study was approved by the Committee for the Protection of Human Subjects at the University of California, Berkeley.

Data collection. Women were interviewed at the time of enrollment (median, 13 weeks gestation), at the end of the second trimester of pregnancy (median, 26 weeks gestation), and following delivery. All interviews were conducted by bilingual interviewers using structured questionnaires in English or Spanish. Interviews obtained demographic information including maternal age, family income, and number of years lived in the United States, as well as body mass index (BMI) (based on self-reported prepregnancy weight and measured height), and pregnancy history. Information on alcohol, tobacco, drug, and caffeine use was also collected. Women were asked about their occupational status during pregnancy, including work in agriculture. Residential history information was collected by asking participants if they had moved since the last interview and, if so, the dates of all moves.

A home inspection was conducted shortly after enrollment (median, 16 weeks gestation) and when the child was 6 months old. For both visits, latitude and longitude coordinates of the participant's home were determined using a handheld global positioning system (GPS) unit. Residential mobility during pregnancy was common, with 53% of all participants moving at least once during pregnancy. For this analysis, a woman was included in the sample if her residential location (latitude and longitude coordinates) was known for 75 days or more of at least one trimester of pregnancy (trimester 1: n = 338; trimester 2: n = 408; trimester 3: n = 390). Because we collected latitude and longitude coordinates at two time points, both residential locations were known for women who moved once during pregnancy. For women who moved more than once, residential location was often known for at least one trimester, allowing us to include the woman in the analyses of that trimester and exclude her from the analyses of trimesters where her residence was unknown.

Birth outcome data were collected from medical records and abstracted by a registered nurse. Delivery data included information on pregnancy complications, maternal weight at delivery, infant birth weight (grams), length, head circumference, and gestational age at birth.

Geographic-based estimates of methyl bromide use. We estimated agricultural use of methyl bromide near each woman's residence using the following variables from the 1999–2000 PUR data: pounds of active ingredient applied, application date, and location. The location of pesticide application is reported for each square mile section (approximately 1.6 km × 1.6 km) defined by the Public Land Survey System (PLSS) (U.S. Bureau of Land Management 2013)

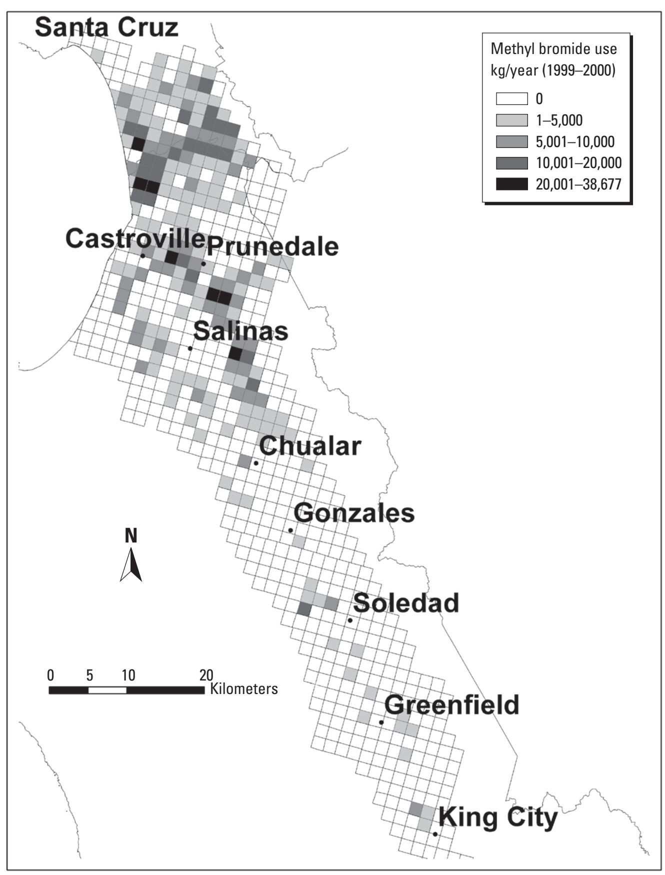


Figure 1. Distribution of methyl bromide use (kg/year) from the California PUR system by section of the PLSS grid in the Salinas Valley, 1999–2000. Data source: California Department of Pesticide Regulation (2012b).

(Figure 1). Before analysis, the PUR data were edited to correct for likely outliers with unusually high application rates using previously developed methods (Gunier et al. 2001).

For each woman, we calculated the amount of methyl bromide applied within a 5-km radius around her home using a geographic information system (GIS). Detailed descriptions of the equations and methods that were used to calculate pesticide use have been published previously (Gunier et al. 2011; Nuckols et al. 2007). Briefly, we calculated nearby methyl bromide by summing the kilograms applied in all 1.6 km × 1.6 km PLSS sections that fell within 5 km of the maternal residence (Figure 2). For sections that intersected the 5-km buffer, we weighted the amount of methyl bromide applied in that section by the proportion of land area that was included in the buffer. We summed these totals over each day of a trimester interval, yielding an estimate of the total amount of methyl bromide (kilograms) applied within 5 km of the maternal residence during each trimester of pregnancy.

We selected a 5-km buffer distance for this analysis because it best captures the spatial scale most strongly correlated with measured ambient methyl bromide concentrations (Honaganahalli and Seiber 2000; Li et al. 2005; Ross et al. 1996). In particular, Li et al. (2005) investigated the empirical relationship between methyl bromide use and ambient air concentrations in the same agricultural region (Salinas Valley) and time period of interest (2000) as our study using a variety of spatiotemporal scales. They found that parameters for the best-fit model of ambient methyl bromide concentrations at monitoring sites were average methyl bromide use during a 7- to 8-week period over the 7 × 7 mile area surrounding the monitoring site (R^2 = 0.95). Accordingly, we chose a GIS buffer radius of 5 km (3.1 miles) around a residence to adequately capture this 7 × 7 mile area.

We analyzed trimester-specific sums of methyl bromide use in kilograms for each woman as both continuous and categorical variables. We log-transformed ($\log_{10}$) continuous methyl bromide variables to reduce the influence of outliers and improve the linear fit of the model. In the categorical analyses, we compared the baseline category of no use (< 1 kg) with moderate use (exposure < median) and high use (exposure ≥ median) groups. To create categories of moderate and high use that were consistent across each trimester, the cut point used was the average of the median values in each of the three trimesters.

Statistical analysis. We used linear regression models to estimate associations between methyl bromide usage during each trimester of pregnancy and birth weight, length, head circumference, and length of gestation. All models of birth weight, length, and head circumference were adjusted for gestational age and gestational age squared to estimate the association with fetal growth while adjusting for length of gestation. Potential confounders considered *a priori* were maternal age and week of initiating prenatal care as continuous variables, and parity (nulliparous vs. multiparous), infant sex, mother's country of birth (born in Mexico vs. other), prepregnancy BMI, family income (at or below vs. above the federal poverty threshold) and mother's work status during pregnancy (ever paid work vs. no paid work) as categorical variables. Missing covariate values for income level (n = 22) were substituted with information from the closest follow-up interview. For women missing height (n = 8), prepregnancy BMI was predicted from a regression model that included age, weight, alcohol consumption, and education as predictor variables. We included covariates in the model if their exclusion changed the estimated coefficient for the main effect by > 10% or if they predicted the outcome (p < 0.10). Smoking and illicit drug use were not included in the model because few women reported these behaviors and they did not influence main effect estimates. Adjusting for exposure to environmental tobacco smoke and alcohol and caffeine use during pregnancy also did not affect the coefficients of interest.

We conducted sensitivity analyses of alternative buffer distances around the maternal residence, including two smaller distances (1 km and 3 km) and a buffer distance that is slightly larger (8 km) than the 7 × 7 square mile area shown to be optimal for estimating exposure in the Li et al. study (2005). For these analyses, methyl bromide use near the residence was categorized into a dichotomous variable [any use (≥ 1 kg) vs. no use (< 1 kg)]. We also carried out additional sensitivity analyses to investigate the influence of outliers in both the dependent and independent variables.

We conducted all statistical analyses using STATA version 11 statistical software (StataCorp LP, College Station, TX).

Results

Most of the women in the study were Latina (96%) and born in Mexico (85%) (Table 1). About half were recent immigrants to the United States, having lived in the country for ≤ 5 years. Most mothers lived in families with incomes < 200% of the federal poverty level (96%), and 78% had not graduated from high school. The median age was 25 years (SD = 5), and few women smoked during pregnancy (6%); consumption of ≥ 1 alcoholic drink per week (1%) and illegal drug use (2%) were also low (data not shown). more than half of the sample was either overweight (40%) or obese (22%). Approximately 4% of deliveries were born with low birth weight (< 2,500 g) and 7% were preterm (< 37 weeks gestational age). Characteristics of women in each trimester subsample were similar to those of the total sample [see

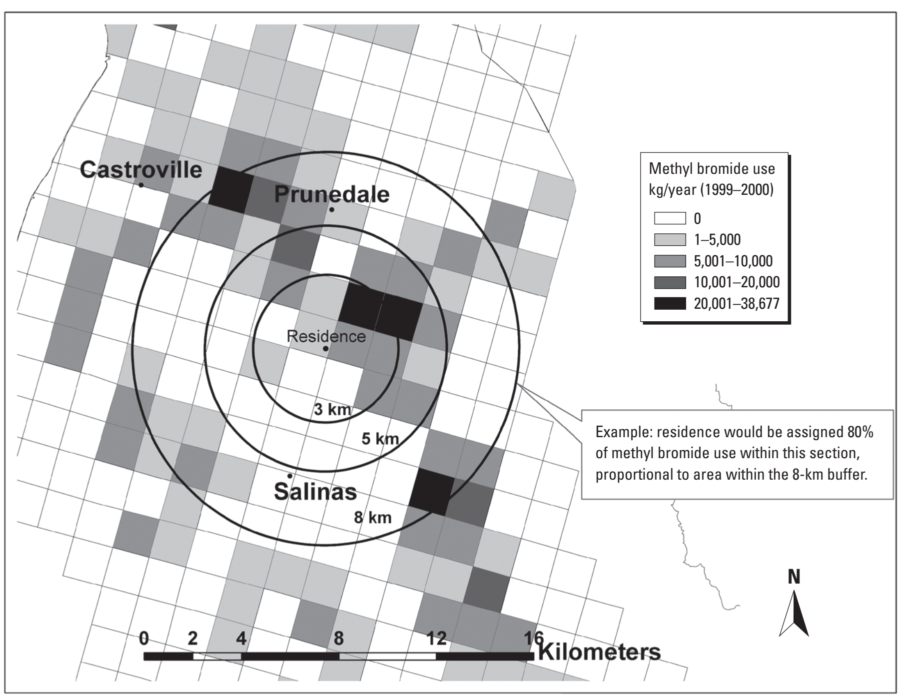


Figure 2. Methods used to determine proximity to methyl bromide use from the California PUR system by section of the PLSS grid illustrated for 3-, 5-, and 8-km radius buffers around a residence (•). Data source: California Department of Pesticide Regulation (2012b).

Supplemental Material, Table S1 (http://dx.doi.org/10.1289/ehp.1205682)].

Table 2 shows the distribution of methyl bromide use for each trimester for the buffer distance of interest (5 km) and the three additional buffer distances used in sensitivity analyses (1, 3, and 8 km). The range of methyl bromide use near residences was similar for trimesters 2 and 3 for each buffer distance, whereas values for trimester 1 were consistently larger due to the presence of 12 outliers (defined as > Q3 + (1.5 × IQR), where Q3 is the value of the 75th percentile (or 3rd quartile) and IQR is the interquartile range). Not surprisingly, the proportion of women living near methyl bromide applications increased as the buffer distance increased. For example, 85% of women lived within 8 km of some amount of methyl bromide use during the first trimester compared to 78%, 60%, and 16% of women for the 5-km, 3-km, and 1-km distances respectively. For the primary buffer distance used in this analysis (5 km), the estimated median amounts of methyl bromide use ranged from 6,010 to 8,201 kg, and the 95th percentile values ranged from 53,685 to 68,893 kg.

Table 3 presents estimated associations between methyl bromide use within 5 km of the home as a continuous variable ($\log_{10}$) and the four birth outcomes of interest. In minimally adjusted analyses, increases in methyl bromide use near residences in the second trimester were associated with decreases in birth weight, birth length, and head circumference. After adjusting for confounders, associations remained; each 10-fold increase of methyl bromide use in the second trimester was associated with a 21.4-g (95% CI: –43.2, 0.4) decrease in birth weight, a 0.16-cm (95% CI: –0.28, –0.04) decrease in birth length, and a 0.08-cm (95% CI: –0.15, –0.01) decrease in head circumference. Model estimates did not support associations between methyl bromide use in the first or third trimesters and fetal growth. Residential proximity to methyl bromide use was also positively associated with gestational age in the first trimester in both crude and adjusted analysis (adjusted β = 0.13 week; 95% CI: 0.03, 0.22).

Proximity to methyl bromide use was also analyzed as a three-level categorical variable (Table 4). The findings are similar to those from the continuous variable analysis. Using the 5-km buffer, moderate use of methyl bromide (vs. no use) nearby during the first trimester was associated with a 0.70-week increase in gestational age (95% CI: 0.21, 1.18), and high use was associated with a 0.59-week increase (95% CI: 0.12, 1.06). Moderate and high methyl bromide use within 5 km of the home during the second trimester were negatively associated with birth weight (β = –93.1 g; 95% CI: –198.0, 11.7 and β = –113.1 g; 95% CI: –218.1, –8.1, respectively) and birth length (β = –0.62 cm; 95% CI: –1.20, –0.03 and β = –0.85 cm; 95% CI: –1.44, –0.27, respectively), with stronger associations with high versus moderate use. In addition, proximity to moderate or high use in the second trimester was negatively associated with head circumference (β = –0.42 cm; 95% CI: –0.76, –0.08 and β = –0.33 cm; 95% CI: –0.67, 0.01, respectively). There was little evidence of associations between proximity to methyl bromide use during the first and third trimesters and birth weight, length, or head circumference.

Sensitivity analyses were conducted using different buffer distances around the maternal residence. Results for second trimester methyl bromide use (any vs. none) are presented in Table 5 using 1-km, 3-km, 5-km, and 8-km distances. Proximity to methyl bromide use within 1 km and 3 km during the second trimester was negatively associated with body length. Additionally, the 3-km distance yields marginally significant associations with reduced birth weight (p = 0.06), reduced head circumference (p = 0.08), and increased gestational age (p = 0.05). Unlike the smaller buffer distances, the 8-km analysis was more consistent with the 5-km buffer analysis; proximity to methyl bromide use during the second trimester was negatively associated with birth

Table 1. Characteristics of study population, CHAMACOS study, Salinas Valley, CA, 1999–2000 (n = 442).

Characteristics	n (%)
Maternal age (years)	
< 20	40 (9.1)
20–24	163 (36.9)
25–29	144 (32.6)
30–34	66 (14.9)
≥ 35	29 (6.6)
Parity	
0	139 (31.5)
≥ 1	303 (68.6)
Race/ethnicity	
Latina	426 (96.4)
Non-Latina, white	7 (1.6)
Other	9 (2.0)
Marital status	
Married or living as married	356 (80.5)
Unmarried	86 (19.5)
Maternal education	
≤ 6th grade	188 (42.5)
Some high school	158 (35.8)
High school graduate	96 (21.7)
Family income	
≤ Poverty	272 (61.5)
Poverty–200%	154 (34.8)
> 200%	16 (3.6)
Country of birth	
United States	59 (13.4)
Mexico	374 (84.6)
Other	9 (2.0)
Years of residence in the United States	
≤ 5 years	230 (52.0)
6–10 years	99 (22.4)
≥ 11 years	63 (14.3)
Entire life	50 (11.3)
Work status during pregnancy	
Did not work	172 (38.9)
Some field or agricultural work	181 (41.0)
Other work	89 (20.1)
Prepregnancy body mass index (kg/m^2)	
Underweight (< 18.5)	2 (0.5)
Normal (18.5–24.9)	170 (38.5)
Overweight (25–29.9)	175 (39.6)
Obese (> 30)	95 (21.5)
Smoked during pregnancy	
Yes	26 (5.9)
No	416 (94.1)
Any moves during pregnancy	
Yes	182 (41.2)
No	260 (58.8)
Low birth weight[a] infant	
Yes	17 (3.9)
No	425 (96.2)
Preterm[b] infant	
Yes	30 (6.8)
No	412 (93.2)

[a]Low birth weight is defined as < 2,500 g. [b]Preterm birth is defined as < 37 weeks gestation.

Table 2. Distribution of methyl bromide use near residences of pregnant women, CHAMACOS study, Salinas Valley, CA, 1999–2000 (n = 442).

Group	n	No nearby MeBr use (%)	Percentile (kg) 25th	50th	75th	95th
1-km radius						
Trimester 1	338	83.7	0	0	0	1,669
Trimester 2	408	86.3	0	0	0	766
Trimester 3	390	86.4	0	0	0	615
3-km radius						
Trimester 1	338	40.2	0	1,498	13,102	27,718
Trimester 2	408	40.2	0	734	7,379	23,455
Trimester 3	390	42.1	0	291	7,318	23,686
5-km radius						
Trimester 1	338	21.6	82	8,201	34,838	68,893
Trimester 2	408	25.5	0	7,419	29,676	53,685
Trimester 3	390	25.4	0	6,010	26,688	59,983
8-km radius						
Trimester 1	338	14.5	2,150	16,278	88,413	163,893
Trimester 2	408	18.9	352	11,984	69,200	129,464
Trimester 3	390	18.7	352	10,751	68,333	143,690

MeBr, methyl bromide.

weight, length, and head circumference, and associations were stronger than estimates from the 5-km analysis. Sensitivity analyses with other trimesters yielded few statistically significant associations: In the 3-km analysis there was a significant positive association with first trimester exposure and gestational age [see Supplemental Material, Table S2 (http://dx.doi.org/10.1289/ehp.1205682)].

Discussion

Living within 5 km of methyl bromide use in the second trimester of pregnancy was associated with decreased birth weight, length, and head circumference, despite a positive association between gestational age and residential proximity to methyl bromide use in the first trimester. The estimates for birth weight were only marginally significant (p = 0.08) among those women living near moderate methyl bromide use, whereas those for head circumference were marginally significant (p = 0.06) among those with high use. Model estimates did not support associations between exposure to methyl bromide during the first and third trimester and fetal growth parameters. Associations with nearby methyl bromide use analyzed as a continuous variable were consistent with those based on categorical exposures: Each 10-fold increase in kilograms of methyl bromide applied within 5 km of the home during the second trimester of pregnancy was associated with a 24.1-g decrease in mean birth weight, a 0.16-cm decrease in mean birth length, and a 0.08-cm decrease in mean head circumference.

The estimated decrease in mean birth weight associated with living near high use during the second trimester (113 g) was about half of the 250-g birth weight decrease generally associated with maternal smoking (Kramer 1987). Nevertheless, the findings suggest that the second trimester may be a critical period for effects of exposure for gestational growth. Findings from studies

Table 3. Associations [β (95% CI)] of proximity to methyl bromide use within a 5-km radius (log_{10}) during pregnancy with fetal growth parameters and length of gestation, CHAMACOS study, Salinas Valley, CA, 1999–2000 (n = 442).

Trimester	Birth weight (g)	*p*-Value	Length (cm)	*p*-Value	Head circumference (cm)	*p*-Value	Gestational age (weeks)	*p*-Value
Minimally adjusted[a]								
Trimester 1	–5.0 (–30.7, 20.8)	0.71	–0.02 (–0.15, 0.12)	0.82	–0.01 (–0.09, 0.07)	0.85	0.12 (0.02, 0.21)	0.02
Trimester 2	–23.4 (–45.9, –0.9)	0.04	–0.16 (–0.28, –0.03)	0.01	–0.08 (–0.16, –0.01)	0.03	0.00 (–0.09, 0.09)	0.95
Trimester 3	–3.4 (–26.6, 19.8)	0.78	0.01 (–0.11, 0.14)	0.82	–0.06 (–0.13, 0.02)	0.15	0.05 (–0.05, 0.15)	0.30
Adjusted[b]								
Trimester 1	–11.1 (–36.4, 14.3)	0.39	–0.03 (–0.17, 0.11)	0.69	–0.03 (–0.11, 0.05)	0.43	0.13 (0.03, 0.22)	0.01
Trimester 2	–21.4 (–43.2, 0.4)	0.05	–0.16 (–0.28, –0.04)	0.01	–0.08 (–0.15, –0.01)	0.04	–0.00 (–0.09, 0.09)	1.00
Trimester 3	–0.8 (–23.5, 21.8)	0.94	0.01 (–0.12, 0.14)	0.90	–0.05 (–0.12, 0.03)	0.22	0.03 (–0.06, 0.13)	0.52

[a]All models of birth weight, length, and head circumference were adjusted for gestational age and gestational age squared. [b]Adjusted for maternal age, parity, prepregnancy BMI, poverty, country of birth, and week of initiating prenatal care.

Table 4. Categorical analysis of associations [β (95% CI)] of proximity to methyl bromide use within a 5-km radius during pregnancy with fetal growth parameters and length of gestation, CHAMACOS study, Salinas Valley, CA, 1999–2000 (n = 442).

Group	Range of use (kg)	*n*	Birth weight (g)[a]	*p*-Value	Length (cm)[a]	*p*-Value	Head circumference (cm)[a]	*p*-Value	Gestational age (weeks)[b]	*p*-Value
Trimester 1										
None	< 1	73	Reference		Reference		Reference		Reference	
Moderate[c]	1–14,690	121	–13.8 (–141.1, 113.6)	0.83	–0.16 (–0.85, 0.54)	0.66	–0.25 (–0.64, 0.15)	0.21	0.70 (0.21, 1.18)	0.01
High[d]	14,690–148,137	144	–27.7 (–149.9, 94.5)	0.66	–0.09 (–0.76, 0.58)	0.80	–0.06 (–0.44, 0.32)	0.75	0.59 (0.12, 1.06)	0.01
Trimester 2										
None	< 1	104	Reference		Reference		Reference		Reference	
Moderate	1–14,690	152	–93.1 (–198.0, 11.7)	0.08	–0.62 (–1.20, –0.03)	0.04	–0.42 (–0.76, –0.08)	0.02	–0.03 (–0.47, 0.41)	0.89
High	14,690–76,306	152	–113.1 (–218.1, –8.1)	0.04	–0.85 (–1.44, –0.27)	< 0.01	–0.33 (–0.67, 0.01)	0.06	–0.06 (–0.51, 0.38)	0.78
Trimester 3										
None	< 1	99	Reference		Reference		Reference		Reference	
Moderate	1–14,690	155	14.0 (–93.1 121.1)	0.80	–0.04 (–0.64, 0.56)	0.90	–0.27 (–0.62, 0.07)	0.12	0.22 (–0.23, 0.68)	0.33
High	14,690–77,079	136	–23.0 (–133.2, 87.2)	0.68	0.02 (–0.60, 0.64)	0.95	–0.26 (–0.62, 0.09)	0.15	0.18 (–0.29, 0.64)	0.46

[a]Adjusted for maternal age, parity, prepregnancy BMI, poverty, country of birth, week of initiating prenatal care, gestational age, and gestational age squared. [b]Adjusted for maternal age, parity, prepregnancy BMI, poverty, country of birth, and week of initiating prenatal care. [c]Moderate use is defined as less than the median (14,690 kg) among participants with any methyl bromide exposure. [d]High use is defined as greater than the median (14,690 kg) among participants with any methyl bromide exposure.

Table 5. Categorical analysis of associations [β (95% CI)] of proximity to any methyl bromide use (vs. none) in the second trimester with fetal growth parameters and length of gestation, CHAMACOS study, Salinas Valley, CA, 1999–2000 (n = 442).

Group	*n*	Birth weight (g)[a]	*p*-Value	Length (cm)[a]	*p*-Value	Head circumference (cm)[a]	*p*-Value	Gestational age (weeks)[b]	*p*-Value
1-km radius									
None	352	Reference		Reference		Reference		Reference	
Any	56	–61.7 (–181.2, 57.8)	0.31	–0.70 (–1.37, –0.04)	0.04	0.07 (–0.32, 0.45)	0.73	–0.23 (–0.73, 0.27)	0.37
3-km radius									
None	164	Reference		Reference		Reference		Reference	
Any	244	–81.2 (–165.3, 2.9)	0.06	–0.56 (–1.03, –0.09)	0.02	–0.25 (–0.52, 0.02)	0.08	0.35 (–0.00, 0.70)	0.05
5-km radius									
None	104	Reference		Reference		Reference		Reference	
Any	304	–103.1 (–196.5, –9.6)	0.03	–0.73 (–1.25, –0.21)	0.01	–0.37 (–0.68, –0.07)	0.02	–0.05 (–0.44, 0.35)	0.81
8-km radius									
None	77	Reference		Reference		Reference		Reference	
Any	331	–150.7 (–254.9, –46.6)	0.01	–1.03 (–1.61, –0.46)	< 0.01	–0.42 (–0.76, –0.08)	0.02	–0.02 (–0.46, 0.42)	0.94

[a]Adjusted for maternal age, parity, prepregnancy BMI, poverty, country of birth, week of initiating prenatal care, gestational age, and gestational age squared. [b]Adjusted for maternal age, parity, prepregnancy BMI, poverty, country of birth, and week of initiating prenatal care.

investigating the effects of maternal smoking (Reeves and Bernstein 2008) and prenatal exposure to wildfires (Holstius et al. 2012) suggest that both the second and third trimesters may be critical periods of growth. In these studies, the authors cite oxidative stress, hypoxia, and suppression of placenta growth hormone as plausible mechanisms.

The results from our sensitivity analyses suggested stronger associations as the buffer distance increased, with negative associations with all three fetal growth parameters for usage within 5-km and 8-km buffer areas. The lack of consistent associations with shorter buffer distances may have been attributable at least partly to exposure misclassification; Li et al. (2005) concluded that using smaller buffers (< 5 km) to determine methyl bromide use underestimates measured outdoor air concentrations. Previous studies using GIS to assess residential exposure to methyl bromide have used a much smaller buffer distance than the present analysis (Cockburn et al. 2011; Reynolds et al. 2004; Rull et al. 2009). These studies selected a buffer distance of 500 m or 0.5 mile (~ 800 m) for all pesticides, but did not use air monitoring data to confirm the validity of these buffer sizes for exposure assessment. In the study by Cockburn et al. (2011), a 500-m buffer was justified based on a previous study that observed high specificity for serum DDE concentrations using a 1-km GIS buffer to estimate organochlorine exposure (Ritz and Costello 2006). Although this shorter buffer distance might be appropriate for assessing exposure to other pesticides, it does not appear to be sufficient for assessing exposure to fumigants, which are likely to drift much further away from the application site (Honaganahalli and Seiber 2000; Li et al. 2005; Woodrow and Krieger 2007). Regulations in California recognize the potential for methyl bromide to drift far from the application site and so restrict methyl bromide use at the township level (6 × 6 square mile sections) to a maximum of 77,848 kg in a calendar month to reduce outdoor air concentrations (California DPR 2010).

The main limitations of this study are that exposure to methyl bromide was based on residential proximity to reported agricultural use, not measured personal air concentrations. Thus time spent in areas with no methyl bromide use or exposure away from home, including at work, was not taken into account. In addition, in our study area and time period, use of chloropicrin, a chemical often used in conjunction with methyl bromide applications, was very highly correlated with methyl bromide use (Spearman correlation = 0.95). As a result, it is not possible to separate associations with methyl bromide from associations with chloropicrin in this study. Use of another pesticide, diazinon, was also correlated with methyl bromide use, but much less strongly (Spearman correlation = 0.44). Future analyses will examine whether diazinon is associated with birth outcomes in this population.

Although we estimated exposure to a specific pesticide that was selected *a priori* based on toxicity and volume of use, other agricultural pesticides could also be associated with fetal growth. However, previous analyses of this cohort did not indicate associations between decreased fetal growth and organophosphate metabolites measured in maternal urine (Eskenazi et al. 2004) or organochlorine concentrations in maternal serum (Fenster et al. 2006).

Methyl bromide use is seasonal, with the most use occurring between August and October. Thus, it is possible that the association we found reflects seasonal patterns in birth weight rather than second-trimester methyl bromide use. However, we did not observe any seasonal patterns in birth weight in this population. Additionally, controlling for birth between February and April (corresponding to a second trimester during August–October) in the multivariable models did not change the results (data not shown).

We did not use a dispersion model incorporating meteorological data to estimate methyl bromide concentrations because dispersion models have not predicted fumigant concentrations as well (R^2 = 0.55–0.82) as the regression model approach (R^2 = 0.95) that we used (Honaganahalli and Seiber 2000; Li et al. 2005). Additionally, location of methyl bromide use was reported to 1-square-mile units. The PUR reporting system does not contain information on applications to specific fields, so it is not possible to ascertain where in the PLSS section the material was applied. However, the potential impact of this misclassification would be small because most PLSS sections fell entirely within the larger buffer distances (e.g., 5 and 8 km) used in our analysis.

Another potential limitation is that women who lived near high use of methyl bromide (vs. moderate or no use) were more likely to live in and around the city of Salinas. It is possible that unmeasured factors related to this group of women might have confounded our results; however, associations remained after controlling for several potential confounders, including maternal education and income. In addition, associations with fetal growth parameters were seen with both moderate and high use of methyl bromide.

Previous studies of perinatal outcomes and agricultural pesticide exposures have relied on the address given in birth certificates and have not incorporated environmental monitoring information in the exposure models (Shirangi et al. 2011). In contrast, for most women, we were able to capture residential location throughout pregnancy, incorporate residential mobility, and estimate exposure separately for each trimester (Canfield et al. 2006). With slightly more than half of our original sample moving at least once during pregnancy, accounting for residential history was important to reduce possible exposure misclassification. Furthermore, residential location was determined using a GPS, which is more accurate than geocoding self-reported addresses (Ward et al. 2005). Another strength of the study was that fetal growth parameters were obtained from medical records, which generally provide more accurate information than birth certificates (Lain et al. 2012). Additionally, because methyl bromide is highly volatile (U.S. EPA 2006), very little exposure to methyl bromide occurs from dietary ingestion or residues brought home on the clothes and skin of occupationally exposed household members; therefore, exposure misclassification related to these sources is not a concern.

The results of this study suggest that living near agricultural applications of methyl bromide may be associated with decreased infant birth weight and other measures of fetal growth. Our finding that residential proximity to methyl bromide use in the first trimester of pregnancy was associated with longer duration of gestation is somewhat puzzling and counter to our expectations. No other epidemiologic studies have specifically examined methyl bromide exposure and fetal growth; therefore, additional studies are needed to confirm the associations we observed. Methyl bromide use in the Salinas Valley declined from 850,000 kg in 2000 to 565,000 kg in 2010 but still represented 29% of soil fumigant use (California DPR 2001a, 2012a). Although critical use exemptions for methyl bromide use are being phased out (U.S. EPA 2012), the lack of fumigant alternatives may prolong its use in the state of California.

References

Breeman W. 2009. Methylbromide intoxication: a clinical case study. Adv Emerg Nurs J 31:153–160.

California Air Resources Board. 2001. Ambient Air Monitoring for Methyl Bromide and 1,3-Dichloropropene in Monterey and Santa Cruz Counties – Fall 2000. Sacramento, CA:California Air Resources Board. Available: http://www.cdpr.ca.gov/docs/emon/pubs/tac/tacpdfs/mebr2000.pdf [accessed 27 September 2011].

California DPR (Department of Pesticide Regulation). 2001a. 2000 Annual Pesticide Use Report Preliminary Data: Monterey County Indexed by Chemical. Sacramento, CA:California DPR. Available: http://www.cdpr.ca.gov/docs/pur/pur00rep/chemcnty/monter00.pdf [accessed 20 June 2012].

California DPR (Department of Pesticide Regulation). 2001b. Summary of Pesticide Use Report Data 2000, Indexed by Chemical: Preliminary Data. Sacramento, CA:California DPR. Available: http://www.cdpr.ca.gov/docs/pur/pur00rep/00chem.htm [accessed 27 March 2011].

California DPR (Department of Pesticide Regulation). 2010. Division 6. Pesticides And Pest Control Operations Chapter 2. Pesticides Subchapter 4. Restricted Materials Article 4. Field Fumigation Use Requirements. Sacramento, CA:California DPR. Available: http://www.cdpr.ca.gov/docs/legbills/rulepkgs/10-002/text_final.pdf [accessed 27 September 2011].

California DPR (Department of Pesticide Regulation). 2012a. 2010 Annual Pesticide Use Report Indexed by Chemical, Monterey County. Sacramento, CA:California DPR. Available: http://www.cdpr.ca.gov/docs/pur/pur10rep/chemcnty/monter10_ai.pdf [accessed 6 June 2012].

California DPR (Department of Pesticide Regulation). 2012b. Pesticide Use Reporting (PUR). Sacramento, CA:California DPR. Available: http://www.cdpr.ca.gov/docs/pur/purmain.htm [accessed 6 June 2012].

California DPR (Department of Pesticide Regulation). 2012c. The top 100 pesticides used pounds of active ingredients statewide in 2010 (all sites combined). Available: http://www.cdpr.ca.gov/docs/pur/pur10rep/top_100_ais_lbs10.pdf [accessed 23 March 2012].

Canfield MA, Ramadhani TA, Langlois PH, Waller DK. 2006. Residential mobility patterns and exposure misclassification in epidemiologic studies of birth defects. J Expo Sci Environ Epidemiol 16:538–543.

Cockburn M, Mills P, Zhang X, Zadnick J, Goldberg D, Ritz B. 2011. Prostate cancer and ambient pesticide exposure in agriculturally intensive areas in California. Am J Epidemiol 173:1280–1288.

Eskenazi B, Harley K, Bradman A, Weltzien E, Jewell NP, Barr DB, et al. 2004. Association of *in utero* organophosphate pesticide exposure and fetal growth and length of gestation in an agricultural population. Environ Health Perspect 112:1116–1124.

Fenster L, Eskenazi B, Anderson M, Bradman A, Harley K, Hernandez H, et al. 2006. Association of *in utero* organochlorine pesticide exposure and fetal growth and length of gestation in an agricultural population. Environ Health Perspect 114:597–602.

Gunier RB, Harnly ME, Reynolds P, Hertz A, Von Behren J. 2001. Agricultural pesticide use in California: pesticide prioritization, use densities, and population distributions for a childhood cancer study. Environ Health Perspect 109:1071–1078.

Gunier RB, Ward MH, Airola M, Bell EM, Colt J, Nishioka M, et al. 2011. Determinants of agricultural pesticide concentrations in carpet dust. Environ Health Perspect 119:970–976.

Holstius DM, Reid CE, Jesdale BM, Morello-Frosch R. 2012. Birth weight following pregnancy during the 2003 southern California wildfires. Environ Health Perspect 120:1340–1345.

Honaganahalli PS, Seiber JN. 2000. Measured and predicted airshed concentrations of methyl bromide in an agricultural valley and applications to exposure assessment. Atmosph Environ 34:3511–3523.

Kishi R, Itoh I, Ishizu S, Harabuchi I, Miyake H. 1991. Symptoms among workers with long-term exposure to methyl bromide. An epidemiological study. Sangyo Igaku 33:241–250.

Kramer MS. 1987. Determinants of low birth weight: methodological assessment and meta-analysis. Bull World Health Organ 65:663–737.

Lain SJ, Hadfield RM, Raynes-Greenow CH, Ford JB, Mealing NM, Algert CS, et al. 2012. Quality of data in perinatal population health databases: a systematic review. Med Care 50:e7–e20.

Langård S, Rognum T, Fløtterød O, Skaug V. 1996. Fatal accident resulting from methyl bromide poisoning after fumigation of a neighbouring house; leakage through sewage pipes. J Appl Toxicol 16:445–448.

Li LY, Johnson B, Segawa R. 2005. Empirical relationship between use, area, and ambient air concentration of methyl bromide. J Environ Qual 34:420–428.

Lifshitz M, Gavrilov V. 2000. Central nervous system toxicity and early peripheral neuropathy following dermal exposure to methyl bromide. J Toxicol Clin Toxicol 38:799–801.

Majewski MS, McChesney MM, Woodrow JE, Prueger JH, Seiber JN. 1995. Aerodynamic measurements of methyl bromide volatilization from tarped and nontarped fields. J Environ Qual 24:742–752.

Minnesota Department of Health. 1999. Health Consultation: Exposure to Methyl Bromide as a Result of Fumigation at ADM Milling Company. Minneapolis, MN:Minnesota Department of Health. Available: http://www.health.state.mn.us/divs/eh/hazardous/sites/hennepin/adm0399.pdf [accessed 6 April 2011].

National Research Council. 2000. Methyl Bromide Risk Characterization in California. Washington, DC:National Academy Press.

Nuckols JR, Gunier RB, Riggs P, Miller R, Reynolds P, Ward MG. 2007. Linkage of the California Pesticide Use Reporting Database with spatial land use data for exposure assessment. Environ Health Perspect 115:684–689.

Reeves S, Bernstein I. 2008. Effects of maternal tobacco-smoke exposure on fetal growth and neonatal size. Expert Rev Obstet Gynecol 3:719–730.

Reynolds P, Hurley SE, Goldberg DE, Yerabati S, Gunier RB, Hertz A, et al. 2004. Residential proximity to agricultural pesticide use and incidence of breast cancer in the California Teachers Study cohort. Environ Res 96:206–218.

Reynolds P, Von Behren J, Gunier RB, Goldberg DE, Harnly M, Hertz A. 2005. Agricultural pesticide use and childhood cancer in California. Epidemiology 16:93–100.

Ritz B, Costello S. 2006. Geographic model and biomarker-derived measures of pesticide exposure and Parkinson's disease. Ann NY Acad Sci 1076:378–387.

Roberts E, English PB, Grether JK, Windham GC, Somberg L, Wolff C. 2007. Maternal residence near agricultural pesticide applications and autism spectrum disorders among children in the California Central Valley. Environ Health Perspect 115:1482–1489.

Ross LJ, Johnson B, Kim KD, Hsu J. 1996. Prediction of methyl bromide flux from area sources using the ISCST model. J Environ Qual 25:885–891.

Rull RP, Gunier RB, Von Behren J, Hertz A, Crouse V, Buffler PA, et al. 2009. Residential proximity to agricultural pesticide applications and childhood acute lymphoblastic leukemia. Environ Res 109:891–899.

Shirangi A, Nieuwenhuijsen M, Vienneau D, Holman CD. 2011. Living near agricultural pesticide applications and the risk of adverse reproductive outcomes: a review of the literature. Paediatr Perinat Epidemiol 25:172–191.

United Nations Environment Programme (UNEP). 2000. The Montreal Protocol on Substances that Deplete the Ozone Layer. Nairobi, Kenya:UNEP.

U.S. Bureau of Land Management. 2013. Public Land Survey System Shapefile. Available: http://www.blm.gov/ca/gis/ [accessed 7 May 2013].

U.S. EPA (U.S. Environmental Protection Agency). 2006. Report on Food Quality Protection Act (FQPA) Tolerance Reassessment and Risk Management Decision (TRED) for Methyl Bromide, and Reregistration Eligibility Decision (RED) for Methyl Bromide's Commodity Uses. EPA 738-R-06-026. Available: http://www.epa.gov/opp00001/reregistration/REDs/methyl_bromide_tred.pdf [accessed 26 February 2013].

U.S. EPA (U.S. Environmental Protection Agency). 2012. Protection of Stratospheric Ozone: The 2013 Critical Use Exemption from the Phaseout of Methyl Bromide. Fed Reg 77(241):74435–74449. Available: http://www.gpo.gov/fdsys/pkg/FR-2012-12-14/pdf/2012-30225.pdf [accessed 21 February 2013].

Ward MH, Nuckols JR, Giglierano J, Bonner MR, Wolter C, Airola M, et al. 2005. Positional accuracy of two methods of geocoding. Epidemiology 16:542–547.

Woodrow JE, Krieger RI. 2007. Assessing exposure to agricultural fumigants in outdoor and indoor air environments. In: Assessing Exposures and Reducing Risks to People from the Use of Pesticides (Krieger RI, ed). Washington, DC:American Chemical Society, 70–86.

Yagi K, Williams J, Wang, NY, Cicerone RJ. 1993. Agricultural soil fumigation as a source of atmospheric methyl bromide. Proc Natl Acad Sci 90:8420–8423.

Attachment 9

MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

2014 REPORT OF THE METHYL BROMIDE TECHNICAL OPTIONS COMMITTEE

2014 Assessment

United Nations Environment Program
Montreal Protocol on Substances that Deplete the Ozone Layer

United Nations Environment Programme (UNEP)
2014 Report of the Methyl Bromide Technical Options Committee

2014 Assessment

The text of this report is composed mainly in Times New Roman.

Composition of the Report: Methyl Bromide Technical Options Committee

Coordination: Marta Pizano, Mohammed Besri, Ian Porter, MBTOC Co-Chairs.

Final editing and layout: Marta Pizano, Ian Porter, Mohamed Besri, MBTOC Co-Chairs

Reproduction: UNEP/ Ozone Secretariat, Nairobi
Date: February, 2015

Under certain conditions, printed copies of this report are available from:

United Nations Environment Programme
Ozone Secretariat
P.O. Box 30552
Nairobi, Kenya

This document is also available in portable document format from:

http://ozone.unep.org/Assessment_Panels/TEAP/Reports/MBTOC/index.shtml

ISBN: 978-9966-076-08-3

Methyl Bromide Technical Options Committee:

Co-Chairs: Mohamed Besri (Morocco); Marta Pizano (Colombia); Ian Porter (Australia)

Members: Jonathan Banks (Australia), Chris Bell* (UK), Fred Bergwerff (The Netherlands), Aocheng Cao (China), Peter Caulkins* (USA), Ricardo Deang* (Philippines), Raquel Ghini (Brasil), Ken Glassey (New Zealand), Alfredo Gonzalez (Philippines), Michelle Marcotte* (Canada), Takashi Misumi (Japan), David Okioga* (Kenya), Christoph Reichmuth (Germany), Jordi Riudavets (Spain), John Sansone* (USA), Sally Schneider* (USA), JL Staphorst (South Africa), Akio Tateya (Japan), Robert Taylor* (UK), Alejandro Valeiro (Argentina), Ken Vick (USA), Nick Vink (South Africa), Chris Watson* (UK), Jim Wells* (USA), Eduardo Willink (Argentina), Suat Yilmaz (Turkey).

* Retired from MBTOC December 31st, 2014.

In memoriam – Antonio Bello Pérez

MBTOC meeting (soils group), Alassio, Italy, August 2008

Antonio Bello is third from the left

Shortly after finishing this Assessment Report, our colleague and great friend, Professor Antonio Bello (CSIC, Madrid, Spain), former member of MBTOC, passed away. This is a shock and a very sad event for the MBTOC family. For many years, Antonio was a pillar of MBTOC. His research on alternatives to MB, particularly on biofumigation, not only made a great contribution to MB phase-out, but also provides a sustainable option with large benefits for the future of our planet. Antonio committed his life to science, to the protection of the ozone layer and to making the world a better place for future generations. In Antonio, we have lost a great scientist and unforgettable friend. He was a wise man who selflessly shared his knowledge with anyone asking for his advice. We will always keep him in our thoughts and prayers and we will never forget Antonio's generosity, graciousness and kindness. Rest in peace our beloved friend.

UNEP
2014 REPORT OF THE
METHYL BROMIDE
TECHNICAL OPTIONS COMMITTEE

2014 ASSESSMENT

Table of Contents

List of Tables

List of Figures

Glossary of Acronyms

1,3-D	1,3-Dichloropropene
A5	Article 5 Party
AITC	Allyl isothiocyanate
ASD	Anaerobic soil disinfestation
CUE	Critical Use Exemption
CUN	Critical Use Nomination
DOI	Disclosure of Interest
EDN	Ethylene dinitrile
EU	European Union
EPA	Environmental Protection Agency
EPPO	European Plant Protection Organisation
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
ISPM	International Standard Phytosanitary Measure
LPBF	Low Permeability Barrier Film (including VIF films)
MB	Methyl bromide
MBTOC	Methyl Bromide Technical Options Committee
MI	Methyl iodide
MITC	Methyl isothiocyanate
MOP	Meeting of the Parties
MS	Metham sodium
Non-A5	Non Article 5
NPPO	National Plant Protection Organisation
OEWG	Open Ended Working Group
Pic	Chloropicrin
QPS	Quarantine and Pre-shipment
SF	Sulfuryl fluoride
TEAP	Technology and Economics Assessment Panel
TIF	Totally Impermeable Film
USA	United States of America
VIF	Virtually Impermeable Film
VOC	Volatile Organic Compound
WMO	World Meteorological Organisation

1

Chapter 1. Executive Summary

1.1. Mandate and report structure

Under Decision XXIII/13 taken at the Twenty-Third Meeting of the Parties to the Protocol in 2011, the Parties requested the Assessment Panels to update their 2010 reports in 2014 and submit them to the Secretariat by 31 December 2014 for consideration by the Open-ended Working Group and by the Twenty Seventh Meeting of the Parties to the Montreal Protocol, in 2015.

As required under Decision XIII/13, the MBTOC 2014 Assessment reports on advances since 2010 to replace Methyl Bromide (MB) used under Critical Use by non-Article 5 Parties and continued reduction in methyl bromide use in Article 5 countries to meet the required phase out schedule in 2015 with specific reference to challenges associated to the phase-out and its sustainability. It also reports on QPS uses, which are presently exempt from controls under the Montreal Protocol. It reports on technically and economically feasible alternatives for non-QPS and QPS uses of MB and gives actual examples of their successful commercial adoption around the world. It shows trends in methyl bromide production and consumption in both Article 5 and non-Article 5 Parties, estimated levels of emissions of MB to the atmosphere, and strategies to reduce those emissions.

1.2. The Methyl Bromide Technical Options Committee (MBTOC)

As at December 2014, MBTOC had 29 members: 12 (41%) from Article 5 parties and 17 (59%) from non-Article 5 parties. Members came from 7 Article 5 and 9 non-Article 5 countries. After the renomination process in 2014 MBTOC numbers have reduced to has twenty members in 2015, 10 from Article 5 and 10 from non-Article 5 Parties.

1.3. Methyl bromide control measures

Methyl bromide was listed under the Montreal Protocol as a controlled ozone depleting substance in 1992. Control schedules leading to phase-out were agreed in 1995 and 1997. There are a number of concerns apart from ozone depletion that also led countries to impose severe restrictions on methyl bromide use including toxicity to humans and associated operator safety and public health, and detrimental effects on soil biodiversity. In some countries, pollution of surface and ground water by methyl bromide and its derived bromide ion are also of concern.

The control measures, agreed by the Parties at their ninth Meeting in Montreal in September 1997, were for phase out by 1 January 2005 in non-Article 5 countries and for Parties operating under Article 5 of the Protocol (developing countries) a 20% cut in production and consumption, based on the average in 1995-98, from 1 January 2005 and phase out by 1 January 2015. Since 2003, nine non-Article 5 Parties have submitted nearly 150 applications for 18,700 tonnes for'critical uses' after 2005 for non-QPS purposes under Article 2H of the Montreal Protocol.By 2014 the number had declined to three applications for 267 tonnes for use in 2016. Use of methyl bromide under the 'Critical Use' provisions is available to 'Article 5 countries after 2015 and accordingly in 2014 three Article 5 Parties submitted six nominations for use of 500 tonnes in 2015.

Although QPS uses must be officially reported under Article 7 of the Protocol they continue to be exempt from controls under Article 2H.

1.4. Production and consumption trends

At the time of writing this report, all Parties had submitted data to the Ozone Secretariat for controlled uses in 2013. Although a few cases of data gaps remain from past years, reported data is much more complete than in the past. All tonnages are given in metric tonnes in this report.

In 2013, global *production* for the methyl bromide uses controlled under the Protocol was 2,493 tonnes, which represented 9% of the 1991 reported production data (66,430 tonnes). Less than 0.5% of production occurred in Article 5 countries.

Global *consumption* of methyl bromide for controlled uses was reported to be 64,420 tonnes in 1991 and remained above 60,000 tonnes until 1998. Global consumption was estimated at 8,148 tonnes in 2009 and declined to about 2,953 tonnes in 2013. Historically, in non-Article 5 regions, about 91% of methyl bromide was used for pre-plant soil fumigation and about 9% for stored products and structures.

The official aggregate baseline for non-Article 5 countries was about 56,083 tonnes in 1991. In 2005 (the first year of critical use provisions), non-Article 5 consumption had been reduced to 11,470 tonnes, representing 21% of the baseline. Many non-Article 5 countries achieved complete phase out for controlled uses before 2009 (New Zealand, Switzerland and countries of European Community), the two latter Parties for all uses by 2011. Israel and Japan phased out for controlled uses in 2011 and 2012 respectively (for preplant soil uses). For the remaining uses phase-out or substantial reductions have occurred in most sectors; the USA, which was the largest non QPS user of MB historically, has indicated that 2016 will be the last year of MB for its remaining preplant soil use in the strawberry fruit sector. Many Article 5 Parties previously included among the largest users now report complete phase-out (i.e. Brazil, Turkey, Lebanon, Zimbabwe, Morocco). Other Article 5 Parties have made very significant reductions in their consumption since 2005 and aggregate consumption is now at 14% of the baseline (86% has been replaced).

In 2014, the Meetings of the Parties approved CUEs of 485.589 tonnes for use in 2016 in three non-Article 5 Parties and 333.257 tonnes for 2015 in Article 5 Parties.

1.4.1. Consumption trends at national level

In 1991 the USA, European Community, Israel and Japan used nearly 95% of the methyl bromide consumed in non-Article 5 countries. In 2013 permitted levels of consumption (for CUEs) in these four Parties was 2.2%, 0% and 0% and 3.3% of their respective baselines, although in 2014 Japan reached total phase out.

The Article 5 consumption aggregate baseline is 15,870 tonnes (average of 1995-98), with peak consumption of more than 18,100 tonnes in 1998. Many Article 5 countries increased their methyl bromide use during the baseline years. Total Article 5 consumption reduced to 2,276 tonnes in 2013, which is 14% of the baseline. A MBTOC survey of ozone offices, regional networks and national experts in 2014 provided information on the breakdown of methyl bromide uses in major methyl bromide-consuming countries. In 2013, an estimated 93% was used for soil and 7% for commodities/structures, not including QPS, in Article 5 regions. Since soil uses of methyl bromide have predominated historically, the reduction in consumption of methyl bromide for soil fumigation has been the major contributor to the overall reduction in global consumption of methyl bromide. Consumption of methyl bromide for structural and commodity purposes has also declined significantly.
The vast majority of Article 5 parties achieved the national freeze level in 2002. In 2005, 94% of Article 5 parties (136 out of 144) either reported zero consumption or achieved the 20% reduction step by the required date; and in many cases they achieved this several years earlier than required by the Protocol. Presently, all Article 5 Parties are in compliance with this reduction step. Fifty-six Article 5 parties (38%) have never used MB or reported zero MB consumption since 1991. The total number of Article 5 parties that have consumed MB (currently or in the past) is 91, or 62% of the total 148 Article 5 parties. Of the 91 MB-user countries, 73 (80%) have phased out MB, and only 18 still reported consumption in 2013.

1.5. Alternatives to methyl bromide

MBTOC assumes that an alternative (Refer Decision IX/6 1(a)(ii)) demonstrated in one region of the world would be technically applicable in another unless there were obvious constraints to the contrary e.g., a very different climate or pest complex. Additionally, it is recognised that regulatory requirements, or other specific constraints may make an alternative available in one country but unavailable in another specific country or region. When evaluating CUNs, MBTOC accounts for the specific circumstances of each Party.
MBTOC was able to identify alternatives for over 98% by mass of controlled uses in 2013.

1.5.1. Impact of registration on availability of alternatives

MBTOC considers that technical alternatives exist for almost all remaining controlled uses of methyl bromide. However regulatory or economic barriers may exist that limit the implementation of some key alternatives and this can affect the ability to completely phase-out methyl bromide in some countries.

Chemical alternatives in general, including methyl bromide, have issues related to their long-term suitability for use. In the EU, methyl bromide use was completely stopped (for all uses including QPS) in 2010, mainly due to health issues; in the USA and several other countries, methyl bromide and most other fumigants are involved in a rigorous review that could affect future regulations over their use. Thus, consideration of the long-term sustainability of treatments adopted as alternatives to methyl bromide is still vitally important; both chemical and non-chemical alternatives should be considered for adoption for the short, medium term and longer term.

1.5.2. Alternatives for soil treatments

The reduction in consumption of methyl bromide for soil fumigation has been the major contributor to the overall reduction in global consumption of methyl bromide for controlled uses with amounts used in 2013 falling 85% from about 57,400 tonnes in 1992 to less than 450 tonnes, in non-Article 5 Parties and about 2,210 tonnes in Article 5 Parties.

The main crops for which methyl bromide is still being used in non-Article 5 countries are strawberry fruit, and strawberry runners. Some uses previously considered under the CUN process have been partially reclassified as QPS (e.g. forest nurseries). Crops still using methyl bromide in 2013 in Article 5 Parties included cucurbits, strawberry fruit, ginger, nurseries (strawberry and raspberry runners) tomatoes and other vegetables.

Since the 2010 MBTOC Report, adoption of chemical and non chemical alternatives to replace methyl bromide as a pre-plant soil fumigant has shown significant progress, particularly due to improved performance of new formulations of existing chemical fumigants (1,3 D/Pic, Pic alone, metham sodium) and new fumigants (ie dimethyl disulfide), but also due to increased uptake of non chemical alternatives i.e. grafted plants on resistant rootstocks, improved steaming methods, substrate production, biofumigation.

In 2008, a one to one replacement to MB, iodomethane (methyl iodide) was registered in several countries (USA, New Zealand), however the manufacture of this fumigant was withdrawn in 2012. Dimethyl disulfide (DMDS) is now registered in the USA (not California) and other countries. The world has seen an increase in regulations on alternatives, with tighter regulations on all fumigants particularly in the EU.

1.5.2.1. Chemical alternatives

The following fumigants are currently available in many regions and are the main alternatives that have been adopted as alternatives for MB.

- Chloropicrin (trichloronitromethane) (Pic), which is effective for the control of soilborne fungi and some insects and has limited activity against weeds. Combination with virtually or totally impermeable films (VIF, TIF) is an effective strategy to reduce application rates keeping satisfactory efficacy.
- 1,3-Dichloropropene (1,3-D), which is used as a nematicide and also provides effective control of insects and suppresses some weeds and pathogenic fungi. 1,3- D as a single application has no effect in controlling fungi or bacteria, for this reason it is often combined in mixed formulations with chloropicrin. As with chloropicrin, 1,3-D can be combined with virtually or totally impermeable films (VIF, TIF) with satisfactory efficacy.
- Fumigants which are based on the generation of methyl isothiocyanate (MITC), e.g. dazomet, metham sodium and metham potassium, are highly

effective at controlling a wide range of arthropods, soilborne fungi, nematodes and weeds, but are less effective against bacteria and root-knot nematodes. For this reason their use is often found in combination with other chemical treatments or IPM controls. The efficacy of MITC against fungal pathogens is variable, particularly against vascular wilts.

- Dimethyl disulfide (DMDS), which has been registered recently, appears to be highly efficient against various nematodes, including *Meloidogyne* spp, but is less effective on fungal pathogens. Again, DMDS is more effective when combined with VIF or TIF films.
- Isothiocyanates (ITCs) are sulfur-containing compounds produced by many members of *Brassicaceae* plant family, showing insecticidal and herbicidal activity. Research has demonstrated that they can be used as a pre-plant soil fumigant alternative for broad-spectrum control of weed seeds, nematodes and diseases. Allyl isothiocyanate (AITC) was registered in the USA in September 2013 (but not in California) for many types of vegetables and turf. Its small buffer zone requirement gives it an advantage over other fumigants. AITC is expected to be registered in the near future in other countries including Mexico, Canada, Italy, Spain, Turkey, Morocco, Japan and Israel.
- Sulfuryl fluoride (SF) is an insecticide fumigant gas, widely used for insect and rodent control in post-harvest commodities and structures. SF was registered in China as a nematicide fumigant for cucumber in 2014. This fumigant has a shorter plant-back time than other fumigants including MB and can be applied when soil temperatures are low. These features give this fumigant a significant advantage over other soil fumigants.
- Trials with other chemicals such as abamectin, fluensulfone and certain fungicides are also providing promising options for soilborne pest and disease management in several countries.

The future of soil disinfestation lies in combining available fumigants with other methods, or other fumigants and non-chemical fumigants to obtain acceptable performance. Combined fumigant treatments can expand the pest control spectrum and lead to performance levels that match and even surpass those of MB. Examples include 1,3-D/Pic, 1,3-D or 1,3-D/Pic and MITC, DMDS + Pic and others.

Lack of registration of some MB alternatives as well as regulatory constraints have hampered MB phase-out in some countries where MB is still being used under a critical use exemption.

1.5.2.2. Non chemical alternatives

- Grafting, resistant rootstocks and resistant varieties are increasingly used to control soilborne diseases in vegetables, particularly tomatoes, cucurbits, peppers and eggplants in many countries. They are generally adopted as part of an integrated pest control system, or combined with an alternative fumigant or pesticide, and have led to the reduction or complete replacement of methyl bromide use in several sectors in different countries. Recent studies focus on improving the tolerance of vegetables to abiotic stresses including soil salinity, drought, heavy metals, organic pollutants and low and high temperatures.
- Soilless culture is a rapidly expanding cropping practice worldwide, primarily for protected agriculture, which has offset the need for methyl bromide, especially in some flower crops, vegetables and for seedling production including forest seedlings. In particular, flotation systems, based on soilless substrates and

hydroponics, have replaced the majority of the methyl bromide for tobacco seedling production worldwide. This growing system can be used in combination with other options, for example compost, grafted plants and/ or biocontrol agents, providing very good results.

- Steam disinfestation is an increasingly attractive strategy to control soilborne pathogens and weeds both in greenhouses and field crops. New developments of steam application methods are aimed at reducing costs and extend its use on crops grown outdoors. Development of more efficient and economic steam application equipment, currently in progress, suggests that steam is approaching wider commercial feasibility.
- Solarisation is now increasingly combined with biofumigation or low doses of fumigants, as part of IPM programs to replace MB for controlling soilborne pathogens and weeds in many crops including vegetables and ornamentals with excellent results.
- Anaerobic soil disinfestation (ASD) is a biologically based, non-fumigant, pre-plant soil treatment developed to control a wide range of soilborne plant pathogens and nematodes in numerous crop production systems used for example in Japan, The Netherlands and the USA. Commercial use of ASD is currently limited by cost and uncertainty about its effectiveness for controlling different pathogens across a range of environments. Its feasibility is largely impacted by moisture and availability of appropriate carbon sources. However, active research is underway to adjust this promising option.

1.5.2.3. Combination of chemical and non chemical alternatives

The combination of chemical with a range of non-chemical alternatives continues to expand as effective strategies to overcome problems due to the narrow spectrum of activity of some single control methods. The efficacy of grafted plants for example, can be greatly enhanced by combining it with solarisation and biofumigation, green manures, and chemicals such as MITC generators, 1,3-D and non- fumigant nematicides. Combinations of fumigant alternatives (1,3-D/Pic, MNa/Pic) with LPBF or relevant herbicides have been shown to be effective for nutsedge (*Cyperus* spp.). Finding alternatives for nursery industries has proven more difficult as growers are uncertain of the risk of spread of diseases provided by the alternative products. Further, regulators often lack the data to determine if alternatives meet the quality standards (e.g. certification requirements).

Crop specific strategies implemented in non-Article 5 and Article 5 regions are discussed in detail in the 2014 Assessment Report. These include alternatives used for the key sectors where it was necessary to phase-out methyl bromide in specific climates, soil types and locations, as well as application methods and other considerations.

1.5.2.4. Alternatives for strawberry runners

In 2014, MB is still used in three non-A5 Parties either as a critical use (Australia, Canada) or under a QPS exemption (USA). Mexico is continuing use in 2015 and under a critical use exemption, but trials with alternative fumigants (1,3-D/Pic, metham sodium) are giving encouraging results.

In Australia, the northern production region fully transitioned in 2009 to mixtures of 1,3-D/Pic and Pic alone, however in the cooler southern regions in heavy soil types these alternatives are phytotoxic causing losses of up to 40%, or are ineffective and no alternatives have been adopted except for the use of substrate production of foundation stock. The industry does, however, produce its early generations of runners using soil less culture, which reduces the need for disinfestation with MB/Pic. This system is not economically feasible for later generations..

In Canada in 2008, several regions transitioned to alternatives mainly Pic alone, however owing to its lack of registration in Prince Edward Island the request for a critical use continues.

In the EU (France, Italy, Poland, Spain), growers are using improved application techniques for old fumigants, such as metham sodium and dazomet to grow runner plants.In some countries where MB has been phased-out, there have been market shifts where growers may produce their own plants or where industries import runners produced in other countries.

1.5.3. Alternatives for treatment of post-harvest uses: food processing structures and durable commodities (non-QPS)

Parties and scientists around the world continue to conduct research aimed at identifying and adopting alternatives to MB for controlling pests causing problems in the structures and commodities sectors. However, as of 2015, all postharvest uses of MB have been phased out in non-A5 Parties and no CUNs have been submitted for these uses for 2016. Some small usage for structures (flour mills), grain and dried foodstuffs remained in Article 5 Parties in 2013.

The main alternatives to the disinfestation of flourmills and food processing premises are sulfuryl fluoride (including combinations of SF and heat) and heat (as full site or spot heat treatments). Some pest control operators report that full control of structural pests in some food processing situations can be obtained without full site fumigation through a more vigorous application of IPM approaches. Other pest control operators report success using a combination of heat, phosphine and carbon dioxide.

Phosphine fumigation has emerged as the leading treatment of infested commodities. Although phosphine is the fumigant of choice to replace MB in many postharvest treatments, some problems with its use need attention, particularly the possible development of resistance in the pests to be controlled.

Treatment of commodities with sulfuryl fluoride has also expanded. The fumigant is used for the treatment of grain, cotton and timber. The substance is also used for disinfestation of museums in the USA. SF is in use for disinfestations of museums (structures) against insect pests in Japan. SF is now intensely used for disinfestation of bulk grain in Australia, also for resistance management of phosphine. China has three factories producing SF for local use and export.

1.5.3.1. Regulatory considerations

Many commercial companies have undertaken significant efforts and Parties to conduct research, apply for registration, and register alternatives to optimize their legal use. The registration of chemicals for pest control, including MB, is however under continuous review in many countries.

Additional registration issues arise where treatments will be used on food commodities or where treatments used in food processing buildings might transfer residues to food because the maximum residue limits (MRLs) for the residual chemicals must also be registered in importing countries.

1.5.3.2. Update on progress in research into methyl bromide alternatives

Many avenues of research have been pursued in the attempt to find realistic alternatives to MB for the remaining commodity and structural treatments conducted worldwide, as well as and in quarantine or preshipment. These include studies on alternative fumigants such as phosphine, sulphuryl fluoride and ozone, on controlled atmospheres with elevated temperature or raised pressure, on microwave, radio frequency or ionizing radiation, or on heat. Carbon dioxide and ethyl formate is also considered as an alternative chemical for disinfestation.

1.5.3.3. Alternatives to methyl bromide for treating dates

Pest infestations in the field pose serious post harvest problems for all date varieties. Historically, dates have been disinfested prior to storage with ethyl formate, ethylene dibromide or ethylene oxide, and more recently with MB. Fumigation with MB forces a high proportion of larvae and adults to emigrate from the fruit before they succumb, which is essential to meet some religious and food quality requirements. The specific situation of high moisture dates, at one point indicated as critical in A5 countries producing dates is now considered resolved. Phosphine fumigation, supplied by tablet formulations or a phosphine generator has largely replaced post harvest MB fumigation in Algeria, Tunisia, Egypt, Jordan, UAE, KSA and other countries.

1.5.3.4. Dry cure pork product in SE USA – the remaining MB critical use in non-A5 Parties

Natural pork products are subject to pest infestation, in part because of the lengthy storage time required for flavour development. The pests most commonly reported are red-legged ham beetles *Necrobia rufipes* and ham mites *Tyrophagus putrescentiae.* Although pest control is being achieved without MB in many countries producing cured ham products, particular conditions present in the USA have made this use very difficult to replace.

Mites are acknowledged to be very difficult to kill with phosphine, and in tests of the effectiveness of SF in 2008, control of the ham mites required three times the US legal limits of SF. Extensive research is under way indicating that the active ingredients that show the most promise as potential methyl bromide alternatives are propylene glycol, butylated dhydroxytoluene (BHT), and lard. Propylene glycol (PG) is likely the most feasible food-grade ingredient that could be used to control ham mites but is relatively expensive. Currently, no fully effective treatment has been found which controlled the target pests at commercial scale for Southern cured pork production. MBTOC's review and analysis indicates merit for further research and refinement by pest control fumigators, and in particular for improving the efficacy of SF fumigations as methyl bromide replacements.

1.5.3.5. Special review on controlling pest eggs with sulfuryl fluoride

Fumigation with SF is one of the pest control methods adopted by some parties as the principal alternative to methyl bromide in some major postharvest and structural uses. The lack of full effectiveness of SF against eggs of pests is mentioned in several critical use nominations. MBTOC collated available data on the fumigation of eggs of stored product insects and especially those occurring in rice and flourmills, the situations of particular concern where SF is a potential or actual methyl bromide replacement. Summaries of published mortality data and lethal responses of eggs of 28 economically important insects and mites following fumigation with sulfuryl fluoride at 20°C are included. Pest species are sorted into groups that are probably, possibly or unlikely to be controlled at 1,500 g h m^{-3} at at 26.7°C (80°F) and 24 h exposure. This ct-product is the maximum rate that is allowed under the registration of SF as a pesticide (‘label’ rate) for control of all developmental stages of stored product pest, such as specified in the ‘Fumiguide’, a proprietary guide to the use of SF as a postharvest and structural fumigant.

1.5.3.6. Other alternatives

Research on the use of propylene oxide and ethyl formate as methyl bromide continues and these chemicals are being adopted in several countries. Other chemical options include methyl iodide, MITC and CO_2, ozone, nitric oxide, and carbonyl sulfide (COS).

Adoption of Controlled Atmospheres (CA) and Modified Atmospheres (MA) as a means to control pests in stored commodities continues to increase. CA and MA treatments offer large commercial and small packing houses, even farmers, effective postharvest pest control options useful for most durable commodities (and even non-food commodities such as museum and historical artifacts), under a very wide range of circumstances, without using chemical fumigants. The CA treatment is based on creating a low-oxygen environment within a structure causing death of pests.

The use of irradiation as a phytosanitary treatment has increased with an undetermined part of this volume directly replacing methyl bromide fumigation. In 2013, about 5,800 tonnes of fresh fruit were irradiated for import into the US.

In Europe - especially in Germany - and in the US, parasitic wasps and predators now comprise a significant parts of pest management programs for facilities and stored products. Heat, cold and essential oils, are further options being researched and for which adoption has occurred around the world.

1.5.3.7. Integrated Pest Management

IPM is a sustainable pest risk management approach combining biological, cultural, physical and chemical tools in a way that minimizes economic, health, and environmental risks. A reduction in use of pest control chemicals in food processing, and using less toxic chemicals is a goal of most IPM practitioners. Modern strategies concentrate on approaches where the infestation itself is limited at an early stage to prevent later mass growth and necessities for acute and immediate control. Biological control addresses the need of finding ways to attack the first intruders into a storage system.

1.6. Alternatives to methyl bromide for quarantine and pre-shipment applications (exempted uses)

Article 2H exempts methyl bromide used for QPS treatments from phase-out for quarantine and pre-shipment purposes. Methyl bromide fumigation is currently often a preferred treatment for certain types of perishable and durable commodities in trade worldwide, as it has a well-established, successful reputation amongst regulatory authorities.

QPS uses are usually for commodities in trade, but one Party has classified some preplant soils uses of methyl bromide as quarantine uses. Similar uses by other Parties have remained under controls of the Montreal Protocol and have or are being phased out. Alternatives to these uses are discussed in detail in Chapter 5 on alternatives for pre-plant soil fumigation.

Quarantine treatments are generally approved on a pest and product specific basis, and following bilateral negotiations, which may require years to complete. This process helps ensure safety against the incursion of harmful pests.. For this and other reasons, replacing methyl bromide quarantine treatments can be a complex issue. Many non-methyl bromide treatments are, however, published in quarantine regulations, but they are often not the treatment of choice. Nevertheless, partial or complete adoption of alternatives to methyl bromide for QPS has occurred since the 2010 MBTOC Assessment Report. The European Community banned all uses of methyl bromide in its 27 member states including QPS, as of March 2010. Other countries show significant reductions in their methyl bromide consumption for QPS. In response to Decisions XX/6 and XXI/10 MBTOC estimated that between 31 and 47% of the MB used for QPS purposes could be replaced with immediately available alternatives.

Global production of methyl bromide for QPS purposes in 2013 was 9,915 tonnes, increasing by about 12% from the previous year. Production occurs in four parties, USA, Israel, Japan and to a much lesser extent, China. Although there are substantial variations in reported QPS production and consumption on a year-to-year basis, there is no obvious long-term increase or decrease.

QPS consumption has remained relatively constant over the last decade. In 2009 the QPS use exceeded non-QPS for the first time, being 46% higher. This was partly due to the continued decrease in the non-QPS uses, as well as recategorisation by some Parties of uses previously considered non QPS to QPS. For example since 2003 an amount of methyl bromide included in the initial baseline estimates for controlled MB uses, between 1400 to 1850 t, has been recategorised to QPS MB use for the preplant soil treatment of propagation material. In 2013, reported QPS consumption was over three times larger than controlled consumption.

In 2013, QPS consumption in A5 Parties (5,521 tonnes) represented 56% of global consumption; non-A5 Party consumption, at 4,307 tonnes was 46%. Overall, consumption in Article-5 Parties has trended upward over the past 15 years, whereas consumption in non-A5 Parties. Global consumption averaged 10,850 tonnes over the period 1999 to 2013 and in 2013 (9,830 tonnes) remained close to the average.

On a regional basis, consumption in the Latin America & Caribbean, Africa and Eastern Europe regions has remained much lower since 1999 than in Asia and North America. In 2013, an analysis of global consumption (including both A5 and non-A5 Parties in the regions where appropriate), Asia accounted for 47% of global QPS consumption.

While there remain some data gaps and uncertainties, information supplied by the Parties allowed MBTOC to estimate that four uses consumed more than 80% of the methyl bromide used for QPS in 2008: 1) Sawn timber and wood packaging material (ISPM-15); 2) Grains and similar foodstuffs; 3) Pre-plant soils use; 4) Logs; and 5) Fresh fruit and vegetables. On the basis of these estimates and currently available technologies to replace methyl bromide for QPS, MBTOC calculated that about 31% of global consumption.

Because it is approved by IPPC for compliance to ISPM-15, the main adopted alternative to methyl bromide for wood packaging material is heat (now including dielectric heating); non-wooden pallets provide an additional option. Alternatives for logs include phosphine, sulfuryl fluoride, EDN (cyanogen) and other alternative fumigants; heat, irradiation and water soaking (immersion) and debarking provide further options. Methyl bromide used as a quarantine treatment in grains and similar foodstuffs could be replaced by alternative fumigants (phosphine, sulfuryl fluoride), by controlled atmospheres or by temperature treatments (heat or freezing). Preshipment treatments in grains and similar foodstuffs could be replaced by fumigants, protectants, controlled atmospheres and integrated systems. For pre-plant soil treatments, alternative fumigants are available, provided the alternatives meet certification standards; substrates may be used at least partially in the propagation systems.

For perishables, there are various approved treatments, depending on product and situation, including heat (as dry heat, steam, vapour heat or hot dipping), cold (sometimes combined with modified atmosphere), modified and controlled atmospheres, alternative fumigants, physical removal, chemical dips and irradiation. In 2013, about 5,800 tonnes of fresh fruit were irradiated for import into the US, representing a dramatic increase of 6,500% over usage of this technique in 2007.

The technical and economic feasibility of alternatives to methyl bromide used for QPS in all countries mainly depend on the efficacy against quarantine pests of concern, the infrastructural capacity of the country, end-use customer requirements, phytosanitary agreements where relevant, and logistical requirements and regulatory approval for the use of the alternative. In the absence of regulatory or economic incentives to adopt alternatives and assuming methyl bromide is in most cases the lowest cost effective system at present, an alternative would not be voluntarily adopted unless it performed as well or better at the same market cost. Technically feasible alternatives will have limited market acceptance if they are more costly – and in the world of bulk commodities, it is difficult to entice end buyers to pay a higher price for goods treated with alternatives.

1.7. Progress in phasing-out methyl bromide in Article 5 parties

Progress made in phasing out controlled uses of methyl bromide in Article 5 countries is addressed in view of the phase-out date of 1st January 2015. Challenges and factors that could potentially put the sustainability of the phase-out at risk are analysed together with the major technologies implemented and the factors that have assisted MB phase-out in MLF projects and other efforts to replace MB.

By end of 2013 (the last date for which official data were available at the time of writing this report), about 86% of the controlled uses of MB in Article 5 Parties had been phased out. This was primarily achieved through MLF-funded projects implemented by the agencies of the Montreal Protocol, and has taken place at different rates in different regions. This chapter includes a list of the main types and objectives of such projects together with the main alternatives successfully replacing MB in different countries and regions.

The projects showed that for all locations and all crops or situations tested, one or more of the alternatives proved comparable to methyl bromide in their effectiveness in the control of pests and diseases targeted in the projects in these Article 5 countries.

By December 2014 the Multilateral Fund (MLF) had approved a total of 398 methyl bromide projects in more than 80 Article 5 Parties. This included 44 demonstration projects for evaluating and customising alternatives; 130 initiatives for the preparation of new projects, awareness raising, data collection, policy development and others; 95 technical assistance and training projects; and 129 investment projects for phasing-out methyl bromide.

MLF projects approved by December 2013 were scheduled to eliminate a total of 13,939 metric tonnes of MB in Article 5 countries. The total phase-out achieved by MLF projects by December 2013 was 12,165 tonnes (Table 7-3), which is 87% of the total due to be phased out by the projects, a figure which is higher than in previous years.

Projects have encouraged the combination of alternatives (chemical and non-chemical) as a sustainable, long-term approach to replacing methyl bromide. This has often implied that growers and other users change their approach to crop production or pest control and may even have to make important changes in process management. Adapting the alternatives to the specific cropping environment and local conditions (including economic, social and cultural conditions) is essential to success.

The projects showed that very large MB reductions are feasible over periods of 4 – 5 years, especially in cases where governments and MB users make constructive efforts to register, transfer and adopt existing alternatives, and where a full range of key stakeholders were involved. Early phase-out has brought by additional benefits to Article 5 Parties for example by improving production practices, making productive sectors more competitive in international markets and training large numbers of growers, technical staff and other key stakeholders.

Hurdles faced by Article 5 Parties include factors that go beyond the technical and economic feasibility of the alternatives including market drivers (ability to meet specific market windows), consumer issues, sufficient installed capacity to develop an implement an alternative and regulatory factors.

Challenges that may put the sustainability of the phase-out at risk include the continued unrestricted supply of MB in light of the exemption for QPS uses and the long term viability of some alternatives (for example when pests become resistant to an alternative or when regulations restrict the use of an alternative). Lack of registration of some alternatives are also an obstacle.

In accordance with Montreal Protocol controls, four Article 5 Parties have submitted CUNs for exemptions in 2015 and 2016.

1.8. Emissions from methyl bromide use and their reduction

Montreal Protocol restrictions on the use of MB are having greater impact on atmospheric MB than thought possible 10 years previously. The current understanding of the global annual budget (sources and sinks) for MB indicates that the global MB budget is not balanced and that there is potential for current identified sinks to exceed current identified sources by approximately 30 k tonnes. This implies that there may have been either large under reporting of MB production and consumption or that there are unidentified MB sources. Some of these may come from industrial processes, for example the production of purified tetraphthalic acid (PTA) or may be from unidentified natural sources. Resolving the current global budget imbalance requires a better understanding of the oceanic sources and sinks, industrial sources and natural vegetative sources of MB.

Overall total (natural and anthropogenic) MB emissions have declined from in excess of 120 k tonnes per year in 1995-1998 to 85 k tonnes in 2012, driven almost entirely by the declining consumption of non-QPS MB.

In 1995-1998, manufactured MB used in fumigation (48 k tonnes/year) accounted for about 40% of all identified MB sources; by 2012, thanks to countries taking steps to reduce the use of MB for non-QPS purposes, fumigation use had declined to just over 10% (10 k tonnes) of all identified sources, with QPS use accounting for about 8% of all identified sources. The total fumigation use of MB has declined by 80% over this period and the non-QPS fumigation use has declined by over 90%. The impact of the relatively recent and currently limited MB recapture on the global MB budget is likely to be small (less than 200 tonnes recaptured globally per annum (MBTOC estimate).

Owing to the short atmospheric half-life of MB (0.7 years) in the stratosphere, changes in emission of MB at ground level are rapidly reflected in changes in tropospheric and stratospheric MB concentrations.

The latest WMO scenarios suggest that further reductions in atmospheric concentrations are possible over the next few years, but will only occur if the remaining non-QPS uses in developing countries (A5 Parties) and the few non-A5 and A5 critical uses are phased out, and if emissions or use of MB for QPS are reduced significantly. In 2014, the use of MB for QPS was at least three times the total used for non-QPS in non-A5 and A5 countries.

Under current usage patterns, the proportions of applied MB eventually emitted to the atmosphere are estimated by MBTOC to be 41 – 91%, 85 - 98%, 76 – 88% and 90 - 98% of applied dosage for soil, perishable commodities, durable commodities and structural treatments respectively. These figures, weighted for proportion of use and particular treatments, correspond to a range of 67 - 91% overall emission from agricultural and related uses, with a mean estimate of overall emissions of 77%.
Best estimates of annual MB emissions from fumigation use in 2013 of 8781 tonnes were 52% lower than in 2009, which totalled 17,041 tonnes.

Emission volume release and release rate to the atmosphere during soil fumigation depend on a large number of key factors. Of these, the type of surface covering and condition; period of time that a surface covering is present; soil conditions during fumigation; methyl bromide injection depth and rate; and whether the soil is strip or broadacre fumigated are considered to have the greatest effect on emissions.

Studies under field conditions in diverse regions, together with the large scale adoption of Low Permeability Barrier Films (LPBF), have confirmed that such films allow for conventional methyl bromide dosage rates to be reduced. Typically equivalent effectiveness is achieved with 25–50% less methyl bromide dosage applied under LPBF compared with normal polyethylene containment films.

Parties have been urged to minimise emissions of MB in situations where they still use MB and are unable to adopt non-ozone depleting alternatives. This includes both QPS treatments and fumigations carried out under CUEs (Decisions VII/7(c), IX/6). For QPS treatments, Decisions VII/5(c) and XI/13(7) urge Parties to minimize use and emissions of methyl bromide through containment and recovery and recycling methodologies to the extent possible.

Worldwide many fumigations continue to be conducted in poorly sealed enclosures, leading to high rates of leakage and gas loss. QPS treatments with MB could have been prevented from entering the atmosphere by the fitting of recapture and destruction equipment. For the 7,456 tonnes used for commodity and structural treatments, principally for QPS use, at 70% recapturable, 5,219tonnes could have been prevented from entering the atmosphere by the fitting of recapture and destruction equipment.

At this time, there remain no processes for MB approved as a destruction process under Decision XV/9 and listed in any updates to annex II of the report of 15 MOP that listed approved destruction processes by source and destruction method. However, the situation is currently under review (Decision XXII/10).

There are now several examples of recovery equipment in current commercial use. All these units use are based on absorption of used methyl bromide on activated carbon or liquid scrubbing with nucleophilic reagents. Some are designed for recycling of the recaptured methyl bromide while others include a destruction step to eliminate the sorbed methyl bromide, thus minimising emissions. There is increasing adoption of these systems, though this has been driven by considerations other than ozone layer protection, e.g. occupational safety issues or local air quality. In the absence of regulations, companies reported they would not invest in the systems, because their competitors (who had not made the investment) would then have a cost advantage.

1.9. Economic criteria

During CUN evaluations, MBTOC assesses the financial feasibility of alternatives available to the Party (Decision IX/6), because an alternative may be considered technically feasible, but may not be economically feasible. Measurement of the economic implications of the use of methyl bromide or an alternative can in most cases be done satisfactorily by means of a partial budget analysis, a practical tool to compare alternative production practices.

2

Chapter 2. Introduction to the Assessment

2.1. Methyl Bromide

Methyl bromide (MB) is a fumigant that has been used commercially since the 1930's (Anon, 1994). It has been used to control a wide spectrum of pests including fungi, bacteria, soil-borne viruses, insects, mites, nematodes, rodents and weeds or weed seeds. MB has features that make it a versatile biocidal with a wide range of applications. In particular, it is a gas that is quite penetrative and usually effective over a broad range of temperatures. Its action is usually sufficiently fast and it airs rapidly enough from treated systems to cause relatively little disruption to crop production or commerce.

MB was listed under the Montreal Protocol as a controlled ozone depleting substance in 1992. Additional control schedules leading to phase-out for non quarantine and preshipment (QPS) uses (with specific exceptions) were agreed to in 1995 and 1997. Since 2005, exemptions have been allowed for 'Critical Uses' in non A5 Parties and will be allowed in 20015 for A5 Parties under Decision IX/6. Additionally some non A5 Parties have used small amounts of methyl bromide (< 20 t) after 2005 under the 'Emergency Use' provisions under Decicion IX/7 of the Montreal Protocol.

MB use for QPS treatments, where it performs a dual role for QPS treatments by facilitating trade as well as preventing the accidental import of exotic pests that can incur substantial costs for control and if possible eradication. The Protocol specifically excluded QPS from control measures in 1992 because at that time the Parties estimated that there were no alternatives to MB that gave the same level of protection for the diverse range of treatments carried out with this fumigant. Since this time, MBTOC and the QPS Taskforces have conducted several reviews for the Parties which demonstrate that alternatives are available for 31 to 47% of the uses of MB for QPS (TEAP, 2009c; 2010c), however no further controls have as yet been implemented.

A number of concerns over methyl bromide apart from ozone depletion have also led countries to impose severe restrictions on its use. These concerns include residues in food, toxicity to humans and associated operator safety, public health, and detrimental effects on soil biodiversity. In some countries, pollution of surface and ground water by MB and its bromide ion are also concerns.

2.1.1. MB uses identified in Articles of the Protocol

MB is classified as a "controlled substance" under the Montreal Protocol (Article 1 and Annex E). The Articles of the Protocol refer to four main categories of MB uses, and each is subject to different legal requirements. Table 2-1 lists the four categories, and indicates those for which information is provided in this MBTOC report.

Two of the categories - the non-QPS fumigant uses and laboratory and analytical (L&A) uses - are subject to the phase-out schedules under Articles 2 and 5, with authorised Critical Use Exemptions (CUE). The phase-out schedules are summarized in Table 2-2 below. The other two categories of MB uses – QPS and feedstock used in industrial processes – are not subject to phase-out schedules but are subject to reporting requirements under the Protocol.

This report focuses primarily on the non-QPS and QPS fumigant uses. Feedstock is mentioned in this report only when discussing statistics on global MB production for all uses in Chapter 3. L&A uses are also included in general statistics on MB production in Chapter 3 but no breakdown is available. L&A uses are not discussed in MBTOC reports because they are assessed in the reports of the Chemical Technical Options Committee (CTOC).

Because the phase-out of controlled uses (non-QPS) of MB is now so well advanced – as of 1st January 2015 such uses are only authorised under the CUE process for both Article 5 and non-Article 5 Parties – QPS uses now comprise the largest category of MB use by the Parties of the Montreal Protocol (see Chapter 3). QPS us of MB has thus become the largest, non-controlled ODS emission (among the substances presently included in the Montreal Protocol).

TABLE 2-1. CLASSIFICATION OF MB USES UNDER THE MONTREAL PROTOCOL, INDICATING RELEVANT SECTIONS IN THIS ASSESSMENT REPORT

MB uses	Status under the Montreal Protocol	Relevant information in MBTOC Assessment
Non-QPS fumigant uses	Subject to production and consumption phase-out schedules of Articles 2 and 5, trade and licensing controls of Article 4, and data reporting requirements of Article 7. Critical Use Exemptions can be authorised by the MOP for specific uses that meet the criteria in Decision IX/6 and other relevant decisions in Article 5 and non-Article 5 Parties.	Chapters 1-3 and 5-9
QPS fumigant uses	Exempted from reduction and phase-out schedules. Subject to Article 7 data reporting requirements	Chapter 4 and several sections in chapter 6
Laboratory and analytical uses	Subject to production and consumption phase-out schedules of Articles 2 and 5 except for the specific Critical Use Exemptions under Decision XVIII/15. Subject to data reporting under Annex II of the Sixth Meeting of the Parties	L&A uses are covered in CTOC reports. Chapter 3 statistics on MB production include L&A, but no breakdown is available
Feedstock used in the manufacture of other chemicals	Exempted from phase-out schedule under Article 1. Subject to Article 7 data reporting requirements	Chapter 3 statistics on MB production

2.2. MBTOC mandate

The Methyl Bromide Technical Options Committee (MBTOC) was established in 1992 by the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer to identify existing and potential alternatives to MB. MBTOC, in particular, provides recommendations and advice to the Parties on the technical and economic feasibility of chemical and non-chemical alternatives for controlled uses of MB. Additionally, from 2003, MBTOC has had the task of evaluating Critical Use Nominations submitted by non- Article 5 Parties to the Montreal Protocol and by Article 5 Parties from 2014. MBTOC provides recommendations on such nominations, for review and endorsment by the Technology and Economic Assessment Panel (TEAP) and then consideration by the Parties. MBTOC presently works as a single committee and its members have distinct expertise in the uses of MB and its alternatives following areas: Soils (pre-plant fumigation), Structures and Commodities SC) and Quarantine and Pre-Shipment (QPS).

MBTOC is a subsidiary body of TEAP, the Panel that advises the Parties on scientific, technical and economic matters related to ozone depleting substances and their alternatives. Information contained in MBTOC's reports contribute to the Parties' deliberations on appropriate controls for MB and its alternatives and for endorsement of use by the Parties for critical uses. Parties review MBTOC and TEAP's recommendations and may accept, reject of modify these recommendations when taking decisions on CUE requests.

TABLE 2-2. PHASE-OUT SCHEDULES AGREED AT THE NINTH MEETING OF THE PARTIES IN 1997

Year	Non-Article 5 countries	Article 5 countries
1991	Consumption/ production baseline	
1995	Freeze	
1995-98 average		Consumption/ production baseline
1999	25% reduction	
2001	50% reduction	
2002		Freeze
2003	70% reduction	Review of reductions
2005	Phaseout with provision for CUEs	20% reduction
2015		Phaseout with provision for CUEs

Source: UNEP, Ozone Secretariat, 2015. Montreal Protocol Handbook.

Critical and emergency uses may be permitted after phaseout if they meet agreed criteria. Emergency uses may be of up to 20 metric tonnes.
Parties are urged to use stocks of MB for their critical uses. Such stocks need to be reported to the Ozone Secretariat.
Quarantine and pre-shipment (QPS) uses and feedstock are exempt from reductions and phaseout.

Decisions encouraging advanced phaseout:

- Countries may take more stringent measures than those required by the schedules (Article 2 of the Montreal Protocol).
- In applying the QPS exemption, all countries are urged to refrain from use of MB and to use non-ozone-depleting techniques wherever possible (Decisions VII/5 and XI/13).
- A number of developing and industrialised countries signed Declarations in 1992, 1993, 1995, 1997, 2003 and 2004 stating their determination to phase out MB as soon as possible.

2.3. Committee process and composition

At December 2014, MBTOC had 29 members; 17 (59%) from non-Article 5 and 12 (41%) from Article 5 Parties. These members came from seven Article 5 and nine non- Article 5 countries. Representation from diverse geographic regions of the world promotes balanced review and documentation of alternatives to MB, based on the wide-ranging expertise of Committee members. Many MBTOC members were nominated by their governments; however MBTOC co-chairs also have the authority to appoint members in full consultation with the focal points from their country of origin.

In accordance with new and revised Terms of Reference for TEAP and its Technical Options Committees, terms for all MBTOC members expired at the end of 2014 (Decision XXIII/10 (9)). Terms of service are now set at four years with the option of reappointment for ensuing terms. Several members have however resigned at the end of 2014, mostly non-A5 members who lacked the appropriate financial commitment from their Parties or other sources to attend MBTOC meetings. At and at the time of posting this report (February 2015) MBTOC membership stood at 20 members, 10 from Article 5 Parties, coming from nine countries and 10 members coming from seven non-Article Parties.

In accordance with the terms of reference of TEAP and TOCs, MBTOC members participate in a personal capacity as experts and do not function as representatives of governments, industries, non-government organisations (NGOs) or others (Annex V of the report of the 8th Meeting of the Parties). Members of MBTOC contribute substantial amounts of work in their own time. For construction of this Assessment Report, MBTOC met formally in Stellenbosch, South Africa (March, 2014) and Frankfurt, Germany (August, 2014). To produce each chapter as efficiently as possible, MBTOC sub-committees worked primarily on chapters covering their specific topics and topics affecting all chapters were discussed and agreed by the entire committee. Assessment structure and contents were agreed during these formal meetings. The Assessment was finalised by email, to produce a consensus document of the Committee.

MBTOC co-chairs and members working on this MBTOC 2014 Assessment Report are listed in Appendix 2. The co-chairs acted as coordinators and lead authors for the main chapters of this Assessment and members worked on those chapters most suited to their particular expertise.

2.4. UNEP Assessments

The first interim assessment on MB for the Protocol was completed in 1992. A full assessment of the alternatives to MB was completed in 1994 and reported to the Parties in 1995 (MBTOC, 1995) as a result of Decisions taken at the fourth Meeting of the Parties to the Montreal Protocol held in 1992. The second MBTOC Assessment was presented to Parties in 1998 (MBTOC, 1998), the third in 2002 (MBTOC, 2002), the fourth in 2006 (MBTOC, 2007) and the fifth in 2010 (MBTOC, 2011). The 2014 Assessment Report is MBTOC's sixth.

MBTOC progress reports on advances in alternatives to methyl bromide and other issues related to methyl bromide were included in annual TEAP reports to the Parties (1999; 2000; 2001; 2002; 2003; 2004; 2005 ab; 2006 ab; 2007 ab; 2008 ab; 2009 ab; 2010 ab; 2011 ab; 2012 ab; 2013 ab; 2014 ab). Assessment Reports and TEAP Progress and CUN Reports can be found at http://ozone.unep.org/teap/Reports/MBTOC/index.asp .

Under Decision XXIII/13 (2) taken at the Twenty-Third Meeting of the Parties to the Protocol in 2010, the Parties requested the Assessment Panels to update their 2010 reports in 2014 and submit them to the Secretariat by 31 December 2014 for consideration by the Open-ended Working Group and by the Twenty-Seventh Meeting of the Parties to the Montreal Protocol, in 2015. This MBTOC 2010 Assessment reports provides an update on advances since 2010.

2.5. Definition of an alternative

In this report, following guidance given in Annex 1 of 16 MOP report, MBTOC defined 'alternatives' as:

> *' any practice or treatment that can be used in place of methyl bromide. 'Existing alternatives' are those alternatives in present or past use in some regions. 'Potential alternatives' are those in the process of investigation or development.*
> *MBTOC assumed that an alternative demonstrated in one region of the world would be technically applicable in another unless there were obvious constraints to the contrary e.g., a very different climate or pest complex.*

This definition of 'alternatives' is consistent with that used in previous Assessments.

MBTOC is not required in its terms of reference to conduct economic studies on MB and alternatives, however annually it reports on the Parties economic statements on MB and alternatives when requesting CUEs. As per Decision IX/6 and others, alternatives to MB must be technically and economically feasible. Additionally, it was recognised that regulatory requirements, environmental issues and social constraints may make an alternative unavailable in a specific country or region. MBTOC did not omit alternatives from discussion on such grounds in this Assessment report, although MBTOC reports on CUNs do fully consider the availability or lack of availability in specific locations.

2.6. Report structure

In addition to the *Executive Summary* (Chapter1) and this Introductory Chapter (Chapter 2), the assessment report contains the following chapters:

Chapter 3: Methyl bromide production, consumption and progress in phase-out for controlled uses provides statistics on MB production, consumption and major uses from 1991 to the present day, focusing on controlled uses. The chapter has been written in four major parts. The first part provides a brief overview of the major trends, the second part discusses MB production and supply, the third describes consumption in non-Article 5 countries and the fourth describes consumption in Article 5 countries. The two last parts describe the trends in MB fumigant uses by crop or sector.

Chapter 4: Quarantine and Pre-shipment covers MB and alternative treatments for Quarantine and Pre-shipment (QPS) of durable and perishable commodities, including discussion of:

- Production and consumption of MB for QPS purposes
- International (IPPC) standards influencing MB use for quarantine Technical and economic feasibility of alternatives to the main categories of MB use for QPS purposes.
- Constraints to adoption of alternatives

Chapter 5: Alternatives to Methyl Bromide for soil treatment covers a range of alternatives for pre-plant soil fumigation. Discussion includes:

- Commercial alternatives available at a large scale
- Chemical and non chemical alternatives including emerging chemical technologies
- Combined alternatives
- Crop specific strategies
- Adoption of alternatives in Article 5 and non-Article 5 regions

Chapter 6: Structures and Commodities: Methyl Bromide Uses and Alternatives for Pest Control includes discussion on: alternative fumigants such as phosphine and sulfuryl fluoride (including regulatory issues), non-chemical methods such as heat treatment and controlled atmosphere. A section dealing with available alternatives for high moisture dates is also included.

Chapter 7: *Factors assisting the methyl bromide phase-ou in Article 5 countries and remaining challenges* discusses Multilateral Fund (MLF) projects carried out by Article 5 countries that were instrumental in replacing MB in Article 5 Parties. It identifies the main types and objectives of MLF projects, the major technologies being implemented and alternatives adopted on a commercial scale. It discusses lessons learned and barriers to the adoption of alternatives. The chapter outlines other factors that have contributed to MB phase-out, such as voluntary efforts of growers and others undertaken in both Article 5 regions. In view of the phase-out date of 1st January 2015 already in place, it addresses challenges and factors that could potentially put the sustainability of the phase-out at risk.

Chapter 8: Methyl Bromide Emissions discusses:

- Inadvertent and intentional MB emissions.
- Emissions estimated from soil, perishable and durable commodities and structural fumigation treatments.
- Containment techniques.
- Using "best practice" methods to reduce emissions
- Developments in MB recovery and recycling systems.

Chapter 9: Economic Issues Relating to Methyl Bromide Phase-out updates discussion on economic issues influencing adoption of alternatives to MB, in response to Decision Ex.I/4. The chapter outlines the main Decisions of the Parties relating to assessments of the economic feasibility of alternatives in critical use nominations. It covers a significant number of recently published peer- reviewed publications on this topic and identifies the main categories and economic approaches used by different authors to date. It shows that further investigation would be needed to provide a better understanding of the economic impacts of the methyl bromide phase-out, in particular in countries outside of the USA and especially in Article 5 countries.

Appendix 1 contains case studies of adoption of alternatives for preplant (soils) uses of methyl bromide in both Article 5 and non-Article 5 Partes. It also presents one case study based on Japan's strategy to minimise MB use for QPS purposes.

Appendix 2 contains a list of MBTOC members, area of expertise, country of origin and affiliation.

Disclosure of Interest (DOI) statements can be found at the ozone secretariat website and are updated once a year at minimum, or sooner if a members' situation changes in a manner that is relevant to the DOI.

2.7. References

Anon (1994). Methyl bromide annual production and sales for the years 1984–1992, Methyl Bromide Global Coalition Washington, DC

MBTOC (1995). 1994 Report of the Methyl Bromide Technical Options Committee: 1995 Assessment. UNEP: Nairobi. 304pp.

MBTOC (1998). Report of the Methyl Bromide Technical Options Committee. 1998 Assessment of Alternatives to Methyl Bromide. UNEP: Nairobi. 374pp.

MBTOC (2002). Report of the Methyl Bromide Technical Options Committee. 2002 Assessment of Alternatives to Methyl Bromide. UNEP: Nairobi. 451pp.

MBTOC (2007). Report of the Methyl Bromide Technical Options Committee. 2006 Assessment of Alternatives to Methyl Bromide. UNEP: Nairobi. 469pp.

MBTOC (2011). Report of the Methyl Bromide Technical Options Committee. 2010 Assessment of Alternatives to Methyl Bromide. UNEP: Nairobi. 400pp.

TEAP (1999). April 1999 Report of the Technology and Economic Assessment Panel. UNEP: Nairobi. 245pp.

TEAP (2000). Report of the Technology and Economic Assessment Panel. April 2000. UNEP: Nairobi. 193pp.

TEAP (2001). Report of the Technology and Economic Assessment Panel. April 2001. UNEP: Nairobi. – 112pp.

TEAP (2002).Report of the Technology and Economic Assessment Panel, April 2002. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme. April 2002

TEAP (2003). Report of the Technology and Economic Assessment Panel, October 2003. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2004). Report of the Technology and Economic Assessment Panel, October 2004. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2005a). Report of the Technology and Economic Assessment Panel, May 2005. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2005b) Report of the Technology and Economic Assessment Panel, October 2005. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2006a). Report of the Technology and Economic Assessment Panel, May, 2006. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2006b). Report of the Technology and Economic Assessment Panel, October, 2006. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2007a). Report of the Technology and Economic Assessment Panel, April, 2007. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2007b). Report of the Technology and Economic Assessment Panel, August, 2007. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2008a). Report of the Technology and Economic Assessment Panel, May 2008. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2008b). Report of the Technology and Economic Assessment Panel, October, 2008. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2009a). Report of the Technology and Economic Assessment Panel, May, 2009. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2009b). Report of the Technology and Economic Assessment Panel, October, 2009. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2009c). QPS Task Force Report. UNEP, Nairobi, Kenya, online: ozone.unep.org, TEAP.org, 332 pp.

TEAP (2010a). Report of the Technology and Economic Assessment Panel, May, 2010. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2010b). Report of the Technology and Economic Assessment Panel, October, 2010. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2010c). May 2010 Progress Report. Vol. 2, Chapter 8: Decision XXI/10 Quarantine and Pre-Shipment Report. UNEP: Nairobi, Kenya, online: ozone.unep.org, 295 pp, 89-158.

TEAP (2011a). Report of the Technology and Economic Assessment Panel, May, 2011. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2010b). Report of the Technology and Economic Assessment Panel, October, 2011. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2012a). Report of the Technology and Economic Assessment Panel, May, 2012. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2012b). Report of the Technology and Economic Assessment Panel, October, 2012. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2013a). Report of the Technology and Economic Assessment Panel, May, 2013. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2013b). Report of the Technology and Economic Assessment Panel, October, 2013. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2014a). Report of the Technology and Economic Assessment Panel, May, 2014. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

TEAP (2014b). Report of the Technology and Economic Assessment Panel. CUN for Methyl Bromide. October, 2014. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi.

3

Chapter 3. Methyl Bromide production, consumption and progress in phase out (controlled uses)

3.1. Introduction

This chapter provides statistics on MB production, consumption and major uses from 1991 to the present day for both non-exempted (controlled) and QPS uses.

The first part of this chapter refer to non-QPS fumigant uses, generally referred to as controlled uses or controlled production/consumption, to distinguish them from other MB uses which presently do not have phase-out schedules under the Protocol, namely QPS and feedstock used in industrial processes. Chapter 4 of this Assessment Report makes reference to exempted or QPS uses, presently more than three times higher than controlled uses.

In the Montreal Protocol, "Calculated levels of production" refer to the amount of controlled substances produced, minus the amount destroyed by technologies approved by the Parties and minus the amount entirely used as feedstock in the manufacture of other chemicals. For methyl bromide, this does not include the amounts used by the Party for quarantine and pre-shipment applications.

Under the Protocol, MB consumption at the national level is defined as ‘production plus imports minus exports, minus QPS, minus feedstock’. It thus represents the national supply of MB for uses controlled by the Protocol (i.e. non-QPS).

Consumption may be different from actual use as MB imported in a particular year for may be consumed in another. Further, stocks of MB already accounted for as consumption may be used in later years. As per Article 7 of the Protocol, Parties are obliged to report production and consumption of MB on a yearly basis (by 30 September of each year). At the time of writing this report, all Parties had reported consumption for 2013 to the Ozone Secretariat, which allows for thorough analysis of consumption trends (Note: two A5 Parties did not report controlled consumption, however their consumption levels have been at zero for more than five years, so it could be assumed that consumption has remained negligible and should not in any way impact results).

3.2. *Methyl Bromide global production and supply for controlled uses*

MB is normally supplied and transported as a liquid in pressurised steel cylinders or cans, since it is a gas at normal atmospheric pressure. Cylinders typically range in capacity from 10 kg to 200 kg, although MB can also be stored in much larger pressurised containers of more than 100 tonnes. In some countries, albeit fewer each year due to health and hazard concerns, MB is still supplied as disposable canisters of approximately 1 lb or 0.454 kg or 1.5 lb (0.75 kg).

3.2.1. Global production for all uses

The information on MB production is compiled from the ODS data reports submitted by Parties under Article 7. All tonnes stated in this chapter are metric tonnes. Table 3-1 below shows the trends in global production, as reported to the Ozone Secretariat by Parties, for all uses, for the years in which data is available (1991 and 1995-2013). (Production per intended use was not discriminated in the early days and it was presented as an aggregate amount).

Trends in the reported production of MB for all *controlled* uses (excluding QPS and feedstock) in all non-article 5 and Article 5 countries are shown in Figure 3-1.

In 2008, a report noted that nearly half of the global anthropogenic emissions of MB in 2005 arose from QPS uses that were not restricted by the Montreal Protocol (Ravishankara *et al*, 2008). The Scientific Assessment Panel report also calculated that if MB production for QPS uses were to cease in 2015, from 2007 to 2050 the total chlorine and bromine in the atmosphere would be reduced by 3.2%. (SAP, 2007; Montzka, 2009). The most recent report from the Scientific Assessment Panel (SAP, 2014) corroborates and further expands this issue. See Chapters 4 and 9 and of this Report on QPS uses and emissions of MB for more detailed information on this topic.

Table 3-2 shows the reported purposes of the total MB that was produced in 2013, compared to the 2009 data in the previous MBTOC Assessment Report. In 2009, essentially equal amounts of MB were produced for use as a fumigant for non-QPS, as for QPS uses. In 2013, however the situation is substantially different, with about 10% of total global production intended for controlled uses (non-QPS fumigant), while 90% was intended for uses that are not controlled under the Protocol.

TABLE 3-1. REPORTED MB PRODUCTION FOR ALL PURPOSES, 1984-2013 (METRIC TONNES).

Year	Fumigant Non-QPS & QPS		Chemical feedstock		Total production [a]	
	MBTOC estimates	Reported by Parties	MBTOC estimates	Reported by Parties	MBTOC estimates	Reported by Parties
1984	41,575		3,997		45,572	
1985	43,766		4,507		48,273	
1986	46,451		4,004		50,455	
1987	52,980		2,710		55,690	
1988	56,806		3,804		60,610	
1989	60,074		2,496		62,570	
1990	62,206		3,693		65,899	
1991	73,602	69,995 [a]	3,610	3,610	77,212	73,605 [a]
1992	72,967		2,658		75,625	
1993	71,157		3,000		74,157	
1994	71,009		3,612		74,621	
1995		65,284		4,754		70,038
1996		67,979		3,104		71,082
1997		69,760		3,829		73,589
1998		70,875		4,448		75,323
1999		61,517		4,453		65,970
2000		56,533		13,132		69,665
2001		45,134		3,190		48,324
2002		40,236		4,331		44,567
2003		36,565		6,759		43,324
2004		35,970		8,012		43,982
2005		32,909		5,014		37,923
2006		29,910		4,475		34,385
2007		25,861		5,224		31.085
2008		19,158		5,097		24,255
2009		20,110		6,408		26,519
2010		19,271		7.019		26,290
2011		13,991		4.699		18,690
2012		12,729		3.910		16,639
2013		12,407		12.459		24,866

a. Total production includes laboratory and analytical uses, but no specific statistics are available on this use.

Sources: data estimates from MBTOC 2002 and 2006 Assessment Reports and Ozone Secretariat data available for 1991 and 1995–2013

TABLE 3-2. REPORTED MB PRODUCTION IN 2013 BY INTENDED PURPOSE

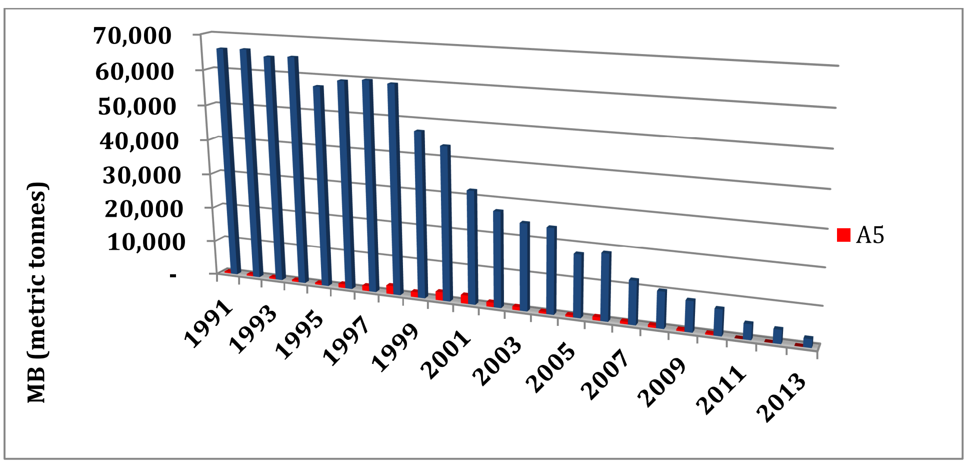
Intended purpose	Reported MB production in 2009		Reported MB production in 2013	
	Metric tonnes	%	Metric tonnes	%
Fumigant non-QPS	11,166	37%	2,493	10%
Sub-total of uses controlled by the MP	**11,166**	**37%**	**2,493**	**10%**
Fumigant for QPS	8,922	37%	9,915	40%
Feedstock	6,408	26%	12.459	50%
Sub-total of uses not controlled by MP	**15,330**	**63%**	**22,374**	**90%**
Total – all uses, controlled and not controlled	**26,506**	**100%**	**24,867**	**100%**

Source: Database of Ozone Secretariat of November 2014.

3.2.2. Global production for controlled uses

Figure 3-1 shows the trend in reported global MB production for all controlled uses from 1991 to 2013 (excluding QPS and feedstock). It illustrates that MB production has occurred primarily in Non-Article 5 Parties, and that global production for controlled uses in 2013 continued the downward trend, totalling 2,493 tonnes or 8.84% of the baseline.

FIGURE 3-1. HISTORICAL TRENDS IN REPORTED GLOBAL MB PRODUCTION* FOR ALL CONTROLLED USES, EXCLUDING QPS AND FEEDSTOCK, 1991 - 2013 (METRIC TONNES)



* Data for 1991 and 1995-2013 were taken from the Ozone Secretariat dataset of December 2013. Data for 1992-94 were estimated from Table 3.1 of the 2002 MBTOC Assessment Report (MBTOC, 2002), Table 3.1 of the 2006 MBTOC Assessment Report (MBTOC, 2007) and Table 1 above.

Non-A5 countries have reduced their MB production for controlled uses from about 66,000 tonnes in 1991 (non-Article 5 baseline) to about 2,326 tonnes in 2013.These figures include production for export to A 5 countries (for Basic Domestic Needs).

A5 countries reduced their MB production for controlled uses from a peak of 2,397 tonnes in 2000 to 167 tonnes in 2013, which represents 13% of their baseline.

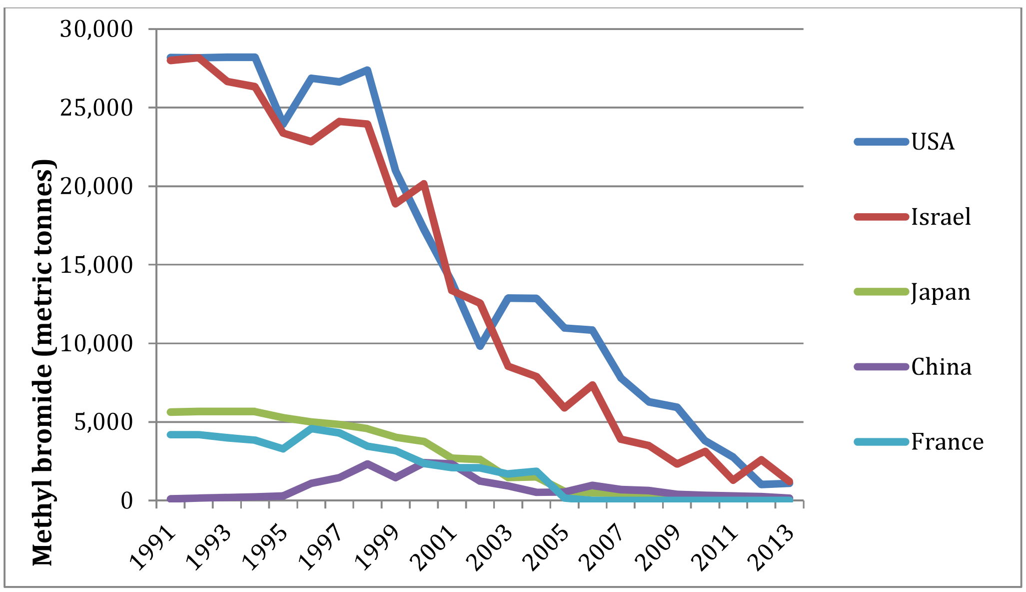
3.2.3. Major producer countries

In 2013 Israel and the USA remained the major producers globally of MB for controlled uses, accounting for 49% (1,218 tonnes) and 45% (1,107 tonnes) respectively, of global production.

Presently, the only A5 Party reporting production of MB is China with 167 metric tonnes in 2013. France, Ukraine and Romania, which produced MB in the past, have now closed down their factories entirely.

Figure 3-2 presents production trends in major MB producing countries for controlled uses for the period 1991 to 2013.

FIGURE. 3-2. GLOBAL MB PRODUCTION TRENDS 1991 – 2013 (CONTROLLED USES)



Source: Ozone Secretariat Database, December 2014

3.2.4. Production facilities

In previous Assessment Reports (MBTC 2002; 2006; 2010), MBTOC has reported on methyl bromide production facilities around the world. In 2000, about 14 facilities in eight countries produced MB for controlled and/or exempted uses, and by 2006 the number had fallen to about 9 facilities in five countries. In 2010, about eight facilities produced MB in five countries.

During the 1990s, six non-A5 countries produced MB (France, Israel, Japan, Romania[1], Ukraine and the US). As reported in the 2010 Assessment, Ukraine ceased production by 2003, while Romania and France ceased production by 2005 and 2006 respectively (MBTOC, 2011; Ozone Secretariat Data Access Centre, December 2014). As a result, the number of non-A5 countries that produce MB fell to three -

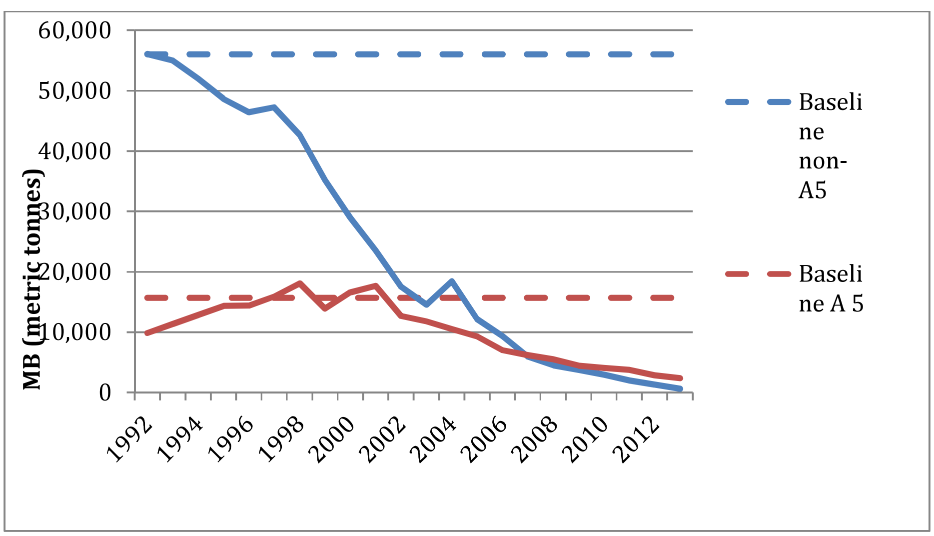
Israel, Japan and US- and these continue to report production as shown in the previous section.

In the past, three A5 countries produced MB (China, India and Korea DPR) but since 2002 only one Article 5 country (China) has officially reported MB production to the Ozone Secretariat. Korea DPR ceased production in 1996, and India was believed to have ceased production in 2003 (Ozone Secretariat Data Access Centre, 2014). However, some companies in India indicate in their websites that they manufacture MB for QPS, non-QPS and/or feedstock uses (e.e. ICRA, 2014). Since 2002, India has not officially reported any MB production under Article 7. For an indicative list of companies producing MB in 2010 please refer to the MBTOC 2010 Assessment Report (MBTOC, 2011).

3.3. Trends in global MB Consumption (and phase-out) for controlled uses

On the basis of Ozone Secretariat data, consumption for controlled uses was estimated to be about 64,420 tonnes in 1991 and remained above 60,000 tonnes until 1998. It was reported to fall to about 8,148 tonnes in 2009, and again to 2,953 tonnes in 2013 as illustrated by Figure 3-3. Consumption in Article 5 Parties was higher than that of non-Article 5 Parties for the first time in 2007. This trend continued up to 2013, when all Article 5 Parties together reported a consumption of 2,342 tonnes (approx. 80% of global consumption for controlled uses) whilst non-Article 5 Parties reported 611 tonnes[1] (approx. 20% of the global consumption).

FIGURE 3-3. BASELINES AND TRENDS IN MB CONSUMPTION IN NON-A 5 AND A 5 REGIONS, 1991 – 2013 (METRIC TONNES)



Source: MBTOC estimates (for early years only) and Ozone Secretariat December 2014.

[1] Consumption for non-A5 Parties was calculated from authorized exempted quantities (critical uses) for non-A5 Parties.

3.3.1. Global consumption by geographical region

An analysis of Ozone Secretariat data revealed that the end of 2013 global consumption of MB for controlled uses was reduced by almost 96% with respect to the global aggregate baseline, as shown in Table 3-3 below. The geographical regions that have made the greatest reductions in consumption in the period 1991-2013 were Europe (100% phase-out), Asia & Pacific and North America (97% reduction). Latin America made the smallest reduction (74%) in this period.

TABLE 3-3. GLOBAL CONSUMPTION OF METHYL BROMIDE BY GEOGRAPHIC REGION, 2013 (METRIC TONNES)

Region	Regional baseline [a]	2013 consumption	% Reduction 1991-2013	Number of Parties
Africa	4,471	340	92%	53
Latin America & Caribbean	6,389	1,637	74%	33
Asia & Pacific [b]	14,657	331	97%	58
Europe [c]	21,472	0	100%	49
North America [d]	25,729	601	97%	2
TOTAL	**72,718**	**2,899**	**96%**	**195**

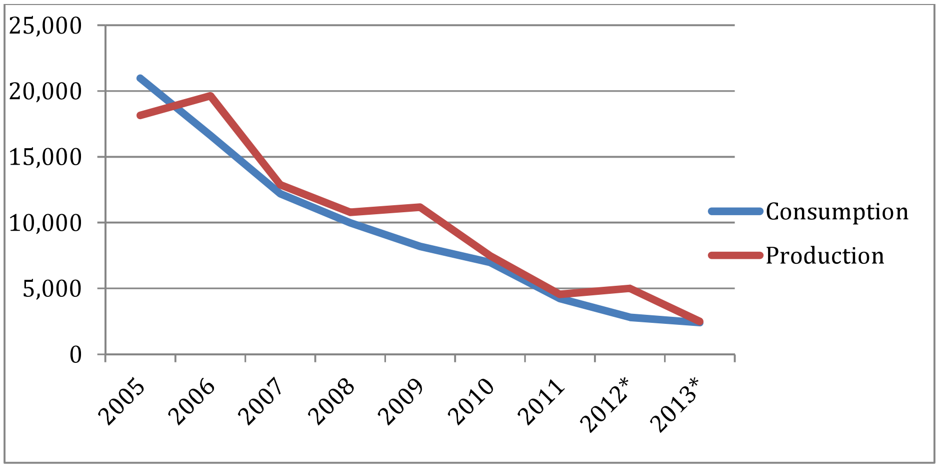
a. Aggregate regional baselines as provided in the database of Ozone Secretariat of November 2014, compiled from 1991 consumption in non-Article 5 countries and 1995-1998 averages in Article 5 countries.
b. The relatively high baseline in this region arises from the historical consumption in Japan and Israel. Asia & Pacific comprises Asian countries (including the middle East), plus Australia and New Zealand
c. The European region comprises the EU, Eastern Europe, Switzerland, Scandinavia and CEIT countries.
d. The North American region comprises US and Canada.
Source: Database of Ozone Secretariat of November 2013.

3.3.2. Production vs. Consumption

When comparing production vs. consumption, it is found that since 2005, a surplus of about 7,760 tonnes of MB produced for controlled uses has accumulated during this nine-year period. This may be due to stocks or to lack of reporting of consumption in some countries or to stocks which have been produced and held for long periods and yet to be consumed. Figure 3-4 illustrates the comparison between global production and consumption of MB for controlled uses between 2005 and 2013 as reported to the Ozone Secretariat.

Please note that the apparent consumption reported by Israel for 2012 (1082 tonnes) and 2013(16 tonnes) is in fact "Production for export to A5 countries for their Basic Domestic Needs (BDN) that did not get exported in the year of production". Therefore the amounts would appear as consumption under Israel, but will be exported in future years. The reported amounts have thus been transferred to the production category since Israel's controlled consumption is presently zero. This information is usually presented in the "Consolidated record of cases of excess production or consumption attributable to stockpiling in accordance with decision XVIII/17 and XXII/20" which is included in the annual data report presented to the MOP.

FIG. 3-4 GLOBAL PRODUCTION VS. GLOBAL CONSUMPTION OF MB FOR CONTROLLED USES 2005 - 2013



Source: Ozone Secretariat Data Access Centre, January 2015

- See comment on Israel reported consumption above.

3.4. Trends in methyl bromide consumption (and phase-out) in Non-Article 5 countries for controlled uses

Figure 3-5 shows the trends in MB consumption in the major Non-A 5 consuming countries for the period between 1991 and 2013. The official baseline for Non-A 5 countries was 56,084 tonnes in 1991 and since then the consumption has declined steadily. Trends in MB consumption in major Non-A 5 regions can be summarised as follows:

- In 1991 the USA, European Union, Israel and Japan used 95% of the MB consumed in Non-Article 5 countries.

- In the past, MB was consumed for controlled uses by 43 out of 48 Non-A 5 countries. Only 3 of these countries continue to use MB, which is being applied under CUEs (Table 3-5).

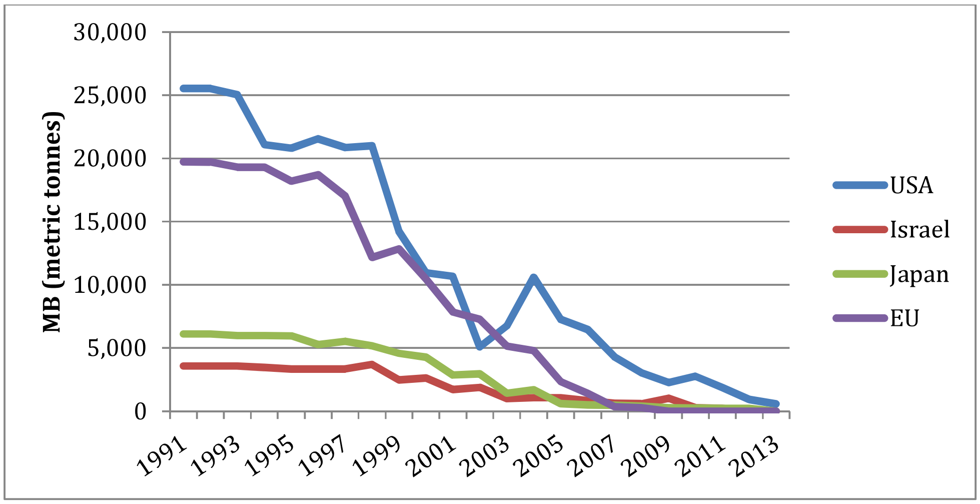
- The US was the highest consumer of MB for much of the period from 1991 to 2013, and its consumption has fluctuated more than that of other countries. US consumption increased after 2002, and then fell to pre-2002 levels in 2007 and to about 1% of its baseline in 2013. Recategorisation of some controlled uses for preplant soil uses in nursery industries to QPS has assisted the US to meet this level. CUEs approved from 2013 onwards have reduced requested amounts significantly, mainly as a result of the registration of additional alternatives. In 2014, the USA submitted a CUN for strawberry fruit – the largest remaining soil pre-plant use – for the last time (for use in 2016).

- Consumption in the EU, the second-highest consumer, showed a steady downward trend since 1999, falling to a low level of authorised consumption in 2008 (under the CUE process) and reaching 0% in 2009. Methyl bromide consumption ceased completely in the EU for both controlled and exempted (QPS) uses in 2010 because MB failed to meet the safety requirements of EU pesticide legislation.

- Japan and Israel have now reached 100% phase-out of MB for controlled uses

An analysis of national MB consumption as a percentage of national baseline in Parties that were granted critical use exemptions (CUE) appears in Table 3-4.

FIGURE 3-5. NATIONAL MB CONSUMPTION IN US, EU, JAPAN AND ISRAEL, 1991 – 2013



Source: Database of Ozone Secretariat in November 2014, reports of the Meetings of the Parties to the Montreal Protocol, and national licensing and authorisation documents relating to consumption. MBTOC estimates for several data gaps in the period 1992 – 1996. (a) Aggregate data for the EU comprising all current member states.

The reported actual consumption is often lower than the authorised CUE tonnage (see Table 3-7). In general, Parties have made significant reductions in MB consumption for CUEs. As noted previously, the EU discontinued submission of CUNs by the end of 2008 and stopped all consumption of MB in 2010.

Japan requested critical uses for the last time in 2011 for use in 2013 and Israel in 2011 for use in 2012. Israel however has reported consumptions of 1082.3 tonnes and 16.2 tonnes for controlled uses respectively in 2012 and 2013.

TABLE 3-4. METHYL BROMIDE CONSUMPTION[(A)] IN RELATION TO NATIONAL BASELINES IN NON-A 5 PARTIES THAT HAVE BEEN GRANTED CUES

Party	MB consumption [(a)], tonnes (percentage of national baseline)										
	1991 baseline	2003	2005	2006	2007	2008	2009	2010	2011	2012	2013
Australia	704	182 26%	119 17%	55 8%	46 7%	41 6%	33 5%	34 5%	35 5%	33 5%	32 4.4%
Canada	200	58 29%	54 27%	42 21%	38 19%	33 16%	28 14%	34 17%	21 11%	16 8%	13 3.5%
EU	19,735	5,162 26%	2,341 13%	1,410 8%	354 3%	275 1%	0 0%	0 0%	0	0	0 (0%
Israel	3,580	992 28%	1,072 30%	841 23%	638 18%	600 17%	611 17%	291 8%	225 6%	0[c]	0[c] 0%
Japan	6,107	1430 23%	595 10%	489 8%	479 8%	393 6%	279 5%	267 4%	240 4%	220 3.5%	3.3 0.01%
New Zealand	135	21 15%	30 22%	27 20%	7 5%	0 0%	0 0%	0 0%	0	0	0 0%
Switzerland	43	11 24%	4 9%	4 9%	0 0%	0 0%	0 0%	0 0%	0	0	0 0%
United States[d]	25,529	6,755 26%	7,255 28%	6,475 25%	4,302 17%	3,028 12%	2,272 9%c	2,764 11%	1855 7%	923 4%	562 2.2%

Source: Ozone Secretariat database, November 2014.

a. Authorized levels of consumption as authorised by MOP decisions for 2010-2013 which do not always match reported consumption at the Ozone Secretariat for 1991-2009.
b. Baseline of the 27 EU countries that were member states in 2005. The members of the European Union for which the MOP authorised CUEs in 2005/6 were Belgium, France, Germany, Greece, Ireland, Italy, Latvia, Malta, Netherlands, Poland, Portugal, Spain, and the United Kingdom (13 countries). The EU authorised CUEs for 2007 in France, Italy, Netherlands, Poland and Spain (5 countries) and for Poland and Spain for 2008 (2 countries).
c. Israel reported a consumption of 1082.3 tonnes and 16.2 tonnes for controlled uses respectively in 2012 and 2013, even though no CUEs were requested or authorised for these years. This was explained to be "Production for export to A5 countries for their Basic Domestic Needs (BDN) that did not get exported in the year of production". Therefore the amounts would appear as consumption but will be exported in future years.
d. Since 2005, the US has recategorised MB uses for a number of sectors from non-QPS and this has influenced their proportion of consumption against their baseline.

3.4.1. Number of countries consuming MB

About 92% of non-Article 5 countries, i.e. 44 of the total of 48 countries have consumed MB for uses controlled by the Protocol at least on one occasion since 1991. Of these, 86% (38 of 44) no longer consume MB. Consumption data does not include QPS. The member countries of the European Union provide an illustration of the changing patterns of MB use. In the past, 26 of the 27 current countries of the European Community consumed MB for uses controlled by the Protocol. In 2005/6, 13 of these countries still consumed some MB for CUEs. By 2008, only 2 EU countries consumed MB for CUEs, and phase out was completed by the end of 2008 as indicated in Figure 3-7.

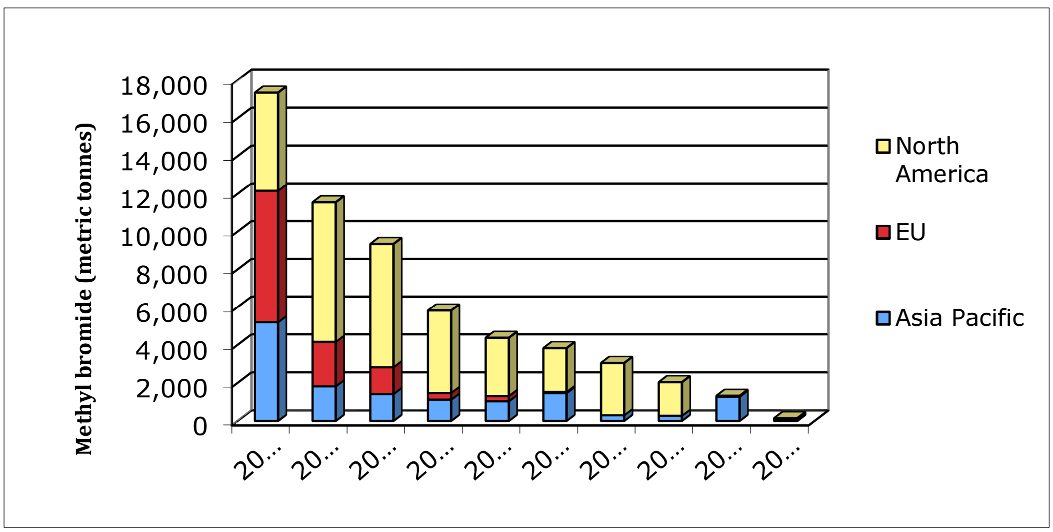
A total of 20 Parties requested CUEs in 2005/6. In 2007 this number fell to 12 Parties, a reduction of 40%, and in 2009 it fell further, to 5 Parties. In 2014, 3 non-A5 Parties requested CUNs (together with 3 A-5 Parties, making use of this provision for the for the first time, in light of the 2015 MB phase-out deadline for this group of Parties).

3.4.2. Consumption by geographical region

The proportions of consumption have changed substantially in non-Article 5 geographical regions since 2002 and particularly since 2006 as the CUE process developed. This is indicated in Figure 3-6 below.

There was a proportional change in consumption to North America (comprising the United States and Canada), which accounted for about 30% (5,181 tonnes) of total non-A5 consumption in 2002, to about 83% (3,269 tonnes) in 2010 (3,954 tonnes) and about 94% of total non-Article 5 authorised consumption in 2013. As mentioned before, authorised consumption is not always in coincidence with reported consumption since Parties may choose to use lesser amounts or draw required amounts from stocks.

FIGURE 3-6. MB CONSUMPTION IN NON-ARTICLE 5 COUNTRIES BY GEOGRAPHIC REGION, AS REPORTED UNDER ARTICLE 7, 2002 - 2013 (METRIC TONNES)



Europe: EU, other non-Article 5 Parties in Europe and non-Article 5 CEITs
Asia: Israel, Japan
Pacific: Australia, New Zealand
Source: Ozone Secretariat database, November 2014
North America: Canada and the United States
Source: Ozone Secretariat Database, January 2015

3.4.3. Trends in nominations for critical use exemptions

This section analyses trends in Critical Use Exemptions in non-Article 5 parties since the inception of the process in 2005. In addition to the quantities authorised for CUE consumption (production + imports), which were described in some sections above, Table 3-5 considers quantities authorised for CUE uses (called 'critical use categories' in MOP Decisions) up to 2014. In addition, some stocks may have been used to support sectors seeking critical use or other sectors. The MOP Decisions on CUEs used in this analysis were Decisions Ex.I/3, XVI/2, Ex.II/1, XVII/9 and XVIII/13.

TABLE 3-5. TREND IN TOTAL TONNAGE OF CUNS AUTHORISED 2005-2014.

Phase in procedure	2005	2008	2009	2010	2011	2012	2013	2014
Nominated amounts submitted to the MOP	18,704.00	8297.739	6244.487	4044.380	2692.366	1460.163	740.533	483.589
Amounts authorised* under the CUE 'use categories' by MOP Decisions	16,050.00	6996.115	5254.933	3572.183	2343.024	1261.304	610.888	483589

Source: Data compiled from TEAP/MBTOC reports, Decisions of MP meetings, national authorisations relating to CUEs, and Accounting Framework reports submitted to the Ozone Secretariat.

3.4.4 Trends for preplant soil uses

In the 2010 round, 27 nominations (CUNs) were submitted for preplant soil uses; of these, 9 were for 2011and 18 for 2012. In the 2014 round and 4 for 2015. Amounts approved by the Parties totaled 230 tonnes for 2011; 1164 t for 2012 and 412 for 2015 (6).

TABLE 3-6. SUMMARY OF MBTOC FINAL RECOMMENDATIONS FOR 2011/2012 AND OF CUNS RECEIVED IN 2013 FOR 2015, BY COUNTRY, FOR PREPLANT SOIL USE OF MB (TONNES)

Country	CUEs Approved Amounts for 2011 to 2016					
	2011	2012	2013	2014	2015	2016
Australia	**5.950**	29.760	29.760	29.760	29.76	29.76
Canada		5.261	5.261	5.261	5.261	5.261
Israel	224.497		-	-	-	-
Japan	234.396	216.120	-	-	-	-
USA		913.311	461.186	415.067	373.660	231.540
Total	**230.447**	**1164.452**	**496.207**	**450.088**	**408.681**	**266.561**

3.4.5 Trends in postharvest and structure uses

Four Parties submitted eight CUNs for the use of MB in structures and commodities in 2010 for use in 2011 and 2012, while one Party submitted only two in 2013 for use in 2015 and one in 2014 for 2016 as shown in Table 3-7.

TABLE 3-7. POST-HARVEST STRUCTURAL AND COMMODITY CUE 2011 - 2013

Party	Industry	2011	2012	2013	2014	2015	2016
Australia	Rice consumer packs	4.870	3.653	1.187	1.187	-	-
Canada	Flour mills	14.107	11.020	5.044	5.044	-	-
Canada	Pasta manufacturing facilities	2.084	-	-	-	-	-
Japan	Chestnuts	5.350	3.489	3.317	-	-	-
USA	Dried fruit and nuts (walnuts, pistachios, dried fruit and dates and dried beans)	5.000	2.419	0.740	0.740	-	-
USA	Dry commodities/ structures (processed foods, herbs and spices, dried milk and cheese processing facilities) NPMA	17.365	0.2	-	-	-	-
USA	Smokehouse hams (Dry cure pork products) (building and product)	3.730	3.730	3.730	3.730	3.24	3.24
USA	Mills and Processors	135.299	74.510	22.80	22.80	-	-
TOTAL		**187.805**	**99.021**	**33.501**	**33.501**	**3.24**	**3.24**

Source: Critical Use Nominations and MOP Decisions on Critical Use Exemptions

The total MB volume nominated in 2014 for non-QPS post-harvest uses was 3.24 metric tonnes (for dry cure pork), and MBTOC recommended this amount, which was approved by the MOP. In contrast, in 2006, seventeen Parties had submitted CUNs and MBTOC recommended 781.076 tonnes of MB for CUN use for structures and commodities.

3.5 MB consumption trends (and phase-out) in Article 5 Parties for controlled uses

The information about MB consumption in this section has been compiled primarily from the Ozone Secretariat database available in mid January 2015. At the time of making this analysis all Article 5 Parties (except two, but these have reported zero consumption for more than five years) had submitted national consumption data for 2013, which allows for a thorough analysis.

3.5.1. Total consumption and general trends

Figure 3-7 shows the trend in MB consumption in Article 5 countries for the period between 1991 and 2013. Overall trends can be described as follows:

- The Article 5 baseline was 15,867 tonnes (average of 1995-98), rising to a peak consumption of more than 18,125 tonnes in 1998. Article 5 consumption was reduced to 28% of baseline in 2009 (4,435 tonnes) and 14% of baseline in 2013 (2,276 tonnes).

- The vast majority of Article 5 Parties continued to make progress in achieving reductions in MB consumption at a national level, particularly in 2013 (and even further expected in 2014) as the final phase-out deadline of 1st January 2015 grew closer. Trends at the national level can be described as follows:

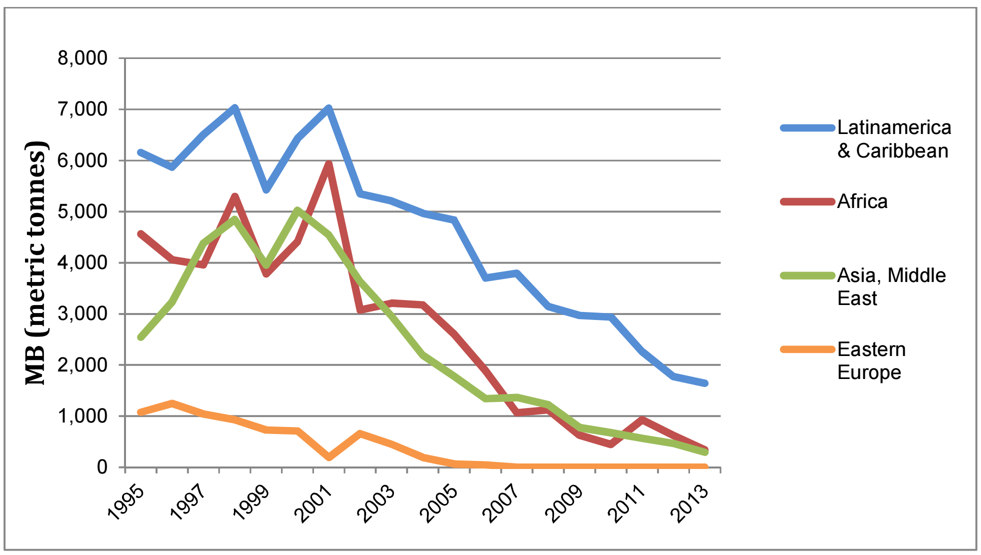
- At the time of preparing this report all Article 5 Parties had reported MB comsumption for 2013 (except Croatia and the Central African Republic but these two countries have reported zero consumption for over ten years), . Only 18 Parties (12%) out of 148 reported MB consumption totalling 2,276 metric tons.

- Seven A5 Parties concentrated almost the total of the remaining MB consumption in 2013. Of this, 72% was located in Latin America and Caribbean, 15% in Africa[2] and 13% in the Asia/ Pacific region.

- Within the top ten consuming A5 Parties in 2013, four concentrate nearly 75% of the remaining controlled consumption in 2013. However, Mexico, the top consumer at 540 metric tonnes in 2013, has already indicated zero consumption in 2014, in compliance with the phase-out schedule agreed with the Executive Committee through the MLF funded project that assisted them in adopting alternatives to MB.

- Three of the of the top consumers have requested CUNs in 2014 for 2015 use: Mexico (for strawberry runners and raspberry nurseries), China (for ginger) and Argentina (for strawberry fruit, tomatoes en peppers).

FIGURE 3- 7. MB REGIONAL CONSUMPTION TRENDS IN ARTICLE 5 COUNTRIES 1991 – 2013



Source: Ozone Secretariat database, 2014

3.5.2. Article 5 national consumption as percentage of national baseline

The great majority of Article 5 countries have achieved considerable MB reductions at national level. With respect to compliance, most Article 5 countries achieved the MP freeze as scheduled in 2002. By 2003, 82% of Article 5 Parties (117 out of 142 Parties) had achieved the 20% reduction step earlier than the scheduled date of 2005,

---

[2] Corrected consumption figures reported by South Africa to the Ozone Secretariat in 2014 changed these figures with respect to previous MBTOC reports.

as indicated in Table 3-8. All A5 Parties have been in compliance with this step since 2009. For further details see Table 3-11.

TABLE 3-8. STATUS OF COMPLIANCE IN ARTICLE 5 COUNTRIES, 2003 - 2013.

MB consumption as % of national baseline, and status of compliance with 20% reduction step	Number of Article 5 countries			
	2003	2005	2009	2013
MB consumption was 0 - 80% of national baseline	117	136	147	147
MB consumption was more than 80% of national baseline	25	8[a]	0	0
Total	142	144	147	148[3]

Source: Database of Ozone Secretariat in November 2014. For additional details refer to
a. Ecuador, Fiji, Guatemala, Honduras, Libya, Tunisia, Turkmenistan, Uganda.
Source: Database of Ozone Secretariat in November 2014.
[3] South Sudan is reporting under the Protocol since 2012.

3.5.3. Number of Article 5 countries consuming methyl bromide for controlled uses

As in other sections of this chapter, this analysis of MB consumption covers controlled uses only, not exempted QPS uses. Fifty-six Article 5 parties (38%) have never used MB or reported zero MB consumption since 1991. The total number of Article 5 parties that have consumed MB (currently or in the past) is 91, or 62% of the total 148 Article 5 parties. Of the 91 MB-user countries, 73 (80%) have phased out MB, and 18 still reported consumption in 2013.

3.5.4. Small, medium and large Article 5 consumers

Table 3-9 shows the diversity of MB consumption patterns in Article 5 countries. In 2009, 93% of Article 5 countries consumed 0-100 tonnes, 6% consumed 101 – 500 tonnes and <1% (only 1 country) consumed 500 tonnes. In 2013, the number of large consumers (>500 tonnes) decreased from 11 countries in 2001 to 6 countries in 2005, and one country in 2009. No countries remain in this category at present.

TABLE 3-9. NUMBER OF SMALL, MEDIUM AND LARGE VOLUME CONSUMER COUNTRIES, 2009 VS. 2013

MB consumption per country	Number of Article 5 countries	
	2009	2013
0 tonnes	117	130
Small: > 0 – 100 tonnes	20	12
Medium: 101 – 500 tonnes	9	6
Large: > 500 tonnes	1	0
Total number of countries	147	148[3]

Source: Database of Ozone Secretariat in December 2014. [3] South Sudan is reporting as a separate Party to the Protocol since 2012

3.5.5. Major consumer Article 5 Parties

Great progress has been achieved in Article 5 countries that consumed the greatest quantities of MB. In 2009, 8 of these countries still reported consumption between 100 and 500 tonnes while in 2013 only 6 Parties remained in that category (with no Party reporting consumption above 500 tonnes). The top 15 MB consuming countries together accounted for 80% of the Article 5 baseline in the past, and about 86% of total Article 5 consumption in 2000-01. National details are provided in Table 3-10.

TABLE 3-10. FIFTEEN LARGEST ARTICLE 5 CONSUMERS OF MB IN THE PAST, AND PRESENT PROGRESS IN PHASE OUT

Country	National MB consumption (tonnes)			MB eliminated from peak year to 2013	MB eliminated from baseline year in 2013	2013 top consumers
	Peak year [a]	Baseline*	2013			
China	3,501	1,837	167	95%	90%	6º
Morocco	2,702	1,162	0	100%	100%	-
Mexico	2,397	1,885	540	78%	71%	1º
Brazil	1,408	1,186	0	100%	100%	-
Zimbabwe	1,365	928	0	100%	100%	-
Guatemala	1,311	668	400	69%	40%	3º
South Africa	1,265	1,005	234	81%	77%	5º
Turkey	964	800	0	100%	100%	-
Honduras	852	432	0	100%	100%	-
Argentina	841	686	420	50%	39%	2º
Thailand	784	305	0	100%	100%	-
Costa Rica	757	571	0	100%	100%	-
Egypt	720	397	92	87%	77%	7º
Chile	497	354	276	44%	22%	4º
Lebanon	476	394	0	100%	100%	-
Total of former top 15 countries	19,840	12,610	2,129	89% average	83% average	-

[a] Maximum level of national MB consumption in the past. * 1995-1998 average
Ozone Secretariat Database January 2015.

The top 15 countries reduced MB consumption by 83% from 1995-98 baseline on average. By 2013 these large consumers phased out 89% of their historical peak use of MB. Notably, several have phased-out completely, in advance of the 2015 deadline, for example Brazil, Morocco, Turkey, Zimbabwe, Lebanon and Costa Rica.

3.5.6. Assessment of progress in phase-out in Article 5 countries

The trends and indicators analysed above lead to the conclusion that Article 5 countries have achieved significant progress in reducing and phasing out MB, as illustrated by the following summary of the situation in 2013:

- Many Article 5 countries have implemented MLF projects and other activities that have led to MB reductions and phase out;

- Article 5 countries reduced their production for controlled uses from a peak of 2,397 tonnes in 2000 to 167 tonnes in 2013, which represents 13% of their baseline.
- Only 18 countries from a list of 148 are still using MB in 2013.
- Latin America with 71% of the remaining MB consumption is the slowest region in reducing its use: Mexico, Argentina, Guatemala and Chile were the world's top 4 MB consumers for controlled uses in 2013.
- Large consumption (>500 tonnes) remains in only one Article 5 country. Other 6 countries remain medium consumers (101-500 tonnes), while 12 are small ones (<100 tonnes).

3.6 Methyl Bromide use by sector – Controlled uses

3.6.1. Where Methyl Bromide was historically used

Since the beginning of the MB phase-out process some key sectors using this fumigant and which clearly needed alternatives became apparent. Sectors such as tomatoes, strawberries, peppers, eggplants, cucurbits, flowers and stored grain of different kinds were particularly impacted by the MB phase-out in some countries. The tobacco industry in general, used large amounts of MB for seedling production. In many countries, structures such as mills and warehouses were often disinfested with MB fumigation.

Soil uses were traditionally much larger than uses for postharvest and structures (about 90% vs. 10% of total consumption) but technically and economically feasible alternatives were equally important for both sectors.

Table 3-11 describes historic uses of MB for both controlled and exempted uses. The following sections provide an analysis of present, remaining uses of MB (as at 2013).

TABLE 3-11. HISTORIC USES OF METHYL BROMIDE WORLDWIDE

In soil:	• As a preplant treatment to control soil borne pests (nematodes, fungi and insects) and weeds of high-value crops such as cut flowers, tomatoes, strawberry fruit, cucurbits (melon, cucumber, squash), peppers and eggplant.
	• As a treatment to control 'replant disease' in some vines, deciduous fruit trees or nut trees;
	• As a treatment of seed beds principally against fungi for production of a wide range of seedlings, notably tobacco and some vegetables;
	• As a treatment to control soilborne pests in the production of pest-free propagation stock, e.g. strawberry runners, nursery propagation materials, which in some cases need to meet certification requirements;
In durables:	• As a treatment to control quarantine pests in import-export commodities or restrict damage caused by cosmopolitan insect pests in stored products such as cereal grains, dried fruit, nuts, cocoa beans, coffee beans, dried herbs, spices, also cultural artefacts and museum items;
	• As an import-export treatment to control quarantine pests and in some cases fungal pests in durable commodities such as logs, timber and wooden pallets, artefacts and other products;
In perishables:	• As an import-export treatment to control quarantine insects, other pests and mites in some types of fresh fruit, vegetables, tubers and cut flowers in export or import trade;
In "semi-perishables"	• As a treatment to control cosmopolitan or quarantine insects, to prevent fermentation or inhibit sprouting and fungal development in products that have high (>25% wb) or very high (>90%) moisture contents, for example high moisture dates and fresh chestnuts, and also some stored vegetables, e.g. yams, and ginger;
In structures and transport:	• As a treatment to control insects and rodents in flour mills, pasta mills, food processing facilities and other buildings;
	• As a treatment to control cosmopolitan or quarantine insect pest and rodents in ships and freight containers, either empty or containing durable cargo.

Source: MBTOC 2006 Assessment Report

3.6.2. Present MB applications (controlled uses in 2013)

The data reported in this section was compiled from several sources. MBTOC estimated the relative proportion of MB use in the soil and postharvest sectors in non-Article 5 countries by examining CUEs that have been authorised by the MOP Decisions and, where available, by national authorisation or licensing procedures.

Further, MBTOC carried out a survey amongst Article 5 ozone offices in about fifteen key countries that reported consumption larger than 5 metric tonnes of MB in 2012. 'The survey was also sent to countries reporting use higher than 50 tonnes of MB for QPS purposes and results of this analysis can be found in Chapter 6 of the Assessment Report. The survey sample covered over 90% of the A5 MB consumption for non-QPS purposes in 2013.

Most A 5 countries are implementing or have completed MLF projects and therefore keep updated information on MB use categories. As a result the quality of information on MB uses in A 5 countries is now more reliable than the past. However, some countries were able to provide only estimates rather than national survey data, and some countries did not submit a reply, so the MBTOC survey results in this chapter should be regarded as estimates rather than precise data. MBTOC also contacted UNEP-DTIE CAP offices in the three Article 5 regions where these operate (Latin America, Asia/ Pacific and Africa), national experts and NOU's and implementing agencies and is very grateful for the valuable information and help provided. Results from the survey and other sources mentioned above were used for the preparation of the following graphs.

3.6.3. Global overview of fumigant uses

MB has been used commercially as a fumigant since the 1930's (MBGC, 1994). It is a highly versatile product, used in many different applications. MB is mainly used for the control of soilborne pests (such as nematodes, fungi, weeds, insects) in high-value crops, and to a lesser extent for the control of insects, rodents and other pests in structures, transport and commodities. These categories of use can also be divided into two major groups:

- Quarantine and pre-shipment (QPS) uses, which were estimated to account for about 77% of total MB fumigant use in 2013 (as controlled uses are phased out, QPS use has become proportionally higher; it was reported at about 38% of total uses in 2005). These uses are not subject to Protocol reduction schedules. QPS uses include wooden pallets, durable commodities in the import/export trade, transport and some perishable commodities. Detailed information on QPS is provided in Chapter 4 of this Assessment Report.

- Non-QPS uses, which were estimated to account for approximately 23% of MB fumigant usage in 2013. These uses are controlled under the Protocol and as such are subject to phase-out schedules. Non-QPS uses include soil fumigation, structures (mills and food processing) durable stored products, semi-perishables and some transport.

Data on production and consumption of MB for QPS purposes is now much more accurate than in the past, since reported information was made public after the 20th MOP (Dec XX/6). The non-QPS tonnage was calculated on the basis of the tonnage of CUE uses authorised by the MOP and by parties during the licensing phase for non- Article 5 Parties and the results of the MBTOC survey of MB uses in Article 5 countries. Amounts used for QPS purposes are those reported by Parties and posted at the Ozone Secretariat website. Using this data, MBTOC estimated that approximately 77% of global use was for QPS (9.827 tonnes), while approximately 23% was used for non-QPS (2,882 tonnes). The latter comprised an estimated 94% for soil fumigation and about 6% for postharvest (durable commodities and structures) as indicated in Table 3-12.

TABLE 3-12. ESTIMATED USE OF MB FOR QPS AND NON-QPS IN 2005 AND 2013

Major sectors	Reported MB use in 2005 (mt)	% of total	Reported use in 2013	% of total
QPS	10,825	34%	9.827	77%
Non-QPS comprising:-	20,968	66%	2,882	23%
Soil			2,698	93%
Commodities			179	7%
Structures			5	0%
Total QPS & non-QPS	**31,793**	**100%**	**12,709**	**100%**

Sources: Reported MB production for QPS in database of Ozone Secretariat of December 2014, CUE uses authorised by MOP Decisions and by parties during licensing, and MBTOC survey of MB uses for controlled and exempted uses in Article 5 countries carried out in 2014.

3.6.3.1. Quarantine and pre-shipment

In 2013 the reported MB production for QPS was 9,915 tonnes. This represented about 80% of total global MB production for all purposes. Consumption for QPS uses was 9,827 tonnes. Detailed discussion on production, consumption and use of MB for QPS purposes can be found in Chapter 6 of this Assessment Report.

3.6.3.2. Non-QPS sectors

MBTOC has estimated that the total non-QPS use can currently be allocated to major sectors as follows: approximately 93% for soil fumigation, about 6% for commodities and less than 1% for structures in 2013. In non-Article 5 countries the estimated proportions in 2013 were approximately 92% for soil uses, about 8% for structures and durables. The results of the MBTOC survey indicated that Article 5 countries in 2013 used approximately 94% of MB for soil fumigation, and 6% for structures and durable commodities.

3.6.4. Non-QPS uses in non-Article 5 countries

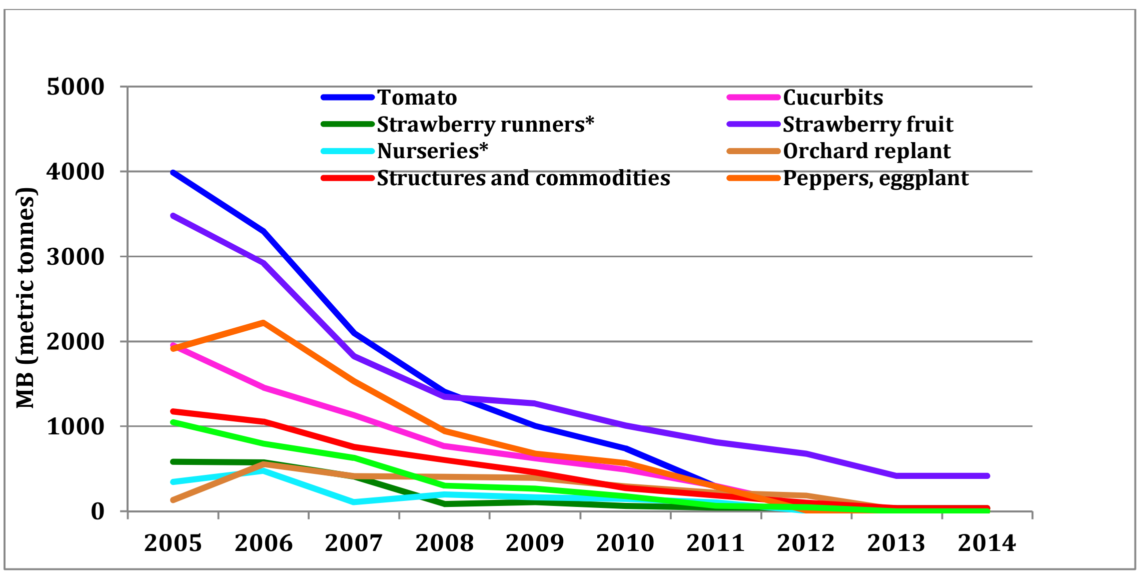
The remaining controlled uses of MB in non-Article 5 countries are allowed since 2005 as critical use exemptions only, and this has been fully followed by all non-A5 Parties. However, in 2011, Kazakhstan ratified the Protocol's Copenhagen Amendment and thus came into non-compliance with methyl bromide obligations, with a reported consumption of 10 tonnes of MB in 2011 and 32 tonnes in 2013. At the 26th MOP of November 2014, Kazakhstan presented a plan t return to compliance now contained in Decision XXVI/13, whereby they will cease all production for controlled uses by 1st January 2015 (except under the critical exemption process, should they find it necessary to apply).

CUEs have been authorised by the Meetings of the Parties for the following crops in specific circumstances: tomatoes, strawberry fruit, peppers, eggplant, cucurbits, ornamentals (cut flowers and bulbs), orchard replant, nurseries, strawberry runners, and several miscellaneous crops.

The postharvest uses of MB comprise specific circumstances in food processing structures such as flour mills, pasta mills, durable commodities such as dried fruits, nuts, rice, and other products such as cheese in storage, cured pork products in storage and fresh market chestnuts.

Figure 3-8 illustrates the trends in the CUE tonnage authorised by MOP Decisions for individual major crops and postharvest uses, from 2005 to 2014. Some parties made further reductions in the CUE tonnages during the licensing procedures, but these reductions are not taken into account in Figure 7. Substantial reductions in the MOP-authorised tonnage can be seen for all crops since 2005, and in fact complete phase-out has been achieved in most crops. The USA has indicated that 2014 was the last year of submission of a CUN for strawberry fruit (for use in 2016). This leaves strawberry runners as the sole soil sector for which CUN are being requested by non-A5 Parties at present.

FIGURE 3-8. MAJOR USES OF MB CUES AUTHORISED BY MOP FOR NON-ARTICLE 5 PARTIES, 2005–2014.



* The USA classifies MB uses for nurseries (including strawberry runners) as QPS and are not accounted for here

Source: Authorised lists of CUEs in Decisions published in the reports of the meetings of the Parties to the Montreal Protocol 2004-2014.

The chart indicates metric tonnes authorised for CUEs by MOP Decisions. Some parties made further tonnage reductions (not shown in this chart) during the licensing procedures.

3.6.5. Major soil uses in non-Article 5 countries

This section examines the trends in the soil uses for major crops in the period 2005-2011. In Figure 8, the left-hand chart shows the quantity of MB authorised by MOP Decisions for strawberry fruit CUEs in individual parties. (Some parties made further reductions in CUEs at the licensing phase but these reductions are not shown in the Figure above). The number of countries using CUEs for strawberry fruit was 8 in 2005, 2 in 2010 (Israel and US) and only one since 2011 (USA). The total CUE tonnage authorised by MOP Decisions for strawberry fruit was reduced by over 90% since 2005. Additional reductions were also made at national level during the licensing phase, but are not shown in these graphs. The USA has indicated that 2014 was the last year they have requested a CUE for strawberry fruit (for use in 2015)

The total CUE tonnage initially authorised for tomatoes by the MOP in 2005 has now been completely replaced. The number of countries that received CUEs for tomato was 5 in 2005, and 2 in 2010 (Israel and USA). Nominations for this use from non-A5 Parties ceased completely in 2010. As indicated in Fig. 3-8 above, other key sectors included cucurbits, peppers and eggplant, ornamentals (cut flowers and bulbs) and orchard replant. All of these sectors have now fully transitioned to alternatives in non-A5 Parties.

3.6.6. Structures and commodities uses in non-Article 5 countries

Postharvest uses can be divided into structures and commodities. Structures comprised more nearly 70%of the postharvest CUE tonnage authorised in 2013, but requests for critical uses in structures have now stopped completely. The only postharvest use remaining at present is for cure ham in the USA. See section 3.4.5 and table 3-7.

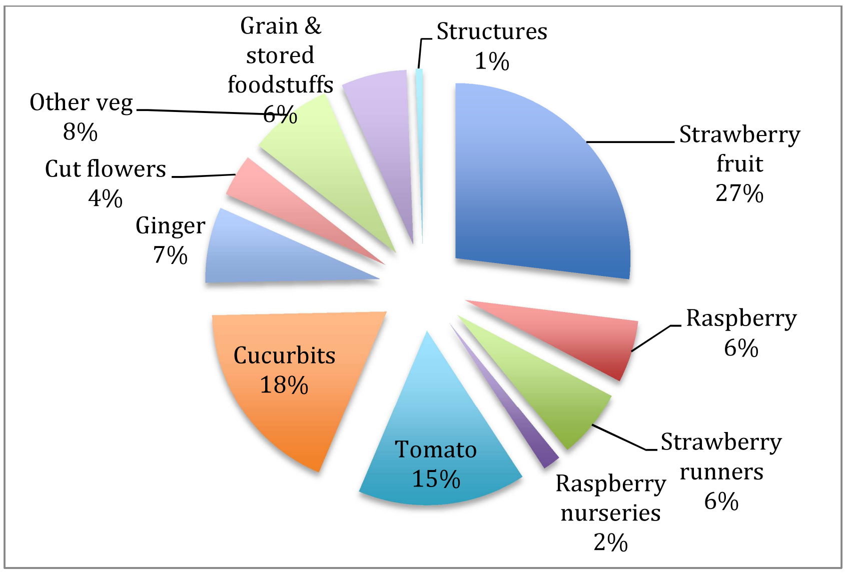
3.6.7. Major controlled uses in Article 5 countries

This section provides an overview of major controlled (non-QPS) uses in Article 5 countries. The recent MBTOC survey carried out in 2014, identified the major MB uses in 2013 as follows: approximately 94% was used for soil fumigation (i.e. for treatment of soil before planting crops), approximately 6% for durable commodities and less than 1% for structures (excluding QPS). These survey results should be regarded as estimates rather than precise data. Percentage variations between results obtained in 2005, 2009 and 2013 are not directly comparable, since in that period large MB users have phased out completely and others have significantly reduced consumption. This may result in sectors that were small in the past now occupying a larger proportion of the total.

Figure 3-12 presents the survey results for A5 countries, indicating that the major crops/ sectors using MB in 2013 were cucurbits (i.e. melon, cucumber and similar crops) (18%), tomatoes (15%) strawberry fruit and other berries (raspberries, blueberries, blackberries; this use particularly reported in Mexico) (33% combined), cut flowers (4%) ginger (7%), strawberry runners and raspberry nurseries (8% combined), and other vegetables 8% (peppers, eggplant, green beans and others). About 7% of the MB used was allocated to the postharvest sector, 6% to grain and stored foodstuffs and about 1% to structures (flour mills).

Chapters 5 and 6 of this Assessment Report contain information on alternatives to MB for these key sectors. Further detailed information can also be found in previous MBTOC Assessment Reports of 2010, 2006 and 2002.

FIGURE 3-12. MB USE SURVEY RESULTS: MAJOR CROPS USING MB IN ARTICLE 5 COUNTRIES IN 2009.



Source: MBTOC survey of MB uses for controlled purposes (via the Ozone Secretariat) and MBTOC estimates

3.6.8. Critical Use Nominations from Article 5 Parties

With the 2015 deadline for complete phase-out of controlled uses of MB now in force for Article-5 Parties, nominations for critical uses have now been submitted for some sectors as shown in Table 3-13. As noted in previous sections, critical use nominations have been submitted in the past by non-Article 5 Parties in all of these sectors.

TABLE 3-13. CUNS (TONNES) SUBMITTED BY ARTICL-E5 PARTIES IN 2014 AND 2015 FOR 2015 AND 2016 (FIGURES IN METRIC TONNES)

Country	Sector	CUN Request for 2015 or	CUE Approved for 2015	CUN Request for 2016 *
Argentina	Strawberry fruit	110.0	64.30	77.0
	Tomato	145.0	70.0	100.0
China	Ginger (Field)	90.0	90.0	90.0
	Ginger (Protected)	30.0	24.0	24.0
Mexico	Raspberry nurseries	70.0	43.539	56.018
	Strawberry nurseries	70.0	41.418	64.960
South Africa	Commodities	-	-	70.0

* To be decided at 27th MOP, November 2015

3.7. References

ICRA (2014). Intech Pharma Private Ltd. Accessed January 2015. http://www.icra.in/Files/Reports/Rationale/Intech%20Pharma_r_07102014.pdf

MBTOC (2011) Methyl Bromide Technical Options Committee 2010 Assessment Report. UNEP, Nairobi, 424 pp.

Montzka, S. (2009) The influence of methyl bromide from QPS applications on the ozone layer. Presentation on Scientific Assessment Panel report. Workshop on methyl bromide use for quarantine and pre-shipment purposes, 3 November 2009, MoP-21, Port Ghalib.

Ozone Secretariat (2014) Data Access Centre database of ODS data reported by Parties to the Montreal Protocol under Article 7, website accessed November 2014.

Ravishankara, A.R, Kurylo, M.J, and Ennis, C.A (eds.) (2008) Trends in Emissions of Ozone-Depleting Substances, Ozone Layer Recovery, and Implications for Ultraviolet Radiation Exposure. Synthesis and Assessment Product 2.4. Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Compiled under the auspices of the National Research Council (NRC) and National Science and Technology Council. November 2008. Department of Commerce, NOAA's National Climatic Data Center, Asheville, NC, p.22, 44, 53.

SAP (2007) Scientific Assessment of Ozone Depletion: 2006. World Meteorological Organisation, Geneva. p.8.3 and 8.29.

SAP (2014). Scientific Assessment of Ozone Depletion. UNEP, Nairobi http://ozone.unep.org/Assessment_Panels/SAP/Scientific_Assessment_2014/Scientific_Assessment_Report_2014.pdf

4

Chapter 4. Alternatives to methyl bromide for Quarantine and Pre-shipment applications

4.1. Introduction

Quarantine and pre-shipment (QPS) treatments with methyl bromide (MB) are used to kill pests on perishable and durable commodities listed as quarantine pests (quarantine); on durable and perishable commodities or in trade to render them "practically free" of noxious pests and other organisms (pre-shipment), QPS treatments are also used on soils, and in structures and commodities to eliminate or control exotic organisms of quarantine significance. Periodic QPS uses of MB have been made within countries to try and prevent spread of pests, when an exotic pest is found in a new region. Since 2003, some countries have interpreted that treatment to avoid movement of soil pests within a country on propagation material may also qualify for QPS MB use.

QPS treatments with methyl bromide (MB) are generally applied to commodities in trade between countries and between quarantine regions inside a country. *Perishable commodities* include fresh fruit and vegetables, cut flowers, ornamental plants, fresh root crops and bulbs. *Durable commodities* are those with low moisture content that, in the absence of pest attack, can be safely stored for long periods and include foods such as grains, dried fruits and beverage crops and non-foods such as cotton, wood products and tobacco and other non-agricultural goods that may harbour quarantine pests such as tyres, household goods, and industrial goods.

The production and consumption of methyl bromide (MB) for QPS is exempted from the control measures (phaseout) agreed under Article 2H para 6 of the Montreal Protocol. Since the MBTOC 2010 Assessment Report, MBTOC has continued providing detailed information on alternatives to MB for QPS uses through the TEAP Progress Reports as well as responses to Decisions from the MOP (i.e. Decisions XXIII/5 and XXIV/15, see Table 4-1), following previous work reported in detail in the MBTOC 2010 Assessment Report (see MBTOC, 2011, chapter 6).

Development of methyl bromide alternatives for Quarantine applications on commodities continues to be a difficult process, exacerbated by the multitude of commodities being treated, the diverse situations where treatments are applied, a constantly changing trade and regulatory landscape, requirements for bilateral agreement on QPS measures, requirement for very high levels of proven effectiveness, often for several different target species, lack of patent coverage or other commercial protection for some potential alternatives, and the low price and plentiful supply of methyl bromide for QPS purposes. Regulations favouring methyl bromide treatment or prescribing methyl bromide alone are a major barrier to adoption of alternatives as often there is little incentive for the regulation to be changed.

4.2. Reasons for QPS uses of methyl bromide

Many perishable and durable commodities in trade and storage can be attacked by pests including insects, mites and fungi, causing loss of quality and value. These commodities may also carry pests and diseases that can be a threat to agriculture, health or the environment. There are a wide variety of measures that can be taken to manage these pests so that the damage they cause or risk that they pose is lowered to an acceptable level. Fumigation with MB is one such measure.

Most current uses of MB on durables and perishable commodities worldwide are highly specialised. MB use has been in routine use for decades as a well-developed system with a good record of successful use. Some examples of current QPS uses include:

- Fumigation of cut flowers found to be infested on arrival in the importing country with quarantine pests (quarantine treatment)
- Fumigation of fruit before export to meet the official phytosanitary requirements of the importing country for mandatory fumigation of an officially-listed quarantine pest (quarantine treatment)
- Fumigation of grain before export to meet the importing country's existing import regulations that require fumigation of all export grain consignments (pre-shipment treatment)
- Fumigation of log exports either prior to shipment or on arrival against official quarantine pests.

Further examples of treatments that may be QPS have been provided in previous reports.
Requirements for MB alternatives are often compared with MB's properties which include such desirable features as:

- Rapid speed of treatment. This is particularly useful for perishable products that must be marketed rapidly;
- Low cost for fumigation;
- Relatively non-corrosive and applied easily to shipping fumigation facilities, containers or to bagged, palletised or bulk commodities 'under sheets';
- A long history of recognition as a suitable treatment by quarantine authorities;
- Broad registration for use;
- Good ability to penetrate into the commodity where pests might be located; and
- Rapid release of gas from the commodity after exposure

MB also has a number of undesirable features including:

- A high level of toxicity to humans;

- Odourless, making it difficult to detect;
- A significant ozone depleting potential;
- Adverse effects on some commodities, particularly loss of viability, quality reduction, reduced shelf life and taint;
- Slow desorption from some commodities and at low temperatures, leading to hazardous concentrations of MB in storage and transport subsequent to fumigation; and
- Excessive bromide residues retained in the product.

In certain situations, MB is the only treatment approved by national quarantine authorities for QPS applications for international trade. Quarantine treatments are supported by extensive scientific data documenting the responses of pests to MB to verify a high level of treatment efficacy for pests that are considered to be serious threats to the importing country. Intracountry quarantines are aimed at curtailing the spread, containing or eradicating spread of quarantine pests that may be established in a restricted area or region of that country. In some cases, production of propagation material of certified high plant health status is considered a quarantine activity. Pre-shipment treatments are aimed at ensuring that products in international trade meet set standards of lack of pests.

4.3. Definitions of Quarantine and Pre-shipment

4.3.1. Origin and original intent of the QPS exemption

At the 1992 Meeting of the Parties in Copenhagen that established methyl bromide as a controlled Ozone Depleting Substance, Article 2H of the Protocol specifically excluded QPS from control measures when it stated, *inter alia*:

> *'The calculated levels of consumption and production ...shall not include the amounts used by the Party for quarantine and pre-shipment applications'*

This was the first time that QPS was mentioned in the Protocol documentation. Definition of 'quarantine' and 'pre-shipment' was deferred to a later meeting.

At the time that Article 2H was agreed in Copenhagen in 1992, the Parties understood that there were no alternatives to MB for a diverse range of treatments carried out with MB for QPS. The Parties recognised that although QPS consumption was about 10% of global MB consumption at the time, this volume was nevertheless very significant in allowing inter- and intra-country trade in commodities *in the absence of site-specific alternatives*.

Unless site specific alternatives to MB were available for QPS that were tested and approved in both A 5 and non-A 5 countries, there was a strong likelihood of disruption to international trade if the exemption for QPS were not available.

Invasions by new pest species into a country or region can have serious adverse effects economically and on agricultural production and natural resources. The combined economic costs of new pests may be significant, with implications for environmental policy and resource management; yet full economic impact assessments are rare at a national scale.

The containment and eradication of a newly discovered pest is generally difficult, often highly controversial, and frequently requires substantial resources costing millions of dollars and the commitment of all involved, however there are many examples of successful eradication campaigns (MBTOC, 2011). Methyl bromide treatment is considered an important tool for some eradication and containment attempts. It was successfully used in the eradication of khapra beetle from both western USA in the 1950s and more recently from Perth, Western Australia (Emery *et al.,* 2010). It was recently being used as a soil fumigant to contain and possibly eradicate the exotic nematodes *Globodera pallida* and *R. rostochiensis* in parts of USA (TEAP, 2009).

4.3.2. 'Quarantine' and 'Pre-shipment'

The scope of the QPS exemption set out in Article 2H paragraph 6 has been clarified in Decisions VII/5 and XI/12 of the Protocol relating to the terms 'Quarantine' and 'Pre-shipment'. TEAP (2002) has provided some discussion and examples of cases that might or might not fall within the QPS exemption. There is also discussion of the scope of the exemption from control under the Protocol for QPS uses of methyl bromide in TEAP (1999) and the UNEP/IPPC (2008) publication 'Methyl Bromide: Quarantine and Pre-shipment Uses'. Differences in interpretation of the scope and application of the QPS exemption by individual Parties have led to some differences in the uses that were reported as QPS in the data accessed by MBTOC.

Specifically, the Seventh Meeting of the Parties decided in Decision VII/5 that:

a) *"Quarantine applications",* with respect to methyl bromide, are treatments to prevent the introduction, establishment and/or spread of quarantine pests (including diseases), or to ensure their official control, where:

   i. *Official control is that performed by, or authorised by, a national plant, animal or environmental protection or health authority;*
   ii. *Quarantine pests are pests of potential importance to the areas endangered thereby and not yet present there, or present but not widely distributed and being officially controlled*

b) *"Pre-shipment applications"* are those treatments applied directly preceding and in relation to export, to meet the phytosanitary or sanitary requirements of the importing country or existing phytosanitary or sanitary requirements of the exporting country;

The definition of 'Pre-shipment' is unique to the Montreal Protocol. It is given and elaborated in Decisions VII/5 and XI/12. The Eleventh Meeting of the Parties decided in Decision XI/12 that pre-shipment applications are *"those non-quarantine applications applied within 21 days prior to export to meet the official requirements of the importing country or existing official requirements of the exporting country"*.

As per decision VII/5, official requirements are those, which are "performed by, or authorised by a national plant, animal, environmental, health or stored product authority".

The definition of a quarantine pest under the Montreal Protocol differs from that under the IPPC (International Plant Protection Convention) by one word, 'economic': the Montreal Protocol refers to *"pests of potential importance"* while the Convention definition refers to "*pests of potential economic importance*". However, under the IPPC, it has been clarified in a supplement to ISPM No. 5 that 'economic' includes the effect of changes (e.g. in biodiversity, ecosystems, managed resources or natural resources) on human welfare.

The IPPC deals with pests of plants, and not of livestock, which would have potential economic impact, again including environmental considerations. The scope of the IPPC is analysed in further detail in MBTOC and TEAP reports (MBTOC, 2011, TEAP, 2010). Its definition of a quarantine pest relates to official control, specifically pests of propagation material and seeds for planting, and do not include pests that affect quality in storage.

The Montreal Protocol's definition covers environmental and other pests that might endanger a region without direct quantifiable economic loss. An interpretation of Decision VII/7 is that the use of methyl bromide as a quarantine treatment may only be for pests that are officially recognised as quarantine pests and must be officially authorised by a competent authority.

QPS treatments under the Montreal Protocol relate not only to official phytosanitary treatments, but may also apply to 'sanitary' treatments, e.g., against human or animal pathogens and vectors (e.g. mosquitoes), covered by International Agreements (IAs, multilateral agreements) such as the World Animal Health Organisation (OIE) and World Health Organization (WHO).

Pre-shipment treatments target non-quarantine pests that may be present in both the exporting and importing country. These pests are usually ones that affect storage or end-use quality of the exported commodities, and are outside the direct scope of the IPPC. However, the model Phytosanitary certificate from Guidelines for Phytosanitary Certificates provided in ISPM 12 contains the following optional clause: "They are deemed to be practically free from other pests." This relates to Pre-shipment uses where a certification is needed to meet commodity shipping requirements.

As a result of the broad coverage of the Montreal Protocol QPS concept, the actual QPS uses are covered by several different International Agreements and domestic regulatory bodies.

4.4. Decisions relating to QPS use of methyl bromide

Since 1992, there have been various Decisions taken by the Parties to the Montreal Protocol related to this QPS exemption. These have concerned definitions and clarification of definitions, and have also requested TEAP to conduct closer evaluations of MB uses for QPS purposes and their possible alternatives or opportunities for reducing emissions. TEAP has responded to these Decisions through its MBTOC as well as appointing special task forces.

Table 4-1 below lists decisions relating to QPS uses of MB and summarises the main issues comprised by each. Reports prepared in response to such Decisions – when requested by the Parties – can be found at the Ozone Secretariat website.

TABLE 4-1: SUMMARY OF DECISIONS RELATING TO QPS USES OF METHYL BROMIDE

Decision No.	Decision title	Summary
VI/11(c)	Clarification of «quarantine» and «pre-shipment» applications for control of methyl bromide	Gives definitions of quarantine and pre-shipment. Urges non-A5 Parties to refrain from MB use and use non ozone-depleting technologies whenever possible. Where MB is used Parties are urged to minimise emissions and use containment and recovery and recycling methodologies to the extent possible
VII/5	Definition of «quarantine» and «pre-shipment» applications	Provides definitions for QPS. In applying them, all countries are urged to refrain from the use of MB and to use non-ozone depleting technologies when possible. Where MB is used, Parties are urged to minimise emissions and use MB through containment and recovery and recycling methodologies to the extent possible
XI/12	Definition of pre-shipment applications	Defines a maximum time period of 21 days prior to export for application of treatments to qualify as 'Pre-shipment'
XI/13	Quarantine and pre-shipment	Requests that the 2003 TEAP Report evaluate the technical and economic feasibility of alternatives that can replace MB for QPS uses; and to estimate the volume of MB that would be replaced by the implementation of such alternatives, reported by commodity and/or application. Requests Parties to review their national regulations with a view to removing the requirement for the use of MB for QPS where alternatives exist. Urges Parties to implement procedures to monitor the uses of MB by commodity and quantity for QPS uses. Encourages the use of recycling and recovery technologies for those uses with no feasible alternatives
XVI/10	Reporting of information relating to quarantine and pre-shipment uses of methyl bromide	Requests TEAP to establish a QPS Task Force to prepare the report under Dec XI/13; requests Parties to submit information on QPS uses of MB if not already done so. Requires TF to report on the data submitted by Parties in response to the April 2004 methyl bromide QPS for the 25th OEWG. Data to be presented in a written report in a format aggregated by commodity and application so as to provide a global use pattern overview, and to include available information on potential alternatives for those uses identified by the Parties' submitted data
XVII/9	Critical-use exemptions for methyl bromide for 2006 and 2007	To request the QPSTF to evaluate whether soil fumigation with MB to control quarantine pests on living plant material can in practice control pests to applicable quarantine standards, and to evaluate the long-term effectiveness of pest control several months after fumigation for this purpose, and to provide a report in time for the 26th meeting of the OEWG.
XX/6	Actions by Parties to reduce methyl bromide use for quarantine and pre-shipment purposes and related emissions	Requests the QPSTF, in consultation with the IPPC secretariat, to review all relevant, currently available information on the use of MB for QPS applications and related emissions; to assess trends in the major uses; available alternatives; other mitigation options and barriers to the adoption of alternatives; and to determine what additional information or action may be required to meet those objectives.

XXI/10	Quarantine and preshipment uses of methyl bromide	Requests the TEAP and its MBTOC in consultation with other relevant experts and the IPPC to submit a review on the technical and economic feasibility of alternatives for a. Sawn timber and WPM (ISPM 15); b. Grains and similar foodstuffs; c. Pre-plant soil use; and d. Logs, including their current availability and market penetration rate and their relation with regulatory requirements and other drivers for the implementation of alternatives. Also requests an update on estimated replaceable quantities of MB used for QPS purposes distinguishing between A5 and non-A5 parties and a description of a draft methodology including assumptions, limitations, objective parameters and variations within and between countries that TEAP would use for assessing the technical and economical feasibility of alternatives, of the impact of their implementation and of the impacts of restricting the quantities of MB production and consumption for QPS
XXIII/5	Quarantine and pre-shipment uses of methyl bromide	Invited Parties in a position to do so to report on the amount of MB used to comply with phytosanitary requirements of destination countries, and on phytosanitary requirements for imported commodities that must be met with MB. And requested TEAP/MBTOC to summarize article 7 data on QPS and provide regional analysis; provide guidance on procedures and methods for data collection on MB use for QPS; and prepare a concise report based on responses received.
XXIV/15	Reporting on information on quarantine and pre-shipment use of methyl bromide	Requested Parties to comply with the reporting requirements of Article 7 and to provide data on the amount of methyl bromide used for quarantine and pre-shipment applications annually and invited Parties in a position to do so, on a voluntary basis, to supplement such data by reporting to the Secretariat information on methyl bromide uses recorded and collated pursuant to the recommendation of the Commission on Phytosanitary Measures. A possible request to TEAP to undertake a trend analysis of MB consumption in the QPS sector to be considered at the OEWG33 and MOP25

Source: Montreal Protocol Handbook and Ozone Secretariat website, 2015

4.5. Policies on QPS uses of methyl bromide

4.5.1. Legislation that requires methyl bromide use for QPS

Use of MB for QPS for commodity treatments is mostly associated with international trade where regulations are usually imposed by the importing country on the exporting country. MB is used in response to either pests found during inspection and/or needed for a phytosanitary certificate, which requires the commodity to be free from quarantine pests and MB may be used or certified that MB has been applied at the rate required by the importing country. The driving force for what treatments are required, allowed or not allowed are those of the importing country. In the case of bilateral trade and quarantine use, the importing country may allow the treatment to be conducted in the importing country, but often the treatment must be conducted in the exporting country. In many cases, QPS use of MB is covered by a number of national and local regulations, which often need to be considered in conjunction with one another.

There are also instances where internal regulations are imposed by national or state jurisdictions to use MB for movement of commodities across state or county borders. These relate to movement of quarantine pests that are known to be absent within the state or county.

MBTOC has encountered very few regulations that required or specified MB use only, however those that do tend to use substantial amounts of MB such as in the log trade. There are many regulations that require plants to be free of insect and other pests, with MB as the only practical fumigant available especially at portside in the importing country i.e. when inspection at the importing port finds quarantine pests fumigation with MB may be the only available way to destroy the infestation, short of destroying the shipment. In some cases where MB is not deleterious to the commodity and relatively cheap, there may be little incentive to search for alternatives especially since the alternative treatments usually have to be developed in the exporting country which may lack resources to do this.

Research to develop and confirm effectiveness of alternatives for quarantine treatments for international trade is expensive and time consuming and generally must be done in the exporting country because only they have access to the pest in question. A very high level of efficacy (often Probit 9 – LD 99.9968%) is usually required for quarantine pests where methyl bromide fumigation is used as the major or sole control step.

4.5.2. Policies and recommendations on methyl bromide and its alternatives under the International Plant Protection Convention

Some international standards produced by the IPPC (ISPMs) relate directly or indirectly to phytosanitary (quarantine) processes that either use methyl bromide at present or avoid the need for QPS methyl bromide treatments. The main standards relating to methyl bromide are:

Other ISPM standards (https://www.ippc.int/index.php?id=ispms&no_cache=1&L=0) relevant to methyl bromide treatments and alternatives are:

- ISPM No. 02 (2007) Framework for pest risk analysis
- ISPM No. 10 (1999) Requirements for the establishment of pest free places of production and pest free production sites
- ISPM No. 11 (2004) Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms
- ISPM No. 12 (2001) Guidelines for phytosanitary certificates
- ISPM No. 14 (2002) The use of integrated measures in a systems approach for pest risk management
- ISPM No. 15 (2006) Treatment of Wood Packaging Materials
- ISPM No. 16 (2002) Regulated non-quarantine pests: concept and application
- ISPM No. 18 (2003) Guidelines for the use of irradiation as a phytosanitary measure
- ISPM No. 21 (2004) Pest risk analysis for regulated non quarantine pests
- ISPM No. 22 (2005) Requirements for the establishment of areas of low pest prevalence

- ISPM No. 24 (2005) Guidelines for the determination and recognition of equivalence of phytosanitary measures
- ISPM No. 26 (2006) Establishment of pest free areas for fruit flies (Tephritidae)
- ISPM No. 28 (2009) Phytosanitary treatments for regulated pests
- ISPM No. 29 (2007) Recognition of pest free areas and areas of low pest prevalence
- ISPM No. 30 (2008) Establishment of areas of low pest prevalence for fruit flies (Tephritidae)

The main ISPM that specifically deals with a major volume use of methyl bromide is ISPM 15, as revised (IPPC 2009b). The standard deals with the disinfestation of wood packaging material in international trade as a quarantine measure against various pests of wood and forests. The standard contains specifications for both heat treatment and methyl bromide fumigation, whilst recognising that methyl bromide is an ozone-depleting substance (IPPC 2006, 2009). The ISPM 15 standard was revised in 2009 and encourages national quarantine authorities to promote the use of an approved MB alternative: *'NPPOs are encouraged to promote the use of alternative treatments approved in this standard'* (CPM-4 report, April 2009, p.11 of Appendix 4).

ISPM 15 was updated at CPM-8 in April 2013, incorporating another heat treatment, the dielectric heating (e.g. microwave, radio frequency), for wood packaging material composed of wood not exceeding 20 cm that must be heated to achieve a minimum temperature of 60 °C for 1 continuous minute throughout the entire profile of the wood (including its surface). The prescribed temperature must be reached within 30 minutes from the start of the treatment. The Technical Panel on Phytosanitary Treatments (TPPT) accepted the treatment schedule without a thickness limit and recommended the IPPC Standards Committee to send it for member consultation.

Dielectric heating Radio frequency (RF) uses much lower frequencies than microwaves (MW), so the RF wave has a longer penetration depth than the MW, and can be used to treat wood with larger dimensions than the 20 cm accepted by ISPM 15. Another characteristic of dielectric heating (DH) is the potential for selectively heat materials, offering an advantage over conventional heating for insect control due to the selective heating of insects due to their higher water content in relation to the wood itself. Another advantage of dielectric heating systems is that they are reported to convert 50–70% of the energy to heat, in comparison to 10% efficiency in conventional ovens.

Another alternative to methyl bromide for fumigation of wood packaging material that is under review under IPPC panels and in process of approval is sulfuryl fluoride (SF). TPPT accepted 2 different schedules, one for the PineWood Nematode (PWN) and insects and other for insects only, and recommended to the IPPC Standards Committee for adoption by the CPM. The different treatments, one for wood-borne insects (less severe schedule) and for PWN and wood-borne insects (with a more severe schedule) were established because this would make the treatments more targeted and prevent unnecessarily high dosing of timber not infested with PWN. The treatments are meant to be used on debarked wood, not exceeding 20 cm in cross-section and not exceeding 60% moisture content.

Other recent reviews and recommendations that may impact MB use for QPS purposes are:

- **Cold treatments** for *Bactrocera tryoni* on oranges (*Citrus sinensis*), on tangors (*Citrus reticulata* × *C. sinensis*), on lemons (*Citrus limon*) in the process for approval. The TPPT accepted the schedules and recommended to the IPPC Standards Committee for adoption by the CPM to be included in ISPM 28.

- **Irradiation treatment** for mealybugs (Pseudococcidae) for all fruits and vegetables in the process for approval. The TPPT accepted the schedule and recommended to the IPPC Standards Committee for adoption by the CPM to be included in ISPM 28.

- **Vapour heat treatment** for *Bactrocera tryoni* on mangoes (*Mangifera indica)* in the process for approval. TPPT accepted the schedule and recommended the IPPC Standards Committee to send it for member consultation.

4.5.2.1. Phytosanitary Temperature Treatments Expert Group

The Phytosanitary Temperature Treatments Expert Group (PTTEG) was created under the support of the IPPC. The mission of the PTTEG is to provide a mechanism where critical phytosanitary temperature treatment issues can be addressed through discussion and collaborative research. The Expert Consultation on Cold Treatments (ECCT) meeting was organized by the IPPC Secretariat and hosted by the National Plant Protection Organization (NPPO) of Argentina in December 2013. The objective of the Meeting was to provide the foundation for submissions of phytosanitary treatments to be considered for International Standards for Phytosanitary Measures through the scientific input of the participants from data gathered from scientific research. Seventeen experts from 10 different countries participated.

The group agreed that any research should focus on the sound scientific reasoning behind each step of development of cold phytosanitary treatments and not detailed prescription conducting of phytosanitary treatment. The ECCT identified a series of issues to be addressed by cold treatment researchers based on scientific, technical and logistical reasons. Finally the ECCT participants agreed that work on cold treatments and networking among researchers would be useful and agreed to form a new group that would also cover all temperature phytosanitary treatments. The ECCT participants name this group “Phytosanitary Temperature Treatments Expert Group” and the scope of this group can be extended for all phytosanitary treatments in order to provide a mechanism where critical phytosanitary treatment issues can be addressed through discussion and collaborative research and providing scientific analysis and review of global phytosanitary treatments issues and new information. The group agreed to have a next meeting in August 2015 in Nelspruit, South Africa.

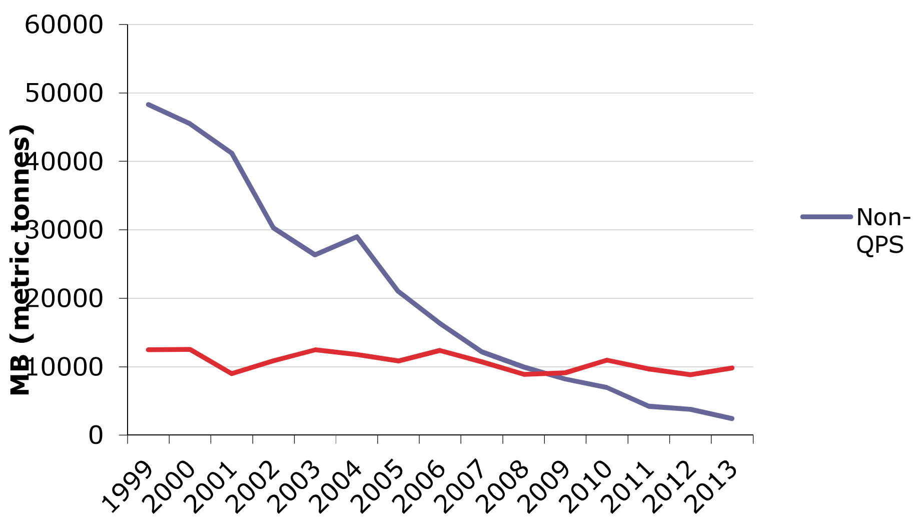
4.6. *Production and consumption of MB for QPS uses*

4.6.1. Introduction

Since 1999 there has been a continuous reduction in controlled uses of methyl bromide ("non-QPS") as alternatives have been adopted in the majority of countries countries in observance of the phase-out deadlines agreed undert the Protocol. By the end of 2013, the last date for which official consumption data were available at the time of writing this report, 88% of controlled uses of MB in Article 5 Parties and 98% of such uses in non-Article 5 Parties had been replaced.

In contrast, QPS consumption has not decreased but remained relatively constant over the last decade, as shown in Figure 4-1. In 2009 the QPS use exceeded non-QPS for the first time, being 46% higher. This was partly due to the continued decrease in the non-QPS uses, as well as recategorisation by some Parties of uses previously considered non QPS to QPS. Since 2003 an amount of methyl bromide included in the initial baseline estimates for controlled MB uses, between 1400 to 1850 t, has been recategorised to QPS MB use for the preplant soil treatment of propagation material. In 2013, reported QPS consumption was over three times larger than controlled consumption.

FIGURE 4-1: COMPARISON OF NON-QPS AND QPS CONSUMPTON IN THE PERIOD 1999 TO 2013

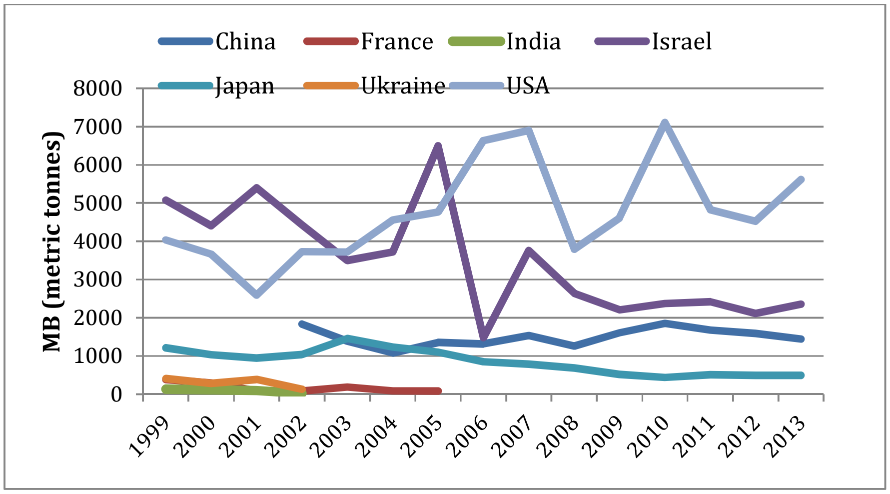


Source: Ozone Secretariat Database, January 2015

4.6.2. QPS Production trends

Global production of methyl bromide for QPS purposes in 2013 was 9,915 tonnes, increasing by about 12% from the previous year. Although there are substantial variations in reported QPS production and consumption on a year-to-year basis, there is no obvious long term increase or decrease. QPS production currently occurs in four Parties (USA, Israel, China and Japan), as indicated in Figure 4-2. According to the Article 7 reports, QPS production in France, Ukraine and India ceased by 2003, 2003 and 2006 respectively. In A5 countries, India last reported QPS production in 2002 and has not reported any production since that time. China's production each year has ranged from 1,077 to 1,836 tonnes since 2002. Compared to 2010, the quantity of QPS produced in 2013 increased in Israel and the USA, but declined slightly in China and Japan (Figure 4-2). Japan shows a reduction trend, whereas the USA and Israel have shown relatively large annual fluctuations over the last 15 years as shown.

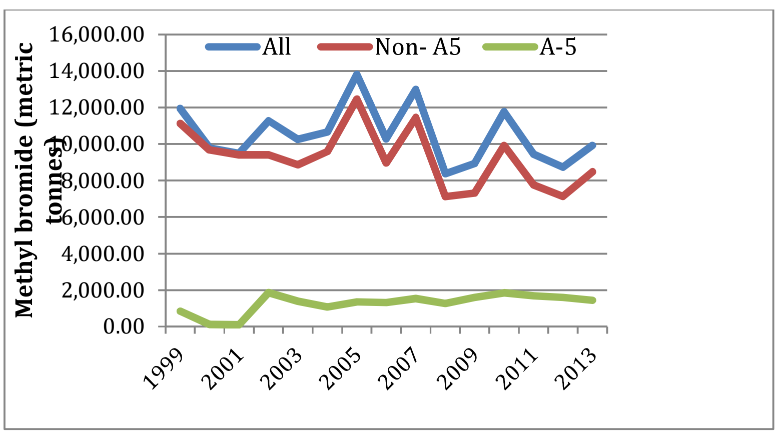
FIGURE 4-2: METHYL BROMIDE PRODUCTION FOR QPS PURPOSES, PER PARTY 1999 TO 2013



Source: Ozone Secretariat Database, January 2015

The global production trend closely follows that of non-A5 Parties (Fig. 4-3)

FIGURE 4-3: GLOBAL, NON-A5 AND A5 QPS PRODUCTION FROM 1999 TO 2013

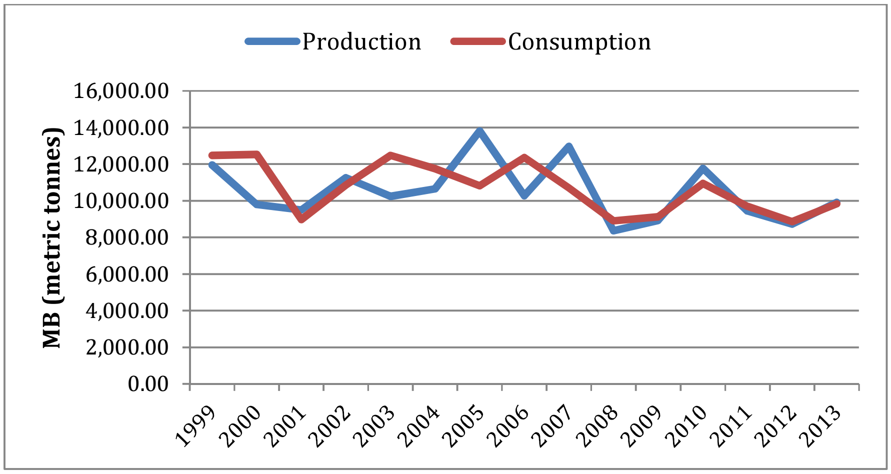


Source: Ozone Secretariat website data access centre, January 2015

4.6.3. Production vs consumption

In 2013, global QPS consumption was slightly lower than global production. However, production and consumption fluctuate from year to year (Fig. 4-4). Production has exceeded consumption in several years since 1999. It may indicate that producers produce more QPS than can be consumed in the year of production, leading to consumption that exceeds production in the following year.

FIGURE 4-4. GLOBAL CONSUMPTION AND PRODUCTION OF QPS FROM 1999 TO 2009



Source: Ozone Secretariat website data access centre, December 2014

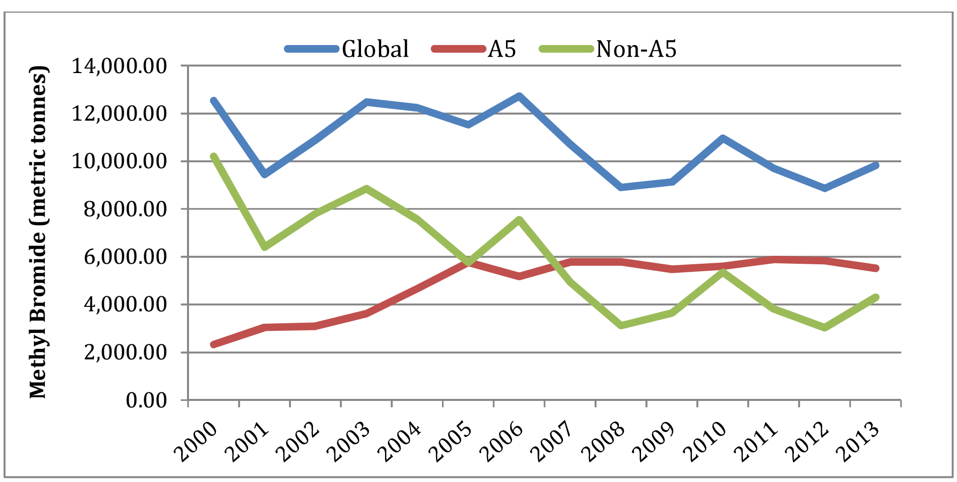
4.6.4. QPS Consumption trends

4.6.4.1. Global QPS consumption

In 2013, QPS consumption in A5 Parties (5,521 tonnes) represented 56% of global consumption; non-A5 Party consumption, at 4,307 tonnes was 46%. In 2012 the proportions were somewhat different with A5 consumption representing 66% of global consumption and non-A5 consumption 34%.

Overall however, consumption in Article-5 Parties has trended upward over the past 15 years (Fig. 4-5), whereas consumption in non-A5 Parties has trended downward over the same time period, with global QPS consumption remaining relatively stable overall. Global consumption averaged 10,850 tonnes over the period 1999 to 2013 (Fig. 4-5, top line), and in 2013 (9,830 tonnes) remained close to the average.

FIGURE4-5: GLOBAL, NON-A5 AND A5 CONSUMPTION OF QPS FROM 1999 TO 2013



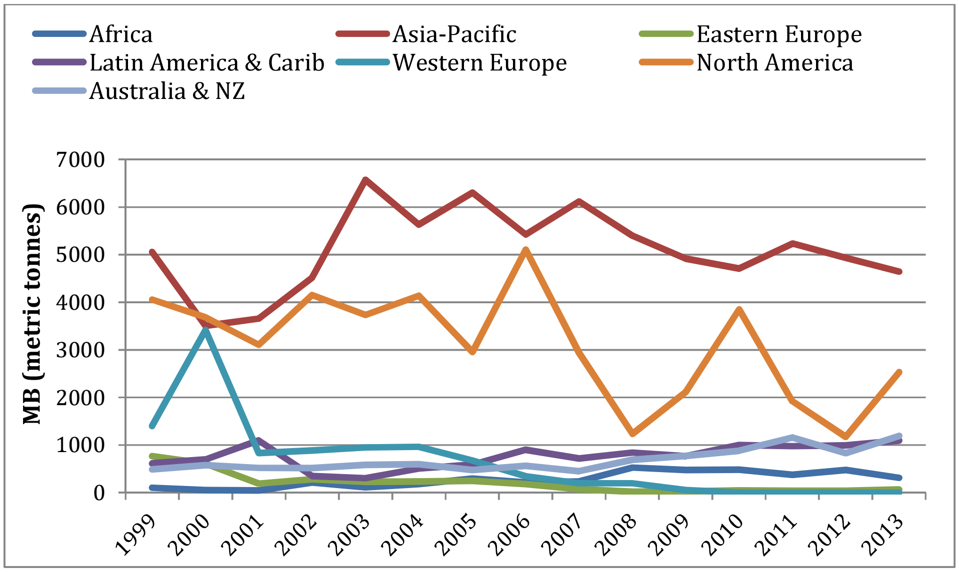
Source: Ozone Secretariat Database January 2015

4.6.4.2. *Regional consumption*

Regional consumption of MB for QPS purposes over the past fifteen years was analyzed on the basis of data reported by Parties for 2013. The regions shown in Figs 4-6 and 4-7 include both A-5 and non-A5 Parties when these are located in the same region.

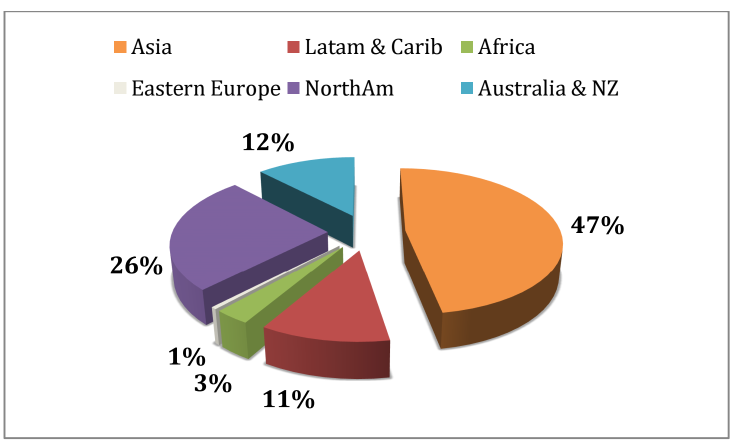
Wide variations are noted for North America (the USA comprises over 99% of this consumption since Mexico has been included in the "Latin America & Caribbean region). An upward consumption trend is noted in Australia & NZ group as well as in the African and Latin American regions.

FIGURE 4-6: REGIONAL CONSUMPTION OF QPS FROM 1999 TO 2009



Consumption in the Latin America & Caribbean, Africa and Eastern Europe regions has remained much lower since 1999 than in Asia and North America. In 2013, an analysis of global consumption (including both A5 and non-A5 Parties in the regions where appropriate), Asia consumed 4,641 tonnes, which corresponds to 47% of global QPS consumption (Fig 4-7).

FIGURE 4-7: REGIONAL CONSUMPTION OF QPS IN 2013

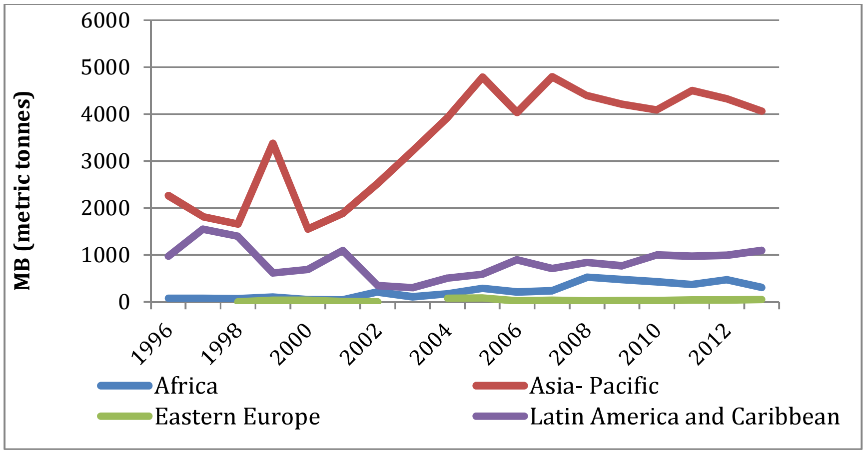


Source: Ozone Secretariat Database, January 2015

4.6.5. Article 5 QPS consumption

When considering A5 regions only, Asia emerges once again as the largest consuming region (Fig. 4-8). This region contains large consumers like China, Vietnam and the Republic of Korea. Since 2010, Latin America continues an upward consumption trend whilst Africa shows a decrease in recent years.

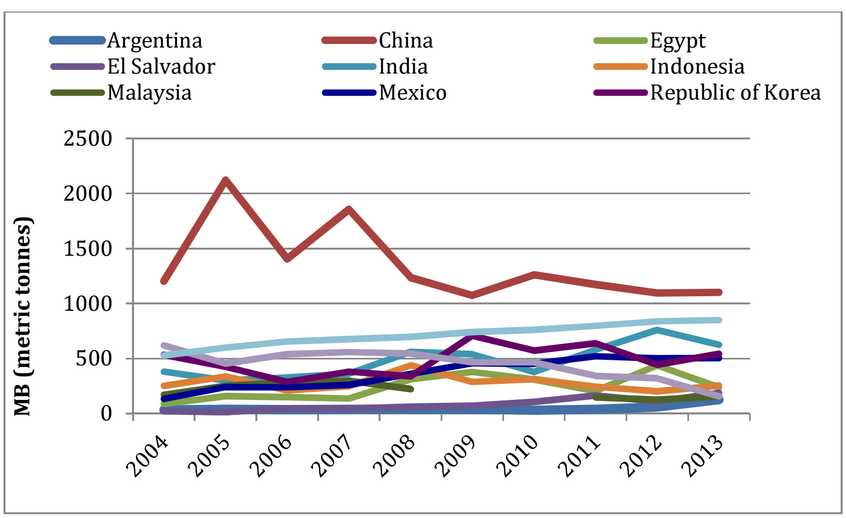
FIG. 4-8 MB QPS CONSUMPTION IN ARTICLE 5 REGIONS 1996-2013



The consumption in eleven A5 Parties that reported consumption of more than 100 tonnes in 2013 is shown in Fig. 4-9. These eleven A5 Parties accounted for 90% of the total A5 QPS consumption in 2013. China was the largest consumer in 2013 (1,102 tonnes) followed by Viet Nam (850 tonnes), India (625 tonnes), Korea (542 tonnes) and Mexico (503 tonnes).

The Ozone Secretariat database shows that seventy-three A5 Parties have reported consumption of QPS at least once in the period 1999 to 2013. A further 74 (51%) A5 Parties have never reported consumption of QPS during this period. Fig 4-9 shows the consumption trend in the eleven A5 Parties reporting consumption larger than 100 tonnes of MB for QPS in 2013 for the period between 2004 and 2013.

FIGURE 4-9 . QPS CONSUMPTION TREND IN A5 PARTIES THAT REPORTED CONSUMPTION ABOVE 100 TONNES IN 2013



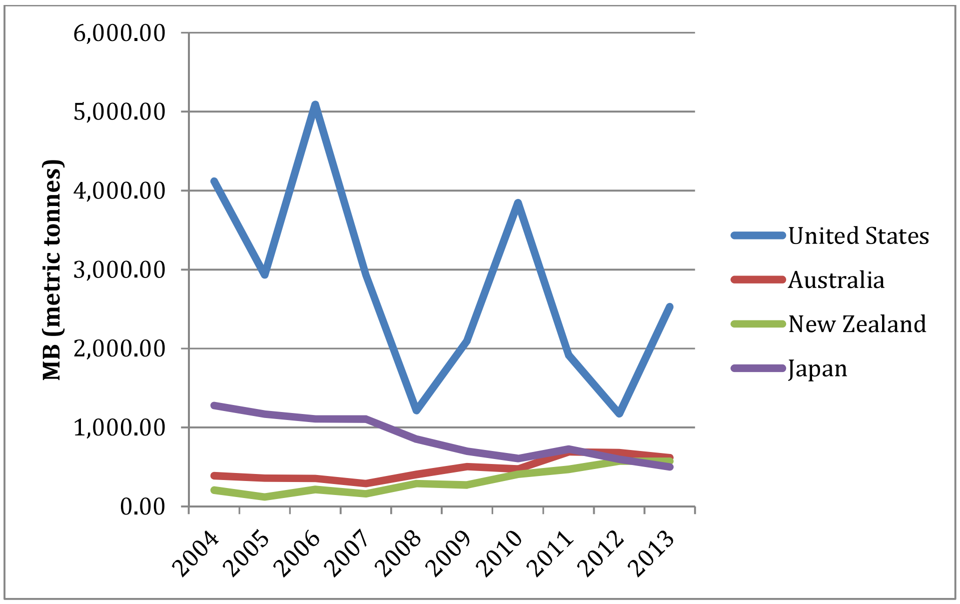
Source: Ozone Secretariat Database, December 2014

4.6.5.1. Non-A5 QPS consumption

The Ozone Secretariat database shows 23 non-A5 Parties had reported consumption of QPS at least once in the period 1999 to 2013. The consumption of QPS reported by non-A5 Parties in 2013 totalled 4,037 tonnes. Four non-A5 Parties consumed 98% of the QPS reported by non-A5 Parties in 2013.

Fig. 4-10 shows the consumption by the highest-consuming four non-A5 Parties from 2004 to 2013 that each consumed more than 100 tonnes of QPS in 2009.

FIGURE 4-10. TRENDS IN QPS CONSUMPTION IN NON-A5 PARTIES THAT REPORTED CONSUMPTION OF MORE THAN 100 TONNES IN 2013



Source: Ozone Secretariat Database, January 2015

The consumption reported by the USA in 2013 (2528 tonnes) was significantly larger than in 2012 (1,171 tonnes), but about 49% lower than its maximum QPS in 2006 (5,089 tonnes). Japan's consumption in 2013 (499 tonnes) continued a steady reduction trend from peak consumption in the past 10 years of 1,637 tonnes in 2000. Conversely, both Australia and New Zealand have increased QPS in each year since 2007.

The EU adopted legislation in 2008 and 2009 that banned consumption of methyl bromide including QPS from 19 March 2010.

4.7. Main Uses of Methyl Bromide for QPS purposes

4.7.1. Main individual categories of use by volume

At various stages since 1994, TEAP and MBTOC have carried out surveys and/or contacted national experts in order to compile information about major QPS uses, and to estimate methyl bromide volumes used in some cases (e.g. MBTOC 1995, 1998, 2003, 2007, 2011). More recently, MBTOC conducted a new survey on QPS uses amongst Parties reporting QPS consumption of 20 metric tonnes or larger, with help from the Ozone Secretariat; this provided a list of 31 A-5 Parties and 5 non-A5 Parties. Responses were received by more than half of these Parties, providing very helpful information to MBTOC, which was highly appreciated.

In keeping with past Decisions (i.e. XX/6), MBTOC followed the same categories of use for QPS as those used by the IPPC, with some additions and modifications. These were as used in Annex 6 of 3CPM – *Recommendation for the replacement or reduction of the use of methyl bromide as a phytosanitary measure* (IPPC, 2008) and are given in Table 4-2. The additional categories marked with an asterisk in were added to cover areas not covered by the IPPC.

TABLE 4- 2: MAIN CATEGORIES OF MB USE FOR QPS PURPOSES

Category	Uses
Commodities	Bulbs, corms, tubers and rhizomes (intended for planting)
	Cut flowers and branches (including foliage)
	Fresh fruit and vegetables
	Grain, cereals and oil seeds for consumption including rice (not intended for planting)
	Dried foodstuffs (including herbs, dried fruit, coffee, cocoa)
	Nursery stock (plants intended for planting other than seed), and associated soil and other growing media
	Seeds (intended for planting)
	Soil and other growing media as a commodity, including soil exports and soil associated with living material such as nursery stock*
	Wood packaging materials
	Wood (including sawn wood and wood chips)
	Whole logs (with or without bark)
	Hay, straw, thatch grass, dried animal fodder (other than grains and cereals listed above)
	Cotton and other fibre crops and products
	Tree nuts (e.g. almonds, walnuts, hazelnuts)
Structures and equipment	Buildings with quarantine pests (including elevators, dwellings, factories, storage facilities)
	Equipment (including used machinery and vehicles) and empty shipping containers and reused packaging
Soil as agricultural land*	Pre-plant and disinfestation fumigation of agricultural land*
Miscellaneous small volume uses	Personal effects, furniture, air* and watercraft*, artifacts, hides, fur and skins

Source: IPPC (2008) list of categories; *Not on IPPC (2008) list

4.7.2. Quantity of methyl bromide used

Dosages of MB at 80-200 g h m^{-3} mainly control insects, mites and vertebrate pests but higher rates typically exceeding 5000 g h m^{-3} are required for control of nematodes, snails and fungi; and for devitalising seeds.

A general analysis on categories of use by volume was conducted, on the basis of information received from Parties in response to the survey conducted by MBTOC in 2014 amongst key Parties, supplemented by information contained in past QPS reports (TEAP, 2009, MBTOC, 2011, TEAP, 2012) as well as data from previous surveys of QPS uses (TEAP 2006, UNEP/ ROAP 2008).

While there remain some data gaps and uncertainties, MBTOC (and previously the QPSTF) were able to make estimates that covered more than 80% of total global 2013 reported QPS use or consumption by volume, with over 75% of this resulting from 5 major categories of use as shown in Fig. 4-11. There were some differences in these categories when comparing A5 vs non-A5 (Figs 4-12 and 4-13). This analysis confirmed that the five largest consuming categories of methyl bromide for QPS:

1) Sawn timber and wood packaging material (ISPM-15)
2) Grains and similar foodstuffs
3) Pre-plant soils use and
4) Logs.
5) Fresh fruit and vegetables

The first four uses consumed more than 80% by weight of the methyl bromide used for QPS in 2013. These findings are generally consistent with previous MBTOC reports (TEAP, 2009; MBTOC, 2011). On the basis of these estimates, TEAP calculated in 2009 that 31% to 47% of global consumption in 2008 by the first four categories of use could be replaced with available alternatives (TEAP, 2009; 2010).

FIGURE 4-11. ESTIMATED GLOBAL CATEGORIES OF MB USE (QPS PURPOSES) IN, 2013

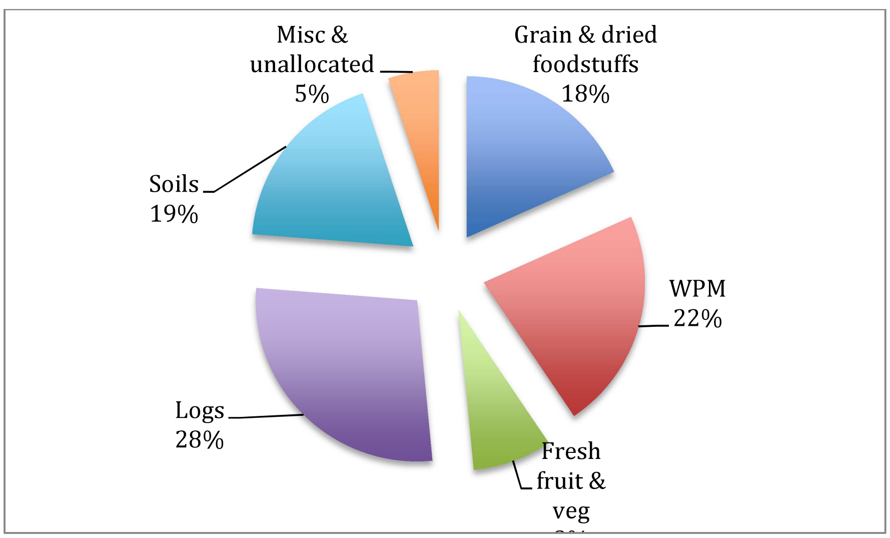


FIGURE 4-12 . ESTIMATED CATEGORIES OF MB USE (QPS PURPOSES) IN ARTICLE 5 PARTIES IN 2013

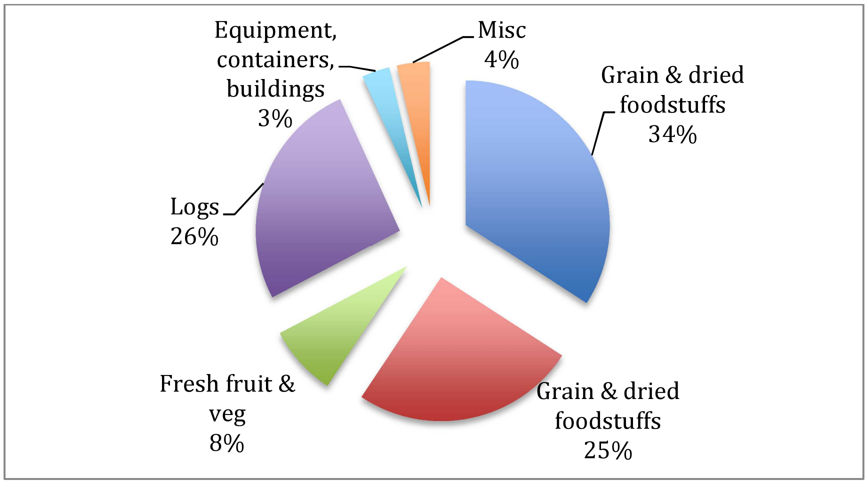
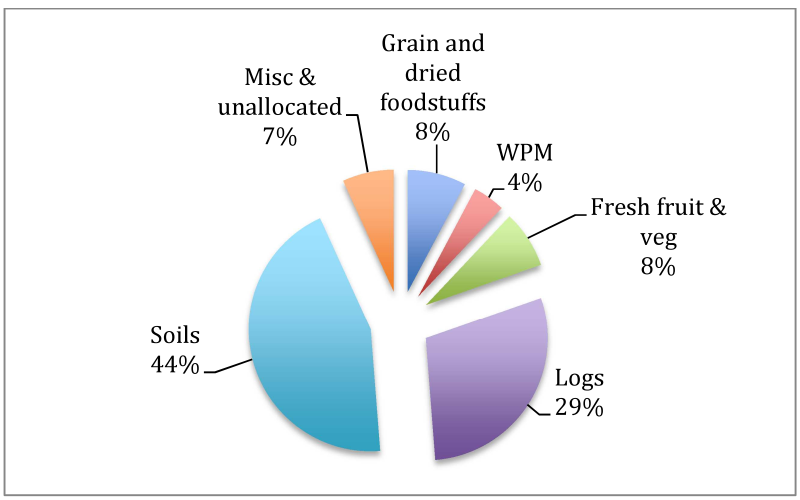


FIGURE. 4-13. ESTIMATED CATEGORIES OF MB USE (QPS PURPOSES) IN ARTICLE 5 PARTIES IN 2013



Sources: MBTOC survey of QPS uses in A5 parties with reported consumption at or above 100 tonnes; 2010 MBTOC Assessment Report; 2009 TEAP/ MBTOC Reports (TEAP, 2009, 2010); Rodas, 2013; NOUs, regional networks and national experts

4.8. *Key quarantine pests controlled with methyl bromide*

Target pests for QPS treatments vary from country to country even for the same commodity, and the procedures for handling the issue of defining the target pests may also differ.

For pre-shipment treatments required by official authorities, the objective of treatments is to produce goods that are 'pest-free', or sometimes to some standard sampling level. While in practice the target species are typically insect pests (beetles, moths and psocids) that are widely distributed and associated with quality losses in storage, treatments are also expected to eliminate the other living insect species that may contaminate commodities during harvesting, storage and handling, even when they do not pose a direct threat to the quality of the commodity.

For quarantine treatments, the National Plant Protection Organisations (NPPOs) of particular countries publish master lists of regulated pests, being recognised quarantine pest species. These can be found through the IPPC portal. Only some of these pests are controlled by methyl bromide as the treatment of choice or exclusive approved treatment. Some quarantine authorities have regulations for species not found in their country that require quarantine action if the species is known to be a pest that would cause damage or vector diseases in their country or if there is evidence to suggest a risk of such damage. Likewise species that would substantially endanger human or animal health or comfort, especially by spreading exotic disease, would likewise be considered a quarantine species. Species of quarantine concern to one country will not necessarily be of concern to another country: the pest might attack a crop not grown in the country, climatic conditions in the country might not be favourable to establishment of the species or the country might already have the species in their country. Nonetheless, there are certain groups of organisms that are responsible for most quarantine action in the world currently involving methyl bromide treatment.

Table 4-3 shows the main target pests of quarantine significance in the major classes of methyl bromide use, by volume, for plant Quarantine purposes.

TABLE 4-3: MAIN TARGET PESTS OF PLANT QUARANTINE SIGNIFICANCE IN THE MAJOR CLASSES OF MB USE FOR QPS PURPOSES

Treated commodity or situation	**Main target quarantine pests**
Whole logs, not debarked	Various species of bark beetles, wood borers, Sirex spp., pinewood nematodes, fungi (oak wilt, *Ceratocystis ulmi*).
Solid wood packaging	Various species of bark beetles, wood borers, Sirex spp., pinewood nematodes (*Bursaphelenchus xylophilus*).
Grain and similar foodstuffs	*Trogoderma* spp., particularly *T. granarium*; *Prostephanus truncatus*; *Sitophilus granarius*; cotton boll worm, various snails.
Fresh fruit and vegetables	Numerous species of Tephritidae (fruit flies), thrips, aphids, scale insects and other sucking bugs, various Lepidoptera and Coleoptera, various mites.
Soil for crop production, including propagation material	Exotic nematodes such as the Pale Potato Cyst Nematode (*Globodera pallida)*,Golden nematode (*Globodera rostochiensis),,* exotic weeds, including *Orobanche* spp. Regulations in the USA also allow general 'certification' of nematodes to be considered QPS.

Key quarantine pests that are sometimes controlled in international trade with methyl bromide that lie outside the scope of the IPPC include various mosquito species (human and animal disease vectors, nuisance species), tramp ant species including red imported fire ant (*Solenopsis invicta*) (animal and ecological health, invasive species), rodents (disease vectors, stored product pest), snakes (invasive species), and cockroaches (human health disease vectors).

4.9. Existing and potential alternatives for the major QPS use categories

Previous MBTOC and TEAP reports have provided details of existing alternatives for various QPS uses (e.g. MBTOC 1995, 1998, 2002, 2007; TEAP 1999, 2007, 2009, 2010). The 2002, 2006 and 2010 MBTOC Assessment Reports (MBTOC 2002, 2007, 2011) provided detailed discussion of alternatives to QPS methyl bromide use on commodities in specific circumstances. Detailed reports on QPS and alternatives are further given in TEAP (2003), produced in response to Decision XI/13(4) and in TEAP (2009 ab, 2010) in response to Decisions XX/6 and XXI/10.

Existing alternatives to MB for QPS treatment of perishable and durable commodities are based on

1. Pre-harvest practices and inspection procedures
2. Non-chemical (physical) treatments and
3. Chemical treatments.

Many quarantine treatments are 'post-entry'. This is where a treatment is required either if inspection finds a quarantine organism in the shipment at the port of entry or quarantine or other treatments have been insufficient to adequately manage the risk of importing quarantine pests in sufficient numbers to be a quarantine threat. Many countries prohibit imports of particular cargoes where the risk of carrying quarantine pests is unacceptable and there is no system or treatment available to manage this risk to an adequate level. This avoids the need for post-entry quarantine measures, including methyl bromide fumigation.

Treatment options are often more restricted for post-entry quarantine treatments than for pre-shipment. In many post-entry situations, fumigation with MB is the only technically and economically available and approved process to meet quarantine standards to allow importation, due to limited infrastructure to apply alternative. Cargos are often containerized and removal (unpacking and treating) from the container is uneconomic. MB fumigation may be ordered before the commodity can be released for distribution and rejection or destruction remains the default option if the treatment is not carried out.

NPPOs may publish listings of approved treatments for imports, with specifications varying according to phytosanitary requirements of receiving countries and pest risk. MB may be specified as a quarantine treatment, but often there are also approved alternatives. A listing of alternatives for various Quarantine uses was given in the IPPC recommendation (IPPC 2008) to its contacting Parties on preferential use of alternatives in place of MB, together with considerations affect the choice of a phytosanitary measure to replace methyl bromide use. The listing is reproduced in Table 4-4.

Additional information on alternatives to MB for the main QPS uses is provided below. The reader is strongly encouraged to also consider the documents described at the beginning of this section.

TABLE 4-4: EXAMPLES OF POTENTIAL PHYTOSANITARY TREATMENTS THAT CAN REPLACE OR REDUCE METHYL BROMIDE USE FOR QPS PURPOSES

List of articles fumigated	Examples of phytosanitary treatments to consider to replace or reduce methyl bromide[3]
Bulbs, corms, tubers and rhizomes (intended for planting)	Hot water, pre-plant quarantine soil sterilization (steam or chemical), pesticide dip, or a combination of these treatments
Cut flowers and branches (including foliage)	Controlled atmosphere (CO2, N2) + combination treatment, hot water, irradiation, phosphine, phosphine/carbon dioxide mixture, pyrethroids + carbon dioxide, ethyl formate + carbon dioxide
Fresh fruit and vegetables	Cold treatment, high-temperature forced air, hot water, irradiation, quick freeze, vapour heat treatment, chemical dip, phosphine, combination of treatments, ethyl formate + carbon dioxide
Grain, cereals and oil seeds for consumption including rice (not intended for planting)	Heat treatment, irradiation, ethyl formate, carbonyl sulphide, phosphine, phosphine + carbon dioxide, sulfuryl fluoride, controlled atmospheres (CO2, N2)
Dried foodstuffs (including herbs, dried fruit, coffee, cocoa)	Heat treatment, carbon dioxide under high pressure, irradiation, ethyl formate, phosphine, phosphine + carbon dioxide, controlled atmosphere (CO2, N2), sulfuryl fluoride, propylene oxide-+-
Nursery stock (plants intended for planting other than seed), and associated soil and other growing media	Hot water, soil sterilization (steam or chemical e.g. methyl isothiocyanate (MITC) fumigants), pesticides dip, phosphine, combination of any of these treatments
Seeds (intended for planting)	Hot water, pesticide dip or dusting, phosphine, combination treatments
Wood packaging materials	Heat treatment, now including dielectric heating (contained in Annex 1 of ISPM No. 15 and its revisions). Further alternative treatments may be added in the future.
Wood (including round wood, sawn wood, Wood chips)	Heat treatment, kiln-drying, removal of bark, microwave, irradiation, MITC/sulfuryl fluoride mixture, methyl iodide, chemical impregnation or immersion, phosphine, sulfuryl fluoride
Whole logs (with or without bark)	Heat treatment, irradiation, removal of bark, phosphine, sulfuryl fluoride. MITC/sulfuryl fluoride mixture, methyl iodide.
Hay, straw, thatch grass, dried animal fodder (other than grains and cereals above)	Heat treatment, irradiation, high pressure + phosphine, phosphine, sulfuryl fluoride
Cotton and other fibre crops and products	Heat treatment, compression, irradiation, phosphine, sulfuryl fluoride CO_2
Tree nuts (almonds, walnuts, hazelnuts etc.)	Carbon dioxide under high pressure, controlled atmosphere (CO2, N2), heat treatment, irradiation, ethylene oxide, ethyl formate, phosphine, phosphine + carbon dioxide, propylene oxide, sulfuryl fluoride
Buildings with quarantine pests (including elevators, dwellings, factories, storage facilities)	Controlled atmosphere (CO2, N2), heat treatment, pesticide spray or fogging, phosphine, sulfuryl fluoride
Equipment (including used agricultural machinery and vehicles), empty shipping containers and reused packaging	Controlled atmosphere (CO2, N2), heat treatment, steam, hot water, pesticide spray or fogging, phosphine, sulfuryl fluoride
Personal effects, furniture, crafts, artefacts, hides, fur and skins	Controlled atmosphere (CO2, N2), heat treatment, irradiation, ethylene oxide, pesticide spray or fogging, phosphine, sulfuryl fluoride

[3] Examples are given that are generally applicable and likely to meet prevailing standards for treatment or disinfestation. Some alternatives may not be appropriate on particular commodities within the general category or in specific situations.

4.9.1. Sawn timber and wood packaging material (WPM)

This section excludes logs and covers only quarantine treatments of wood that has been sawn into lumber and wooden packaging material derived from sawn timber. This material is mostly free of bark, but may include sapwood as well as heartwood. Sapwood is often present in lumber and can contain insects even in logs that have been debarked. For imports of lumber into some countries such as China and Korea do not require fumigation but inspect on arrival and fumigate if pests are detected; other countries such as India require fumigation of lumber containing sapwood. Japan sapwood is categorized as logs and it is inspected and treated in import quarantine (MBTOC, 2011). Sawn timber may be traded or made into pallets, dunnage and other packing material associated with either international or domestic trade.

4.9.1.1. Heat treatment

The only alternative treatment to methyl bromide treatment approved and accepted internationally under ISPM-15 for treatment of wood packaging materials (wood packaging material) is heat treatment, including kiln drying and more recently dielectric heating (e.g. microwave) see section 4.5.3. When using heat treatment (including kiln drying), a temperature of at least 56°C, core temperature, must be maintained for at least 30 minutes (IPPC 2006). For dielectric heating, a schedule of 60ºC for one minute throughout the entire profile of wood without a thickness limit has been accepted (IPPC 2011, 2013a).

Dielectric heating Radio frequency (RF) uses much lower frequencies than microwaves (MW), so the RF wave has a longer penetration depth than the MW, and can be used to treat wood with larger dimensions than the 20 cm accepted by ISPM 15. It also has the potential to selectively heat materials and is more energy efficient than conventional ovens.

The revised version of the ISPM-15 standard (IPPC 2009) specifically encourages the use of heat where feasible in preference to methyl bromide, because of the ozone-depleting properties of methyl bromide.

The use of the heat treatment in many countries to meet ISPM-15 is substantial and continues to increase. In general, heat treatment requires a somewhat higher level of infrastructural support compared with MB, but has been shown to be cost effective and practical in many locations. A variety of facilities are in use to achieve the specified heat dosage for ISPM-15. They include timber kilns (present in many countries), modified freight containers or similar enclosures with either hot water heating (China) or electrical or gas heating (Australia, Jamaica, New Zealand, Japan and EU member states). Heat has been used in many Article 5 countries for many years (e.g. Morocco, Colombia, Argentina, Mexico and Ecuador). A recent review (Rodas, 2013) indicates that several countries in Central America – Guatemala, Honduras, Costa Rica and Panama – treat between 70 and 100% of their WPM with heat to comply with ISPM-15 regulations. Heat treatments are reported as economically feasible and easy to implement due to the fact that they can be integrated with kiln drying.

Kiln drying of sawn timber (lumber) exceeds the temperature thresholds and duration criteria defined in ISPM-15, thereby providing an alternative quarantine treatment to methyl bromide where insect and nematodes are pests of quarantine concern. Higher temperatures are required for control of fungi, but some timber (especially hardwoods) can be damaged by the high temperature treatment.

Microwave heat treatment is likely to be more economically viable, particularly in a pass-through conveyor configuration designed to eradicate wood materials infected with pinewood nematode, this is because dielectric modalities such as microwaves heat polar molecules through the profile of the wood simultaneously (Hoover *et al*., 2010).

4.9.1.2. Chemical alternatives

Fumigation is preferred when goods are present on wood packaging material that needs to be disinfested to meet the requirements of ISPM-15, and the goods are likely to be damaged by heat.

The only officially-recognised chemical option at present is methyl bromide but sulfuryl fluoride, and phosphine continue to be under consideration. SF fumigation of WPM is now in the process for approval. TPPT accepted 2 different schedules, one for the PineWood Nematode (PWN) and insects and other for insects only; and recommended to the IPPC Standards Committee for adoption by the CPM. The different treatments, one for wood-borne insects (less severe schedule) and for PWN and wood-borne insects (with a more severe schedule) were established because this would make the treatments more targeted and prevent unnecessarily high dosing of timber not infested with PWN. The treatments are meant to be used on debarked wood, not exceeding 20 cm in cross-section and not exceeding 60% moisture content (IPPC, 2013ab).

In 2013, synthetic pyrethroid usually applied premixed and propelled by CO_2 has replaced several tonnes of MB for the treatment of containerised export sawn timber infested with hitchhiking adult *Arhoplusferus* beetles during the summer when being shipped from New Zealand to Australia.

Some National Plant Protection Organisations recognise other treatments for wood packaging material and similar products, instead of methyl bromide or heat treatments undertaken according to the treatment criteria contained in ISPM-15. These treatments may be post entry or prior to export and are generally based on bi-lateral agreements between countries interested in a specific trade. Australia, for example, requires off shore treatments of timber packaging and dunnage that have not been treated in accordance with ISPM-15 to be treated at specified dosages of several alternatives, including fumigation with sulfuryl fluoride, or ethylene oxide or treatment with heat, gamma irradiation or some timber preservatives (ICON 2009).

4.9.1.3. Alternatives to wood pallets and other wooden packaging materials.

Alternative packaging methods avoid the need for methyl bromide fumigation or heat treatment. Plastic pallets (often made from recycled plastic) are commercially available and are used by many companies in the EC, the US and many other regions of the world. Cardboard pallets can be suitable for loads of about 3,000 kg and are available commercially in Australia, the EC, Kenya, New Zealand, the US and others. These materials are exempt from the requirements of ISPM-15.

Particularly in Article 5 Parties, the added expense of using alternative materials to wood as well as in some cases lack of raw materials with which to make such pallets, places constraints on access to pallets that are not made of wood. The reuse of ISPM 15 compliant wood packaging is common.

4.9.2. Alternatives for logs

There is active research in progress to develop alternatives for logs but gaining the required efficacy data is difficult as laboratory rearing has not yet been achieved to the numbers required. Most insects are seasonal, and the commodity is large and variable.

Methyl bromide is the most widely used fumigant for logs, however it does have some limitations including limited penetration across the grain and into wet timber. Most arthropods associated with timber are quite susceptible to methyl bromide but much higher dosages are required to kill fungi (Rhatigan *et al.,* 1998). Green logs are problematic to treat due to the high moisture content (80%), presence of bark (very adsorbent), size and large volumes. Overall, methyl bromide is currently the best log fumigant that is registered and available.

Treatments of logs may need to be rapid, such as at point of export or import, to avoid charges and congestion at ports associated with occupying restricted port area for the treatment. Where quarantine treatments can be applied outside port areas, such as prior to export or in-transit, alternatives to methyl bromide that take a longer time can be used. Many pests of quarantine significance, which attack green wood, do not re-infest dry and debarked wood.

Specific QPS alternatives for logs are discussed below, followed by discussion of some processes under development.

4.9.2.1. Reduction in methyl bromide dosage

Treatment specifications for logs have not been harmonised worldwide and schedules vary with the importing country of import and the target pest, given that quarantine security requirements are set by the importing country in accordance with their unique quarantine requirements—a right guaranteed by the World Trade Organization. For example, Korea requires 25 gm^{-3} for 24h at 12-15°C (Yu *et al.* 1984), India 64gm^{-3} 11-15°C, China 120 gm^{-3} for 16h at 5-15°C, and Malaysia requires 128 gm^{-3} for 24 hour exposure at the higher temperature of 21°C. Nevertheless, significant savings of methyl bromide could be achieved by reducing the fumigation rate in situations where the use can be shown to be excessive.

4.9.2.2. Phosphine

New Zealand has pioneered the use of phosphine for the in-transit fumigation of *Pinus radiata* logs destined for China. It is now routinely used as a quarantine and pre-shipment measure, which unlike MB can be applied in-transit, and has partially replaced methyl bromide for this purpose. However, phosphine in-transit can only be used to treat logs shipped below deck in the holds, which are about two-thirds of each shipment.

Phosphine is less expensive than methyl bromide for the treatment of logs when it is applied at the point of export as an in-transit treatment. On longer transits phosphine can be more cost effective than methyl bromide. This is because, compared to methyl bromide, the dosage rate is lower, and it is faster to apply which reduces costly moorage time in the port. The sailing time is sooner as the ship avoids having to stay in port for at least 36 hours while the hold is fumigated and then vented. A fumigation technician is required for the voyage to add more fumigant, monitor for leaks and vent the holds. This method can only be used for logs stowed in the holds, which is normally about two-thirds of the cargo, and the balance of the cargo on deck must be fumigated with methyl bromide under tarpaulin on the wharf prior to export.

4.9.2.3. Sulfuryl fluoride

Sulfuryl fluoride is a similar fumigant to methyl bromide except that the fumigation temperature or concentration usually needs to be higher to achieve the same level of pest mortality for all stages including the egg stage. Sulfuryl fluoride is reported to have a large global warming potential (Papadimitriou *et al.,* 2008). Data continues to be collected in the USA and China on the efficacy of sulfuryl fluoride for controlling wood pests as an alternative for the disinfestation of logs. Sulfuryl fluoride penetrates timber somewhat better than does methyl bromide (Scheffrahn and Thoms, 1993; Ren and Lee, 2010).

Sulfuryl fluoride is registered or licensed for use in many countries including the Australia, EU, Japan, US and Canada, and is one of the most promising equivalent replacements for MB for logs and sawn timber, having similar properties and exposure requirements, with significantly better penetration of wood (Scheffrahn *et al*., 1992). Registration activities are in progress in China and India (Jeffers *et al.,* 2012).

There is a perception that sulfuryl fluoride will not control egg stages of quarantine pests and will not work at common ambient temperatures. Dow AgroSciences believes that good efficacy on eggs is possible by adjusting exposure rates and/or times (Scott Boothey, pers. comm.) Adoption of SF may further be constrained by its cost

4.9.2.4. EDN

Ethanedinitrile or EDN, also known as cyanide is now registered in Australia for the treatment of logs and timber, however the controls on the use such as buffer zones, recapture and withholding period mean that there has been little uptake to date. Export logs to China continue to be treated with methyl bromide as currently only Malaysia accepts EDN as a quarantine treatment.The registration process is also progressing in New Zealand, SE Asia, South Africa, Israel and being reviewed in a number of additional countries. Market acceptance tests are currently being run in many of these regions as well (Jessup et al, 2012).

4.9.2.5. Other fumigants

Recent research in the Czech Republic (Stejzkal *et al*, 2014) reports promising results with HCN (hydrogen cyanide) for controlling pinewood nematodes (*Bursaphelenchus* *xylophilus*) and Asian longhorned beetles (*Anoplophora glabripennis*) in wood and timber. Penetration rates of HCN into wooden blocks as well as its biological efficacy against these pests were evaluated.

Research on alternatives for logs evaluating the efficacy of MI and MITC/SF mixtures has been completed in Japan and both treatments are under the process of inclusion under the relevant regulations.

4.9.2.6. Heat

Heat treatment has been accepted as a quarantine treatment for logs and timber to be shipped to the USA and many other countries for many years (e.g. USDA 1996). The general specification requires the wood to reach a core temperature of 71°C for 60 minutes. Kiln drying of timber to a moisture content of less than 20% using temperatures over 70°C is often a commercial requirement but also has long been accepted as a quarantine treatment by most importing countries. Currently, 56°C core temperature for 30 minutes is required under ISPM-15 for wood packaging material.

Heat treatment of unprocessed logs is an approved risk mitigation measure for importation into the USA (Morrell 1995). Steam heat is a more effective quarantine measure than dry heat (USDA 1994; Dwinell 2001). Moist heat treatment is an integral part of log conditioning prior to peeling and has the additional benefit of eliminating quarantine pests.

4.9.2.7. Irradiation

Gamma irradiation is currently approved for the disinfestation of logs into Australia at a rate of 10 kGy (1.0 Mrad). However, its practical application must overcome a number of hurdles, not the least being the construction of large irradiators to handle logs and bulk wood products.

Irradiation is limited by poor penetration into freshly cut logs, potential damage and dose-dependent degradation of wood products such as fibre board and paper, variation in effect on different insect groups, and very high dosages required to eliminate fungi (Morrell 1995). No continuing work on irradiation treatment of logs is known to MBTOC.

4.9.2.8. Water soaking or immersion

Water soaking or immersion provides a way to control pests on imported logs. Immersion of some logs destined for plywood manufacture is a useful process as it improves the quality of the products. The storage of logs in water or under water spray has long been accepted as an effective treatment for terrestrial insects and fungi. Salt water immersion of logs for 30 days is an approved treatment for logs into Japan but contamination of waterways with bark is an issue. The upper surface of the logs above the water level is sprayed with an insecticide mixture such as dichlorvos as part of the pest management strategy (Reichmuth 2002).

The potential for use of water soaking for quarantine treatment of imported logs is limited by the large area of water required and the undesirable side effects of ponding large volumes of logs, making its application on a large scale unlikely.

4.9.2.9. *Debarking*

Bark removal has long been a key strategy in reducing contamination of logs and a way to reduce the risk of logs and sawn timber carrying certain insects and fungi of quarantine concern. While debarking removes surface contamination and also bark and cambium, which are areas particularly prone to pest attack, it does not affect insects and fungi already in the wood (USDA 1992). Many countries require debarking of all imported logs. Because of the high cost, and the requirement by customers in major Asian markets that bark remain on logs, its application as a quarantine treatment is limited and frequently only carried out on high value logs.

4.9.3. Alternatives for grains and similar foodstuffs

Methyl bromide fumigation continues to be used for pre-shipment treatment of cereal grains where logistical constraints at point of export, or importing country specifications, preclude the use of alternatives, mainly phosphine.

There are different alternative treatments of choice for grains to meet appropriate QPS standards, depending on whether the treatment is officially required by national authorities for common and cosmopolitan insects that attack or are associated with grain in storage and transport (i.e., pre-shipment), or they are for control and elimination of specific regulated quarantine pests.

Export cereal grains, such as rice and wheat, are prone to infestation by a number of cosmopolitan grain pests that cause damage when in storage and are unacceptable to modern market standards. Most of the methyl bromide fumigations are pre-shipment treatments that target non-quarantine pests. These pre-shipment treatments are officially required by official regulations of some exporting countries or by official requirements of some importing countries. Examples of pre-shipment treatments have been reported previously (TEAP 1999, 2002; MBTOC 2002, 2011). Export cereal grains, similar products and associated packaging from some locations may also be subject to quarantine treatments against specific insect pests, notably Khapra beetle (*Trogoderma granarium*), *Prostephanus* species or contaminants such as specific snails (e.g. *Cochlicella* spp.) or seed-borne diseases such as Karnal bunt (*Tilletia indica*).

Many countries have strict quarantine regulations on grain and other durables originating from countries where Khapra beetle occurs. Typically, only methyl bromide treatment is specified against this quarantine pest, using double normal dosages for stored product disinfestation often with extended exposure period. For instance, cereal products from Khapra beetle areas for import into Australia require 80 gm^{-3} of methyl bromide for 48 hours at 21°C with an end point concentration at 48 hours of 20 gm^{-3} (ICON 2009).

4.9.3.1. *Alternatives for quarantine treatments*

Methyl bromide treatment of grains for quarantine purposes continues to be often the only accepted and convenient treatment in many cases. There appear to be no drivers away from this situation in the absence of measures to curtail methyl bromide use for QPS purposes.

The USDA PPQ Treatment Manual (USDA 2009) contains many treatment schedules specific to Khapra beetle and most involve fumigation with methyl bromide. Heat treatment at a high temperature and prolonged exposure (7 minutes at 65.5°C) is given as the only approved alternative to methyl bromide and can only to be used when specifically authorised by the APHIS.

Heat treatment is a good alternative to methyl bromide for controlling many stored product pests, including Khapra beetle. Despite its tolerance to temperatures of about 41°C, Khapra beetle is quite susceptible at higher temperatures, more so than some common storage pests such as *Rhyzoperta dominica*. There are old but good quality data to substantiate heat susceptibility of stored product pests in general (see MBTOC, 2011).

In the past, *T. granarium* was quite susceptible to phosphine e.g. Hole *et al.* (1976), which made phosphine a potential alternative to methyl bromide against this pest. However, with the frequent development phosphine resistance by *T. granarium* in the Indian subcontinent, phosphine is not currently an option for controlling this pest.

Some winter wheat fields in Texas were infected with Karnal bunt disease, *Tilletia indica*, in 2001. Karnal bunt was detected in Arizona in March 1996, in Texas in 1997 and in South Africa in 2000 (Staphorst, pers. comm, 2014). The 2001 detection in Texas was significant because it occurred outside the quarantine area in Texas (J. Schaub pers. comm. 2010). When infected grain was harvested and transferred to storage bins, the bins and grain handling equipment became infected. Methyl bromide fumigation of emptied contaminated storage bins requires a high dosage (240 gm^{-3}) for 96 hours to meet quarantine standards. Steam heating to a point of runoff in bins also is an effective alternative to methyl bromide providing surface temperatures reach 77°C (Dowdy 2002). Microwave technology used in laboratory tests was reported as effective in controlling Karnal bunt (*Tilletia indica)* teliospores in 10 seconds compared to 96 hours using methyl bromide (Ingemanson, 1997). Scale up to large quantities of grain is problematic.

Japan imports about 30 million tonnes of grain including wheat, maize and soybean. Methyl bromide is the fumigant of preference for treatment of these imports. There is no approved treatment schedule other than methyl bromide where granary weevil (*Sitophilus granarius*) is detected in the grain. This flightless pest, widespread in most countries, is a listed object of quarantine in Japan. The quantity of methyl bromide used for grains in Japan is larger than for any other category except whole logs (PPS 2007). Phosphine fumigation using aluminum phosphide tablets has been included in the plant quarantine treatment schedule in Japan (MAFF, 1971). The treatment with phosphine takes many days and is thus unsuitable where there is insufficient capacity at import ports to allow long holding periods. Methyl bromide treatments typically take less than 48h. Phosphine is not accepted for controlling *Sitophilus* because the pupal stage could not be killed completely at the dosage rates and fumigation conditions used in commercial quarantine fumigation (Mori and Kawamoto, 1966). On the other hand, sulfuryl fluoride has higher efficacy against pupal stages of several stored product insects, although the egg stage is the most tolerant (Furuki *et al.* 2005; Bell *et al.,* 2003). Fumigating with a mixture of phosphine and sulfuryl fluoride gas kills all stages of *Sitophilus* species, using the good properties of both fumigants. Tests with mixtures of phosphine and sulfuryl fluoride were conducted in Japan and a sequential fumigation that consists of a sulfuryl fluoride fumigation for 24 hours and a phosphine fumigation for 48 hours was decided to be effective to eliminate all stages of Sitophilus species (Misumi et al., 2011).

Freezing has been used successfully for controlling the coffee berry borer, *Hypothenemus hampei*, in green coffee. *H. hamoei* is a serious pest of coffee which, although reported in many coffee growing countries, is generally classified as a quarantine pest to delay spread or avoid reintroductions. Temperatures in the range of −13.9 to −15.5 ºC for 48 h were found to provided 100% control of all life stages and the treatment appeared more economical and acceptable compared with fumigation with methyl bromide, especially for small-scale and organic growers and millers in Hawaii who ship green coffee beans to other islands for custom roasting (Hollingsworth *et al.,* 2013).

Alternative treatments to methyl bromide are needed for various snails of quarantine significance (e.g. *Achitina fulica*, *Cernuella* spp. *Theba pisana*). Methyl bromide fumigation is usually the only approved quarantine measure for these pests when associated with grain shipments. Other processes, including HCN and CO_2 fumigations, may be more effective (e.g. Cassells *et al.,* 1994), but are not approved and not registered.

4.9.3.2. Alternatives for pre-shipment treatments

Methyl bromide fumigation was used widely in the past to fulfill requirements for pre-shipment treatment of grain. In general, other processes are cheaper and more convenient and methyl bromide use for this purpose has decreased to the stage where it is typically used only in situations where the rapid action of methyl bromide confers technical and economic benefits.

There are well known, standard processes for protection and disinfestation of stored grain in storage and transport. Grain and similar dry foodstuffs, either bagged or in bulk, can be delivered to an export point in a '*pest-free'* condition without recourse to methyl bromide fumigation (see MBTOC 2007, 2011). The choice of alternative is dependent on the commodity or structure to be treated, the situation in which the treatment is required, the accepted level of efficacy and the cost and the time available for treatment. Some alternatives (e.g. some fumigants, heat treatment) may be implemented as 'standalone' or 'in-kind' treatments to replace methyl bromide whilst others may be used in combination to achieve the required level of control.

These processes, theoretically, can avoid the need for any further treatment against infestation at the export port. In practice, consignments may be brought to the export point in infested condition. Also, particularly in humid, tropical situations, there is often a high invasion pressure from pests at the export point. As a result, an insecticidal process (usually fumigation) must be used to ensure the grain meets the exporter's or importer's official regulations for lack of infestation.

In some cases, the pre-shipment treatment is used to disinfest ship holds or other conveyances before placing grain or similar commodities in the ship hold, in order to prevent infestation from contaminated holds during shipment.

Pre-shipment treatments in general are aimed at a lower standard of pest control than quarantine. While quarantine treatments lead to a commodity free of regulated quarantine pests, pre-shipment only requires the consignment to be "*practically free*" of pests. This lower level of security gives some wider choice of alternatives, with reduced requirements for efficacy testing.

Alternatives to methyl bromide fumigation for pre-shipment of cereal grains, including rice, vary with situation, particularly the required speed of action. In some export situations, there is sufficient capacity at the port, to allow slower acting alternative treatments to be used easily, with treatment times of 7 days or more for full effectiveness.

In many export situations, a high throughput is required, where there is limited space at the port for treatments and as demurrage costs on waiting vessels is high. Typical turnaround times for methyl bromide for a shipment can be 24-48 hours, a time that has to be accommodated in the organisation of the export consignment under pre-shipment treatment.

Some importing countries may specify fumigation at point of export as a pre-shipment treatment, with indications as to what treatments are acceptable. In cases where methyl bromide is specified as one treatment, phosphine fumigation may be specified as an alternative. However, several countries specify use of methyl bromide as the only acceptable QPS treatment of imported grain from specified exporters

Phosphine fumigation is in widespread use for this purpose, for both bagged and bulk consignments. Transition to phosphine for the pre-shipment of grains has been driven largely by economic consideration. Increasing health regulations associated with avoiding worker exposure to methyl bromide are likely to further encourage use of alternatives.

Treatment of bulk or bagged grain in ships with phosphine after loading can replace some current pre-shipment uses of methyl bromide. However, this may be interpreted as falling outside 'pre-shipment' and may not meet regulatory requirements of some exporters and importers who require grain to be practically pest-free before loading. Phosphine treatments may be conducted at the dockside, in lighters or barges prior to loading a ship, or in the ship after loading and before sailing. In suitable ships, in-transit phosphine treatment gives an effective post-export treatment.

The International Maritime Organisation recommendations on safe use of pesticides in ships and shipping containers describe the safe use of both phosphine and methyl bromide at port and in-transit (IMO 2008ab). The Organisation specifically recommended that cargoes should not be fumigated in ships with methyl bromide prior to sailing due to the risks resulting from the difficulty in ventilating the cargo effectively (IMO 1996). As an alternative to methyl bromide, for safety and efficacy reasons, in-transit treatment with phosphine is restricted to specially-designed bulk carriers, tanker-type vessels and other ships where the holds are gastight or can be made so (Semple and Kirenga 1997). In addition, equipment must be installed to circulate the phosphine through the cargo mass (Watson *et al.* 1999). The circulation equipment ensures that the gas penetrates throughout the load and can be aired from the load prior to unloading. In-transit treatment of bulk grain is in widespread use, potentially avoiding the need for methyl bromide treatment prior to shipment where import and export regulations permit.

Recently for example, the Indonesian Applied Research Institute of Agricultural Quarantine (ARIAQ) has established phosphine fumigation protocols using ECO2FUME for QPS treatment of major commodities in the country such as rice and other stored grains, coffee, cacao, tobacco, pineapple, and mangosteen. Additional phosphine fumigation protocols are currently being developed for other commodities such as wood chips, cut flowers and other export fruits and vegetables. The Indonesian AQA is also working on bilateral agreement with importing countries in the adoption of ECO2FUME for QPS treatment (Tumambing, 2013). A comprehensive "Technical Manual for Liquid Phosphine (ECO2FUME)" in Bahasa Indonesia and English version was produced and later approved for implementation by the Indonesia AQA. The said technical manual will serve as a reference guide for all Indonesian fumigators involved in QPS treatment of different import and export commodities using ECO2FUME.

Controlled atmosphere technologies have some usage at present, but have potential for much more widespread adoption. The application of CA technique in e.g., Vietnam, is also certificated by the Plant Protection Department of Vietnam as a qualified treatment practice for phytosanitary objects. This certification allows users to control insects for import of phytosanitary objects, without using any toxic chemicals. Necessary documentation such as a Phytosanitary certificate to declare that the products have been inspected and/or tested and to state that the products are considered to be free of quarantine pests is provided, based on the treatment certificate of a CA treatment.

Direct application of pesticide to the grain will also will give pest-free grain to inspection standards, sometimes with a holding period before inspection to allow for action of the pesticide on the pests. Rapid acting pesticides for direct application include dichlorvos and cypermethrin. The use of methyl bromide alternatives is limited by various registration issues and also by market and end user requirements, some of which require 'residue-free' grain.

Sulfuryl fluoride fumigation is restricted by the availability and registration of the fumigant to only a few countries at this time. However, it is now used routinely as an alternative to methyl bromide for pre-shipment treatment of grain e.g., in Australia.

Although heat is technically feasible, its use is limited by the high cost of heat treatment facilities that are able to heat grain moving at fast handling speeds, such as when loading or discharging, compared to the costs of facilities to implement other alternatives. Small scale heat disinfestation facilities for bulk grain, operating at a relatively slow speed of tens of tonnes per hour throughput, are commercially available.

4.9.4. Alternatives for pre-plant soils use for propagative material and nursery uses

4.9.4.1. Treatment of soil with methyl bromide to control pest incursions

Pests that are accidentally introduced to an area where they are not known to occur is called an 'incursion'. When an incursion of a pest occurs, such as a soil pest, disease or weed, it is important to implement a control measure as soon as possible to prevent the pest spreading. During this time, the pest is under "*official control*" and it is considered a quarantine treatment. If the spread stays restricted, the pest may stay under official control until such time that the pest is eradicated which is the ultimate goal.

Methyl bromide has been selected for many years by phytosanitary organisations to treat incursions. Treatment of soil to eliminate officially-recognised quarantine pests, either in soil transported as a substrate or treated *in situ*, is consistent with the Montreal Protocol's definition of a QPS use. Examples include:

- Soil or substrate that is either imported or exported as a commodity (to grow plants in) was sometimes fumigated with methyl bromide as a quarantine measure in Malaysia[4]

- Soil *in situ* was fumigated for controlling and containing quarantine pest, such as the pale potato cyst nematode *Globodera pallida,* which is a quarantine pest in the United States. Occurrence is limited to the State of Idaho. The movement of plant materials from the State and designated quarantined areas within the State are restricted by State Regulations[5]. In 2007 and 2008, a total of 217 tonnes of methyl bromide were used to control incursions of the potato cyst nematode (TEAP 2009)

- Soil fumigated with methyl bromide in Australia prior to 2006 to control and eliminate branched broomrape, which is an exotic quarantine pest (parasitic plant) that has a limited distribution within the country.

If the pest/disease/weed spreads rapidly then it may lose its official control status. In that case methyl bromide use is no longer considered a quarantine treatment. Methyl bromide can still be used providing an exemption is granted for this use under the CUE process e.g., Israel use for broomrape prior to 2010. However, the CUE approval takes longer than one year during which time the pest can spread, and therefore methyl bromide is not an ideal solution for the initial control of a pest incursion.

Alternatives are being sought to replace the use of methyl bromide where it is known to not be fully effective in controlling pests or in cases where there are restrictions on its use. MBTOC is unaware of studies which report directly on the relative efficacy of alternatives to methyl bromide to manage pest incursions. However, fumigants

[4] TEAp, 2009 (QPSTF Report) and MBTOC survey sof MB uses 2009 qnd 2010 Some of Malaysia's total QPS consumption of 5.05 tonnes in 2007 and 0.5 tonnes in 2009 was reported to have been used for treatment of soil as a substrate

[5] Federal Register Vol 73 No. 177, Sept 11, 2008; USDA 2007. Regulations 301.86 to 301.89

used to the disinfest soil as a result of work in the non-QPS sector can provide guidance on the suitability of alternatives for controlling pest incursions (See chapter 5). Methyl bromide was not totally effective in controlling branched broomrape incursions in Australia. Alternatives to methyl bromide are now used to manage the incursions (Faithful and Maclaren, 2004). In the US, fumigants designated for use for preventing incursions are permitted to be used at rates higher than those specified on the label. This designation opens up the opportunity for the temporary use of non-MB soil fumigants to control pest incursions.

4.9.4.2. Treatment of soil with methyl bromide to control pests in propagated plants

MB can also be used to control pests, diseases and weeds in soil to meet official certification standards. Treatments of soil-in-situ against endemic pests on nursery plants to meet certification standards was about 25% of the QPS consumption reported by non-Article 5 Parties (TEAP 2010). The USA is the only Party that classifies pre-plant soil fum,igation with methyl bromide for certification as a QPS use. All other Non-Article 5 Parties classify such treatments as normal soil use that would require an annual CUE approval, if alternatives to methyl bromide are not available.

The treatments with methyl bromide in the US target only nematodes that are found in strawberry nursery runners, forest nurseries, turf grass, bulbs, ornamental plant nurseries and seed potatoes. The US maintains a QPS exemption for use of MB for these uses complies with 'Federal Register Rule' (FR68). This Rule covers only '*plants for planting'* that are '*moved from one distinct locality to another*' and for '*official quarantine requirements specifying that the underground portions of the propagative material must be free from quarantine pests*'. The Rule only applies to propagative material to meet official quarantine requirements of the destination to which such material in transported. However, the quarantine pests present at the source must not be present at the destination, in order to be consistent with the intent of the FAO definition of 'Quarantine' and the definition used in the Montreal Protocol.

The limited data available (Horner 1999, De Cal *et al*. 2004, Mann *et al*. 2005) indicates that methyl bromide fumigation of the soil and other fumigant alternatives cannot guarantee the soil is entirely free of pathogens, especially fungal pathogens**..** In addition, soil disinfestation with methyl bromide, whilst often being an effective tool for minimising disease levels on nursery stock, does not guarantee a reduction in disease levels to zero, but only to a low and undefined level.

Although QPS methyl bromide has not been reported for fungal pathogen control, the prospects of control to the standard required for certification appear limited. Horner (1999) showed that root material infested with *Phytophthora fragariae* could still survive MB:Pic/70:30 fumigation when placed at depths of 12 to 30cm in soil and, moreover, that these infested roots could still cause both root and crown root symptoms. They also showed that alternative fumigants, e.g. chloropicrin or 1,3-D/Pic produced similar results to the MB/Pic treatments. De Cal *et al.* (2004) isolated *P. cactorum* (in up to 7% of plants), *Fusarium* (3%), *Pythium* (2.5%), *Verticillium* (0.2%) and *Colletotrichum* (0.2%) from strawberry runners produced in soils disinfested with methyl bromide. In these examples, disease levels were higher than would normally be expected to meet certification standards for disease tolerance (usually <1% of plants affected).

Similarly, Mann *et al*. (2005) showed that hot-gas MB (100%, 60 g m^{-2}) did not eradicate consistently buried inoculum of *Fusarium oxysporum, Rhizoctonia solani, Rhizoctonia fragariae* or *Sclerotium rolfsii* placed at depths of 10, 20 and 40cm in a clay-loam soil, particularly at soil depths of 40 cm. Another study showed that injected MB:Pic (30:70, 50 g m^{-2}) did not eradicate buried inoculum of *Phytophthora cactorum, F. oxysporum, R. solani, R. fragariae* or *S. rolfsii.* Survival was generally low, mostly at depths of 20 and 40 cm in soil and was higher when samples were taken further away from the injection point for methyl bromide.

Production of high health propagative materials remains a significant challenge in some sectors (ie strawberry runners) as Parties transition away from MB (Zasada *et. al*., 2010). Alternatives, particularly combinations of existing alternatives including the 3 way system (1,3-D, Pic and metham), and 1,3-D/Pic are being widely adopted to replace use of MB for critical uses. Some have been used to replace methyl bromide for the production of certified plant nursery material. MBTOC notes that many countries have phased out methyl bromide and alternatives are now used for production of certified plants or plants required to meet stringent high health standards. The EU phased out MB in nursery production between 1992 and 2007 (EC Management Strategy, 2009). Chemical alternatives in commercial use for this purpose include dazomet, metham sodium, and 1,3-D (with restrictions as stated in Chapter 5 of this report). In A5 countries, certified plant materials are produced without MB; for example, substrates are used for certified citrus and banana propagative materials in Brazil (Ghini, pers. comm., 2014); grape, pear, apple, and citrus propagative materials are produced in Argentina without MB (Valeiro, pers. comm., 2014).

Japan phased out MB in nurseries in 2005. Alternatives in commercial use include dazomet, chloropicrin, 1,3-D, and MITC (Tateya pers. comm., 2010). A recent publication gives an excellent overview of the situation for the strawberry nursery industry around the world (Lopez- Aranda, 2012).

The use of substrates also offers another alternative method to methyl bromide which avoids the need for soil fumigation with any chemical to grow crops, however it is often too expensive. Several industries in some countries (ornamentals, cucurbits, tomatoes, strawberries) have nevertheless adopted soilless production where economically feasible (i.e. can include only certain stages of the propagation system), to avoid the need to grow crops in soils that can harbour endemic and exotic pathogens and pests.

4.9.5. Alternatives for fresh fruit and vegetables

Although the vast majority of horticultural products globally are harvested and placed on the market without any postharvest treatment, some of the trade in horticultural products enters the market only after a treatment has been carried out on the harvested product that aims to kill any pests that are of concern. Such treatments can be important for reducing the risk of accidentally transferring pests present in the export country but not in the importing country. These treatments may be applied either pre-shipment, in-transit or on arrival depending on the phytosanitary requirements of the importing country.

Postharvest insect control treatments applied to horticultural commodities may include physical treatments (such as cold, heat, controlled/modified atmospheres, removal, irradiation, radio/microwave frequencies, pressure/vacuum), fumigation treatments with either Generally Recognised As Safe (GRAS) compounds (i.e. ozone, ethyl formate), or higher risk fumigants (i.e. methyl bromide, phosphine, sulphuryl fluoride, carbonyl sulphide, cyanogen) or insecticidal dips. Some postharvest practices currently used, such as coolstorage, can be utilised as a disinfestation treatment (or part thereof) if efficacy can be demonstrated. In addition, computing power and visual and spectral systems have now reached the point where insects can be detected "in line" (during packing), and thus fruits with insects might be excluded during packing.

MBTOC (2002) recorded more than 300 alternative quarantine treatments for perishable commodities that had been approved by a National Plant Protection Organisation (national quarantine authorities). Ensuing MBTOC Assessment Reports (2007, 2011) also provide ample information in this respect.

Approved alternatives, which are presently in use include cold treatments, various types of heat treatments, heat + controlled atmospheres, pesticide dips or sprays, wax coating, pest removal (e.g. by brushing), alternative fumigants, irradiation, crop production in areas free from quarantine pests, the systems approach, and inspection procedures.

The type of alternative treatment to methyl bromide that can be applied to kill insects on horticultural products tends to be specific to individual crops, cultivars, pests, markets and even growing regions. Alternatives to methyl bromide should be cost-effective, practical to apply within the logistics chain, and sufficiently effective against a wide range of insects.

New solutions are also being increasingly targeted to be "soft" solutions that leave no residues, and in some cases even reduce agrichemical residues that were applied pre-harvest.
Restrictions on residues are increasing in many markets and there has been renewed interest in utilising postharvest disinfestation treatments that do not leave residues, to control pests that have previously been controlled by residue-contributing preharvest measures, and even to decrease residues after harvest (e.g. water blasting or hot water treatments). Non-chemical disinfestation may become a marketing advantage (healthy fruit) and a valuable alternative to methyl bromide (Chevin *et al.* 2000).

Certain quarantine treatment technologies such as irradiation are not universally accepted, which slows their adoption. Other treatments such as heat or cold can be faster to implement since they are not chemicals that require registration. Area-wide pest management programs lower pest levels before harvest and improve the quarantine security provided by any postharvest treatments. These lead to "Systems Approaches" which capitalize on cumulative pest mortality from multiple control components to achieve quarantine security in an exported commodity. Standardized phytosanitary measures and research protocols are needed to improve the flow of information when countries propose to trade in a regulated commodity (Follett and Neven 2006).

4.9.5.1. Cold treatment

Cold storage is used for the majority of fresh produce to extend its postharvest life and can effectively control many pest species. An advantage of cold treatments is that they can be applied in transit. However, evidence of compliance with insecticidal, in-transit requirements of the importing country can be difficult to produce for compliance purposes. Cold treatments are generally not suitable for tropical and subtropical fruit as they are more susceptible to chilling injury. However, some cold-sensitive commodities can be preconditioned at temperatures near to the chilling threshold to enhance tolerance to a subsequent disinfestation cold storage treatment.

In general, the order of susceptibility for some market access pests on produce from most susceptible to most tolerant (indication of the number of days required for ~99% mortality at 0^oC) is: mealybug (18-30) < lightbrown apple moth (34-76) < leafrollers (46) = codling moth (66-152) < mites (26% @ 90 days). It is important to note that effective lethal times are generally more for pests on fruit than for the same pest/life stage off fruit. Cold storage is generally a long treatment and depends on the susceptibility of the species and life stage to low temperatures. Some fruit can be stored for many weeks before export.

Cold treatment is a long used MB alternative for importation of citrus fruit into the US from areas of the world indigenous for quarantined species of fruit flies. Because of discovery of surviving fruit fly larva in cold treated fruit, the effectiveness of this protocol was put in doubt. USDA scientists, working with scientists from South Africa, Argentina and Kenya are revising the protocols to ensure its continued use as a MB alternative.

Cold treatments for *Bactrocera tryoni* on oranges (*Citrus sinensis*), on tangors (*Citrus reticulata* × *C. sinensis*), on lemons (*Citrus limon*) in the process for approval. The TPPT accepted the schedules and recommended to the IPPC Standards Committee for adoption by the CPM to be included in ISPM 28 (IPPC, 2011).

4.9.5.2. Heat treatments

Heat is generally acceptable from the environmental standpoint but is energy-intensive and could be questioned with respect to CO_2 emissions. Applied treatments range from 40 to 50^oC for minutes to hours. Heat treatments are usually required to bring the core temperature of the largest fruit in the coolest part of the treatment chamber to the specified temperature and hold it for the required time. The temperature, duration and application method must be precise and uniform to kill pests without damaging the commodity.

Heat treatment is suitable for controlling internal and external pests, as the treatment penetrates in to the commodity. Heat treatments can be applied as hot water or hot air. Hot air treatments can be applied as a high relative humidity ("vapour heat") or low relative humidity heat treatment (HTFA).

For more susceptible commodities, conditioning treatments prior to heat treatments can increase their tolerance to subsequent heat treatment (Hara, 1977). However, any conditioning treatment needs to be thoroughly investigated, as the tolerance of the pest to heat treatment may also be enhanced thereby reducing its usefulness as a disinfestation treatment.

Most of the hot air disinfestation research carried out use a high temperature forced air (HTFA) system (low relative humidity) system that overcomes the problem of water condensing on the surface causing commodity damage, which can occur when the vapour heat treatment is used. Many heat treatments have been approved by regulatory authorities for disinfesting fruit flies from tropical and subtropical fruit products. The cost of heat treatments has been reported to be 6-7 times more than that of methyl bromide fumigation (USEPA, 1996). HTFA treatments have been developed and are operating as quarantine pre-shipment treatments in the Pacific region (Williamson and Williamson, 2003; Waddell *et al.,* 2004), the US (USDA, 2001), Mexico (Shellie and Mangan, 1995) and others.

Vapour heat treatment uses air saturated with water vapour whereby heat is transferred by the condensation of water vapour on the cooler fruit surface. It is mainly used for the disinfestation of fruit flies on subtropical fruit, with a specification for most products is 44.5oC for 8.75 hours and then immediately followed by cooling. Commercial facilities operate in many countries including Australia, the USA, Thailand, Taiwan, and the Philippines. The USDA has approved vapour heat treatment for bell pepper, some citrus, eggplant, mango, papaya, pineapple, squash, tomato and zucchini. Vapour heat treatment for *Bactrocera tryoni* on mangoes (*Mangifera indica*) in the process for approval. The TPPT (Technical panel on Phytosanitary Treatments) accepted the schedule and recommended the IPPC Standards Committee to send it for member consultation (IPPC, 2014).

High temperature can also be combined with controlled atmospheres to decrease the severity of the treatment (time or temperature) while maintaining high pest mortalities. The relative mortality responses of leafrollers to a wide range of HTCA treatments have been identified (Whiting, 1999). A controlled atmosphere/temperature treatments system (CATTS) has been effective in disinfesting cherries from codling moth (Nevin and Drake, 2000).

Hot water treatment offers an additional option for heat treatment and involves immersing a batch of fruit in heated water for a specified time at a specified temperature. Short but high temperature hot water treatments were shown to be an effective non-chemical method for controlling fungal pathogens in citrus without human health risks associated with the chemical fungicides. The research was carried out because of increasing concern with the use of such fungicides, particularly in the diets of children, as well as concerns with widespread occurrence of fungicide-resistance isolates, with environmental problems associated with the disposal of water used in packing operations, and with the limited number of fungicides available to control rots in citrus (Irtwange 2006). The researchers postulated that the same temperatures that were used to control the fungi may also control insects on the surface of the citrus. Longer treatments are required for internal pests such as fruit fly, to heat the whole fruit but such longer duration treatments are likely to damage many crops. Generally, hot water treatments are more effective at the same temperature than hot air treatments, because of faster heat transfer in water and the more uniform heating of the fruit by use of high water flow, and therefore hot water generally costs less to apply

4.9.5.3. Controlled and modified atmospheres (CA, MA)

CA treatments at ambient have been used for many years to prolong the storage life of many commodities and to control pests, in particular in grains and nut crops. Research has demonstrated its efficacy against pests for fresh commodities. In general, the most effective CAs at ambient were below 1% O_2 and above 20% CO_2 for insect control.

Most insecticidal treatments using CA require long exposures, ie, six days were required to control flower thrips (*Thrips obscuratus*) on kiwifruit flowers at 2% O_2, 18% CO_2, 20°C (Potter *et.al,* 1994) while carbon dioxide concentrations of >30% at 20°C were shown to kill onion thrips (*Thrips tabaci*) on onions after at least 24 hours of fumigation. These long treatment times may not be acceptable for some markets as they miss the period of highest market prices. In addition, prolonged exposure to low O_2 and/or high CO_2 has a detrimental effect on some fresh fruits.

Cold storage can be applied in combination low oxygen and/or high carbon dioxide atmospheres and this is referred to as controlled atmosphere (CA) cold storage. The ability of cold storage to control pests can be improved when cold storage is combined with controlled atmospheres. The more cold tolerant species include codling moth, mites, apple leafcurling midge. When cold storage is combined with controlled atmosphere, the time to cause high pest mortality can be further reduced (i.e. leafrollers – Whiting *et al.* 2000) in most cases, but not always (i.e. scale insects, Whiting *et al.* 2003).

Navarro *et al.,* (1999) showed that the addition of CO_2 halved the amount of MB required to kill larvae when compared with MB without CO_2. The amount of methyl bromide could be reduced still further at elevated temperatures.

Hot, forced, moist air with a linear heating rate of 12°C/h to a final chamber temperature of 46°C under a 1% oxygen and 15% carbon dioxide environment has been successfully used to control codling moth, *Cydia pomonella* (L.), and oriental fruit moth, *Grapholita molesta*, a serious pests of apples for whisch strict quarantine restrictions are in place in some countries (Neven and Rehfield-Ray (2006).

Non-chemical quarantine treatments, using a combination of short duration high temperatures under low oxygen, elevated carbon dioxide atmospheric environment were also developed by Neven and Rehfield-Ray (2006) to control western cherry fruit fly, *Rhagoletis indifferens* in sweet cherries

4.9.5.4. Removal

There is a range of techniques that can be used to remove insects from fruits physically. A significant advantage of treatments that remove insects compared with those that simply kill insects is that absence of insects on arrival in overseas markets means that the product line is much more likely to pass official phytosanitary inspection.

Use of rotating brushes during packing (generally prior to quality checking and grading) is a common practice in most fruit crops. This is carried out either on dry brushes or with lightly wetted brushes. Such treatments remove dirt and other material from fruit, and in doing so they also remove exposed pests such as thrips, mites, beetles and Collembola. However, they will not remove insects and mites that are well protected by either their structure e.g. scale insects or insects within cocoons fastened to the surface, or because they are protected by coverings or location in crevices or structures of the fruit e.g. under calyx.

Removal by water blasting (or high pressure water washing) is also in use. This can be done for longer durations (10-20 seconds) over rotating brushes, or for very short times without brushes.

Moderate pressure / high volume water systems were developed successfully for citrus to dislodge scale. These washers been used in a number of countries including the USA, Israel, New Zealand and South Africa, also for other fruits such as apples. Although water blasting is generally carried out using cold water, the value of killing and removing mould spores and insects using hot water and additives has been examined in the Western US (Bai *et al., 2006;* Hansen *et al*, 2006; Neven *et al.,* 2006; Spotts *et al,* 2006).

A high-pressure apple washer was developed in New Zealand that oriented fruit and sprayed them with a much shorter (generally 0.5 to 1 second) higher pressure water treatment. In Australia, A higher pressure low volume treatment has proved to be successful in avocado (Jamieson, 2005), and water blasting is now a requirement for avocados entering the USA. Water blasting is also very effective in removing pine pollen (*Pinus radiata*) from the base of fruit, and spray residues.

4.9.5.5. Ionising irradiation

Various forms of ionizing irradiation have been investigated as disinfestation treatments. Including as alternatives to MB The three major forms are gamma irradiation, electron beam, and x-ray. Gamma irradiation is generated from radioactive isotopes, which causes public concern with the safety of isotope transport, long-term storage and facility location. Electron beam irradiation does not use radioactive material, and therefore does not have the same public concerns. Gamma irradiators have better penetration and can treat packaged or bulk products, while electron beam accelerators more effectively treat products in thin layers (2-5 cm thickness). X-ray irradiation has better penetration than electron beam. However, the technology using X-rays is a recent development for disinfestation and published reports more limited than for research based on gamma and electron beam.

Generally, irradiation doses from 0.05 to 0.2 kGy are sufficient for quarantine security, but the exact dose varies with the insect being targeted. The USDA-accepted treatment dose for fruit flies is 75-150 Gy. However, other insects, such as moths, require a dose of ~250 Gy At these doses the insects are not necessarily killed but will not continue development. In these cases, evidence of exposure to irradiation is required to satisfy phytosanitary inspectors that the insects although alive are sterile and present no biological risk.

An advantage of irradiation compared with some other non-fumigation methods is that the treatment is fast, residue-free and fruit can be treated in the final packaging. Three challenges exist with using irradiation as a quarantine treatment. Firstly, compared with other treatment options the capital costs of irradiation are high, which means treatments must be made in a few central locations. Secondly, irradiation can render the pest stages sterile, rather than dead, leaving the government or quarantine inspector uncertain as to whether the insects were exposed to irradiation, whether all the insects were treated, or whether the pest entered the commodity following irradiation. Thirdly, irradiation does not have regulatory approval as a food treatment in all markets and has poor consumer acceptance in some, although this is changing and may be less of an issue in the future. In the past, consumers have been concerned with food safety issues relating to irradiated products.

Nevertheless, the use of irradiation as a phytosanitary treatment has increased s, with an undetermined part of this volume directly replacing methyl bromide fumigation. In 2013, about 5,800 tonnes of fresh fruit were irradiated for import into the US. This is a dramatic increase of 6,500% with respect to 2007 (Jeffers, 2014). Most PPQ treatments occur in the exporting country (and are thus pre-cleared), for example Mexico, South Africa, Thailand and Vietnam (Jeffers, 2014).

Other products traded with an irradiation treatment include purple sweet potatoes from Hawaii, mangoes from India; guava, mangoes and papayas from Mexico; grapes from South Africa; lychees, mangosteen and rambutan from Thailand; and Dragon fruit from Vietnam. Irradiation treatments have recently shown to provide sufficient quarantine security against the mango pulp weevil, *Sternochetus frigidus,* an important quarantine pest preventing the export of mangoes from the Philippines to the United States and other countries (Obra *et al*, 2014). Additionally, about 175 million lbs of spices are irradiated each year in the US as a treatment against microbial contamination.

Irradiation treatment for mealybugs (Pseudococcidae) for all fruits and vegetables in the process for approval. The TPPT accepted the schedule and recommended to the IPPC Standards Committee for adoption by the CPM to be included in ISPM 28 (IPPC, 2011, 2014).

4.9.5.6. Radio frequencies and microwaves

Radio-frequency (RF) and microwave energy are sources of heat that involve the application of electromagnetic energy at 10-30,000 MHz. Because of the congested bands of radio-frequency and microwaves already being used for communication purposes, regulatory bodies have allocated five frequencies for industrial, scientific and medical applications: 13.56, 27.12, 40.68 MHz in the RF range and 915 and 2,450 MHz in the microwave range. It is important to develop effective means to deliver thermal energy uniformly to every part of the fruit where insect pests may reside, to shorten treatment time and minimize thermal impacts on the fruit quality. RF heating has the advantage of fast core heating of fruits because of direct interaction between the RF energy and the fruit tissue to raise the centre temperature quickly, especially for large fruits. At some wavelengths, insects can be selectively heated without adversely heating the fruit (Schneider *et al.,* 2003).

RF and microwave treatments to control pests on various commodities have mainly focused on control of beetles and moth larvae (Lagunas-Solar *et al, 2007;* Birla *et al,* 2008a). For internal pests, RF has been used in combination with water immersion to obtain uniform temperature increases in both the core and surface of the commodity (Tiwari, 2008).

The prospects of using radiation energy sources for post-harvest pest control has received increasing attention in recent years, particularly in the area of microwave (Purohit *et al*., 2013; Manickavasagan *et al*., 2013) or radio wave frequencies (Jiao *et al*., 2012; Wang et al., 2013). The use of ionizing radiation in this field has recently been reviewed by Hallman (2013).

4.9.5.7. Pressure treatments

Pressure techniques (mainly below barometric pressure – vacuum) have been investigated as a means for pest control on commodities for many years.

A pressure-based method for rapid and effective insect and mite control that combines pressure, controlled atmosphere and volatiles, was developed by the University of California and Plant & Food Research in New Zealand. The method is known as 'metabolic stress disinfection and disinfestation' (MSDD) and combines physical and volatile treatments to disinfest plant products. It has been shown to be a rapid and effective method for controlling microbial and arthropod pests, applicable to a range of commodities (Lagunas-Solar, 2006).

4.9.5.8. Alternative Fumigation Treatments

Fumigation is a widely used treatment employed to eliminate pests from a range of commodities including fruits and vegetables. During fumigation, a chemical with a high vapour pressure is introduced into a closed space and maintained at a certain level for a specified minimum time.

A 'Generally Recognised As Safe' (GRAS) status for a compound is determined by the US Food and Drug Administration. GRAS compounds are considered safe for use with human food (Anon, 1993a). The advantage of treatments utilising GRAS compounds is that they are already accepted by the USDA-APHIS-PPQ after a series of strict criteria have been satisfied. GRAS substances may therefore be excluded from mandatory premarket approval by the United States Food and Drug Administration when used on produce to control pests.

4.9.5.8.1. Ethyl formate

Ethyl formate is a plant volatile. It is classified as a GRAS compound and therefore considered safe for use in conjunction with food (Anon, 1993a). Ethyl formate is flammable and explosive when mixed with air at concentrations required to kill pests, but formulations in CO_2 reduce this risk significantly. Ethyl formate is currently registered in Australia, Switzerland, Italy, United Kingdom, United States, Germany, Canada and New Zealand. VAPORMATE™ (16.7 wt% ethyl formate dissolved in liquid CO_2) is registered and used through other regions.

Vapormate™ is being increasingly used for disinfestation of fresh fruit and other perishables in situations where MB could be used, particularly where target pests are on the outside of the treated commodity. Vapormate is a rapid acting, non-residual post-harvest fumigant for the control of insects (adults, juveniles and eggs) in stored grain, oilseeds, dried fruit, nuts, fresh produce (e.g. bananas, blueberries) and cut-flowers, enclosed food containers and food processing equipment (Finkelman *et al*., 2012). It is also a naturally occurring compound in the environment and present in some plants/food products.

As alternative to MB for the disinfestation of nitidulid beetles (the proportion of insects found outside the feeding sites and nitidulid beetles from artificial feeding sites under laboratory conditions), the effect of various dosages of Vapormate was tested at 30°C and after a fixed exposure time of 12 h. Exposure of artificially infested feeding sites (larvae of *Carpophilus* spp.) to a concentration of 280 g m^{-3} of Vapormate caused 69.3% disinfestation and 79.9% mortality, 350 g m^{-3} resulted in 72.7% disinfestation and 98.8% mortality, and the optimal results were obtained at 420 g m^{-3} that caused 69.6% disinfestations and 100% mortality. Commercial pilot-plant tests were carried out by applying 420 g m^{-3} Vapormate for 12 h within a 9 m^3 flexible liner of gas-impervious laminate (polypropylene/ aluminum/ polyethylene) to cover crates containing infested dates. Disinfestation (removal of larvae from infested dates) was tested on naturally infested dates that resulted in average 100% disinfestation and 95% mortality, while with the artificially infested dates, disinfestation was 97% and mortality 96%. In a second series of tests, a commercial rigid fumigation chamber of 95.6 m^3 was used. After 12 h of exposure, 100% mortality was recorded in all date samples.

Mitcham *et al*., (2011) and Pupin *et al*., (2011) reported mortality test with Vapormate. Bean thrips are a quarantine pest of navel oranges in some countries. The authors showed that fumigation for one hour of thrip-infested navel oranges at 5˚C with 31 mg/l ethyl formate gave a 100% kill of over 35,000 thrips treated in the test. The fumigation had no deleterious effect on the navel orange quality. Fumigation of some varieties of table grapes with Vapormate at a concentration effective for quarantine control against the light brown apple moth, did however reduce the quality of export quality grapes. Additional testing is in progress to determine whether this damage could be minimized by changing the fumigation parameters.

Vapormate use is increasing and has been successfully applied for controlling surface pests on export blueberries in New Zealand where some 120 consignments have been treated in shelf ready packaging. The consignments have passed phytosanitary inspection with no live pests found immediately after treatment (Glassey, pers. comm., 2014). This contrasts with MB fumigation where some pests can take some days to die at rates suitable for the fruit. Apples infested with eucalyptus weevil have been successfully treated in four large field trials with ethyl formate at 50-55g m^{-3} for 24 hours at 4-8°C with no harm to the apples (Agarwal *et al*., 2012). Vapormate also successfully controlled overwintering spotted spider mites *Tetranychus urticae*, on persimmons within 6 h at 5°C with a ct products of 147.98 g h m^{-3} and the grape-myrtle scale *Asiacornoccus kaki* deleterious with 41.12 g h m^{-3} to result in 99% mortality (Cho *et al*., 2012).

In Japan, mortality tests are carried out with a mixture of ethyl formate gas and carbon dioxide for controlling the leafminers *Liriomyza sativae and L. trifolii*, spider mites *Tetranychus cinnabarinus* and *T. Kanzawai*, scales and mealybugs. All spider mites except for diapause adults of *T. kanzawai* were killed with the gas mixture at a dosage rate of 250 g m^{-3}, and diapause adults were killed at 350 g m^{-3}. Control of pupal stages of both leaf miners was less complete (Yamada *et al*., 2012).

Five species of scales (*Diaspis boisduvalii, Aonidiella auranti*, and *Coccus hesperidum*) and mealybugs (*Planococcus citri* and *Dysimicoccus brevipes*) were fumigated with a gas mixture of ethyl formate and carbon dioxide using the same formulation as Vapormate. All tested developmental stages of *D. boisduvalii*, *A. auranti,* and *C. hesperidum* were completely killed at a fumigation dosage of 150 g m^{-3} after treatment for 3 h at 15°C. Crawler, nymph, and adult *D. brevipes* were more tolerant than *P. citri*; however, these stages of both mealybugs were completely killed (100 %) at dosages of 100 g m^{-3} of the gas mixture. Among the five species tested, the least susceptible stage were the eggs of *P. citri*. They were killed (100%) with the described gas mixture with 350 g m^{-3} dosage rate under vacuum (<18–22 kPa) (Misumi *et al*., 2013a).

Possible quality changes in banana, pineapple, strawberry, grapefruits, Satsuma mandarin, squash, string bean, parsley and broccoli are also investigated in Japan. It has been found that the gas mixture of ethyl formate and carbon dioxide is an effective quarantine treatment for fruits that could be adopted in the future. Some degree of damage has been observed on leafy vegetables, but changes in flavour were observed in parsley (Misumi et al., 2013b).

The residues from ethyl formate quickly break down to levels occurring naturally in food and in the environment. Ethyl formate is effective at low temperatures and therefore does not reduce the shelf life of products. Its activity is strongly synergised by CO_2. While the price per kilo is comparable to methyl bromide it is more expensive to be successfully applied due to the higher application rate, but with lower phytotoxicity and immediate death of pests. Thalaviassundaram and Roynon (2012) found that ethyl formate penetrated through the commercial cardboard and plastic wrapping of sultanas.

Vapormate is now registered in South Korea and used as a quarantine treatment for fumigating some imported fruits including bananas (Lee *et al*., 2009). This fumigant is registered in Australia and New Zealand for a range of postharvest durable commodities including grains, but not yet as a quarantine treatment. Vapormate is registered and widely adopted for disinfestation of dates in Israel for use by the date industry as an alternative to MB (Navarro, 2006; Finkleman *et al*, 2010). According to a new Tunisian law, MB is now banned for use in all newly built packing houses (Dhouibi personal communication). Registration of Vapormate (ethyl formate+CO_2) for dates is under way in Tunisia (Dhouibi, 2013). Registration is also progressing in South East Asia, South Africa, the USA. The BOC South Pacific Company is continuing with industry market acceptance tests (Linde 2013).

4.9.5.8.2. Ozone

Ozone (O_3) is a naturally occurring compound that provides protection from the negative effects of ultraviolet light (UV). It is a colourless or bluish gas, heavier than air with a characteristic odour of electrical sparks. It can be generated by electrical discharges in air, and is currently used in the medical industry to disinfect medical equipment of micro-organisms and viruses. It is also used for reducing colour or odour and for removing taste, colour and environmental pollutants in industrial applications (Kim *et al,* 1999).

Ozone is classified as a GRAS compound and recently there have been increased efforts to develop and use ozone as a postharvest disinfestation tool in the USA. Recently, small, energy-efficient high-output portable ozone generators with ducted outputs have been commercially developed, generating sufficient concentration and volume to treat large volumes such as sea containers. Such units have the potential to provide an overnight treatment for a container while consuming a modest amount of electricity.

Ozone has the potential to cause damage to fresh produce and for this reason, concentrations of less than 50 ppm should be investigated. Ozone may need to be used in combination with cold storage if treatment times exceed eight hours. Reduced airflow is thought to severely decrease ozone efficacy. Humidity may also play a role in ozone efficacy. Ozone was six times more toxic at high than low relative humidity (Margosan and Smilanick, 2002).

4.9.5.8.3. Essential oils and volatile organic compounds

The fumigant activity of a large number of essential oils and essential oil components extracted from aromatic plants was evaluated on cut flower quarantine pests *Bemisia tabaci*, *Frankliniella occidentalis* and *Liriomyza huidobrensis* (Kostyukovsky *et al.* 2002). The most active compound had similar insecticidal qualities as methyl bromide against major insect pests of dry stored food. A concentration of 10 and 20 g/m3 and exposure time of 2 and 4 h, respectively, were sufficient to obtain 100% mortality of adult *B. tabaci* and *F. occidentalis*. A 50-60 g/m3 concentration for 2 h killed *L. huidobrensis* larvae.

Lacey *et al.* (2009) tested the effects of volatile organic compounds (VOCs) emitted by the endophytic fungus *Muscodor albus* on codling moth adults, neonate larvae, larvae in infested apples, and diapausing cocooned larvae in simulated storage conditions. Although adjustments are still needed with respect to exposure times and dosages, data on treatment of several stages of codling moth with *M. albus* VOCs indicate that the fungus could provide an alternative to broad spectrum chemical fumigants for codling moth control in storage and contribute to the systems approach to achieve quarantine security of exported apples.

4.9.5.9. Non GRAS fumigants

4.9.5.9.1. Phosphine

Most reports concerning the efficacy of phosphine fumigation for fruits and vegetables as well as cut flowers have used the metallic phosphide pellets. Fumigation with 0.5 – 4.5 g/m^3 phosphine (from metallic pellets) for 12-96 h at ambient temperatures can be effective against a wide range of insects The efficacy of phosphine applied as metallic pellets is reduced at lower temperatures and therefore its use below 10°C is not recommended. However, pure phosphine can be used at cool storage temperatures and be effective at concentrations that do not damage fresh produce.

In cut flowers, a dosage of 0.3 g/m3 phosphine for 4.5 h gave complete mortality of *Myzus persicae* and some mortality of larvae of *Strepsicrates ejectana*. Fumigation for 6 h with 1.4 g phosphine/m3 killed all pupae and most larvae of *S. ejectana*. Most of 19 species of cut flowers showed no sign of damage either immediately after fumigation or 7 days later. Williams *et al.* (2000) reported that the phosphine cylinder gas formulation $ECO_2FUME^{®}$ (phosphine with CO_2 as a carrier gas) was recently registered for a 15-h treatment of cut flowers. Very recently, Zhang *et al* (2015) reported that phosphine with or without CO_2 can achieve 100% mortality of Western flower thrips, *Frankliniella occidentalis*, an insect species which is widely distributed in China but limits exports of cut flowers as it is listed as a quarantine pest in some importing countries. The treatment had no adverse effects on vase life and damage indices of two oriental lily cultivars at 1.66mgL−1 PH3 and 12% CO2 for 16 h, and at 2.29mgL−1 PH3 without CO2 gas for 2 d at 5 ◦C.

Trials have indicated that phosphine fumigation usually resulted in satisfactory mortality of insects, but the quality of treated fruit could be reduced either because of the presence of ammonia in the phosphine (phytotoxic) or the relatively high fumigation temperature of over 15°C (Horn and Horn, 2004). In response to the problems encountered with fumigation using metallic phosphine, two types of cylinder phosphine gases that do not contain ammonia have been developed and commercialised by Cytec Industries Inc (2005).

$ECO_2FUME^{®}$ is a cylinder gas mixture of 2% phosphine and 98% CO_2. Phosphine is the active ingredient and carbon dioxide is used as a propellant and flame inhibitor. The gas mixture can be directly released into storage for fumigation. Fumigation using ECO_2FUME is safe and convenient (Cytec Industries Inc), but it could be considered expensive as it contains only 2% phosphine. $VAPORPH_3OS^{®}$ is a cylinder gas of 100% pure phosphine designed for use in conjunction with Cytec-approved blending equipment (i.e. The Horn Diluphos System) to dilute pure phosphine safely with air, therefore greatly reducing the cost of fumigation. The Horn Diluphos System (HDS) invented by Fosfoquim S.A., Chile, is an automated system that allows the direct dilution of pure phosphine (i.e. $VAPORPH_3OS^{®}$ from Cytec) with air to below the combustion limit. This allows the injection of a phosphine–air mixture into an enclosed space to fumigate with concentrations up to 10,000 ppm phosphine without risk of ignition (Horn *et al,* 2003). Application of HDS for fumigation of fresh fruits and vegetables in cooled fumigation chambers, cooling chambers or controlled atmosphere chambers at low temperatures between -1.5 and 15°C has been patented (United States Application 20050265892; Hort *et al*, 2005).

Trials conducted on the fruit fumigation showed that cylinderised phosphine can effectively kill all stages of insects using 1400 ppm at 0-6°C in 48-72 hours and a residue level below the maximum residue limit of 0.01 mg/kg (Cavisin *et al.* 2006). For treatment of exported cut flower and foliage in New Zealand, a shorter fumigation time of 4 hours is in commercial use with $ECO_2FUME^{®}$ under vacuum conditions.

Magnesium phosphide pallets, applied inside a chamber with the aid of a Speedbox (Detia-Degesch) to ensure rapid and uniform fumigant delivery, was found effective for controlling *Anastrepha fraterculus* fruit flies in feijoa (*Acca sellawiana)* in Colombia (Rodríguez *et al*, 2010), as well as thrips and aphids potentially associated with cut basil (*Ocymum* sp) without damaging these fresh products.

Pure phosphine has been used in Chile for the last ten years to fumigate apples, plums, peaches, citrus, pears, grapes, kiwifruit, cherry, nectarine, persimmons, avocados, quince and apricots. The HDS/VAPORPH$_3$OS technology was reported to be effective in controlling obscure mealybug (*Pseudococcus viburni*); codling moth (*Cydia pomonella)*; eulia (*Proeulia* spp.*)*; fruit tree weevil (*Naupactus xanthographus)*; Mediterranean fruit fly (*Ceratitis capitata)*; fruit flies (*Rhagoletis* spp., *Bactrocera* spp., *Anastrepha* spp.*)*; Chilean false red mite (*Brevipalpus chilensis)*; and *Thrips* spp.

Trials in New Zealand have shown good potential for low-temperature phosphine fumigation against horticultural pests: scale insects (*Hemiberlesia rapax* and *Aspidiotus nerii*), lightbrown apple moth (*Epiphyas postvittana*) and codling moth (*Cydia pomonella*) (Wimalaratne *et al.,* 2009). Insect resistance to phosphine is an emerging problem, particularly in developing countries. Resistance has occurred primarily because of poor sealing and non-compliance with minimum exposure times. Therefore, it is considered important to use the correct exposure and application technology to avoid development of resistance.

4.9.5.9.2. Aerosol sprays and insecticidal dips/ sprays

Aerosol sprays containing pyrethrin, permethrin and or dichlorvos are available for postharvest application. Pyrethrum aerosols are regarded as safe chemicals, have short application time, are relatively cheap, and are effective against a range of surface pests. Pyrethrum is only effective on contact with the pest and breaks down easily in sunlight.
Permigas™ (active ingredient pyrethrins, permethrin, piperonyl butoxide) is registered for used against aphids in capsicums (1.2 g/m^3 for 4-6 hours) and tropical armyworm in kumara (2 g/m^3 for 4-6 hours). Insectigas™ with 5% dichlorvos and Pestigas (active ingredient pyrethrum) are also commercially available.

Floragas™ containing pyrethrins and permethrin is registered for use against aphids and thrips on cut flowers. When protea flowers were treated in an enclosed chamber for 12 h with a combination of pyrethrin (Pestigas™) and dichlorvos (Insectigas™), both propelled by CO_2, the combination was more effective than either of the gases used alone.

Contact pesticides can be applied quickly and easily as a postharvest chemical dip or an inline, low volume spray application. Pyrethrum products are effective against a broad range of insects. They have low toxicity to other animals and a short half-life, and are regarded as an environmentally friendly alternative to many other insecticides used postharvest, such as Dimethoate. Residues need to remain below MRL limits for export markets.

There are also health and safety concerns with insecticidal dips including environmental concerns with disposal and potential costs of registration. In a situation where there is no non-chemical alternative, these chemical treatments may warrant further investigation.

4.9.5.10. Systems approach

The value of integrating pre-plant management activities and post-harvest processing when developing overall procedures to minimise the impact of insects from the field to the final packaging is well recognized (Scheider *et al,* 2003). In fact the IPPC has developed standards to this respect - ISPM 14 (2002) (see section 4.5.3. of this report).

There is a wide variety of pests of quarantine significance, varying according to origin and country of destination, that are controlled by these approved treatments. These include fruit flies, mealybug, thrip, aphids, mites and other pests. In many cases, the approved treatments apply to a particular situation, i.e. a particular commodity with particular pest(s) from a particular country or region and a particular quarantine concern of the importing country (MBTOC, 2007, 2011). Each approved treatment may be applicable to just one or several species of fruit fly, for example. However, in some cases an approved treatment covers many species, such as 'external feeders' and 'insects'.

In Chile, *Brevipalpus chilensis* is a primary pest of wine grapes and of economic importance as a quarantine pest on table grapes, kiwifruit, clementines, lemons, mandarins, custard apples, figs and persimmons. Its likely presence requires mandatory methyl bromide treatment for commodities exported to the USA and other countries (Gonzalez 2006). Stone fruit were also found to carry female *B. chilensis* hidden in the pedicel cavity at very low population densities and a few eggs were deposited down in the cavity also (less than 0.3% of fruits infested with females). The miticide dicofol was effective for controlling mites in the vineyards, and newer acaricides such as abamectin, acrinathrin, bifenthrin, propargite and spirodiclofen have also shown to be effective. With the view to reducing the use of methyl bromide treatments for table grapes exported to the USA, and documented evidence of control of this quarantine pest in the field, the Systems Approach was proposed by Chile as a condition of entry without the need for methyl bromide fumigation. Its implementation has reduced Chile's consumption of MB for QPS (Correa, pers. comm 2014).

Williams *et al.* (2000) treated oranges infested with larvae of Queensland fruit fly (*Bactrocera tryoni*) for 16-h at 20°C with an initial phosphine concentration of 0.98 gm^{-3}, which resulted in 96.4% mortality of fly larvae. Although the level of mortality was significant it was insufficient to meet the mortality requirements for interstate (99.5%) or export trade (99.9%). Exposure times, temperatures and phosphine concentrations were all increased in subsequent fumigations. In the final series of fumigations with export grade Washington Navel oranges the exposure time was 48 h at 23 or 25°C, using an initial phosphine dosage of 1.67 gm^{-3}. The concentration was topped up to about 0.7 gm^{-3} after 24 h. No adverse effects on the oranges were observed, and a mortality of 99.998% was achieved with > 48 000 larvae exposed. This would meet requirements for interstate trade in Australia and possibly also some international trade, particularly if incorporated as part of a Systems Approach.

Alternative treatments for perishable products may be carried out in the country of origin, or in-transit in some instances, or in the importing country as outlined below. However, for reasons of practicality, fumigation with methyl bromide may at present be the only available treatment in lieu of destruction or rejection of the consignment if inspection at the port of entry reveals pests of concern.

4.9.5.11. Treatments in the country of origin

Some of the approved alternative methods, notably Systems Approaches, pest free areas and pre-export inspection requirements, can only be carried out in the country of origin. For some important quarantine pest species such as fruit flies and codling moth, some importing countries require that perishable commodities undergo a mandatory treatment or procedure prior to export. Exporters sometimes prefer to carry out quarantine treatments in the country of origin for economic reasons. The cost of materials and labour for quarantine treatments can be lower in the exporting country, particularly if the destination country is a non-A5 country with higher labour costs or high charges for port demurrage.

In many cases, fixed facilities are needed for carrying out treatments e.g. heat, cold, controlled atmospheres, and it can be cheaper for the exporters to locate and operate the facilities in the country of origin than in the importing country, i.e. it is more efficient to treat all the commodity at the point of origin than to treat the commodity after it has been dispersed to several different ports. Taiwan, for example, has four vapour heat treatment facilities and pack houses which have been approved by the Australian quarantine authorities for mangoes exported to Australia, while the Philippines has five registered treatment facilities for mango (AQIS 2009). For certain treatments such as methyl bromide and heat there is a product quality penalty, however, for treating perishables before transit because the earlier treatment significantly reduces the shelf life of the treated commodity compared to treatment after transit. On the other hand, cold treatments and controlled atmospheres can improve the shelf-life and quality of perishable commodities (such as flowers and fruit) if carried out prior to export.

For perishable products, pest control based on pre-harvest practices, as part of the Systems Approach as described in ISPM No. 14, must include cultural techniques leading to pest reduction, they must have an agreement on the area of any pest-free zones, and be subject to inspection in order to receive certification. In these cases, regulatory approval depends on a number of factors including knowledge of the pest-host biology, evidence of commodity resistance to the pest, trapping and field treatment results, monitoring of pests and diseases, and careful documentation.

4.9.5.12. In-transit treatment

In some cases the approved alternative treatments (e.g. cold, controlled atmospheres) are allowed to be carried out while commodities are being transported to their destination in a truck, shipping container or ship hold that has the relevant equipment. The quarantine authorities in the USA, for example, have approved the equipment installations in a number of ships and in hundreds of shipping containers for in-transit cold treatments (CPHST 2009a, 2009b). For example, citrus shipped from Spain to the US treated by cold treatment in transit.

USDA scientists have developed a system to remotely collect, analyze and report data from long term treatments performed in transit including ships at sea. Some treatments, such as cold, can be effective alternatives to MB but require a long time to be effective but must be monitored to ensure treatment parameters are met continuously. This satellite based technology will ensure success of the treatments and prevent MB having to be used at conclusion of transit because the cold treatment went out of compliance during transit.

4.9.5.13. Treatments on arrival in the importing country

As already explained, when products arrive in an importing country and are found to need a quarantine treatment, MB tends to be the prevalent treatment in a number of countries, due to logistic issues such as a lack of rapid pest identification facilities and lack of alternative treatment facilities at ports of entry. Quarantine authorities in the USA, for example, have approved a total of about 116 quarantine treatment facilities for imported products in 28 states (primarily for methyl bromide fumigation). In many US states, only methyl bromide and phosphine facilities appear to be available at present for carrying out quarantine treatments on imported perishable products (APHIS 2008ab).

4.10. Constraints to adoption of alternatives for QPS uses

4.10.1. Economic

Methyl bromide for QPS purposes continues to be in plentiful and unrestricted supply, as expected under the exemption from phaseout under Article 2H para 6. The cost of methyl bromide gas to end users is a relatively small component of the total cost of a QPS treatment. Compliance costs associated with the handling and use of a highly toxic gas to exacting occupational, environmental and effectiveness standards, increases the overall cost of conducting QPS methyl bromide treatments. Nevertheless the methyl bromide treatment costs present a competitive barrier to the development and adoption of any new alternative processes.

Cost of methyl bromide to the end user and the fumigator, has remained relatively stable over the last 10 years, with price approximately in the range $US 4-16 per kilo in many developed and developing countries. The advantage that methyl bromide enjoys arises in part because methyl bromide based systems do not include the costs of the damage to the ozone layer and ultimately to human health. The extent of such costs is however not known. In addition, other QPS systems also have unaccounted costs to the environment and human health. Sulfuryl fluoride and heat for example, also carry environmental impacts. Again, the extent of these costs is not known.

In the absence of regulatory or economic incentives to adopt alternatives and assuming methyl bromide is in most cases the lowest cost effective system at present, an alternative would not be voluntarily adopted unless it performed as well or better at the same market cost. Technically feasible alternatives will have limited market acceptance if they are more costly – and in the world of bulk commodities, it is difficult to entice end buyers to pay a higher price for goods treated with alternatives.

If however the goal is to replace methyl bromide with alternatives while maintaining protection against high risk pests as a primary goal and market forces have not resulted complete adoption of alternatives, then alternative actions such as the following may be considered to encourage further steps.

A large number of Parties have reported no use of MB for QPS altogether as discussed previously in this Chapter. In some cases methyl bromide alternatives are in use, even though their market prices are higher. This has occurred for diverse reasons – such as health or safety concerns about methyl bromide, idiosyncratic circumstances or because the users anticipate that methyl bromide will be banned or taxed and they expect their early adoption will soon result in higher profits.

In many cases, MB is an established and traditional practice, not subjected to the rigorous and expensive efficacy testing that might be required of a new entrant in the market. It is also often the case that MB alternatives are more practical when applied at the point of origin, thus relocating the quarantine barrier offshore. More options may be available at that location including strategies to ensure product health during the production process. Factors of scale may also be relevant in this respect: large quantities of products at the point of origin may allow for more cost efficient treatment, for example by justifying installation of irradiation facilities, cold or heat treatment facilities, and others, which would not be feasible at points of entry.

However, treatment with MB often affects product quality negatively, which mainly translates into a reduced shelf life. This makes some exporters reluctant to apply treatments before export. Finally, most alternatives are more expensive than fumigation with MB at the port of entry, which further deters from their development and adoption.

4.10.2. Regulatory (including health issues)

Countries have regulations that list requirements allowing for a commodity to be imported into their boundaries, including quarantine treatment requirements. In some cases, the only treatment that is listed as acceptable is MB, indicating that there are no available data to prove the efficacy of alternatives at a level which is consistent with the country's quarantine security requirements.

Regulations prescribing MB treatment alone are a major barrier to adoption of alternatives as often there is little incentive for the regulation to be changed. Also, often the data have not been generated to prove effective control of all pests with an alternative to a standard similar to MB and Parties are unwilling to approve the alternative in the absence of this information.
Constraints to adoption of alternatives for treating soil where crops will be grown with MB are mainly regulatory – that is, alternatives not being registered at the location where treatment occurs or being restricted by regulations. Certification regulations sometimes do not recognise other treatments different to MB to achieve the high plant health status required, although developments in this respect are beginning to occur (CDFA, 2009).

The registration of a new chemical or extension of the label are often a very onerous and expensive tasks, which can take years to resolve and require considerable data on safety and efficacy. For many countries the potential volume of use is too small or cannot guarantee the intellectual property rights to justify registration.

4.10.3. Post-entry quarantine measures

Given that activity normally taken place at ports, it is frequently considered impractical to establish treatment facilities such as for irradiation or other similar measures for treating goods infested with quarantine pests due to space or environment restrictions. Further, treatments are generally performed by private contractors not government authorities, which means there has to be sufficient through-put on a continuing basis to justify the costs of facilities as well as the training and maintaining of staff to operate them. Even if treatments are available in the area, quarantine officers will often not allow the product to be moved from the port for treatment due to risks of pest dissemination. In view of this, if pests are discovered at the port of entry, it is important to have access to a wide spectrum treatment which is fast and portable, generally fumigation. Presently, four fumigants are widely available for use: methyl bromide, phosphine and, to a lesser extent, sulfuryl fluoride and HCN. For a variety of reasons including tradition, efficacy, registration, occupational health and safety issues and speed of action, methyl bromide frequently is the leading available fumigant for use at many ports at present.

Decision on the actual treatment to be applied is made by the importing country. According to the particular case, it may even be decided that no treatment is necessary.

Identification of quarantine pests, the absence of trained insect identifiers at port facilities continues to fuel the use of MB for unnecessary quarantine treatments at national Ports of Entry. Import commodities that are found to be infested with insects, mites are other quarantine organisms upon inspection at Ports of Entry are usually fumigated with MB unless the contaminating organism is identified authoritatively and confirmed to not be a pest of quarantine significance. The potential damage caused by introduced quarantine pests to the environment, agriculture, forestry and human and animal health when introduced into a country where they currently don't exist is so great that countries must provide an eradicating treatment which generally means MB. There is no doubt that unnecessary fumigations are performed because there are not resources available to the Port of Entry to make definitive identification possible.

4.11. References

Agarwal, M., Ren, Y., Newman, J., Cheng, H. 2012. Eradication of eucalyptus weevils in apples by ethyl formate. Navarro et al., 2012a, 266-271.

Anon (1993). Code of federal regulations, food and drugs. Office of the Federal Register National Archives and Records Administration, Washington DC.

APHIS (2008a) Eastern Treatment Facilities Listing by State. List of approved treatment facilities in the Eastern region, update: 10/02/08. Animal and Plant Health Inspection Service, US Department of Agriculture. http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/Eastern_Facilities.pdf

APHIS (2008b) Western Treatment Facilities Listing by State. List of approved treatment facilities in the Western region, update: 10/02/08. Animal and Plant Health Inspection Service, US Department of Agriculture. http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/Western_Facilities.pdf

AQIS (2009) Import Conditions database. Australian Quarantine and Inspection Service. http://www.aqis.gov.au/icon32/asp/ex_querycontent.asp

Bai J, Mielke EA, Chen PM, Spotts RA, Serdani M, Hansen JD, Neven LG (2006). Effect of high-pressure hot-water washing treatment on fruit quality, insects, and disease in apples and pears: Part I. System description and the effect on fruit quality of d'Anjou' pears. *Postharvest Biology and Technology* 40(3): 207-215.

Bell, C. H., T. J. Wontner-Smith and N. Savvidou (2003). Some properties of sulphuryl fluoride in relation to its use as a fumigant in the cereals industry. Pp 910 – 915 in: Advances in stored product protection proceedings of the 8th international working conference on stored product protection, York, UK 22-26 July 2002.

Birla S, Wang S, Tang J, Tiwari G (2008). Characterization of radio frequency heating of fresh fruits influenced by dielectric properties. *Journal of Food Engineering* 89(4): 390-398.

Cassells J., H.J. Banks and P.C. Annis (1994). Mortality of snails, *Cernuella virgata* and *Cochlicella acuta*, exposed to fumigants, controlled atmospheres or heat disinfestation. In: *Proc. 6th International Working Conference on Stored-Product Protection*, 17-23 April 1994, Canberra, Australia. pp. 50-55.

CDFA (2009). California Departent of Food and Agriculture. http://www.cdfa.ca.gov/phpps/PE/Nursery/pdfs/NIPM_7.pdf

Chervin, C., S. Kreidl, A. Hamilton and S. Whitmore (2000). "Non-chemical disinfestation: A freezing approach." *Proceedings of the XXV International Horticultural Congress*, Pt 8(518): 187-192.

Cho, J.-H, Park, C. G., Yoo, M., Kim, B.-S., Lee, B.-H. 2012. Comparative toxicity of ethyl formate for control of pests of sweet persimmons for export. Navarro et al., 2012a, 310-314.Correa, A. 2014 pers comm

CPHST (2009a) In-transit cold treatment ship database. Treatment Quality Assurance Unit, Center for Plant Health Science and Technology, Animal and Plant health Inspection Service, US department of Agriculture. https://treatments.cphst.org/vessels/printVesselDB.cfm.

CPHST (2009b) In-transit cold treatment container database. Treatment Quality Assurance Unit, Center for Plant Health Science and Technology, Animal and Plant health Inspection Service, US department of Agriculture. https://treatments.cphst.org/vessels/containerList.cfm

Cytec Industries Inc (2005). Phosphine gas products. http://www.cytec.com/business/Phonsphine/Products/PhosphineGas.shtm [accessed 1 October 2009

De Cal, A., Martínez-Terceno, A., López-Aranda, J.M. and Melgarejo P. (2004) Alternatives to methyl bromide in Spanish strawberry nurseries. Plant Disease 88(2): 210-214.

Dhouibi, M. H. 2013. Résultats des recherches menées à l'échelle nationale sur les alternatives au CH_3Br. In : Proceedings du Workshop sur les alternatives au Bromure de Méthyle pour la Desinfestation des Dattes. 15 Mai 2013 in Grand Hotel Tunis. Dowdy, A.K. (2002). Use of non-chemical methyl bromide alternatives in the USA. In: Proc. International Conference on Alternatives to Methyl Bromide. 5-8 March 2002, Sevilla. Office for Official Publications of the European Communities: Luxembourg.

Dwinell, L.D. (2001). Potential use of elevated temperature to manage pests in transported wood. Exotic Forest Pests Online Symposium, April 2001.

Emery, R.E., Chami, M., Garel, N., Kostas, E. and Hardie, D.E.(2010). The use of hand-held computers (PDAs) to audit and validate eradication of a post-border detection of Khapra Beetle, *Trogoderma granarium,* in Western Australia. Proc. 10th International Working Conference on Stored-Product Protection, Lisbon. Julius-Kühn-Archiv, 425, 1033-1039.

Faithful, I. and D. Maclaren, (2004). Branched Broomrape - Management: State prohibited weed. Department of Sustainability and Environment, State of Victoria, Australia. http://www.dse.vic.gov.au/dpi/nreninf.nsf/

Finkelman, S., Navarro, S., Navarro, H., Lendler, E. 2012. "VAPORMATETM" an alternative fumigant for QPS treatments. Navarro et al., 2012a, 247-253.

Follett, P. A. and L. G. Neven (2006). Current trends in quarantine entomology. *Annual Review of Entomology* 51: 359-385.

Furuki S. I., A. Miyanoshita and T. Imamura (2005). Toxicity of sulfuryl fluoride to the developmental stages of the maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curdulionidae), at different exposure periods. *International pest control* 47(3): 133-138.

Glassey, K. (2014). Personal communication. MBTOC member, New Zealand

Gonzalez, R. H. (2006). Biology, quarantine risks and control alternatives of the grape flat mite, *Brevipalpus chilensis* Baker (Acarina: Tenuipalpidae). *Revista Fruticola* 27(3): 77-88.

Hallman, G.J. 2013. Control of stored product pests by ionising radiation. Journal of stored Products Research 52, 36-41.

Hansen JD, Heidt ML, Neven LG, Mielke EA, Bai J, Chen PM, Spotts RA (2006). Effect of high-pressure hot-water washing treatment on fruit quality, insects, and disease in apples and pears: Part III. Use of silicone-based materials and mechanical methods to eliminate surface pests. *Postharvest Biology and Technology* 40(3): 221-229.

Hara A (1997). Market quality in disinfested flowers, foliage and propagative material. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions. San Diego, California.

Hole, B.D., C.H. Bell, K.A. Mills, K.A. and G. Goodship (1976). The toxicity of phosphine to all developmental stages of thirteen species of stored product beetles. *Journal of Stored Products Research*, 12, 235-244.

Hollingsworth, R. G., Jang, E., Follett, P. 2013. Freezing as a treatment to prevent the spread of Hypaenemus jampei (Coleoptera: Curculionidae) in coffee. Journal of Economic Entomology 106, 653-660.

Hoover, K. Uzunovic, A, Gething, B. Dale, A.,Leung, K. Ostiguy, N.,and Janowiak, J., (2010) Lethal temperature for pinewood nematode, Bursaphelenchus xylophilus, in infested wood using microwave energy. In print. Presented to the Technical Panel on Phytosanitary Treatments.

Horn, P. 2012. Control of *Brevipalpus chilensis* with phosphine on fresh fruits under cold storage fumigations. Navarro et al., 2012a, 231-235.

Horn, P. 2012. Control of *Brevipalpus chilensis* with phosphine on fresh fruits under cold storage fumigations. Navarro et al., 2012a, 231-235.

Horn F, Horn P, Tumambing J, Gock D, McSwigan B (2003). Fumigation field trial tour of the Horn Diluphos System using Cytec VAPORPH3OS® on stored grain in Australia. Australian Postharvest Technical Conference. Canberra, Australia, CSIRO Stored Grain Research Laboratory. Pp. 174-182.

Horn F, Horn, P (2004). Fresh fruit fumigation with phosphine as alternative for methyl bromide. 2004 Annual Research Conference on Methyl Bromide Alternatives and Emissions Reductions. Orlando, FL, Methyl Bromide Alternatives Outreach. Fresno, CA.

Horn FF, Horn FP, Horn PP, Horn JP, Diaz RM. (2005). Procedure of fumigation with a high concentration of pure phosphine free from ammonia at low temperature for the control of pests in fruits without damaging its quality. US patent 25265892.

Horner, I.J. (1999). Alternative soil fumigant trials in New Zealand strawberry production. In: Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions, San Diego, California, USA

ICON. (2009). Timber packaging and dunnage. All countries. http://www.aqis.gov.au/icon32/asp/ex_casecontent.asp?intNodeId=8849077&intCommodityId=17670&Types=none&WhichQuery=Go+to+full+text&intSearch=1&LogSessionID=0 . Accessed 18 September 2008.

Irtwange, S (2006). Hot water treatment: a non-chemical alternative in keeping quality during postharvest handling of citrus fruits. *Agricultural Engineering International* 8: Invited Overview 5.

IMO (2008a). Recommendations on the safe use of pesticides in ships applicable to the fumigation of cargo transport units. MSC. 1/Circ. 1265. 9 June 2008. 11 pp.

IMO (2008b). Recommendations on the safe use of pesticides in ships applicable to the fumigation of cargo holds. MSC. 1/Circ. 1264. 27 May 2008. 15 pp.

IMO. (1996). Recommendations on the safe use of pesticides in ships. International Maritime Organisation, London. ISBN 92-801-1426-3.

Ingemanson, M. (1997). MIDS infrared technology – effective, benign, affordable. In: Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, November 3-5, 1997, San Diego, California.

IPPC (2006). ISPM No. 15. Guidelines for regulating wood packaging material in international trade (2002) with modifications to Annex 1 (2006). IPPC: Rome. 11 pp.

IPPC (2007) ISPM No. 28Phytosanitary treatments for regulated pests

IPPC (2008) International Standards for Phytosanitary Measures. ISPM 28: Replacement or reduction of methyl bromide as a phytosanitary measure. FAO, Roma, Italia, 9 pp.

IPPC (2009a). ISPM No. 28. Phytosanitary treatments for regulated pests. IPPC: Rome. 28 pp.

IPPC (2009b). International standards for phytosantary measures. Revision of ISPM No. 15. Regulation of wood packaging material in international trade. https://www.ippc.int/servlet/CDSServlet?status=ND0xMzM5OSY2PWVuJjMzPSomMzc9a29z

IPPC, (2011). Phytosanitary treatments for regulated pests. https://www.ippc.int/publications/phytosanitary-treatments-regulated-pests

IPPC. (2013a). ISPM 15. Regulation of wood packaging material in international trade. https://www.ippc.int/publications/regulation-wood-packaging-material-international-trade-0.

IPPC. (2013b). 2013 December ECCT meeting report. https://www.ippc.int/publications/2013-december-ecct-meeting-report

IPPC, (2014). Report of the Technical Panel of Phytosanitary Treatments, Bali, Indonesia. https://www.ippc.int/publications/2014-june-tppt-meeting-report-bali-indonesia.

Jamieson L, Dentener, PR, Krishna, H, Martin, N (2005). Effectiveness of treatments for mite eggs – a literature review. In Jamieson LE, Dentener PR, Krishna H, Martin N 2005. Effectiveness of treatment for mite eggs – a literature review, and preliminary experiments. Client Report. No. 17509.

Jeffers, L. 2014. PPQ Phytosanitary irradiation program. Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 4-6 November in Orlando, FL, USA, MBAO conference, www.mbao.org, Paper 43.

Jeffers, L., Thoms E. M., Morgan, M. 2012. ProFume® gas fumigant: A Methyl Bromide alternative for US log exports to China. In: Obenauf, G. L. (ed.), Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 6-8 November in Orlando, FL, USA, MBAO conference, www.mbao.org, MBAO, 33-1.

Jiao, S., Johnson, J. A., Tang, J., Wang, S. 2012. Industrial scale radio frequency treatments for insect control in lentils. Journal of stored Products Research 48, 143-148.

Kim J, Yousef A, Dave S (1999). Application of ozone for enhancing the microbiological saftey and quality of foods: a review. *Journal of Food Protection* 62(9): 1071-1087.

Kostyukovsky, M., U. Ravid and E. Shaaya (2002). The potential use of plant volatiles for the control of stored product insects and quarantine pests in cut flowers. *Acta Horticulturae* 576: 347-358.

Lacey, L. A., D. R. Horton, D. C. Jones, H. L. Headrick and L. G. Neven (2009). Efficacy of the biofumigant fungus *Muscodor albus* (Ascomycota: Xylariales) for control of codling moth (Lepidoptera: Tortricidae) in simulated storage conditions. *Journal of Economic Entomology* 102(1): 43-49.

Lagunas-Solar M, Essert T, Pina U, Zeng N, Truong T (2006). Metabolic stress disinfection and disinfestation (MSDD): a new, non-thermal, residue-free process for fresh agricultural products. *Journal of the Science of Food and Agriculture* 86(12): 1814-1825.

Lagunas-Solar M, Pan Z, Zeng N, Truong T, Khir R, Amaratunga K (2007). Application of radiofrequency power for non-chemical disinfestation of rough rice with full retention of quality attributes. *Applied Engineering in Agriculture* 23(5): 647-654.

Lee, B.-H., Kang, M.-K., Park, M.-G., Sung, B.-K., Kim, T.-J. 2009. Commercial application of Vapormate™ as quarantine fumigant in imported fruits. In: Proceedings of the regular meeting of the pesticide science society of Korea, 57

Linde 2013 http://cropscience.linde-gas.com/en/products_services/vapormate.html

Liu, Y.-B. 2011. Potential of oxygenated phosphine fumigation for postharvest pest control. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 31 October – 2 November in San Diego, CA, USA, MBAO conference, www.mbao.org, 53-1 – 53-4.

Liu, Y.-B. 2012. Oxygenated phosphine fumigation for control of *Nasonovia ribisnigri* (Homoptera: Aphidae) on harvested lettuce. Journal of Economic Entomology 105, 810-816.

Lopez-Aranda, J 2012. Methyl Bromide Alternatives (Chemical and Nonchemical) for Strawberry Cultivation in Conventional Areas of Production. Proceedings of the VII International Strawberry Symposium 2012, Beijing, China. *ActaHorticulturae*

MAFF (Ministry of Agriculture, Forestry, and Fisheries) (1971). Quarantine prospectus for import grains. Director's notice Nosei, No.2628, 6 February 1971 (in Japanese)

Manickavasagan, A., Alahakoon, P. M. K., Al-Busaidi, T. K., Al-Adawi, S., Al-Wahaibi, A. K., Al-Raeesi, A. A., Al-Yahyai, R., Jayas, D. S. 2013. Disinfestation of stored dates using microwave energy. Journal of stored Products Research 55, 1-5.

Strike out, in QPS: Mayfield III, A. E., Fraedrich, S. W., Taylor, A., Merten, P., Myers, S. W. 2014. Efficacy of heat treatment for the thousands cankers disease vector and pathogen in small black walnut logs. Journal of Economic Entomology 107, 174-184.

Mann, R.C., Mattner, S.W., Gounder, R.K., Brett R.K. and Porter I.J. (2005). Evaluating novel soil fumigants for Australian horticulture. Pp 34-1 – 34-4 In: Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions, Oct 31 - Nov. 3 2005, San Diego, California, USA.

Margosan S, Smilanick J (2002). Mortality of *Botrytis cinerea*, *Monilinia fructicola*, *Penicillium digitatum*, and *Rhizopus stolonifer* spores after exposure to ozone gas. http://postharvest.ucdavis.edu/Ipm/objectives_2000.shtml#margosan2 [accessed 1 October2009

Mattner, S. Porter, I.J., Gounder, R.K., Guijarro, B. Williams, E.N. (2010). Maintaining biosecurity and market access in the Australian strawberry industry following methyl bromide phase out. *Acta Horticulturae* 883 99-106.

MBTOC (1995). 1994 Assessment Report of the Methyl Bromide Technical Options Committee. UNEP, Nairobi.

MBTOC (1998). 1998 Assessment Report of the Methyl Bromide Technical Options Committee. UNEP, Nairobi.

MBTOC (2002). 2002 Assessment Report of the Methyl Bromide Technical Options Committee. UNEP Nairobi.

MBTOC (2007). 2006 Assessment Report of the Methyl Bromide Technical Options Committee. UNEP, Nairobi, Kenya, 485 pp.

MBTOC (2011). 2010 Assessment Report of the Methyl Bromide Technical Options Committee. UNEP, Nairobi Kenya, 400 pp.

Misumi, T., M. Aoki and H.Kitamura 2011. Synergistic and suffocative effects of fumigation with a lower-concentration phosphine and sulfuryl fluoride gas mixture on mortality of Sitophilus species (Coleoptera: Dryophthoridae), a stored-product pest. part 2: Susceptibility test on *Sitophilus zeamais* for fumigation with a gas mixture, and verification test of a sequential fumigation with two fumigants. Res. Bull. Pl. Prot. Japan 47 (In press).

Misumi T., Ogawa, N., Yamada, K., Shukuya, T. 2013a. Susceptibilities of five species of scales (Diaspididae and Coccidae) and mealybugs (Pseudococcidae) to fumigation with a gas mixture of ethyl formate and carbon dioxide under normal atmospheric pressure or vacuum. Res. Bull. Pl. Prot. Japan 49, 1-9.

Misumi T., Yamada, K., Naito, H., Ogawa, N., Shukuya T. 2013b. Influence of gas mixture fumigation of ethyl formate and carbon dioxide on several characteristics of fresh fruits and vegetables (bananas, pineapples, strawberries, grapefruits, Satsuma mandarins, squashes and other vegetables). Res. Bull. Pl. Prot. Japan 49, 19 - 27.

Mitcham, E., Pupin, F., Bikoba, V., Basi, B. 2011. Control of bean thrips and light brown apple moth with Vapormate^{TM}. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 31 October – 2 November in San Diego, CA, USA, MBAO conference, www.mbao.org, 51-1 - 51-2.

Mori, T. and N. Kawamoto (1966). Studies on the properties and effect of fumigant aluminum phosphide. *Research Bulletin of Plant Protection Japan* 3:24–35 (in Japanese).

Morrell, J.J (1995). Importation of unprocessed logs into North America: A review of pest mitigation procedures and their efficacy. *Forestry Products Journal* 45(9):41-50.

Navarro, S., E. Donahaye, G. C. Sabio, M. Rindner, R. Dias and A. Azrieli (1999). Reducing MB dosage or exposure time using CO_2 with methyl bromide or CO_2 with heat. Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, San Diego, California, USA.

Navarro, S. 2006. Postharvest treatment of dates. Stewart Postharvest Review 2, 1-9.

Neven, LG and L. Rehfield-Ray (2006). Combined heat and controlled atmosphere quarantine treatments for control of western cherry fruit fly in sweet cherries. *Journal of Economic Entomology* 99(3): 658-663.

Neven, LG and L. Rehfield-Ray (2006b). Confirmation and efficacy tests against codling moth and oriental fruit moth in apples using combination heat and controlled atmosphere treatments. Journal of Economic Entomology 99(5): 1620-1627.

Nevin L, Drake S 2000. Comparison of alternative postharvest quarantine treatments for sweet cherries. Postharvest Biology and Technology 20: 107-114.

Obra, G. B., Resilva, S. S., Follett, P. A., Lorenzana, L. R. J. 2014. Large-scale confirmatory tests of a phytosanitary irradiation treatment against *Sternochetus frigidus* (Coleoptera: Curculionidae) in Philippine mango. Journal of Economic Entomology 107, 161-165.

Papadimitriou V. C., R.W. Portmann, D.W. Fahey, J. Mühle, R.F. Weiss and J.B. Burkholder (2009). Experimental and theoretical study of the atmospheric chemistry and Global Warming Potential of SO2F2. *Journal of Physical Chemistry* A, 2008, 112 (49): 12657-12666.

Potter, MA, Carpenter, A, Stocker, A and Wright, S (1994). Controlled atmospheres for the postharvest disinfestation of *Thrips obscuratus* (Thysanoptera:Tripidae). *Journal of Economic Entomology* 87(5): 1251-1255

PPS (Plant Protection Statistics) (2007) Report of imported plants for categories in 2007 (in Japanese).

Pupin, F., Bikoba, V., Biasi, W. B., Pedroso, G. M., Ouyang, Y., Grafton-Cardwell, E., Mitcham, E. J. 2013. Postharvest control of western flower thrips (Thysanoptera: Thripidae) and California red scale (Homoptera: Diaspididae) with ethyl fromate and its impact on citrus fruit quality. Journal of Economic Entomology 106, 2341-2348.

Purohit, P., Jayas, D.S., Yadav, B.K., Chelladurai, V., Fields, P.G., White, N.D.G. 2013. Microwaves to control *Callosobruchus maculatus* in stored mung bean (*Vigna radiata*). Journal of stored Products Research 53, 19-22.

Reichmuth, C.H. (2002). Alternatives to methyl bromide for the treatment of wood, timber and artefacts in the European community. In: International Conference on Alternatives to Methyl Bromide, March 2002, Seville, Spain.

Ren, Y. L., Lee, B.-H., Padovan, B. 2011. Penetration of methyl bromide, sulfuryl fluoride, ethanedinitrile and phosphine into timber blocks and the sorption rate of the fumigants. Journal of stored Products Research 47, 63-68.

Rhatigan, R.G., Morrell, J.J. and Filip, G.M. 1998. Toxicity of methyl bromide to four pathogenic fungi in larch heartwood. Forest Products Journal 48: 63-67.

Rodas, R. (2013). Uso de Bromuro de Metilo en cuarentena y pre-embarque en Centroamérica. En: Taller sobre Alternativas al Bromuro de Metilo, Managua, Nicaragua Diciembre 12 y 13 de 2013 (UNEP/ MARENA)

Rodríguez, J.C., J.F. Rodríguez and J. García 2010. Tolerancia de estados inmaduros de *Anastrepha fraterculus* (Diptera: Tephritidae) al fosfuro de magnesio. Resúmenes Sociedad Colombiana de Entomología (Socolen) XXXVII Congreso, Bogotá, Colombia, Junio 30- Julio 2, 2010.

Schaub, J. MBTOC member. pers. comm. 2010

Scheffrahn, R.H. and E.M. Thomas (1993). Penetration of sulfuryl fluoride and methyl bromide through selected substrates during fumigation. *Down to Earth* 48 (1).

Schneider, S.M., E.N. Rosskopf, J.G. Leesch, D.O. Chellemi, C.T. Bull & M. Mazzola. 2003. USDA-ARS Research on alternatives to methyl bromide: Pre-plant and post-harvest. Special issue: Pest management research in the USDA Agricultural Research Service. *Pest Management Science* 59(6/7): 814-826.

Scott Boothey (2010) Personal communication.

Semple, R. L. and K.I. Kirenga. (1997). Facilitating regional trade of agricultural commodities in Eastern, Central and Southern Africa. Phytosanitary standards to restrict the further rapid spread of the larger grain borer (LGB) in the region. Dar es Salaam, Tanzania. Dar Es Salaam University Press.

Shellie K, Mangan R (1995). Heating rate and tolerance of naturally degreened 'Dancy' tangerine to high temperature forced air for fruit fly disinfestation. *Hort Technology* 5(1): 40-43.

Spotts RA, Serdani M, Mielke EA, Bai J, Chen PM, Hansen JD, Neven LG, Sanderson PG (2006). Effect of high-pressure hot water washing treatment on fruit quality, insects, and disease in apples and pears: Part II. Effect on postharvest decay of d'Anjou pear fruit. *Postharvest Biology and Technology* 40(3): 216-220.

Stejskal, V., O. Douda, M. Zouhar, M. Manasova, M. Dlouhy, J. Simbera and R. Aulicky (2014) Wood penetration ability of hydrogen cyanide and its efficacy for fumigation of *Anoplophora glabripennis*, *Hylotrupes bajulus* (Coleoptera), and *Bursaphelenchus xylophilus* (Nematoda), International Biodeterioration & Biodegradation 86: 189 -195.

Tateya, A. (2010). MBTOC member pers. comm.

TEAP. (1999). Report of the Technology and Economic Assessment Panel April 1999, Volume 2: Essential Use Exemptions, QPS Applications for Methyl Bromide, Progress and Control of Substances and other Reporting Issues. UNEP:Nairobi: 227pp.

TEAP (2002) . Report of the Technology and Economic Assessment Panel May 2002. UNEp Nairobi, 110 pp,

TEAP (2009a). Report of the Technical and Economic Assessment Panel. May, 2009. Ozone Secretariat, UNEP, Nairobi

TEAP (2009b). Report of the Technology and Economic Assessment Panel. QPSTF Report. UNEP, Nairobi

TEAP. (2006). Report of the Technology and Economic Assessment Panel. Progress Report. May, 2006. Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme, Nairobi

TEAP (2007). Report of the Technology and Economic Assessment Panel. Progress Report. May, 2007.

TEAP (2003). Report of the Technology and Economic Assessment Panel. Progress Report. May, 2003.

TEAP (2010). Report of the Technology and Economic Assessment Panel. Progress Report. May, 2010.

TEAP (2012). Report of the Technology and Ecoonomic Assessment Panel Progress Report, May 2012.

Thalavaisundraram, S., Roynon, J. 2012. Penetration capacity of VAPORMATE™ TM into commercially plastic wrapped cardboard boxes filled with sultanas for controlling stored product pests. In: Navarro et al., 2012a, 384-388.

Tiwari G, Wang, S, Birla, SL, Tang, J (2008). Effect of water-assisted radio frequency heat treatment on the quality of 'Fuyu' persimmons. *Biosystems Engineering* 100(2): 227-234.

Tumambing, 2013. ECO2FUME phosphine fumigant as a prinary alternative to methyl bromide for QPS application in Indonesia. MBAO 4-6 November 2013, San Diego, California, USA

UNEP/ IPPC, (2008). Methyl Bromide: Quarantine and Preshipment uses. United Nations EnvironmentProgramme, Nairobi, Kenya, 16 pp.

UNEP/ ROAP (2008). Report to UNEP CAP ROAP Programme Bangkok. Quarantine and preshipment used for methyl bromide in ROAP and potential for their replacement. Prepared by Jonathan Banks, 45 pp

USDA (1992): Pest risk assessment of the importation of *Pinus radiata* and Douglas fir logs from New Zealand. USDA, Forest Service. Miscellaneous Publication No. 1508

USDA. (1994). Importation of logs, lumber, and other unmanufactured wood articles: environmental impact statement.

USDA. (1996). Importation of logs, lumber, and other unmanufactured wood articles. 7CFR319.40 USDA Animal and Plant Health Inspection Service. Washington, DC.USDA 1996

USDA. (2009). PPQ Treatment Manual. http://www.aphis.usda.gov/import_export/plants/manuals/ports/treatment.shtml. Accessed Accessed 20 September 2009.

USDA (2001). United States Department of Agriculture AQIS Treatment manual

USEPA (1996). Heat treatment to control pests on imported timber. Methyl bromide case study, 10 case studies, Volume 2. U.S. Environmental Protection Agency. http://mbao.org/heatlog2.html [accessed 1 October 2009

Valerio, A. 2014. Pers comm. Alejandro Valeiro, MBTOC member

Waddell B, Cruickshank, VM, Dentener, PR (1988). Postharvest Disinfestation of *Nysius huttoni* on 'Granny Smith' apples using controlled atmosphere coolstorage DSIR.

Waddell B, Edwards G, Jamieson L, Laidlaw W (2004). Streamlining development of postharvest heat treatments for disinfesting fruit. *International Congress of Entomology*. Brisbane.

Wang, D., Tang, J., Johnson, J. A., Cavalieri, R. P. 2013. Heating uniformity and differential heating of insects in almonds associated with radio frequency. Journal of stored Products Research 55, 15-20

Watson, C.R., Pruthi, N., Bureau, D., Macdonald, C. and J. Roca. (1999). In transit disinfestation of bulk and bagged commodities: a new approach to safety and efficiency. In: Proc. *7th International Working Conference on Stored-product Protection*, Beijing, 1998, pp. 462-471.

Whiting D, Jamieson, LE, Spooner, KJ, Lay-Yee, M (1999). Combination high-temperature controlled atmosphere and cold storage as a quarantine treatment against *Ctenopseustis obliquana* and *Epiphyas postvittana* on 'Royal Gala' apples. Postharvest Biology and Technology 16(2): 119–126.

Whiting D, Jamieson, LE, Connolly, PG (2000). Mortality responses of the brownheaded and black-lyre leafrollers to controlled atmosphere and air cold storage treatments for kiwifruit. *New Zealand Plant Protection* 53: 365-370.

Whiting D (2003). Potential of controlled atmosphere and air cold storage for postharvest disinfestation of New Zealand kiwifruit. 8th International CA Conference, *Acta Horticulturae* ISHS. Pp. 143-147.

Williams P, Hepworth, G, Goubran, F, Muhunthan, M, Dunn, K (2000). Phosphine as a replacement for methyl bromide for postharvest disinfestation of citrus. *Postharvest Biology and Technology* 19(2): 193-199.

Williamson M and Williamson J (2003). Heat-based quarantine technologies (post harvest disinfestation): current status and future opportunities in the Pacific region. Australian Postharvest Horticulture Conference. Brisbane, Australia. Pp. 106-108.

Wimalaratne SK, van Epenhuijsen CW, Brash DW, Page BBC, Somerfield KG, Bycroft BL, G MAR, Klementz D 2009. Control of codling moth larvae and eggs using phosphine at coolstore temperatures. Plant & Food Research Confidential Report. No. 2406.

Yamada, K., Shukuya, T., Ogawa, N., Misumi, T. 2012. Mortality test of ethyl formate fumigation for leaf miner (*Liriomyza sativae*, *Liriomyza trifolii*) and Spider Mite (*Tetranychus cinnabarinus*, *Tetranychus kanzawai*). Res. Bull. Pl. Prot. Japan 48, 13□17 .

Yu K.Y., Y.W. Chung, M.H. Lee and J.W. Jae. (1984). Study on shipboard fumigation of the imported logs. *Korea Journal of Plant Protection* 23: 37-41.

Zasada, I.. Walters A.T.W., and Hanson B.D.,. (2010). Challenges in Producing Nematode- and Pathogen-free Fruit and Nut Nursery Crops in the United States. Outlooks on Pest Management 21:246-250.

Zhang, F., Y. Wang, B. Liu, L. Ren, S. Gong and L. Tao. (2015). Low temperature phosphine fumigation for postharvest control of western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae) on oriental lily. Postharvest Biology and Technology 100: 136-141.

5

Chapter 5. Chemical and non-chemical alternatives to Methyl Bromide for pre-plant soil uses

5.1 Introduction

Since the 2010 Assessment Report, widespread adoption of alternatives to methyl bromide (MB) for pre-plant soil fumigation has occurred in many A5 and non-A5 countries previously using MB for preplant soil fumigation, whether as controlled uses (A5 Parties) or as critical uses (non-A5 Parties) with MB. MBTOC has identified feasible alternatives for virtually all soil uses of MB; however, regulatory barriers and cost may restrict their full adoption across all sectors worldwide.

This chapter focuses on economically and technically feasible alternatives for pre-plant soil fumigation, both chemical and non-chemical. Over the years, MBTOC has identified various key chemical alternatives that perform consistently across most regions and sectors for example, 1,3-D/Pic, Pic alone, a 3-way treatment involving 1,3-D, Pic and metham sodium, DMDS, and many non-chemical alternatives. The latter include for example resistant cultivars, grafting, substrates, steam, solarisation, biofumigation, organic amendments, anaerobic soil disinfestations (ASD) and biological control. There are now numerous examples of key productive sectors around the world (A5 and non-A5) previously using MB, which have successfully adopted these alternatives in a wide range of cropping systems. A combined IPM approach has most often yielded the best results.

The 2014 MBTOC Assessment Report focuses primarily on those alternatives that have been adopted by a significant number of users. However, effective soil treatments thatmay be limited to specific areas due to, for example the availability of active ingredients, climatic factors, cultural practices, regulatory constraints and economic issues are also addressed. A large number of research and review articles have been published on alternatives to MB and at least two thorough meta-analyses considering hundreds of international studies (Porter *et al.,* 2006, Belova *et al*., 2013) now provide the Parties with information on the relative effectiveness of alternatives in many sectors.

In 2014, the total amount of MB nominated for soil critical uses was 917.191 t. This amount represents 4 % of the amount nominated in 2005 (18,704.241 t) (TEAP, 2014a). In 2005, MB for critical uses was requested by 10 non-A5 countries in addition to the European Union. In 2014, 3 non-A5 countries submitted nominations for critical uses of MB (for use in 2016) and for the first time, by 3 A5 countries (for 2015). This is in clear contrast with over 100 CUNs submitted in 2003 for 2005, when the critical use process began for non-A5 Parties.

5.2. *Chemical alternatives*

Soil-borne pathogens(fungi, bacteria, viruses and nematodes), weeds and some insect pests can cause serious losses in various crops, especially in intensive cultivation cropping systems, and this is often a reason why growers resort to fumigating the soil.

Since the 2010 MBTOC Assessment Report, important changes in the registration and commercial adoption of chemical alternatives to MB have taken place. In all EU member states for example, fumigants once regarded as MB alternatives (chloropicrin, 1,3-D, MITC generators) are now subject to increasingly stringent regulations restricting or even preventing their use (e.g. European Directives 91/414/EEC, 2009/128/EC, Colla *et al.,* 2014). Since 2008 efforts to register two new fumigants- iodomethane (methyl iodide, MI) and dimethyl disulfide - were conducted in several countries, however MI registration has subsequently been withdrawn by the manufacturer almost worldwide. Further, some initially promising chemicals included in the previous MBTOC reports have seen little further development, for example propargyl bromide, sodium azide, propylene oxide, formaldehyde, carbonyl sulphide and cyanogen. Alternative fumigants that are currently available and widely used are described in more detail in the following sections.

5.2.1 Single chemical alternatives

5.2.1.1 Chloropicrin

Chloropicrin (trichloronitromethane) (Pic) is effective for controlling soilborne fungi and some insects but has limited activity against weeds (Ajwa *et al.,*2003). Pic has provided satisfactory and consistent control of various soil borne fungal diseases in many crops including vegetables, ornamentals and ginger (Gullino *et al.,* 2002;Chow 2009;Li *et al.,* 2014a).

Pic applied in conjunction with virtually or totally impermeable films (VIF, TIF) has been shown to be an effective strategy to reduce application rates whilst keeping satisfactory efficacy (Chow, 2009).However, the increase in Pic use in the strawberry sector following MB phaseout has been reported to lead to a higher incidence of *Macrophomina phaseolina* in many countries such as Israel (Zveibil and Freemen, 2005, 2009), USA (Daugovish, 2011ab; Koike, 2008, Koike *et al* 2009), Australia (Fang *et al.,* 2011ab) and Spain (Avilés *et al.,* 2008, 2009).In addition, regulatory constraints continue to limit Pic use in some countries.

Pic at 40 g/m^2 provided control of diseases of ginger at levels similar to those achieved with MB. This treatment yielded excellent long-term control of all target pathogens.Pic injection covered with VIF, is considered an effective alternative for control of the major soilborne pathogens of ginger in Shandong (Li *et al.,* 2014a).

5.2.1.2. 1,3-Dichloropropene (1,3-D)

1,3-D is an effective nematicide, which also control of insects, some weeds and pathogenic fungi (Ajwa *et al.,*2003; Qiao *et al.*, 2010, 2011, 2012abc .) This fumigant can achieve similar efficacy to MB when combined with high barrier films (VIF, TIF) at reduced dosages (Chow, 2009).

In California, USA, agricultural fumigant use regulations restrict complete transition from MB to alternative fumigants. 1,3-D and Pic are being used on approximately half of California strawberry production fields, but geographic use limits and buffer zones set by the California Department of Pesticide Regulation for 1,3-D/Pic restrict a more complete replacement of MB with this option (Jayesh *et al.,* 2011.)

Xiaoxue *et al.,* (2013) reported that Telone C-35, a commercial formulation of 1,3-D/Pic, significantly reduced the germination of many weed seeds such as *Digitaria chinensis*, *Eleusina indica*, *Portulaca oleracea* and *Stellaria media,* while maintaining high marketable tomato yields, with no significant differences withMB/Pic.

A gelatin capsule formulation of 1,3-D/Pic developed in China produces less environmental emissions and potential human hazards than 1,3-D/Pic used as a fumigant. The gel capsule formulation was reported to reduce soil populations of *Fusarium* spp., *Phytophthora* spp., *Pythium* spp. and *Meloidogyne* spp. at a dosage 30 or 50g/m^2, whilst producing marketable yields equal to those obtained with either MB or1,3-D/CP liquid injection treatments (Wang *et al*., 2013)

5.2.1.3. Methyl isothiocyanate (MITC)

Methyl isothiocyanate (MITC) fumigants such as dazomet, metham sodium, metham ammoniun and metham potassium, are highly effective for controlling a wide range of arthropods, soilborne fungi, nematodes and weeds, but less effective against bacteria and root-knot nematodes. In California, US, early season severe stunting from sting nematode was observed within the untreated controls and all metham sodium and metham potassium treatments (Noling and Cody, 2013). MITC fumigants prove more effective when combined with Pic and/or 1,3-D. This is the basis for the very effective 3-way system developed in the South East USA, which is widely used at present (Culpepper, 2008).

5.2.1.4. Dimethyl disulfide (DMDS),

DMDS is now registered in many A5 and non-A5 countries. It has been recently registered in the US, but not yet in California, so cannot presently be considered as an alternative for the Californian strawberry fruit sector (Belova *et al.,* 2013; Devkota *et al.,* 2013). DMDS has proven highly efficient for the control of various soil-borne nematodes of many crops including tobacco (Zannon *et al.,* 2014), carrot (Curto *et al.,* 2014) and other vegetables in different countries (Abuzeid 2014; Heller *et al* 2009,2010; Sasanelli *et al.,* 2014: Westerdhal and Beem, 2013; Leocata *et al.,* 2014; Fritch *et al.,* 2014). This fumigant can also control yellow nutsedge (*Cyperus* spp) (McAvoy and Freeman, 2013) and its efficacy can be enhanced when applied with VIF or TIF films (Fouillet, *et al.,*2014).

5.2.1.5. Allyl isothiocyanate (AITC)

Allyl isothiocyanate (AITC or mustard oil) is a naturally occurring pungent compound that is widely used as a culinary herb and in traditional medicine (Alpizar *et al*., 2014). Isothiocyanates (ITCs) are sulfur-containing compounds produced by many members of *Brassicaceae* plant family (Avato et al., 2013). AITC compounds have shown insecticidal and herbicidal activity and research has demonstrated that they can have practical application for weed control in polyethylene-mulched fields (Bangarwa *et al.,* 2012; Devkota *et al.,* 2013). Based on toxicity data, AITC has been found to have potential as a fumigant for controlling some insects (Paes *et al*., 2012; Saglam and Ozder, 2013; Yilmaz and Tunaz, 2013) and can also be used as a pre-plant soil fumigant alternative for broad-spectrum control of weed seeds, nematodes and diseases (Allan and Leon, 2013; Wu *et al*., 2011). AITC was registered in the USA in September 2013 (but not in California) for eggplant, pepper, tomato, carrot, onion, potato, strawberry, asparagus, broccoli, cauliflower, cucumber, squash, melons and turf. Its small buffer zone requirement gives it an advantage over other fumigants.

AITC is expected to be registered in the near future in other countries including Mexico, Canada, Italy, Spain, Turkey, Morocco, Japan and Israel (Allan and Leon,2013).

5.2.1.6 Sulfuryl fluoride

Sulfuryl fluoride (SF) is an insecticide fumigant gas, widely used for insect and rodent control in post-harvest commodities. It is also used to treat structures, vehicles and wood products for controlling drywood termites, wood-infesting beetles and other insect pests. In China, SF is registered as a nematicide fumigant for cucumber since 2014, at a rate of 50-70g/m^2 (Cao *et al.,* 2014). SF has a shorter plant-back time than other fumigants including MB and can be applied when soil temperatures are low , due to its low boiling point.These features give this fumigant a significant advantage over other soil fumigants.

5.2.1.7 Abamectin

Abamectin is formulated as a mixture of 80% avermectin B_{1a} and 20% avermectin $B_{1b,}$both being fermentation products of *Streptomyces avermitilis*, a naturally occurring soil actinomycete. Trials and commercial use in China have shown good efficacy of this product for the control of nematodes (Qiao *et al.,* 2012). Abamectin is registered in China and is considered a key alternative to MB for the control of nematodes in cucumber, tomato, watermelon, pepper and tobacco crops.

5.2.1.8 Fluensulfone

Fluensulfone (Nimitz, MCW-2) is a new nematicide, showing good efficacy for nematode control in carrot, cucumber and cantaloupe at rates of 2-8 kg/Ha. Results were found to not differ significantly from1,3-D at 84l/ha (Westerdahl and Chiller ., 2014).

5.2.1.9 Fungicides

Phytophthora capsici crown and root rot of squash is difficult to manage because all commercial cultivars are highly susceptible to this soil borne pathogen.Vegetable growers have traditionally relied on foliar fungicide applications to control this pathogen, despite their limited and inconsistent efficacy. Foliar, drip chemigation and soil drenches with fungicides have recently gained interest as a mean to improve control of *P. capsici* (Meyer and Hausbeck, 2013) as in general they are more effective than foliar applications. Drenches of fluopicolide, mandipropamid, or dimethomorph also reduce plant death and prevent yield loss associated with root and crown rot, an effect generally not achieved with foliar applications of these same compounds (Meyer and Hausbeck, 2013).

5.2.2 Combinations of chemical alternatives

Combined fumigant treatments can expand the pest control spectrum and lead to performance levels that match and even surpass those of MB. A well-known commercial product is the mixture of 1,3-D and Pic, which is sold under brand names such as Telopic™, Telodrip™, Inline™ and others and is widely used to control soil borne nematodes and fungi (Ajwa *et al.,*2003;Gamliel *et al.,* 2005;Minuto *et al.,*2006.) Combined treatments can help decrease the likelihood of some fumigants quickly degrading in soils. Accelerated degradation and loss of activity of metham sodium which reportedly occurs in some soil types can be reduced when using a formalin-metham sodium mixture, that effectively controls *Verticillium* wilt and other diseases (Triky-Dotan *et al.,*2009). Fumigant mixtures can however lead to negative interactions and may thus present challenges, such as needing to apply the products sequentially to avoid problems. Further research is needed to explore additional effective fumigant combinations.

Fumigant mixtures or sequential applications integrating non-chemical control practices (an IPM approach) have been shown to provide pest control and yield increases equivalent to those achieved with MB. Two statistical analyses on strawberry fruit and tomato crops have shown that across a wide variety of locations, climates, soil conditions and pest pressures, a number of chemical combinations have consistently shown equivalent effectiveness to MB (Porter *et al.,*2006; Belova *et al.,* 2013).

5.2.2.1. 1,3-D/ Pic

As mentioned earlier, 1,3-D and Pic are widely used in co-formulations for pre-plant control of nematodes, weeds and fungi. Recently, more stringent regulations to control soil-air emissions of these fumigants have encouraged research to reduce their emission potential. Information has become available, which can be used to refine buffer zone estimates for chloropicrin where it is applied at lower rates (Ashworth *et al.,* 2013).

1,3-D/Pic is a key alternative to MB,which is widely accepted commercially for controlling soil nematodes and fungi and has consistently shown to be as effective as MB (Ajwa *et al.,*2003, 2004; Minuto *et al.,*2006; Porter *et al.,*2006; Ji *et al.*, 2013). Application costs are similar or lower than those of MB. Various formulations of 1,3-D/Pic are currently registered in many countries, with TC-35 being the main one replacing MB.In the EU however, decisions related to 1,3-D and soon expected for Pic may significantly change the availability of these chemicals (e.g. European Directives 91/414/EEC, 2009/128/EC) (Colla *et al.,* 2014), with serious impact for example in Spain, where the majority of productive sectors previously using MB had switched to 1,3-D/Pic by 2006 (Porter *et al.,*2006).In the US, present regulations on 1,3-D relating to regional quotas (e.g. township caps), buffer zones, karst topography and mandatory personal protective equipment are regularly under review this has somewhat restricted its uptake as an alternative toMB in California and Florida. Further, application of 1,3-D/Pic in heavy, cold soils (<10°C) can result in phytotoxicity issues for example in strawberry runner crops (Mattner *et al.,* 2014) and in vegetables (Desager and Csinos, 2005).

A gelatin capsule formulation of 1,3-D/Pic developed in China has been previously described.

5.2.2 2. 1,3-D and MITC

Combinations of 1,3-D and MITC fumigants have been used in Europe, as well as in Canada and other countries, (although their future availability in EU countries is uncertain Colla *et al.,* 2014). 1,3-D combined with metham sodium increases control of weeds and soilborne pathogens (Ajwa *et al.,* 2003). In particular, sequential application of metham sodium following reduced rates of 1,3-D/Pic EC or Pic alone controls soilborne pests in strawberries and produces yields equivalent to standard MB/Pic fumigation, without any negative effects (Ajwa and Trout .,2004). This combined treatment may however be limited by longer plant-back periods, degradation in sandy soils and some compatibility issues with otherfumigants (Ajwa *et al.,* 2003). A combined treatment of 1,3-D and dazomet was found to be more effective than either1,3-D or dazomet alone and provided results similar to methyl bromide with respect to pest control, plant mortality and plant yield (Mao *et al,*. 2012).

5.2.2.3. MITC, 1,3-D/Pic

The combination of these three fumigants has gained interest in the last ten years as a highly effective option to control nematodes, fungi, weeds and soil insects However it can be phytotoxic and may require long plantback periods (Porter *et al.,* 2006, 2007). The product was withdrawn from registration in the USA in 1992, but is still registered in Canada, Mexico and other countries, and has outperformed MB for control of pathogens in trials on strawberries in Australia (Porter *et al.,* 2006). It was found to provide better fungal, nematode and weed control than 1,3-D/Pic alone (Ajwa *et al.,*2002; Porter *et al.,*2006: Candole *et al.,*2007).

5.2.2 4. Formalin and metham sodium

A mixture of formalin and metham sodium (MS) can broaden the pathogen control spectrum and result in a synergistic effect particularly with respect to fungal pathogens; it can also be used in soils prone to accelerated degradation of MS (Di-Primo *et al.,* 2003; Gamliel *et al.,*2005; Tricky-Dotan *et al.,*2009). It is reported to control *Fusarium oxysporum* f.sp. *radicis-lycopersici, Monosporoascus cannonballus*, and *Rhizoctonia solani*, which are often difficult to control with other chemicals. The synergistic effect was also evident at reduced dosages (Di-Primo *et al.,*2003; Gamliel *et al.,* 2005). Formalin and MS react strongly when mixed together, so should be applied from separate containers (Gamliel*et al.,*2005).

5.2.2.5. Dazomet/1,3-D and dazomet/DMDS

Combinations of 1,3-D and dazomet displayed positive synergistic activity on nematodes, soil-borne fungi and weeds in laboratory trials (Van Wambeke 2007; Van Wambeke *et al.,*2009; Mao *et al.,* 2012). Field trials also showed good control of soilborne disease at levels equivalent to MB with respect to plant mortality, plant height, and yield in greenhouse cucumber (Mao *et al.,* 2012). A combination of DMDS and dazomet at half dose rate revealed positive synergistic effects on nematodes, soilborne fungi and weeds (Van Wambeke *et al.,* 2009; Mao *et al.,* 2014a). Greenhouse trials on cucumbers also yielded good results (Mao *et al.,*2014b).

5.2.2.6. Chloropicrin/DMDS

In fresh market tomato, DMDS/Pic offers an effective alternative to MB for managingyellow nutsedge and other soil-borne pests in tomato (McAvoy and Freeman , 2013).

Pic was first used on strawberry crops in California, USA , to control Verticillium wilt and other soil-borne fungi. DMDS has shown good control of several soilborne fungi and nematodes in trials conducted in France, Italy, and California (García-Méndez *et al*., 2009; Heller *et al.,* 2009; López-Aranda *et al*., 2009ab.

5.2.3 Application methods

MB or its chemical alternatives should be applied in such a manner as to provide good penetration of the soil profile for maximum contact with the pathogens or pests. The method of choice will depend on the fumigant used, whilst considering worker safety and environmental impact.

5.2.3.1. Shallow injection (Shank injection)

Mechanized injection rigs, which apply MB, MB/Pic or alternative fumigants and their combinations at depths of 15 to 30 cm in soil (called 'shallow or shank injection') and which are immediately sealed with tarps in strips (rows) or broadacre are most often used when applying fumigants. Fumigants may be injected into pre-formed beds or beds may be formed as part of the application process at the time of injection, covering them with plastic mulch as part of the operation. Strip application generally results in less fumigant per hectare than broad-acre application, and although may provide an opportunity for re-colonization from untreated furrows is used with excellent results in many parts of the world.

5.2.3.2. Deep injection

'Deep injection' at approximately 80 cm depth, which does not require plastic mulching is also used. It is carried out mainly as strip fumigation, or as an auger application to individual tree or vine holes prior to planting and replanting in deciduous orchards, vineyards and other plantations, and mainly in the USA (Browne *et al.,*2006*,* 2009).

5.2.3.3. Manual application

Fumigants can also be applied manually using simple equipment. In the case of MB, this involved pre-vaporizing the gas in a 'hot gas' method or directly from a punctured canister as a cold gas on soil that is pre-tarped with plastic mulch. The use of canisters has now been banned in many countries due to safety concerns.

The **hot gas** method is suited for small-scale operations or enclosed spaces where machinery is difficult to operate. Liquid MB from cylinders under pressure is vaporized in a heat exchanger and then dispersed under plastic covers over the top of the soil. As MB is a heavy gas, it permeates into soil. This was the main application method used in A5 countries and the predominant method used in greenhouses (glass and plastic), tobacco seedling production and potting soils in both non-A5 and A5 countries and for outdoor fumigation in A5 countries.

The **cold gas method (canisters)** is simple but often inefficient. Small steel canisters of less than 1 kg are placed under thick plastic sheets and then punctured to release the gas into soil, taking care to not damage the plastic barrier and thereby increase risk to the user. Canisters have been banned in all non-A5 countries and remain registered only in a few A5s such as China, Jordan, and Egypt.

A novel application method for 1,3-D and/or Pic is that of controlled release capsules**,** which has been developed in China. Gelatin capsules are manually placed in 15 cm deep furrows in the soil and have shown equivalent efficacy to both MB and 1,3-D/CP liquid injection treatments (Wang *et al*., 2013)

Fumigants can also be applied through drip irrigation lines. This method was sometimes used for applying MB in greenhouse crops, but is more widely used with alternative chemicals. In the US, drip application has become important for 1.3-D/Pic mixtures and emulsifiable formulations of Pic and 1,3-D followed sequentially by metham sodium. Application through drip irrigation improves fumigant distribution in the soil, allows for reduced dosages and better control of emissions, especially when combined with barrier films (Ajwa *et al*.,2002). Although drip application is economically feasible, its effectiveness over a three-year period for controlling *Macrophomina* and *Fusarium* attacking strawberries in certain high pest pressure areas in California has been questioned (Koike *et al.,* 2011; 2013, Gordon *et al.,* 2011).

5.2.4 Registration Issues in some A5 and non A5 countries

Lack of registration of some MB alternatives as well as regulatory constraints have hampered MB phase-out in some countries where MB is still being used under a critical use exemption. This section focuses on countries submitting CUNs in 2014.

5.2.4.1. Non-Article 5 Countries

Australia: The registration of methyl iodide (MI) for strawberry runners in Australia was withdrawn by Arysta Lifesciences in 2012. BOC/Linde also withdrew further funding to generate the registration data for EDN in 2010, and Nordiko decided to not pursue registration of recaptured MB. These situations have forced Australia to develop and implement a completely new research program to replace MB involving integrated soil disinfestation with combinations of existing registered fumigants. New formulations of 1,3-D/PIC (20/80 and 40/60) are being trialed in an effort to reduce phytotoxicity and yield loss occurring at higher concentrations. The new formulations are being co-applied with MITC and include post-transplant herbicide applications.

Canada: PIC100, which has been registered by PMRA, is considered the most feasible MB alternative for strawberry runners; however, Prince Edward Island (PEI) authorities have not granted a license for its use on PEI due to potential groundwater (GW) concerns. A GW study was planned with the expectation that PIC100 may be cleared for use in PEI to replace MB in 2017, however the study was halted in mid 2014. In 2011, 1,3-D was detected in PEI GW, and its license for use on strawberry runners in PEI was revoked.

USA: Pic alone at high rates has allowed for continued transition away from MB in California strawberries and the Party has indicated that 2016 will be the last year for MB CUE use on strawberries in California. A new MB alternative, mustard oil with allyl isothiocyanate (AITC) was registered in September 2013 on strawberries, peppers, tomatoes, eggplants, carrots, potatoes, broccoli, cauliflower, cucumber, squash, melons, asparagus and turf but not yet in California. It offers the advantage of very small buffer zone requirements compared to MB and other fumigants.

In 2014, township caps for 1,3-D in California were limited to 90,250 lbs (1X) whereas previously some township caps were 2X. The impact of this new restriction on townships with heavy use of 1,3-D on strawberries is not known at this time. Until now,PIC-Clor 60 had allowed for increased strawberry acreage to be treated with 1,3-D under the existing township caps. In December 2012 EPA implemented new soil fumigant labels providing enhanced protection for workers and bystanders. One new requirement is large buffers around treated fields where the buffer zone distance varies with the size of the treated field, the application rate, soil type and tarp impermeability. The impact of these new label restrictions is not yet known.

5.2.4.2. Article 5 Countries

Argentina: Efforts to transition away from MB used on tomatoes, peppers and strawberries in high pest pressure areas is hampered by the lack of registration of some alternatives – particularly Pic alone and dazomet.

China: Currently, small-scale ginger growers are using canisters of MB (cold gas) under a CUE. The only registered alternative is Pic, which has not provided adequate nematode control and requires longer fumigation time under low temperature conditions. The Party anticipates registration of other MB alternatives (1,3-D, dazomet, MS and DMDS) possibly by 2018.

Mexico: Preliminary research trials on strawberry and raspberry nurseries show promising results with 1,3-D/Pic, Pic/MS and MS alone. Further trials are required to assist final transition away from MB can occur.

5.3. Non-chemical alternatives

5.3.1. Grafting

Grafting has been used for almost a century in Asia to control soilborne pathogens,improve plant yield and promote plant vigor (Louws *et al*., 2010; Yilmaz *et al*., 2011; Foster and Naegele, 2013;Keinath and Hassell, 2013,2014). Commercial adoption of grafting has increased all over the world in the past 30 years (Besri 2008; Louws *et al*., 2010; Schwarz *et al*., 2010). Vegetable grafting was introduced to the

United States more than 20 years ago, and its use by commercial growers and home gardeners has steadily increased (Miles *et al*., 2013ab).

Grafting is an environment-friendly option and often a major component of IPM strategies devised to manage biotic and abiotic stresses in vegetable crops. One of its great advantages is that it can successfully control a wide spectrum of diseases such as *Fusarium, Verticilium, Pyrenochaeta, Monosporascus, Phytophthora*, *Pyrenochaeta*, *Meloidogyne*, some viruses (CMV, ZYMV, PRSV, WMV-II,TYLCV) (Louws *et al*., 2010; Ricárdez-Salinas *et al*., 2010;Yilmaz *et al*., 2011; Kousik *et al.,* 2010, 2012; Cohen *et al* 2012;Gilardi *et al.,* 2013;Erin *et al.,* 2013) and bacteria (Suchoff *et al.,* 2013).Along with reducing disease impact, grafting increases yield, improves fruit quality, promotes growth, extends production periods and crop longevity, allows for more efficient fertilizer use, and increases tolerance to soil salinity, low temperature, drought and flooding (Gisbert *et al*., 2011ab; Karaca *et al*., 2012; Çandır *et al*., 2013; Wahb-Allah**,** 2014). Moreover grafting allows for a lower plant density without compromising yield in some vegetables like tomato, watermelon and melon (Ricárdez-Salinas *et al*., 2010).

Recent studies focus on improving the tolerance of vegetables to abiotic stresses including soil salinity, drought, heavy metals, organic pollutants and low and high temperatures (Schwarz *et al.*, 2010; Colla *et al.*, 2012a; Öztekin and Tuzel, 2011, Wahb-Allah**,** 2014). Temperature fluctuations can affect rootstock resistance to nematodes (Verdejo-Lucas *et al.,* 2013) and controversial results have been reported with respect to the effects of grafting on vegetable fruit quality (Turhan *et al*.,2011, Wahb-Allah 2014, Chávez-Mendoza *et al.,* 2013, Karaca *et al*., 2012, Gisbert *et al.,* 2011ab).

Crown rot caused by *Phytophthora capsici* in various vegetables was successfully controlled with commercial bottle gourd rootstocks with resistance to this pathogen (Chandrasekar *et al*., 2012). Interspecific hybrid rootstocks restricted *F. oxysporum* f. sp. *Niveum* movement into the watermelon scion, suppressed wilt symptoms, and increased fruit yields in an infested field (Keinath and Hassell, 2014).There is evidence of pathogenic variation among some isolates of *Phytophthora* spp. affecting solanaceous crops and their rootstocks as well as new diseases or re-emerging pathogens such as *Colletotrichum coccodes* and *Rhizoctonia solani* (Giraldi *et al.,* 2014b*)*.

The best performance of grafted plants is achieved when used as a component of IPM programs combining non-chemical and chemical options (Bogoescu *et al.,* 2010, Yilmaz *et al.,* 2011). Preplant soil fumigation with 1,3-Dcombined with grafting is widely used to control root knot nematodes and soilborne diseases of different crops (Bogoescu *et al*., 2010). Soil solarisation combined with grafting significantly increased cucumber yield and reduced soilborne pathogens and nematodes in Turkey (Yilmaz *et al*., 2011). In Italy, grafting plus solarisation successfully controlled *Phytophthora capsici* on bell peppers (Morra *et al.*, 2013). In Romania, metham sodium plus grafting resulted in significant yield increase and reduction in soilborne pathogens in cucumber, watermelon and tomato (Bogoescu *et al*., 2010, 2011,2014).

5.3.2. Resistant cultivars

Resistant cultivars offer an excellent option for managing soilborne diseases and nematodes in various crops particularly vegetables and strawberries (Christos *et al*., 2011; Jari *et al*., 2011; Fang *et al.,* 2012; Pérez-Jiménez *et al.*, 2012; Ogai *et al*., 2013.) In recent years, grafting resistant cultivars has provided a powerful tool to manage biotic and abiotic stresses in many types of vegetables (King *et al*., 2008; Gisbert *et. al.,* 2011ab). In addition to healthy plants, resistant cultivars achieve high quality and yields and are able to overcome adverse effects of abiotic stresses like soil salinity, drought, low and high temperatures (Öztekin and Tuzel, 2011; Colla *et. al*., 2012a, Wahb-Allah, 2014).

Although the development of resistant cultivars and rootstocks is time demanding (5 - 15 years depending on crop species) and requires substantial research, improvement programs are under way all over the world due to their usefulness and economical value (Chandrasekar *et. al*., 2012; Guan *et. al.*, 2012; Oumouloud *et. al*., 2013;Fery and Thies 2011ab; Ogai *et al.,* 2013,)

New resistant cultivars to key pathogens attacking strawberries have been developed (Shaw *et al*., 2010; Fang *et al.,* 2012; Koike *et al*., 2013; Whitaker *et al*., 2012). In California, Daugovish *et al*., (2011abc) reported that outbreaks of *Macrophomina phaseolina* and *Fusarium oxysporum* have increased in recent years causing plant collapse and yield reduction. Several strawberry cultivars showed moderate resistanceto *F. oxysporum,* however all tested cultivars were susceptible to *M. phaseolina.* Fang *et al.,* (2012) evaluated yields and resistance of strawberry cultivars to crown and root diseases in Western Australia and found that cv. Festival was the most resistant to *Fusarium oxysporum* wilt*,* binucleate *Rhizoctonia* AG-A, *Cylindrocarpon destructans,Pythium ultimum* and *Phoma exigua* under controlled conditions. Differentlevels of resistance to various soil borne pathogens in strawberry cultivars has been reported in Spain (Pérez-Jiménez *et al*., 2012) and Korea (Lee *et al*., 2012).

Although resistant cultivars offer many advantages, certain conditions may limit their use including the appearance of new diseases, new races that overcome resistance genes, presence of a diverse range of nematodes, soil borne fungi andviruses in the same field and high pathogens pressure (Tanyolaç and Akkale, 2010; Chandrasekar, *et.al*, 2012, Villeneuve *et al.,* 2014). Individual cultivars may perform differently depending on soil type, fertilization and cultural practices (Shaw *et al*., 2010, Daugovish *et al*., 2011.)

5.3.3. Substrates

Substrates have replaced MB particularly in protected, high-cash crops demanding excellent quality, healthy plants. Although the initial investment is typically high, increased productivity and yield due to higher planting densities and improved quality generally compensate the extra costs. Several countries have developed substrate systems that are cost effective employing locally available materials (Thomas *et al*., 2011; Fennimore *et al*., 2013a).

In soilless culture, *Phytophthora cactorum* has been reported as an important threat for strawberry propagation and production, for which no reliable non-chemical control measures are available. Pathogen dissemination can be reduced by disinfecting irrigation water with slow sand filtration leading to reductions of 45-65% in disease severity. A complementary strategy to reduce damage caused by *P. cactorum* is to enhance disease suppressive properties of the soilless substrate (Evenhuis *et al.,* 2014).

Substrates are used alone or in combination with other alternatives. Substrates and compost with suppressive effects towards selected soilborne pathogens are of practical interest (Colla *et al*., 2012). Grafted plants were shown to grow more vigorously and produce higher yields when grown on substrates than when grown on soil (Marcic and Jakse, 2010).When incorporated into the substrate, biocontrol agents may play a role in suppressing soilborne diseases (Pugliese *et al*., 2014).

5.3.4. Steam

Steam disinfestation is an increasingly attractive strategy to control soilborne pathogens and weeds both in greenhouses and field crops (Gelsomino *et al*., 2010). Its use dates back as early as 1888, but in the 1960s it was substituted by cheaper chemical treatments, mainly MB (Gay *et al*., 2010). Soil steaming is very effective and is considered a valid alternative to MB for controlling soil pathogens and weeds, especially in high value greenhouse crops (Gelsomino *et al*., 2010). Steaming offers the additional advantage of posing no environmental or worker safety issues such as are associated with chemical fumigants (Fennimore *et al*., 2013).

Steam should heat the soil to a temperature of 60-80°C at 10 - 20 cm depth, depending on the target organisms.The duration and amount of steam needed to reach these temperatures will depend on various soil factors, including texture, type and moisture content, but also on the type of equipment and fuel used.

Steam disinfestation resulted in strawberry fruit yields that were comparable to those produced in fumigated soils. Additional work is in progress to evaluate efficacy in large-scale production systems in different strawberry production districts in California (Samtani *et al*., 2012; Fennimore *et al*., 2013). Further, steam may allow wider land utilization near urban areas in California, where buffer zones restrict strawberry production since fumigants cannot be applied (Fennimore *et al*., 2011).

High temperatures may result in eradication of beneficial microorganisms and result in rapid reinfestation of treated soil by soil-borne pathogens found in irrigation water, seeds or plantlets (Roux-Michollet *et al*., 2010). For this reason it is recommended to not overheat the soil, and incorporate compost or biocontrols into the soil as soon as the steaming treatment ends.

New developments of steam application methods aimed at reducing costs and extend its use on crops grown outdoors, were tested by evaluating efficacy against selected soilborne pathogens (Colla *et al*., 2012b). Development of more efficient and economic steam application equipment, currently in progress, suggests that steam is approaching wider commercial feasibility (Fennimore *et al.,* 2013b).Gilaldi *et al.,* (2014) compared the efficacy of different steaming methods (sub-surface steam injection, surface steam application by means of iron plate and sheet steaming) for controlling selected soil-borne pathogens *(Fusarium oxysporum* f. sp. *raphani*, *F. oxysporum* f. sp. *Conglutinans* and *F. oxysporum* f. sp. *basilica*) in sandy-loam soil. The steam injection system was the most efficient in terms of chlamydospore reduction.

5.3.5. Hot water

Hot water treatment is used in Japan to control *Fusarinum oxysporum*, particularly in repeated cropping systems such as celery (Fujinaga *et al.,* 2005) and involves injecting water from a portable boiler into the field. This treatment is useful for soil sterilization in protected houses for ornamental and vegetable crops. Hot water treatment at a rate of200l/ m^2 controls nematodes and root rot diseases of autumn-winter muskmelon but at very cost which has reduced its use(Gyoutoku *et al*., 2007).

5.3.6. Solarisation

Soil solarisation is a method using high temperatures produced by capturing solar energy to control soil-borne pests. The soil is heated with a plastic tarp, which is left in place for a period of time that varies according to irradiation and air temperature. When properly applied, the plastic sheets allow the sun's radiant energy to be trapped in the soil, heating the top 30 to 45 cm and killing a wide range of soilborne pests (Gamliel and Katan, 2012)
The effect of solarisation is stronger at the soil surface and decreases with soil depth. The maximum soil temperature in the field is usually 40 - 70ºC at a depth of 5 cm and 30° - 37°C at 45 cm. Although some pests may be killed within a few days, 4 to 6 weeks of exposure to the full sun during the summer is usually required to ensure control of many others (Katan and Gamliel, 2012ab)

Negative side effects observed in several cases with soil steaming and fumigation, e.g. phytotoxicity and pathogen reinfestation due to the creation of a biological vacuum, have been rarely reported with solarisation (Katan and Gamliel, 2012a; Antoniou *et al.,* 2014).

This method was initially developed in Israel in the mid seventies (Katan *et al.,* 1976), showing its effective control on *Verticilliun dahliae* of tomato and eggplant.Soil solarisation research is still very dynamic (Katan, 2014) and studies are being carried all over the world for different crops including tomatoes, tobacco, melons, peppers, strawberries, and flowers. Solarisation has been successfully used in MB phase-out initiatives for example in Egypt (Mokbel, 2013); Mexico (Muñoz Villalobos, 2013); Argentina (Mollinedo, 2013), Spain (Castillo García, 2012); Costa Rica (Monge-Pérez, 2013), Greece (Antoniou *et al.,* 2014), Turkey (Yucel *et al.,* 2014), Spain (Guerrero-Diaz *et al.,* 2014) and Italy (D'Anna *et al.,* 2014). In Italy, soil solarisation reduced infections caused by *P. lycopersici* to levels comparable to MB fumigation and better than metham sodium and metham potassium (Vitale *et al.,* 2011).Lombardo *et al.,* (2012) reported that solarisation efficiently controlled tomato soil pathogens and enhances plant growth and fruit yield. Solarisation is thus considered an effective alternative to MB in greenhouse tomato production in many countries where it is applied alone or in combination with other alternatives within IPM programs (Katan, 2014).

An interesting adaptation of solarisation where relatively small amounts of substrate can be solarized inside a “solar collector” was devised and used in Brazil to replace MB used by thousands of pot plant growers (UNEP; 2014, Ghini, 2014, Ghini *et al* 2007).

5.3.7. Biofumigation

Biofumigation is the practice of using volatile chemicals released from decomposing plant biomass to control soil borne pests, including nematodes, bacteria and fungi (Oka, 2010; Mowlick *et al.,* 2013). Numerous studies focus on the role of glucosinolates (GLSs) and cognate isothiocyanates (ITC) as bionematicides. These chemicals, containing sulfur, are released from Brassicaceae, commonly known as the ‘‘mustard’’ plant family (Argento *et al.,* 2013). The use of Brassica cover crops and their associated degradation compounds as biofumigants to manage soilborne pathogens offer vegetable growers an alternative toMB. Many pathogens attacking pepper (*Rhizoctonia solani*, *Sclerotium rolfsii*, *Pythium* spp.) have been successfully managed by biofumigation using oilseed radish (*Raphanus sativus*), 'Pacific Gold' mustard (*Brassica juncea*) or winter rapeseed (*Brassica napus*). Cover crops were disked into soil in spring and immediately covered with virtually impermeable film to reduce escape of volatile pesticidal compounds. Concentrations of isothiocyanates, the compounds primarily responsible for such pesticidal activity, were highest following incorporation of mustard with rapeseed yielding the second highest ITC concentrations, whilst radish yielded very low ITC concentrations (Hansen and Keinath, 2013).

Garlic residues were used to control root-knot nematodes in tomato, and sulfur-containing compounds might be responsible for the inhibition of *M. incognita*. (Gong *et al.,* 2013).The presence of large amounts of sulfur compounds in *Allium* species suggests that the residues of these plants may be used in soil biofumigation. The active molecules in *Allium* sp. were determined to be dimethyl disulfide (DMDS) and dipropyl disulfide (DPDS) (Arnault *et al.,* 2013).The growth stage of plants has an influence on the biofumigant potential of plant materials against soil borne pathogens (Morales-Rodriguez *et al.,* 2012). In Spain and other countries, many different types of residues are used for biofumigation with excellent results (Díez-Rojo *et al.,* 2010). This technology has been transferred to different countries and sectors for example Ecuador (Castellá-‘Lorenzo *et al*, 2014).

Biofumigation and biosolarisation are used as part of IPM programs to replace MB for controlling soilborne pathogens and weeds in many crops including vegetables and ornamentals with good results. Biofumigation combined with antagonistic microorganisms provided very good control of *Phytophthora* blight of pepper plants by regulating soil bacterial community structure (Wang *et al.,* 2014). The success of this strategy is influenced by the pest complex, soil characteristics, type and availability of the soil amendment, and climatic conditions (Ozores-Hampton *et al.,* 2012; Korthals *et al.,* 2014; Morales-Rodriguez *et al.,* 2014).

5.3.8. Organic amendments

Substantial quantities of organic amendments are produced annually around the world from different sources including plant residues, animal manures, peat, compost, biosolids (sewage sludge), organic wastes from municipal yards, paper mills, timber, paper products, dairy, poultry, fish, meat and vegetable processing industries (Nunez-

Zofio *et al*., 2013; Thangarajan *et al*., 2013;Morales-Rodríguez *et al.,* 2014). Recycling these organic substances in agriculture offers several advantages such as improving plant growth, yield, soil carbon content, microbial biomass and activity, alleviating the negative effects of salinity, restoring soil fertility and suppressing soilborne pathogens (Melero-Vara*et al*., 2011; Ji *et al*., 2012; Cellier *et al*., 2014; Tartoura *et al*., 2014).Organic amendments may be pathogen and site specific (Bonanomi *et al*., 2010; Mennan and Melakeberhan, 2010), so that an organic amendment suppressive to one pathogen could be ineffective, or even conducive, to others (Michel and Lazzeri, 2010; Oka, 2010; Thangarajan *et al*., 2013).

Organic amendments are used alone or in combination with other control options such as solarisation, biosolarisation or grafting (Klein *et al.,* 2012, Koron *et al.,* 2014). Their success may vary with the location, materials used, and target pests. In Spain,Melero-Vara *et al*.,(2011) treated soil with poultry manure alone or combined with solarisation to control carnation wilt caused by *Fusarium oxysporum* f. sp. *dianthi* (Fod) in greenhouses. Results showed that the addition of poultry manure in Fod-infested soil led to better disease control than soil solarisation alone, improved carnation yield and quality, and also increased plant vigor, thus providing a satisfactory alternative to MB. In another study,soil amendments with mustard and canola cover crops for management of *Phytophthora* blight on squash provided the greatest disease reduction and increased squash yield significantly compared with the non-treated control (Ji *et al*., 2012). Nunez-Zofio *et al*., (2013) reported that application of sugar beet vinasse followed by solarisation reduced the incidence of *Meloidogyne incognita* in pepper crops while improving soil quality. In contrast, Michel and Lazzeri (2010) stated that green manures and organic amendments did not improve plant yield or corky root control in tomato.Similarly, soil amendment with a turnip cover crop was not effective for reducing yellow nutsedge growth and tuber production, and did not improve bell pepper growth and yield compared to fallow plots at any initial tuber density (Bangarwa *et al.,* 2011).Mashela *et al.,* (2013)reported that the efficacy of crude extracts of *Brassica oleracea* leaves in nematode suppression and tomato productivity was dependent on soil microbial activities.

Enhancement of disease suppression properties in soils is very important for sustainable agricultural farming systems (Postma *et al.,* 2014). A soil amendment consisting of hydrolyzed fish and fish emulsion induced suppressiveness against *F. oxysporum* f. sp. *Lycopersici* and reduced disease incidence and severity in tomato, whilst increasing plant growth. For *F. oxysporum* f. sp. *lactucae*, the two amendments inhibited microconidia germination in the substrate (Bettiol *et al.,* 2014)

The effectiveness of organic soil amendments is improved when other cultural practices that support the establishment and growth of pest suppressive soil microbial communities and promote the development of vigorous, stress-free root systems of the plant hosts are used. Crop rotation, soil solarisation, and host resistance are examples of other pest management tactics that can enhance the performance of organic soil ammendments (Chellimi *et al.,* 2014).

Composting processes, optimum compost production methods, as well as compost composition and quality parameters and application methods should be evaluated before implementing this option at the commercial level (Savigliano *et al.,* 2014).

Pugliese *et al*.,(2014) and Lodha *et al.,* (2014) reported that compost suppressiveness varies according to the type of waste used and the composting process followed.

5.3.9. Anaerobic soil disinfestation (ASD)

ASD is a biologically based, non-fumigant, pre-plant soil treatment developed to control a wide range of soilborne plant pathogens and nematodes in numerous crop production systems used for example in Japan, The Netherlands and the USA (Shennan *et al.,* 2014; McCarty *et al.*, 2014;Rosskoph *et al.* 2010;Daugovish *et al,*. 2011). In Japan, this technology is known as “soil reduction redox potential”, “reductive soil disinfestation (RSD)”, “biological soil disinfestation (BSD)”, “or anaerobic soil disinfestation (ASD)”and is widely disseminated among vegetable growers (Shinmura 2003; Momma *et al.,* 2013).Bacterial populations in the soil are essential for an effective ASD treatment. (Hong *et al.,*2012.)

Soil treatment by ASD entails the incorporation of a labile carbon source, covering with plastic sheet and irrigating the top soil to saturation (5 cm irrigation) to create conditions conducive to anaerobic decomposition of the added C source (McCarty *et al.*, 2014). ASD is widely used in Japan and is being tested in other countries with encouraging results, but still with some inconsistencies. The feasibility of this alternative is largely impacted by moisture and the availability of an appropriate carbon source (Yilmaz *et al.,* 2011; Lombardo *et al*., 2012; Melero-Vara *et al*., 2012;Nyczepir *et al*., 2012).Suppression of soil borne fungal pathogens by BSD maybe attributed to anaerobic soil conditions, high soil temperature, organic acids generated and metal ions released into soil water. BSD used in Japan consists of mixing rice or wheat bran into the soil, followed by flooding the soil with water and then covering with plastic for at least three weeks to allow microorganisms to proliferate and deplete oxygen in the soil creating anaerobic,reductive conditions to inhibit soil pathogens. Populations of soil bacteria are essential for an effective ASD treatment.

Commercial use of ASD is currently limited by cost and uncertainty about its effectiveness for controlling different pathogens across a range of environments (Shennan *et al.,* 2014; Shennan *et al.,* 2010). Its feasibility is largely impacted by moisture and availability of appropriate carbon sources (Yilmaz *et al*., 2011; Lombardo *et al*., 2012; Melero-Vara *et al*., 2012; Nyczepir *et al*., 2012).

In coastal California, an ASD treatment using rice bran was shown to be consistently effective in sandy-loam to clay-loam soils for suppressing *Verticillium dahliae* and obtaining yields comparable to a fumigant control. Economic feasibility and the need for ensuring high nitrogen concentrations still limits the commercially use of ASD (Muramoto *et al* 2014). This technology has been adopted in the Florida vegetable sector (Butler *et al.,* 2012), and in California strawberries (Shennan *et al.,* 2011). On-farm demonstrations in Tennessee are in progress (Butler *et al.,* 2012).ASD technology using diluted ethanol instead of wheat bran as a carbon source has been developed (Momma *et al.,* 2010; Kobara *et al*., 2011; 2012).

Anaerobic soil disinfestation has been studied in multiple countries for the suppression of plant pathogenic fungi and bacteria. Recent work in the US has included studies on weed control and nematode management (Rosskopf *et al.,* 2014), however Zavatta *et al.,* (2014) reported that in organic strawberry/vegetable production in coastal California, weed suppression by ASD was limited.

5.3.10. Biological control

Biocontrol agents for soilborne pathogens and root pests mainly include non-pathogenic fungi, bacteria and other antagonists. *Trichoderma* spp., *Bacillus* spp. and steptomycetes show such characteristics and can also act as plant growth promoting organisms (Babalola *et al.,*2010; Sanchez-Tellez *et al.,* 2013; Mancini *et al.,* 2014).

In Honduras, the MB replacement strategy in the melon sector includes massive applications of two strains of *Trichoderma harzianum* and one strain of *Bacillus subtilis* isolated from the Choluteca region where most of the melon production occurs,to control soilborne pathogen such as *Fusarium oxysporum* and *Monosporascus cannonballus* (Michel, 2009; Martínez *et al.,* 2010, Arias 2013). Several *Trichoderma* species, such as *T.asperellum, T. harzianum, T.polysporum, T. viride* and *T. virens* are successfullyused as biological control agents against a variety of phytopathogenic fungi (Hermosa *et al.,* 2013; Kaewchai *et al.,* 2009). Biocontrol agents can be reared and multiplied directly at farms (Arias, 2013). *Trichoderma* may be propagated on a substrate of rice hulls, bran and flour with calcium nitrate or in a liquid suspension of water, sugar molasses and calcium nitrate. *B. subtilis*is also propagated on rice or a liquid suspension of sugar and sterile molasses. Biocontrol agents are then incorporated into the soil at the pre-plant stage and throughout the cropping cycle. (Castellá-Lorenzo *et al.,* 2014;Reyes, 2013, pers. Commun; Arias, 2013)

In Italy, biological control of *Sclerotinia sclerotiorum* with*Coniothyrium minitans* is commercially used. In the USA *Streptomyces lydicus* has been registed to control some soilborne pathogens (Behal, 2000).

5.3.11. Crop rotation and inter-croping

Plant inter-cropping can be used as an efficient strategy in MB replacement programs. In China, rotations of castor-oil plant, hot pepper or crown daisy with cucumber, significantly reduced infection by *Meloidogyne incognita* (Dong *et al.,* 2012). Kokalis *et al.,* (2013) selected several cover crops for their susceptibility to invasion and galling by *Meloidogyne arenaria*, *M. incognita*, and *M. javanica* and their potential as organic amendment components in anaerobic soil disinfestation (ASD) applications. Development of ASD techniques for reducing soilborne pest populations during summer months in Florida has provided insight into some of the effects of these cover crops on root-knot nematode populations (Butler *et al.,* 2012ab).

Much research has been conducted on the use of marigolds (*Tagetes* spp.) used as a cover crop for nematode suppression and some commercial adoption of this technique has occurred. Tagetes is reportedly more effective than nematicides or soil fumigants in some cases, but can also have a negative impact on cash crop growth and yield (Cerruti *et al.,* 2010) depending on how they were used (e.g. intercrop/cover crop/soil amendment, seeding rate, time between marigold and cash crop), the cultivar, species or races of target nematodes, temperature, or age of the marigold plants. Future research should focus on developing field IPM programs that take advantage of the nematode-suppressive potential of marigold (Cerruti *et al.,* 2010).

5.4. Combination of alternatives: IPM

Pest and disease management should aim to reduce pest infestation by manipulating one or more of the biotic or abiotic components involved in the disease with minimal disturbance to the environment and natural resources, whilst managing all inoculum sources (Katan, 2014; Gamliel, 2014). Integrated pest management (IPM), is a holistic approach that in addition to effective pest control, takes into consideration environmental, social, economic and regulatory issues. The basis of the IPM approach is the combination of control methods including chemical and non-chemical options (biological,physical, cultural). Soil health, training, interactions between pesticides, risk assessments, appropriate application methods and adapting IPM to each cropping system are additional issues needing consideration (Katan, 2014; Gamliel, 2014).

In many non-A5 and A-5 countries, successful IPM programs have been implemented, which do not rely on MB or other soil fumigants and which render agricultural sectors more competitive in international markets, increasingly requiring products grown within environment-friendly standards (Castellá-Lorenzo *et al.,*2014).

In Spain, IPM programs are efficiently used in strawberry production (Chamorro *et al.,* 2014). Melero-Vara *et al.,* (2012) demonstrated that soil solarisation alone did not provide sufficient control of root-knot nematode (*Meloidogyne incognita)*, but when it was combined with raw or pelletized poultry manure, led to similar crop yields after 9 months as 1,3 D/Pic. Organic manure treatment should be applied at the start of each successive growing season.

In India, *Macrophomina phaseolina* is the most destructive soil borne plant pathogen in the arid regions causing charcoal rot in many high value crops. Combining *Brassica* amendments such as mustard residues or mustard oil cake with one summer irrigation was found effective for reducing incidence of *Macrophomina;* this effect was improved when a prolonged exposure of the soil to dry summer heat preceeded the treatment (Mawar and Lodha, 2014).

In Italy, Gilardi *et al.,* (2014a) developed a strategy to control *Fusarium oxysporum* f. sp. *conglutinans* and *F.oxysporum.*f. sp. *raphani,*causal agents of fusarium wilt of rocket and basil,by combining amendments and soil solarisation. An IPM strategy combining grafting and compost treatment to control *Phytophthora capsici*on bell pepper has also been developed (Gilaldi *et al.,* 2013).

In Poland, Chalanske *et al.,* (2014) reported that growing tomato grafted plants in fumigated soil has limited influence on the final yield when the pressure from soil-borne pests and pathogens is low.

In Turkey, Boegoescu *et al.,* (2014) reported that grafting combined with soil disinfestation with metham sodium led to significant reduction in the incidence of *Fusarium oxysporum* f. sp. *melongenae, Verticillium dahlia* and *Meloidogine incognita* on eggplant.

In USA, a soil treatment consisting of solarisation plus a wheat based organic amendment was as effective as preplant fumigation with MB in increasing peach tree survival for at least 6 years after orchard establishment (Nyczepir *et al.,* 2012). ASD plus solarisation is effective for managing plant-parasitic nematodes. Efficiency of this combination is comparable to MB for plant pathogen inoculum survival (Butler *et al.,* 2012).

5.5 Crop specific strategies

5.5.1. Strawberry fruit

Intensive cultivation of strawberries increases populations of soilborne pathogens, which often leads to soil disinfestation. In California, problems are reported in fields that were not fumigated with MB/Pic for a few years and are mainly associated with two pathogens: *Macrophomina phaseolina* and *Fusarium oxysporum* f. sp. *Fragariae* (Koike *et al.,* 2013).

A meta analysis conducted by Belova *et al.*(2012) does not support the technical superiority of MB over its alternatives, and shows that several economical and technically feasible alternatives are available for strawberries in California, in particular 1,3-D/Pic 65:35 formulation.

In Morocco,drip applied metham sodium (MS) at a dosage of 200 to 250 g /$m^2$is successfully used to control fungi attacking strawberries (*Rhizoctonia solani, Verticillium dahliae*, *Phytophthora cactorum*) and more than 40 species of weeds including C*ynodon dactylon, Chenopodium* sp*,* and *Amaranthus sp*. Yields and quality obtained with metham sodium were equivalent to those achieved with MB in the past (Chtaina and Besri, 2006; Chtaina, 2008).

In Turkey, the main soilborne pathogens of strawberry are *Fusarium oxysporum, Rhizoctonia solani* and *Macrophomina phaseolina*. Solarisation plus dazomet at a rate of 400 kg/ha was found effective for controlling diseases, nematodes and weeds in this crop, but some farmers are also adopting solarisation plus manure as a feasible option (BATEM, 2008).

In Lebanon, chemical alternatives (metham sodium and 1,3-D/Pic) and soil solarisation are widely applied with great success in many regions (UNEP/MLF/MoE/UNIDO, 2004).In Egypt, metham sodium combined with solarisation and bio-control agents is widely used by large-scale open field strawberry growers (UNIDO, 2008a).

In Chile, previous MB users are mainly adopting chemical alternatives, particularly metham sodium and 1,3-D/Pic, and in Mexico the situation is similar (UNIDO, 2008b; UNIDO, 2010)

In California, USA, fumigant use regulations have impacted the transition from MB to alternatives as previously described. Combined treatments involving steam and soil amendments like mustard seed meal (MSM), showed very favorable results in terms of yield and quality as well as weed and pathogen control. An economic analysis showed returns far exceeded costs of steam treatment (Fennimore *et al.,* 2013a). A further 5-year project is under way (Fennimore *et al.,*2013b) to facilitate the adoption of strawberry production systems that do not use MB and focus on non-fumigant alternatives (soil-less production, biofumigation, anaerobic soil disinfestation, steam). Strawberry fruit yields from substrate production were comparable to those obtained with conventional methods. Anaerobic soil disinfestation also resulted in fruit yields that were comparable to those from conventionally fumigated soils.

The increase in crown and root rot incidence, caused by *M. phaseolina* in Israel may be related to the phase-out of MB, but this pathogen is being effectively controlled with metham sodium (Zveibil *et al.,* 2012).

5.5.2. Tomato and pepper

Effective chemical and non-chemical alternatives to MB have become available for tomato and pepper crops, and MB use has been entirely phased out in all developed countries and the vast majority of developing countries (TEAP, 2014).

Chemical and non-chemical alternatives including resistant varieties, grafting, soilless cultivation, solarisation, biofumigation, biodisinfestation, ASD, biocontrols, organic amendments and steam application have been adopted alone or in combination to prevent the damages of soilborne pathogens and weeds in many countries of the world (Christos *et al*., 2011; Martinez *et al*., 2011; Yilmaz *et al*., 2011; Nunez-Zofio *et al*., 2013; Ogai *et al*., 2013; Butler *et al*., 2014; Elgorban *et al*., 2014; Martin *et al*., 2014).

In China, Ji *et al.,* (2013) indicated that Telone C-35 was an excellent MB alternative in tomato production. Its efficacy is increased if included within an IPM program.

Resistant cultivars provide an excellent option to manage soilborne diseases and nematodes in tomato and pepper as they offer various advantages including healthy plants, high-quality yields and tolerance to adverse abiotic stresses such as soil salinity, drought, low and high temperatures (Öztekin and Tuzel, 2011; Colla *et. al*., 2012a; Wahb-Allah**,** 2014). The emergence of new diseases or new races of pathogens that overcome resistance, as well as very high pest pressures may limit the use of resistant cultivars under certain conditions (Kousik *et al.,* 2010; Tanyolaç and Akkale, 2010.)

Grafting is widely adopted in the tomato and pepper sectors around the world. This technique offers various advantages as described in section 4.3.1 of this report.

Substrate production is often combined with other options like resistant cultivars, grafting and biocontrol agents, and is an effective and well established system for tomato and pepper in Northern Europe and some Mediterranean countries. As stated previously, initial costs may be high but are offset by increased productivity and yield (Marsik and Jakse, 2010; Colla *et al*., 2012b).Biocontrol agents have proven to effectively control many soilborne pathogens in substrate production systems (Pugliese *et al*., 2014).

In Spain, repeated applications of biosolarisation greatly reduced Fusarium populations (reductions greater than 72%), an effect similar to or even greater than that of MB (Martinez *et al.,* 2011). In Italy, *Pyrenochaeta lycopersici* infections were significantly reduced by solarisation, at levels comparable to MB and greater than metham sodium and metham potassium (Vitale *et al.,* 2011).In Turkey, solarisation combined with grafting considerably improved early flowering time, plant vigor, early and total yields and decreased nematode and Fusarium wilt damages in cucumber (Yilmaz *et al*., 2011). Sugar beet vinasse as a soil amendment applied before solarisation drastically decreased the incidence of *Meloidogyne incognita* in pepper crops and improved soil quality in Spain (Nunez-Zofio *et al*., 2013).Other organic materials including manure, decomposed plant materials or organic by-products from different sources to soil before solarisation increase the effectiveness of solarisation as decribed previously (Guerrero *et al*., 2010; Martinez *et al.,* 2011).

Various chemical alternatives including Pic,1,3-D, MITC, DMDS, AITC, SF, abamectin, dazomet and metham sodium are presently available to control soilborne diseases, nematodes and weeds in tomato and pepper production around the world (Wu *et al.,* 2011; Qiao *et al.,* 2012ab; Cao *et al.,* 2014). They can be used alone or in combination, or together with non-chemical options (Wang *et al.,* 2013; Mao *et al.,* 2012, 2014). Some phytotoxicity and environmental problems are associated with certain chemicals under specific conditions, as well as regulatory constraints in certain countries may limit their use. (Daugovish and Fennimore, 2011; Belova *et al.,* 2013; Devkota *et al.,* 2013).

5.5.3. Cucurbits

MB use in cucurbit crops was almost entirely phased-out in A5 countries in 2014. Since cucurbits alone amounted to about 32% of total MB consumption for controlled uses in A5 countries in 2009 (TEAP, 2010), this is an achievement worth noting.

Cucurbit grafting has gained increased interest in many countries proving economically feasible, accessible and sustainable(Louws *et al*., 2010; Schwarz *et al*., 2010; Yilmaz *et al*., 2011**).** Grafting is used to control nematodes, particularly root knot **(***Meloidogyne* spp.) in many A5 countries including Chile (Ban *et al*., 2014), China (Liu *et al*., 2014), Egypt (Amin and Mona, 2014) and Turkey (Yilmaz *et al*., 2011). Some of the rootstocks provide reasonable resistance to Fusarium wilt in melon (Ricárdez-Salinas *et al*., 2010), watermelon (Mohamed *et al*., 2012; Keinath and Hassell, 2014) and cucumber (Yilmaz *et al*., 2011), in Mexico, Egypt, USA and Turkey, respectively. Grafted watermelon plants showed significantly lower Verticillium wilt severity than non-grafted plants in the USA (Miles *et al*., 2013). Grafting increases plant growth and yield without reducing fruit quality in watermelon (Karaca *et al*., 2012; Mohamed *et al*., 2012; Çandır *et al.*, 2013). Certain cucurbit rootstocks increase tolerance to soil salinity, drought, low temperature and flooding (Schwarz *et al*., 2010; Öztekin and Tuzel, 2011; Colla *et al.*, 2012; Wahb-Allah**,** 2014). In Mexico, it is possible to use a lower plant density when growing grafted watermelon and melon, without any yield reduction (Ricárdez-Salinas *et al*. 2010). Suitable rootstocks of watermelon promoted plant tolerance to low potassium stress in China (Huang *et al*., 2013).

Grafting works best when used within an IPM approach. In Turkey, solarisation combined with grafting induced earlier flowering times, improved plant vigor, enhanced yield and decreased damage caused by nematodes and Fusarium wilt in cucumber (Yilmaz *et al*., 2011) In Romania, grafted plants grown on soils treated with metham sodium was successful for controlling soilborne pathogens affecting cucumber and watermelon, and significantly increased yields (Bogoescu *et al*., 2010).

Other alternatives available for cucurbit production include soil amendments such as mustard and canola cover crops, which significantly reduce damage from *Phytophthora* blight and increase yield in squash (Ji *et al*., 2012). In China, SFprovided good efficacy against root-knot nematodes (*Meloidogyne* spp.) and moderate activity against *Fusarium* spp. and weeds (*Digitaria sanguinalis*) in cucumber and tomato (Cao *et al*., 2014). Gelatin capsules of 1,3-D/Pic described previously provide another good option. (Wang *et al*, 2013).

5.5.4. Ginger

The main soil-borne pathogens of ginger are root-knot nematodes (*Meloidogyne* spp.), Pythium root rot, (*Pythium* spp.), bacterial wilt (*Ralstonia solanacerum)* and weeds, mainly nutsedge (*Cyperus rotundus*).They are aggressive pathogens that may lead to total crop loss (Anonymous, 2009). Presently, the only chemical alternative registered in China is chloropicrin (Pic), which is effective against fungal and bacterial pests but is less effective against root-knot nematodes and weeds. Low temperature and strong winds can reduce the effect of fumigation and lead to phytotoxicity. Further, the fumigation window for Pic use is short, and plant-back periods are longer than those of MB (Mao *et al*, 2014).

1,3-D has good efficacy against nematodes in ginger (Qiao, 2012) but is not registered for this crop in China. 1,3-D/Pic is thus not available, although research with this mixture shows good results. MI/Pic also showed good efficacy to control pathogens and nematodes of ginger in China, but again this mixture is not registered (Li, 2014). Non-chemical alternatives are not currently feasible due to factors such as cost, time of required application and operational requirements. For example, solarisation and bio-fumigation cannot be used in winter because of low temperatures.

A granule formulation of azoxystrobin and metalaxyl-M and a wettable powder formulation of cyazofamide are applied in Japan during the growing season for controlling ginger root rot. (Tateya, 2009; Yazuaki, 2012; Morita, 2012).

Soilless cultivation is widely used in Hawaii, USA and Malaysia (Hepperly, 2004; Yaseer, 2012).

5.5.5 Nurseries

5.5.5.1 Perennial crop field nurseries

Many types of propagation material (bulbs, cuttings, seedlings, young plants, sweet potato slips, strawberry runners, and trees) are subject to high health standards and treatments intended to provide control of pests and pathogens affecting these materials should be able to achieve an acceptable yield and quality. For propagative materials a clean root system (or clean bulbs) is essential, as it is critical to prevent the spread of economically important pests and pathogens from the nursery fields to the production fields. The required level of pest and pathogen control for propagative material must remain effective over this entire growing cycle.

In many countries, there are regulations related to nursery stock (certification), which can either specify a level of control that must be achieved or the use of approved soil treatments that are accepted for insuring a high level of control. Even if such regulations are not present,for non-certified stock, the market sets the standard that must be met. In either case, lack of a clean root system could mean a 100% loss in marketable product for the grower and in the past MB has commonly been used to meet clean propagative material standards. In some cases, sufficient data and grower experience allowed growers to transition from the 98:2 formulation of MB to 67:33 or 50:50 formulations depending on the pest or pathogen to be controlled and level of severity of the infestation (De Cal *et al.,* 2004; Porter *et al.,* 2007). Research trials, indicate that some alternative fumigants and combinations (such as 1,3-D/Pic) provide control comparable to MB under specific circumstances (Hanson *et. al.*, 2010; Schneider *et.al.*, 2008; Schneider *et al.*, 2009ab; Stoddard *et al.*, 2010;Walters *et al.*, 2009). As these materials meet the requirements for efficacy and consistency,regulatory entities incorporate them into the lists of approved certified nursery soil treatments (McKenry, 2011). For example,the California Department of Food and Agriculture (CDFA) approved the use of 1,3-D or methyl iodide as a certified nursery stock soil treatment for certain crops under specific conditions (CDFA, 2009). Although the latter is not available, 1,3/D offers an alternative to MB for the crops involved.

An alternate approach,where economically feasible and an acceptable product can be obtained, i.e., root system of acceptable size and quality is to use soil-less substrate production systems.

Production of high health propagative materials remains a significant challenge in some sectors (ie strawberry runners) as Parties transition away from MB (Zasada *et. al.*, 2010). The consequences of failed treatment not only impact the propagative material, but can also jeopardize the performance of MB alternatives in the fruiting fields.

5.5.5.2. Current commercial use status

The EU phased out MB in nursery production between 1992 and 2007 (EC Management Strategy, 2009). Chemical alternatives in commercial use for this purpose include dazomet, metham sodium, and 1,3-D (with restrictions as stated previously). Non-chemical alternatives include substrates, grafting, resistance, steam, and crop rotations. Japan phased out MB in nurseries in 2005. Alternatives in commercial use include dazomet, chloropicrin, 1,3-D, and MITC (Tateya pers. comm., 2010). MB is used in the US to meet certified nursery regulations (this use is allowed in the US under the QPS exemption). Alternatives in commercial use for nurseries include chemical (1,3-D, Pic, metham sodium) and non-chemical options (substrates, resistant varieties,steam) alternatives (CDFA, 2009).

In A5 countries, certified plant materials are produced without MB; for example, substrates are used for certified citrus and banana propagative materials in Brazil (Ghini, pers. comm., 2014); grape, pear, apple, and citrus propagative materials are produced in Argentina without MB (Valeiro, pers. comm., 2010).

5.5.5.3 Strawberry nurseries

MB was the fumigant of choice for over 60 years in this industry, because it provided nursery stock of high plant health to meet the requirements of the fruit industry. This may have been to meet certification or standards required by export markets, and also assisted the industry to avoid litigation from strawberry growers for movement of diseases. A recent publication gives an excellent overview of the situation for the strawberry fruit and nursery industries worldwide (Lopez- Aranda, 2012).

A single strawberry runner can expand to several million runners by year five of the runner production system, so the potential impact of spreading a pest or disease is tremendous. For this reason, few alternatives to MB are considered suitable. MI/Pic mixtures, 1,3-D/Pic and Pic alone in some situations, substrate production of plug plants and to a lesser extent where regulations prevent the use of the above alternatives, MITC generators (metham sodium and dazomet) are the alternatives being adopted.

In 2014, MB is still used in three non-A5 Parties either as a critical use (Australia, Canada) or under a QPS exemption (USA). A number of A5 Parties (Argentina, Chile, China, Egypt, Mexico,Vietnam and others) used MB for strawberry runner production and several have already phased out MB in strawberry nursery industries (e.g., Brazil, Lebanon, Morocco, Turkey). Mexico is continuing use in 2015 and under a critical use exemption, but trials with alternative fumigants (1,3-D/Pic, metham sodium) are giving encouraging results.

In Australia, the northern production region fully transitioned in 2009 to mixtures of 1,3-D/Pic and Pic alone, however in the cooler southern regions in heavy soil types these alternatives are phytotoxic causing losses of up to 40%, or are ineffective and no alternatives have been adopted except for the use of substrate production of foundation stock. Of the alternatives being evaluated methyl iodide was being considered by Australia as a one-to-one replacement, but registration is no longer being sought (Mattner *et al*., 2010).

Alternative fumigants deliver similar fruit yields to MB/Pic, but the incidence of diseases caused by previously obscure pathogens, such as *Fusarium* spp. and *Macrophomina phaseolina*, has increased.Certification authorities do not approve the use of substitute fumigants (1,3-D/Pic, Pic, dazomet and metham sodium) for runner production. The industry does, however, produce its early generations of runners using soil less culture, which reduces the need for disinfestation with MB/Pic. This system is not economically feasible for later generations because runner prices would need to increase by more than 500% to make them viable. Current research is investigating the combined use of low-rate fumigants and herbicides for soil disinfestation in the runner industry, with the aim of reducing the risk of crop phytotoxicity from individual products (Mattner *et al.,* 2014).

In Canada in 2008, several regions transitioned to alternatives mainly Pic alone, however owing to its lack of registration in Prince Edward Island the request for a critical use continues. Canada is awaiting an outcome for registration of Pic alone, but new studies are still needed to validate that there are no ground water contamination risks associated with its use. Substrate production appears suitable for at least a proportion of the runner chain production in these countries (i.e., nuclear, foundation and possibly some of the mother stock). This technique has been adopted widely in higher latitude regions as a means to produce runners for the shorter season northern markets, but the altered physiology of plug plants and cost of capital structures has been a limitation to date for the production of runner plants for performance over the long production seasons (6-8 months) presently given by existing runners produced with MB for temperate markets.

In the EU (France, Italy, Poland, Spain), growers are using improved application techniques for old fumigants, such as metham sodium and dazomet to grow runner plants (Lopez Aranda, 2012) in preference to moving to substrate production. In these countries, national permits can be granted for emergency use of 1,3-D/Pic use annually, however the industries are uncertain of the future use of many alternatives (Lopez- Aranda, 2012).

In some countries where MB has been phased-out, there have been market shifts where growers may produce their own plants (e.g.Japan) or where industries import runners produced in other countries (e.g., Moroccan growers import runner plants from Spain and substrate plants from France). In Turkey, the industry presently uses solarisation and metham sodium treatment.

5.6. Key chemical and non-chemical strategies adopted in several key MB user countries that have now completely phased out

As part of this assessment report, a number of countries were contacted to provide an estimate of the main chemical and non chemical alternatives that had been adopted as of 2014 in the major sectors which had previously used methyl bromide. Responses were received from technical experts in France, Italy and Japan.

Additionally several published reports have reviewed the adoption and/or effectiveness of alternatives in regions where methyl bromide has been completely phased out, such as SE USA (Noling, 2014; Vallad *et al*, 2014) and Spain (Lopez Aranda, 2012; Lopez Aranda *et al*, 2009a,b).

TABLE 5-1. CHEMICAL AND NON-CHEMICAL ALTERNATIVES[A] ADOPTED AND USED IN 2014 TO COMPLETELY REPLACE PREPLANT SOIL USE OF MB IN FRANCE

Sector	MB used in past (t)	Alternatives[a] used in 2014 and adopted to completely replace preplant soil use of MB in France	
		Chemical	Non-chemica
Carrots	10	Dazomet (100%)	
Cucumber	60	1,3-D and dazomet	Grafting, soil less
Cut-flowers	75	Metham/dazomet alone or combined with solarisation	Soil less. soil solarisation
Forest tree nursery	10	Metham/dazomet (100%)	
Melon	10	1,3 D and metham sodium	Grafting - rotation
Orchard replant	25	Metham sodium (80%) Dazomet (20%)	rotation
Pepper	27.5	Metham sodium (70%) Dazomet (30%)	Rotation -green manure
Strawberry fruit	90	Metham 80 %, Dazomet 20 %	Soil less systems
Strawberry runners	40	Metham sodium 90 % Dazomet 10 %	
Tomato	135	Metham (50%), 1,3 D (30%), dazomet (20%)	Grafting, soil less
Eggplant	27.5	Metham sodium and dazomet	Grafting , crop rotations

[A]Proportions shown refer to the breakdown for the chemical fumigants only

TABLE 5-2. CHEMICAL AND NON-CHEMICAL ALTERNATIVES[A] ADOPTED AND USED IN 2014 TO COMPLETELY REPLACE PREPLANT SOIL USE OF MB IN ITALY.

Sector	Maximum MB amount requested for CUNs	Alternatives[a] used in 2014 and adopted to completely replace prepplant soil use of MB in Italy	
		Chemical	Non-chemical
Tomato protected	1300	1,3-D/Pic . 1,3 D + Rootstocks, 1,3-D and Metham 35%, Metham or dazomet 25%	Resistant rootstocks 35% Soilless 5%
Cut flowers (protected)	250	1,3-D/Pic 30%; Metham/solarisation 20%	Soilless 50%
Eggplant (protected)	280	Non fumigant nematicides + Rootstocks 30%	Rootstocks 65%, Soilless 5 %
Eggplant (protected - other)	280	Non fumigant nematicides + Rootstocks 30% Metham 35 %	Rootstocks 20% Soilless 5%
Watermelon (protected)	180	Non fumigant nematicides + Rootstocks 20%	Rootstocks 80 %
Pepper (protected)	220	Metham 40% Dazomet 5% Rotation with fumigated crops 35%	Rootstocks 5% Solarisation 10% Soilless 5 %
Strawberry Fruit (Protected)	510	1,3-D/Pic 50% Pic 10% Dazomet 20%	Solarisation 10%
Strawberry Runners	100	Metham 20%, 1,3-D/Pic 75%, Dazomet 5%	

[A]Proportions shown refer to the breakdown for the chemical and non-chemical treatments

TABLE 5-3. RESTRICTIONS ON THE USE OF CHEMICAL FUMIGANT ALTERNATIVES IN ITALY. SIMILAR RESTRICTIONS ARE PRESENT IN OTHER MEMBER STATES OF THE EU

Chemical alternative	Restrictions on Use
Chloropicrin	Since June 2013 chloropicrin is only allowed under an emergency use (120 days) only for tomato, strawberry, ranunculus and anemone
1,3-D	Is admitted only for emergency uses (120 days) only for carrot, strawberry, melon and tobacco
Dazomet	Registered but legally only allowed once every 3 years in the same field
Metham Sodium	Registered for essential uses (that do no include strawberry) until 31/12/2014. After 01/01/2015 it will be admitted in open field at a reduced rate only with plastic.

TABLE 5-4. CHEMICAL AND NON-CHEMICAL ALTERNATIVES[A] ADOPTED AND USED IN 2014 TO COMPLETELY REPLACE PREPLANT SOIL USE OF MB IN JAPAN FOR THE CRITICAL USES. IN THE PAST, JAPAN WAS ONE OF THE LARGEST USERS OF MB FOR SOIL FUMIGATION. TE SECTORS ABOVE WERE DIFFICULT SETORS WITH UNIQUE ISSUES GLOBALLY.

Sector	MB requested for CUNs in 2005(t)	Alternatives used in 2014 and adopted to completely replace preplant soil use of MB in Japan		Main Target disease
		Chemical	Non Chemical	
Cucumber	88.3		1. Roots removed from growing in soil composting root debris, cattle manure and soil aeration 2. Bio-degradable pots to prevent root contact with virus in soil. 3. Removal of diseased plants	Kyuri green mottle mosaic virus; KGMMV
Ginger – field	119.4	1) 1,3 D/Pic, Pic alone, dazomet and dazomet & Pic. 2) Pesticide mixtures on rhizomes incl. azoxystrobin and metalaxyl M, cyazofamid, propamocarb hydrochloride liquid 3) Herbicides for weeds. eg. trifluralin, sethoxydim and glufosinate-ammonium	1. Disease free rhizomes 2. Infected plant debris humified by irrigation and cultivation. plowing 3. Hand weeding for weeds	Pythium zingiberis (Root rot disease)
Ginger – protected	22.900	2) and 3) above.	1. Disease free rhizomes 2. Solarisation (3 wks) treatment by double mulching on the soil surface and on the tunnel	Pythium zingiberis (Root rot disease)
Melon	194.100	1,3-D/Pic to control Monosporascus cannonbollus and nematodes	1. Biocontrol with attenuated virus vaccine of SH33b to control CGMMV 2. Biocontrol with resistant strain from respective production region to control MNSV	M.cannonbonematodes, Green Mottle Mosaic Virus (CGMMV), Necrotic Spotted Virus (MNSV)

Sector	MB requested for CUNs	Alternatives used in 2014 and adopted to completely replace preplant soil use of MB in Japan		Main Target disease
Peppers (green and hot)	189.9		1. Biodegradable pots and soilless media to avoid soil contact and plant damage. 2.ELISA used to predict soil population levels. 3.Attenuated virus vaccine of AVP08 to control virus disease.	Pepper Mild Mottle Virus (PMMoV)
Watermelon	126.3		1. Biodegradable pots and soilless media to avoid soil contact and plant damage 2. Soilless bags 3. Paper pots 5. Crop rotation	Cucumber Green Mottle Mosaic Virus (CGMMV)
Fumigants generally registered for crops above		Chloropicrin, dazomet, 1,3-dichloropropen, mixture of chloropicrin and 1,3-dichloropropene, mixture of 1,3-dichloropropene and methyl isothiocyanate, carbam sodium.		

5.7. Remaining and emerging Challenges

5.7.1 Non-Article 5 Parties

The key alternatives, Pic, 1,3-D and MI are subject to regulations affecting their uptake for the remaining uses of MB. In some countries,Pic is still not registered while registration of MI is generally no longerpursued.

Methods that avoid the need for fumigation (e.g. substrates, grafting, resistant varieties, solarisation, ASD) continue to expand worldwide and these technically feasible technologies become more cost effective every year. Continuous review of the economics of these technologies is required to support evaluation of critical use nominations.

Nursery uses are the most significant remaining use for MB worldwide and more studies are required to characterize the risks imposed by the use of alternatives in these industries.

MB continues to be classified differently for nursery applications by several Parties despite the target pests and crops being similar in several countries. Canada supplied a useful summary of their interpretation of this use (Canada CUN, 2012, p.19). There is an emergence of new or re-emergence of previously controlled pathogens in fields that have used MB alternatives for a few years. Examples include *Macrophomina* and *Fusarium* on strawberry.

5.7.2. Article 5 Parties

Developing countries have moved towards achieving the final phase-out of MB by 1st January 2015 as set by the Montreal Protocol. In many A5 countries, this phase out was achieved before the deadline, mainly with support from MLF-funded investment projects and in some cases through projects funded directly by A5 and non-A5 Parties through bilateral cooperation, and/or agricultural producers. The projects identified many economically and technically feasible alternatives, both non-chemical and chemical, which are as efficient as MB. Combinations of alternatives were generally encouraged as a sustainable, long-term approach for replacing MB. This has often implied that growers and other users change their approach to crop production or pest control including investments and training (which the projects normally support). Early phase-out of MB has proven beneficial to A5 parties in many instances, by improving production practices, increasing the competitiveness of certain agricultural products in international markets and training large numbers of growers, technical staff and other key stakeholders.

Some challenges persist, for example controlling bacterial diseases and nematodes affecting ginger in China, as well as complete adoption of alternatives for strawberry and raspberry runners in Mexico and possibly other countries.

Further analysis on challenges encountered by A5 Parties to complete and sustain MB phase-out is found in Chapter 7 of this report.

5.8 References

Abou Zeid, N.M. and Noher, A.M. (2014). Efficacy of DMDS as methyl bromide alternative in controlling soil borne diseases, root-knot nematode and weeds on pepper, cucumber and tomato in Egypt. Acta Hort. (ISHS) 1044:411-414

Ajwa H. A., Klose S., Nelson S. D., Minuto A., Gullino M. L., Lamberti F., Lopez Aranda J. M. (2003). Alternatives to methyl bromide in strawberry production in the United States of America and the Mediterranean region.Phytopathol.Mediterr. 42, 220-244.

Ajwa H.A, and Mona O. (2013**).** Allyl Isothiocyanate and Dimethyl Disulfide for Strawberry Production, Procceedings of the annual international research conference on methyl bromide alternatives and emission reduction. San Diego, California, Nov 4-6, 3

Ajwa H.A, Trout, T, Mueller, J, Wilhelm, S, Nelson, S.D., Soppe, R., Shatley, D.(2002). Application of alternative fumigants through drip irrigation systems .*Phytopathology*, 92, 1349-1355.

Ajwa H.A., Trout T. (2004). Drip application of alternative fumigants to Methyl Bromide for strawberry production. HortScience 39, 1707-1715.

AKIB 2013. Sektörel Bazında Aralık 2013 İhracat Verileri. http://www.akib.org.tr/tr/ihracat-ihracat-istatistikleri.html

Allan M. and Leon C. (2013). IRF135, allyl isothiocyanate (AITC) regulatory and development update. In: 2013 Annual International Research Conference On Methyl Bromide Alternatives And Emissions Reductions, San Diego.

Alpizar Y.A., Boonen B., Gees M., Sanchez A., Nilius B., Voets T., Talavera, K. (2014). Allyl isothiocyanate sensitizes TRPV1 to heat stimulation. Pflugers Archiv-European Journal of Physiology,466, 507-515.

Amin AW, Mona A.W. (2014) .Protecting cucumber from *Meloidogyne incognita* using graft onto resistant cucurbit rootstocks and antagonistic marigold as an alternative to nematicide. *Pakistan Journal of Nematology* 32(1), 51-58.

Anonymous, (2009). Australia Ginger Growers Association Inc. The Australia ginger industry, overview of market trends and opportunities. The State of Queensland, Department of Employment, Economic Development and Innovation

Antoniou, P.P., Tjamos E.C. and Giannakou J.O. (2014). low-cost and effective approaches of soil disinfestation of plastic house or open field crops in Greece. Acta Hort. (ISHS) 1044:29-41

Argento, S. Raccuia, S. A. Melilli, M. G. Toscano, V. Branca, F. (2013). Brassicas and their glucosinolate content for the biological control of root-knot nematodes in protected cultivation. Acta Horticulturae; 2013. 1005:539-544.

Arias E. (2013). Eliminación total de bromuro de metilo en Honduras. Presentación durante la Reunión de la Red Latinoamericana de Oficiales de Ozono, Kingston, Jamaica, Octubre 2013.

Arnault I., Fleurance C., Vey F., Du Fretay G., and Auger J., (2013).Use of Alliaceae residues to control soil-borne pathogens. In: Industrial Crops and Products, 49, 265-272.

Ashworth D, Van Wesenbeeck I., Stanghellini M, (2013).Effect of Co-formulation of 1,3-D and Chloropicrin on Emission from Soil. Annual international research conference on methyl bromide alternatives and emissions reductions, Nov 4-6, 2013, San Diego, California

Avato P., D'Addabbo T., Leonetti P., Argentieri M.P. (2013). Nematicidal potential of Brassicaceae. Phytochemistry Reviews 12, 791-802.

Avilés M., Castillo S., Bascon J., Zea-Bonilla T., Martín-Sánchez P.M., Pérez-Jiménez R.M. (2008) First report of *Macrophomina phaseolina* causing crown and root rot of strawberry in Spain. Plant Pathology 57, 382.

Avilés M., Castillo S., Borrero C., Castillo M.L., Zea-Bonilla T., Pérez-Jiménez R.M. (2009).Response of strawberry cultivars: 'Camarosa', 'Candonga' and 'Ventana' to inoculation with isolates of *Macrophomina phaseolina*. ActaHorticulturae, 842, 291-294.

Babalola O.O. (2010). Beneficial bacteria of agricultural importance. In: Biotechnology letters, 32 (11), 1559-1570.

Ban S G, Katja-Žanić K, Dumičić G, Raspudić E, Selak G V, Ban D. (2014). Growth and yield of grafted cucumbers in soil infested with root-knot nematodes. *Chiılean Journal Of Agricultural Research* 74(1), 29-34.

Bangarwa S.K., Norsworthy J.K., Gbur E.E. (2012). Allyl Isothiocyanate as a methyl bromide alternative for weed management in polyethylene-mulched tomato. Weed Technology26, 449-454.

Bangarwa, S. K.Norsworthy, J. K.Mattice, J. D. Gbur, E. E. (2011). Yellow nutsedge interference in polyethylene-mulched bell pepper as influenced by turnip soil amendment.*Weed Technology*. 25: 3, 466-472.

Barres M.T., Bello A, Jordá C, Tello J.C., (2006). La Eliminación del Bromuro de Metilo en la Protección de Cultivos como Modelo Mundial para la Conservación del Medio Ambiente. MAPA, Madrid, 515 pp.

Barros A. F., Campos V. P., da Silva J.C.., Pedroso M. P., Medeiros F.H.., Pozza E.A., and Reale A.L., (2014). Nematicidal activity of volatile organic compounds emitted by Brassica juncea, Azadirachta indica, Canavalia ensiformis, Mucuna pruriens and Cajanus cajan against Meloidogyne incognita. In: Applied Soil Ecology, 80, 34-43.

BATEM, 2008. Phasing out methyl bromide in Turkey / Final report156 pp

Behal V. (2000).Bioactive products from *Streptomyces.* Adv. Appl. Microbiol. 47:113-156.

Bello A, Díez Rojo MA, López Pérez JA, Castro I, Gallego A. (2011). Biodesinfección de Suelos. Sociedad Española de Agricultura Ecológica (SEAE), Ministerio de Medio Ambiente, Medio Rural y Marino, Madrid.(http://vimeo.com/18675250)

Bello A, Díez Rojo MA, López Pérez JA. (2013). Biodesinfección de suelos, investigación participativa y desarrollo rural. Cambio climático, destrucción de la capa de ozono. XXI Jornadas Técnicas Estatales SEAE. Desarrollo Rural, Innovación Agroecológica y Agricultura Ecológica en la PAC. Alcalá de Henares, Madrid, 26-27 septiembre, 15 pp.

Bello A, González JC. (2012). Agroecología y Complementariedad Agraria. 250 pp. http://www.agroecologia.net/recursos/publicaciones/publicaciones-online/2012/libro-agroecologia-bello/libro-agroecologia-bello-sec.pdf

Bello A, Jordá C, Tello JC.(2010). Agroecología y Producción Ecológica**.** CSIC, Catarata, 77 pp.

Bello A, Porter I, Díez Rojo MA, Rodríguez Kabana R. (2008).Soil biodisinfection for the management of soil-borne pathogens and weeds.*3rd Int. Biofumigation Symposium*, 21 – 25 Jul., CSIRO Discovery Centre, Canberra, 35 p.

Belova A., Narayan T Olkin I.,,(2013) .Methyl bromide alternatives for strawberry and tomato pre-plant uses: A meta-analysis. *Crop Protection*, *54*, ,*1-14*

Besri M. (2008). Cucurbits grafting as alternative to methyl bromide for cucurbits production in Morocco. Proceedings MBAO Conference, Orlando (FL). 60,1-5pp.

Bettiol, W., Forner, C. and Mattos, L.P.V. (2014). Development of suppressiveness to *Fusarium oxysporum* in container media and soil amended with fish emulsion and fish hydrolyzed. Acta Hort. (ISHS) 1044:133-138

Bettiol, W., Rivera, M.C., Mondino, P., Montealegre, J.R., Colmenárez, Y.C. (2014).Control biológico de enfermidades de plantas en America Latina y el Caribe. Facultá de Agronomia, Montevideo. Uruguay. 404 p. http://portal.fagro.edu.uy/index.php/intensific-agr/file/367-control-biologico-de-enfermedades-de-plantas-en-america-latina-y-el-caribe.html

Bogoescu M., Doltu M., Sora D., Tanasa N. (2010). Greenhouse grafting cucumber crop - Methyl bromide alternative in Romania.*Acta Horticulturae*, 883, 129-134.

Bogoescu M., Doltu M., Lordache B., Vintila M., Sora D., Mohora A.(2011). The grafting tomatoes crop an alternative for vegetable growers. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca*.Horticulture 68, 215-221.

Bogoescu, M., Doltu, M. and Sora, D. (2014).Prevention and control of soilborne diseases and nematodes in eggplants crop by grafting plants combined with soil fumigation. Acta Hort. (ISHS) 1044:331-336

Bonanomi G., Antignani V., Capodilupo M., Scala F. (2010). Identifying the characteristics of organic soil amendments that suppress soilborne plant diseases. *Soil Biology and Biochemistry*, 42, 136-144.

Browne G., Holz B., Upadhyaya S., Lampinen B., Doll D., Schmidt L., Edstrom J., Shafii M., Hanson B., Wang B., Gao S., Klonsky K. (2009).Integrated pre-plant alternatives to methyl bromide for almonds and other stone fruits.Annual International Conference on Methyl Bromide Alternatives and Emission Reductions,Orlando, Florida USA.

Browne G.T., Connell J.H., Schneider S.M. (2006). Almond replant disease and its management with alternative pre-plant soil fumigation treatments and rootstocks. Plant Disease, 90 (7), pp. 869-876.

Bull D. L, Ivie G W., MacConnell J. G, Gruber V. F, Ku Chia C., Arison B. H, Stevenson J. M, Vanden H. William J.A (1984) Fate of avermectin B1a in soil and plants. Journal of Agricultural and Food Chemistry 32. (1):94-102.

Butler D, Kokalis-Burelle N. Muramoto J., Shennan C., McCollum T. Rosskoph E. (2012a) .Impact of anaerobic soil disinfestation combined with soil solarisation on plant-parasitic nematodes and introduced inoculum of soilborne plant pathogens in raised-bed vegetable production. Crop Protect. 39, 33-40

Butler D., Inwood E., McCarty G., Sams C..Wszelaki A., Dee M., Ownley B., Kokalis-Burelle N. Rosskopf E. (2012b). Optimizing anaerobic soil disinfestation for Tennessee.Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions, Maitland, Florida USA.

Butler, D.M., Rosskopf, E.N., Kokalis-Burelle,N., Albano, J.P., Muramoto, J., and Shennan, C. (2012c) .Exploring warm-season cover crops as carbon sources for anaerobic soil disinfestation (ASD). Plant and Soil ,355,149-165.

Butler D. M., Kokalis-Burelle N., Albano J. P., McCollum T. G., Muramoto J., Shennan, C., Rosskopf E. N. (2014). Anaerobic soil disinfestation (ASD) combined with soil solarisation as a methyl bromide alternative: Vegetable crop performance and soil nutrient dynamics. *Plant and Soil*, 378, 365-381.

Canada Critical Use Nomination (2012). CDN01 CUN14. Soils Strawberry Runners PEI. Quarantine and Pre-shipment: Page 19

Çandır E.,Yetişir H., Karaca F., Üstün F. (2013). Phytochemical characteristics of grafted watermelon on different bottle gourds (*Lagenariasiceraria*) collected from the Mediterranean region of Turkey. *Turkish J Agriculture and Forestry* 37, 443-456

Candole B.L., Csinos A.S., Wang Q. (2007). Concentrations in soil and efficacy of drip-applied 1,3-D+chloropicrin and metham sodium in plastic-mulched sandy soil beds Crop Protection 26,1801–1809

Cao A. (1999) The new alternative of methyl bromide--avermectin. In: Research Progress in Plant Protection and Plant Nutrition China Agriculture Press, pp 327-328.

Cao A., Guo M., Yan D., Mao L., Wang Q., Li Y., Wang P. (2014). Evaluation of sulfuryl fluoride as a soil fumigant in China. Pest Management Science 70, 219-227.

Cao Y. (1994) Control of cucumber root knot nematode by using avermectin 1.8EC (in Chinese).Chinese Agricultural Science Bulletin 10:16-18.

Carabedian H., Gundy S.D. (1983) Use of avermectin for the control of *Meloidogyne incognita* on tomatoes. Journal of Nematology 15 (4):503-510.

Castellá-Lorenzo, G., Savigliano, R. and Pizano, M. (2014). Breaking the bondage to methyl bromide in agriculture – UNIDO experience. Acta Hort. (ISHS) 1044:281-287

Castillo García J., Amaya Uribarri G., Astiz M., Sádaba Díaz de Rada S., (2012). Guía de biofumigación y solarización de suelos en invernadero; Revista Navarra Agraria, Spain; Nº 190, 2012, págs. 21-22

Castro Lizazo I, Díez Rojo MA, López Pérez JA, Díaz Viruliche L, Bello A.(2011). Biodesinfección de Suelos en Producción Ecológica.Dossier SEAE. Valencia. 56 pp. http://www.agroecologia.net/recursos/publicaciones/dossiers/dossier-biodesinfeccion.pdf

CDFA (2009).California Department of Food and Agriculture.http://www.cdfa.ca.gov/phpps/PE/Nursery/pdfs/NIPM_7.pdf

Cerruti R., Koon-Hui W., Ploeg A.,McSorley R. (2010) .Using marigold (*Tagetes* spp.) as a cover crop to protect crops from plant-parasitic nematodes. *Applied Soil Ecology*, *Volume 46, Issue 3*, *307-320*

Chałańska, A., Ślusarski, C., Uliński, Z., Meszka , B., Sobiczewski, P., Malusá , E. and Ciesielska, J. (2014). The effectiveness of grafting and soil fumigation on the performance of greenhouse tomatoes. Acta Hort. (ISHS) 1044:263-268

Chamorro, M., Domínguez, P., Medina, J.J., Miranda, L., Soria, C., Romero, F., López Aranda, J.M., Guzman, C. and De los Santos, B. (2014). Chemical and non-chemical soil fumigation treatments for strawberry in huelva (spain). Acta Hort. (ISHS) 1044:275-279

Chandrasekar S.K., Donahoo R D., Hassell, R. (2012).Resistance in watermelon rootstocks to crown rot caused by*Phytophthora capsici. Crop Protection*39, 18–25

Chávez-Mendoza C., Sánchez E., Carvajal-Millán E., Muñoz-Márquez E.,Guevara-Aguilar A. (2013). Characterization of the nutraceutical quality and antioxidant activity in bell pepper in response to grafting.*Molecules*, 18, 15689-15703

Chellemi, D.O., Noling, J.W. and Sambhav, S. (2014). Organic amendments and pathogen control: Phytopathological and agronomic aspects. Acta Hort. (ISHS) 1044, 95-103

Chow E. (2009). An update on the development of TIF mulching films.Proc. 2009 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions.San Diego, Oct 29-Nov 1.

Christos I. R,, Ebrahim M. K., Naved S. (2011). Response of local and commercial tomato cultivars and rootstocks to *Meloidogynejavanica*infestation *Ausralian Journal of Crop Science* 5(11),1388-1395

Chtaina N., (2008a). Phase out of methyl bromide in the cut flower and banana production. UNIDO project TF/MOR/00/001 contract (ONUDI/ Institute of Agronomy and Veterinary medicine**,** Rabat Morocco) N° 2002/089. Final report, December 2008, 64 pp

Chtaina N., (2008b). Phase out of methyl bromide in soil fumigation in strawberry production. UNIDO project MP/MOR/00/164 contract (ONUDI/ Institute of Agronomy and Veterinary medicine**,** Rabat Morocco) N° 2001/261. Final report, 2008., 80pp

Chtaina N., 2005. Les fumigants nematicides à base du 1,3 dichloropropène, comme alternative au bromure de méthyle sur bananier. Pack info N° 24: 19-20

Chtaina N., Besri M., (2006). Case Study 26.: Morocco-Phase out of methyl bromide in the strawberry, banana and cut flower in Morocco. 2006 assessment report of the methyl bromide technical option committee (MBTOC) .UNEP, 424-427, 453 pp.

Cohen R., Omari N., Porat A., Edelstein M., (2012). Management of *Macrophomina* wilt in melons using grafting or fungicide soil application: Pathological, horticultural and economical aspects .*Crop Protection*, *35*, *58-63*

Colla G., Rouphael Y., Rea E. (2012a). Grafting cucumber plants enhance tolerance to sodium chloride and sulfate salinization. *Scientia Horticulturae* 135, 177–185.

Colla P., Gilardi G., Gullino M. L. (2012b). A review and critical analysis of the European situation of soilborne disease management in the vegetable sector.*Phytoparasitica* 40, 515-523.

Colla, P., Garibaldi A. and Gullino M.L. (2014).consequences of European pesticide policies enforcement in soil disinfestation sector . Acta Hort. (ISHS) 1044:363-366

Culpepper S., Sosnoskie L., Rucker K., Tankersley B., Langston D. (2008). DMDS or the 3-Way: Which is moreeffective in Georgia? Annual Int. Research Conf. on Methyl Bromide Alternatives and EmissionsReductions, 11-14 Nov, Orlando (Fl), 20-1, 20-5.

Curto G., Dongiovanni C.,Sasanelli N., Santori A. and Myrta A.(2014). Efficacy ofdimethyl disulfide (DMDS)in the control of the root-knot ncmatocle .*Meloidogyne incognita* and the cyst nematode Heterodera carotae on carrot in field conditions in Italy. Acta Hort. 1044:405-410.

DAFNP, (2009). Department of Agriculture and Forestry of Nagasaki Prefecture (2009) Establishment of standard technology on strawberry production.Nagasaki Standard Technology of Agriculture and Forestry.

D'Anna F., Iapichino G., D'Anna E. (2014). Effects of soil solarisation with different plastic films on yield performance of strawberry protected plantations in Sicily. Acta Horticulturae; (1015):53-58.

Daugovish O.,Fennimore S. A. (2011a). Non-Fumigant Alternatives for managing *Macrophomina phaseolina* and *Fusarium oxysporum* in California strawberry.http://ashs.confex.com/ashs/2011/webprogram/Paper7280.html

Daugovish O., Koike S., Gordon T., Ajwa H., Legard D. (2011b). Fumigant and strawberry variety evaluations in *Macrophimina phaseolina* and *Fusarium oxysporum* infested fields. International Research Conference on Methyl Bromide Alternatives and Emissions Reductions. http://mbao.org/2011/Proceedings/10

Daugovish O., Muramoto J,, Shannon C., Bolda M., Koike S. (2011c). Anaerobic soil disinfestation for southern California strawberries. Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions, San Diego, California USA.

De Cal, A., Martínez-Terceno, A., López-Aranda, J.M. and Melgarejo P. (2004). Alternatives to methyl bromide in Spanish strawberry nurseries.*Plant Disease* 88(2): 210-214.

Devkota P., Norsworthy J.K., Rainey R. (2013). Comparison of Allyl Isothiocyanate and Metham Sodium with Methyl Bromide for Weed Control in Polyethylene-Mulched Bell Pepper. Weed Technology, 27, 468-474.

Desager, J. and A. Csinos 2005. Phytoxicity associated with drip applied 1,3-Dichlorpropene and chloropicrin in vegetables produced with plastic mulch. HortScience 40(3) 700-7006

Di Primo P., Gamliel A., Austerweil M., Bracha Steiner B., Peretz I., Katan J. (2003).Accelerated degradation of metham sodium and dazomet in soil: Characterization and consequences for pathogen control. Crop Protection 22:635-646.

Díez Rojo MA, López-Pérez JA, Urbano Terrón P, Bello Pérez A. (2011). *Biodesinfección de Suelos y Manejo Agronómico.* Ministerio de Medio Ambiente, Medio Rural y Marino, Madrid, Spain, 414 pp. (http://www.magrama.gob.es/es/calidad-y-evaluacion-ambiental/publicaciones/libro_de_biodesinfección_tcm7-156245.pdf)

Díez-Rojo, M.A., J. P López-Pérez, P. Urbano Terrón and A. Bello Pérez (2010).Biodesinfección de suelos y manejo agronómico. Ministry of the Environment, Government of Spain, Madrid, 408 pp.

Dong L., Huang C.D., Huang L., Li X.,.Zuo Y.,, (2012). Screening plants resistant against *Meloidogyne incognita* and integrated management of plant resources for nematode control. *Crop Protection*, *33 34-39*

Dwight S. (1999) .Reducing methyl bromide in preplant soil treatment for ginger root. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions.

EC Management Strategy. 2009. European Community Management Strategy for the Phase-out of the Critical Uses of Methyl Bromide, April 2009. Annex 4.C. http://ozone.unep.org/Exemption_Information/Critical_use_nominations_for_methyl_bromide/National_Management_Strategy_for_Phase.shtml

Elgorban A.M., Abdel-Wahab M.A., Bahkali A.H.,Al-sum, B.A. (2014). Biocontrol of *Meloidogyne javanica* on Tomato Plants by *Hypocrealixii* (the Teleomorph of *Trichoderma harzianum*).*CLEAN – Soil, Air, Water*. http://onlinelibrary.wiley.com/doi/10.1002/clen.201300430/abstract

Erin N. Rosskopf E.N. Kubota C.,Adkins S, Kokalis-Burelle N,, and. Hong J.C. (2013). Importance of Rootstock and Scion Tomato Mosaic Virus Resistance for Grafting Heirloom Tomatoes .Annual international research conference on methyl bromide alternatives and emissions reductions, Nov 4-6, 2013, San Diego, California, .87

Evenhuis B., Nijhuis, E., Lamers J., Verhoeven J. and Postma J. (2014).Alternative methods to control *phytophthora cactorum* in strawberry cultivated in soilless growing media. Acta Hort. (ISHS) 1044:337-342

Fang X., Phillips D., Verheyen G., Li H., Sivasithamparam K., Barbetti M.J. (2012). Yields and resistance of strawberry cultivars to crown and root diseases in the field, and cultivar responses to pathogens under controlled environment conditions.*Phytopathologia Mediterranea*.51(1), 69-84

Fang X.L, Phillips D., Li H., Sivasithamparam K., Barbetti M.J. (2011a). Comparisons of virulence of pathogens associated with crown and root diseases of strawberry in Western Australia with special reference to the effect of temperature ScientiaHorticulturae 131, 39-48.

Fang X.L., Phillips D., Li H., Sivasithamparam K., Barbetti M.J. (2011b). Severity of crown and root diseases of strawberry and associated fungal and oomycete pathogens in Western Australia.Australasian Plant Pathology 40, 109-119.

Fennimore S.A., Serohijos R., Samtani J.B., Ajwa H.A., Subbarao K.V., Martin F.N., Daugovish O., Legard D., Browne G.T., Muramoto J., Shennan C., Klonsky K. (2013a). TIF film, substrates and nonfumigant soil disinfestation maintain fruit yields. California Agriculture 67, 139-146.

Fennimore S., Miller T. , Goodhue R., Dorn N., Broome J.,Muramoto J., Shennan C.and Martin F.(2013b). Evaluation of an automatic steam applicator in strawberry: 2012-13 resultsAnnual international research conference on methyl bromide alternatives and emissions reductions, Nov 4-6, 2013, San Diego, California 11

Fennimore S., Samtani J., Subbarao K., (2011).Soil disinfestation in strawberry with steam. Proceeding of Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 46-1 – 46-3.

Fery R.L., Thies J.A. (2011a). Truhart-NR-, A root-knot nematode resistant, pimento-type pepper. .*HortScience*. 46(5), 815-816.

Fery R.L., Thies J.A. (2011b). PA-560, A Southern Root-knot Nematode Resistant, Yellow-fruited, Habanero-type Pepper. *HortScience*. 46(6), 946-947.

Foster J.M., Naegele R.P., (2013). Evaluation of Eggplant Rootstocks and Pepper Varieties for Potential Resistance to Isolates of *Phytophthora capsici* from Michigan and New York. Crop protection, 97, 8, 1037-1041

Fouillet T., Rebizak R., Descamps S., Ciesla Y., and Guery B.(2014).Development of a New Gastight Film Containing EVOH. In VIII International Symposium on Chemical and Non-Chemical Soil and Substrate Disinfestation 1044 (pp. 301-305).

Fritsch J., Fouillet T., Charles P., Fargier-Puech P., Ramponi-Bur C., Descamps S., Du Fretay G.,and Myrta A. (2014). French experiences with dimethyldisulfide (DMDS) as nematicide in vegetable crops. Acta Hort. 1044:427-433

Fujinaga M., Kobayashi H,, Komatsu K., Ogiso H., Uehara T., Ono Y., Tomita Y., Ogawara T. (2005). Control of fusarium yellows on celery by soil sterilization with hot water injection using a portable boiler *Annual Report of the Kanto Tosan Plant Protection Society.*No.52. 2005 Page 25-29.

Gamliel A., Triky S., Austerweil M., Peretz-Alon Y., Ucko, O. (2005). Combined soil fumigants: synergistic performance and improved yield. Acta Horticulturae 698, 135-140.

Gamliel A., Stapleton, J. J. (2012). Combining soil solarisation with organic amendments. Pages 109-120. In: Soil Solarisation-Theory and Practice (eds. Gamliel A. and Katan J) APS press, St. Paul MN USA.

Gamliel, A. 2014.application of soil disinfestation in the view of system approach: a bottleneck or a tool for improvement?. Acta Hort. (ISHS) 1044:245-2514.5 Crops specific strategies.

Gamliel A.,& Katan J. (Eds.). (2012). Soil solarisation theory and practice. St. Paul, MN, USA: APS Press, 266 pp.

García Ruíz A, Tello J.C, Avilés Guerrero M, Ordovás Ascaso J. (2009). *Fusariosis del Clavel. Fusarium oxysporum* f.sp. *dianthi. Últimos Avances en su Control*. Edit. Agrotécnicas, 275 pp.

García-Méndez E., García-Sinovas D., Becerril M., De Cal A., Melgarejo P., Martínez-Treceño A., FennimoreS. A., Soria C., Medina J.J.,López-Aranda J.M. (2009). Chemical alternatives to methyl bromide for weed control and runner plant production in strawberry nurseries. HortScience 43, 177-182.

Gay P.,Piccarolo P.,Ricauda A.D.,Tortia C., (2010).A high efficiency steam soil disinfestation system, part I:Physical background and steam supply optimization. Biosystems Engineering107, 74-85.

Gelsomino A., Petrovicová B., Zaffina F., Peruzzi A., (2010). Chemical and microbial properties in a greenhouse loamy soil after steam disinfestation alone or combined with CaO addition. Soil Biology and Biochemistry 42, 1091-1100.

Ghini R. (2014).Climate change and increasing challenges for effective soil disinfestation. Acta Horticulturae 1044: 447-454.

Ghini R.; Patrício F.R.A., Almeida I.M.G. (2007) Control of *Ralstonia solanacearum* in tomato potting medium by the use of a solar collector. Australasian Plant Disease Notes 2, 77-78.

Gilardi G., Demarchi S., Martano G., Gullino M.L. and Garibaldi A. (2014a).Success and failures of grafting pepper against soil-borne pathogens. Acta Hort. (ISHS) 1044:67-71

Gilardi G., Gullino M.L.,Garibaldi A., Ricauda Aimonino D. and Luongo I. (2014b). Different steaming methods to control Fusarium wilt agents under simulated conditions. Acta Hort. (ISHS) 1044:237-242

Gilardi, G., Demarchi, S., Moizio, M., Gullino, M.L. and Garibaldi, A. (2014c). Disease management strategies against fusarium wilt of basil and rocket by combining amendments and soil solarisation. Acta Hort. (ISHS) 1044:319-324

Gilardi, G., Pugliese, M., Colla, P., Gullino, M.L. and Garibaldi, A. (2014d). Management of *Phytophthora capsici* on bell pepper and C*olletotrichum coccodes* on tomato by using grafting and organicamendments . Acta Hort. (ISHS) 1044:257-262

Gilardi G., M. Baudino, M. Moizio, M. Pugliese, A. Garibaldi, M.L. Gullino, (2013a).Integrated management of *Phytophthora capsici* on bell pepper by combining grafting and compost treatment.*Crop Protection*, *53*, *13-19*

Gilardi G., Gullino M. L.,Garibaldi A. (2013b). Critical aspects of grafting as a possible strategy to manage soil-borne pathogens.*Scientia Horticulturae*149,19-21.

Gisbert C., Prohens J., Nuez F. (2011a).Performance of eggplant grafted onto cultivated, wild, and hybrid materials of eggplant and tomato. *International Journal of Plant Production* 5(4), 367-380.

Gisbert C., Prohens J., Raigón M.D., Stommel J.R., Nuez F. (2011b). Eggplant relatives as sources of variation for developing new rootstocks: Effects of grafting on eggplant yield and fruit apparent quality and composition.*Scientia Horticulturae* 128, 14–22.

Gong B., Bloszies S., Li X., Wei M., Yang F. J., Shi Q. H. and Wang X.F., (2013). Efficacy of garlic straw application against root-knot nematodes on tomato. In: Scientia Horticulturae, 161, 49-57.

González J.C., González Ruiz J, Domínguez M, Afonso R, Domínguez E, Domínguez K, Hernández M, López Cepero J, Piedra Buena A, López Pérez JA, Arias Mª, Tello JC, Bello A. (2013). Diversidad y complementaridad en la gestión agroecológica. *XXI Jornadas Técnicas Estatales SEAE: Desarrollo Rural, Innovación Agroecológica y Agricultura Ecológica en la PAC.* Alcalá de Henares, Madrid, 26-27 septiembre, 39 pp. https://docs.google.com/file/d/0B-jLDCjL-kpxWFQ5NDVuNzRmbDg/edit.

González Ruiz J, Domínguez M, Afonso R, Domínguez E, Domínguez K, Hernández M, González JC, Ballester J, Gallego A, López Cepero J, Piedra Buena A, López Pérez JA, Torres Nieto JM, García Ruiz A, Arias M, Lacasa A, Tello JC, Gonzálvez V, Bello A. (2014). Agricultura familiar, investigación agroecológica participativa y formación. *Simposium Agricultura Familiar Agroecológica*, SEAE. Lugo, 18 - 20 Junio, 15 pp.

Gordon T.R., Koike S.T., Daugovish O., Shaw D.V., Larson K.D. (2011). A Comprehensive Approach to Management of Wild Diseases Caused by *Fusarium oxysporum* and *Verticillium dahliae*. California Strawberry Commission Annual Production Research Report, 2010-2011.

GTHB, (2014). The Ministry of Food, Agriculture and Livestock, The General Directorate of Crops Porduction, Annual Statistical Report, November, 2014.http://www.tarim.gov.tr/sgb/Belgeler/SagMenuVeriler/BUGEM.pdf

Guan W., Zhao, X., Hassell, R. Thies, J. (2012). Defense mechanisms involved in disease resistance of grafted vegetables. *HortScience* ,. 47, 2 164-170

Guerrero –Diaz M. M., Ros C., Lacasa C. M., Martinez V., Lacasa A., Fernandez P., Martinez M. A., Nunez-Zofio M., Larregla S., Diez-Rojo M. A., Bello A. (2010). Effect of biosolarisation using pellets of *Brassica carinata* on soil-borne pathogens in protected pepper crops. *Acta Horticulturae* 883, 337-344.

Guerrero-Díaz M.M., Lacasa-Martinez C.M., Hernández A., Martínez V., Martínez M.C., Fernández-Molina, P. and Lacasa A. (2014). Biosolarisation with agro-industrial by product for the control of soilborne pathogens in protected pepper crops in southeast spain. Acta Hort. (ISHS) 1044:157-161

Gullino M.L., Minuto A., Gilardi G., Garibaldi A., Ajwa H., Duafala T. (2002). Efficacy of preplant soil fumigation with chloropicrin for tomato production in Italy. Crop Protection 21: 741-749

Gyoutoku Y., Eguchi T., Moriyama M.,KashioT.,Yokoyama T. (2007). Integrated pest management on autumn-winter muskmelon by using physical and biological control agents. *Research Bulletin of the Kumamoto Prefectural Agricultural Research Center* ,.14,111 -127

Hansen, Z. R. Keinath, A. P. ,(2013). Increased pepper yields following incorporation of biofumigation cover crops and the effects on soilborne pathogen populations and pepper diseases. Applied Soil Ecology;.63:67-77.

Hanson, B.D., Gerik J.S , and Schneider S.M . (2010). Effects of reduced-rate methyl bromide applications under conventional and virtually impermeable plastic film in perennial crop field nurseries. *Pest Management Science*: 66:892-899.

Heller J.J., Korkmaz E.,and Charles P.,(2010). Evaluation of the efficacy of DMDS using drip application for the control of root-knot nematodes (*Meloidogyne* spp.) in Turkey.Acta Hort. 883: 171-174.

Heller J.J., Sunder P., Charles P., Pommier J.J., Fritsch, J. (2009).Dimethyl disulfide, a new alternative to existing fumigants on strawberries in France and Italy. Acta Horticulturae, 842, 953-956.

Hepperly P;, Zee F, Kai R., Arakawa C., Meisner M., Bernard ,Kratky M., ,Hamamoto K., and Sato D.., (2004). Producing Bacterial Wilt–Free Ginger in Greenhouse Culture. Soil and Crop Management. SCM-8 , June 2004.

Hermosa R., Rubio M.B., Cardoza R.E., Nicolás C., Monte E., and Gutiérrez S., (2013). The contribution of *Trichoderma* to balancing the costs of plant growth and defense. In: International Microbiology, 16(2), 69-80.

Hong J., Rosskoph E., Martin K., Kokalis-Burelle N. Butler D. (2012).Insight onto anaerobic soil disinfestation through the lens of molecular biology. Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions, Maitland, Florida USA.

Huang Y., Li J., Hua B., Liu Z., Fan M., Bie Z. (2013). Grafting onto different rootstocks as a means to improve watermelon tolerance to low potassium stress.*ScientiaHorticulturae,* 149, 86–96

Jari S., Michael M., Archana P., Ted R., Steve F., Susan M. (2011). Evaluations of tomato yellow leaf curl virus resistant varieties for commercial production. *The Food Provider.*June- July-August 2011, pp.1-6.

Jayesh B. S., A. Ajwa H.A., Weber J.B., Browne G.T., Susanne Klose, Jonathan Hunzie, Steven A. Fennimore, (2011). Evaluation of non-fumigant alternatives to methyl bromide for weed control and crop yield in California strawberries (*Fragaria ananassa* L.). Crop Protection, Volume 30, Issue 1, January 2011, Pages 45-51

Ji P., Kone D., Jackson K.L., Csinos A.S. (2012). Soil amendments with Brassica cover crops for management of Phytophthora blight on squash. *Pest Management Science*. 68, 639-644

Ji X., Qiao K., Dong S., Wang H., Xia X., Wang K. (2013). Effects of 1, 3-dichloropropene plus chloropicrin on weed seed germination. Crop Protection 45, 1-5.

Kaewchai S., Soytong K., and Hyde K. D., (2009).Mycofungicides and fungal biofertilizers. In: Fungal diversity, 38, 25-50.

Karaca F., Yetişir H., Solmaz İ.,Çandır E., Kurt Ş., Sarı N., Güler Z. (2012). Rootstock potential of Turkish *Lagenaria siceraria* germplasm for watermelon: plant growth, yield, and quality. *Turkish J Agriculture and Forestry* 36, 1101-1716

Katan J. (2014a).*Soil solarisation: the idea, the research and its development*; Phytoparasitica; June 2014; Springer Netherlands

Katan, J. (2014b). Integrated pest management in connection with soil disinfestation. Acta Hort. 1044:19-28

Katan J., Gamliel A. (2012a). Soil solarisation for the management of soilborne pests: the challenge, historical perspective and principles. Pages 45-52. In: Soil Solarisation-Theory and Practice (eds. Gamliel A. and Katan J) APS press, St. Paul MN USA

Katan, J.and Gamliel, A. (2012b). Mechanisms of pathogen and disease control and plant growth improvement involved in soil solarisation. In A. Gamliel & J. Katan (Eds.), *Soil solarisation: theory and practice* (pp. 135–145). St. Paul, MN, USA: APS Press.

KatanJ., and Gamliel A. (2012c). *Soil solarisation: theory and practice* . St. Paul, MN, USA: APS Press, 266 pp.

Katan J., Greenberger A., Alon H., & Grinstein, A. (1976).Solar heating by polyethylene mulching for the control of diseases caused by soil-borne pathogens. Phytopathology, 66, 683– 689.

KatanJ.,& Gamliel A. (2010). Soil solarisation - 30 years on: What lessons have been learned? In U. Gisi, I. Chet, & M. L. Gullino (Eds.),*Recent developments in management of plant diseases* (pp. 265–284). Dordrecht, the Netherlands: Springer.

Keinath A.P**.,-**Hassell R. L. (2014). Control of Fusarium Wilt of Watermelon by Grafting onto Bottle gourd or Interspecific Hybrid Squash Despite Colonization of Rootstocks by *Fusarium.* Plant Diseases, 98,255-266.

Keinath A.P.and Hassell R.L. (2013).Evaluation of grafting to control race 2 of Fusarium wilt on watermelon .Annual international research conference on methyl bromide alternatives and emissions reductions, Nov 4-6, 2013, San Diego, California, 88

King S. R., Davis, A. R., Liu, W., and Levi, A. (2008). Grafting for disease resistance. *Hortscience* 43, 1673-1676.

Klein E., Katan J., Gamliel A. (2011).Soil suppressiveness to Fusarium disease following organic amendments and solarisation; Plant Disease, 95 (2011), pp. 1116–1123

Klein E., Katan J., .Gamliel A., 2012. Soil suppressiveness to *Meloidogyne javanica* as induced by organic amendments and solarisation in greenhouse crops. *Crop Protection*, *Volume 39*, *26-32.*

Kobara Y, Momma N. and Yogo Y. (2012).Biological soil disinfestation (BSD) techniques with diluted ethanol. Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions, Maitland, Florida USA.

Kobara Y. Momma N. and Yogo Y. (2011).Biostimulated redox processes in soils disinfested with ethanol solution. Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions, San Diego, California USA.

Koike S.T. (2008). Crown rot of strawberry caused by *Macrophomina phaseolina* in California. Plant Disease 92, 1253.

Koike S.T., Ajwa H.,Daugovish O., Bolda M., (2009). Fumigant and strawberry variety evaluations in M*acrophomina* and *Fusarium* fields ,http://mbao.org/2009/Proceedings/013DaugovishO.SummaryPathogens.pdf

Koike S.T., Daugovish O., Gordon T., Ajwa H., Othman M., Subbarao K., Bolda M., Legard, D.(2011). Biology and Management of Macrophomina Disease of Strawberry in California.California Strawberry Commission Annual Production Research Report, 2010-2011.

Koike S.T., Gordon, T.R., Daugovish, O., Ajwa, H., Bolda, M., Subbarao, K. (2013).Recent Developments on strawberry plant collapse problems in California caused by *Fusarium* and *Macrophomina .International Journal of Fruit Science* 13 (1-2) , pp. 76-83

Koike S.T., Kirkpatrick S.C., Gordon, T.R. (2009). Fusarium wilt of strawberry caused by *Fusarium oxysporum* in California.Plant Disease 93, 1077.

Koike, S. T.Gordon, T. R. Daugovish, O. Ajwa, H. Bolda, M. Subbarao, K. , (2013). Recent developments on strawberry plant collapse problems in California caused by *Fusarium* and *Macrophomina.* International Journal of Fruit Science; ,13 (1/2):76-83.

Kokalis-Burelle N., Butler D.M. and Rosskopf E.N.(2013) . Effects of cover crops with potential for use in anaerobic soil disinfestation (ASD) on reproduction of M*eloidogyne* spp. Annual international research conference on methyl bromide alternatives and emissions reductions, Nov 4-6, 2013, San Diego, California, 65

Koron D., Sonjak S., Regvar M., (2014). Effects of non-chemical soil fumigant treatments on root colonisation with arbuscular mycorrhizal fungi and strawberry fruit production. Crop Protection, Volume 55, January 2014, Pages 35-41

Korthals G.W., Thoden T. C., van den Berg W., and Visser J.H.M., (2014).Long-term effects of eight soil health treatments to control plant-parasitic nematodes and *Verticillium dahliae* in agro-ecosystems.Applied Soil Ecology, 76, 112-123.

Kousik C. S., Thies J. A., Donahoo R., Hassell R. (2010). Grafting Seedless Watermelons, How and Why? Will Grafting Help With Disease Control?.*Atlantic Coast Agriculture Conference and Trade Show*. pp 38-39

Kousik C.S, Donahoo R.S, Hassell R., (2012). Resistance in watermelon rootstocks to crown rot caused by *Phytophthora capsici.Crop Protection*, *39*, *18-25*

Lambrix V., Reichelt M., Mitchell-Olds T., Kliebenstein D.J., Gershenzon, J. (2001). The *Arabidopsis* epithiospecifier protein promotes the hydrolysis of glucosinolates to nitriles and influences Trichoplusia ni herbivory. Plant Cell, 13, 2793-2807.

Lee N.M., Kim H. J., Kim K. D., Yoo D. L. And Suh J. T. (2012).Characteristics of new ever-bearing strawberry “Gwanha” cultivar for ornamental horticulture. *Korean Journal of Horticultural Sciences and Technology* 30(6): 784-787

Leocata S., Pirruccio G., Medico E., Myrta A.,and Greco N.(2014). Dimethyl disulfide (DMDS): a new fumigant to control root-knot nematodes *Meloidogyne* spp. In protected crops in Sicily, Italy. Acta Hort. 1044:415-420

Li Y., Chi L., Mao L., Yan D., Wu Z., Ma T., Guo M., Wang Q., Ouyang C., and, Cao A.(2014a) Control of Soil-borne Pathogens of *Zingiber officinale* by Methyl Iodide and Chloropicrin in China. Plant Disease, , 384-388

Li Y., Mao L., Yan D., Ma T., Shen J., Guo M., Wang Q., Ouyang C., Cao A. (2014b).Quantification of *Fusarium oxysporum* in fumigated soils by a newly developed real-time PCR assay to assess the efficacy of fumigants for Fusarium wilt disease in strawberry plants, Pest Management Science, (wiley online library.com) DOI 10.1002/ps.3700.

Liu B, Ren J, Zhang Y, An J, Chen H, Xu C, Ren H. (2014). A new grafted rootstock against root-knot nematode for cucumber, melon, and watermelon. *Agronomy for Sustainable Development*.DOI 10.1007/s13593-014-0234-5

Lodha, S., Mawar, R. and Saxena, A. (2014).Compost application for suppression of M*acrophomina phaseolina* causing charcoal rot in arid crops. Acta Hort. (ISHS) 1044:307-312

Lombardo S., Lango A.M.G., Lo Monaco A., Mauromicale G., (2012).The effect of soil solarisation and fumigation on pests and yields in greenhouse tomatoes . *Crop Protection*, *37*, *59-64*

Longo A., Feratto J., Mondino M., Grasso R. (2013). Efecto de diferentes tratamientos de suelos sobre la productividad y calidad de los cultivos de lechuga y tomate en invernadero; Revista FAVE - Ciencias Agrarias 1 (1): 101 - 105. 2002, Argentina.

López Pérez J.A., Roubtsova T, García M de Cara, Ploeg A. (2010). The potential of five winter-grown crops to reduce root-knot nematode damage and increase yield of tomato.*J. Nematol.*42, 120-127.

López-Aranda J.M., Miranda L., Medina J.J., Soria C., Santos B.D.L., Romero F., Pérez-Jiménez R.M.,Talavera M., Fennimore S.A., Santos B.M. (2009a). Methyl bromide alternatives for high tunnel strawberry production in southern Spain.HortTechnology, 19, 187-192.

López-Aranda J.M., Miranda L., Soria C., Pérez-Jiméne, R.M., Zea T., Talavera M., Romero F., De LosSantos B., Vega J.M., Páez J.I., Bascón J., Domínguez F.J., Palencia P., Medina, J.J. (2009b). Chemical alternatives to methyl bromide for strawberry in the area of Huelva (Spain): 2002-2007 results. Acta Horticulturae 842, 957-960.

Lopez-Aranda, J 2012. Methyl Bromide Alternatives (Chemical and Nonchemical) for Strawberry Cultivation in Conventional Areas of Production. Proceedings of the VII International Strawberry Symposium 2012, Beijing, China.*ActaHorticulturae*

López-Elías J., Guerrero-Ruíz J., Huez-López M., Jiménez-León J., Ruiz-Mendoza J. (2014). Biofumigación y solarización del suelo en la producción de sandía (*Citrullus lanatus* (Thunb.) Matsum.&Nakai); European Scientific Journal, January 2014 edition vol.10, No.3 ISSN: 1857 – 7881

Louws F J, Rivard C L, Kubota C. (2010).Grafting fruiting vegetables to manage soilborne pathogens, foliar pathogens, arthropods and weeds. *Scientia Horticulturae* 127, 127–146.

Mancini V., and Romanazzi G., (2014).Seed treatments to control seed-borne fungal pathogens of vegetable crops. Pest management science, 70(6), 860-868.

Mao L., Wang Q., Yan D., Xie H., Li Y., Guo M., Cao, A. (2012). Evaluation of the combination of 1,3-dichloropropene and dazomet as an efficient alternative to methyl bromide for cucumber production in China. *Pest Manage. Sci*. 68, 602-609.

Mao L., Yan D., Wang Q., Li Y., Ouyang C., Liu P., Shen J., Guo M., Cao A., (2014a). Evaluation of the Combination of Dimethyl Disulfide and Dazomet as an Efficient Methyl Bromide Alternative for Cucumber Production in China. *J. Agric. Food Chem*. 62, 4864-4869.

Mao L.., Wang Q.., Yan.D., Ma T., Liu P., Shen J., Li Y., Ouyang C., Guo M., Cao A.. (2014b). Evaluation of chloropicrin as a soil fumigant against *Ralstonia solanacarum* in ginger (*Zingiberofficinale*Rosc.) production in China. PloS one, 9(3), e91767.

Marshall M., Rumsey T., Stapleton J.,(Vandergheynst J.S. (2013). A predictive model for soil temperature during solarisation and model validation at two California field sites; Transactions of the ASABE 2013, American Society of Agricultural Engineers; vol. 56, no1, pp. 117-133 [17 page(s) (article)] (1 p.1/4).

Marsic N.K., Jakse M., (2010).Growth and yield of grafted cucumber (*Cucumis sativus* L.) on different soilless substrates. Journal of Food Agriculture & Environment 8, 654-658.

Martin C.G., Eudoxie G.D., Black K. C., Brathwaite R.A. I., Lauckner B. (2014). Assessing maturity of rotary barrel green waste composts for use as tomato and sweet pepper seedling starter and transplant growth substrates.*International Journal of Vegetable Science* 20, 28-58

Martínez B., Figueroa A., Baday E., and Mejia P.,(2010) Uso de aislamientos de *Trichoderma* para el control de enfermedades en melon en Choluteca. Fitosanidad 14(1):55

Martinez M. A., Martinez M.C., Bielza P., Tello J.,Lacasa A. (2011). Effect of biofumigation with manure amendments and repeated biosolarisation on Fusarium densities in pepper crops.*Journal of Industrial Microbiology and Biotechnology* 38(1), 3-11

Martínez M.A., Martínez M.C., Bielza P, Tello J, Lacasa A. (2009). Effect of biofumigation with manure amendments and repeated biosolarisation on *Fusarium* densities in pepper crops.*J. Ind. Microbiol. Biot.*38, 3-11.

Mashela P., Pofu K., Nzanza B. (2013.) Suitability of *Brassica oleracea* leaves in managing *Meloidogyne incognita* through the ground leaching technology system under microplot conditions. *Acta Agriculturae Scandinavica,* Section B - Soil & Plant Science; 63(1), 19-24.

Mattner, S.W., Milinkovic, M., Merriman, P.R. and Porter, I.J. (2014).Critical challenges for the phase-out of methyl bromide in the Australian strawberry industry. Acta Hort. (ISHS) 1044:367-373

Mattner, S.W., Porter, I.J., Gounder, R.K., Mann, R.C., Guijarro, B. and Williams, E.N. (2010).Maintaining biosecurity and market access in the Australian strawberry industry following methyl bromide phase-out. *Acta Horticulturae* (ISHS) 883: 99-106.

Mawar, R. and Lodha, S. (2014). Combining sub-lethal heating and cruciferous amendments for improved control of M*acrophomina phaseolina*. Acta Hort. (ISHS) 1044:289-293

McAvoy, T. Freeman, J. H. (2013). Yellow nutsedge (*Cyperus esculentus*) control with reduced rates of dimethyl disulfide in combination with totally impermeable film. Weed Technology; 27(3):515-519.

McKenry, M. (2011). Fifty years with a nematode-free nursery program. . In: Annual International Conference on Methyl Bromide Alternatives and Emissions Reductions, San Diego, California USA. http://www.mbao.org/2011/Proceedings/11McKenryM.pdf

Melero-Vara J. M., Lopez-Herrera C. J., Prados-Ligero A. M., Vela-Delgado M. D., Navas-Becerra J. A., Basallote-Ureba, M. J. (2011). Effects of soil amendment with poultry manure on carnation Fusarium wilt in greenhouses in southwest Spain.*Crop Protection*..30(8), 970-976.

Melero-Vara J. M., Vela-Delgado M., Basallote-Ureba, M., López Herrera C., Pelegrín, F., Talavera M. (2012a). Control de las agallas radiculares del clavel mediante enmiendas orgánicas al suelo, seguidas de solarización; XVI Congreso de la Sociedad Española de Fitopatología; Sociedad Española de Fitopatología

Melero-Vara J.M., C. J. López-Herrera, M. J. Basallote- A. M. Prados, M. D. Vela ,F. J. Macias, E. Flor-Peregrín and M. Talavera, (2012b). Use of Poultry Manure Combined with Soil Solarisation as a Control Method for *Meloidogyne incognita* in Carnation. Plant Dis. 96, 7, 990-996

Mennan S., Melakeberhan H. (2010). Effects of biosolid amendment on populations of *Meloidogyne hapla* and soils with different textures and pHs. *Bioresource Technology* 101(18), 7158-7164.

Meyer M. D.and Hausbeck M.K, (2013).Using Soil-Applied Fungicides to Manage Phytophthora Crown and Root Rot on Summer Squash. Plant Dis. 97, 107-112

Michel M., (2009). Implementación de un programa de eliminación de bromuro de metilo en la empresa Excosur. UNIDO Investment project on MB alternatives for melons.

Michel V.V., Lazzeri L. (2010). Green manures and organic amendments to control corky root of tomato.*Acta Hort*. (ISHS) 883, 287-294

Miles C A, Keider P, Hasenhoerly K, Inglis D A. (2013a).Plant Growth, Fruit Yield and Quality, and Tolerance to Verticillium Wilt of Grafted Watermelon and Tomato in Field Production in the Pacific Northwest.*HortScience* 48:1003-1009

Miles C.A, Hesnault L., Johnson S., Kreider P. (2013b). Vegetable grafting: Watermelons. Washington State University Extension Fact Sheet FS100E.htpp://pubs.wsu.edu

Minuto A., GullinoM.L., Lamberti F., D'AddabboT., Tescari E., Ajwa H., Garibaldi A.. (2006). Application of an emulsifiable mixture of 1,3-dichloropropene and chloropicrin against root knot nematodes and soilborne fungi for greenhouse tomatoes in Italy.Crop Protection 25: 1244–1252.

Misawa T., Sinmura A. (2010) Control effectiveness of biological soil disinfestation and some fungicides against Phytophthora rot strawberry caused by phytophthora cactorum and its duration. Ann.Rept.PlantProt. North Japan 61: 80-84 (2010)

MLF (2012) Evaluation of Methyl Bromide projects in Africa – Desk study. UNEP/OzL.Pro/ExCom/66/15. March, 2012. http://www.multilateralfund.org/66/English/1/6615.pdf

Mohamed F., El-Hamed K., Elwan M., Hussien M-A. (2012). Impact of Grafting on Watermelon Growth, Fruit Yield and Quality.*Vegetable Crops Research Bulletin.* 76, 99–118

Mokbel A., Saedy M. (2013). The Potential of Soil Solarisation and Chemical Nematicides in Controlling *Meloidogyne incognita* Infected Grapevine Seedlings; Journal of Life Sciences and Technologies; Vol. 1, No. 1, March 2013.

Mollinedo V. (2013). La solarización: una realidad en la producción hortícola del NOA. Editoras, Mitidieri, M. y Francescangeli N, Serie capacitaciones. no. 5., 1a. ed.; Ediciones INTA. San Pedro. Argentina; p. 42-44.

Momma N., Kobara Y., Uematsu S., Kita N., Shinmura A.,(2013). Development of biological soil disinfestation in Japan. Appl Microbiol Biotechnol DOI 10. 1007/s00253-013-4826-9 Springer-Verlag Berlin Heiderberg 2013 Published online: 03 April 2013

Momma N., Momma M., Kobara Y. (2010).Biological soil disinfestation using ethanol: effect on *Fusarium oxysporum* f.sp.*lycopersici* and soil microorganisms. Journal of General Plant Pathology 76(5): 336-344

Monge-Pérez J. (2013). Producción y exportación de melón (Cucumis melo) en Costa Rica; Revista Tecnología en Marcha; Vol. 27, Nº 1. Pág.93-103. Available at http://www.tec-digital.itcr.ac.cr/servicios/ojs/index.php/tec_marcha/article/viewFile/1700/1562

Morales-Rodríguez C., Palo C.,.Palo E., and.Rodríguez-Molina M.C. , 2014 Control of *Phytophthora nicotianae* with Mefenoxam, Fresh *Brassica* Tissues, and *Brassica* Pellets.Crop protection, 98,77-83

Morales-Rodriguez C., Picon-Toro J., Palo C., Palo E. J., Garcia A., and Rodriguez-Molina C., (2012). In vitro inhibition of mycelial growth of *Phytophthora nicotianae* Breda de Haan from different hosts by Brassicaceae species.Effect of the developmental stage of the biofumigant plants.Pest Management Science, 68, 1317-1322.

Morita Y. (2012) Construction of a Cultivation Manual for Ginger in Open Fields without Methyl Bromide in Kochi Prefecture; Plant Protection 2012 Vol.66 No.12 Page 24-28

Morra L., Bilotto M., Carrieri R., Lahoz E. (2013). Graft and solarisation in controlling *Phytophihora capsici* on bell peppers.*Colture Protette*; 42(1), 64-70.

Mowlick S., Yasukawa H., Inoue T., Takehara T., Kaku N., Ueki K., and Ueki A., (2013). Suppression of spinach wilt disease by biological soil disinfestation incorporated with *Brassica juncea* plants in association with changes in soil bacterial communities. Crop Protection, 54, 185-193.

Muñoz Villalobos J., Macías Corral M., Macías Rodríguez H., Velásquez Valle M., Tapia Vargas L. (2013). Bio-fumigation as Alternative for the Control and Prevention of Pathogens in the Soil in the Pepper Crop (*Capsicum annuum* L.) in the Valley of Nazas, Durango; Revista Agrofaz; volumen 13; número 2; 201; México. Available at http://www.agrofaz.mx/wp-content/uploads/articulos/2013132III_2.pdf

Muramoto, J., Shennan, C., Baird, G., Zavatta, M., Koike, S.T., Bolda, M.P., Daugovish, O., Dara, S.K., Klonsky, K. and Mazzola, M.(2014) .Optimizing anaerobic soil disinfestation for California strawberries. Acta Hort. (ISHS) 1044:215-220

Noling, J (2014). Large Scale Field Demonstration Trialing of Fumigant Alternatives in Florida Strawberry 2013-2014, MBAO, Annual international research conference on methyl bromide alternatives and emissions reductions, Nov 4-6, 2014, Orlando, Florida

Noling, J and Cody M. (2013). Large Scale Field Demonstration Trialing of Fumigant Alternatives in Florida Strawberry 2012-2013, MBAO, Annual international research conference on methyl bromide alternatives and emissions reductions, Nov 4-6, 2013, San Diego, California, 23

Nuñez-Zofio M, Larregla S, Garbisu C. (2011). Application of organic amendments followed by soil plastic mulching reduces the incidence of *Phytophthora capsici* in pepper crops under temperate climate*. Crop Prot.* 30, 1563-1572.

Nuñez-Zofio M, Larregla S, Garbisu C, Guerrero MM, Lacasa CM, Lacasa A. (2013). Application of sugar beet vinasse followed by solarisation reduces the incidence of *Meloidogyne incognita* in pepper crops while improving soil quality*. Phytoparasitica* 41, 2, 181-191.

Nuñez-Zofio M, Larregla S, Garbisu C. (2012). Repeated biodisinfection controls the incidence of *Phytophthora* root and crown rot of pepper while improving soil quality*. Spanish J. Agricultural Research* 10, 794-805.

Nyczepir, A.P., Kluepfel, D.A., Waldrop, V. & Wechter, W.P. (2012) Soil Solarisation and Biological Control for Managing *Mesocriconema xenoplax* and Short Life in a Newly Established Peach Orchard. *Plant Disease*, **96**, 1309-1314.

Ogai R., Kanda-Hojo A., Tsuda S. (2013). An attenuated isolate of Pepper mild mottle virus for cross protection of cultivated green pepper (*Capsicum annuum* L.) carrying the L3 resistance gene. *Crop Protection* 54; 29-34

Oka Y., (2010).Mechanisms of nematode suppression by organic soil amendments-A review. Applied Soil Ecology, 44, 101-115.

Oka Y., Shuker S., Tkachi N., Trabelcy B., and Gerchman Y., (2014).Nematicidal activity of *Ochradenus baccatus* against the root-knot nematode *Meloidogyne javanica*. Plant Pathology, 63, 221-231.

Okon Levy N., Meller Harel Y., Haile Z.M., Elad Y., Rav-David E., Jurkevitch E. and Katan J. (2014).Induced resistance to foliar diseases by soil solarisation and *Trichoderma harzianum*. Plant Pathology.doi: 10.1111/ppa.12255

Oumouuloud A., El-Otmani M., Chikh-Rouhou H., Claver A. G.,Torres R. G., Perl-Treves R.Álvarez, J. M. (2013). Breeding melon for resistance to Fusarium wilt: recent developments. *Euphytica* 192, 155-169.

Oyamada K., Suzuki S. ,Wada E., Saito Y. (2003). Control of Fusarium Wilt (*Fusarium oxysporum* f.sp. *fragariae*) on strawberry by soil reduction.Annual Report of the Kanto-Tosan Plant Protection Society. No.50

Özalp, R. and Aktaş, A., (2008).Türkiye ve Antalya'da sebzeciliğin genel durumu.*Tarımın Sesi Dergisi,* 17:15-18. Antalya.

Ozores-Hampton M., McSorley R., and Stansly P.A., (2012).Effects of long-term organic amendments and soil sanitation on weed and nematode populations in pepper and watermelon crops in Florida. In: Crop Protection, 41, 106-112.

Öztekin G.B., Tuzel Y. (2011). Salinity response of some tomato rootstocks at seedling stage.*African Journal of Agricultural Research* 6(20), 4726-4735

Ozturk, A.; Yilmaz, S.; Kececi, M.; Unlu, A.; Deviren, A.; Ozcelik, A.; Cetinkaya, S.; Cevri, H.; Akkaya, F. and Ozkan, C.F. (2002). Alternatives to methyl bromide for tomato and cucumber production in Turkey.*Proceeding of Alternatives to Methyl Bromide*. Sevilla, Spain. pp. 194-199.

Paes J.L., Faroni L.R.D.A., Dhingra O.D., Cecon P.R., Silva, T.A. (2012). Insecticidal fumigant action of mustard essential oil against *Sitophilus zeamais* in maize grains. Crop Protection, 34, 56-58.

Pérez-Jiménez R. M., De Cal A., Melgarejo P., Cubero J., Soria C., Zea-Bonilla T. Larena I. (2012). Resistance of several strawberry cultivars against three different pathogens.*Spanish Journal of Agricultural Research* 10(2), 502-512

Phillips A.J.L.,(1990) The effects of soil solarisation on sclerotial populations of *Scerotinia sclerotiorum*. Plant Pathol. 39:38-43

Piedra Buena A, García-Alvarez A, Díez-Rojo MA, Ros C, Fernández P, Lacasa A, Bello A. (2007). Use of pepper crop residues for the control of root-knot nematodes.*BioresourTechnol.* 98, 2846-2851.

Porter, I.J., Pizano M;,and Besri M;, 2007. Impact of the Montreal Protocol regulations on preplant soil use and trends in adoption of alternatives. In: Annual International Conference on Methyl Bromide Alternatives and Emissions Reductions, San Diego, California ,USA. http://www.mbao.org/2007/Proceedings/065PorterI2007Final.pdf

Porter, I.J., Trinder L., Partington, D.C (2006). Special report validating the yield performance of alternatives to methyl bromide for preplant fumigation.TEAP/MBTOC Special Report, UNEP Nairobi, May 2006, 97 pp.

Postma, J., Schilder, M.T. and Stevens, L.H. (2014).The potential of organic amendments to enhance soil suppressiveness against R*hizoctonia solani* disease in different soils and crops. Acta Hort. (ISHS) 1044:127-132

Pugliese M., Gullino M. L., Garibaldi A., Marenco, M. (2014a). Control of soilborne pathogens on vegetables grown in greenhouse by microorganisms isolated from compost. *Acta Horticulturae* 1044, 253-256.

Pugliese, M., Gullino, M.L., Garibaldi , A. and Benetti, A. (2014b). Use of compost from different origins to control soilborne pathogens in potted vegetables. Acta Hort. (ISHS) 1044:145-148

Putter I (1981) New insecticides and acaricides and nematiicide-avermectins. Experientia 37:963-964.

Qiao K., Liu X., Wang H., Xia X., Ji X. Wang K. (2012a). In: Effect of abamectin on root-knot nematodes and tomato yield. Pest Management Science , 68, 853–857.

Qiao K., Dong S., Wang H., Xia X., Ji X., Wang K. (2012b).Effectiveness of 1,3-dichloropropene as an alternative to methyl bromide in rotations of tomato (*Solanum lycopersicum*) and cucumber (*Cucumis sativus*) in China. Crop Protection38, 30-34.

Qiao K., Zhu Y., Wang H., Ji X., & Wang K. (2012c).Effects of 1, 3-dichloropropene as a methyl bromide alternative for management of nematode, soil-borne disease, and weed in ginger (*Zingiber officinale*) crops in China. Crop Protection, 32, 71-75.

Qiao K., Shi X., Wang H., Ji X., Wang K. (2011). Managing root-knot nematodes and weeds with 1,3-dichloropropene as an alternative to methyl bromide in cucumber crops in China. Journal of Agricultural and Food Chemistry, 59, 2362-2367.

Qiao K., Jiang L., Wang H., Ji X., Wang K., (2010a). Evaluation of 1,3-dichloropropene as a methyl bromide alternative in tomato crops in China. Journal of Agricultural and Food Chemistry, 58, 11395-11399.

Qiao K., Wang H.Y., Shi X.B., Ji X. X., Wang K.Y. (2010b). Effects of 1,3-dichloropropene on nematode, weed seed viability and soil-borne pathogen. Crop Protection, 29, 1305-1310.

Reyes A.,(2013) Personal communication. UNIDO project, Honduras

Ricárdez-Salinas M..Huitrón-Ramírez M. V., Tello-Marquina J. C., Camacho-Ferre F. (2010). Planting density for grafted melon as an alternative to methyl bromide use in Mexico. *ScientiaHorticulturae,* 126(2), 236-24

Rosskopf E., Kokolis-Burelle N., Butler D., MuramotoJ., Shennan C. (2010). Development of anaerobic soil disinfestation for Florida vegetable and flower production.Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions, Orlando Florida USA.

Rosskopf, E.N., Burelle, N., Hong, J., Butler, D.M., Noling, J.W., He, Z., Booker, B. and Sances, F. (2014).Comparison of anaerobic soil disinfestation and drip-applied organic acids for raised-bed specialty crop production in Florida. Acta Hort. (ISHS) 1044:221-228

Rosskopf E., Kokalis-Burelle N., Hong J., Butler D. (2012).Status of ASD development in Florida. Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions, Maitland, Florida USA.

Roux-Michollet D., Dudal Y., Jocteur-Monrozier L., Czarnes S., (2010). Steam treatment of surface soil: How does it affect water-soluble organic matter, C mineralization, and bacterial community composition? Biology and Fertility of Soils 46,607-616.

Saglam O., Ozder N. (2013). Fumigant toxicity of monoterpenoid compounds against the confused flour beetle, *Tribolium confusum* Jacquelin du Val. (Coleoptera: Tenebrionidae). Turkiye Entomoloji Dergisi-Turkish Journal of Entomology, 37, 457-466.

Samtani J.B., Gilbert C., Ben Weber J., Subbarao K.V., Goodhue R.E., Fennimore S.A., (2012). Effect of steam and solarisation treatments on pest control, strawberry yield, and economic returns relative to methyl bromide fumigation.Hortscience 47, 64-70.

Sanchez-Tellez S. Herrera-Cid R. Besoain-Canales X. Perez-Roepke L. M. Montealegre-Andrade J. R. 2013. In vitro and in vivo inhibitory effect of solid and liquid *Trichoderma harzianum* formulations on biocontrol of *Pyrenochaeta lycopersici*.Interciencia;.38(6):425-429.

Saresh, N.V (2013) Effect of Thickness of Polythene Sheet and Duration of Solarisation on Soil Temperature in Primary Nursery. Indian Forester, [S.l.], p. 58-60, jan. 2013. ISSN 2321-094X. Available at: http://www.indianforester.co.in/index.php/indianforester/article/view/29135 .

Sasanelli N., Dongiovanni C.,Santori A., and Myrta A.(2014) Control of. the root-knot nematode .*Meloidogyne incognita* by dimethyl disulfide (DMDS) applied in drip irrigation on melon and tomato in Apulia and Basilicata (Italy). Acta Hort. 1044:401-403.

Sasser J.N., Kirkpatrick T.L., Dybas R.A. (1982) Efficacy of avermectins for root-knot control in tobacco. Plant Disease 66:691-693.

Savigliano, R., Hanich, Z., Pugliese, M. and Pizano, M. (2014). High quality compost: a promising future for sustainable agro-industry in Morocco. Acta Hort. (ISHS) 1044:119-125

Schneider, S. M. and Hanson B.D. (2009). Effects of fumigant alternatives to methyl bromide on pest control in open field nursery production of perennial fruit and nut plants.*HortTechnology* 19(3): 526-532.

Schneider, S. M., Ajwa H., Trout T.J., and. Gao S.,. (2008). Nematode control from shank- and drip-applied fumigant alternatives to methyl bromide. *HortScience* 43(6): 1826-1832.

Schneider, S. M., Hanson B.D, Gerik J.S, Shrestha A., Trout T.J , and Gao S. (2009). Comparison of shank- and drip-applied methyl bromide alternatives in perennial crop field nurseries.*HortTechnology* 19(2): 331-339.

Schwarz D, Rouphael Y, Colla G, Venema J H. (2010). Grafting as a tool to improve tolerance of vegetables to abiotic stresses: Thermal stress, water stress and organic pollutants. *Scientia Horticulturae* 127, 162-171.

Shaw D.V., Gordon T.R., Larson K.D., Gubler W.D., Hansen J., Kirkpatrick S.C. (2010).Strawberry breeding improves genetic resistance to Verticillium wilt. *California Agriculture* 64(1), 37-41.

Shennan C., Muramoto J., Baird G., Daugovish O., Koike S., Bolda M. (2011). Anaerobic soil disinfestation: California. Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions.San Diego, California USA.

Shennan C., MuramotoJ., Baird G., Fennimore S., Koike S., Bolda M., Daugovish O., Dara S., Mozzola M. Lazarovits G. (2012). Non-fumigant strategies for soil borne disease control in California strawberry production systems.Proc.Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions. Maitland, Florida USA.

Shennan C., MuramotoJ., Baird G., Koike S., Mazzola M. (2013). Optimizing anaerobic soil disinfestation for soilborne disease control Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions. San Diego, California USA

Shennan C., MuramotoJ., Koike S., Daugovish O., Mochizuki M., Rosskoph E., Kokalis-Burelle N. Butler D. (2010).Optimizing anaerobic soil disinfestation for strawberry production in Calofornia.Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions.Orlando, Florida USA.

Shennan, C., Muramoto, J., Lamers, J., Mazzola, M., Rosskopf , E.N., Kokalis-Burelle, N., Momma, N., Butler, D.M. and Kobara, Y. 2014. Anaerobic soil disinfestation for soil borne disease control in strawberry and vegetable systems: current knowledge and future directions. Acta Hort. (ISHS) 1044:165-175

Shinmura A. (2004) Principal and effect of soil sterilization method by reducing redox potential of soil. PSJ Soilborne Disease Workshop Report No.22, 2-12

Shinozaki T., Matsuzaki Y. and Yasunaga T. (2003). Control of Fusarium Wilt by Methyl Bromide Substitution in Strawberry. ?

Shrestha U., Ownley B., RosskophE.,ButlerD.(2013) . Optimization of amendment C:N ratio in an anaerobic soil disinfestation for control of *Sclerotium rolfsii.* Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions.San Diego, California USA.

Stoddard, C. S., Davis M;, Ploeg A.,, and Stapleton J;,. (2010). Methyl bromide alternatives show good potential for sweet potato hot beds. Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions.pp 33-1 to 33-3. http://www.mbao.org/2010/Proceedings/033StoddardSPAW.pdf

Suchoff D.H, Frank J., Louws F.J,, Christopher C., Gunter J.R,, Randall Patterson R., (2013). On-farm grafted tomato trial to manage bacterial wilt. Annual international research conference on methyl bromide alternatives and emissions reductions, Nov 4-6, 2013, San Diego, California, 89

Tanyolaç B., Akkale C. (2010). Screening of resistance genes to Fusarium root rot and Fusarium wilt diseases in F3 family lines of tomato (*Lycopersicon esculentum*) using RAPD and CAPs markers. *African Journal of Biotechnology* 9, 2727-2730

Tateya, A. (2009). Japan big effort to phase-out of methyl bromide by 2013. Annual international research conference on methyl bromide alternatives and emissions reductions, San Diego, California USA http://mbao.org/2009/Proceedings/006TateyaAJapanBigEffortstoPhaseofMethylBromide(090904).pdf

TEAP (2014).May 2014 Progress Report. Chapter XX: Interim evaluation of 2014 critical use nominations for methyl bromide. UNEP Nairobi, Kenya

TEAP(2011). Report of the Technical and Economic Assessment Panel.May, 2011. Ozone Secretariat, UNEP, Nairobi

Thangarajan R., Bolan N.S.,Tian G., Naidu R., Kunhikrishnan A. (2013). Role of organic amendment application on greenhouse gas emission from soil.*Sci Total Environ.*465, 72-96.

Thomas H., Legard D., Sjulin T., Rowe D., Reddy S., Fennimore S., Serohijos R., Low C., (2011). Production of strawberry in substrate. In: Annual International Conference on Methyl Bromide Alternatives and Emissions Reductions, San Diego, California USA.

Titiz, Ş. (2004). Modern Seracılık, Yatırımcıya Yol Haritası. Antalya Sanayici ve İş adamları Derneği.Retma Yayıncılık, Antalya (Modern Greenhouses, Road map for Investors. Association of Antalya Industrialists and Businessmen. Retma Publication, Antalya.)

Tomlin C.D.S. (1997) The pesticide manual, 1997. British Crop Protection Council 49.

Triky-Dotan S., Austerweil M., Steiner B., Peretz-Alon Y., Katan J., Gamliel, A. (2009), Accelerated degradation of metham-sodium in soil and consequences for root-disease management. Phytopathology 99:362-368.

TUİK (2009).Turkey Statistic Foundation (TUİK) (State Institute of Statistics).Agricultural structure and production. Publication no. 2895., Ankara, Turkey.

Turhan A., Ozmen N., Serbeci M.S., Seniz V. (2011). Effects of grafting on different root stocks on tomato fruit yield and quality. *Hort. Sci. (Prague) ,38*,142–149

Ueno K.i, Kaneko K., Taniguchi E. and Nagasawa S. (2006). Control of Fusarium Wilt and Nematode on Strawberry by Soil Reduction in Yamagata Prefecture.*Ann. Rept. Plant Prot. North Japan* 57:62-64

UNEP. (2014). Phasing-out Methyl Bromide in A5 Countries – A success story and its challenges; UNEP Division of Technology, Industry and Economics (UNEP DTIE) OzonAction Programme; available at http://www.unep.fr/ozonaction/information/mmcfiles/7674-e-Phasing_out_Methyl_Bromide_in_developing_countries.pdf

UNEP/MLF/MoE/UNIDO.(2004) Methyl Bromide alternatives project for the strawberry sector in Lebanon.

UNIDO (2008) National phase-out of MB in horticulture and commodities fumigation in Egypt. Project EGY/FUM/38/INV/86

UNIDO (2008).National MB phase-out program in Mexico–Project MP/MEX/08/001/1158-2009

UNIDO (2010). Technical assistance for the national phase-out of MB – Chile

Vallad, G.E.,Boyd N., Noling, J. (2014). A comparison of alternative fumigants to methyl bromide for Florida tomato. , MBAO, Annual international research conference on methyl bromide alternatives and emissions reductions, Nov 4-6, 2014, Orlando, Florida

Vallad G.E., Boyd N. (2013). An allyl isothiocyanate biopesticide for managing weeds, pests, and pathogens in soil. In: 2013 annual international research conference on methyl bromide alternatives and emissions reductions. methyl bromide alternatives outreach, San Diego, California, Nov 4-6, 2013.

Van Wambeke E. (2007). Combinations of reduced rates of 1,3-dichloropropene and dazomet as a broad spectrum soil fumigation strategy in view of methyl bromide replacement. Commun. Agric. Appl. Biol. Sci.72, 61-70.

Van Wambeke E., Ceustermans A., De Landtsheer A., Coosemans, J. (2009). Combinations of soil fumigants for methyl-bromide replacement. Commun. Agric. Appl. Biol. Sci. 74, 75–84.

Verdejo-Lucas S., Blanco M., CortadaL., Sorribas F.J., (2013). Resistance of tomato rootstocks to *Meloidogyne arenaria* and *Meloidogyne javanica* under intermittent elevated soil temperatures above 28 C . *Crop Protection*, *Volume 46*, *April 2013*, *Pages 57-62*

Vervoort M.T. W., Vonk J. A., Brolsma K. M., Schutze W., Quist C. W., de Goede R.G. M., Hoffland E., Bakker J., Mulder C., Hallmann J., and Helder J., (2014). Release of isothiocyanates does not explain the effects of biofumigation with Indian mustard cultivars on nematode assemblages. In: Soil Biology & Biochemistry, 68, 200-207.

Villeneuve F., Latour F., Théry T., Steinberg C., Edel-Hermann V., PitratM. and Daunay M..C. (2014). The control of soil borne vascular diseases: limits of genetic resistance of cultivars and rootstocks for controlling F*usarium oxysporum* f. sp. *melonis* (melon) and V*erticillium* sp. (eggplant). Acta Hort. (ISHS) 1044:57-65

Vitale A., Castello I., Cascone GD, Emilio A., Mazzarella R., Polizzi G. (2011). Reduction of corky root infections on greenhouse tomato crops by soil solarisation in South Italy. *Plant Disease.* 95,(2) 195-201.

Vitale A., Castello I., D'Emilio A., Mazzarella R., Perrone G., Epifani F., Polizzi G. (2013). Short-term effects of soil solarisation in suppressing *Calonectria* microsclerotia; Plant and Soil Journal; July 2013, Volume 368, Issue 1-2, pp 603-617

Wahb-Allah M. A. (2014).Effectiveness of grafting for the improvement of salinity and drought tolerance in tomato (*Solanum lycopersicon* L.).*Asian Journal of Crop Science* 6, 112-122

Walters, T., M. Particka, Zasada I;,, and. Pinkerton J.N. (2011). Productivity and economics of methyl bromide alternatives for raspberry nursery.Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions.http://www.mbao.org/2011/Proceedings/29WaltersT.pdf

Wang Q. J., Ma Y., Wang G. F., Gu Z. G., Sun D., An X., and Chang Z.Z., (2014). Integration of biofumigation with antagonistic microorganism can control Phytophthora blight of pepper plants by regulating soil bacterial community structure. In: European Journal of Soil Biology, 61, 58-67.

Wang Q., Yan D., Mao L., Ma T., Liu P., Wu Z., Li Y., Guo M., Cao A. (2013) Efficacy of 1,3-dichloropropene plus chloropicrin gelatin capsule formulation for the control of soilborne pests. Crop Protection 48, 24-28.

Westerdahl ., L. D., Chiller C.T, (2014).Nimitz (MCW-2) for management of root-knot nematode on annual crop. In: Gullino M.L;, Puglise M. and.Katan J., eds.;Proceedings of the eighth international symposium on chemical and non-chemical soil and substrate disinfestation, Acta Horticulturae, 1044, 353-358

Westerdahl B.B and Beem L.W., (2013). New products for nematode management on annual crops in california . Proceedings of the international research conference on methyl bromide alternatives and emissions reductions . San Diego, California, November 4-6, 7

Whitaker V.M., Chandler C.K., Santos B.M., Peres N.A., Nunes M.C., Ploto A., Sims C. (2012). “WinterstarTM) ‘FL05-107’ Strawberry. HortiScience 47, 296-298

Wu H., Wang C.J., Bian X.W., Zeng S.Y., Lin K.C., Wu B., Zhang G.A., Zhang, X. (2011). Nematicidal efficacy of isothiocyanates against root-knot nematode Meloidogyne javanica in cucumber. Crop Protection,30, 33-37.

Xiaoxue J., Kang Q., Sa D., Hongyan W., Xiaoming X., Kaiyun W., (2013).Effects of 1,3-dichloropropene plus chloropicrin on weed seed germination . Crop Protection, 45, 1-5

Yamada, K., *et al*. (2003). Control of Fusarium wilt on strawberry by Soil Reduction.*Annual Report of the Kanto-Tosan Plant Protection Society* 50, 49-52

Yaseer S. M., Mohamad A.M. , Mahamud S. and Khadzir D., (2012). Effects of substrates on growth and yield of ginger cultivated using soilless culture. J. Trop. Agric. and Fd. Sc. 40(2), 158-168.

Yates S.R., Ashworth D.J, Yates M.D., Luo, L. (2011). Active Solarisation as a Nonchemical Alternative to Soil Fumigation for Controlling Pests; Soil Sci. Soc. Am. J.;. 75:9–16.;

Yasuaki, M. (2012) Construction of a Cultivation Manual for Ginger in Open Fields without Methyl Bromide in Kochi Prefecture Plant Protection 66(12): 24-28

Yilmaz S, Celik I, Zengin S. (2011). Combining effects of soil solarisation and grafting on plant yield and soil-borne pathogens in cucumber. *International Journal of Plant Production* 5(1), 95-104

Yilmaz Y.B., Tunaz, H. (2013). Fumigant toxicity of some plant essential oils and their selected monoterpenoid components against adult American cockroach, *Periplaneta americana* (Dictyoptera: Blattidae). Turkiye Entomoloji Dergisi-Turkish Journal of Entomology 37, 319-328.

Yilmaz, S., Firat, A. F., Mutlu, N. and Surmeli, N. 2005. Recent developments of the vegetable production system in Turkey. Increasing Market-oriented Vegetable Production in Central Asia and the Caucasus through Collabrative Research and Development. Workshop Proceedings; 25-27 April 2005, Tashkent Uzbekistan.

Yilmaz, S., Gocmen, M., Ünlü, A., Aydinşakir, K., Mutlu, N., Baysal, Ö., Sayın, B., Celikyurt, M.A., Fırat, A.F., Çelik, İ. Aktaş, A., Öztop, A., Zengin, S., Devran, Z. and Tekşam, İ., (2008). Phasing out of methyl bromide in Turkey: Final Report, ISBN 9789754072549, 156 p., Antalya.

Yilmaz, S., Ünlü, A., Göçmen, M., Aydinşakir, K., Sayin, B., Kazas, S., Çelikyurt, M.A., Aktaş, A. and Zengin, S (2007). Alternatives to methyl bromide for cut flowers in Turkey. In: Annual International Conference on Methyl Bromide Alternatives and Emission Reductions. San Diego, CA, USA p. 48-1-3.

Yilmaz, S., Ünlü, A., Gocmen, M., Mutlu, N., Aydinşakir, K., Fırat, A.F., Kuzgun, M., Celikyurt, M.A., Sayın, B. and Çelik, İ. (2006). Phase out of methyl bromide for soil fumigation in protected horticulture and cut flower production in Turkey. Final Report, 2006. Antalya, Turkey.

Yonemoto K, Hirota K, Mizuguchi S., Sakaguchi K.,(2006) . Utilization of the sterilization by soil reduction in an open air field and its efficacy against Fusarium wilt of strawberry. Proc. Assoc. Pl. Protec. Shikoku, No41: 15-24

Yücel S., Ozarslandan A., Can C. and Gunaçti H. (2014).Case studies and implications of chemical and non-chemical soil disinfection methods in Turkey. Acta Hort. (ISHS)

Zanon M.J., Guitierrez L.A., and Myrta A.(2014). Spanish experiences with dimethyl disulfide (DMDS) on the control of root-knot nematodes, *Meloidogyne* spp., in fruiting vegetables in protected crops Acta Hort. 1044:421-425.

Zanón MJ, Jordá C. (2008). Eradication of *Clavibacter michiganensis* subsp. *michiganensis* by incorporating fresh crop debris into soil: preliminary evaluations under controlled conditions. *Crop Prot*. 27, 1511-1518.

Zasada, I.. Walters A.T.W., and Hanson B.D.,. (2010). Challenges in Producing Nematode- and Pathogen-free Fruit and Nut Nursery Crops in the United States. Outlooks on Pest Management 21:246-250.

Zavatta, M., Shennan, C., Muramoto, J., Baird, G., Koike, S.T., Bolda, M.P. and Klonsky, K. (2014). Integrated rotation systems for soilborne disease, weed and fertility management in strawberry/vegetable production. Acta Hort. (ISHS) 1044:269-274

Zveibil A, Mor N;, Gnayem N;, , and Freeman S. 2012 Survival, Host–Pathogen Interaction, and Management of *Macrophomina phaseolina* on Strawberry in Israel . Plant Disease ,96:2, 265-272

Zveibil A., Freeman S. (2009). Methods for detection of soilborne pathogens affecting strawberry in Israel.ActaHorticulturae 842, 191-194.

Zveibil A., Freeman S.(2005). First report of crown and root rot in strawberry caused by *Macrophomina phaseolina* in Israel. Plant Disease, 89, 1014.

6

Chapter 6. Alternatives to methyl bromide for structures and commodities

6.1. Introduction

Parties and scientists around the world continue to conduct research aimed at identifying and adopting alternatives to MB for controlling pests causing problems in the structures and commodities sectors. The previous MBTOC Assessment Report (MBTOC, 2011a) includes a chapter on the use of MB alternatives in structures and commodities, which considers about 200 new references published between 2011 and 2006. Further, the MBTOC Assessment Reports of 1994, 1998, 2002 and 2006 refer to research and results which were current at the time when those reports were published. Information contained in these reports is still relevant and should be considered by Parties interested in feasible and available alternatives to MB for structures and commodities. All assessment reports are all available on the Ozone Secretariat homepage. In addition, progress reports published yearly by TEAP (2009; 2010ab; 2011; 2012) and its MBTOC present overviews on the MB phase-out, successful alternatives, remaining challenges and others.

This chapter discusses progress achieved in replacing controlled uses of MB in structures and commodities and analyses remaining challenges in some particular circumstances and sectors (inclusing regulatory issues), which impact the total phase-out. More detailed information is included for those specific uses of MB that have been exempted under the Protocol due to particular difficulties in finding and implementing effective alternatives for such uses.

6.2. Regulatory issues

Since the last MBTOC Assessment Report was published (MBTOC, 2011a), some changes have taken place in relation to the registration of suitable alternative chemicals.

The registration of chemicals for pest control, including MB, is under continuous review in many countries. In Australia and Canada for example, sulfuryl fluoride (SF) is under a re-registration process ; this directly impacts the Canadian mill industry as there is no food tolerance for SF in Canada, meaning that all food products have to be removed from the mill if it is to be SF treated. The lengthy US proposed regulation discusses both the health assessment of residues resulting from the use of SF in structures and commodities, and the legal basis and issues resulting from a proposal to phase out its use. Excerpting short sections of this lengthy regulation can lead misunderstandings so Parties may want to review the entire regulation (EPA 2011).

Fluoride presence in the diet is largely regional, as it concentration is influenced by naturally occurring fluoride (in soils, impacting water), by fluoride additions to drinking water, and to a much lesser extent by fluoride residues resulting from the use of SF as a fumigant. In 2010, the US EPA proposed a regulation on sulfuryl fluoride, which is part of a range of actions to reduce the incidence of fluoride in the diet of some sub-sectors of the US population, particularly children. The US reported to MBTOC in its CUNs that its assessment of the situation is on-going and the current registrations for sulfuryl fluoride have not changed.

Australia on its part has addressed this issue and reassured the public that fluoride presence in the diet is not a problem in that country and that therefore, the approval of SF for pest control in structures and commodities will not be impacted by the proposed US regulation. Canada has not so far established a tolerance for SF contact with food. In Europe, accessibility of SF has been reduced recently and currently it can only be used on empty food processing structures including mills and for dried fruit. Food tolerances in commodities have been reduced to impracticable levels for pest control. Complete egg control has been withdrawn from the label in some countries.

Further regulatory news relate to progress made by Japan in the implementation of necessary logistical and training requirements following its registration of methyl iodide for control of fresh chestnut pests. As part of their CUN of 2011, Japan presented a full phase out plan for the use of MB in chestnuts by 2015.

France and some Baltic countries have registered the Indian phosphine releasing product of United Phosphorous.Cylinderized phosphine (ECO_2 and Vaporphos) has been registered in Thailand, Indonesia, the Philippines, Australia, New Zealand, Papua New Guinea and Turkey. The process of registration is still ongoing in Singapore.

6.3 Update on progress in research into methyl bromide alternatives for commodities and structures

Many avenues of research have been pursued in the attempt to find realistic alternatives to MB for the remaining commodity and structural treatments conducted worldwide, as well as and in quarantine or preshipment situations (Ducom, 2012). These include studies on alternative fumigants such as phosphine, sulphuryl fluoride and ozone, on controlled atmospheres with elevated temperature or raised pressure, on microwave, radio frequency or ionizing radiation, or on heat. The pest control options available for use in the post-harvest commodity and structure area have recently been reviewed by Bell (2013; 2014a, b). Ducom et al. (2014) give an overview on the French and German (European) perspective of stored product disinfestation including the use of phosphine, inert atmosphers and contact insecticides. The following paragraph highlight some important findings from research conducted on alternatives to MB for structures and commodities in various countries around the world.

Research on phosphine has concentrated on combating the spread of resistance by studying the fate and effect of resistant genes in the pest population (Campbell, 2010; Ridley *et al*., 2012; Kaur *et al*., 2012; Daglish *et al*., 2014), and on factors improving the performance of phosphine fumigations (Beckett *et al*., 2010; Ridley *et al*., 2011; Shi *et al*., 2012; Nayak, 2012; Asher, 2012; Bridgeman and Collins, 2012; Newman *et al*., 2012abc).

Research on sulfuryl fluoride has followed requirements for optimum efficacy in treating timber and structures to control pests (Ren *et al*., 2011; Tsai *et al*., 2012; Chayaprasert *et al*., 2012) and on its possible combination with other toxicants (Riudavets *et al*., 2014) or heat (Hartzer *et al*., 2010a).

Practical methods using **ozone** to control pests in silos has received attention (Hardin *et al*., 2010; Hasan *et al*., 2012; McClurkin *et al*., 2013) and **controlled atmosphere** performance at raised temperature (Sen *et al*., 2010; Son et al., 2012) or raised pressure (Noomhorm *et al*., 2013) has seen some progress. The threshold levels for toxic action of various atmospheres in terms of gas concentration and time of exposure have recently been reviewed by Bell (2014c).

The prospects of using radiation energy sources for post-harvest pest control has received increasing attention in recent years, particularly in the area of **microwave** (Purohit *et al*., 2013; Manickavasagan *et al*., 2013) or radio wave frequencies (Jiao et al., 2012; Wang et al., 2013). The use of ionizing radiation in this field has recently been reviewed by Hallman (2013). The use of heat for disinfestation of commodities or structures, either as an enhancement for other control procedures (Sen *et al*., 2010; Akan and Ferizli, 2010; Fields, 2012) or by itself (Subramanyam et al., 2012; Campolo *et al*., 2013) has continued to receive attention in the attempt to raise efficacy levels to that achieved by methyl bromide.

6.4. Fields of application (product/location) where MB has been or will shortly be phased out

6.4.1 Alternatives to MB for rice, [empty] flour mills and dried fruits

For several decades, some fields of application within the section of disinfestation of stored products or empty structures remained without accepted alternatives in some countries. Some Parties claimed that despite robust efforts to replace MB in these fields they had been unable to identify economically equally feasible and equally effective alternatives or to adopt those that had been implemented in other countries in similar situations. The main constraints cited were the high costs associated to the phase in of alternatives, the non-availability of alternative chemicals due to lack of registration and the absence of suitable premises or fumigation buildings in which to apply alternatives. These particularly difficult sectors included:

- Australia's rice processors
- Millers in Canada
- Millers in the United States
- Dried fruit producers in the US

As of 2015 however, all these postharvest uses of MB have been phased out in the non-A5 Parties listed above and no CUNs have been submitted for these uses for

2016. Australia is confident to turn to phosphine as replacement gas and is building the appropriate structures. Some carbon dioxide is also considered as an alternative chemical for disinfestation.

Besides application of heat, SF is the main chemical alternative for disinfestation of empty food and feed plants wherever it is registered for this use. Ethyl formate is used on some commodities in New Zealand and Australia.

6.4.2 Alternatives to MB for treating dates

In its 2006 and 2010 assessment reports, MBTOC described difficulties in finding effective MB alternatives for high moisture dates. Since that time, date producing countries have improved harvesting methods, logistics, pest control treatments and exporting conditions and all these measures are contributing to reducing date spoilage and improving date quality. No CUNs have been submitted for this sector by non-A5 Parties for several years. The alternatives implemented, together with the specific situation of high moisture dates, at one point indicated as critical in A-5 countries producing dates are analysed in detail in the following sections.

6.4.2.1. Decision XV/12 (1): High moisture dates

In 2003, MBTOC noted that technically and economically effective alternatives to MB had not been identified for disinfestation and stabilisation high-moisture dates. In response to this, and at the request of some North African countries, the15th Meeting of the Parties issued Decision XV/12, which states:

> "… That the Implementation Committee and Meeting of the Parties should defer the consideration of the compliance status of countries that use over 80% of their consumption of methyl bromide on high-moisture dates *until two years after the TEAP formally finds that there are alternatives to methyl bromide that are available for high-moisture dates…"*

Since that date, date producing countries have worked to develop technically and economically feasible alternatives and although the MBTOC its 2006 and 2010 Assessment Reports continued to identify hurdles in the implementation of alternatives to MB for disinfestation of high-moisture dates, recent MBTOC reports indicate large progress. In fact, the TEAP/ MBTOC May 2013 Progress report recognises technically and economically feasible chemical (phosphine, phosphine/CO_2, ethyl formate, sulfuryl fluoride) and non-chemical treatments (heat, cold, controlled atmospheres, IPM in the field and in the packing houses) that can be used to effectively replace MB for this use. Alternatives are available for all varieties of dates, including so-called high moisture dates, c.v. Deglet Noor. The latter are of particular importance in Algeria and Tunisia. Optimum choice of treatment is dependent on the variety and particular circymstances, including local pesticide registration.

Phoenix dactylifera has been a staple food in the Middle East and North Africa for thousands of years. A high proportion of the world's date production is concentrated in a few countries in this region : Egypt, Iran, Saudi Arabia, Pakistan, Iraq, Algeria, the United Arab Emirates, Sudan, Oman and Morocco, account for about 90% of the total world production.

Pest infestations in the field pose serious post harvest problems for all date varieties. Historically, dates have been disinfested prior to storage with ethyl formate, ethylene dibromide or ethylene oxide, and more recently with MB in some date producing regions such as Tunisia, Israel and the USA. Fumigation with MB forces a high proportion of larvae and adults to emigrate from the fruit before they succumb, which is essential to meet some religious and food quality requirements.

In the USA, all date types including Deglet Noor are left to dry on the palm to a moisture content of about 23 %, which is safe for storage at ambient temperatures without spoilage from moulding or fermentation. In Arizona, MB was never used for date disinfestation and the California date sector has now adopted alternatives to methyl bromide, replacing significant quantities used previously with mostly phosphine treatment, and to a lesser extent SF. Recent research reports good efficiency of Ethyl Formate, however this fumigant is not registered on dates in the United States.

Israel has adopted heat treatment and ethyl formate. During the heat treatment, insects exit the fruit trying to escape the high temperatures, ensuring that treated dates do not contain dead insects. Ethyl formate in carbon dioxide (Vapormate^{TM}) was successfully tested and is widely adopted for date disinfestation.

In Algeria and Tunisia, Deglet Noor dates are harvested when the moisture content is between 35 and 40% and should be treated and stored in cold rooms. Phosphine fumigation has largely replaced post harvest MB fumigation in Algeria, Tunisia, Egypt, Jordan, UAE, KSA and other countries. The fumigant is either supplied by tablet formulations or a phosphine generator. Dates treated by this process include high-moisture dates e.g., cv'Deglet Noor'referred to in Decision XV/12. Two surveys conducted in 2011 in Tunisia showed that 60 % of the exported dates were fumigated with phosphine and 40 % with MB and other alternatives. The main fumigant used on all types of dates is phosphine ; of 36 packing houses surveyed, 23 used phosphine, and the rest used other alternatives, including cold, cold+ phosphine and heat. Only 2 stations out of the 36 still continued to use MB. No decrease in date quality was reported by the exporting/importing countries. However, some chemical alternatives are not yet available in some countries.

According to Tunisian law, MB fumigation is no longer allowed in newly built packing houses. Application has been made for registration of the ethyl formate/CO_2 fumigant formulation for dates in Tunisia and controlled atmosphere treatments are under consideration. Further, essential oils are under investigation for their suitability of use against the carob moth *Ectomyelois ceratoniae* (Jemâa *et al.,* 2012; 2013)

In view of this situation, MBTOC believes that the high moisture dates issue is solved and has presented information to the Parties in this respect, in its Progress Reports and during Montreal Protocol meetings of the past two years.

6.5 On use of methyl bromide for dry cure pork products in Southeast US as the remaining field of MB application without available feasible alternatives

In some southern US states, typified by at least one season of cool but not freezing weather, and by warm days and cool evenings in another season, and where historically a major salt source was nearby, a natural, cured pork product was developed, utilizing weather changes, salt, sometimes sugar and the most basic of chemical curing agents. According to Kurlanski (2002), there is a 'pork belt' around the globe where the similar climatic conditions and regional availability of salt resulted in different, but similar, parallel development of natural cured pork products. So, natural regional cured pork products were developed, for example, in China, Italy, Germany, Spain, and parts of the Southern United States. There are differences in the pork products produced in these regions resulting from variances in local weather patterns and resulting from historical differences in processing methods and use of additives.

Although most other cured pork methods have been modernized, this tradition of natural and lengthy pork curing continues today in those regions. The pork products have different names, and in the United States this Southern dry cure pork product is often called Country Ham even though it might not be just the leg portion. Production of Country Ham - while small in the context of total cured pork production in the United States-, is not inconsequential. It has been reported to MBTOC that 45 Country Ham facilities produce three to five million hams each year, and these may require fumigation against pests.

All these natural pork products are subject to pest infestation, in part because of the lengthy storage time required for flavour development. The length and situation of the storage rooms and difference in type of curing agents can impact the extent, types and balance of pest infestation of that region's pork product. However, in a survey of American cured pork producers reported to MBTOC, the most significant factor in the development of pest infestation is length of storage. Hams that were stored for longer than six months were more often infested than those stored less than six months. Resolving this is not simply a matter of shortening storage time, however, since storage times of greater than five months is considered necessary for the product to achieve the correct flavour profile and the longer stored hams are considered better quality.

The pests most commonly reported are red-legged ham beetles *Necrobia rufipes* and ham mites *Tyrophagus putrescentiae*. The red-legged ham beetle reportedly causes 50-60% of the infestations and the ham mite causes 60-70% of the infestations. Of these, the most difficult to control are mites. Mites are acknowledged to be very difficult to kill with phosphine, and in tests of the effectiveness of SF in 2008, control of the ham mites required three times the US legal limits of SF (Phillips, *et al*., 2008).

Currently in the United States, there are three fumigants registered to control the pests of Southern cured pork: MB, phosphine and SF.Research in the US can be summarized as first improving integrated pest management and sanitation approaches.

Then, lab scale studies were conducted to determine if the target pests were killed by the approved fumigants, and other known methods of pest control. The approaches successful at lab scale were trialled at larger scale.

Improving IPM and sanitation was difficult to manage in the largely traditional Southern cured pork storage setting. US researchers noted that improved control of pest harbourage in the exterior of the facilities has been conducted. Some companies eliminated grass, trees, and shrubs from their buildings and replacing them with gravel, as suggested by researchers in 2008, to reduced harborage for pests outside their aging houses. These efforts have reduced their use of methyl bromide, but have not eliminated the need to disinfest their dry, cured pork products. Sanitation of storage rooms and equipment in between production runs has reportedly been improved. These aspects are largely meat processing approaches, rather than entomology approaches.

Entomologists have conducted tests to determine if phosphine treatments could be effective against ham pests. Early lab scale tests determined some effectiveness of phosphine against the target pests. Investigators achieved 100% mortality of all life stages of red-legged ham beetles and ham mites with 48 hours exposure at 400 ppm and 1000 ppm of phosphine, respectively (Sekhon et al., 2009b; Sekhon et al., 2010c). In addition, residual phosphine concentrations in dry cured hams that were fumigated for 48 h at 1000 ppm were below 0.01 ppm, the legal residual limit in stored food products (Sekhon et al., 2009b; Sekhon et al., 2010c); and consumer panellists could not detect differences between control and phosphine fumigated samples at 1000 ppm (Sekhon et al., 2009b; Sekhon et al., 2010c). Therefore, phosphine was considered a potential alternative to methyl bromide for controlling arthropod pests of Southern dry cured hams. Further testing with a greater number of mites indicated that a greater concentration of phosphine (>1000 ppm) is likely necessary to kill substantial mite infestations.

These lab scale tests using phosphine led to fumigation trials conducted in 2011 in 30 m^3 shipping containers intended to simulate dry cure aging ham houses at phosphine concentrations ranging between 1000 ppm - 2000 ppm and exposure times of 48 or more hours. Temperature was measured in the ham houses during fumigation and twenty jars with samples of *T. putrescentiae* bioassay and ten samples of *N. rufipes* were placed in each shipping container for each trial. Ten dry cure hams were hung from racks in shipping containers to simulate dry cure aging conditions. Five of these hams were used for mite inoculation and the other 5 hams were used for sensory analysis and phosphine residue testing. The lean portion of the dry cure hams that were used for inoculation was also inoculated with a mixed culture of approximately 1000 mites. Phosphine gas was produced in the shipping containers using magnesium phosphide cells that reached target fumigation doses at between 8 to 12 hours after the fumigation was started.

The post-embryonic mite mortality was 99.8% in the bioassays at two weeks post fumigation when 2000 ppm phosphine was achieved, but the eggs on either the hams or in the bioassays were not controlled, even at concentrations as great as 2000 ppm. If the pest eggs are not controlled the product would be infested again within days.

Investigations presented at 2010 MBAO at temperatures of 20°C or greater, all life stages of red-legged ham beetles were controlled in all fumigation trials. Variations in test conditions indicated that temperatures and exposure time need to be optimized for fumigation since 48 hours was not long enough to control ham mites at 2000 ppm. Ambient temperatures below 15°C decreased the effectiveness of the fumigation against both ham mites and red legged beetles.

For the sensory tests, ham slices were oven baked to an internal temperature of 71°C and served to trained panellists. Sensory tests indicated that trained panellists could not determine differences ($P>0.05$) between phosphine treated dry cured hams and non-fumigated hams. In addition, residual phosphine concentration was below the legal limit of 0.01 ppm w/w in ham slices that were taken from phosphine fumigated hams.

Following this work, one phosphine fumigation trial (Zhao *et al* 2012b) was conducted in a 1,000 m^3 (36,000 cubic feet) processing facility at 1600 ppm. Ham mite assays with live mites were distributed throughout the aging room. After 48 h of fumigation (26°C, 70-80 % RH), there were no living ham mites in the assays. However, phosphine fumigation corroded the electrical switches to the fans, and these switches had to be replaced. In addition, the research needs to be repeated when many hams are infested with mites to determine if it is effective in real world situations. In addition, if phosphine is going to corrode and incapacitate electrical equipment, it may not be adaptable to the industry.

Previously CUNs from the US had described the failure of SF, carbon dioxide, and ozone to control ham mites and red legged ham beetles. Also the US previously reported the results of low pressure and low oxygen concentrations on ham mites under laboratory settings, which took too long to be a viable option at this time.

The results of investigations with carbon dioxide, phosphine, methyl bromide and ozone treatments on *Tyrophagus putrescentiae*, ham mite, and *Necrobia rufipes*, red-legged ham beetle, were presented by Sekhon et al., 2009a, b; Phillips et al., 2011, Sekhon et al., 2010b, 2010c). The studies included eggs and a mixture of adults and nymphs of mites and eggs, large larvae, pupae and adults of beetles. The experiments were conducted for variable times at 23°C at various concentrations of carbon dioxide, phosphine, methyl bromide and ozone. The investigators achieved mortality of all life stages of mites with a content of 60 % carbon dioxide with 144 h of exposure (Sekhon et al., 2009a; Sekhon et al., 2010b). However, fumigation with carbon dioxide would likely not be applicable since ham structures are not air-tight and 144 h is too long of a time to fumigate the hams.

MBTOC explained that other regions employed hot dips of lard or oil to control pests of similar cured pork products. MBTOC also suggested physical exclusion by means of fine mesh or air blowing out of the curing chamber could help avoid mite infestation. Lehms et al. (2012) showed that nets of 30 µm were sufficient to keep out all stages of the mite *Tyrophagus putrescentiae*. This needs to be confirmed in commercial process and to resolve practical questions. For example, the mesh could be used to form a shroud over the hanging shelves of hams to keep mites infesting the aging room from attacking the clean hams. MBTOC suggested that the Party examine these possibilities, and examine increasing the temperature during fumigation to enhance effectiveness; the Party informed MBTOC in 2013 that it is doing this.

Following MBTOC's suggestion to try hot dips, US researchers began a series of laboratory experiments (Zhao et al 2012a) in which 1-cm square cubes of ham were dipped into a test compound of a given concentration for 1.0 minute and then placed in a ventilated glass jar and inoculated with 20 adult mites. Jars were held for 14 days to allow for mite reproduction and population growth, after which the total number of mite adults and nymphs were counted and compared to numbers produced on other treated ham pieces and on control hams dipped in water only. Three groups of experiments were conducted that compared common food oils, synthetic polyols and common legal food preservatives. Among oils tested, 100% lard from pork fat completely prevented mite reproduction on treated ham pieces, while vegetable oils such as olive, corn and soybean had minimal effects on mites. Of the polyols, glycerol had little effect on mites while propylene glycol at 100% or 50% prevented mite reproduction. Other short-chain diols had significant effects on mite reproduction. Of the other food preservatives tested, the various salts of sorbic and propionic acids were effective at preventing mite growth when applied as 10% solutions in water. Research so far suggests that approved food oils and synthetic food preservatives show potential for protecting dry cured hams from mite infestation, and future work will need to address the effects of these additives, if any, on the quality of hams during the aging process and on consumer acceptability.

In additional studies (Zhao *et al*., 2012b), ham slices and 1-cm square cubes were dipped directly into either mineral oil, propylene glycol, 10% potassium sorbate solution or glycerin for 1 minute and dripped on a mesh colander for another minute. Lard was applied directly by rubbing a thin layer to cover the whole piece. Ham cubes (2.5 cm ×2.5 cm × 2.5cm) were used for the mite infestation study. During the study, 20 mites (mostly adult female) were placed on one cube of ham which was placed in a ventilated, mite proof glass container and incubated for 21 days at 27ºC and 70% relative humidity. Mite populations on ham cubes were counted every week. Coatings on ham slices were washed off before cooking. Ham slices were oven baked to internal temperature of 71°C and served to trained panellists for sensory difference from control tests.

Results indicated that both lard and propylene glycol were effective ($P<0.05$) at controlling mite reproduction. No difference was detected in sensory characteristics between control ham slices and samples treated with food grade ingredients. In addition, potassium sorbate and mineral oil did not inhibit mite reproduction but slowed mite growth ($P<0.05$) when compared to the control, and glycerin was ineffective at lowering mite counts ($P>0.05$) when compared to the control.

The majority of research that has been conducted on use of food grade ingredients with meat products has been to prevent water loss and reduce rancidity of meat products. However, a finished ham product needs to lose at least 18% of its original weight during aging. At the same time, the unique flavors of dry cured ham are caused by proteolysis and lipolysis with the presence of oxygen. In this case, water vapor permeability of the films and coatings needs to be considered when choosing a proper coating. Current and future research is being conducted to develop a cost-effective food grade coating with high oxygen and water vapor permeability.

Based on the research studies described above (Zhao *et al*., 2012a), the active ingredients that show the most promise as potential methyl bromide alternatives are propylene glycol, butylate dhydroxytoluene (BHT), and lard. Propylene glycol (PG) is likely the most feasible food-grade ingredient that could be used to control ham mites but is also relatively expensive. BHT is effective at controlling mites on ham pieces at a concentration of 10 %. However, 0.01 % BHT (by fat percentage) is the acceptable level in some meat products. This makes it unlikely that it would be accepted for use, but may have application if it can be washed off the surface and there is less than 0.01% BHT in the finished product. Lard was effective at controlling mites on ham pieces. However, use of lard may prevent moisture loss and transmission of oxygen which would prevent the preservation and flavor development of the ham. However, these 3 ingredients need to be evaluated on whole hams for their ability to control mite infestations. In December of 2012, research was started on whole hams such that the hams are treated with BHT, lard, or propylene glycol. Propylene glycol will be used in food-grade gel coatings to determine if incorporating PG in a gel will prevent evaporation of the PG and prolong its effectiveness at controlling mites. US researchers indicated they will also work with processors to implement PG and other food grade products that may control mites in their plants to determine their impact in industrial settings.

Part of the problem of conducting research on ham mites is the practical difficulty of assessing their presence and counting them due to their small size of less than 0.4 mm.To help resolve this problem, Zhao et al. (2012b) developed a mite trap based on the basic design of a trap first developed in England. This trap consists of a 90 mm disposable plastic Petri dish that is painted black on the entire outer surface. Around the sidewall of the dish are eight evenly spaced holes, approximately 0.5 mm in diameter, at 2 mm above the bottom of the dish for entry of responding mites. A food bait was placed inside the middle of the dish and was a 25 mm diameter circular plug of mite diet, approximately 10 mm high. Mite diet was composed primarily of ground dog food with yeast, glycerin, anti-fungal agent and gelled with 2% agar. Mites respond to the baited dishes, enter the holes in the side wall, and feed to the diet plug where they mate and lay eggs. Laboratory studies confirmed that traps baited with diet were highly attractive to mites compared to unbaited traps. A study was initiated to monitor mite populations in which twenty traps were distributed evenly throughout each of three different ham production facilities for consecutive one-week periods. Mite numbers lured to traps varied from zero to several hundred in one week, and seasonal trapping determined that certain areas of facilities had higher mite activity than other areas. Traps confirmed that fumigation in certain circumstances caused severe reduction in mite populations, and showed that mites would slowly increase activity following fumigation.

In summary, to MBTOC's knowledge no other similar traditional cured pork product is disinfested with methyl bromide. Although there had been some promising results of potential alternatives for mite control in dry cure hams at lab scale, currently, no fully effective treatment has been found which controlled the target pests at commercial scale for Southern cured pork production.

This specific kind of ham presents in some areas of the US - where it is especially preferred as breakfast food - limits to exclude or control pest arthropods like the mite and some beetles. The old ham houses in use and the production and strage procedures ensure on one side the typical taste and organoleptic quality of this food. On the other hand, replacement of MB fumigation within this system can obviously not be performed without changing the quality of the ham. The constraints to replace MB here are well documented in previous reports. Despite robust research supported by the US government and intensive consultations with MBTOC, still no viable alternative has been found to replace methyl bromide as effective and economically feasible disinfestation agent in this sector. The pests of this product are difficult to control to US food hygiene standards -nil tolerance on inspection. There is an ongoing research program focusing on improving processing sanitation, IPM and pest control through a variety of possible fumigants and physical processes (Amoah et al., 2012, 2013; Abbar *et al,* 2013; Phillips et al., 2012 a; b). The results of investigations with various alternative fumigants and nonchemical treatments on the ham mite *Tyrophagus putrescentiae* have not been fully successful (Abbar et al. 2012; 2013; Zhao et al. 2012 a; b). Phosphine treatment using magnesium phosphide controlled the mites but let to inacceptable corrosion damage to exposed electronics (Phillips and Schilling, 2013). Research is ongoing and the change in hygiene and processing including the reconstruction of the houses seems to offer promissing pathways for future MB phase out.

Europe and USA have traditionally produced pork products preserved through processes such as dry-curing, smoking and salting. In the US, all ham would get salt. Salt is what keeps the product from rotting until it loses enough water to retard spoiling. Production requires an aging period for the hams to get the characteristic flavours. Under these aging conditions, the development of pest is a risk to take into consideration. Mold mites are the major pests affecting the final food product and food processing facilities. The main pest mite species is *Tyrophagus putrescentiae*. Other species present are *T. longior* and *T. casei*.

In Europe, for the control of mite infestations, the ham industry is no longer using MB since 2005 due to intensive sanitation and transition to alternatives. However, in the USA, the industry has not been able to entirely adopt available alternatives. Although IPM measures have reduced the number of times MB fumigation is needed, it has not fully eliminated the need for fumigation.

In order to prevent contamination, ham producers have to adopt high standards of sanitary procedures, the same as for other food and meat facilities and companies. In Europe, the old ham facilities nowadays have been transformed into modern meat processing factories. Specifically to avoid mite problems, the following procedures are widely followed in countries like Spain: high sanitation standards and intensive cleaning methods, fumigation of empty structures with PH_3 and use of other authorized pesticides, dipping the hams in oil and lard at 90°C including control of superficially occurring mites, strict control of the relative humidity (RH) during the process (initial 75 % to allow salt penetration and afterwards gradually decrease to 65%) and the control of moulds on and within the ham surface. Regarding the treatment with oil and lard at 90°C, this is applied early during the manufacturing process. This measure has both preventive and curative reasons. Exposure to high temperature kills mites that could be already present on the surface of the ham and lard fills crevices preventing the colonization of mites deep into the ham. Also, lard has another important advantage as it retards the speed of the drying process. Temperature and relative humidity determine the behaviour of mites (Sanchez-Ramos and Castañera, 2005). Controlling both parameters contribute to the prevention of this pest. Hams are maintained at low ambient RH conditions (50 – 60%) mainly during the last period of storage. This prevents the development mites that might have survived the hot oil treatment and avoids the colonization of newly infesting individuals from outside the store. Also, to maintain high hygiene standards inside the rooms, they are thoroughly cleaned when they are empty with use of pesticides within the facilities including the frames for later hanging new hams. These procedures are all together essential and must be followed by the industry.

A number of promising chemical alternatives have been identified. Among fumigants, the use of phosphine appears most promising with some modifications in application technique to avoid corrosion damage to exposed electronics (Phillips, 2013). In comparison, SF at ambient temperature of 25°C is at the regular dosage not effective in eliminating all the egg stages to the level that would effectively control pest mite populations. Recently, research is conducted to determine if its efficacy against mite eggs could be improved at higher fumigation temperatures of 35°C and longer exposure times of 48 h. Also, laboratory studies have been conducted to assess the potential of food-safe preservative coatings (Abbar *et al*., 2013; Zhao *et al*., 2012). These include sorbates and propylene glycol coatings on pieces of dry-cured hams that can repel and/or reduce reproduction.

The effective and feasible commercial use of carbon dioxide against pest mites in the ham industry has not yet been described. On the other hand it is known that exposure to gas mixtures of 50 vol.-% CO_2 in air at 25ºC for 12 days and 90 vol.-% CO_2 for 8 days, respecively, kill all developmental stages of pest mites (Riudavets *et al*., 2009)

6.6 General statements on alternative fumigants

6.6.1 Phosphine

Although phosphine is the fumigant of choice to replace MB in many postharvest treatments, some problems with its use need attention, particularly the possible development of resistance in the pests to be controlled. Very significant resistance has been reported in several species of SPP insects and options for overcoming it have been proposed (Asher, 2012; Bridgeman and Collins, 2012; Nayak, 2012; Newman *et al*., 2012ac; Phillips et al., 2012 c; Tumambing *et al*., 2012b). The fitness of phosphine resistant strains appears to be high so that resistance genes persist in the population in the absence of selection pressure (Daglish et al., 2014).

In the Philippines, several phosphine fumigations of grain, imported tobacco and seeds failed (Andres, 2013) however, phosphine is the only MB alternative available for use in these commodities. To date there are 4 brands of phosphine generating compounds and one cylinderized formulation that are registered and available.

Cylinderized phosphine is generally described (Tumambing *et al*., 2012 a). It has been successfully used for tobacco disinfestation in the Philippines (Andres, 2013) and is reported for use in Indonesia (Vidayanti *et al*., 2012).

Cryptolestes in Australia seems to have become resistant to phosphine to such a degree that it cannot be controlled with this gas at the registered dosage.

Phosphine is increasingly used for the disinfestations of fresh fruits against pest arthropods even at lower temperature of around 5°C (Horn, 2012).

Sulfuryl fluoride and phosphine in combination with heat are promising combinations for pest control in flourmills (Fields, 2012).

A new type of generator (Malushkov *et al*., 2012), which produces the phosphine on site (Ryan and Shore, 2012), an automatic fumigation system (Naik and Shroff, 2012b), a new recirculation system (Zakladnoy et al., 2012) and thermosiphon pipes for better gas distribution (Newman et al., 2012a) have been described.

Older reports confirm the occurrence of phosphine resistant pest insects in stored grain. To address phosphine resistance, fumigators opt to increase dosage and prolong exposure. Target concentration of phospine at 10 days exposure at 30 °C is > 300 ppm. In extreme cases, consecutive fumigation of 10-15 days exposure is resorted to.

6.6.2 Sulfuryl fluoride

Buckley and Thoms (2012) have presented a comprehensive overview on the worldwide use of SF for control of various pests in various products and situations. Noppe et al. (2012) mention the treatment of cocoa beans in the EU and Sen et al. (2012) that of dried apricots, raisins and hazelnuts. Walse (2009) reported on SF against eggs of stored product pests on dried fruit. China has three factories producing SF for local use and export. The fumigant is used for the treatment of grain, cotton and timber. The substance is also used for disinfestation of museums in the USA. SF is in use for disinfestations of museums (structures) against insect pests in Japan (JIIDCP, 2014). SF is now intensely used for disinfestation of bulk grain in Australia, also for resistance management of phosphine (Thoms *et al*., 2012).

Laboratory and field data have been presented for the control of all stages of species of pest insects (Flingelli *et al*., 2014; Lawrence et al., 2012) as well as a new detection device (Naik and Shroff, 2012a).

Sulfuryl fluoride (SF) was registered for stored product protection in 2004 as ProFume® by the DowAgroscience Company (Buckley and Drinkall, 2010). This company undertook a large effort to investigate the necessary CTPs and dosages for control of many pest insects and mites that can infest stored food products and other material. SF has also been registered for control of termites (Meikle et al., 1963) and wood pest insects (Williams and Sprenkel, 1990) under the name Vikane®.. SF has been used for termite control for about 50 years (Kenaga, 1957). SF has been independently developed in China as a grain fumigant and methyl bromide alternative and is produced in that country as previously stated.

From the very first introduction of this compound for pest control in the US it was obvious that eggs of arthropods were the most tolerant developmental stage and that they could not be killed for many species at dosage rates that eliminated the adult stage. Also a strong dependency of the lethal dosages on temperature became soon very evident. This can clearly also be seen from Table 1 when comparing the CTPs for eggs of one species at different given temperatures with higher temperatures leading to lower CTPs for control. Explanations for these dependencies have been suggested by Meikle *et al*. (1963) and Outram (1967a; 1967b). Uptake of SF by eggs compared to other developing stages and adults is much less pronounced and seems to be linked to the properties of the egg shell membranes. On the other hand, the lethal effect seems to be linked to physiological processes that are reduced at lower temperatures. The registration of SF for fumigating food processing structures and commodities by DowAgroscience was accompanied by the introduction of a proprietary computer program (Fumiguide®) to optimise SF fumigation efficiency under particular situations. Inputs to the Fumiguide include many scientific and technical factors that describe an effective fumigation, including species, stage, temperature, exposure period and loss rate of SF due to expected leaks on the base of a gas tightness test, wind speed, and commodity to be treated. All this information has to be introduced by the fumigator to obtain the necessary amount of SF that should be applied in a particular fumigation. In certain cases the guide even gives the top up quantity of additional gas required to achieve the set ct-product, based on gas concentration measurements and identified losses of gas during the treatment. In some countries the Fumiguide is not publicly available, but linked to licencing of SF use by the registrant.

During many fumigations performed in the US after 2004, it was found by practitioners and scientists that mostly all the pests were controlled, provided the recommendations of the Fumiguide were followed. The temperature range of the current Fumiguide is limited to temperatures above 20°C and below 40°C.

One specific information need of Parties concerns the need to understand the function and improve the efficacy of sulfuryl fluoride. Fumigation with SF is one of the pest control methods adopted by some parties as the principal alternative to methyl bromide in some major postharvest and structural uses. The lack of full effectiveness of SF against eggs of pests is mentioned in several critical use nominations. To assist in understanding, and hopefully resolving, this problem, MBTOC prepared a Special Review, which can be found in the TEAP Progress Report of May 2011 (TEAP, 2011). The report included recommendations on SF treatment parameters by pest species for the consideration of Parties and their applicants.. Parties, MBTOC, CUN applicants and researchers continue to note inconsistencies in the observed efficacy of SF in practice. This is of concern as fumigation with SF is one of the pest control adopted by some parties as the principal alternative to methyl bromide in some major postharvest and structural uses. The lack of full effectiveness of SF against eggs of pests is mentioned in several critical use nominations. To assist in understanding, and hopefully resolving, this problem, MBTOC SC prepared a Special Review, given below (section 4.6.2.1) of reported laboratory studies on SF in controlling eggs of stored product insect pests. This review provided a basis for analysis of the lack of full control of pests by SF in some commercial fumigation.

As a result of its review, MBTOC concludes that:

- the target dosage rate of SF, typically a ct-product of 1500 g h m-3 over 24h at 26°C, is insufficient to fully control eggs of some common species of stored product insect pest
- many common pests will be fully controlled (all developmental stages including eggs) to commercial levels under these conditions.

It is important to achieve a high degree of kill of infestations, including the egg stage, under situations where resistance development may be a risk.

MBTOC noted that the actual ct-product experienced by pests, including their eggs, may be less than the free space ct-product under conditions where there are significant barriers to gas distribution, such as packaging materials.

The review and analysis reported here merits further examination and testing by researchers and refinement by pest control fumigators, but at this point, we believe the information could act as a guide to improving the efficacy of SF fumigations as methyl bromide replacements.

6.6.2.1. Extracts of the special review on achieving control of pests including their eggs by sulfuryl fluoride (MBTOC, 2011b)

Fumigations that target only 95% efficacy in killing pest eggs can quickly result in severe reemergence of infestation and can eventually result in pest resistance to the fumigant, after repeated fumigations. Where there is risk of resistance development (e.g. with repeated treatments of infested premises) fumigations should be conducted to achieve a very high level of kill (>99%) of all pest life stages, including eggs. Because of varied mortality responses (including by the tolerant egg stage) to SF, identification of the pests of concern before the fumigation is required to select treatment parameters necessary to achieve full efficacy.

This predermination of the occurring pest species is in accordance to the requirements of the computer program Fumiguide that is used by fumigators applying SF from Dow Agrosciences. Knowledge gained from the pest identification, when coupled with the data shown in the review tables in the Appendix, can be used to determine the treatment parameters necessary for egg mortality. Crucial factors for limiting egg tolerance are temperature and length of exposure, and level of concentration, which operate differently on different species. Other important factors affecting response to SF include the developmental period of the embryo, the structure of the egg shell and other compounds of the egg.

Achieving an effective treatment may require a combination of concentration and time and elevated temperature, which is not currently found elsewhere.

The dosage/mortality values determined in laboratory studies may be used as a basis of commercial dosage recommendations, with allowance for the various inefficiencies and deviations from ideal systems that occur in practice. Reichmuth (2010b) proposed a factor of three times for conversion of laboratory-derived values to commercial applications.

Some researchers and food processing companies have reported inadequate control of pest eggs with SF and difficulties understanding the research in that field. In many situations, pest control methods, used as a single control measure, are not considered to be adequately effective if they do not control the eggs as the facility or commodity will become noticeably infested again from survivors within very few weeks. Some commercial recommendations for the use of SF in food processing structures and commodities target a 95% kill of pests. It is the opinion of MBTOC members that fumigations with less than 99% efficacy of killing pest eggs are undesirable because of possible selection for resistance under situations where the SF fumigant is the sole control measure used and repeated exposures are likely.

The reason for this is that survivors of such repeated unsuccessful fumigations will eventually become resistant to the fumigant -- and the fumigant will not longer be useful, including as a methyl bromide replacement. On the other hand, if other subsequent, additional control measures including IPM processes (e.g. a second fumigation, cooling, heating or further processing) were to be used in addition to the SF fumigation, and if a resulting additive kill-effect could be validated to 99%, then a 95% kill of all stages, with 'complete' kill of adults, may be sufficient both technically and commercially. Additionally, increasing the temperature and/or duration of the fumigation for a particular dosage will also help to increase effectiveness of the fumigation in a gas tight structure.

However, in the absence of MB, it is likely that SF will be used repeatedly as a postharvest fumigant in many applications without achieving full control, thus setting the conditions for pest resistance (i.e., if the treatment(s) are not effective to >99%). Since eggs tend to be much more tolerant than other developmental stages to SF, it is critical that the conditions leading to >99% mortality of eggs are understood if control to >99% efficacy is to be achieved.

Given the problems outlined above, several MBTOC members, led by Prof. Dr. Christoph Reichmuth (Germany) collated available data on the fumigation of eggs of stored product insects and especially those occurring in rice and flourmills, the situations of particular concern where SF is a potential or actual methyl bromide replacement.

In the review only those data points, which showed efficacy of at least 99% are included. Quarantine treatments may require effectiveness much greater than 99% mortality, and so were excluded from the analysis.

Table 6-1 summarises published mortality data and lethal responses of eggs of 28 economically important insects and mites following fumigation with sulfuryl fluoride at 20°C. data for other temperatures can be found in MBTOC, 2011b. Additional information on the pests can be obtained from Reichmuth (2007ab) and in the cited references. This table provides Parties access to research data on specific pest species where control of pest eggs was >99%. Some authors calculated LD95 and spoke of “complete control”, whereas others presented CTPs that were lethal to all eggs in the test (no survivors or no development to adults).

Figure 6-1 presents a bar graph of the reported minimum and maximum ct-products required for 99% efficacy of control of eggs of various pest species.

Table 6-2 sorts pest species into groups that are probably, possibly or unlikely to be controlled at 1,500 g h m^{-3} at at 26.7°C (80°F) and 24 h exposure. This ct-product is the maximum rate that is allowed under the registration of SF as a pesticide (‘label’ rate) for control of all developmental stages of stored product pest, such as specified in the ‘Fumiguide’, a proprietary guide to the use of SF as a postharvest and structural fumigant. This rate is targeted at only 95% mortality.

As with other fumigants, there is a wide range of sensitivity to SF fumigant with different pest species and developmental stage with some insect species tolerating much higher exposures than others. The eggs themselves develop through different stages that differ markedly in uptake of gas and ct-products that can give high mortality (see Table 4-2 where response of eggs with different age are summarised for 20°C as exposure temperaure). The different stages have been prepared in the laboratory by waiting various hours after egg laying before introducing them into a test fumigation. The development of the embryo differs in these eggs of different ages and also the structure of the egg shell and other components of the egg. The kinetics of these processes are strongly dependent on temperature.

Crucial factors for limiting egg tolerance are temperature and length of exposure, which operate obviously differently on different species. The table shows that even for tolerant species such as *Ahasverus advena* at 20°C, length of exposure is the key to reducing the dosage levels required for control to the practically feasible level of 1500 g h m^{-3}. With this species, the CTP depends strongly on exposure time and not so strongly on concentration of SF during the treatment. For *A. obtectus* and *A. advena* with eggs starting to hatch a week after oviposition at 20°C, increasing the exposure to four or seven days greatly affects tolerance at this temperature. The length of the phase of high tolerance in the egg stage (varying between species so some are more tolerant than others) is a fixed proportion of the total egg development time and so is temperature dependent. Development continues during exposure to SF until a susceptible stage is reached. If gas is still present, the egg succumbs.

For use of SF in control of insects that occur in rice storage in Australia, e.g. *Tribolium castaneum* and *Sitophilus oryzae*, necessary basic information for the dosage can be derived from Table 6-2. Unfortunately, *T. castaneum* belongs to the very few species that eggs are pronouncedly more tolerant than eggs of most other species. The maximum ct-product that is recommended by the Fumiguide® (1500 g h m^3) does not guarantee the complete control of all eggs present, at least not at 20°C. Reichmuth (2007b, 2010a, 2010b) has tried to demonstrate the limitations of not killing all the present eggs of a pest species in the context of the speed of rebound time of infestation after a fumigation. The speed of rebound depends on temperature. Typically common stored product pests lay 40 to 200 eggs per female. With a 99% kill of adult females, the remaining female can lay eggs that can then develop into the same level of infestation as before the treatment. Generation times can be a few weeks or months depending on species and temperature. A goal of, for instance, control of only 95% is totally insufficient within the food industry where zero tolerance of insects in food is the rule. It is a weak argument to say that new infestation will occur the very moment after the mill or other object of fumigation has been aerated and reopened. The client and government inspectors regulating the mill or food-processing facility will expect that there will be actually or nearly no surviving pest insects and stages following a SF fumigation.

Schaub (2010) dealt with the financial and economic aspects of fumigation in stored product protection. It is known that in practice, gas leaks, temperature sinks of 10°C, residual flour of 10 cm thick layers may occur. The avoidance of all these factors that can jeopardize the success of a fumigation is nearly impossible.

A fumigation plan which targets or results in less that 99% control is bad fumigation practice and may result in survivors that are more tolerant than the regular field strains. Campbell et al. (2010) dealt with the question of rebound of pest populations, considering field conditions. Harzer et al. (2010b) presented more detailed information on the field fumigations, which led to the results in Harzer et al. (2010a). Ciesla and Ducom (2009), subsequently gave also more detailed information (Ciesla and Ducom, 2010).

Reichmuth and Klementz (2008ab) compared the selection of the appropriate dosage for practical fumigation for methyl bromide and sulfuryl fluoride treatments. It was accepted as a reasonable, conservative approach to multiply the lethal dosage determined in the laboratory with a factor of about three to obtain the practical dosage. With MB, for example, 20 g m^{-3} is an accepted concentration for space fumigations, even though in the lab a concentration of only 5 g m^{-3} results in complete control for most species and stages over the same exposure time. However, with SF, as shown in Table 6-2, the theoretical values from the laboratory were converted into the recommended commercial dosing in the field mostly without giving some tolerance for practical imperfections typically encountered, as discussed. Reichmuth (2010b) proposed a factor of three for this conversion.

Another possibility to overcome the increased tolerance of the egg stage in using SF for insect pest control is the combination with other fumigants (Muhareb, 2009). Xiaoping *et al*. (2008), Ling *et al*. (2008) and Guogang *et al*. (2008) proposed the combination with carbon dioxide, whereas Reichmuth and Klementz (2008a) showed data on the very effective combination of SF with hydrogen cyanide (HCN). Of course, the combined use of heat or elevated temperature and SF offer an opportunity to economise on use of SF and still kill all eggs and other stages present. The use of supplemental heat to achieve sufficient egg kill in SF fumigations has been recommended by MBTOC since its 2008 Progress Report. This technique may also be applicable with packed food.

Walse (pers. comm.) confirmed the range of the necessary ct products to control egg stages (especially the one day old eggs) of the dried fruit beetle with about 4500 g h m^{-3} being necessary even at 25°C. According to Walse (pers. comm.) his unpublished experimental results showed that the ct products for LD50 he observed are slightly higher than those described by Flingelli *et al*. (2012, 2014) especially at the highest experimental temperature. Athanassiou *et al.,* (2012) investigated the efficacy against stored product psocids.

Some infestable stored foodstuffs are typically fumigated after packaging. There is an interrelationship between the permeability of the packaging and the efficacy of SF fumigation.

Some authors (Osbrink *et al*., 1988; Scheffrahn *et al*., 1990) described the permeation of SF through different plastic membranes. Scheffrahn et al. (1990) describes most of what is needed to know on pack permeability to SF and its low rate of permeation compared with methyl bromide through plastic films. On the basis of data from Scheffrahn *et al.* (1990), a 24 hour exposure to SF is unlikely to give lethal (ovicidal) concentrations within an intact laminate bag of rice. This conclusion is based on the likely diffusion and permeation of SF through plastic laminates that are used to package possibly infested processed rice in Australia. The influence of the pinholes is undefined and probably quite variable. It may be useful for Australia to consider the quoted references. Furthermore, it should now be possible to determine the likely SF and fluorine ion (F-) residues that may be formed in the course of an effective fumigation with SF.

TABLE 6-1. CT-PRODUCTS FOR SULFURYL FLUORIDE GIVING >99% MORTALITY OF EGGS OF VARIOUS STORED PRODUCT PESTS, GIVEN IN PUBLISHED LABORATORY AND FIELD TEST RESULTS AT 20°C AND DIFFERENT EXPOSURE PERIODS

Species and strain Laboratory tests	Egg age in days	Ct-product For >99% mortality in g h m-3	Exposure period in days	SF con-centration in g m-3	Reference
Ahasverus advena	All	4656	1.67		Bell (2006)
Ahasverus advena	All	3072	4		Bell (2006)
Ahasverus advena	All	1966	7		Bell (2006)
Acanthoscelides obtectus	All	1070	1		Bell (2006)
Acanthoscelides obtectus	All	605	4		Bell (2006)
Ahasverus advena	All	4656	1.67		Bell (2006)
Ahasverus advena	All	3072	4		Bell (2006)
Ahasverus advena	All	1966	7		Bell (2006)
Acanth. obtectus	All	1070	1		Bell (2006)
Acanth. obtectus	All	605	4		Bell (2006)
Crypt. ferrugineus (PH3 res)	all st	720	1	30	Baltaci et al. (2008)
Crypt. ferrugineus (PH3 res)	all st	720	3	10	Baltaci et al. (2008)
Crypt. ferrugineus (PH3 res)	all st	960	2	20	Baltaci et al. (2008)
Carpophilus hemipterus	2	2400	1	100	Karakoyun and Emekci (2010)
Ephestia cautella	1	1440	1	60	Akan and Ferizli (2010)
Ephestia cautella	2	3360	1	140	Akan and Ferizli (2010)
Ephestia cautella	3	3360	1	140	Akan and Ferizli (2010)
Ephestia elutella	1-4	683 (99)	0.75-2	11.6	Baltaci et al. (2009)
Ephestia elutella	1-4	624 (99)	0.75-2	21.3	Baltaci et al. (2009)
Ephestia kuehniella		1680	2	35	Drinkall et al. (1996)
Ephestia kuehniella		2520	3	35	Drinkall et al. (1996)
Ephestia kuehniella	All	1688	2	35	Klementz et al. (2008)
Ephestia kuehniella	All	1688	2	35	Klementz et al. (2008)
Ephestia kuehniella	All	842	3	11.7	Klementz et al. (2008)
Ephestia kuehniella	1	480	1		Reichmuth et al. (1999)
Ephestia kuehniella	1	960	2		Reichmuth et al. (1999)
Ephestia kuehniella	1	720	3		Reichmuth et al. (1999)

Species and strain Laboratory tests	Egg age in days	Ct-product For >99% mortality in g h m-3	Exposure period in days	SF con-centration in g m-3	Reference
Ephestia kuehniella	2	480	1		Reichmuth et al. (1999)
Ephestia kuehniella	2	960	2		Reichmuth et al. (1999)
Ephestia kuehniella	2	720	3		Reichmuth et al. (1999)
Ephestia kuehniella	3	1440	2		Reichmuth et al. (1999)
Ephestia kuehniella	3	1440	3		Reichmuth et al. (1999)
Ephestia kuehniella	4	1440	2		Reichmuth et al. (1999)
Ephestia kuehniella	4	720	3		Reichmuth et al. (1999)
Ephestia kuehniella	All	1860-2255 (99.4)	1.5-2		Reichmuth et al. (2003)
Oryzaephilus mercator	all st	>720	1	>30	Baltaci et al. (2008)
Oryzaephilus mercator	all st	1440	2	30	Baltaci et al. (2008)
Oryzaephilus mercator	all st	720	3	10	Baltaci et al. (2008)
Oryzaephilus surinamensis		636	1	26.5	Drinkall et al. (1996)
Oryzaephilus surinamensis		1272	2	26.5	Drinkall et al. (1996)
Oryzaephilus surinamensis		958	3	13.3	Drinkall et al. (1996)
Oryzaephilus surinamensis	All	319	1	13.3	Klementz et al. (2008)
Oryzaephilus surinamensis	All	638	2	13.3	Klementz et al. (2008)
Oryzaephilus surinamensis	All	958	3	13.3	Klementz et al. (2008)
Oryzaephilus surinamensis	All	1860-2255	1.5-2		Reichmuth et al. (2003)
Plodia interpunctella		564	1	23.5	Drinkall et al. (1996)
Plodia interpunctella		562	2	11.7	Drinkall et al. (1996)
Plodia interpunctella		842	3	11.7	Drinkall et al. (1996)
Plodia interpunctella	All	281	1	11.7	Klementz et al. (2008)
Plodia interpunctella	All	562	2	11.7	Klementz et al. (2008)
Plodia interpunctella	All	842	3	11.7	Klementz et al. (2008)
Rhyzopertha dominica	All	912	0.83		Bell (2006)
Rhyzopertha dominica	All	762	2.42		Bell (2006)
Rhyzopertha dominica	All	912	5		Bell (2006)
Sitophilus granarius		840	1	35	Drinkall et al. (1996)
Sitophilus granarius		1680	2	35	Drinkall et al. (1996)
Sitophilus granarius		1339	3	19	Drinkall et al. (1996)

Species and strain Laboratory tests	**Egg age in days**	**Ct-product For >99% mortality in g h m-3**	**Exposure period in days**	**SF con-centration in g m-3**	**Reference**
Sitophilus granarius	All	840	1	35	Klementz et al. (2008)
Sitophilus granarius	All	1680	2	35	Klementz et al. (2008)
Sitophilus granarius	All	1339	3	18.6	Klementz et al. (2008)
Stegobium paniceum	All	437	1	18.2	Drinkall et al. (1996)
Stegobium paniceum	All	874	2	18.2	Drinkall et al. (1996)
Stegobium paniceum	All	1310	3	18.2	Drinkall et al. (1996)
Tribolium castaneum	All	960 + HCN (100)	2	20 + 1.5 HCN	Reichmuth and Klementz (2008a)
Tribolium castaneum	All	72 (HCN) (85)	2	1.5 HCN	Reichmuth and Klementz (2008a)
Tribolium confusum		319	1	13.3	Drinkall et al. (1996)
Tribolium confusum		638	2	13.3	Drinkall et al. (1996)
Tribolium confusum		958	3	13.3	Drinkall et al. (1996)
Trogoderma inclusum		437	1	18.2 18.2	Drinkall et al. (1996)
Trogoderma inclusum		562	2	11.7	Drinkall et al. (1996)
Trogoderma inclusum		1310	3	18.2	Drinkall et al. (1996)
Tenebrio molitor	All	1860-2255 (99.5)	1.5-2		Reichmuth et al. (2003)
Trogoderma versicolor	All	437	1	18.2	Klementz et al. (2008)
Trogoderma versicolor	All	562	2	11.7	Klementz et al. (2008)
Trogoderma versicolor	All	1310	3	18.2	Klementz et al. (2008)
Sitophilus zeamais	All	92 + 441 (CO2)	0.25	15.38+ 73.58 (CO2)	Guogang et al. (2008)

Abbreviations: All = all egg ages; all st = all developing stages

FIGURE 6-1. LOWEST AND HIGHEST REPORTED CT-PRODUCTS IN THE LITERATURE FOR THE COMPLETE CONTROL OF EGGS OF THE VARIOUS PEST INSECTS (FROM MBTOC 2011B)

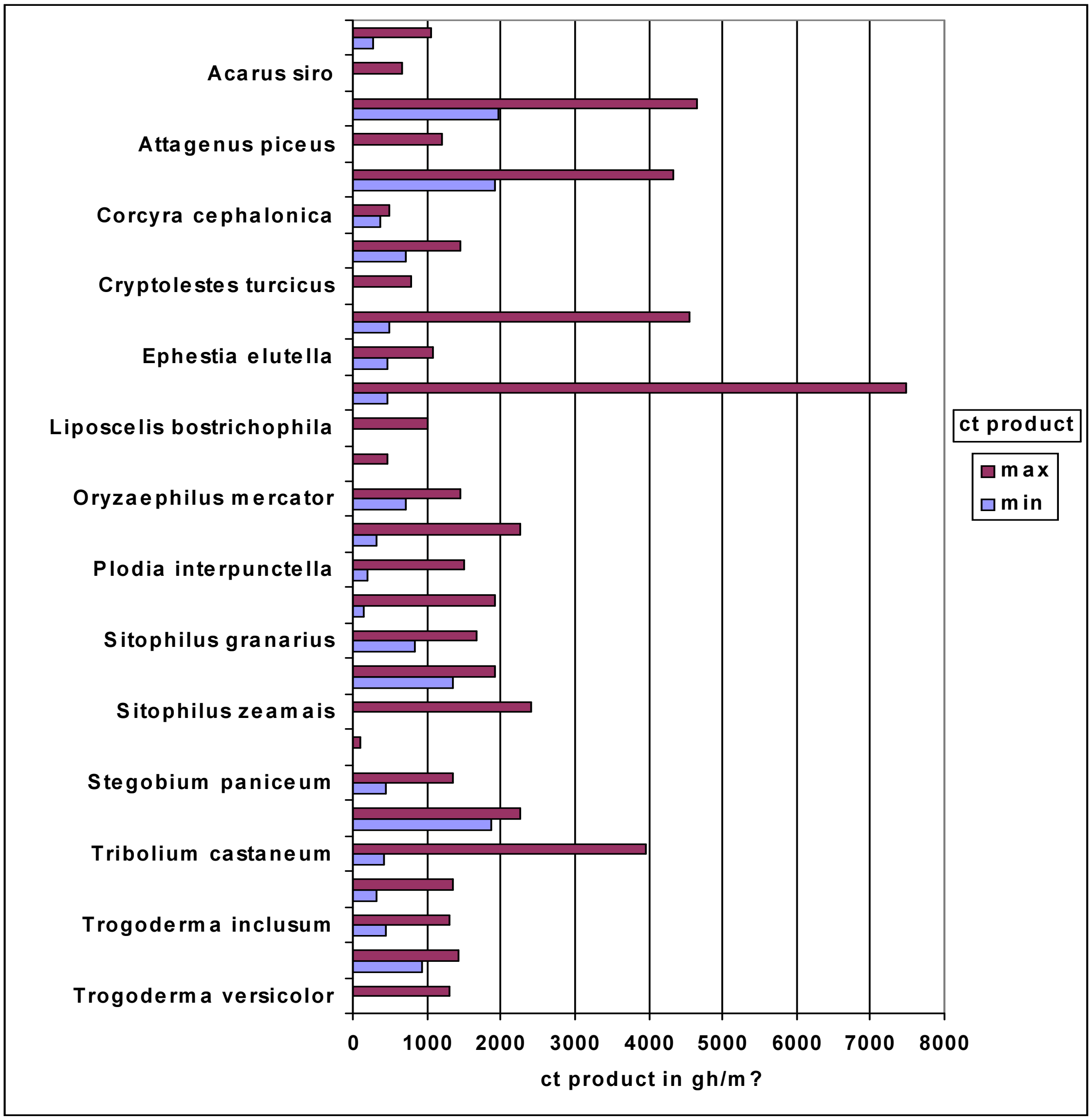


TABLE 6-2. GROUPING OF PEST SPECIES BY PROBABLE, POSSIBLE AND UNLIKE CONTROL OF EGGS BY SULFURYL FLUORIDE AT 1500 G H M^{-3} AT 26.7°C

PROBABLE EGG CONTROL AT 1500 g h m-3 and 26.7°C			
Species: common name	**Species: scientific name**	**ct-product in g h m-3 giving 99% mortality**	**Reference**
Rust-red grain beetle	*Cryptolestes ferrugineus*	~720	Baltaci et. al (2008)
Merchant grain beetle	*Oryzaephilus mercator*	~720	Baltaci et. al (2008)
Warehouse moth	*Ephestia elutella*	~500	Baltaci et. al (2006)
Rice moth	*Corcyra cephalonica*	~500	Barakat et al (2009)
Psocid	*Liposcelis bostrichophila*	1000	Bell et al (2003)
Grain beetle	*Cryptolestes turcicus*	780	Bell et al (2003)
Flour mite	*Acarus siro*	700	Bell et al (2003)
Warehouse beetle	*Trogoderma variabile*	~1000	Bell et al (1999)
POSSIBLE EGG CONTROL AT 1500 g h m-3 and 26.7°C			
Mediterranean flour moth	*Ephestia kuehniella*	500-1300	Baltaci et al (2006); Drinkall et al. (2003); Ducom et al. (2003); Reichmuth and Klementz (2008a)
Indian meal moth	*Plodia interpunctella*	1000-1300	Drinkall et al (2003) ; Ducom et al. (2003)
Confused flour beetle	*Tribolium confusum*	600-1300	Bell et al. (1999); Ciesla and Ducom (2009); Drinkall et al. (2003)
Rice weevil	*Sitophilus oryzae*	1300	Drinkall et al. (2003)
Lesser grain borer	*Rhyzopertha dominica*	1300	Drinkall et al. (2003)
Drugstore beetle	*Stegobium paniceum*	1300	Drinkall et al. (2003)
UNLIKELY EGG CONTROL AT 1500 g h m-3 and 26.7°C			
Almond moth	*Ephestia cautella*	1400	Akan and Ferizli (2010)
Granary weevil	*Sitophilus granaries*	1000-1500	Ducon et al (2003); Reichmuth and Klementz (2008a)
Red flour beetle	*Tribolium castaneum*	1500-1850	Drinkall et al (2003); Ducom et al. (2003); Reichmuth and Klementz (2008a)
Dried fruit beetle	*Carpophilus hemipterus*	~4500	Karakoyun and Emekei (2010)

6.6.3 Propylene oxide

In Japan, propylene oxide is used for treatment of museums to control pest insect and microbial diseases (JIIDCP, 2014). Propylene oxide is used against moulds in the US. The efficacy of propylene oxide in combination with carbon dioxide against eggs of stored product pests was demonstrated (Gautam et al., 2013).

6.6.4 Ethyl formate

VAPORMATE, a mixture of ethyl formate and carbon dioxide, is used in Australia, New Zealand and South Korea to disinfest stored product grain; products like cereal and legume grain (Glassey, personal communication), is further investigated for treatment of various stored products (Finkelman et al., 2012) and against book lice (Wang and Hui, 2012). Ethyl formate is proposed and used for disinfestations of fresh fruit (Agarwal *et al*., 2012), grain (Dojchinov et al., 2009; Ren and Mahon, 2006; Xin *et al*., 2008) and dates (Finkelman *et al*., 2010), beans (Ren and Mahon, 2006) and sorghum (Ren and Mahon, 2006). Thalavaisundaram and Roynon (2012) have described the penetration of the gas into wrapped card board boxes.

6.6.5 Controlled atmospheres

Adoption of Controlled Atmospheres (CA) and Modified Atmospheres (MA) as a means to control pests in food commodities and spaces where food is being stored continues to increase. CA and MA treatments offer large commercial and small packing houses, even farmers, effective postharvest pest control options useful for most durable commodities (and even non-food commodities such as museum and historical artefacts), under a very wide range of circumstances, without using chemical fumigants. For these reasons, the technique has spread widely, quickly and there are several companies offering equipment, service, products and assistance. The CA treatment is based on creating a low-oxygen environment within a structure (new or existing) with airflow control [airtight, gastight]. This technology provides a low-oxygen environment with oxygen levels of less than 1% causing death of pests.

There is an increasing introduction of inert gases with low residual oxygen content (mainly nitrogen and carbon dioxide, including vacuum) into the field of pest control in stored product and material protection (Adler *et al.,*, 2012; Aksoy *et al*., 2012; Andres, 2013; Aulicky *et al*., 2012; Banks, 2012; Biebl and Reichmuth, 2013; Calderón and Barkai-Golan, 1990; Cavalho et al., 2012; Corinth and Reichmuth, 2013; De Bruin *et al*., 2012; Huivi *et al*., 2012; Kucerova *et al*., 2012; Navarro, 2012; Navarro *et al*., 2012; Recichmuth *et al,* 1993; Ren *et al*., 2012; Sabio *et al*., 2012; Sen *et al*., 2012b; Son *et al*., 2012; Sotirouadas, 2012; Tao *et al*., 2012; Wong *et al*., 2012; Zeng *et al*., 2012).

Some facilities for the application of carbon dioxide and nitrogen are being erected in Indonesia and the Philippines (operational by Mai 2014) for control of insects in stored tobacco (cut fillers) (Gonzalez, pers. comm.). In the Philippines, high value stored products (cocoa powder, cut feeders) are treated with nitrogen from cylinders (less than 2 vol.-% oxygen) under tarpaulins, and seeds under hermetic conditions (Tado and Gummert, 2012).

In Albany, Western Australia, large steel bins and gas tight concrete silos have recently been erected for use of nitrogen with very low residual oxygen content of less than 1 vol.-% to treat stored grain prior to export against insects (Banks, personal communication).

Eleven new CA commercial projects were opened in 2011 and the first months of 2012 in the countries Cyprus, France, Greece, Ivory Coast, Singapore, Switzerland, United States and Vietnam by the Dutch company ECO_2. Other companies such as Linde (2013), Messer, and Air Liquide for example, also use controlled atmosphere technologies for pest control. Different commodities and related pest insects are controlled in either gastight constructed treatment rooms or prepared silo complexes by applying Controlled Atmosphere.

During each CA treatment, the following parameters are controlled and monitored to ensure an adequate treatment:

- The temperature within the treatment environment, including inlet temperature, air temperature, product temperature. The required product temperature needs to be reached throughout the products being treated.
- The required level of oxygen needs to be maintained within the treatment environment during the entire treatment process.
- The duration of the treatment is based on the results of research on the response of target pests to CA.
- Circulation within the chambers needs to be managed to achieve an evenly distributed level of CA and temperature within the treatment environment during the treatment process.

Each insect species and its the various life stages has its own optimum conditions to live and consequently its own parameters to be successfully eliminated.

Another application related to insect control is the use of CA or MA, for instance by GrainPro and other companies, offering CA or MA storage bags or 'bubbles' in a wide range of sizes (1 kg – 1000 kg). This application is based on insect control and simultaneous quality preservation during storage of packed commodities such as nuts, coffee, cocoa beans, rice and seeds. Commodities, stored in CA/MA bags are packed under low-oxygen conditions ensuring no discoloration and ageing along with insect control and prevention of insect re-infestation.

A study by Pons *et al*. (2010) established the efficacy of using CO_2 in big bags and containers to prevent pests' development. Four trials were conducted with gastight big bags (900 x 900 x 1000 or 1600 cm). Two of these trials were conducted with polished rice and samples of *Sitophilus oryzae*, one trial with chamomile infested with *Lasioderma serricorne* and one trial with cocoa and samples of *Tribolium confusum* and *Ephestia kuehniella*. Initial contents of CO_2 were higher than 75%, which decreased depending on exposure time (13 to 90 d) and food product. In all four trials the insects presentin the infested samples were controlled with the MA. An additional trial was conducted in a 9 m container containing dried herbs in boxes, big bags and other packaging formats. Twelve infested samples of *L. serricorne* and *Plodia interpunctella* were distributed uniformly at the bottom and top of the container. A concentration between 70% and 15% CO2 was maintained for an exposure time of 18 d. In spite of the decrease in CO_2 content, the treatment was also effective to control all insects present in the samples. The results confirmed that CO_2 could be applied to food products during the storage in big bags and containers to control the occurrence of pests. The authors concluded that modified atmospheres (MA) based on high carbon dioxide (CO_2) offer an alternative to synthetic chemical fumigation for insect pest control in food commodities during storage and shipment processes (Pons *et al*., 2010).

The various forms of hermetic bags are an excellent smallholder innovation with Crop Storage bags (PICS), a triple-lined 80 kilogram plastic bag being one of these. There have been many attempts to get them into routine use. Hermetic bags may deserve economic interest but the initial investment of two US$ eventually loses out compared with the polypropylene bags at fifty cents, despite multiple use and superior performance. Another problem is that for instance some pests like the Larger Grain Borer *Prostephanus truncatus*, can bore out of the bags quicker than the hermetic process kills them. So the integrity of the bag is compromised. Moisture within the bag may also lead to growth of moulds. In general terms, the use of hermetic storage with gas tight plastic bags may be applicable in some situations in Art 5 countries, but mostly in situations where MB was never used or considered for use.

A strong advantage of using CA/MA is that re-infestation after treatment is not possible (as long as the bag or bubble maintains its integrity) and goods are protected against external influences. These bags are convenient and applicable for many of the pest control needs faced by A5 Parties.

6.6.6 Methyl iodide

Although registration for MI has been suspended by its manufacturer in many countries, it is being used in Japan to treat fresh chestnuts since autumn 2014. Arysta Lifesciences Corporation (Japan) announced in 2013 that its MI business was being transferred to Itzusuja Chemical Industries Japan, which initiated promotion for practical use in chestnuts in late 2014 (Arysta, 2013).

6.6.7 MITC and CO_2

This mixture (MITC 30%) is presently registered and used in Japan for the treatment of logs and branches against forest insect pests (FAMIC, 2014).

6.6.8. Ozone

Ozone is frequently mentioned as an alternative to MB for disinfestation of stored products (Hasan *et al*., 2012). Athanassiou *et al*. (2014) describe their results to control *Plodia interpunctella, Tribolium confusum*, *Cryptolestes ferrugineus* and *Oryzaephilus surinamensis* with ozone. All species were tested at three different concentrations, 55, 115 and 210 ppm, for 2, 4, 6 and 8 h, respectively. Generally, at the two highest dose rates, all mobile stages were dead after 6 h of exposure, with *T. confusum* adults being the most tolerant. On the other hand, pupae and especially eggs were less susceptible to ozone, given that mortality did not exceed 85 and 55% for pupae and eggs, respectively, regardless of the dose and the exposure interval.

6.6.9. Nitric oxide (NO)

NO has been shown to be an effective fumigant against various pests of perishable and durable foodstuffs at low temperatures (2°C) under anaerobic conditions, with potential to replace MB fumigation in some applications (Liu, 2013a). MB fumigation of cooled perishables often requires heating the treated commodity to 10°C or more to be effective, with loss of shelf life and quality.

6.6.10. Chlorine dioxide gas

ClO_2 has been successfully tested against all stages of *Tribolium confusum* and *T. castaneum* (Channaiah *et al*., 2012).

6.6.11. Ethylene dinitrile (EDN)

EDN is described as fumigant for logs and timber (Park *et al.*, 2012).

6.6.12. Carbonyl sulfide

COS, developed in Australia, is still under investigation as an appropriate fumigant for control of pest organisms in stored product protection (Liu *et al*., 2012).

6.6.13. Other fumigants

Disinfestations of artifacts, monuments and logs with fumigants other than MB (methyl iodide, sulfuryl fluoride, cypermethrin, especially against the six-toothed bark beetle *Ips sexdentatus* has been reported (Ciesla *et al*., 2012; Floréal *et al*., 2012).

6.7. Other (non-fumigant) alternatives

6.7.1. Irradiation

The use of irradiation as a phytosanitary treatment has increased and in 2013 nearly 13,000 tonnes of irradiated fruit were marketed in the US, a dramatic 6,500% increase since 2007 (Jeffers, 2014). These products include purple sweet potatoes from Hawaii, mangoes from India; guava, mangoes and papayas from Mexico; grapes from South Africa; lychees, mangosteen and rambutan from Thailand; and Dragon fruit from Vietnam. Additionally, about 175 million lbs of spices are irradiated each year in the US as a treatment against microbial contamination.

6.7.2. Biological control

In Europe - especially in Germany - and in the US, parasitic wasps and predators now comprise a significant parts of pest management programs for facilities and stored products e.g. empty factory rooms, and grain and spices, especially in the organic sector (Schöller *et al*., 1997; Schöller, 1998, 2010, 2013; Reichmuth, 2013; Steidle and Niedermayer, 2013,).

6.7.3. Diatomaceous earth

Protectants like diatomaceous earths or other contact insecticides still serve to disinfest grain from pest insects (Korunic *et al*., 2012). Ulrichs and Mewis have investigated the potential of nanostructured silica for arthropod pests (2013). Ciesla and Guéry (2014) report on the combined use of diatomaceous earth and heat against *Sitophilus oryzae*.

6.7.4 Optimized processing and storage design

In grain storage in the Philippines, (mostly rice), improved processing equipment and techniques are implemented (dryers, drying technique, separating machines) to protect grain against pest insects without use of chemical disinfectants (Gonzalez, pers comm).

6.7.5. Heat

Heat has been mentioned again for the treatment of food processing facilities (Subramaniam *et al*., 2012) as well as cold to control beetles and moths (Adler and Reichmuth, 2013). Navarro and Finkelmann (2004) and Navarro *et al,* 2014 report on heat susceptibility of Carpophilus hemipterus eggs and larvae, an insect that are difficult to control and are/were target of MB fumigations. The use of a fluidized bed of wheat as a disinfestation method to control preimmature stages of Sitophilus spp. was again investigated under laboratory conditions (Fleurat-Lessard and Fuzeau, 2014). The lethal temperature ranged from about 1 minute at 60°C to 7s at 150°C. The experiments included also the determination of the relevant food technological properties of the treated wheat. Vacquer *et al*. (2014) report on the first successful heat disinfestation in a large wheat mill in France with electrical heaters from the Hofmeir company.

6.7.6. Essential oils and other plant extracts

Plenty of references describe results of mostly laboratory experiments with extracts of various plants against various stored product pest insects (JSPR and other sources) also as alternatives for the use of MB (Abdelgaleil *et al*., 2012; Ahnadi and Moharrmipour, 2012; Akrami and Moharrmipour, 2012; Jemâa *et al*, 2012; 2013; Haouel *et al*., 2012; Khemira *et al*., 2012; Mbata *et al*., 2012; Negahban *et al*., 2012; Nguemtchouin *et al*., 2013; Olivero-Verbel *et al*., 2013; Wakil *et al*., 2012; Ziaee and Moharrmipour, 2012) and seed borne fungi (Cardiet *et al*., 2012), but prospects for the use as alternatives to MB are limited.

The following table presents information from some of the more recent publications indicating the species of investigated plants and their essential oils. The information on the constituents of the oils reveal that often enough the same compounds are repoted from different pants.

Recently, Tapondjou (2014) gave an excellent overview on the subject, describing many of these botanical chemicals with their potential against insects and fungi. Alltogether 656 plant species from 110 families (especially Lamiaceae) and 119 chemical compounds distributed in 11 structural group types among which 3 (terpenoids, alkaloids and phenolic compounds) seem to possess strong insecticidal activity, have so far been cited in the literature (Boulogne *et al.*, 2012, cited in Tapondjou). In this paper, it is also mentioned that 1064 plant species from 150 families (especially Lamiaceae and Fabaceae), and 284 chemical compounds with 11 types of structure (especially terpenoids, alkaloids and phenolic compounds) bring along antifungal activity. So, in the future it may be interesting if a registration of some of these compounds could be promising as azadirachtin from neem oil or pyrethrum from chrysanthemum.

TABLE 6-3. SELECTED RECENT REFERENCES ON COMPOSITION AND LETHAL AND OTHER PHYSIOLOGICAL EFFECTS ON STORED PRODUCT PEST INSECTS

Plants/essential oils	**Investigated aspects**		
Essential oils Egyptian plants	composition toxicity	*Sitophilus oyzae* *Tribolium castaneum*	Abdelgaleil *et al*. 2012
Medicinal plants	toxicity	*Tribolium castaneum*	Akrami & Moharrmipour, 2012
Botanical substances	toxicity	*Sitophilus oryzae* *Aspegillus westerdijkiae* *Fusarium graminearum*	Cardiet et al., 2012
Eucalytus camaldulensis *Eucalyptus leucoxylon*	Composition toxicity	*Callosobruchus maculatus* *Bruchus lentis* *Bruchus rufimanus*	Haouell *et al*., 2012
Eucalytus camaldulensis	Composition toxicity	*Ectomyelois ceratoniae*	Jemâa *et al*., 2012, 2013
Eucalytus transcontinentalis	Composition toxicity	*Eggs and adults Ectomyelois ceratoniae*.	Khemira et al., 2012
synthetic monoterpenoids: anethole, estragole, carvone, linalool, fenchone,geraniol, terpinene, camphor	oviposition deterrence and mortality	*Callosobruchus maculatus*	Mbata *et al.,* 2012
Essential oils	as repellents	*Tribolium castaneum*	Olivero-Verbel *et al*., 2013
Acacia nilotica *Calotropis procera* *Dodonaea viscosa* *Cassia fistula* *Ocimum basilicum* *Adhatoda vasica* *Ziziphus jujuba*	toxicity	*Tribolium castaneum* *Rhzopertha dominica* *Cryptolestes ferrugineus* *Liposcelis paeta*	Wakil et al., 2012
Carum copticum	toxicity	*Sitophilus granarius*	Ziaee and Moharrmipour, 2012.

6.7.7. Integated Pest Management

The concept of integrated pest and commodity management has been further described (Jayas and Jian, 2012; Plarre, 2013; Vital *et al*., 2012) and possible ways to attract or repel pest insects (Ndomo *et al*., 2012). Within this frame, the use of organisms against pest organisms, offers ways of preventing the occurrence of pests in stored products and also empty structures where products are supposed to be stored in the near future. In so far, MB replacement not only focusses on finding alternative fumigants to control the pests when they have appeared. Modern strategies concentrate on approaches where the infestation itself is limited at an early stage to prevent later mass growth and necessities for acute and immediate control. Biological control addresses the need of finding ways to attack the first intruders into a storage system. Schöller and Prozel (2014) give a broad overwiew on the species of antagonists that are commercially available in Germany for this purpose.

6.8. References

Abbar, S., Schilling, M. W., Phillips, T. W. 2012. Protecting hams from the mite *Tyrophagus putrescentiae* using food safe approaches. In: Obenauf, G. L. (ed.), Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 6-8 November in Orlando, Fl, USA, MBAO conference, www.mbao.org, 44-1.

Abbar, S., Zhao, Y., Schilling, M. W, Phillips, T. W. 2013. Chemical alternatives for suppressing the ham mite, *Tyrophagus putrescentiae*. In: Obenauf, G. L. (ed.), Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 3-7 November in San Diego, CA, USA, MBAO conference. www.mbao.org, 44-1.

Abdelgaleil, S. A. M., Badawy, M. E. I., Mohammed, M. I. E., Shawir, M. S. 2012. Chemical composition and fumigant toxicity of essential oils isolated from Egyptian plants aginst stored product insects *Sitophilus oryzae* (L.) and *Tribolium castaneum* (Herbst). Navarro et al., 2012a, 50-57.

Adler, C., Corinth, H.-G., Reichmuth, Ch. 2000. Modified atmospheres. In: Subramanyam, B., Hagstrum, W. H. (eds.), Alternatives to Pesticides in Stored-Product IPM. Kluwer Academic Publishers, 437 pp, 105-146.

Adler, C., Murray, A. 2012. Taking the tropics home: Controlled atmospheres for the control of tobacco beetles in large scale testing. Navarro et al., 2012a, 488-494.

Adler, C., Reichmuth, Ch. 2013. Untersuchungen zur Abtötung der Dörrobstmotte Plodia interpunctella und des Brotkäfers *Stegobium paniceum* mit Kälte bei -10°C, -14°C und -18°C [Studies to control the Indianmeal moth *Plodia interpunctella* and the drugstore beetle *Stegobium paniceum* with subzero temperatures of -10°C, -14°C and -18°C]. (online: www.JKI.de), Journal für Kulturpflanzen 65, 110-117.

Ahnadi, M., Moharramipour, S. 2012. Toxicity of *Rosmarinus officinales* essential oil against irradiated *Tribolium castaneum*. Navarro et al., 2012a, 295-299.

Akan, K., Ferizli, A. G. 2010. Does sulfuryl fluoride and heat combination overcome the egg-weakness of almond moth? In: Obenauf, G. L. (ed.), Proceedings of the Annual International Reserarch Conference on Methyl Bromide Alternatives and Emissions Reductions, 2-5 November in Orlando, Fl, USA, MBAO conference, www.mbao.org, 56-1 - 56-4.

Akrami, H., Moharrmipour, S. 2012. Fumigant toxicity of two medicinal plant essential oils on *Tribolium castaneum* (Herbst). Navarro et al., 2012a, 91-95.

Aksoy, U., Sen, F., Meyvaci, K. B. 2012. Effect of post-harvest carbon dioxide on storage pests and fruit quality of dried figs. Navarro et al., 2012a, 166-171.

Amoah, B., Schilling, M. W., Phillips, T. W. 2012a . Protecting hams from the mite *Tyrophagus putrescentiae* using food-safe approachges. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 6-8 November in Orlando, Fl, USA, MBAO conference, www.mbao.org, 44-1.

Amoah, B., Schilling, M. W., Phillips, T. W. 2012b. IPM as alternative for the ham mite *Tyrophagus putrescentiae*: monitoring with traps. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 6-8 November in Orlando, Fl, USA, MBAO conference, www.mbao.org, 45-1.

Amoah, B., Schilling, M. W., Phillips, T. W. 2013. Trapping the ham mite, *Tyrophagus putrescentiae*, with a food bait: Toward a monitoring tool for IPM. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 3-7 November in San Diego, CA, USA, MBAO conference, www.mbao.org 37-1.

Andres, A. B. 2013. Alternative Treatments to Phosphine Plates Fumigation in Controlling Cigarette Beetles (*Lasioderma serricorne*) of Stored Expanded Tobacco (ET). MEGA MANILA PEST MANAGEMENT SPECIALISTS INC. Confidential Industrial Report.

Andres, A. B. 2013. Evaluating Resistance to Phosphine of Cigarette Beetles Collected from Philip Morris International Warehouse in Subic, Olongapo City, Philippines. MEGA MANILA PEST MANAGEMENT SPECIALISTS INC. Confidential Industrial Report.

Arysta, 2013. Announcement with regard to methyl iodide – business transfer to Izutsuya Chemical Industries Japan – 8 October 2013, Arysta life sciences Corporation (in Japanese, http://www.agrofrontier.com/yoka/pdf/yoka20131008.pdf).

Asher, P. 2012 Phosphine resistance and solutions. Navarro et al., 2012a, 658.

Athanassiou, Ch. G., Kavallieratos, N.G., Isikber, A. A., Oztekin, M. S. 2014. Insecticidal effect of ozone agaist different life stages of *Plodia interpunctella*, *Tribolium confusum*, *Cryptoestes ferrugineus* and *Oryzaephilus surinamensis*. In: Athanassiou et al. 2014, 224.

Athanassiou, Ch. G., Pasquale Trematerra, P., Kavallieratos, N. G., Weintraub, Ph., G. (eds.) 2014. Proceedings of the meeting of the IOBC, Integrated Protection of Stored Products, 1-4 July 2013 in Bordeaux, France, International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palearctic Regional Section (IOBC-WPRS), Darmstadt, ISBN 978-92-9067-277-7, http://www.iobc-wprs.org, IOBC-WPRS Bulletin 98, 466 pp,

Athanassiou, Ch., Phillips, T., Aikins, M. J., Hasan, M. M., Throne, J. 2012. Effectiveness of sulfuryl fluoride for control of different life stages of stored-product psocids (Psocoptera). Journal of Economic Entmology 105, 282-287.

Aulicky, R., Kucerova, Z., Stejskal, V. 2012. Control of brown-legged mite adults using nitrogen atmosphere. Navarro et al., 2012a, 545-548.

Baltaci, D., Klementz, D., Gerowitt, B., Drinkall, M., Reichmuth, Ch. 2006. Sulfuryl difluoride to control toward premature life stages of *Ephestia elutella* (Hübner). In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 6-9 November in Orlando, Fl, USA, MBAO conference, www.mbao.org106-1–106-4.

Baltaci, D., Klementz, D., Gerowitt, B., Drinkall, M., Reichmuth, Ch. 2008. Sulfuryl fluoride against all life stages of rust-red grain beetle (*Cryptolestes ferrugineus*) and merchant grain beetle (*Oryzaephilus mercator*). In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, November 11-14 in Orlando, FL, USA, MBAO conference, www.mbao.org, 87-1 – 87-3.

Baltaci, D., Klementz, D., Gerowitt, B., Drinkall, M., Reichmuth, Ch. 2009. Lethal effects of sulfuryl fluoride on eggs of different ages and other life stages of the warehouse moth *Ephestia elutella* (Hübner). Journal of stored Products Research 45, 19-23.

Banks, J. 2012. Long term semi-underground hermetic storage of grain. Navarro et al., 2012a, 440-449.

Barakat, D.A., Klementz, D., Reichmuth, Ch. 2009. Response of eggs of *Corcyra cephalonica* towards sulfuryl fluoride. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 29 Oct - 1 November in San Diego, CA, USA, MBAO 61-1 – 61-4. Available online at: http://mbao.org/2009/061Reichmuth.pdf.

Beckett, S.J., Darby, J.A., Forrester, R.I. 2010. The effect of diurnally interrupted doses of phosphine over four days on egg mortality of susceptible and resistant strains of *Sitophilus oryzae* (L.). Journal of stored Products Research 46, 59-65.

Bell C. H. 2014a. Food Safety Assurance Systems: Infestation Management in Food Production Premises. In: Motarjemi, Y., Moy, G., Todd, E. (eds.), Encyclopedia of Food Safety, Volume 4, Waltham, M. A., Academic Press, 189-200.

Bell, C. H. 2006. Factors affecting the efficacy of sulphuryl fluoride as a fumigant. In: Lorini, I. et al. (eds.), Proceedings of the 9th International Working Conference on Stored Product Protection, 15 - 18 October in Campinas, Sao Paulo, Brazil. Brazilian Post-harvest Association - ABRAPOS, Passo Fundo, RS, Brazil, 519-526.

Bell, C. H. 2013. Pest Management. In: Motarjemi, Y., Stadler, R., Lelieveld, H. (eds.), Food Safety Management: A Practical Guide for the Food Industry, Elsevier, 799-820.

Bell, C. H. 2014b. Pest control of stored food products: insects and mites. In: Leileveld, H. L. M., Holah, J., Napper, D. (eds.), Hygiene in Food Processing: Principles and Practice (2nd ed.), Woodhead Publishing Ltd, 494-538.

Bell, C. H. 2014c. Physical and chemical control agent thresholds for action on storage insects. Integrated Protection of Stored Products, IOBC-WPRS Bulletin 98, 299-308.

Bell, C. H., Savvidou, N. 1999. The toxicity of Vikane (sulfuryl fluoride) to age groups of the Mediterranean flour moth (*Ephestia kuehniella*). J. Stored Products Research 35, 233-247.

Bell, C. H., Savvidou, N., Wontner Smith, T. J. 1999. The toxicity of sulfuryl fluoride (Vikane) to eggs of insect pests of flour mills. In: Zuxun, J., Quan, L., Yongsheng, L., Xianchang, T., Lianhua, G. (Eds.), proceedings of the 7th International Working Conferece on Stored-Product Protection, 14-19 October 1998 in Beijing, P. R. China, Sichuan Publishing House of Science & Technology, Oct. 1999, Chengdu Province, P. R. China, Vol. 1, 345-350.

Bell, C. H., Wontner-Smith, T. J., Savvidou, N. 2003. Some properties of sulphur fluoride in relation to its use as a fumigant in the cereals industry. In: Credland, P. F., Armitage, D. M., Bell, C. H., Cogan P. M., Highley, E. (eds.), Advances in Stored Product Protection, Proceedings of the 8th International Working Conference on Stored Product Protection, 22-26 July in York, UK, CAB International, London, 910-915.

Biebl, S., Reichmuth, Ch. 2013. Stickstoff-Behandlung gegen Materialschädlinge [Nitrogen against material pests]. (online: www.JKI.de), Journal für Kulturpflanzen 65, 99-109.

Boulogne, I., Petit, P., Lafontaine, H. O., Desfontaines, L., Merciris, G. L. 2012. Insecticidal and antifungal chemicals produced by plants: a review. Environ. Chem. Lett. 10, 325-347.

Bridgeman, B., Collins, P. 2012. Resistance management in stored products fumigation. Navarro et al., 2012a, 633-637.

Buckley, S., Drinkall, M. 2010. Adoption of sulfuryl fluoride for the control of stored product insects in Europe and future development. Julius-Kühn-Archiv 425, 15-18.

Buckley, S., Thoms, E. 2012. Current status of PROFUME® gas fumigant for disinfestations of commodities. Navarro et al., 2012a, 241-246.

Calderon, M., Barkai-Golan, (eds.) 1990. Food Preservation by Modified Atmospheres. CRC Press, Boca Raton FL, USA, 402 pp.

Campbell, J. F., Toews, M. D., Arthur, F. H., Arbogast, R. T. 2010. Structural fumigation efficacy against *Tribolium castaneum* in flour mills. In: Cavalho, M. O., Fields, P. G., Adler, C. S., Arthur, F. H., Athanassiou, C. G., Campbell, J. F., Fleurat-Lessard, F., Flin, P. W., Hodges, R. J., Isikber, A. A., Navarro, S., Noyes, R. T., Riudavets, J., Sinha, K. K., Thorpe, G. R., Timlick, B. H., Trematerra, P., White, N. D. G. (eds.), Proceedings of the 10th International Working Conference on Stored Product Protection, 27 June – 2 July 2010 in Estoril, Portugal, Julius-Kühn-Archiv 425, Vol. 1, ISBN 978-3-930037-71-1, pdf online: www.jki.bund.de, 352-357.

Campbell, P.M. 2010. Comparison of the mitochondrial proteomes of phosphine-susceptible and –resistant *Tribolium castaneum*. Journal of stored Products Research 46, 197-201.

Campolo, O., Verdone, M., Laudani, F., Malacrino, A., Chiera, E., Palmeri, V. 2013. Response of four stored products insects to a structural heat treatment in a flour mill. Journal of stored Products Research 54, 54-58.

Cardiet, G., Fleurat-Lessard, F., Barreau, Ch. 2012. Fumigant toxicity of some volatile botanical substances against the wheat pest *Sitophilus oryzae* and two seed-born fungi, *Aspergillus westerdijkiae* and *Fusarium graminearum*. Navarro et al., 2012a, 81-90.

Cavalho, M. O., Barbosa, A., Barros, G., Magro, A., Adler, C., Navarro, S., Riudavets, Y., Timlick, B. 2012. Quality preservation of stored rice, using modified atmospheres in Portugal. Navarro et al., 2012a, 156-165.

Channnaiah, L., Wright, Ch., Subramaniam, B., Maier, D. E. 2012. Evaluation of chlorine dioxide gas against eggs, larvae, and adults of Tribolium castaneum and Tribolium confusum. Navarro et al., 2012a, 403-407.

Chayaprasert, W., Maier, D.E., Subramanyam, B., Hartzer, M. 2012. Gas leakage and distribution characteristics of methyl bromide and sulfuryl fluoride during fumigations in a pilot flour mill. Journal of stored Products Research 50, 1-7.

Cho, J.-H, Park, C. G., Yoo, M., Kim, B.-S., Lee, B.-H. 2012. Comparative toxicity of ethyl formate for control of pests of sweet persimmons for export. Navarro et al., 2012a, 310-314.

Ciesla, Y., Ducom, P. 2010. Efficacy against eggs of *Tribolium confusum* and *Tribolium castaneum* after fumigation with sulfuryl fluoride (ProFume®) in flour mills. In: Cavalho, M. O., Fields, P. G., Adler,

C. S., Arthur, F. H., Athanassiou, C. G., Campbell, J. F., Fleurat-Lessard, F., Flin, P. W., Hodges, R. J., Isikber, A. A., Navarro, S., Noyes, R. T., Riudavets, J., Sinha, K. K., Thorpe, G. R., Timlick, B. H., Trematerra, P., White, N. D. G. (eds.), Proceedings of the 10th International Working Conference on Stored Product Protection, 27 June – 2 July 2010 in Estoril, Portugal, Julius-Kühn-Archiv 425, Vol. 1, ISBN 978-3-930037-71-1, pdf online: www.jki.bund.de, Julius-Kühn-Archiv 425, 48-51.

Ciesla, Y., Ducom, P., Reichmuth, Ch., Walse, S. 2009. Harvest and disinfestation of Deglet Noor dates in Coachella Valley (California). Unpublished report for UNEP, 14 November 2009.

Ciesla, Y., Guéry, B. 2014. Efficacy of diatomaceous earth against the rice weevil *Sitophilus oryzae* (L.) after a preventive treatment of wheat. In: Athanassiou et al., 183-191.

Ciesla, Y., Guéry, B., Ducom, P. 2012. Efficacy of methyl iodide, sulfuryl fluoride and cypermethrin against the six-toothed bark beetle *Ips sexdentatus* (Börner). Navarro et al., 2012a, 254-259.

Corinth, H.-G., Reichmuth, Ch. 2013. Kohlendioxid unter atmophärischem und hohem Druck [Carbon dioxide under atmospheric and high pressure]. (online: www.JKI.de, Veröffentlichungen, Nachrichtenblatt und Journal für Kulturpflanzen), Journal für Kulturpflanzen 65, 94-98.

Daglish, G. J., Nayak, M. K., Pavic, H. 2104. Phosphine resistance in *Sitophilus oryzae* (L.) from eastern Australia: inheritance, fitness and prevalence. Journal of stored Products Research 59, in press.

De Bruin, T., Navarro, S., Villers, P., Wagh, A. 2012. Worldwide use of hermetic storage for the preservation of agricultural products. Navarro et al., 2012a, 450-458.

Dojchinov, G., Damcevski, K., Woodman, J., Haritos, V. 2009. Field evaluation of vaporised ethyl formate and carbon dioxide for fumigation of stored wheat. Wiley Interscience, July 2009.

Drinkall M. J., Zaffagnini, V., Süss, L., Locatelli, D. P. 2003. Efficacy of sulfuryl fluoride on stored-product insects in a semolina mill trial in Italy. In: Credland, P. F., Armitage, D. M., Bell, C. H., Cogan P. M., Highley, E. (eds.), Advances in Stored Product Protection, proceedings of the 8th International Working Conference on Stored Product Protection, 22-26 July in York, UK, CAB International, London, 884-887.

Drinkall, M. J., Dugast, J. F., Reichmuth, Ch., Schöller M. 1996. The activity of the fumigant sulfuryl fluoride on stored product insects. In: Wildey, K. B. (ed.), Proc. 2nd International Conference on Insect Pests in the Urban Environment, 7-10 July in Edinburgh, Scotland, UK, 525-528.

Ducom, P. 2012. Methyl bromide alternatives. Navarro et al., 2012a, 205-214.

Ducom, P., Dupuis, S., Stefanini, V., Guichard, A. A. 2003. Sulfuryl fluoride as a new fumigant for the disinfestations of flour mills in France. In: Credland, P. F., Armitage, D. M., Bell, C. H., Cogan P. M., Highley, E. (eds.), Advances in Stored Product Protection, proceedings of the 8th International Working Conference on Stored Product Protection, 22-26 July in York, UK, CAB International, London, 900-903.

Ducom, P., Frérot, E., Reichmuth, Ch. 2014. Relative importance of fumigation in integrated management of stored-grain insect pests in some EU countries (France and Germany). In: Athanassiou et al., 2014. 275-294.

EPA, 2011. Sulfuryl Fluoride; Proposed Order Granting Objections to Tolerances and Denying Request for a Stay. Federal Register Vol. 76 No 12 Page 3444.

FAMIC, 2014. Agrochemical database in Japan, Food and Agricultural Materials Inspection Center (in Japanese, http://www.acis.farmic.go.jp/index_kensaku.htm).

Fields, P. G. 2012. Novel fumigants and heat treatments for flour mills. Navarro et al., 2012a, 333-344.

Finkelman, S., Lendler, E., Navarro, S., Navarro, H., Ashbell, G. 2010. New prospects for ethyl formate as a fumigant for the date industry. 10th International Working Conference on Stored Product Protection. Julius-Kühn-Archiv 425, 359-364.

Finkelman, S., Navarro, S., Navarro, H., Lendler, E. 2012. “VAPORMATETM” an alternative fumigant for QPS treatments. Navarro et al., 2012a, 247-253.

Fleurat-Lessard, F., Fuzeau, B. 2014. High-Temperature-Short-Time (HTST) disinfestation of wheat grain infested by *Sitophilus* spp. pre-emergent stages with a laboratory scale fluidized-bed. In: Athanassiou et al., 213-222.

Flingelli, G., Schöller, M., Klementz, D. W., Reichmuth, Ch. 2014. Einfluss von Temperatur und Expositionsdauer auf die Mortalität von *Tribolium castaneum* Eiern unter Begasung mit Sulfurylfluorid im Hinblick auf die fortschreitende Entwicklung [Influence of temperature and exposure time on the mortality of *Tribolium castaneum* eggs during fumigation with sulfuryl fluoride with regard to the progressive egg development.] (online: www.JKI.de), Journal für Kulturpflanzen 66, 7-14.

Flingelli, G., Schöller, M., Reichmuth, Ch. 2012. Efficacy of sulfuryl fluoride towards eggs of *Tribolium castaneum* (Herbst, 1797). In : Proceedings of the Conference on General and Applied Entomology, 21-24 March 2011 in Berlin, Germany, Mitteilungen der deutschen Gesellschaft für allgemeine und angewandte Entomologie 18, online: http://www.dgaae.de, 447-450.

Floréal, D., Baslé, K., Mounier, A., Queixalos, I., Robbiola, L., Ducom, P., Ciesla, Y., Fritsch, J. 2012. The disinfestations of historical monuments: Gas substitutes for methyl bromide. Navarro et al., 2012a, 222-230.

Gautam, S. G.; Opit, G. O., Walse, S. 2013. Efficacy of propylene oxide in combination with carbon dioxide against eggs of stored-product insect pests. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 3-7 November in San Diego, CA, USA, MBAO conference, www.mbao.org, 29-1.

Guogang, X., Guangli, S., Shengjie, J., Jiade, S., Lichao, J., CaiFeng, Ch., Guanghui, Sh. 2008. Application researches on fumigation by combination of sulfuryl fluoride and carbon dioxide in cereals. In: Daolin, G., Navarro, S., Jian, Y., Chang, T., Zuxun. J., Yue, L., Yang, L., Haipeng, W. (eds.), Proceedings of the 8th International Conference on Controlled Atmosphere and Fumigation in Stored Products, 21-26 September 2008 in Chengdu, China. Sichuan Publishing Group, Sichuan Publishing House of Science and Technology, Chengdu, China, 233-237.

Hallman, G.J. 2013. Control of stored product pests by ionising radiation. Journal of stored Products Research 52, 36-41.

Haouell, S., Khouja, M. L., Boudabous, A., Jemâa, J. M. B. 2012. Use of eucalyptus essential oils as fumigants for the control of three stored food legume weevils. Navarro et al., 2012a, 71-75.

Hardin, J.A., Jones, C.L., Bonjour, E.L., Noyes, R.T., Beeby, R.L., Eltiste, D.A., Decker, S. 2010. Ozone fumigation of stored grain; closed loop recirculation and the rate of ozone consumption. Journal of stored Products Research 46, 149-154.

Hartzer, M., Subramanyam, B., Brijwani, M. Chayaprasert, W., Maier, D. E. 2010a. Methyl bromide, sulfuryl fluoride and heat: effectiveness against red flour beetle. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Reserarch Conference on Methyl Bromide Alternatives and Emissions Reductions, 2-5 November in Orlando, Fl., USA, MBAO conference, www.mbao.org, 67-1 – 67-4.

Hartzer, M., Subramanyam, B., Chayaprasert, W., Maier, D. E., Savoldelli, S., Campbell, J. F., Flinn, P. W. 2010b. Methyl Bromide and sulfuryl fluoride effectiveness agaist red flour beetle life stages. In: Daolin, G., Navarro, S., Jian, Y., Chang, T., Zuxun. J., Yue, L., Yang, L., Haipeng, W. (eds.), Proceedings of the 8th International Conference on Controlled Atmosphere and Fumigation in Stored Products, 21-26 September 2008 in Chengdu, China. Sichuan Publishing Group, Sichuan Publishing House of Science and Technology, Chengdu, China, Julius-KühnArchiv 429, 365-370.

Hasan, M. M., Phillips, T. W., Aikins, M. J. 2012. Potential for ozone fumigation against anobiid beetles infesting stored products as an alternative to methyl bromide. Navarro et al., 2012a, 260-265.

Huiyi, Z., Yang, C., Hongqin, Z., Yanyu, L., Jie, L., Jin, L. 2012. Comparison with pressure swing adsorption and membrane separation nitrogen for reduce oxygen at stored grain in horizontal warehouse. Navarro et al., 2012a, 509-516.

Jayas, D., Jian, F. 2012. Integrated commodity management. Navarro et al., 2012a, 705-714.

Jeffers, L. 2014. PPQ Phytosanitary irradiation program. Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 4-6 November in Orlando, FL, USA, MBAO conference, www.mbao.org, MBAO Paper 43.

Jemâa, J. M. B, Haouel, S., Khouja, L. 2012. Control of the carob moth *Ectomyelois ceratoniae* with essential oil fumigation. Navarro et al., 2012a, 58-62.

Jemâa, J. M. B., Haouel, S., Khouja, M. L. 2013. Efficacy of Eucalyptus essential oils fumigant against *Ectomyelois ceratoniae* (Lepidoptera: Pyralidae) under various space occupation conditions. Journal of stored Product Research 49, 67-71.

Jiao, S., Johnson, J. A., Tang, J., Wang, S. 2012. Industrial scale radio frequency treatments for insect control in lentils. Journal of stored Products Research 48, 143-148.

JIIDCP, 2014. Approved chemicals list for the treatment of cultural heritages, Japan Institute of Insect Damage to Cultural Properties (in Japanese, http://www.bunchuken.or.jp/chemical/).

Karakoyun, N. S., Emekci, M. 2010. The efficacy of sulfuryl fluoride against egg stages of dried fruit beetle. In: Obenauf, G. L. (ed.), proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 2-5 November in Orlando, Fl., USA., MBAO conference, www.mbao.org, 55-1 – 55-4.

Kaur, R., Schlipalius, D.I., Collins, P.J., Swain, A.J., Ebert, P.R. 2012. Inheritance and relative dominance, expressed as toxicity response and delayed development, of phosphine resistance in immature stages of *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae). Journal of stored Products Research 51, 74-80.

Kenaga, E. E. 1957. Some biological, chemical and physical properties of sulfuryl fluoride as an insecticidal fumigant. Journal of economic Entomology 40, 1-6.

Khemira, S., Jemâa, J. M. B., Khouija, M. L. 2012. Fumigant toxicity of *Eucalyptus transcontinentalis* essential oil against eggs and adults of the carob moth *Ectomyelois ceratoniae*. Navarro et al., 2012a, 325-328.

Klementz, D., Rassmann, W., Reichmuth, Ch. 2008. Sulfuryl fluoride – efficacy against *Tribolium castaneum* and *Ephestia kuehniella* and residues of the gas in flour after fumigation of mills. In: Daolin, G., Navarro, S., Jian, Y., Chang, T., Zuxun. J., Yue, L., Yang, L., Haipeng, W. (eds.), Proceedings of the 8th International Conference on Controlled Atmosphere and Fumigation in Stored Products, 21-26 September 2008 in Chengdu, China. Sichuan Publishing Group, Sichuan Publishing House of Science and Technology, Chengdu, China, 533-537.

Korunic, Z., Kalinovic, I., Rozman, V., Loska, A. 2012. One-year protection of stored wheat with several grain protectants. Navarro et al., 2012a, 715-720.

Kucerova, Z., Kyhos, K., Aulicky, R., Stejskal, V. 2012. Improvementof vacuum effect on mortality of *Sitophilus granarius* (Curculionidae) using oxygen chemical absorber in laboratory conditions. Navarro et al., 2012a, 76-80.

Kurlanski, M., Salt: A world history. 2002. Penguin Books, 484 pp.

Lawrence, J., Subramaniam, B., Meier, D. E., Chayaprasert, W. 2012. Efficacy of sulfuryl fluoride against eggs and adults of *Tribolium castaneum* in commercial flour mills. Navarro et al., 2012a, 291.

Lehms, M., Baier, B., Wurst, S., Schöller, M., Reichmuth, Ch. 2012: Zum Eiablageverhalten der vorratsschädlichen Milben *Acarus siro* **und** *Tyrophagus putrescentiae* auf verschiedenen Substraten und durch feinmaschige Gaze [Egg laying behaviour of the stored product pest mites *Acarus siro* and *Tyrophagus putrescentiae* on different substrates and through fine mesh Nylon gauze]. In: Julius Kühn-Institut (ed.), Julius-Kühn-Archiv 438, Proceedings of the 58th Deutsche Pflanzenschutztagung, 10 - 14 September 2012 in Braunschweig, Germany, ISBN 978-3-30037, http://pub.jki.bund.de/index.php/JKA/ article/view/670/2244, 500 pp., 75.

Linde 2013 http://cropscience.linde-gas.com/en/products_services/vapormate.html

Ling, Z., Xinfu, Z., Qing, X., Jiadong, Ch. 2008. Efficacy of sulfuryl fluoride on stored grain pests in a warehouse trial in China. In: Daolin, G., Navarro, S., Jian, Y., Chang, T., Zuxun. J., Yue, L., Yang, L., Haipeng, W. (eds.), Proceedings of the 8th International Conference on Controlled Atmosphere and Fumigation in Stored Products, 21-26 September 2008 in Chengdu, China. Sichuan Publishing Group, Sichuan Publishing House of Science and Technology, Chengdu, China, 579-582.

Liu, Y.-B. 2013a. Nitric oxide as a potent fumigant for postharvest pest control. J. Econ. Entomology 106: 2267-2274.

Liu, Y.-B. 2013b. Prospect of no fumigation for postharvest pest control. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 3-7 November in San Diego, CA, USA, MBAO conference, www.mbao.org, 28-1 – 28-3.

Malushkov, G., Prokopov, D., Tikhonova, L. 2012. Active cell phosphine generator SGF-M2 and fumigation technologies with its use. Navarro et al., 2012a, 353-357.

Manickavasagan, A., Alahakoon, P. M. K., Al-Busaidi, T. K., Al-Adawi, S., Al-Wahaibi, A. K., Al-Raeesi, A. A., Al-Yahyai, R., Jayas, D. S. 2013. Disinfestation of stored dates using microwave energy. Journal of stored Products Research 55, 1-5.

Mbata, G. N., Smith, D., Mcneal, K. 2012. Monoterpenoids as fumigants in the management of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) oviposition deterrence and mortality of developmental stages. Navarro et al., 2012a, 44-49.

MBTOC 2007. 2006 Assessment Report of the Methyl Bromide Technical Options Committee. UNEP, Nairobi, online: ozone.unep.org, 482 pp.

MBTOC 2011a. 2010 Assessment Report of the Methyl Bromide Technical Options Committee. UNEP, Nairobi, online: ozone.unep.org, 398 pp.

MBTOC 2011b. Progress Report 2011, Special Review on achieving control of pest eggs by sulfuryl fluoride. In: TEAP Progress Report, May 2011, 245 pp, online: ozone.unep.org, 108- 136.

McClurkin, J. D., Maier, D. E., Ileleji, K. E. 2013. Half-life time of ozone as a function of air movement and conditions in a sealed container. Journal of stored Products Research 55, 41-47.

Meikle, R. W., Stewart, D., Globus, O. A. 1963. Drywood termite metabolism of Vikane fumigant as shown by labelled pool technique. Journal of Agriculture, Food and Chemistry 11, 226-230.

Mück, O., Stock, A. 2012. Occupational safety in import containers containing fumigants, other gases and volatile substances: Practical experiences. Navarro et al., 2012a, 193-197.

Muhareb, J. 2009. Evaluation of combining sulfuryl fluoride, propylene oxide and carbon dioxide for stored product insect control. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 11-13 November in San Diego, CA, USA, MBAO conference, www.mbao.org, 64-1 – 64-2.

Naik, R. C., Shroff, R. D. 2012a. NDIR based SO_2F_2 detector for fumigation monitoring. Navarro et al., 2012a, 374-378.

Naik, R. C., Shroff, R. D. 2012b. Automatic online phosphine monitoring system for fumigation. Navarro et al., 2012a, 596-599.

Navarro S., Finkelman S., Rindner M., Dias R., 2004. Heat treatment for disinfestation of nitidulid beetles from dates. In: Batchelor, T., Alfarroba, F. (eds), Proceedings of the International Conference on Alternatives to Methyl Bromide, 27-30 September 2004 in Lisbon, Portugal, 297-300.

Navarro, S. 2012. Global challenges for the successful application of MA and hermetic storage. Navarro et al., 2012a, 429-439.

Navarro, S., Athanassiou, Ch., Varnava, A., Vroom, N., Yilasoumis, D., Leandrou, I., Hadjiannou, S. 2012b. Control of stored grain insects by using nitrogen in large concrete silos in Cyprus. In: Navarro et al., 2012a, 478-487.

Navarro, S., Banks, H. J., Jayas, D. S., Bell, C. H., Noyes, R. T., Ferizli, A. G., Emecki, M., Isikber, A. A., Alagusundaram, K. (eds.) 2012a. Proceedings of 9th International Conference on Controlled Atmosphere and Fumigation in Stored Products, 15-19 October 2012 in Antalya, Turkey744 pp., www.caf2012.org.

Navarro, S., Navarro, H., Finkelmann, S. 2014. Mortality of *Carpophilus hemipterus* eggs and larvae under the influence of thermal disinfestation. In: Athanassiou et al., 159-165.

Nayak, M. K. 2012. Managing resistance to phosphine in storage pests: Challenges and opportunities. Navarro et al., 2012a, 609-619.

Negahban, M., Moharrmipour S., Zandi, M., Hashemi, S. A. 2012. Fumigant properties of nano-encapsulated essential oil from *Artemisia sieberi* on *Tribolium castaneum.* Navarro et al., 2012a, 101-105.

Newman, Ch. R., Emery, N. N., Chami, M. 2012c. Eradication of a strain of a strong phosphine resistant insect population from steel farm silos in Western Australia. Navarro et al., 2012a, 644-652.

Newman, Ch., Newman, J., Cheng, H., Ren, Y. 2012a. Investigation of thermosiphons pipes to distribute phosphine gas through garin silos from ground level introduction point. Navarro et al., 2012a, 557-570.

Newman, Ch., Newman, J., Cheng, H., Ren, Y. 2012b. An experimental procedure to eradicate strong phosphine resistant grain insects from unsealed steel silos using ethyl formate. Navarro et al., 2012a, 661-664.

Nguemtchouin, M. G. M., Ngassoum, M. B, Chalier, P., Kamga, R., Ngamo, L. S. T., Cretin, M. 2013. *Ocimum gratissimum* essential oil and modified montmorillonite clay, a means of controlling insect pests in stored products. Journal of stored Products Research, 49, 57-62.

Noomhorm, A., Sirisoontaralak, P., Uraichuen, J., Ahmad, I. 2013. Efficacy of atmospheric and pressurized carbon dioxide or air against *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) and *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) in milled rice. J. Stored Products Research 54, 48-53.

Noppe, H., Buckley, S., Ruebsamen, B. 2012. Possibilities of PROFUME gas fumigant for the commercial fumigation of stored cocoa beans in EU. Navarro et al., 2012a, 379-383.

Olivero-Verbel, J., Tirado-Bellestas, I., Caballero-Gallardo, K., Stashenko, E. E. 2013. Essential oils applied for the food act as repellents towards *Tribolium castaneum*. J. Stored Products Research 49, 145-147.

Osbrink, W. L. A., Scheffrahn, R. H., Hsu, R.-C., Su, N.-Y. 1988. Sulfuryl fluoride residues of fumigated foods protected by polyethylene film. Journal of Agriculture and Food Chemistry 36, 853-855.

Outram, I. 1967a. Factors affecting the resistance of insect eggs to sulphuryl fluoride – The uptake of sulphuryl^{35}S fluoride by insect eggs. Journal of stored Products Research 3, 255-260.

Outram, I. 1967b. Factors affecting the resistance of insect eggs to sulphuryl fluoride – II: The distribution of sulphuryl^{35}S fluoride in insect eggs after fumigation. Journal of stored Products Research 3, 353-358.

Park, Ch.-G., Cho, J.-H., Yoo, M., Kim, B.-S., Lee, B.-H., Ren, Y.L. 2012. Ethanedinitrile (C_2N_2): Timber and log fumigation update. Navarro et al., 2012a, 421-425.

Phillips, T., and W. Schilling 2013. Fumigation alternatives for the ham mite, *Tyrophagus putrescentiae*: Challenges and prospects. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 3-7 November in San Diego, CA, USA, MBAO conference, www.mbao.org, 38-1.

Phillips, T. W., Hasan, M. M., Aikins, M. J. 2012a. Potential for phosphine and sulfuryl fluoride as replacements for methyl bromide to control pests of dried meat. Navarro et al., 2012a, 280.

Phillips, T. W., Hasan, M. M., Aikins, M. J., Abbar, S., Amoah, B. 2012b. Non-chemical treatments for potential disinfestation of two major arthropod pests of Southern dry-cured hams. Navarro et al., 2012a, 542.

Phillips, T. W., Hasan, M. M., Aikins, M. J., Mahroof, R. 2011. Fumigation and IPM. Alternatives for arthropod pests of museums. J. Ent. Acarol. Res. 43, 205-210.

Phillips, T. W., Hasan, M. M., Aikins, M. J., Schilling, M. W. 2008. Efficacy of sulfuryl fluoride to control ham mites and red-legged ham beetles. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emission Reduction, 11-14 November in Orlando, FL, USA, MBAO conference, www.mbao.org, 89-1 - 89-2.

Phillips, T. W., Opit, G. P., Aikins, M. J., Hasan, M. M. 2012c. Phosphine resistance in major stored grain insects in the USA. Navarro et al., 2012a, 659.

Plarre, R. 2013. Review: More than a pest magement tool – 45 years of practical experience with insect pheromones in stored-product and material protection. Journal of Plant Diseases and Protection 120, 145-152.

Pons, M.J., Camara, A.G., Guri, S., Riudavets, J. 2010. The use o carbon dioxide in big bags and containers for the control of pests in food products. In: Cavalho, M. O., Fields, P. G., Adler, C. S., Arthur, F. H., Athanassiou, C. G., Campbell, J. F., Fleurat-Lessard, F., Flin, P. W., Hodges, R. J., Isikber, A. A., Navarro, S., Noyes, R. T., Riudavets, J., Sinha, K. K., Thorpe, G. R., Timlick, B. H., Trematerra, P., White, N. D. G. (eds.), Proceedings of the 10th International Working Conference on Stored Product Protection, 27 June – 2 July 2010 in Estoril, Portugal, Julius-Kühn-Archiv 425, Vol. 1, ISBN 978-3-930037-71-1, pdf online: www.jki.bund.de, 414- 418.

Pupin, F., Bikoba, V., Biasi, W. B., Pedroso, G. M., Ouyang, Y., Grafton-Cardwell, E., Mitcham, E. J. 2013. Postharvest control of western flower thrips (Thysanoptera: Thripidae) and California red scale (Homoptera: Diaspididae) with ethyl fromate and its impact on citrus fruit quality. Journal of Economic Entomology 106, 2341-2348.

Purohit, P., Jayas, D.S., Yadav, B.K., Chelladurai, V., Fields, P.G., White, N.D.G. 2013. Microwaves to control *Callosobruchus maculatus* in stored mung bean (*Vigna radiata*). Journal of stored Products Research 53, 19-22.

Reichmuth, Ch. 2007a. Fumigants for pest control in wood protection. In: Noldt, U, Michels, H. (eds.), Proceedings of an International Symposium on "Wood Pest Insects in Focus – Alternative Measures to Preserve Historical Buidings", 28-30 June in Detmold, Germany, Merkur Verlag, Detmold, 265 pp, 137-162.

Reichmuth, Ch. 2007b. Safer and more efficient use of fumigants to reduce the dosage. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Conference on Methyl Bromide Alternatives and Emissions Reductions, (MBAO), 29 October 29 – 1 November in San Diego, CA, USA, MBAO conference, www.mbao.org, 79-1 – 79-2.

Reichmuth, Ch. 2010a. Pest control and constraints in flour mills. In: Reichmuth, Ch. (ed.), International European Symposium on Stored Product Protection „Stress on Chemical Products", 25-26 May 2009 in Berlin, Julius-Kühn-Archiv 429, online : www.jki.bund.de, 10-13.

Reichmuth, Ch. 2010b. Fumigants in stored product protection. In: Reichmuth, Ch. (ed.), International European Symposium on Stored Product Protection „Stress on Chemical Products", 25-26 May 2009 in Berlin, Julius-Kühn-Archiv 429, online : www.jki.bund.de, 429, 56-64.

Reichmuth, Ch. 2013. Aussichten für Vorratsschädlinge [Prospects for stored product pests]. (online: www.JKI.bund.de), Journal für Kulturpflanzen 65, 85-93.

Reichmuth, Ch., Klementz, D. 2008a. How to overcome the egg-weakness of sulfuryl fluoride – combination of control methods. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 11-14 November in Orlando, Fl., USA., MBAO conference, www.mbao.org, 88-1 – 88-4.

Reichmuth, Ch., Klementz, D. 2008b. Pest control in stored product and material protection with sulfuryl fluoride. In: proceedings of the Conference on General and Applied Entomology, 26.2. – 1.3. 2007 in Innsbruck, Östereich, Mitteilungen der deutschen Gesellschaft für allgemeine und angewandte Entomologie 16, Giessen, online: http://www.dgaae.de, 309-312.

Reichmuth, Ch., Rassmann, W., Binker, G., Fröba, G., Drinkall, M. J. 2003. Disinfestation of rust-red flour beetle (*Tribolium castaneum*), saw-toothed grain beetle (*Oryzaephilus surinamensis*), yellow meal worm (*Tenebrio molitor*), Mediterranean flour moth (*Ephestia kuehniella*), and Indian meal moth (*Plodia interpunctella*) with sulfuryl fluoride in flour mills. In: Credland, P. F., Armitage, D. M., Bell, C. H., Cogan P. M., Highley, E. (eds.), Advances in Stored Product Protection, Proceedings of the 8th International Working Conference on Stored Product Protection, 22-26 July in York, UK, CAB International, London, 736-738.

Reichmuth, Ch., Schneider, B., Drinkall, M. J. 1999. Sulfuryl fluoride (Vikane) against eggs of different age of the Indian meal moth *Plodia interpunctella* (Hübner) and the Mediterranean flour moth *Ephestia kuehniella* Zeller. In: Zuxun, J., Quan, L., Yongsheng, L., Xianchang, T., Lianhua, G. (Eds.), Proceedings of the 7th International Working Conferece on Stored-Product Protection, 14-19 October 1998 in Beijing, P. R. China, Sichuan Publishing House of Science & Technology, Oct. 1999, Chengdu Province, P. R. China, Vol. 1, 416-422.

Reichmuth, Ch., Unger, A., Unger, W., Blasum, G., Piening, H., Rohde-Heer, P., Plarre, R., Pöschko, M., Wudtke A. 1993. Nitrogen-flow fumigation fort he preservation of wood, textiles, and other organic material from insect damage. In: Navarro, S., Donahaye, E. (eds.), Proceedings of an International Conference on Controlled Atmospheres and Fumigation in Grain Storage, 11-13 June 1992 in Winnipeg, Canada, Jerusalem Caspit Press Ltd, 121-128.

Ren, Y. L., Lee, B.-H., Padovan, B. 2011. Penetration of methyl bromide, sulfuryl fluoride, ethanedinitrile and phosphine into timber blocks and the sorption rate of the fumigants. Journal of stored Products Research 47, 63-68.

Ren, Y. L., Mahon, D. 2006. Fumigation trials on the application of ethyl formate to wheat, split faba beans and sorghum in small metal bins. Journal of stored Products Research 42, 277-289.

Ren, Y. L., Yang, C., Newman, J., Agarwal, M., Kostas, E., Cheng, H. 2012. Nitrogen application offers for both control of insect and grain quality. Navarro et al., 2012a, 471-477.

Ridley, A. W., Burrill, P. R., Cook, C. C., Daglish, G. J. 2011. Phosphine fumigation of silo bags. Journal of stored Products Research 47, 349-356.

Ridley, A. W., Schlipalius, D.I., Daglish, G.J. 2012. Reproduction of phosphine resistant *Rhyzopertha dominica* (F.) following sublethal exposure to phosphine. Journal of stored Products Research 48, 106-110.

Riudavets, J., Castañé, C., Alomar, O., Pons, Mª. J., Gabarra, R. 2009. Modified Atmosphere Packaging (MAP) as an alternative measure for controlling nine pests that attack processed food products. Journal of Stored Products Research 45, 91-96.

Riudavets, J., Pons, M.J., Gabarra, R., Castane, C., Alomar, O., Vega, L.F., Guri, S. 2014. The toxicity effects of atmospheres with high content of carbon dioxide with addition of sulphur dioxide on two stored-product pest species. Journal of stored Products Research 57, 58-62.

Ryan, R. F., Shore, W. P. 2012. The use of gaseous phosphine by onsite mixing. Navarro et al., 2012a, 358-362.

Sabio, G. C., Dator, J. V., Austria, M. C., Mesa, V. G. 2102. Laboratory studies on the application of hermetic storage for preserving arabica coffee. Navarro et al., 2012a, 523-534.

Sánchez-Ramos, I., Castañera, P. 2005. Effect of temperature on reproductive parameters and longevity of *Tyrophagus putrescentiae* (Acari: Acaridae). Experimental and Applied Acarology 36, 93-105.

Schaub, J. 2010. Five economic principles applied to stored product protection. In: Reichmuth, Ch. (ed.), International European Symposium on Stored Product Protection „Stress on Chemical Products“, 25-26 May 2009 in Berlin, Julius-Kühn-Archiv 429, online: www.jki.bund.de, 429, 23-25.

Scheffrahn, R. H., Hsu, R.-C., Su, N.-Y. 1990. Evaluation of polymer film enclosures as protective barriers for commodities from exposure to structural fumigants. Journal of Agriculture and Food Chemistry 38, 904-908.

Schöller, M. 1998. Biologische Bekämpfung vorratsschädlicher Arthropoden mit Räubern und Parasitoiden – Sammelbericht und Bibliographie [Biological control of stored product arthropods with predators and parasitoids – a review and bibliography]. In: Reichmuth, Ch. (ed.), Wichtige Arbeitsschwerpunkte im Vorratsschutz, Mitteilungen der Biologischen Bundesanstalt für Land- und Forstwirtschaft, Heft 342, Parey Buchverlag Berlin, 341 pp., online: www.jki.bund.de, 85-189.

Schöller, M. 2010. Biological control of stored product insects in commodities, food processing facilities and museums. In: Cavalho, M. O., Fields, P. G., Adler, C. S., Arthur, F. H., Athanassiou, C. G., Campbell, J. F., Fleurat-Lessard, F., Flin, P. W., Hodges, R. J., Isikber, A. A., Navarro, S., Noyes, R. T., Riudavets, J., Sinha, K. K., Thorpe, G. R., Timlick, B. H., Trematerra, P., White, N. D. G. (eds.), Proceedings of the 10th International Working Conference on Stored Product Protection, 27 June – 2 July 2010 in Estoril, Portugal, pdf online: www.jki.bund.de, Julius-Kühn-Archiv 425 (1), 596-606.

Schöller, M. 2013. Checkliste der mit Vorräten assoziierten Insekten Deutschlands [Checklist of stored product insects in Germany]. Journal für Kulturpflanzen 65, 192-203.

Schöller, M., Prozell, S. 2014. Stored-product insects and their natural enemies in Germany: a species-inventory. In: Athanassiou et al., 27-34.

Schöller, M., Prozell, S., Al-Kirshi, A.-G., Reichmuth, Ch. 1997: Towards biological control as a major component of integrated pest management in stored product protection. Journal of Stored Products Research 33, 81-97.

Sekhon, R. K., Schilling, M. W., Phillips, T. W., Hasan, M. M., Aikens, M. J., Mikel, W. B. 2009a. Chemical composition of dry cured hams fumigated with carbon dioxide. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emission Reduction, 10-13 November in San Diego, CA, MBAO conference, www.mbao.org, 58-1 – 58-3.

Sekhon, R. K., Schilling, M. W., Phillips, T. W., Hasan, M. M., Aikens, M. J, Mikel, W. B. 2009b. Chemical composition of dry cured hams fumigated with phosphine. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emission Reduction, 10-13 November in San Diego, CA, MBAO conference, www.mbao.org, 59-1 – 59-3.

Sekhon, R. K., Schilling, M. W., Phillips, T. W., Hasan, M. M., Aikens, M. J. Mikel, W. B. 2010a. Sulfuryl fluoride fumigation effects on the safety, volatile composition, and sensory quality of dry cured ham. Meat Science 84, 505-511.

Sekhon, R. K., Schilling, M. W., Phillips, T. W., Hasan, M. M., Aikens, M. J., Nannapaneni, R., Mikel, W. B. 2010b. Effects of carbon dioxide and ozone treatments on the volatile composition and sensory quality of dry cured ham. Journal of Food Science 75, 452-458.

Sekhon, R. K., Schilling, M. W., Phillips, T. W., Hasan, M. M., Aikens, M. J., Corzo, A. Mikel, W. B. 2010c. Effects of phosphine and methyl bromide fumigation on the volatile flavor profile and sensory quality of dry cured ham. Meat Science 86, 411-417.

Sen, F., Aksoy, U., Tan, G. 2012a. Determining effect of sulfuryl fluoride fumigation on dried aprocots, raisins, and hazelnuts quality. Navarro et al., 2012a, 315-320.

Sen, F., Meyvaci, K. B., Turanli, F., Aksoy, U. 2010. Effects of short term controlled atmosphere treatment at elevated temperature on dried fig fruit. Journal of stored Products Research 46, 28-33.

Sen, F., Meyvaci, K. B., Turanli, F., Aksoy, U. 2012b. Influence of controlled atmosphere treatment on storage pests and qualöity of sun-dried fig fruits. Navarro et al., 2012a, 517-522.

Shi, M., Collins, P.J., Ridsdill-Smith, J., Renton, M. 2012. Individual-based modelling of the efficacy of fumigation tactics to control lesser grain borer (*Rhyzopertha dominica*) in stored grain. Journal of stored Products Research 51, 23-32.

Son, Y., Chon, I, Neven, L., Moon, Y., Cho, D., Kim, Y. 2012. Controlled atmosphere and temperature treatment systems to disinfest peach fruit moth, *Carposina sasakii* Matsumura (Lepidoptera: Carposinidae) on apples. Navarro et al., 2012a, 279.

Sotirouadas, V. 2012. Controlled atmospheres: Low-oxygen disinfestation of post harvest commodities in chambers and silos in Greece. Navarro et al., 2012a, 466-470.

Steidle, J. L. M., Niedermayer, S. 2013. Was Professor Hase noch nicht wußte: Biologische Bekämpfung von Vorratsschädlingen mit der Lagererzwepe: Vergangenheit, Gegenwart und Zukunft [Biological control of stored product pests using the parasitoid *Lariophagus distinguendus*: Past, presence and future]. (online: www.JKI.de), Journal für Kulturpflanzen 65, 123-126.

Subramaniam, B., Hulasare, R., Brijwani, M., Leitman, M. 2012. Effectiveness of heat treatments against *Tribolium castaneum* life stages in two commercial food-processing facilities. Navarro et al., 2012a, 281-290.

Tado, C. J. M., Gummert, M. 2012. Status and prospects of hermetic storage of rice seeds in the Philippines. In: Navarro et al., 2012a, 459-465.

Tao, Z, Shiwei, L., Yanyu, L., Yang, C., Guangtao, L., Yongkui, C., Zihai, Z. 2012. Mortality of four stages of *Lasioderma serricorne* (Fabricius) exposed to low oxygen. In: Navarro et al., 2012a, 17-25.

Tapondjou, A. L. 2014. Phytochemicals and semio-chemical use in integrated protection of stored products programs. In: Athanassiou et al., 83-97.

TEAP 2010. May 2010 Progress Report. Vol. 2, Chapter 8: Decision XXI/10 Quarantine and Pre-Shipment Report. UNEP: Nairobi, Kenya, online: ozone.unep.org, 295 pp, 89-158.

TEAP 2010. Report of the Technology and Economic Assessment Panel, May 2010 - Volume 2 Progress Report. UNEP, Nairobi, Kenya, online: ozone.unep.org, 279 pp.

TEAP 2011. Report of the Technology and Economic Assessment Panel, May 2011 - Volume 2 Progress Report. UNEP, Nairobi, Kenya, online: ozone.unep.org.

TEAP 2012. May 2012 Progress Report. Chapter 10: Quarantine and Pre-Shipment uses of Methyl Bromide – Response to Decision XXIII/5. UNEP, Nairobi, Kenya, online: ozone.unep.org, 267 pp, 164-216.

Thalavaisundraram, S., Roynon, J. 2012. Penetration capacity of VAPORMATE™ TM into commercially plastic wrapped cardboard boxes filled with sultanas for controlling stored product pests. In: Navarro et al., 2012a, 384-388.

Thoms, E., Annetts, R., Williamson, P., Cornally, D., Bishop, S., Ryan, R. 2012. Evaluation of PROFUME® gas fumigant (sulfurylfluoride) in ambient air adjacent to a bulk grain storage in Australia. In: Navarro et al., 236-240.

Tsai, W.-T., Mason, L. J., Chayaprasert, W., Maier, D. E., Ileleji, K. E. 2011. Investigation of fumigant efficacy in flour mills under real-world fumigation conditions. Journal of stored Products Research 47, 179-184.

Tumambing, J., Depalo, M., Garnier, J. P., Mallari, R. 2012a. ECO_2FUME and $VAPORPH_3$PHOS phosphine fumigants – Global application updates. In: Navarro et al., 2012a, 363-373.

Tumambing, J., Mallari, R., Widayanti, S., Hararap, I. S., Salazar, G. 2012b. Phosphine fumigation protocols using ECO_2FUME® for complete control of strongly resistant cigarette beetle, *Lasioderma serricorne*, in Indonesia. In: Navarro et al., 2012a, 624-632.

Ulrichs, Ch., Mewis, I. 2013. Nanostrukturierte Silikate: Insektizide Wirkung und neue Entwicklungen [Nanostructured silicas – insecticidal effects and new developments]. (online: www.JKI.de), Journal für Kulturpflanzen 65, 118-122.

Vacquer, B., Lethuillier, L., Brunel, M., Fraterno, R., Fleurat-Lessard, F. 2014. First application in France of heat disinfestation of a large wheat mill. In: Athanassiou, Ch. G. et al., 243-251.

Vital, P. S. R. V. S., Roy, S., Modak, A., Venkat, P. S. R. A., Vegi, V. R., Ramana, M. R. S. V., Rajeshakar, R. 2012. Post fumigation product management: Hygiene and infestation management in leaf operations (HIMILO): An IPM system and on-line quality audit to protect fumigated tobacco stocks for long periods from cigarette beetle *Lasioderma seccicorne*. In: Navarro et al., 2012a, 738-739.

Wakil, W., Riasat, T., Saeed, N., Ashraf, M., Yasin, M. 2012. Fumigant activity of some essential oils aginst four major insect pests of stored grain. In: Navarro et al., 2012a, 389-395.

Walse, S. 2009. Ovicidal efficacy of sulfury fluoride to stored-product pests of dried fruit. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emission Reduction, 9 – 12 November in San Diego, CA, USA, MBAO conference, www.mbao.org, 60-1 - 60-2.

Walse, S. 2012. Personal communication. January 2013

Wang, D., Hui, L. 2012. Comparative mortality of *Liposcelis entomophila* (Enderlein) to ethyl formate in empty bins. In: Navarro et al., 2012a, 416-420.

Wang, D., Tang, J., Johnson, J. A., Cavalieri, R. P. 2013. Heating uniformity and differential heating of insects in almonds associated with radio frequency. Journal of stored Products Research 55, 15-20

Widayanti, S., Harahap, I. S., Sunjaya. 2012. Efficacy and registration status of ECO_2FUME 2 LG against *Tribolium castaneum* (Herbst), *Sitophilus zeamais* Motschulsky and *Oryzaephilus surinamensis* (L.) on milled rice in Inonesia. In: Navarro et al., 2012a, 411-415.

Williams, L.H., Sprenkel, R.J. 1990. Ovicidal activity of sulfuryl fluoride to anobiid and lyctid beetle eggs of various ages. Journal of entomological Science 25, 366-375.

Williams, R. E. 2009. Control of carob moth (*Ectomyelosis ceratonia*) in fresh dates fumigated with ProFume®. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emission Reduction, 9-12 November in San Diego, CA, USA, MBAO conference, www.mbao.org, 63-1.

Williams, R., Thoms, E., 2008. ProFume® update: Post-harvest commercial acceptance and performance in the US. In: Obenauf, G. L. (ed.), Proceedings of the Annual International Research Conference on Methyl Bromide Alternatives and Emission Reduction, 11-14 November in Orlando Fl, CA, USA, MBAO conference, www.mbao.org, 84-1 – 84-2.

Wong, F., Castañé, C., Riudavets, Y. 2012. Lethal effect of CO_2 modified atmospheres on eggs of different age of two bruchid species. In: Navarro et al., 2012a, 26-31.

Xiaoping, Y., Yuxin, Ch., Guaogan, X., Juan, Z., Jiade, S., Guangli, Sh, Shengjie, J., Jialiang, W. 2008. Mortality of three stored product pests exposed to sulfuryl fluoride in laboratory and field tests. In: Daolin, G. et al. (eds.), Proceedings of the 8th International conference on Controlled Atmosphere and Fumigation, 21-26 September 2008, Chendu, Sichuan Publishing House of Science and Technology, Chengdu, 191-195.

Xin, N., Ren, Y. L., Forrester, R. I., Xue Ming, Mahon, D. 2008. Toxicity of ethyl formate to adult *Sitophilus oryzae* (L.), *Tribolium castaneum* (Herbst) and *Rhyzopertha dominica* (F.). Journal of stored Products Research 44, 241-256.

Yamada, K., Shukuya, T., Ogawa, N., Misumi, T. 2012. Mortality test of ethyl formate fumigation for leaf miner (*Liriomyza sativae*, *Liriomyza trifolii*) and Spider Mite (*Tetranychus cinnabarinus*, *Tetranychus kanzawai*). Res. Bull. Pl. Prot. Japan 48, 13□17 .

Yongxue, D., Wang, J., Dou, W., Yang, Z., Jiang, T.-K. 2010. Fumigation activities of ethyl formate on different strains of *Liposcelis bostrychophila*. In: Proceedings of the 10th International Working Conference on Stored Product Protection. Julius-Kühn-Archiv, 459-463.

Yongxue, D., Wang, J., Li, J. 2008. Toxicity of ethyl formate of adults of *Liposcelis entomophila*. In: Proceedings of the 8th International Conference on Controlled Atmosphere and Fumigation in Stored Products, 21-26 September 2008, Chendu, P.R.China, Sichuan Publishing House of Science and Technology, Chengdu, 212-238.

Yongxue, D., Wang, J., Li, J. 2008. Toxicity of ethyl formate of adults of *Liposcelis entomophila*. In: Daolin, G., Navarro, S., Jian, Y., Chang, T., Zuxun. J., Yue, L., Yang, L., Haipeng, W. (eds.), Proceedings of the 8th International Conference on Controlled Atmosphere and Fumigation in Stored Products, 21-26 September 2008 in Chengdu, China. Sichuan Publishing Group, Sichuan Publishing House of Science and Technology, Chengdu, China, 212-238.

Zakladnoy, G., Abdiushev, M., Soskin, M. 2012. Phosphine recirculation system in a metal bin. In: Navarro et al., 2012a, 603-606.

Zeng, L., Lao, Ch., Guo, Ch, Xian, Q, Zhen, M. 2012. Effects of controlled atmospheres for insect control and quality preservation of milled rice using three ways to reduce oxygen. In: Navarro et al., 2012a, 501-508.

Zhao, Y., Phillips, T. W., Abbar, S., Mikel, W. B., Schilling, M. W. 2012a. Effects of various food-grade coatings on mite mortality and sensory quality of dry cured ham. In: Obenauf, G. (ed.), Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 6-8 November in Orlando, FL, USA, MBAO conference, www.mbao.org, 77-1 - 77-3.

Zhao. Y., Phillips, T. W., Aikins, M. J., Mikel, W. B., Schilling. M. W. 2012b. Sensory evaluation and pest mortality of dry cured ham fumigated with phosphine in a simulated ham aging house. In: Obenauf, G. (ed.), Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 6-8 November in Orlando, FL, USA, MBAO conference, www.mbao.org, 78-1 – 78-3.

Ziaee, M., Moharrmipour, S. 2012. Fumigant toxicity of *Carum copticum* essential oil against *Sitophilus granarius*. In: Navarro et al., 2012a, 96-100.

7

Chapter 7. Factors assisting the methyl bromide phaseout in Article 5 countries and remaining challenges

7.1. Introduction

As per the mandate of Decision XXIII/12, this chapter updates the progress made in phasing out controlled uses of methyl bromide in Article 5 countries. In view of the phase-out date of 1st January 2015 already in place, it addresses challenges and factors that could potentially put the sustainability of the phase-out at risk. The major technologies implemented and the factors that have assisted MB phase-out in MLF projects and other efforts to replace MB are discussed.

By end of 2013 (the last date for which official data were available at the time of writing this report), about 86% of the controlled uses of MB in Article 5 Parties had been phased out. This was primarily achieved through MLF-funded projects implemented by the agencies of the Montreal Protocol, and has taken place at different rates in different regions. This chapter includes a list of the main types and objectives of such projects together with the main alternatives successfully replacing MB in different countries and regions. Detailed information on consumption trends in Article 5 countries including the key sectors using MB can be found in Chapter 3 of this Assessment Report.

Various information sources were used in compiling this chapter: the Data Access Centre of the Ozone Secretariat (accessed December 2014/ January 2015), the project database of the MLF Secretariat (accessed December 2014), MLF project reports submitted by governments, information provided by national specialists and implementing agencies, and published papers listed in section 7.3.

7.2. Methyl Bromide phase-out in Article 5 regions overview

Although overall MB phase-out has progressed substantially in all A-5 regions, this has occurred at different speeds (see section 3.5.1 and Fig 7-1 of this report). The phase-out situation up to 2013 (as reported to the Ozone Secretariat) is presented below in Table 7-1. This will however change substantially for 2014 given the phase-out deadline of 1st January 2015. Mexico, for example, the largest A5 consumer in 2013, has already informed that its MB consumption for controlled uses in 2014 was zero.

The pace at which MB has been successfully replaced seems to be in direct relation to the consuming sectors involved, and particular circumstances present in individual countries, including developments concerning new crops (with challenging requirements, pests or diseases) or large expansion of existing crops where newcomers to such sectors (growers and other stakeholders) are not sufficiently trained on the use of alternatives. Regulatory issues (e.g. registration of alternatives) and political issues (e.g. difficulties in restricting MB imports and tracking their final use) may also contribute to this (UNEP, 2014).

TABLE 7-1. REPORTED MB CONSUMPTION FOR CONTROLLED USES IN A-5 REGIONS IN 2013 AND PHASE-OUT ACHIEVED WITH RESPECT TO REGIONAL BASELINES

Region	Baseline	2013 consumption (metric tonnes)	% phase-out (as per regional baseline)
Africa*	4473	340	92%
Asia-Pacific	4104	294	93%
Eastern Europe	900	0	100%
Latin America & Caribbean	6391	1643	74%
TOTAL	**15,866**	**2277**	**86%**

Source: Ozone Secretariat Database, January 2015
* These figures have changed since previous reports due to corrected consumption reports from South Africa

7.3. MLF projects in Article 5 Countries

The Multilateral Fund (MLF) was established under Article 10 of the Montreal Protocol to provide financial assistance to Article 5 countries for phasing out ODS including MB. Assistance for MB issues was provided as early as 1994 and projects to assess the feasibility of alternatives became eligible for support from the Fund in 1995. In 1997, the Executive Committee of the MLF convened a group of experts to develop a strategy and guidelines for MB phase-out projects, which were adopted in 1998, and revised in 2000. In essence, this work helped outline the priority sectors where MB needed to be replaced in Article 5 countries, established guidelines for investment and non-investment projects, and recommended approaches to project development. These inputs were instrumental for the MLF's four implementing agencies (UNEP, UNDP, UNIDO and the World Bank), to prepare and implement the different kinds of projects in conjunction with interested Parties (UNEP, 2014). Project preparation and implementation followed a logical approach, with particular project types targeted at specific goals, as described in Table 2.

In addition to MLF efforts, a number of MB projects have been funded from other sources, by Article 5 countries themselves - for example China – or by the Global Environment Facility (GEF), or bilateral assistance for example from the governments of Australia, Germany (GTZ, now GIZ), Italy, Canada and Spain. In some countries farmers or exporters associations or private enterprises have also financed experiments to identify or adapt alternatives to MB; examples include those in Morocco, Egypt, Jordan, Lebanon and Kenya. In all projects, costs are shared with a local counterpart institution and key stakeholders, for example growers or their trade organizations.

MLF projects, together with voluntary efforts from growers and users, have made a major contribution to the MB reductions described in Chapter 3. A description of the main types of MLF projects is included in Table 7-2 below together with an overview of the main alternatives selected and adopted in Article 5 countries.

Technical descriptions and other information on alternative technologies are not covered in this chapter but are provided in Chapters 5 (alternatives for soil treatments) and 6 (alternatives for commodity and structural treatments).

TABLE 7-2. TYPES OF MB PROJECTS DEVELOPED WITH ASSISTANCE FROM THE MLF, GOALS AND ACHIEVEMENTS

Project Type	Goals and achievements
Technical Assistance and Training	Play a key role in improving data collection on MB consumption, integrating the NOUs to phase-out activities and developing or strengthening policy packages aimed at sustaining the phase-out achieved. Normally not aimed at replacing specific quantities of MB but this has on occasion been achieved
Demonstration	Instrumental in raising awareness on MB phase-out, identifying consuming sectors and evaluating suitability of alternatives. Generally not aimed at phasing-out a particular amount of MB. Served to identify problems hindering adoption of alternatives (inappropriate involvement of key stakeholders, lack of participation from NOUs, alternatives being inappropriate for specific sector).
Investment	Generally implemented once successful alternatives have been identified during the demonstration stage. Carry agreement from the country to phase out MB consumption for controlled uses by a given deadline, and to support sustainability of the phase-out achieved with a policy package aimed at banning future MB use for controlled uses.

Source: UNEP, 2014

7.3.1. Number and cost of MLF projects

By December 2014 the MLF had approved a total of 398 projects in more than 80 Article 5 countries, with an approved expenditure of approximately USD $137 million (MLF, pers comm 2015). This included all types of MB-related activities: demonstration projects, technical assistance, training, project preparation, workshops, awareness raising and MB phase-out projects. The latter are also called investment projects, multi-year projects or national phase-out plans and are normally geared at full phase-out before or at the 2015 deadline.

The figures below provide data on MLF projects approved between 1992 and December 2014 (MLF, 2014):

- **Demonstration projects** – 44 were approved since 1992 (2 were cancelled).
- **Technical assistance -** 74 projects concerning information and awareness-raising activities such as workshops, technical assistance, information exchange on MB phase-out and alternatives, policy development and various other activities (one cancelled).
- **Training** – 21 projects
- **Project preparation** – 130 initiatives for the preparation of new projects, including the collection of data on MB uses (11 cancelled); and
- **Investment or MB phase-out projects** – 129 projects. This category is the one showing the largest increase since 2006.

MLF projects approved by December 2013 were scheduled to eliminate a total of 13,939 metric tonnes of MB in Article 5 countries (MLF, 2015). The total phase-out achieved by MLF projects by December 2013 was 12,165 tonnes (Table 7-3), which is 87% of the total due to be phased out by the projects, a figure which is higher than in previous years.

TABLE 7-3: IMPACT OF MLF MB PROJECTS APPROVED AS AT DECEMBER 2013

Project type	MB phaseout approved in projects (tonnes)	Phase-out achieved by December 2013 (tonnes)
Investment	13,403.7	11,425.5
Demonstration	38.7	38.7
Technical assistance	486.3	690.7*
Training	10.5	10.5
Total	**13,939.2**	**12,165.4**

Source: MLF Secretariat, January 2015

* Technical Assistance projects implemented in Yemen, Syria and Mexico achieved greater phase-out than planned.

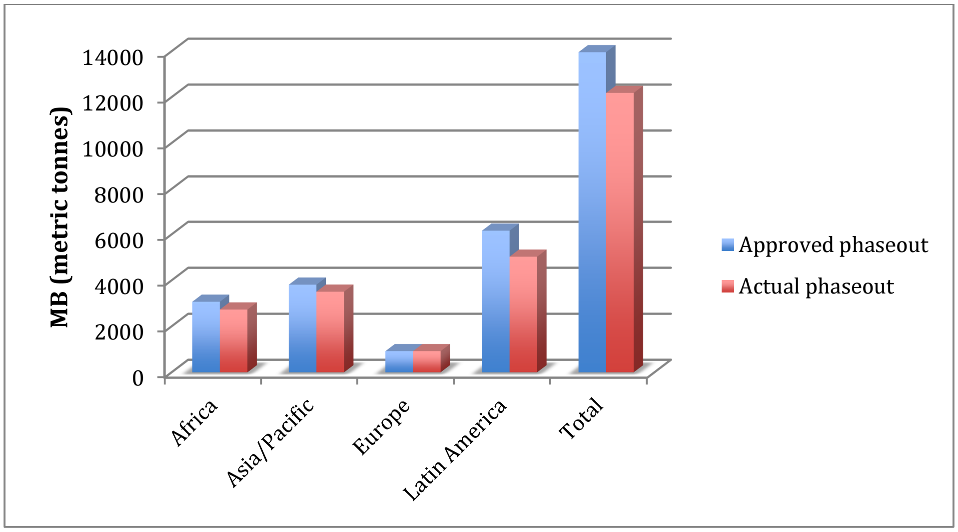
Table 7-4 and Fig.7-1 present an analysis of the phase-out achieved through the different types of projects in the Article 5 regions. Please note that demonstration and technical assistance projects are not tied to specific phase-out but in some cases have replaced MB use.

TABLE 7-4. PHASE OUT ACHIEVED PER REGION AND APPROVED FUNDS FOR PROJECTS

Region	No. Projects	Impact (metric tonnes)	Phased out (metric tonnes)	US$ approved
Africa	108	3,065	2,727 (89%)	32,765,636
Asia and the Pacific	101	3,812	3,506 (92%)	36,509,047
Europe	33	919	919 (100%)	9,675,984
Latin America and the Caribbean	122	6,159	5,028 (82%)	54,367,588
Africa (regional)	9	2.5	2.5	1,896,068
Asia and the Pacific (regional)	3	-	-	210,505
Latin America and the Caribbean (regional)	7	-	-	702,761
Global	15	-	-	1,086,072
Total	398	13,957.5	12,182.5 (87%)	137,213,660

Source: MLF, January 2015

FIG. 7-1. AMOUNTS OF METHYL BROMIDE PHASED-OUT BY REGION, THROUGH MLF PROJECTS AS AT DECEMBER 2013



Source: MLF, January 2015

7.3.2. Demonstration projects

Demonstration projects were not intended to reduce or phase-out MB consumption, but rather at transferring technologies to Article 5 regions from countries that already used alternatives, evaluating and comparing performance and efficacy of successful alternatives (including yields, costs, etc.) under the specific circumstances found in Article 5 countries. The projects considered differences in agricultural practices, resource availability, climatic conditions and other relevant factors. Table 7-5 provides a summary of demonstration projects implemented in the past. Detailed information on these projects can be found in the MBTOC 2002, 2006 and 2010 Assessment Reports (MBTOC 2002, 2007, 2011).

These projects evaluated a wide range of chemical and non-chemical alternatives, in diverse situations, climates, soil types and cropping systems, and involved many different types of MB users, ranging from small producers with less than 0.5 ha, to medium and large producers, who produced under low, medium and higher levels of technical sophistication (which does not necessarily correlate with size of operation).

With very few exceptions, demonstration projects enabled the identification of suitable alternatives for all key sectors using MB. They also helped highlight possible barriers and constraints to commercial adoption of alternatives, which were taken into account when implementing investment projects.

TABLE 7-5. DEMONSTRATION PROJECTS FUNDED VIA THE MLF AND BILATERAL AGREEMENTS AND KEY SECTORS ADDRESSED

Region	Country	Crops covered in demonstration projects (soil fumigation)	Postharvest sectors covered
Latin America and Caribbean	Argentina	Tobacco, protected vegetables, tomato, flowers, strawberry	Cotton and citrus
	Brazil	Tobacco	
	Chile	Tomato, pepper	Commodities
	Colombia	Banana	
	Costa Rica	Melon, cut flowers,	
	Cuba	Tobacco	
	Dominican Republic	Tomato, melon, tobacco, flowers	
	Ecuador	Flowers	
	Guatemala	Broccoli, melon, tobacco, tomato, flowers	
	Jamaica		Tobacco, stored commodities, flour mills
	Mexico	Tomato, strawberry fruit, melon, flowers, tobacco	Structures (warehouses and flourmills)
	Uruguay	Cucumber, pepper, tomato seedbeds, tobacco, nurseries	
Africa	Algeria		Dates
	Botswana	Tomatoes and cucurbits	
	Cameroon	Tobacco	
	Egypt	Strawberry, tomato, cucurbits	Stored grain
	Kenya	Flowers	Stored grain
	Morocco	Tomato, cucurbits, strawberry fruit, flowers, bananas, greenbeans	
	Senegal		Peanut seed
	Tunisia		Dates
	Zimbabwe	Tobacco, cut flowers	Stored grain
Asia	China	Tobacco, tomatoes, cucumber, strawberries, ginseng, ginger	Stored grain
	Indonesia		Stored products: milled rice, wood products
	Jordan	Cucumber, tomato, other soil uses	
	Lebanon	Tomato, cucurbits, eggplant, strawberry fruit, strawberry runners	
	Malaysia		Stored timber
	Philippines	Banana, other soil uses	Flour mills, stored grain
	Sri Lanka	Tea plantations	
	Syria	Post-harvest and horticulture	
	Thailand		Stored grain: rice, maize, tapioca, feed grains, pulses
	Vietnam	Flowers, vegetables	Stored grain, rice, silos, timber
Eastern Europe / CEIT	Croatia	Tobacco	
	Macedonia	Tobacco, horticultural seedlings, vegetables	
	CEIT region	Tomato, cabbage, pepper, celeriac, strawberry	
	Turkey	Tomato, cucumber, flowers, strawberry, pepper, eggplant	

7.3.3. Phase-out projects

Phase-out projects (also called investment projects, multi-year agreements, national phase-out plans or sector plans) aimed to replace MB use by assisting the commercial adoption of alternatives that have been identified as technically and economically feasible for a particular country and crop situation, either as a result of demonstration projects carried out previously or from experience derived from similar sectors, regions and circumstances. They normally included schedules or timetables for national MB reductions that lead to phase-out earlier or by 2015.

These projects have normally provided assistance to growers and other MB users in the adoption of MB alternatives, for example in the form of equipment and materials, by training large numbers of direct users and extension staff on the effective application of alternative methods, and/or by providing technical expertise. The projects also helped with the development and implementation of policy measures to restrict MB after its phase-out, and facilitating registration of alternatives when necessary. Such policy measures also help ensure that MB imported for QPS (exempted) uses does not end up being used in controlled applications.

Phase-out projects have particularly addressed those sectors where MB use was most relevant in Article 5 regions: strawberries (fruit and runners), cucurbits, cut flowers and ornamental plants, tobacco seedlings, tomato, pepper and eggplant, green beans, ginger, bananas and fruit tree production. The majority of projects in the postharvest sector have been for stored grain and dried foodstuffs, and some have included structures such as warehouses and flourmills.

The projects showed that very large MB reductions are feasible over periods of 4 – 5 years, especially in cases where governments and MB users make constructive efforts to register, transfer and adopt existing alternatives.

7.3.4. Alternatives chosen in investment projects

In general terms, two broad categories of alternatives to MB can be considered: 1) In-kind alternatives or systems, consisting of replacing MB with another fumigant having similar or comparable effects (e.g. alternative fumigants) and 2) not-in-kind systems, which work best when implemented within an integrated approach and do not provide a direct, one-to-one replacement (see Table 7-6).

The fact that MB uses should not ideally be replaced by one in-kind alternative was highlighted in past MBTOC Assessment reports (1994, 1998, 2002, 2007, 2011) and was confirmed in MLF projects. This often meant that growers and other stakeholders had to change their approach to production and even make changes in process management, mostly related to the implementation of IPM practices but also time management as some alternatives require longer exposure times than MB. Reluctance to change has often been cited as one of the major reasons delaying adoption of alternatives, even above economic concerns.

Projects conducted in Article 5 countries have demonstrated that a similar range of alternatives as those of non-Article 5 countries can be successfully adopted. Differences in costs, logistics and resource availability can lead to a preference for different alternatives in Article 5 compared to non-Article 5 countries.

TABLE 7-6. MAIN CATEGORIES OF ALTERNATIVES TO METHYL BROMIDE

Alternatives	Soils	Post-harvest	Comments
In-kind	Soil fumigants (1,3-D, Pic, metham sodium, dazomet, metham potassium, DMDS	Phosphine, sulfuryl fluoride, HCN, EDN	Meant to perform as direct replacements to MB. May not be sustainable in time due to regulatory issues
Not in-kind	Grafting, substrates, floating trays, steam, compost, biocontrol, solarisation, resistant cultivars, crop rotation and inter-cropping, organic amendments biofumigation	Heat (full and spot treatments), cold, vacuum, pheromones, contact insecticides	Work best and give the most sustainable result when combined, within an IPM strategy

Table 7-7 lists the main alternatives adopted by some Article 5 countries by region and the degree to which they have currently displaced MB use (many have phased out MB completely). For a detailed description of alternatives please refer to Chapters 5 and 6 of this Assessment Report.

TABLE 7-7. TECHNOLOGIES ADOPTED IN MB PHASEOUT PROJECTS, BY REGION

Region	Country	Soil technologies selected	Postharvest technologies selected	% MB replaced by 2013*
Latin America and Caribbean	Argentina	Chemicals (1,3-D/Pic, MS, DMDS), steam, floating trays, grafting		39% of baseline
	Bolivia	Steam, substrates		Phased out
	Brazil	Floating trays, substrates, metham sodium, steam, solarisation (solar collector)		Phased out
	Chile	1,3-D/pic, steam, steam + Trichoderma, metham (rotary-spading injection), methyl iodide		22% of baseline
	Costa Rica	1,3-D/pic, metham, solarisation, biocontrols, steam		Phased out
	Cuba	Floating trays. Steam, grafting, biocontrols	Phosphine + CO_2 and heating, sulfuryl fluoride	Phased out
	Dominican Rep.	Floating trays, solarisation, metham sodium, steam, substrates		Phased out
	Ecuador	Substrates, chemicals, biofumigation		Phased out
	Guatemala	Chemicals, grafting, biocontrols		60% of baseline
	Honduras	Chemicals, floating trays, grafting, biocontrols		Phased out

Region	Country	Soil technologies selected	Postharvest technologies selected	% MB replaced by 2013*
	Mexico	Grafting, chemicals, IPM, steam, solarisation	Phosphine + CO_2	71% of baseline
	Peru	Steam, floating trays, solarisation, biocontrols, biofumigation		Phased out
	Uruguay	Solarisation + chemicals (1,3-D/Pic, MI, MS, DMDS), biofumigation, steam		Phased out
Africa	Congo	Metham, IPM		Phased out
	Egypt	Substrates, steam, biofumigation, grafting	Phosphine, PH_3 + CO_2	77% of baseline
	Kenya	Metham (rotary-spading injection), substrates, steam, grafting, IPM	Phosphine, PH_3 + CO_2	Phased out
	Malawi	Floating trays, chemicals (metham sodium, dazomet)		Phased out
	Morocco	1,3-D/pic, metham, grafting, solarisation + chemicals, steam, substrates, compost		Phased out
	Senegal		Phosphine, (tablets of metallic phosphide) IPM,	Phased out
	Sudan		Phosphine, IPM	77% of baseline
	Uganda	Metham (rotary-spading injection), steam, substrates		Phased out
	Zimbabwe	Steam, IPM, floating trays	Phosphine	Phased out
Asia	China	Metham sodium, grafting, chloropicrin, 1,3-D, limited biocontrol	Phosphine	91% of baseline
	Indonesia		Phosphine, IPM	Phased out
	Iran	Steam, solarisation, with IPM	Phosphine, IPM, Metallic phosphides	99% of baseline
	Jordan	Solarisation, grafted plants, chemicals, biocontrols, others		98% of baseline
	Lebanon	1,3-D,, 1,3-D/ Pic, metham sodium, solarisation, solarisation + reduced doses of chemicals, grafting, crop rotation, biofumigation, floating trays		Phased out
	Libya	Solarisation + chemicals (low doses), substrates, grafting.		Phased out
	Philippines		Phosphine + CO_2 IPM	Phased-out
	Syria		Phosphine + CO_2 IPM	Phased out
	Thailand		Phosphine, CO_2, aluminium phosphide, IPM, sulfuryl fluoride, controlled atmospheres	Phased out

Region	Country	Soil technologies selected	Postharvest technologies selected	% MB replaced by 2013*
	Turkey	Grafting, metham sodium, 1,3-D, 1,3-D/Pic, solarisation, substrates, grafting, resistant varieties, steam (limited), dazomet	CO_2 and magnesium phosphide	Phased out
	Tunisia*		Phosphine + CO_2	20% of baseline
	Vietnam		IPM, phosphine, CO_2, sulfuryl fluoride, controlled atmospheres	63% of baseline
Eastern Europe / CEIT	Bosnia & Herzegovina	Floating trays, solarisation, biofumigation		Phased out
	Bulgaria [a]	Metham (rotary-spading injection), dazomet		Phased out
	Croatia	Floating trays		Phased out
	Hungary	Metham (rotary-spading injection), dazomet		Phased out
	Macedonia	Floating trays, solarisation+biofumigation		Phased out
	Poland [a]	Metham (rotary-spading injection), dazomet, steam		Phased out
	Romania	Chemicals, grafting, solarisation + 1,3-D/ Pic, metham sodium		Phased out

Sources: UNIDO, UNDP, World Bank, national experts and Desk Studies on Methyl Bromide Projects, MLF, 2005b, MLF, 2007, Evaluation of MB projects in Africa MLF, 2012. Data Access Centre of Ozone Secretariat, January 2015.
[a] GEF regional project in CEIT countries
* Consumption in Tunisia has been exempted as falling under Dec XV/12, but this exemption is now under review as alternatives for high moisture dates have become available (see Chapter 6 of this report)

7.3.5. Crop specific technology choices in A5 countries

Detailed descriptions of the main alternatives selected for the key sectors using MB is in A5 countries can be found in Chapters 5 and 6. Table 7-8 below presents a summary of alternatives that have successfully replaced MB in the key sectors previously using this fumigant. It is once again noted that most often, the combination of these alternatives within an IPM approach gives the best results.

TABLE 7-8. MAIN ALTERNATIVES ADOPTED FOR KEY SECTORS PREVIOUSLY USING MB IN ARTICLE 5 PARTIES

Sector	Main alternatives	Examples of countries where adopted
SOILS		
Strawberry fruit	1,3-D/ Pic, Pic alone, metham potassium, substrates	Argentina, Mexico, China, Egypt, Morocco, Turkey, Chile, China
Strawberry runners	1,3-D/ Pic, metham sodium, steam, solarisation	Argentina, Mexico, Lebanon, Turkey, Chile
Cucurbits	Grafting, solarisation, metham sodium, biocontrols, resistant cultivars	Mexico, Morocco, Turkey, Costa Rica, Guatemala, Honduras, China
Tomato, pepper, eggplant	Grafting, solarisation, 1,3-D/Pic, metham sodium, DMDS, substrates, compost, biocontrols, resistant cultivars	Turkey, Mexico, Argentina, Morocco, China
Cut flowers and ornamental crops	Substrates, steam, solarisation, biofumigation, chemicals (1,3-D/Pic, metham sodium)	Kenya, Ecuador, Uganda, Brazil, Mexico, Colombia, Argentina, Costa Rica, Dominican Republic
Nurseries	Substrates, steam+ biocontrols, 1,3-D/Pic	Chile, Brazil, Costa Rica, Colombia, Kenya, Argentina
Tobacco	Floating seed trays, dazomet, metham sodium	Argentina, Brazil, Zimbabwe, Malawi, Zambia, Cuba, Peru, Macedonia, Croatia
STRUCTURES AND COMMODITIES		
Grain, coffee, cocoa, rice, dried fruit, nuts and other foodstuffs	Phosphine, phosphine+CO_2, controlled atmospheres	Turkey, Sudan, Egypt, Kenya, Viet Nam, Thailand, China, Indonesia, Singapore
Flour mills, food processing premises	Heat, sulfuryl fluoride, IPM	Egypt, Thailand, Viet Nam, Jamaica

7.3.6. Lessons learned from projects

A review of 2013 consumption data (the last date for which officially reported consumption was available at the time of preparing this report) shows very significant progress in phasing out MB as the established phaseout deadline of 2015 approached.

The implementation of MLF projects has provided many useful experiences that can be summarised as follows:

- As controlled uses are phased out it has become increasingly important to document and characterise QPS uses more closely, to prevent 'leakage' to other uses, and to strengthen policy measures relating to MB use.
- Technically effective alternatives to MB have been found for virtually all pests, diseases and weeds, however a small number of sectors and situations still pose challenges, for example ginger in China and strawberry nurseries in Mexico.

- The cost and profitability of alternatives was found to be acceptable or comparable to MB in many projects. However it is desirable to make further efforts to reduce the costs of alternatives in some specific situations, to prevent users reverting to MB.
- While a number of projects have promoted alternatives that will be environmentally sustainable in the longer term (such as IPM and non-chemical approaches), some projects focussed primarily on chemical alternatives. Chemical treatments, particularly fumigants, are likely to face increasing regulatory restrictions worldwide in future.
- The capability to adapt to site-specific conditions is essential to the success of any alternative.
- Projects demonstrated that successfully evaluated alternatives can be adopted by large numbers of growers in developing countries in periods of 2-4 years within proactive projects. Also, activities related to demonstration projects led larger or more technically prepared growers to adopt alternatives at their own initiative.
- Involvement of an ample range of key stakeholders is essential to the success of a project or the phase out achieved.

7.4. Constraints on adoption and remaining challenges

Although technically feasible alternatives have been identified for virtually all uses of MB, it quickly became clear that each alternative system needed to be judged against the local situation and commercial environment. Various issues beyond the economic feasibility of alternatives impact the long-term sustainability of the proposed alternatives have been identified, for example:

- Market drivers - specific market windows requiring precise technical and business skills
- Consumer issues - preference for certain certification schemes or eco-labels
- Installed capacity - sufficient and economically feasible airfreight and/or cold storage
- Regulatory factors – registration and commercial of alternatives
- Sufficient consumption volume of a given input to develop a market and ensure availability of an alternative.

7.4.1. Challenges

Particular challenges or concerns, which could put at risk the sustainability of the phase-out achieved still remain, for example:

- **The continued, unrestricted supply of MB.** As long as no controls are in place, continuing, plentiful production of MB for allowable QPS purposes provides a base production capacity and scale for the industry that can keep MB prices at a level where it is still attractive for non-QPS users. This situation, often combined with well-funded promotional efforts for MB use, negatively impact the phase-out achieved. Initiatives taken by the Parties in previous years to evaluate the feasibility of adopting alternatives for QPS have shown that it is easily possible to replace a proportion of the MB used for this purpose.

- **Deviation of use**. Many A-5 countries have expressed concern over illegal trade and/or use, and in particular, the diversion of MB imported for QPS uses into controlled applications. Consumption for QPS has shown an upward trend in many A-5 countries over the last decade, and although increased trade could partly explain this, the difficulty in tracking actual final use of imported MB is often referred to.

- **Long-term viability of some alternatives**. Restrictions and bans on chemical alternatives as a result of environmental or health concerns may arise. Further, essential inputs for implementing some alternatives may become unavailable or too expensive. The switch to alternatives may allow for the more frequent presence of pests or diseases that were secondary in the past (or controlled to a very large extent with MB). Pest resistance to alternatives may also arise; this is for example a very real possibility when fumigating grain with phosphine, as already stated in this report.

- **Ensuring the continuity of project activities and achievements, once the projects are finished,** particularly training and awareness-raising. Creating linkages with other environmental/sustainability initiatives, promoting information exchange within productive sectors locally or at the regional level and others, can provide good options in this respect

In summary, willingness, commitment and a proactive approach are necessary for the successful adoption of alternatives and there are instances where reluctance to change appears to be the major barrier to successful adoption of alternatives.

A further constraint noted in Article 5 countries is the lack of registration of the more modern chemical alternatives (MLF 2005, ab, MLF 2012). This pertains for example in some countries to DMDS, 1,3-dichloropropene and its different formulations with chloropicrin as well as chloropicrin alone for soil uses, and sulfuryl fluoride in the postharvest sector. However, progress has occurred in many countries and these new chemicals or formulations are increasingly registered. In many countries, substantial MB reductions and phase-out have been achieved using non-chemical alternatives that do not require registration.

Large CUEs requested by some non-Article 5 countries in the past were reported to slow the progress of MLF projects and other phase-out initiatives in a number of Article 5 countries because confidence in alternatives and the feasibility of achieving MB reductions was impacted. Recent large reductions in CUNs however seem to have provided encouragement to Article 5 countries to complete their phase-out by the scheduled date. However some Article 5 countries have also requested CUNs as discussed in the following section.

7.5. *Critical Use Nominations in Article 5 Parties*

As per Montreal Protocol guidelines, Article 5 Parties can only use MB for controlled purposes under the Critical Use exemption as of 1st January 2015 and exemptions may be requested up to two years in advance. CUNs from four Article 5 Parties were received for the first time in 2014, for 2015 use. One Party later withdrew its request, leaving six CUNs all for the soil sectors, for strawberry and raspberry runners, ginger, tomatoes, peppers and strawberry fruit. MBTOC assessed these nominations and in some cases recommended adjustments for lower amounts on the basis of Decision IX/6.

In 2015, four Parties have again submitted CUNs, which will be assessed by MBTOC this year. More information on CUNs can be found in Chapter 3 of this report and in annual TEAP reports, plus the "Handbook for Critical Use Nominations" prepared by MBTOC (see http://ozone.unep.org/Assessment_Panels/TEAP/Reports/MBTOC/Handbook_CUN-version7-1-April_2013.pdf)

7.6. *References*

MBTOC (1995). 1994 Report of the Methyl Bromide Technical Options Committee: 1995 Assessment. UNEP: Nairobi. 304pp.

MBTOC (1998). Report of the Methyl Bromide Technical Options Committee. 1998 Assessment of Alternatives to Methyl Bromide. UNEP: Nairobi. 374pp.

MBTOC (2002). Report of the Methyl Bromide Technical Options Committee. 1998 Assessment of Alternatives to Methyl Bromide. UNEP: Nairobi. 451pp.

MBTOC (2007). Report of the Methyl Bromide Technical Options Committee. 1998 Assessment of Alternatives to Methyl Bromide. UNEP: Nairobi, 475 pp.

MLF. (2005a). Final Report on the evaluation of Methyl Bromide Projects. Montreal, 4-8 July 2005. Synthesis evaluation report (document UNEP/Ozl.Pro/ExCom/46/7)

MLF. (2005b) Evaluation of Methyl Bromide phase-out projects. Sub-sector reports and case studies. June, 2005. Reuben Ausher, Alejandro Valeiro, Marta Pizano, Jeurgen Boeye and Otto Mueck, Consultants

MLF (2007). Extended desk study on low volume methyl bromide projects. UNEP/OzL.Pro/ExCom/53/8 and Annexes 29 October 2007

MLF (2012) Evaluation of Methyl Bromide projects in Africa – Desk study. UNEP/OzL.Pro/ExCom/66/15. March, 2012. http://www.multilateralfund.org/66/English/1/6615.pdf

MLF (2014) Database of MLF projects, Multilateral Fund Secretariat, Montreal, accessed January 2015.

MLF, 2015, Personal communication. Multilateral Fund Secretariat for the Montreal Protocol

MPS (2005) Facts about MPS certification programme. MPS Codelist of crop protection agents. Milieu Programma Sierteelt (MPS), Honselersdijk.

Ozone Secretariat (2014) Data Access Centre. Database of ODS data submitted by Parties under Article 7, accessed December 2014.

UNEP (2014) Phasing out methyl bromide in developing countries: A success story and its callenges. Written by Marta Pizano. Uinted Nations Environment Programme UNEP/DTIE Paris 54 pp.

8

8. Methyl bromide emissions

8.1. Introduction

The phase out of MB under the Montreal Protocol has emphasised protecting the ozone layer from the destructive effects of MB through a schedule of progressive reductions in production and consumption of MB. The Parties have taken several explicit decisions calling for steps to minimise emissions of MB in applications where it is still used under Decisions which allow exemption from phaseout. These include the Critical Use Exemptions (Decision IX/6) and exemptions for QPS use (Article 2H, Decisions VII/5(c) and XI/13(7)). There is opportunity for Article 5 countries to adopt emission control technologies during progress towards full phase-out of MB in 2015 and for any 'Critical Uses' that may be granted by the Parties for subsequent use after 2015. As a consequence of several emission reduction technologies to date has been a reduction in dosage rates due to an increased efficiency of the use of MB. This chapter as with the past assessment reports continues to refine the best estimate of the level of emissions for the uses of MB as at 2013, the most recent year for which there is a good data set of consumption and use available. It also provides a summary of the impact of regulation of these emissions on the ozone layer, updates on developments in reducing emissions of MB, particularly the use of barrier films and reduced MB dosages for soils, and the potential for recapture, recycling and destruction for commodity and structural treatments.

8.2. Atmospheric Methyl Bromide

8.2.1. Global Sources and Emissions

Methyl bromide has both natural and anthropogenic sources. The current understanding of the global annual budget (sources and sinks) for MB is summarised in Table 8-1 and Figure 8-1. The current error estimates (range) for the 2012 MB budget are given in the caption to Table 8.1. The budget data continue to suggest that the global MB budget is not balanced. Current identified sinks exceed current identified sources by approximately 30 k tonnes (nearly 40% of identified sources). This imbalance has persisted from pre-Montreal Protocol phase-out (1995-1998) to recent times (2013). It is likely that the MB sinks are more accurately known than the sources. This implies that there may have been either large under reporting of MB production and consumption or that there are unidentified MB sources. Some of these may come from industrial processes, for example the production of purified tetraphthalic acid (PTA) or may be from unidentified natural sources.

The natural sources of MB are dominated by the oceans (about 30 k tonnes per year) and terrestrial plants (about 10 k tonnes per year). The MB sinks include chemical losses in the atmosphere (60 k tonnes per year), loss to the ocean and to soils (each about 30 k tonnes per year). In 2012 about half of MB emissions were anthropogenically-influenced and half were natural.

The ocean is the largest source of MB and the second largest sink. Resolving the current global budget imbalance requires a better understanding of the oceanic sources and sinks, industrial sources and natural vegetative sources of MB. This will require a more comprehensive set of MB observations in the marine boundary layer and in the ocean, and a representative survey of industrial, and vegetative emissions, particularly in the tropics, with better global coverage and year-round observations. This requires extensive and year-round shipboard, aircraft and surface observations and which are currently beyond the resources of the global MB observation community. Because of MB's relatively low concentration in the atmosphere, future satellite-borne instruments are unlikely to be able to address this 'data-poor' MB issue.

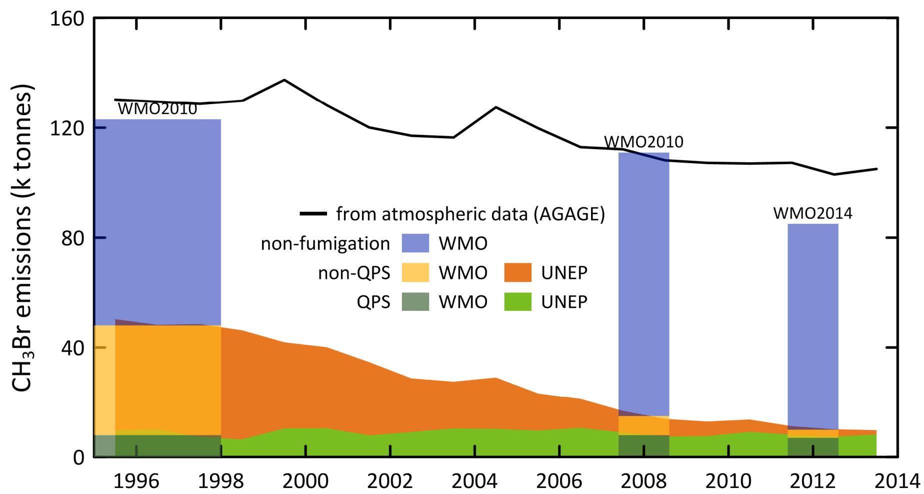
Australia is addressing this global lack of tropical observations of atmospheric MB by establishing a tropical atmospheric research facility at Gunn Point (12°S) in the Northern Territory and instigating continuous MB measurements in partnership with Cambridge University.

Historically, the largest anthropogenic source of MB emission is from fumigation of soils and commodities and structures, where about 50 k tonnes per year were emitted to the atmosphere between 1995 to 1998 from non-QPS MB use (85%: largely soil fumigation) and QPS use (15%: largely grain and wood products fumigation including QPS). As Montreal Protocol restrictions on the consumption of MB for non-QPS use have been implemented, this total fumigation source of emissions has reduced to about 10 k tonnes by 2012 (30% non-QPS, 70% QPS).The uncertainty of fumigations emissions is about ±15% (WMO 2014).

Today, the largest estimated anthropogenically-influenced MB source is biomass burning in agriculture and biofuel use, approaching 25 k tonnes in 2012, and this is not controlled under the Montreal Protocol. The uncertainty of the biomass burning MB emissions is about ±40% (WMO 2014). As discussed above there is a large unknown source of a similar amount possibly from industrial processes or natural systems. Agricultural crops (rapeseed, rice) release about 5 k tonnes of MB per year and leaded petroleum about 2 k tonnes per year. The uncertainty on both these sources is about ±50% (WMO 2014). Potential minor sources of MB emissions are from uses as a chemical feedstock. Overall total (natural and anthropogenic) MB emissions have declined from in excess of 120 k tonnes per year in 1995-1998 to 85 k tonnes in 2012, driven almost entirely by the declining consumption of non-QPS MB (Table 8-1, Figure 8-1).

In 1995-1998, manufactured MB used in fumigation (48 k tonnes/year) accounted for about 40% of all identified MB sources; by 2012, thanks to countries taking steps to reduce the use of MB for non-QPS purposes, fumigation use had declined to just over 10% (10 k tonnes) of all identified sources, with QPS use accounting for about 8% of all identified sources. The total fumigation use of MB has declined by 80% over this period and the non-QPS fumigation use has declined by over 90%. The impact of the relatively recent and currently limited MB recapture on the global MB budget is likely to be small (less than 200 tonnes recaptured globally per annum (MBTOC estimate).

FIGURE. 8-1. TOTAL AND ANTHROPOGENIC GLOBAL MB EMISSIONS



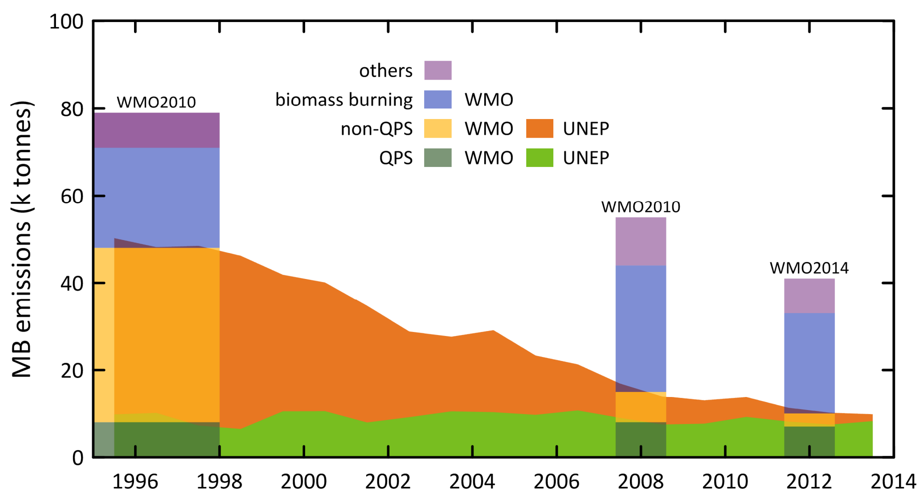


Figure 8.1. Total (top) and anthropogenic (bottom) global methyl bromide emissions from atmospheric data (AGAGE; Rigby et al., 2011, 2014; see text below), and as reported in WMO 2010 and 2014 (Montzka & Reimann, 2011; Carpenter & Reimann, 2014) and as derived from UNEP consumption data (http://ozone.unep.org/Data_ Reporting/Data_Access/ , see text below) and a fumigation emissions model (UNEP: Montzka & Reimann, 2011). Current non-fumigation sources are largely oceans (40%), biomass burning (25%) and vegetation (20%).

TABLE 8-1. ESTIMATED GLOBAL METHYL BROMIDE SOURCES (EMISSIONS) AND SINKS (K TONNES): 1996-1998, 2008, 2012 (MONTZKA & REIMANN, 2011; CARPENTER & REIMANN, 2014)

Sources	1995-1998[a,b]	2008[c]	2012[a]	Comments
Anthropogenic	80	56	41	
fumigation: non-QPS	40	7	3	only source controlled by MP
fumigation: QPS	8	8	7	
biomass burning	23	29	23	biofuels, open-field
rapeseed	5	5	5	
leaded petroleum	3	<6	<3	
rice agriculture	<1	<1	<1	
Natural	43	54	44	
oceans	32	42	32	
salt marsh	7	7	7	
plants	2	2	2	mangroves, shrubs
fungus	2	2	2	
wetlands	<1	<1	<1	largely peat lands
Total Sources	123	111	85	

Sinks	1995-1998[a]	2008[b]	2012[a]	Comments
atmosphere	-81	-67	-60	oxidation, photolysis
soils	-40	-32	-27	
oceans	-41	-49	-30	
Total Sinks	**-162**	**-148**	**-117**	

[a] Carpenter *et al.,* 2014

[b] Source uncertainty ranges (WMO 2014): fumigation (±15%), biomass burning (±40%), petroleum (±60%); other terrestrial (±50%), oceans (±30%); sink uncertainty ranges (WMO 2014): atmosphere (±15%), soil (±30%), ocean (±30% (WMO 2014)

[c] Montzka *et al.,* 2011

8.3. Summary of impact of regulation of MB emissions

By 2013, the MB phase-out has led to a 33% fall in total MB (65% of anthropogenic bromine) in the troposphere from the mid-1990s as measured at Cape Grim, Tasmania, Australia (Figure 8-1). Owing to the short atmospheric half-life of MB (0.7 years) in the stratosphere, changes in emission of MB at ground level are rapidly reflected in changes in tropospheric and stratospheric MB concentrations. This is in contrast to almost all other ODSs regulated under the Protocol as these usually have much longer atmospheric half-lives. The Scientific Assessment Panel (WMO, 2007) rated the importance of MB in contributing to ozone layer recovery as higher than previously calculated, because MB atmospheric reductions were greater than previously anticipated.

The 2010 Science Assessment of Ozone Depletion: 2010 report (Montzka *et al.* 2011) reported that by 2008 'total tropospheric bromine had decreased from its peak values in 1998', and ' total bromine in the stratosphere is no longer increasing and showing signs of decreasing slightly'. These recent changes have largely been a consequence of regulation and phase out of MB.

In 2010, it was reported (Porter *et al*. 2010) that prior to the onset of the widespread use of MB as a soil and structural fumigant in the 1960s, the historical background or baseline concentration of MB in the atmosphere was around 5.3 ppt (Figures 8-1 and

8-2). The concentration then grew rapidly through the 1970s to the late 1990s due to large anthropogenic (man-made) use of MB (up to 72,000 tonnes annually). In the mid 1990's the concentration reached 8-9 ppt (about 60% above the 1950s natural baseline concentrations), but started falling in the late 1990s as a result of the MB reductions imposed by the Montreal Protocol. The rate of decline has been relatively constant and by 2014, this level has fallen to nearly 6 ppt as measured in 2013 (Figs 8-2 and 8-3).

In 2003, it was predicted that MB levels in the southern hemisphere would fall to about 7 ppt before levelling off (Fig. 9.3, A1 WMO, 2003). However, by 2007 the levels had continued to fall to 6.5 ppt and show signs of falling further. As discussed above recent measurements and modelling show that the MB has fallen to nearly 6 ppt, more than anticipated by recent scenario modelling (WMO 2011, WMO 2014). It is clear is that the Montreal Protocol restrictions on the use of MB are having greater impact on atmospheric MB than thought possible 10 years previously.

The latest WMO scenarios (Fig. 8-3, A1 WMO, 2014) suggest that further reductions in atmospheric concentrations are possible over the next few years, but will only occur if the remaining non-QPS uses in developing countries (A5 Parties) and the few non-A5 and A5 critical uses are phased out, and if emissions or use of MB for QPS are reduced significantly. In 2014, the use of MB for QPS was at least three times the total used for non-QPS in non-A5 and A5 countries. The estimated MB emissions from QPS in 2009 are 8 Gg (8000 tonnes, Table 8-1).

FIG. 8-2. IMPACT OF MB RESTRICTIONS IN NON-QPS USE ON REDUCTION IN BROMINE CONCENTRATIONS IN THE TROPOSPHERE SINCE THE LATE 1990'S*

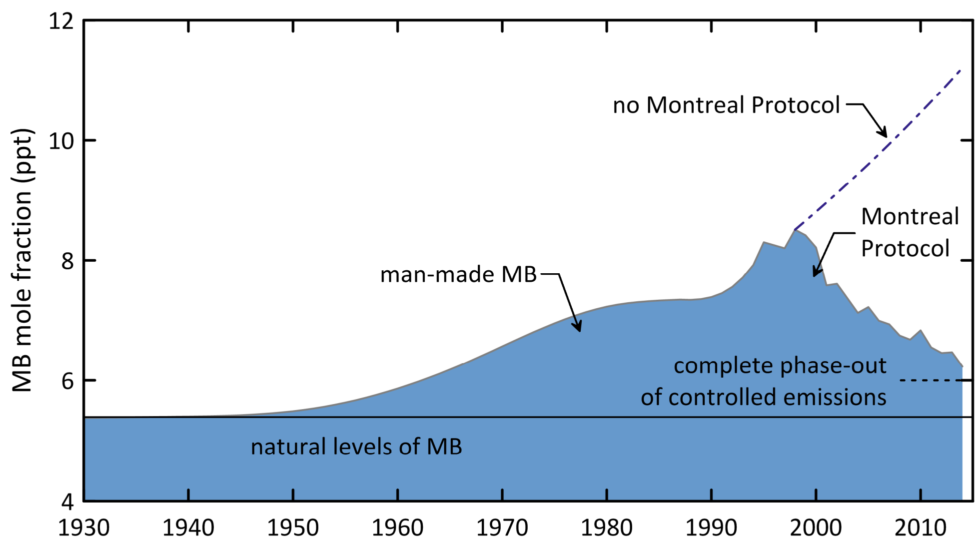
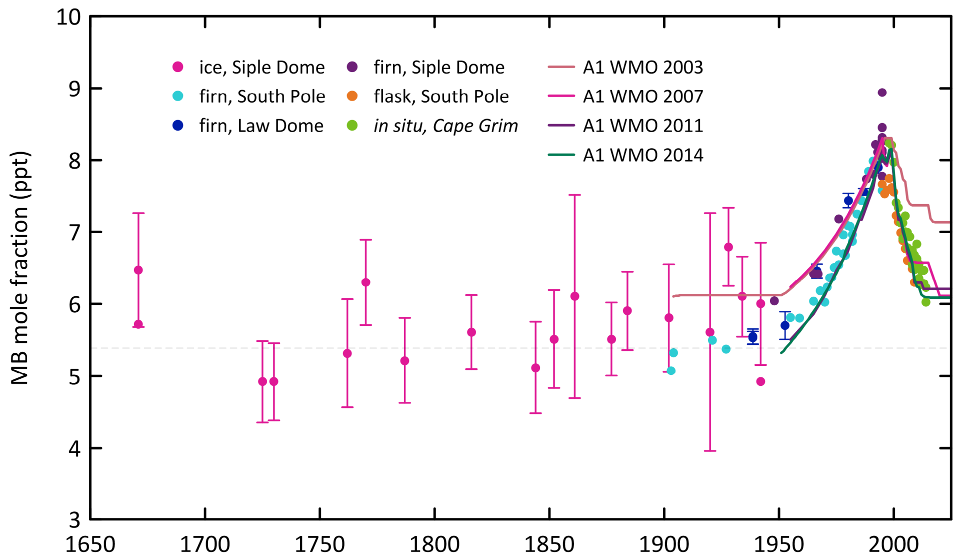


Fig. 8-2. Based on MB data from Antarctic air (firn) and Cape Grim, Tasmania. The *solid line* indicates MB levels from natural sources (i.e. the historic baseline); the *dashed line* indicates the approximate level that MB concentrations would fall to if all non-QPS MB uses were phased-out. The possible MB growth scenario without the regulations of the Montreal Protocol (1.7% per year) is estimated from atmospheric MB trends 1989-1998.

FIGURE. 8-3 HISTORIC METHYL BROMIDE MEASUREMENTS (PPT = 10 $_{12}$ MOLAR) IN THE SOUTHERN HEMISPHERE OVER THE PAST 350 YEARS (THE DASHED LINE REPRESENTS THE APPROXIMATE NATURAL MB EQUILIBRIUM).



MB data are from Cape Grim, Tasmania, and various atmospheric and ice/firn sampling sites in Antarctica compared to modelled CH 3 Br levels in 2003, 2007, 2011, 2015 (WMO) updated from summary in Porter *et al*., 2010

FIG. 8-4. MAN-MADE (QPS + NON-QPS) AND TOTAL (FROM ATMOSPHERIC DATA) GLOBAL EMISSIONS OF METHYL BROMIDE

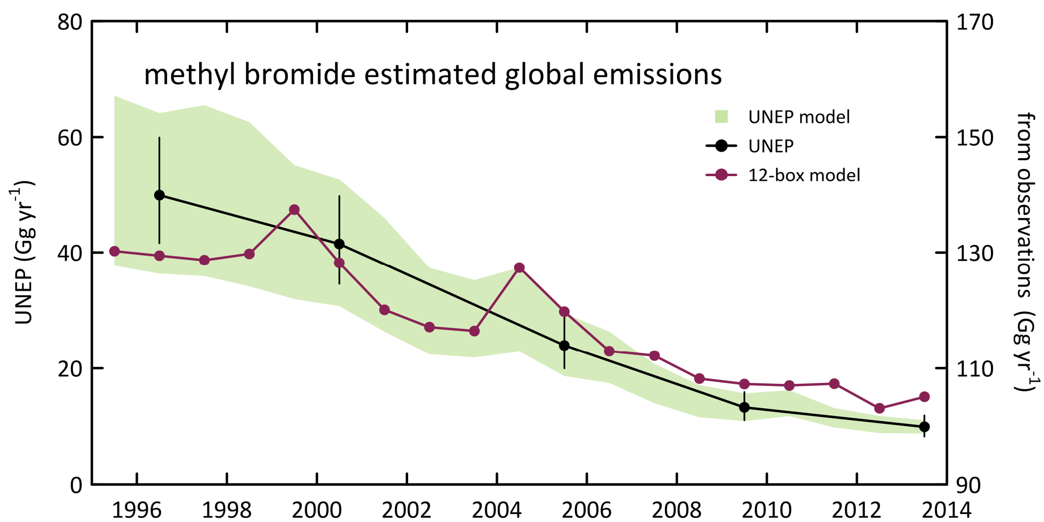


Fig. 8-4. Estimated emissions of anthropogenic (man-made) methyl bromide (MB) from fumigation (left axis), including QPS, using the UNEP model (green range); UNEP consumption data (black) for 1996, 2000, 2005, 2009 and 2013, sourced from either the MBTOC Assessment Reports of 1998, 2002, 2006 and 2010 or data reported by Parties under Article 7 to the Ozone Secretariat. The 12-box model data (red) use AGAGE global atmospheric observations (Rigby *et al*. 2014) (right axis).

8.4. MB emissions from current uses for soil, commodities and structures

All the MB applied during fumigation will be released to the atmosphere excepting that reacting irreversibly with treated materials (e.g. soil components, commodities or structural materials) or which is recaptured and destroyed. Since there is insignificant use of recapture and destruction at this time to influence significantly global emissions, the only 'sink' within the MB fumigation process is a reaction to give inorganic, non-volatile bromide ion. From the capacities of currently installed recapture equipment known to MBTOC, is estimated that the MB recaptured and destroyed in 2013 was not greater than 200 tonnes.
Table 8-2 includes estimates for emissions from application to soils. It is not possible to give a precise average emission as the distribution of emissions over the global range of practices cannot be estimated because of lack of data. However, it is likely that the true value lies within the range quoted.

TABLE 8-2. ESTIMATED GLOBAL USAGE OF MB AND EMISSIONS TO ATMOSPHERE IN 2013 FOR DIFFERENT CATEGORIES OF FUMIGATION BY MAJOR USE CATEGORY, INCLUDING QPS USE (EXCLUDES FEEDSTOCK).

Type of fumigation and commodity/use	Estimated usage		Estimated emissions	
	tonnes	%	tonnes	% (*a*)
Non QPS				
Preplant soil fumigation	2200	19	1408	64 (46-91)
Structures, commodities and perishables	290	2.5	265	92 (85-98)
Sub Total- non QPS	***2490***	***22***	***1673***	***67***
QPS				
Preplant soil fumigation	1650	15	1056	64 (46-91)
Timber and wooden packaging	4402	39	3874	88
Durables and miscellaneous	2063	18	1537	75 (51-98)
Perishables	701	6.2	641	92 (85-98)
Sub Total- QPS	***8816***	***78***	***7108***	***81***
Total estimated fumigant use	**11,306**	**100**	**7539 - 10370**	**67 - 91**
Best estimate over all categories			**8781**	77 *(c)*

a For original sources of estimates, see MBTOC 1995 with minor subsequent adjustments

b Fluxes of MB through LPBF tarps are very low, but loss can occur after lifting the tarp. This is very dependent on the duration of tarping and the soil type and conditions (Yates, 2005; Fraser *et al.*, 2006). Experimentally, very low emissions can be obtained (e.g. 6%, Yates, 2005; <4% Yates et al, 2009). Regulations in 2013 prevented use of barrier films in specific places (e.g. California) and price and availability mean they are not used in some soil sectors in many countries.

c MBTOC recognises that the true value of emissions may differ from this best estimate.

The overall usage figures given in Table 8-2 are derived from a combination of reported 2013 global production for QPS, usage in 2013 in Article 5 and non-Article 5 countries as authorised for CUE purposes (Chapter 3, Section 3.7.5) and use of stockpiles as reported annually by Parties under Decision XVI/6. The usage figures for the individual sectors are based on tonnages estimated from these data sources.

Under current usage patterns, the proportions of applied MB eventually emitted to the atmosphere are estimated by MBTOC to be 41 – 91%, 85 - 98%, 76 – 88% and 90 - 98% of applied dosage for soil, perishable commodities, durable commodities and structural treatments respectively. These figures, weighted for proportion of use and particular treatments, correspond to a range of 67 - 91% overall emission from agricultural and related uses, with a mean estimate of overall emissions of 77%.
Best estimates of annual MB emissions from fumigation use in 2013 of 8781 tonnes (Table 8-2) were 52% lower than in 2009, which totalled 17,041 tonnes. There have been substantial reductions in usage for soil fumigations for controlled uses, counterbalanced to some extent by increases in fumigation of timber and wood packaging materials treated to meet Quarantine and Preshipment requirements and the recategorisation of some soils uses to QPS. It appears that the usage on perishables was overestimated in the 1994 and 1998 MBTOC Assessments.
Estimated usage is based on QPS consumption data (this Assessment), authorised CUE use for 2013 and MBTOC survey of Article 5(1) consumption and use, excluding feedstock. Reported use of stocks is included in calculations but no allowance for unreported use (see Table 8.2)

8.5. Emission Reduction through Better Containment

MB is a gas at normal ambient temperatures (boiling point at normal atmospheric pressure: 4°C). During fumigation some of the gas becomes sorbed on the treated materials or the packaging/palleting in commodity treatments or into the soil for preplant treatments. Some of the sorbed MB remains unchanged and will air off at the end of the treatment, but a portion of the sorbed MB is converted into non-volatile residues. Except for this portion, all the MB applied during fumigation will eventually be emitted to the atmosphere. During any fumigation operation there are four distinct sources or opportunities for MB to be emitted to the atmosphere:

i. By leakage during the set up and actual fumigation treatment.
ii. During unintentional discharge of some unreacted MB during applications when changing cylinders, lifting rigs from soil to reverse direction, etc.
iii. During international 'off gassing' or discharge of unreacted MB after completion of fumigation of commodities and structures after a set exposure period.
iv. Following treatment when the treated soil, commodity or structure emits any sorbed, unreacted MB over an extended period of time.

All but the third situation can be controlled or reduced by better containment (sealing and film permeability) of the fumigation site (Section 8.3 (soil treatments) and fumigation enclosure (Section 8.6 (commodities)). Leakage and uncontrolled emissions in these instances are undesirable. They reduce effectiveness of the treatment as well as having worker safety and local air quality implications.
Reduction of emissions in intentional discharge can be controlled by a reduction in MB dosage applied or by recapture of the MB followed by recycling, reclamation or destruction (Sections 8.8 and 8.9). For most commodity and structural fumigation operations, intentional venting following fumigation results in the largest discharge (emission) to the atmosphere. Theoretically, this MB is available for recapture and reuse or destruction, although there are several problems that lead to reduced recapture efficiencies.

Even though only a small fraction of added gas may be present after termination of a fumigation and subsequent airing it can, lead to sufficient air concentrations in some situations to present possible health hazards to workers and bystanders.

8.5.1. Soil fumigation

It is generally understood, that MB emissions to the atmosphere from soil fumigation can come from any of three major sources:

v. permeation through plastic sheets and leakage through joins and holes during fumigation;

vi. leakage from edges during fumigation and edges when laying and venting injection rigs; and

vii. desorption and venting from soil after lifting the sheets after fumigation.

Degradation is due to reaction with soil organic matter and some mineral constituents as well as other reaction pathways such as hydrolysis (De Heer *et al.* 1983; Duncan and Yates 2003).

8.5.2. Use of barrier films and other plastic covers to reduce emissions

Barrier films have become a very effective measure to reduce emissions by up to 50%. Since the 1998 assessment report there have been many studies looking at the advantages of a number of different types of barrier films. These have progressively included testing and application of virtually impermeable films (VIF films), semi-impermeable films (SIF) and totally impermeable films (TIF). VIF films typically comprise a LLDPE sandwich containing nylon; SIF films include a LDPE sandwich containing HDPE and TIF comprise a polyethylene sandwich containing two adhesive layers ("Admer") and a central layer of ethyl vinyl alcohol ("EVAL"). Studies under field conditions in a number of regions (Table 9.2), together with the large scale adoption of barrier films in Europe support the use of these films as a means to reduce MB dosage rates and emissions. Controlled studies have also shown substantial reductions in MB emissions using a number of techniques in addition to changing film type (Yates 2005; Fraser *et al.* 2006).
It is estimated in commercial practice, that emission ranges from 40-92% occur from the use of standard polyethylene (PE) and 35 - 87% for the wide range of barrier films that have been used (Table 8-2). The relatively high emission rates quoted are because figures include the emission after the tarp is removed. Recent studies with TIF Totally Impermeable Films) (Chow *et al.* 2009) have shown reductions in emissions of 22- 45% of the applied MB (Ntow *et al.* 2009).Under experimental conditions with full tarping, not strip treatment, and extended exposure periods, emissions were shown to be even lower during tarping, ie. < 6% of applied MB (Yates 2005, Papiernik *et al.* 2004; Ntow *et al.* 2009; Yates *et al*. 2009). Ntow *et al.* (2009) showed that when compared to standard PE films, TIF films can reduce peak emissions during the first 24 hours by up to 85% when MB was applied below 45cm; 80.5% when potassium thiosulphate was applied and 67% when the TIF film was used with shallow shank injection of MB at 30 cm. TIF films may be so effective that off gassing becomes a greater issue when the tarp is lifted and this may pose concerns to worker safety. Fraser *et al.* (2006) stated that a Virtually Impermeable Film (VIF), a semipermeable barrier film (metallised with aluminium) and more recently TIF were 6 to 9 times more effective in blocking MB flux to the atmosphere during fumigation and recent studies have continued to show that this can lead to a reduction

in dosage rates of at least 30-50 % for similar efficacy (Villahoz *et al*. 2008; Gao *et al*. 2013; Qin *et al*. 2011; Qin *et al*. 2014).

Table 8-3 shows that typically equivalent effectiveness is achieved with 25 –50% less MB dosage applied under the LPBF films (VIF, SIF (semi-impermeable films), TIF) compared with normal polyethylene fumigation films. Recent advances in the cost and technical performance of barrier films, especially metallised polyethylene films have reduced cost and extended their suitability for use with MB and also several of the fumigant alternatives, e.g. Pic clor 60 (60% chloropicrin/40% 1, 3-D); methyl iodide, 1,3-D (Fennimore *et al.* 2006; Gao *et al.* 2009) alternatives. Previous difficulties with sealing and gluing barrier films are no longer seen as a technical barrier to their implementation as new application technologies (i.e. glues, polyethylene edges and perforated films) have solved earlier problems.

The use of low permeability barrier films (VIF or equivalent) became compulsory in the member states of the European Union (EC Regulation 2037/2000) in 2000 and were used with the majority of critical uses granted in the US outside of California which had a regulation (California Code of Regulations Title 3 Section 6450(e)) against their use until recently. The Californian regulation was implemented because of concerns over possible worker exposure due to off gassing of MB when the film is removed or when seedlings are planted, but this has since been revised. In most other regions of the world, LPBF films are considered technically feasible, but may not be practical for MB fumigation because of small areas leading to lack of availability or high cost.

There is some use of barrier films in A5 countries, but generally the remaining uses for preplant soil use is with standard permeable PE films due to their low cost, however all remaining uses of MB should be encouraged to use such films to reduce dosage rates and emissions.

8.5.3. Adjustments of dosage rates in MB/Pic formulations to reduce emissions

Barrier films reduce MB emissions from soil fumigation by retaining the introduced MB in the soil for extended periods to allow the gas to degrade by reaction with soil components. Maximal degradation and thus reduction in emissions is obtained (Yates *et al.* 1998) when:

- the entire field is covered with barrier film;
- all film strip over-laps are well glued and sealed;
- the barrier film edges are sealed (buried under soil);
- the MB is injected deeply in the soil;
- the film is kept on the field, completely sealed, for more than 10 days; and
- the soil temperature, moisture and organic matter content are optimal - medium temperatures, moist soil, and high organic matter.

Barrier films are less effective at reducing MB emissions from soil fumigation (Rice *et al.* 1996; Thomas 1998; Wang *et al.* 1999, Yates *et al.* 2009) when:

- only part of the field is covered with barrier film (i. e. with strip or bed fumigation);
- any of the film strip over-laps become unglued or are otherwise unsealed;
- any of the film edges anywhere around the field become unsealed;
- the film seal is broken before 10 days have passed; and

- soil temperature, moisture, organic matter are in any way sub-optimal (hot, dry soil or very wet soil with little organic matter).

Studies have shown that with traditionally laid LDPE or HDPE films, most unreacted MB either passed through the films or was emitted from the edges of the film (Yates, 2005). In general, fumigation films remain in place for 5 to 7 days and with standard films this ensures maximum effectiveness of the applied dosage. With barrier films, even though lower dosages of MB are used, longer periods of tarping may be required to ensure complete degradation of the applied MB, to effectively reduce MB emissions and to avoid off gassing of unreacted MB when the tarps are removed.

8.5.4. Adjustments of dosage rates in MB/Pic formulations to reduce emissions

One key strategy to reduce MB dosage and therefore relative emissions has been the adoption of MB:Pic formulations with lower concentrations of MB (e.g. MB:Pic 50:50, 30:70 or less). These formulations are considered to be equally as effective in controlling soilborne pathogens as formulations containing higher quantities of MB (e.g. 98:2, 67:33) (e. g. Porter *et al.,* 1997; Melgarejo *et al.,* 2001; Lopez-Aranda *et al.,* 2003). Formulations containing high proportions of chloropicrin in mixtures with MB have been adopted widely by many countries to meet Montreal Protocol restrictions where such formulations are registered or otherwise permitted. Their use can be achieved with similar application machinery which allows co-injection of MB and chloropicrin or by use of premixed formulations. Consistent performance has been demonstrated with both barrier (Table 9.2.) and non barrier films. Fig 9.2 demonstrates the reduction in dosage rates achievable with barrier films compared to standard fumigation films

8.5.5. Other cultural management methods to reduce emissions

Irrespective of what surface barrier is used to contain MB during soil fumigation, there are a number of key factors, which affect emissions of MB during soil fumigation. Past reports (Yates, 2005, 2006, Yates *et al.* 2009) have shown that manipulation of many other factors can reduce emissions of applied MB, but the extent to which these factors are practiced by industry is unreported. These studies concluded that emissions can be reduced by improving containment of the MB gas and by increasing degradation time, however natural soil degradation is insufficient to reduce fumigant emissions to the atmosphere. Methods to improve containment included barrier films as discussed above, but also improvements in cultural factors of the cropping system including soil management, e.g. strip verses broadacre treatment, increased containment time, addition of sulphur containing fertilisers, increasing organic matter, soil water content, soil compaction and surface sealing with water.
Previous assessment reports have covered these factors, however as they are important they are repeated here for reference, especially as the A5 Parties are now applying for critical uses for which the information contained here could assist reduction of emissions of MB.

8.5.5.1. Soil characteristics

Studies of MB degradation in various soil types have shown that soil type greatly affects degradation, depending upon the time the MB is held in the soil. High organic matter and soil water content and increasing bulk densities are major factors, which assist reduction in emissions (Gan *et al.,* 1997; Thomas, 1998; Yates, 2005).

8.5.5.2. Fumigation period

Tarps left on soil for longer periods increase the residence time of the MB in the soil, thereby decreasing emissions. Wang *et al.* (1997a) demonstrated that emissions were reduced from 64% with PE tarps to 37.5% with VIF over a 5 day exposure, and from 56.4% to less than 3% respectively for a 10 day exposure with a sandy loam soil.

8.5.5.3. Irrigation, organic amendments and fertilisers

MB emissions can be reduced if the air filled porosity of the soil is reduced by increasing the water content. The presence of water increases the hydrolysis of MB to bromine ions. Irrigation reduces the variability in the distribution of MB in the soil, thus achieving a more reliable fumigation result (Wang *et al.,* 1997a).

In laboratory and field studies, Yates (2005, 2006) reported that the use of ammonium thiosulphate fertilizer added to the surface of soil could reduce emissions from 60 to less than 10%, and irrigation and surface sealing with water were an inexpensive way to reduce emissions.

The above results supported earlier work that addition of nitrogen fertilisers and organic amendments enhance degradation of MB. Lime, ammonia fertiliser and ammonia oxidation bacteria also increased the degradation rate of MB in soil (Ou *et al.,* 1997; Gan *et al*., 1997). These products have been shown to enhance degradation of MB. However, further research is required to identify their use for emission reduction.

8.5.5.4. Soil surface structure

A light rolling (pressing) of soil immediately after shank application closes furrows and seals the soil surface. This decreases direct emission from the injection points (channelling) within the first 24 hours after application and may assist reduction of total emissions (Anon 1997). Yates (2005) showed that surface compaction could reduce emissions from 90 to 64% of the applied MB.

8.5.5.5. Depth of injection

Emissions of MB can be reduced by injecting the material deep into the soil. The extent of the reduction depends upon soil conditions. For example, in field and laboratory studies, increasing the depth of injection from roughly 25 to 60 cm resulted in a 40% decrease in emissions under tarped conditions (Yates *et al.,* 1996). In laboratory studies, it was shown that increasing injection depth delays the occurrence of maximum volatilisation flux and also decreases cumulative emissions (Gan *et al.,* 1997; Yates, 2005). Deeper shank injections increased the path distance, thus increasing the residence time for degradation (Wang *et al.,* 1997ab) and minimising emissions.

8.5.5.6. Broadacre vs. strip

Strip fumigation (bed fumigation) can reduce the amount of MB applied by 20-40% as only the crop rows are treated rather than the entire field. This technique was common in many vegetable crops and most strawberry crops outside California before phase out. However, the ‘edge effect’ predominates and losses of MB from the edge of the bed tends to offset some of the advantages of strip fumigation with regard to emission reduction.

8.5.6. Regulatory practices to reduce MB emissions from soil

There are a number of practices in use in various parts of the world that result in reduced MB emissions from soil treatments, including:

- Limiting the frequency of MB fumigation by requiring intervals of 12–60 months between treatments. Alternative treatment methods could be implemented in the intervening period such as IPM, steam, solarisation, alternative fumigants and predatory fungi treatments. Reductions of 17–50% are feasible by implementing a reduction in fumigation frequency (refer to Table 8.1 in Anon. 1997).
- Imposing permit systems which could ensure that only technically necessary fumigation would be carried out (e.g. The Netherlands in 1981, Belgium 2005).
- Adjusting pesticide controls. For instance, MBTOC has suggested maximum dosage rates for specific uses, which suggest the likely maximum dosage rate required to achieve effectiveness (TEAP 2010).
- Regulating the users of MB to contractors only and licencing and training operators responsible for fumigation.
- Where possible, shifting practices from 'hot gas' methods using high concentrations of MB to soil injection that uses mixtures of MB/chloropicrin at lower MB concentrations, or substitute other chemical and non chemical treatments.

TABLE 8-3. RELATIVE EFFECTIVENESS OF MB/PIC FORMULATIONS APPLIED IN COMBINATION WITH LOW PERMEABILITY BARRIER FILMS (LPBF)[A] COMPARED TO THE COMMERCIAL STANDARD MB/PIC FORMULATION APPLIED UNDER STANDARD LOW DENSITY POLYETHYLENE FILMS (LDPF). [A] THE LBPF FILMS INCLUDE VIRTUALLY IMPERMEABLE (VIF), SEMI-IMPERMEABLE (SIF) AND TOTALLY IMPERMEABLE FILMS (TIF)

Country	Region	Commodity	Brand or Type of Barrier Film	Untreated	Methyl Bromide/Chloropicrin Mixtures (Product rate per treated area)															Notes	Reference
					Std film		Barrier Film – Relative yield compared to standard polyethylene														
				Yield	MB/Pic Formuln.	Product Rate	Not Spec	98:2	98:2	67:33	67:33	67:33	67:33	67:33	67:33	50:50	33:67				
						kg/ha	300	400	300	98	196	200	294	336	392	200	200				
MB Dosage rate (g/m2)								392	294	66	131	134	197	225	263	100	66				
Spain	Vinderos	Strawb. Runner	VIF - NotSpec	74	50:50	400											93			Fusarium, Phytophthora, Pythium, Rhizoctonia and Verticillium	De Cal et al 2004 a,b
	Navalmanzano			78	50:50	400											80				
Spain	Vinderos	Strawb. Runner	VIF - Not Spec	68	50:50	400										114	102			Fusarium, Cladosporium, Rhizoctonia	Melgarejo et al 2003
	Navalmanzano			34	50:50	400										76	75				
Spain	Avitorejo	Strawb. Fruit	VIF - Not Spec		50:50	400											97			2003 results	Lopez-Aranda et al 2003
	Malvinas				50:50	400											99				
Spain	Valencia	Strawb. Fruit	VIF - Not Spec	59	Not Spec	600	94													1998 Fusarium At 10cm & 30cm	Bartual et al 2002
				53	Not Spec	600	93													1999 results	
Spain	Avitorejo	Strawb. Fruit	VIF - Not Spec	80	67:33	400										112				Meloidogyne and weeds (unspec.)	Lopez-Aranda et al 2001a
	Tariquejo			54	67:33	400										106					
Spain	Moguer/Cartaya	Strawb. Runner	VIF - Not Spec		50:50	392										99				Inoculum not specified	Lopez-Aranda et al 2001b
Spain	Cabeza, Nav.	Strawb. Runner	VIF - Not Spec	74	67:33	400						105, 92								1998 Two sites	Melgarejo et al 2001
	Arevalo, Nav.			84	50:50	400										104, 104				1999 results, nurseries	
	Vinaderos, Nav.			49	50:50	400										95, 123				2000 results, nurseries	
Spain	Huelva	Strawb. Fruit	VIF - Not Spec	82	67:33	400						101								1997-1998 Inoc.unspecified	Lopez-Aranda et al 2000
				72	67:33	400						102								1998-1999 Inoc. Unspecified	
				68	67:33	400						109								1999-2000 Inoc. Unspecified	

Country	Region	Commodity	Brand or Type of Barrier Film	Untreated	Methyl Bromide/Chloropicrin Mixtures (Product rate per treated area)													Notes	Reference
					Std film		Barrier Film – Relative yield compared to standard polyethylene												
				Yield	MB/Pic Formuln.	Product Rate	Not Spec	98:2	98:2	67:33	67:33	67:33	67:33	67:33	67:33	50:50	33:67		
						kg/ha	300	400	300	98	196	200	294	336	392	200	200		
MB Dosage rate (g/m2)								**392**	**294**	**66**	**131**	**134**	**197**	**225**	**263**	**100**	**66**		
Spain	Moncada	Strawb. Fruit	VIF - Not Spec	60	98:2	600			95									1998 No major pathogens but Fusarium buried 10cm&30cm.	Cebolla et al 1999
				54	98:2	600			91										
France	Douville	Strawb. Fruit	VIF - Not Spec	65	Not Spec	800		99										Inoculum not specified	Fritsch 1998
NZ	Havelock North	Strawb. Fruit	VIF - Not Spec	83	67:33	500								98				Phytophthora present	Horner 1999
USA	Florida	Pepper	VIF Plastopil	69	67:33	392					78							Nutgrass	Gilreath et al.s 2005
			VIF Plastopil	69	67:33	392				99								Present	
			VIF Vikase	69	67:33	392					83								
			VIF Vikase	69	67:33	392				86									
USA	Florida	Strawb Fruit, Cantaloupe	Barrier - Pliant, Metallised		98:2 67:33	Trials on 18 Commercial Farms between 2000-2004; no increase in disease or weeds when rates reduced up to 50% under VIF wrt. polyethylene												Nutgrass and pathogens present	Noling and Gilreath 2004
USA	California	Strawb. Fruit	VIF - Not Spec	72	67:33	336								108				Inoculum not specified	Ajwa et al 2004
				80	67:33	392									96				
USA	Florida	Tomato	VIF - Not Spec	31	67:33	392					111		93		114			Nutgrass and rootknot nematodes	Hamill et al 2004
USA	California	Strawb. Fruit	VIF - Not Spec	75	67:33	392									106				Ajwa et al 2003, 2004, 2009
				83	67:33	392									111			Watsonville, high pathogen pressure	
				65	67:33	392									102				
USA	Florida	Tomato	VIF - Not Spec		67:33	392	"No significant reduction in yield"												Noling et al 2001
USA	California	Strawb. Fruit	VIF - Not Spec	45	67:33	364									116				Duniway et al 1998
USA	Georgia	Nurseries	VIF – not spec		67:33	389	See reference												Carey and Godbehere, 2004
USA	California	Roses			67:33 98:2	392 392	See reference												Hanson et al, 2006; 2009
USA	Florida	Pepper	VIF – not spec		67:33	392	See reference												Santos and Gilreath, 2004
USA	Florida	Pepper	VIF – not spec		67:33	392	See reference												Santos et al, 2005
USA	California	Ornamentals	VIF – not spec		67:33	392	See reference												Klose 2007, 2008
Unweighted averages (relative % yield)				66			94	99	93	93		102		103	108	104	91		

8.6. *Structural and commodity fumigation - sealing for emission minimisation*

Post-harvest disinfestations of commodities and structures using MB are performed, or should be performed, under well sealed conditions that limit loss of the fumigant to atmosphere during the exposure period. Commodity fumigations may be carried out either in fixed-wall structures such as fumigation chambers, in transport vehicles including containers and ships or under gastight tarpaulins.

Controlled conditions allow manipulation of the key fumigation parameters: dosage, temperature and time. Greater control of emissions is potentially more easily achieved in an enclosed structure than in relatively uncontrolled field situations. Providing the fumigation enclosure is relatively gastight, the dosage of MB can be reduced by increasing either the temperature or the exposure time, or both, providing the commodity is able to tolerate the conditions. Forced air circulation reduces the range of concentration - time (*ct*) products experienced within the enclosure, thus reducing the need for high dosage rates to compensate for areas that may otherwise receive insufficient concentrations of fumigant.

As noted in previous Assessments, developing high temperature schedules, with or without longer fumigation durations, could also reduce MB use providing the marketability, including food safety of the produce is acceptable. Improving the gas tightness of fumigation facilities will minimise leakage of MB into the atmosphere. Simple test criteria have long been available to the industry for determining the gas tightness of chambers (e.g.Bond, 1984) and these may be part of the mandatory fumigation requirements for trade (Quarantine treatments) of many perishable commodities e.g. as in APHIS PPQ manual (http://www.aphis.usda.gov/import_export/plants/manuals/index.shtml) .

8.7. *Fumigant Recapture and Destruction*

8.7.1. Scope for emission reduction by recapture

Parties have been urged to minimise emissions of MB in situations where they still use MB and are unable to adopt non-ozone depleting alternatives. This includes both QPS treatments and fumigations carried out under CUEs (Decisions VII/7(c), IX/6). One approach to minimising emissions is to adopt recapture technology, with subsequent destruction or reuse of the MB.

The discussion below concentrates mainly on availability and operation of recapture technologies for well-contained commodity and structural fumigations, including QPS applications. Some attempts have been made to apply recapture to soil fumigations, but the geometry and situation of soil fumigations render this problematic, and no systems, to knowledge of MBTOC, are in current use.

At this time, there remain no processes for MB approved as a destruction process under Decision XV/9 and listed in any updates to annex II of the report of 15 MOP that listed approved destruction processes by source and destruction method. However, the situation is currently under review (Decision XXII/10). Parties have previously submitted information on recapture processes for MB in use, following Decision XVII/11. This information and a review thereof is given in TEAP Report (TEAP 2006).

8.7.2. Efficiencies and potential quantities of MB available for recapture

For maximum 'recapturable' MB from a fumigation, losses within and from the system must be minimised. During any fumigation operation there four distinct opportunities for MB to be lost or emitted to the atmosphere:

i. by leakage during the actual fumigation treatment.
ii. during venting of the fumigation space immediately after fumigation or removal of the cover sheets where a deliberate discharge to the atmosphere takes place.
iii. following treatment when the treated commodity, packaging or structure slowly emits any sorbed MB.
iv. by reaction when sorbed MB is converted irreversibly to nonvolatile products

Situation (i) and, to some extent, (iii) can be controlled or reduced by better containment of the fumigation site. Leakage in these instances is undesirable from the fumigation perspective as it reduces the effectiveness of the treatment, as well as having worker safety implications (e.g. Baur *et al.* 2009).

The proportion of added non-volatile bromide residue formed as a result of a treatment is a direct measure of the proportion of the applied MB *not* emitted to atmosphere, provided an allowance is made for natural or added bromide ion already present prior to treatment. Only the remaining MB is available for recapture and/or destruction.

The proportion of applied MB converted to fixed residues, and thus not released to the atmosphere, varies widely with the particular treatment situation and treated material. It is influenced, *inter alia*, by the mass of material within the enclosure (the filling ratio) and its temperature and moisture content, and the exposure time. Longer exposure periods, higher temperatures, higher moisture contents and greater mass of material all lead to lower potential recapturable MB.

Methyl bromide may be temporarily and reversibly lost from the gas space within the fumigation enclosure through physical sorption on or in materials in the enclosure. This includes dissolving in fats and oils, surface adsorption and capillary condensation. In a fumigation it typically takes a few hours to approach equilibrium for this reversible sorption. Subsequent to the intentional exposure to the fumigant, the sorbed MB may volatilise from the treated commodity quite slowly, sometimes taking several days to reach low levels of emission. The rate of sorption and desorption is strongly dependent on the materials treated, their state and their dimensions.

There remains remarkably little firm quantitative field data published on the production of bromide ion or other measures of loss of MB from particular systems that could be used to estimate the maximum total quantity of MB available from fumigations.

The general overall potential for recovery from enclosed space fumigation, such as almost all QPS treatments, can be estimated from the total emissions expected. Estimated emissions and ranges for various categories of fumigation, including commodity and structural fumigation, are given in Table 8-2 (above).

As an approximation, most postharvest and structural fumigations have at least 85% of the applied dosage present at the end of the fumigation as MB in some form, *including* that lost by leakage. Fumigations of oily and high protein materials, such as nuts or oilseeds, may have 50% or even less available. The proportion of this theoretical limit that can actually be recaptured depends mainly on how much is lost by from the enclosure during the fumigation.

TEAP (2002) estimated that about 86% of the applied MB used in commodity and structural (space) fumigations remained as unreacted MB in some form at the end of the fumigation exposure period. This figure of 86% implies an average loss by reaction of 14% of applied dosage. In practice some leakage is inevitable and the time required for total desorption may be excessive. On the basis that 15% (8% loss from leakage, 6% residual material and other inefficiencies) of the originally applied material is lost from the system under best practice, TEAP (2002) estimated that 70% of applied material could be recovered from structure, commodity and QPS fumigations. The actual figure achievable in practice will vary substantially from this average figure according to the particular situation.

Since the material that reacts irreversibly with the commodity or structures does not contribute to emissions, and the reversibly sorbed material will eventually be released and is thus potentially recapturable, the only losses from the system relate to leakage and ventilation losses. With these less than 10% per day from well sealed systems (see below), there is theoretical potential for reduction of MB emissions of more than 90% of the quantity applied through adoption of recapture and efficient containment. Almost all QPS treatments are carried out under conditions that could potentially lead to a reduction in over 90% of applied dosage being emitted to atmosphere, though this would need adoption of substantially improved containment compared with much current practice.

QPS purposes could have been prevented from entering the atmosphere by the fitting of recapture and destruction equipment (TEAP 2002). For the 7,456 tonnes used for commodity and structural treatments (from Table 8-2), principally for QPS use, at 70% recapturable, 5,219tonnes could have been prevented from entering the atmosphere by the fitting of recapture and destruction equipment.

In current practice, many fumigations are conducted in a way where there are losses from the system that prevent this theoretical 70% recaptureable value being attained routinely.

Worldwide many fumigations continue to be conducted in poorly sealed enclosures, leading to high rates of leakage and gas loss. It is not uncommon to find <10% of applied MB present after a 24 h exposure, particularly with structural fumigations. For maximum potential for recapture, many fumigation enclosures would need substantially improved sealing to restrict leakage to a low level. Banks and Annis (1984) estimated loss rates of as low as 5 to 10% per day were achievable in most structures with appropriate sealing.

In good fumigation practice, such as specified by AQIS (2006), there is a residual gas level present after a fumigation. Table 8-4 gives the residual gas levels expected at various times.

TABLE 8-4. MINIMUM CONCENTRATIONS OF MB REMAINING AT VARIOUS TIMES FOR QUARANTINE FUMIGATIONS (AQIS 2006).

Time after dosing (h)	Minimum % concentration remaining
0.5	75
1	70
2	60
4	50
12	35
24	30

These values are aimed at achieving effective kill under practical quarantine conditions. They are not specifically targeted at achieving minimum emissions (losses by leakage) during fumigation. They provide a guide to what is typically achieved in good current commercial practice. With better sealing levels, relative MB concentrations remaining, even at long exposures, can be substantially improved. The figures underlie the need to minimise exposure periods if it is desirable to achieve maximum potential for recapture.

These minima represent minimum recapturable MB. They do not take into account desorbable MB. This may be as much as 50% of applied dosage with sorptive materials. Treatments of perishables are typically for less than 4 hours, but timber and durables may be exposed for 24 h or longer, to allow for full distribution and penetration of the fumigant.

The current version (IPPC 2013) of the ISPM 15 standard for treatment of solid wooden packaging materials in export trade have set a retention of 50 % of the initial standard dosage at the end of the 24h fumigation period (Table 8-5). This high level of retention is difficult to achieve in practice, requiring very good fumigation practice, including very good sealing levels and low filling ratios.

Consequently, some fumigators are adding extra MB at the start of the ISPM15 fumigations to compensate for high leakage so that specified minimum concentrations at the end of the exposure are met. This process uses additional MB and reduces the proportion of MB added that is in practice available for recapture. The level of retention of 50% of initial dosage may not be possible practically for some log fumigations carried out under gasproof sheets.

TABLE 8-5. ISPM 15 STANDARD FOR TREATMENT OF SOLID WOOD PACKAGING MATERIAL. DOSAGE RATES AND FINAL CONCENTRATIONS. (IPPC 2013).

Temperature	Dosage (g m^{-3})	Minimum concentration (g m^{-3}) at 24h:	% retention at 24 h
21°C or above	48	24	50
16°C or above	56	28	50
10°C or above	64	32	50

8.8. Efficiency of recapture

The efficiency of recapture/destruction can be described in several ways. For dilute MB sources, the same general concepts may be applied as for dilute CFC sources. These are the overall Destruction Efficiency (DE), the Recovery and Destruction Efficiency (RDE) and the Destruction and Removal Efficiency (DRE). These various measures of efficiency of destruction, and thus ozone protection, are defined (TEAP 2002, a, b; 2006).

Parties have submitted DRE information for some recapture systems in use in 2006, summarised in TEAP (2006). Equivalent information for currently installed commercial units have not been published.

Well designed, sized and operated recapture systems based on activated carbon as recapture medium have almost complete recovery of MB. Fumigant concentrations are typically 10-100 g m^{-3} entering the recapture system and much less than the low, tolerable workspace concentrations (about 0.004 g m^{-3}) on exit, giving DREs of >99.9%.

In order for a carbon-based recapturing unit to be considered for use by USDA APHIS, it must meet the following specifications (USA 2009):

A system should:

- accommodate a variety of enclosure types (portable chamber and fixed chamber)
- accommodate MB monitoring sensors in the air flow (number and placement of sensors will depend on the size of the equipment)
- accommodate the fumigant concentrations and temperature conditions listed in this (Treatment) manual
- ensure that all untreated ventilation air is under negative pressure (in the event of a leak, ambient air will leak into the system instead of contaminated air escaping from the system)
- leak-tight (includes valves, ducts, canisters)
- provide a minimum adsorptive capacity of 1 pound of MB per 10 pounds of carbon (The quality of the carbon will determine the adsorptive capacity. A lower quality carbon could cause a ration of 1 pound of MB per 20-25 pounds of carbon.)
- provide between 4 and 15 complete gas exchanges per hour
- provide flow and pressure system monitoring
- provide onsite installation, training, and continual technical support
- reduce emissions of MB by at least 80%
- retain approved fumigation and aeration times as mandated by the PPQ Treatment Manual
- not exceed 500 ppm (2 oz/1000 ft3) MB gas released to the atmosphere and provide the ability to document MB concentration levels

8.9. Commercial and developmental processes for MB recapture, with destruction or recovery

A number of techniques have been proposed or investigated for their potential to recapture MB after fumigation operations. In some cases the recaptured MB is recovered in liquid or gaseous form, but usually the MB is subsequently destroyed or released by further processing after recapture. While versions of many of the approaches given below have been in some commercial application, recapture on activated carbon is currently the main system in full scale, commercial use.

Research, developmental and industrial recapture and emission reduction systems for gas streams of methyl bromide fumigant diluted in air, as present at the end of a fumigation include:

- Capture on activated carbon, with subsequent treatment to destroy sorbed methyl bromide by rinsing with aqueous thiosulphate solution or other reagents, disposal in secure landfill and thermal (hot air or steam) desorption for reuse or further processing.

- Capture on specialised zeolite with subsequent thermal desorption and reclamation

- Liquid (aqueous) scrubbing with various nucleophilic reagents, including thiosulphate, ammonia-based mixtures and ethylene diamine

- Low temperature recondensation

- Combustion systems

- Gas phase reaction with ozone, sometimes assisted by sorption of the methyl bromide on to carbon.

- Microbial degradation

Details and discussion of these processes are given in the 2010 MBTOC Assessment Report. There is continuing research to improve operation of these recapture technologies (e.g. Vasireddy, 2014, Mitch, 2014, Hall, 2014).

Current operational commercial installations include sorption on activated carbon (Nordiko 2015, Joyce, 2014) and liquid scrubbing by unspecified nucleophilic reagent (Sword, 2014).

Economics will tend to favour destruction over recycling in situations while new MB continue to be easily obtained for QPS purposes and destruction technologies are relatively cheap, including allowance for disposal of products of the destruction system.

Despite Decisions VII/5(c) and XI/13(7) that urge Parties to adopt MB recovery and to minimise emissions for QPS MB treatments, there are no installations known to MBTOC that have been commissioned prior to 2014 specifically for ozone-layer protection. However there are increasing numbers of installations, based on active carbon systems that are designed to recapture MB after well-contained commodity treatments.

These units are being attached to MB fumigations in port areas and other urban environments to scrub emissions from fumigations to comply with local regulations for toxic gas emissions, air and environmental quality and worker safety.

Most of the recovery technologies mentioned above are complex in nature. In many cases, they are likely to be a significant part of the total cost of a new fumigation facility or to contribute significant capital cost or hire costs to apparatus associated with mobile treatment units. Most have significant running costs compared with costs of treatments

Because of the extra costs associated with recapture, it is unlikely there will be substantial adoption without some incentives or regulatory intervention. Adoption in the absence of such measures or other requirements, such as local air quality specifications, will place early adopters at a competitive disadvantage compared with those that chose not to adopt recapture.

The technologies are unlikely to become widely used to assist ozone layer protection without further international and national economic and regulatory drivers.

Recapture and recycling processes have the potential to provide a means of reducing emissions from a range of fumigation operations, and making MB supplies available as a transitional measure for uses where MB alternatives are most difficult to implement.

8.10. References

Ajwa H.A., Fennimore, S., Kabin, Z., Martin, F., Duniway, J., Browne, G., Trout, T., Kahn, A. and Daugovish, O. (2004). Strawberry yield with chloropicrin and inline in combination with metham sodium and VIF. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions 3-6 November 2004, Orlando, Florida, USA.

Ajwa, H.A.,. Fennimore, S, Kabin, Z., Martin, F., Duniway, J., Browne, G., Trout, Goodhue T R., and L. Guerrero (2003). Strawberry yield under reduced application rates of chloropicrin and InLine in combination with metham sodium and VIF. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, 3-6 November 2003, San Diego, California, USA.

Ajwa H, Sullivan D., Stanghellini M., Ntow W., Holdsworth M., and Hunzie J. (2009). Volatilization Losses of Methyl Bromide and Chloropicrin from Drip Fumigated Beds Covered with Totally Impermeable Tarp. In 'Annual International Research Conference on MB Alternatives and Emissions Reductions'Nov 10-13,San Diego, 2009.

Anon. (1997). Provision of services with regards to the technical aspects of the implementation of EC legislation on ozone depleting substances. Methyl Bromide Background May 1997. B7-8110/95/000178/MAR/D4. Technical report prepared for DGXI of the Commission of the European Communities. Prospect C&S Consultants, Brussels.

Anon (2010). The 2010 Assessment of the Scientific Assessment Panel. United Nations Environment Programme (UNEP), Nairobi, Kenya, 2010. http://ozone.unep.org/Assessment_Panels/SAP/Scientific_Assessment_2010/index.shtml

Bartual, R., Cebolla, V., Bustos, J., Giner, A., Lopez-Aranda, J. M. (2002). The Spanish project on alternatives to methyl bromide. (2): The case of strawberry in the area of Valencia. Acta Hort. 567: 431-434.

Baur, X,, Poschadel B. and Budnik L. T. (2009). High frequency of fumigants and other toxic gases in imported freight containers - underestimated occupational and community health risk. Occup Environ Med. October 26, 2009, 17 pp.

Bond, E. J. (1984). *Manual of fumigation for insect control.* FAO Plant Production and Protection Paper No. 54, FAO, Rome, 432 p.

Carpenter, L. J., S. Reimann, J. B. Burkholder, C. Clerbaux, B. D. Hall, R. Hossaini, J. C. Laube, and S. A. Yvon-Lewis. (2014) Update on Ozone-Depleting Substances (ODSs) and Other Gases of Interest to the Montreal Protocol.*Scientific Assessment of Ozone Depletion: 2014* .

Cebolla, V., Bartual, R., Giner, A and. Bustos, J. (1999). Two years effect on some alternatives to Methyl Bromide on strawberry crops. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reduction 1999. 1-4 November, 1999, San Diego, California, USA.

Chow, E. (2009). An update on the development of TIF mulching films In 'Annual International Research Conference on MB Alternatives and Emissions Reductions' Nov 10-13,San Diego, 2009.

Clerbaux, C. and D. Cunnold, Long-Lived Compounds, Chapter 1 in Scientific Assessment of Ozone Depletion 2006, Global Ozone Research and Monitoring Project-Report No. 50, 1.1- 1.63, WMO, Geneva, Switzerland, 2007.

Daniel, J. and G. Velders, Ozone Depletion Potentials and Global Warming Potentials, Chapter 8 in Scientific Assessment of Ozone Depletion 2006, Global Ozone Research and Monitoring Project-Report No. 50, 8.1- 1.39, WMO, Geneva, Switzerland, 2007.

De Cal, A., Martínez-Terceno, A., López-Aranda, J.M. and Melgarejo P. (2004a) Alternatives to methyl bromide in Spanish strawberry nurseries. Plant Disease 88(2): 210-214.

De Cal, A., Melgarejo, P., Martinez-Treceno, A., Salto, T., Martinez-Beringola, M. L., Garcia-Baudin, J. M., Garcia-Sinovas, D., Garcia-Mendez, E., Becerril, M., Medina, J. J., Lopez-Aranda, J. M. (2004b) Chemical alternatives to MB for strawberry nurseries in Spain. 2003 Results. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reduction 2004. 31 October - 3 November, 2004, Orlando, Florida, USA, pp. 17-1.

De Heer, H., Hamaker, P. and Tuinstra, C.G.M. (1983). Use of gas tight plastic films during fumigation of glasshouse soils with MB. *Acta Horticulturae*, 152, 109-126.

Dungan R. S. and Yates, S. R. (2003) Degradation of fumigant pesticides. Vadose Zone Journal 2:279-286 (2003)

Fennimore S.A., Shem-Tov S., Ajwa H., and Weber J.B.(2006) Retention of broadcast-applied fumigants with impermeable film in strawberry. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reduction 2006. 6-9 November 2006, Orlando, Florida. pp. 12-1 – 12-4.

Fraser, P, Coram, S., Dunse, B. Macfarling-Meure and Derek, N. (2006). Methyl bromide emissions through barrier films. CSIRO Report to Department of Primary Industries Victoria, August, 2006

Fritsch, J. (1998). Strawberries crops in France: different methods to apply methyl bromide and metam sodium in open fields. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reduction 1998. 7-9 December, 1998, Orlando, Florida

Gao, S., Qin, R.,Hanson, B., Wang, D., Browne, G., and Gerik, J. (2009). Measuerment and Assessment of Field Emission reductions. In 'Annual International Research Conference on MB Alternatives and Emissions Reductions' Nov 10-13,San Diego, 2009.

Gao, S., Hanson, B., Qin, R., Cabrera, J., Gerik, J., Wang, D., Browne, G. (2013). Totally impermeable film (TIF) reduces emissions in perennial crop fumigation. *California Agriculture* 67(4):217-221.

Gan, J.; Yates, S.R.; Spencer, M.V.; Yates, M.V.; Jury, W.A. (1997). Laboratory-scale measurements and simulations of effect of application methods on soil MB emission. *Journal of Environmental Quality*, 26(1) 310-317.

Gilreath J.P., Motis T.N. and Santos B.M. (2005a). *Cyperus* spp. control with reduced methyl bromide plus chloropicrin doses under virtually impermeable films. Crop Protection 24, 285-287.

Hall, W. (2014). The recapture and reuse of methyl bromide on activated carbon . Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions. November 4-6, 2014, Orlando, Florida, USA. Paper 36.

Hamill, J. E., Dickson, D. W., T-Ou, L., Allen, L. H., Burelle, N. K. and Mendes, M. L. (2004). Reduced rates of MBR and C35 under LDPE and VIF for control of soil pests and pathogens. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions 2004. 31 October - 3 November, 2003, Orlando, Florida, USA, pp. 2-1.

Hanson, B.D., J.S. Gerik, S.M. Schneider.(2009). Evaluation of reduced Methyl Bromide rates in field grown perennial crop nurseries. Proceedings Western Society of Weed Science. 62:17.

Hanson, B., J. Gerik and S. Schneider (2006). Evaluation of reduced Methyl Bromide rates and alternative fumigants in field grown perennial crop nurseries. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, Orlando, Florida, USA.

Horner, I.J. (1999). Alternative soil fumigant trials in New Zealand strawberry production. In: Annual International Research Conference on Methyl Bromide Alternatives and Emission Reductions, San Diego, California, USA

IPPC 2013. ISPM No. 15. Regulation of wood packaging material in international trade.. IPPC: Rome. 20 pp. https://www.ippc.int/sites/default/files/documents/20140630/ispm_15_2009_en_2014-06-16_201406301411--243.8%20KB.pdf

Joyce, P (2014). Commercial scale Q/PS methyl bromide emissions control. . Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions. November 4-6, 2014, Orlando, Florida, USA. Paper 37

Klose S., H.A. Ajwa, S.S. Tov, S.A. Fennimore, K.V. Subbarao, J. D. MacDonald, H. Ferris, F. Martin, J. Gerik , M.A. Mellano and I. Greene (2007). Shank and drip applied soil fumigants as potential alternative to methyl bromide in California-grown cut flowers. In: Annual International Conference on Methyl Bromide Alternatives and Emission Reductions. Sandiago, CA, USA p. 47-1-2.

Klose, S. (2008). Weed and disease control in California- grown floricultural crops without Methyl Bromide soil fumigation (Abstr.) In: Proceedings of the 2008 Joint Annual Meeting, 5 – 9 October 2008

Lopez-Aranda, J. M., Romero, F., Montes, F., Medina, J. J., Miranda, L., De Los Santos, B., Vega, J. M., Paez, J. I., Dominguez, F., Lopez-Medina, J., Flores, F. (2001a). Chemical and Non-Chemical Alternatives to MB Fumigation of Soil for Strawberry. 2000-2001 Results. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions 2001. 5-9 November, 2001, San Diego, California, USA, pp. 40-1.

Lopez-Aranda, J. M., Medina, J. J., Miranda, L., De Los Santos, B., Dominguez, F., Sanchez-Vidal, M. D., Lopez-Medina, J., Flores, F. (2001b). Agronomic Behaviour of Strawberry Coming From Different Types of Soil Fumigation in Nurseries. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions 2001. 5-9 November, 2001, San Diego, California, USA, pp. 38-1.

Lopez-Aranda, J. M., Medina, J. J., Miranda, L., Dominguez, F. (2000). Three Years of Short-Term Alternatives To MB on Huelva Strawberries. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reduction 2000. 6-9 November, 2000, Orlando, Florida, USA, pp. 10-1.

Lopez-Aranda, J. M., Miranda, L., Romero, F., De Los Santos, B., Montes, F., Vega, J. M., Paez, J. I., Bascon, J., Medina, J. J. (2003). Alternatives to MB for Strawberry Production in Huelva (Spain). 2003 Results. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions 2003. November, 2003, San Diego, California, USA pp. 33-1.

López-Aranda J.M., Miranda L., Medina J.J., Soria C., Santos B.D.L., Romero F., Pérez-Jiménez R.M.,Talavera M., Fennimore S.A., Santos B.M. (2009a). Methyl bromide alternatives for high tunnel strawberry production in southern Spain.HortTechnology, 19, 187-192.

MBTOC (1995). United Nations Environment Programme (UNEP) Methyl Bromide Technical Options Committee (MBTOC) 1994 Assessment of the Alternatives to Methyl Bromide. United Nations Environment Programme, Nairobi: 304pp.

MBTOC (1998). United Nations Environment Programme (UNEP) Methyl Bromide Technical Options Committee (MBTOC) 1998 Assessment of the Alternatives to Methyl Bromide. United Nations Environment Programme, Nairobi: 358pp.

MBTOC (2002). United Nations Environment Programme (UNEP) Methyl Bromide Technical Options Committee (MBTOC). 2002 Report of the Methyl Bromide Technical Options Committee. 2002 Assessment. United Nations Environment Programme, Nairobi.

MBTOC (2006). United Nations Environment Programme (UNEP) Methyl Bromide Technical Options Committee (MBTOC). 2006 Report of the Methyl Bromide Technical Options Committee. 2006 Assessment. United Nations Environment Programme, Nairobi. 453pp.

MBTOC (2011). United Nations Environment Programme (UNEP) Methyl Bromide Technical Options Committee (MBTOC). 2010 Report of the Methyl Bromide Technical Options Committee. 2006 Assessment. United Nations Environment Programme, Nairobi. 400pp.

Melgarejo, P., De Cal, A., Salto, T., Martinez-Beringola, M. L., Martinez-Treceno, A., Bardon, E., Palacios, J., Becerril, M., Medina, J. J., Galvez, J., Lopez-Aranda, J. M. (2001). Three Years of Results on Chemical Alternatives To Methyl Bromide For Strawberry Nurseries in Spain. In: Annual International Research

Conference on Methyl Bromide Alternatives and Emissions Reduction 2001. November 5 - 9, 2001, San Diego, California, USA. pp. 93-1.

Mitch, W. (2014). Destruction of methyl bromide on activated carbon using thiosulfate or electricity. . Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions. November 4-6, 2014, Orlando, Florida, USA. Paper 38.

Montzka, S. and P. Fraser (2003) Controlled Substances and Other Gas Sources, Chapter 1 in: Scientific Assessment of Ozone Depletion, 2002, Global Ozone Research and Monitoring Project Report No. 47, Geneva, 1.1-1.83, WMO, Geneva, Switzerland, 2003.

Montzka, S., S. Reimann, A. Engel, K. Kruger, S. O'Doherty, W. Sturgess, D. Blake, M. Dorf, P. Fraser, L. Froidevaux, K. Jucks, K. Kreher, M. Kurylo, A. Mellencki, J. Miller, O.-J. Nielsen, V. Orkin, R. Prinn, R. Rhew, M. Santeee, A. Stohl & D. Verdonik (2011). Ozone-Depleting Substances (ODSs) and Related Chemicals, Chapter 1 in Scientific Assessment of Ozone Depletion: 2010, WMO Global Ozone Research and Monitoring Project – Report No. 52, 1.1-1.108.

Noling, J. W. and Gilreath, J. P. (2004). Use of virtually impermeable plastic mulches (VIF) in Florida strawberry. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, November 3-6, 2004, Orlando, Florida, USA. pp. 1-1.

Noling, J. W., Gilreath, J. P. and Rosskopf, E. R. (2001). Alternatives to Methyl Bromide Field Research Efforts For Nematode Control in Florida. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions , 5-9 November, 2001, San Diego, California, USA. pp. 14-1.

Nordiko 2015. Mobile Log Fumigant Recapture System. http://www.epa.govt.nz/search-databases/HSNO%20Application%20Register%20Documents/HRC08002_Nordiko%20Mobile%20Log%20Fumigant%20Recapture%20System.pdf. Accessed 14 February 2015.

Ntow, W. Ajwa H., Sullivan D., Hunzie1, J. (2009). Chloropicrin and Methyl Bromide Emissions Reduction by Using Totally Impermeable Film. In 'Annual International Research Conference on MB Alternatives and Emissions Reductions'Nov 10-13,San Diego, 2009.

Ou, L., Joy, P.J., Thomas, J.E.;,Hornsby, A.G. (1997). Stimulation of microbial degradation of MB in soil during oxidation of an ammonia fertilizer by nitrifiers. *Environmental Science and Technology.* 31, 717-722.

Papiernik, S. K., Yates,S. R., Dungan, R. S., Lesch, S. M., Zheng, W. and Guo M. (2004). Effect of surface tarp on emissions and distribution of drip-applied fumigants. *Environ. Sci. Technol.*, 38 (16), 4254–4262.

Porter, I. Banks, J., Mattner, S. and Fraser, P. (2010) Global phaseout of methyl bromide under the Montreal Protocol: implications for bioprotection, biosecurity and the ozone layer. In :*Challenges for Plant Protection in the 21st Century*. Gullino L. and Chet, E (eds). Springer Publishing, New York .

Qin R1, Gao S, Ajwa H, Sullivan D, Wang D, Hanson BD. (2011)Field evaluation of a new plastic film (vapor safe) to reduce fumigant emissions and improve distribution in soil. J Environ Qual. 40:1195-203

Qin, R., Daugovish, O., Gao, S., Hansen,B., Gerik, J., Ajwa, H. (2014).. Soil Fumigation applied through deep drip tapes in totally impermeable film in mulched raised-bed systems for strawberry production. 2014 ASHS Annual Conference

Rice, P., Anderson, T., Clink, J. and J. Coats. (1996). The influence of soil environment variables on the degradation and volatility of methyl bromide in soil. *Environ. Toxicol. Chem.* 15(10): 1723-1729.

Santos, B., J.P. Gilreath and T.N. Motis (2005). Managing nustedge stunt nematode in peppers with reduced Methyl Bromide plus chloropicrin rates under Virtually Impermeable Films. *HortTechnology* 15(3): 596 - 599

Santos, B.M. and J.P. Gilreath (2004). *Cyperus* spp. control with reduced Methyl Bromide rates under VIF in pepper. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, Orlando, Florida, USA, 2004.

Swords, P. (2014). F.A.S.T. System : Fumigant Disposal and Scrubbing Treatment. . Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions. November 4-6, 2014, Orlando, Florida, USA. Paper 39.

TEAP (2002). TEAP Task Force on Destruction Technologies Report. UNEP, Nairobi.

TEAP (2006). Report of the UNEP Technology and Economic Assessment Panel . September 2006. Evaluations of 2006 Critical Use Nominations for methyl bromide and related matters. UNEP: Nairobi. viii + 129 pp.

TEAP (2009). Report of the UNEP Technology and Economic Assessment Panel . September 2009. Evaluations of 2009 Critical Use Nominations for methyl bromide and related matters. UNEP: Nairobi. 103 pp.

Thomas, W. (1998). Feasibility of using gas impermeable tarps to reduce MB emissions associated with soil fumigation in the United States. *United States Environmental Protection Agency Report*. Jan 26, 1998.

USA (2009). Methyl bromide Quarantine and Preshipment interim management strategy. October 30, 2009. 33pp.

Vasireddy, S. (2014). Enhanced catalysts for combustion of CH3Br: MOX-CEO2 (M= Mn, Co). . Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions. November 4-6, 2014, Orlando, Florida, USA. Paper 40.

Villahoz, M,D., Garza, F., Barrows, P. and Sanjurjo, M. (2008). TIF (Totally Impermeable film). An Innovative Film for Much, Broadcast Fumigation and greenhouses in Agriculture. In: Annual International Research Conference on MB Alternatives and Emissions Reductions. Orlando, Florida, USA, November 11-14, 2008

Wang, D., Yates, S., Gan, J. and J. Knuteson. (1999). Atmospheric volatilization of methyl bromide, 1,3-dichloropropene, and propargyl bromide through two Plastic films: transfer coefficient and temperature effect. *Atmospheric Environment.* 33: 401-407.

Wang, D.; Yates, S.R.; Ernst, F.F.; Gan, J.; Gao, F.; Becker, J.O. (1997a). MB emission reduction with optimized field management practices, *Environmental Science and Technology.* 31: 3017-3022.

Wang, D.; Yates, S.R.; Ernst, F.F.; Gan, J.; Jury, W.A. (1997b). Reducing MB emission with a high barrier plastic film and reduced dosage. *Environmental Science and Technology*. 31: 3686-3691.

WMO (World Meteorological Organization) (2003). Scientific Assessment of Ozone Depletion: 2002, United Nations Environment Programme (UNEP), Nairobi, Kenya, 2003

WMO (2007) (World Meteorological Organization). Scientific Assessment of Ozone Depletion: 2006, United Nations Environment Programme (UNEP), Nairobi, Kenya.

WMO (2011) (World Meteorological Organization). Scientific Assessment of Ozone Depletion: 2010, United Nations Environment Programme (UNEP), Nairobi, Kenya.

WMO (2015) (World Meteorological Organization). Scientific Assessment of Ozone Depletion: 2014, United Nations Environment Programme (UNEP), Nairobi, Kenya

Yates, S.R. (2005). Reducing bystander exposure by emission reduction. Annual International Research Conference on MB Alternatives and Emissions Reductions. Oct 31 - Nov 3, 2005. San Diego, California, USA

Yates, S. (2006). Developing a simple low-cost approach for evaluating emission reduction methods. In: Annual International Research Conference on MB Alternatives and Emissions Reductions. Orlando, Florida, USA, November 3 – 6, 2006

Yates, S, Papierknik S., Chellemi D, Wang D, Gao S, Hanson B, Ajwa H, Browne G, Kluepfel D. (2009). Update of film permeability measurements for USDA-ARS area-wide research project. In 'Annual International Research Conference on MB Alternatives and Emissions Reductions'Nov 10-13,San Diego, 2009.

Yates, S. R., Gan, J., Wang, D and Ernst, F.F. (1996). MB emissions from agricultural fields. Bare-soil deep injection. *Environmental Science and Technology,* 31: 1136-1143.

Yates, S. R., Wang, D., Gan, J. and F.F. Ernst. (1998). Minimizing methyl bromide emissions from soil fumigation. *Geophysical Research Letters,* 25(10): 1633-1636.

9

Chapter 9. Economic issues

9.1. Introduction

During CUN evaluations, MBTOC assesses the financial feasibility of alternatives available to the Party (Decision IX/6), because an alternative may be considered technically feasible, but may not be economically feasible. Measurement of the economic implications of the use of methyl bromide or an alternative can in most cases be done satisfactorily by means of a partial budget analysis, a practical tool to compare alternative production practices. In the case of a Soils nomination, the analysis consists of measuring the costs of methyl bromide treatment and the revenues of the relevant crop when methyl bromide is used, as well as the treatment costs and revenues for technically feasible alternatives. Only the costs that actually change as a result of the use of the alternative need be considered, hence the name partial budgeting. So, for example, if tractor use increases as a result of the use of the alternative, this change in cost needs to be taken into account. If the use of fertilizer or any other input remains unchanged, however, this item can then be ignored.

The main advantage of partial budgeting is its simplicity. However, because prices change continuously and randomly (i.e. they are stochastic), the results are often unstable, even in the short term. In those cases where stochastic prices are thought to influence decisions, economists typically assess prices using more stable estimates of supply and demand, typically in the form of a partial equilibrium analysis. This is based on the assumption, among others, that changes in one market do not have spillover effects on all other markets. Again, this assumption is made for the sake of simplicity, but is not always realistic. There are circumstances where a general equilibrium analysis would be required, namely where a change in prices or another variable such as supply or demand has knock-on effects on other markets. So, for example, as methyl bromide use is phased out it will no longer be readily available, so that it's price will be expected to rise and this increase will increase the speed of adoption of alternatives.

The analyses described thus far all use current prices to measure the economic effects of using methyl bromide and it's alternatives. However, prices may be distorted through government action. For example, high tariffs against imports of chloropicrin will distort its domestic price and thereby influence the economics of the use of methyl bromide and it's alternatives. When such price distortions are thought to be dominant, an economic analysis using 'shadow' prices may be called for. In this event, economists try and establish what the prices would have been in the absence of the distortion in question.

Finally, conventional economic analysis only considers the 'visible' differences in outcome as a result of the use of methyl bromide or it's alternatives. However, economists recognize the existence of 'externalities', which arise when the costs or benefits of an action are not all taken into account by the relevant decision maker. For example, the full benefits of the phase-out of methyl bromide are not taken into account in a partial budget analysis, where only changes in the user's revenue are measured while the benefits to society of less ozone depletion are ignored. Economists can however include these benefits, but first need to put a monetary value to the benefit, using surrogate prices measured with techniques such as 'willingness to pay'.

It is evident that the techniques discussed here differ in their need for more and more information. For this reason, it does not make sense to use techniques that are not necessary. This is reflected in the state of the published literature on the economic feasibility of alternatives to methyl bromide. The literature is dominated by partial budgeting: 16 of the 20 articles published in the peer reviewed and 'grey' literature over the period 2010 to 2014 use this technique[6]. This review focuses on the other four publications. Furthermore, a case study of the economics of moving the production of strawberry runners to soilless cultures in different countries is planned to illustrate the factors that need to be taken into account in the process of establishing when an alternative is technically feasible. This case study will be provided at a later date.

9.2. Other techniques

As noted in previous Assessment and Progress Reports, **Norman (2005)** provided the most comprehensive ex ante analysis of the impact of the methyl bromide phase-out on the California strawberry industry. In a follow-up study, **Mayfield and Norman (2012)** point out correctly that it is impossible to advise Parties on the economic feasibility or otherwise of methyl bromide and its alternatives because they (the Parties) have yet to arrive at a consensus definition of what standard must be met. At best it could be argued (as MBTOC has proposed) that it cannot mean that users of methyl bromide do not have to change their production practices or that there are no changes in costs (p 93).

The authors point out that the data on economic feasibility are not plausible given that the adoption of alternatives has increased, that strawberry yields have increased, and that the acreage under strawberries has increased (Mayfield and Norman, 2012: 99). In their view farmers are likely to have modified their production practices (e.g. input substitution, different weeding methods) and to have learned while implementing new procedures. Furthermore, even if costs increase, some of this cost may be shifted to consumers given the particular relative elasticity of demand and of supply, as shown in Norman (2005).

Larsen (2014) has conducted a political economy analysis that rests on the observation that farm workers have relatively little political and economic power (her argument is based on the California strawberry industry, but is generalizable to other places where farm workers share the same lack of influence). This disables them from protesting against the use of methyl bromide, which has the effect of making alternatives more expensive. As growers cannot change the circumstances (including wages) of workers unilaterally because of competition, it will be up to consumers to take up these and similar causes.

Niu *et al.* (2013) argue that Integrated pest management (IPM) is an alternative to fumigation of food processing facilities, and has the added benefit that it may reduce insecticide resistance, improve worker safety, and reduce environmental and consumer concerns about pesticide residuals. They use a Geographic Information System (GIS) to measure both the treatment costs as well as the costs of failing to control insects.

[6] These are provided in the reference list.

Petersen *et al.* (2013) propose a method for assessing the actual cost of sanitary and phytosanitary regulations for 47 fresh fruit and vegetable product imports into the USA from 89 exporting countries over the period 1996–2008. Importantly, the results confirm that these measures generally reduce trade, but that this effect is weakened over time as exporters accumulate experience, and it eventually vanishes.

9.3. References

Abou-Zeid N.M., Mahmoud N.A., Khalil A E. (2011). Efficiency of certain methyl bromide alternatives and their economical feasibility on tomato infected with root-knot nematode and fungi under field condition in Egypt. 4eme Conference Internationale sur les Methodes Alternatives en Protection des Cultures. Evolution des cadres reglementaires europeen et francais. Nouveaux moyens et strategies Innovantes, Nouveau Siecle, Lille, France, 8-10 mars 2011. 606-613.

Bangarwa S.K., Norsworthy J.K., Rainey R.L., Gbur E. E. (2010). Economic returns in plasticulture tomato production from crucifer cover crops as a methyl bromide alternative for weed management. *Hort. Technology* 20: 764.

Barrett C.E., Zhao X., Hodges A.W. (2012). Cost benefit analysis of using grafted transplants for root-knot nematode management in organic heirloom tomato production. *Hort. Technology* 22: 252

Carroll C., Carter C., Goodhue R., C.-Y. Cynthia Lin, Subbarao K. (2013). Bio economic modelling of an imported disease in California lettuce. In: Joint Annual Meeting of the Agricultural & Applied Economics Association AAEA & CAES, Washington, D.C., August 4-6, 2013.

Devkota P., Norsworthy J.K., Rainey R. (2013). Efficacy and economics of herbicide programs compared to methyl bromide for weed control in polyethylene-mulched tomato. *Weed Technology*: 27: 580.

Djidonou D., Zhifeng G., Zhao X. (2013). Economic analysis of grafted tomato production in sandy soils in northern Florida. *Hort. Technology* 23: 613

Ferrer M.C., Fonsah R., Escalante E.G., Cesar L. (2011). Risk-efficient fumigant-mulching system alternatives for bell pepper production. *Journal of the American Society of Farm Managers and Rural Appraisers*

Fonsah, E.G., Ferrer M.C., Escalante C., Culpepper S. (2012). Financial analysis of methyl bromide and mulch alternatives for bell pepper in Georgia. In: UGA Cooperative Extension Bulletin 1411

Larsen J. (2014). Farmworkers and strawberry cultivation in Oxnard, California: a political economy approach. In: *Scripps Senior Theses.* Paper 502. Available at http://scholarship.claremont.edu/scripps_theses/502

Mayfield E.N., Norman C.S. (2012). Moving away from methyl bromide: Political economy of pesticide transition for California strawberries since 2004. *Journal of Environmental* Management: 106: 93

Niu, L., Adam B.D., Arthur, F., Campbell, J. (2013). A GIS approach to measuring economic costs of integrated pest management tools in rice processing facilities. In: AAAE Annual Meeting, August 4-6, 2013, Washington, D.C.

Norman, Catherine S., 2005, Potential impacts of imposing methyl bromide phaseout on US strawberry growers: a case study of a nomination for a critical use exemption under the Montreal Protocol, Journal of Environmental Management 75: 167–176

Peterson E., Grant J., Roberts D., Karov V. (2013). Evaluating the trade restrictiveness of phytosanitary measures on U.S. fresh fruit and vegetable imports. *American. Journal of Agricultural Economics* 95: 842.

Rivard C.L., Sydorovych O., O'Connell, S. Peet M.M, Louws F.J. (2010). An economic analysis of two grafted tomato transplant production systems in the United States. *Hort Technology* 20: 794

Samtani, J.B., Gilbert C., Weber J.B., Subbarao, K.V., Goodhue R.E., Fennimore S.A. (2012). Effect of steam and solarisation treatments on pest control, strawberry yield, and economic returns relative to methyl bromide fumigation. *HortScience* 47: 64.

Sayin B., Celikyurt M.A., Yilmaz S., Celik, I. (2010). Economic evaluation of chemical and non-chemical soil disinfestation applications for tomato production in Turkey. *Acta Horticulturae* 883: 91

Tohamy A., Abou-Zeid N.M., Khalil M.S. (2012). Vegetable grafting: An alternative method for soil fumigation with methyl bromide—The Egyptian experience In: Conference of the American Phytopathological Society poster session. Available at http://www.apsnet.org/meetings/Documents/2012_Meeting_Abstracts/aps12abP297.htm

Walters T., Particka M., Zasada I., Pinkerton J.N. (2011). Productivity and economics of methyl bromide alternatives for raspberry nursery. Proc. Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions. http://www.mbao.org/2011/Proceedings/29WaltersT.pdf

Waterfield G., Zilberman D. (2012). Pest management in food systems: an economic perspective. *Annual Review of Environment and Resources* 37: 223.

Xiang C., Zhengfei G., Vallad G.E. (2014). An economic analysis of fumigation alternatives, the methyl bromide ban, and its implication: evidence from the Florida tomato industry. In: Annual Meeting Agricultural & Applied Economics Association, Minneapolis, MN, July 27- 29, 2014.

Annex 1

Case Studies

1. *Alternatives for preplant (soils) uses in Article 5 Parties*

The projects have provided useful experiences on the substitution of MB and the adoption of alternatives at the commercial level. Following are four examples of successful phase out of MB in economically important sectors for Article 5 countries.

Case Study 1. Alternatives to MB for floriculture in Brazil

Initial situation

In Brazil, the ornamental plant and cut flowers sector is an active, fast-growing agribusiness geared at both export and internal markets, with an estimated value of US$ 2 billion/year. Diverse environmental conditions allow production of many different species throughout the year in open field or greenhouses, but soil borne plant pathogens can cause heavy economic losses. MB was thus used in the past for disinfecting substrates and growing disease-free seedlings, and also for pre-plant soil fumigation. In 2002, the Government of Brazil issued an administrative rule establishing a phase-out schedule of controlled uses of MB by type of crop with a complete ban for all controlled uses by 2007.

Description of the alternative (s) implemented

Non-chemical alternatives were selected to replace MB in floriculture. This included a solar collector for treating substrates used as potting mixes, steam treatment for soil, biological control and organic matter amendments.
The solar collector was developed to disinfest substrate using solar radiation, (Ghini 2014).

The equipment comprises six aluminum tubes (15-cm diameter) placed in parallel rows in a wooden box (1.5m×1.0m×0.3 m), covered with transparent plastic film. Soil or substrates are placed inside the tubes through the upper hatch, during the early morning, and recovered through the lower hatch, after 24 hours of treatment in a sunny day. After treatment, the substrate can be used immediately or can be stored. In Brazil, this equipment can be used throughout the year. Temperatures above 70 C are easily obtained inside the aluminum tubes during sunny days, which result in the control of several soil-borne plant pathogens, including species of *Fusarium, Pythium, Rhizoctonia, Sclerotium, Sclerotinia, Phytophthora, Meloidogyne and Ralstonia* (Ghini *et al*., 2007; Ghini 2014).

Steam was the alternative of choice for the treatment of soil. A mobile steam injector was adapted in order to guarantee homogeneous application of the steam.
Biological control consisting of 4 commercial products containing *Trichoderma* spp. and two with *Paecilomyces lilacinus* are registered in Brazil for soil treatment to control soil borne pathogens (Bettiol *et al*., 2014).

Several different types of organic matter are used to induce soil or substrate supressiveness alone or associated with biological agents for flower production in Brazil. The main organic matters are compost tea, poultry manure, chicken litter, cattle manure and shrimp peeling.

Actions for alternative (s) implementation

UNIDO and the Ministries of the Agriculture and Environment of Brazil implemented a project jointly to totally phase-out MB in floriculture. The growers' associations received a kit comprising a boiler powered by eucalyptus wood (with capacity of 600 kg / h of steam) and a mobile steam injector for soil. A total of 28 boilers, 27 mobile steam injectors, and 823 solar collectors were donated to the associations on a rotation basis according to the reported consumption of MB in the period 2002 - 2006. A training program on alternative technologies was included within the project, and farmers and private companies were encouraged to implement the use of biological control agents and organic amendments. Neither solar collectors nor steam require regulatory approval.

Crop yields, and control of soil borne pests

The solar collector provides the same level of control as MB, and has no impact on occupational health and environmental contamination. Another advantage is the increased growth of plants and better flower quality. The treatment does not sterilize the substrate, and thus helps prevent reinfestation, since beneficial microorganisms are preserved. Disinfestation with steam does not provide residual protection, so this option needs to be implemented within an IPM approach including biological agents and organic amendments, to keep diseases controlled during the production period.

Costs and profitability

For Brazilian growers, the solar collector was economically cost effective (cost being less than MB fumigation). It should be considered that this is basically a one-time expense. Soil steaming is expensive, but farmers in Brazil find it to be a cost-effective alternative, particularly because they are able to use of wood instead of gasoline or diesel fuel.

Current situation

Farmers are successfully using the alternatives for MB treatment of soil, and are currently disseminating the technologies to other farmers. Solar collectors offer an inexpensive, efficient and safe system for the production of healthy seedlings, besides being easy to build and operate. The MB phase-out was not only a matter of protecting the ozone layer, but also an opportunity for growers to adopt non-chemical technologies, making them more competitive in the international market.

References

Bettiol, W., Rivera, M.C., Mondino, P., Montealegre, J.R., Colmenárez, Y.C. (2014). Control biológico de enfermidades de plantas en America Latina y el Caribe. Facultá de Agronomia, Montevideo. Uruguay. 404 p. http://portal.fagro.edu.uy/index.php/intensific-agr/file/367-control-biologico-de-enfermedades-de-plantas-en-america-latina-y-el-caribe.html

Ghini R.; Patrício F.R.A., Almeida I.M.G. (2007) Control of *Ralstonia solanacearum* in tomato potting medium by the use of a solar collector. *Australasian Plant Disease Notes* 2, 77-78.

Ghini, R. Climate change and increasing challenges for effective soil disinfestation. *Acta Hort.* 1044: 447-454.

Provided by Raquel Ghini, Embrapa, Brazil, MBTOC Member

Case Study 2. Alternatives to methyl bromide in the strawberry fruit, banana and cut flower sectors of Morocco: New developments, current situation and future challenges

Chtaina and Besri (2006) published a case study on alternatives to MB in the strawberry fruit, banana and cut flower sectors. Since that date, more research has been conducted and new developments on alternatives are available, which form the focus of this case study.

Initial situation

The government of Morocco committed to early MB phase-out by 2008, of 259 tonnes of MB used in the strawberry sector, 60 tonnes used in the banana sector and 42 tonnes in the cut flower sector. The phase-out program was financed by two MLF investment projects managed by UNIDO as implementing agency. This has led to a gradual elimination of MB during the period 2003-2008.

Description of the implemented alternatives

The Department of Plant Pathology of the Hassan II Institute of Agronomy and Veterinary Medicine, Rabat, Morocco was in charge of the implementation of the projects in mention. Research conducted by the department staff members and its graduate students and allowed for the development of technically and economically feasible alternatives to MB.

- *Strawberry fruit sector*

Drip applied metham sodium (MS) has been used successfully to control fungi (*Rhizoctonia solani, Verticillium dahliae, Phytophthora cactorum*) and weeds (more than 40 species e.g. *Cynodon dactylon, Chenopodium* sp, *Amaranthus* sp.). MS at a dosage of 510 g/l of active ingredient is injected at a rate of 200 to 250 g /m2. During the past 7 years, MS has been the only product used by the farmers in the strawberry sector, showing high efficacy and economic feasibility. In addition, it does not require any modification of the cropping system. Currently, about 2000 tons of MS are used annually in the strawberry sector. Yields and fruit quality are considered equivalent to those achieved with MB in the past (Chtaina and Besri, 2006; Chtaina, 2008a).
DMDS is now registered in Morocco and initial research results are very promising (unpublished data). Soil less culture technology using various substrates has been developed and its use is increasing (unpublished data).

- *Protected banana sector*

Between 2002 and 2004, an alternative combining soil solarisation and drip fumigation with 1,3-D as a broadcast or row treatment was developed to control banana nematodes (*Meloidogyne javanica, Helicotylenchus multicincthus*) (Chtaina, 2005). 1,3-D is injected at a dosage of 20 ml/m2. This method requires the installation of drip tapes connected to the main pipeline independently of the existing sprinkler irrigation system used in banana greenhouses. The major disadvantage of this method is the time and labor needed for installing drip irrigation and plastic mulch prior to the treatment (Chtaina, 2005), which has led to nil use of this alternative. At present, nematode control in the banana sector relies on nematicides applied after planting e.g. fenamiphos, cadusafos, oxamyl and fosthiazate in granular or liquid formulations. DMDS has been registered on banana in 2012 and is currently tested.

- Cut flower sector

In the cut flower sector, the situation is similar to the one described for the banana sector. Solarisation combined with drip application of 1,3-D/Pic, controls *Fusarium* spp, *Rhizoctonia* spp and nematodes (*Heterodera sachtii* and *Meloidogyne* spp.). This alternative does not require modifications of the cropping system since the existing drip irrigation system can be used to apply the fumigant (Chtaina, 2008b).

Costs of the alternatives

Table 1: Cost of the different listed alternatives (2014)

MB and alternatives	Crop	Total application cost US$/ 1000 m^2
MB	All	640 (1)
Metham sodium at high dosage (127, 5 g /m^2 of active ingredient) or 250 ml / m^2 of commercial product of 510g/l ai.)	Strawberries	250 (2)
Granular (G) or liquid post plantation nematicides (1 to 2 applications) - phenamiphos (Nemacur 10G): 50g/plant - cadusafos (Rugby à 10 G) : 20g /plant - Fosthiazate (Memathorin 10 G: 20g /plant	Banana	30 Per application
Solarisation + 1,3-D 65%+ chloropicrin 35% at. 450 kg /Ha	Cut flowers	350 (1)

(1) Broad acre application. (2) Row acre application

Regulatory agency acceptance

All chemical alternatives are registered in Morocco. New MS and 1,3 D formulations are registered. However, Morocco is confronted to the European pesticide regulatory controls, which may have serious repercussions on crops particularly where nematodes are of great importance such as in cut flower, tomato, bean, cucumber, melon, etc.

Future challenges

Morocco will face at least two major challenges in the future:

In the strawberry sector: Repeated applications of MS may lead to accelerated fumigant degradation, and a management strategy to prevent this problem is required (Triky-Dotan *et al*., 2009).

In the cut flower and banana sector: 1,3-D is the main alternative used, especially for nematode control. However, in the EU, 1,3-D use is being restricted under various regulations. The situation is completely different in Morocco. In this country, only 1800 t of 1,3-D are used in the region of Agadir. In addition, the piezometric groundwater level is at least 200 meters.

References

Chtaina N., 2005. Les fumigants nematicides à base du 1,3 dichloropropène, comme alternative au bromure de méthyle sur bananier. Pack info N° 24: 19-20

Chtaina N., M. Besri, 2006. Case Study 26. Morocco-Phase out of methyl bromide in the strawberry, banana and cut flower in Morocco.2006 assessment report of the methyl bromide technical option committee (MBTOC). UNEP, 424-427, 453 pp.

Chtaina N., 2008a. Phase out of methyl bromide in soil fumigation in strawberry production. UNIDO project MP/MOR/00/164 contract (ONUDI/ Institute of Agronomy and Veterinary medicine, Rabat Morocco) N° 2001/261. Final report, 2008. pp 80

Chtaina N., 2008b.Phase out of methyl bromide in the cut flower and banana production. UNIDO project TF/MOR/00/001 contract (ONUDI/ Institute of Agronomy and Veterinary medicine, Rabat Morocco) N° 2002/089. Final report, December 2008. pp 64

Triky-Dotan S., Austerweil M., Steiner B., Peretz-Alon Y., Katan J., and Gamliel A., 2009. Accelerated Degradation of Metham sodium in Soil and Consequences for Root-Disease Management Phytopathology Vol. 99, No. 4, 2009: 362-368

Provided by Professor Noureddine Chtaina n.chtaina@iav.ac.ma, Project manager, UNIDO MB projects, and Prof. Mohammed Besri m.besri@iav.ac.ma, MBTOC cochair, Hassan II Institute of Agronomy and Veterinary Medicine, Rabat, Morocco

Case Study 3. Adoption of alternatives to methyl bromide in the vegetable sector in Turkey

Vegetable Sector in Turkey

Total vegetable production of Turkey is around 28,5 million tons with protected vegetables comprising 4,7 million tons (GTHB, 2014). Tomato is the most important crop in both open field and protected production

Table 1. Vegetable production in Turkey in 2013

Vegetables	Production (tons)
Tomato	11,820,000
Watermelon	3,887,324
Pepper	2,159,348
Onion	2,058,342
Cucumber	1,754,613
Melon	1,699,550
Eggplant	826, 941
Other Vegetables	4,242,000
Total	28,448,118

There are approximately 150,000 protected vegetable growers in Turkey (Titiz 2004, Yılmaz *et al*., 2008). The vegetable sector has grown rapidly and in 2013, a total export value of US $1,105 million was reported (AKİB, 2013).

Methyl bromide use in Turkey

MB was mainly used to control soil borne pathogens and nematodes (Table 2) prevailing in protected vegetable production (tomato, pepper, cucumber, eggplant). A consumption of 487.6 tonnes of MB was reported for the Turkish vegetable sector in 2000.

Table 2. Main soil borne pathogens prevailing in Turkey

Host plant	Key pathogens	Secondary pathogens
Tomato	*Meloidogyne* spp., *Fusarium ox*. f.sp. *radicis-lycopersici, Fusarium oxysporum.* f.sp. *lycopersici*	Sclerotinina sclerotiorum
Cucumber	*Meloidogyne* spp.,	Verticillium spp.
Pepper	*Meloidogyne* spp., *Fusarium solani*, *Phytophthora capsici*	Sclerotinia sclerotiorum
Eggplant	*Meloidogyne* spp. *Fusarium oxysporum*. f.sp. *melonganea*, *Verticillium* spp.	-

Two demonstration projects and one investment project on alternatives to MB were implemented with funding from the MLF (Öztürk *et al*., 2002), and led to complete phase-out of MB for controlled uses in 2006 (Yılmaz *et al*., 2006 (Table 3).

Table 3. Methyl bromide phase-out schedule in agricultural sectors in Turkey

Horticulture and Cut-flower Sub-Sectors				**Total Methyl Bromide Consumption***	
Years	Expected Reduction (ODP tonnes)	Consumption (ODP tonnes)	Consumption (tonnes)	Consumption (ODP tonnes)	Consumption (tonnes)
2000	0.0	292.2	487.6	342.6	571.0
2001	0.0	292.2	487.6	332.6	554.3
2002	29.3	263.6	439.3	293.4	489.0
2003	58.6	204.7	341.1	225.4	375.7
2004	58.6	146.1	243.5	167.4	279.0
2005	87.9	58.2	97.0	78.4	130.6
2006	58.6	00.0	00.0	20.4	34.0

* Including horticulture and flower sub-sectors. Consumption for QPS and lab uses not included
Actions for Replacing Methyl Bromide

To support the early phase-out commitment, the following actions were taken:

Legislative actions: The Ozone Office (MEUD) coordinated the phase-out and the General Directorate of Food and Control (MFAL), coordinated MB imports in accordance with the agreed MB phase-out schedule. Agricultural practices and chemical uses were brought into compliance with EU regulations. Imported MB is presently sold only by quarantine services located in Istanbul, Izmir, and Mersin provinces. The MB phase-out action plan and a new regulation "Phasing out Agricultural Uses of MB" was published in the Official Gazette on the 23rd of June 2000. Sales and import of MB were defined by regulation 25427/2004.

Project Actions: Four projects were carried out to phase out MB in the horticulture sector of Turkey (Yılmaz *et al*., 2006) implemented by UNIDO and the World Bank.

Research Actions: The 4 projects considered chemical and non-chemical alternatives. Steam was very efficient but too costly to apply, bio-fumigation (chicken manure) resulted in a salinity problem (Öztürk *et al*., 2002). Other technologies included solarisation (S), S+chemicals [metham sodium (MS), dazomet (D) and 1,3-D], grafting, soilless culture and bio-fumigation. A strong IPM component was included.

Training Actions: Training was an integral part of the phase-out projects and included workshops, grower and technical personnel meetings, field visits, direct trainings in the field, national and international training programs, radio and TV programs and others. Nearly 1,000 technical assistants working in extension services, research institutes and the private sector were trained. A total of 12,087 growers were visited and directly trained on IPM, cultivation techniques (irrigation, fertilization etc.), soilless culture and bio-control agents. Project staff and leading growers participated in study tours in Austria, China, Colombia, Cuba, Netherlands, Italy and Spain where they increased their knowledge and experience on vegetable and cut flower production, IPM and MB alternatives. Approximately 77,000 brochures on 27 subjects, 2,000 posters and billboards, 12,000 books related to good agricultural practices (GAP) implementations on 5 different vegetables and 9 reports were published and distributed to relevant stakeholders (Yılmaz et al., 2006, 2008).

Good Agricultural Practices (GAP): Project staff identified 2,368 leading greenhouse growers who were then trained on GAP, and supported with goods, equipment and technical information from the project budget. Selected greenhouses were regularly visited by the project personnel between 2004 and 2006. Growers were trained on keeping records on pests, diseases, climate control, soil management, growing techniques etc. Eight books were published related to GAP implementation in vegetables. (Yılmaz et al., 2006, 2008).

Extension Actions: Trained extension staffs from Antalya, Adana, Mersin, İzmir, Isparta and Muğla Provinces were instrumental for disseminating knowledge and expertise to growers and played a very important role in both the demonstration and phase-out projects (Yılmaz et al., 2006).

Description of Alternatives Implemented

Chemical and non-chemical alternatives were used to replace MB in the Turkish horticulture sector. Solarisation alone or in combination with low dosages of chemicals, bio-fumigation, grafting, soilless culture and steaming were very successful especially in the vegetable sector to control soilborne diseases, nematodes and weeds, with each of these options showing advantages and disadvantages.

Solarisation (S) alone or combined with low dosages of chemicals (S + 1,3-D for nematode control, S + MS or Dazomet or Methyl iodide for soil-borne diseases control) was effective to control soilborne pathogens in the vegetable sector under the favorable climatic conditions of the Mediterranean Region (Yilmaz et al., 2007-2008). Nevertheless, cancelling of 1,3-D registration due to the environmental concerns and the high cost of Methyl iodide limited their use in Turkey. Year-round solarisation in conjunction with VIF plastic provided much better results than solarisation in the summer only, providing very good yield and quality in eggplant, melon and cucumber (Yilmaz et. al., 2011).

Bio-fumigation was efficiently applied in conjunction with solarisation, but availability and cost of fresh manure generally limited its use (Öztürk et al., 2002; Yılmaz et al., 2006).

Grafting adoption expanded rapidly since 1998 in the vegetable sector, reaching 150 million grafted plants by 2013 (personal communications with grafted seedling companies). It is a viable alternative to MB to control soil borne pathogens and delivers high quality yields especially in watermelon, eggplant and tomato (Yilmaz et. al., 2011; Karaca et al., 2012). This technology was also used in pepper and melon, however some compatibility problems between rootstocks and scions persist.

Soil-less culture is feasible for vegetables and cut flower. However it is a technically demanding option for growers with high initial costs. In spite of this, its use has increased in recent years.

Steam turned out to be too costly for horticulture production due to high fuel prices and was not a viable alternative. However, it might be used to steam seedling and soilless culture beds (Yılmaz et al. 2006, 2008).

Lessons learned

New techniques such as soilless culture, grafting, steam, compost and chemicals as well as novel growing techniques were introduced and accepted by Turkish growers. Solarisation was the cheapest and most effective alternative when combined with some chemicals. The importance of monitoring and traceability of crops and pests was understood by growers and the usefulness of IPM and GAP in vegetable sector was demonstrated in model greenhouses to project stakeholders. Strong coordination and collaboration among academicians, researchers, extension staff, growers, companies, consultants, dealers, and policymakers was achieved during the project. MB use for soil was completely and irreversibly phased out in Turkey without putting any burden on growers.

References

AKIB 2013. Sektörel Bazında Aralık 2013 İhracat Verileri. http://www.akib.org.tr/tr/ihracat-ihracat-istatistikleri.html

GTHB, 2014. T.C. Gida Tarim Hayvancilik Bakanligi, Bitkisel Uretim Verileri. http://www.tarim.gov.tr/sgb/Belgeler/SagMenuVeriler/BUGEM.pdf

Karaca, F., Yetişir; H., Solmaz İ., ElifÇandır, E., Kurt, Ş., Nebahat Sarı, N., and Güler Z. 2012. Rootstock potential of Turkish *Lagenariasiceraria* germplasm for watermelon: plant growth, yield, and quality. Turkish J Agriculture and Forestry 36:1101-1716

Özalp, R. and Aktaş, A., (2008). Türkiye ve Antalya'da sebzeciliğin genel durumu. *Tarımın Sesi Dergisi,* 17:15-18. Antalya.

Ozturk, A.; Yilmaz, S.; Kececi, M.; Unlu, A.; Deviren, A.; Ozcelik, A.; Cetinkaya, S.; Cevri, H.; Akkaya, F. and Ozkan, C.F. (2002). Alternatives to methyl bromide for tomato and cucumber production in Turkey. *Proceeding of Alternatives to Methyl Bromide*. Sevilla, Spain. pp. 194-199.

Titiz, Ş. (2004). Modern Seracılık, Yatırımcıya Yol Haritası. Antalya Sanayici ve İş adamları Derneği.Retma Yayıncılık, Antalya (Modern Greenhouses, Road map for Investors. Association of Antalya Industrialists and Businessmen. Retma Publication, Antalya.)

TUİK (2009). Turkey Statistic Foundation (TUİK) (State Institute of Statistics). Agricultural structure and production. Publication no. 2895., Ankara, Turkey.

Yilmaz S, Celik I, Zengin S. (2011). Combining effects of soil solarisation and grafting on plant yield and soil-borne pathogens in cucumber. *International Journal of Plant Production* (2011) 5(1): 95-104

Yilmaz, S., Fırat, A.F., Mutlu, N. and Sürmeli, N. (2005). Recent Developments and Constrains Confronting Vegetable Production Systems in Turkey.

Yilmaz, S., Gocmen, M., Ünlü, A., Aydinşakir, K., Mutlu, N., Baysal, Ö., Sayın, B., Celikyurt, M.A., Fırat, A.F., Çelik, İ. Aktaş, A., Öztop, A., Zengin, S., Devran, Z. and Tekşam, İ., (2008). Phasing out of methyl bromide in Turkey: Final Report, ISBN 9789754072549, 156 p., Antalya.

Yilmaz, S., Ünlü, A., Göçmen, M., Aydinşakir, K., Sayin, B., Kazas, S., Çelikyurt, M.A., Aktaş, A. and Zengin, S (2007). Alternatives to methyl bromide for cut flowers in Turkey. In: Annual International Conference on Methyl Bromide Alternatives and Emission Reductions. San Diego, CA, USA pp. 48-1-3.

Yilmaz, S., Ünlü, A., Gocmen, M., Mutlu, N., Aydinşakir, K., Fırat, A.F., Kuzgun, M., Celikyurt, M.A., Sayın, B. and Çelik, İ. (2006). Phase out of methyl bromide for soil fumigation in protected horticulture and cut flower production in Turkey. Final Report, 2006. Antalya, Turkey.

Prepared by S. Yilmaz (MBTOC member) and K. Aydinsakir

Case Study 4. Phasing out MB in tomato and cucumber by combining resistant cultivars, grafting, avermectin and soil fumigants in China

Initial situation

Cucumber and tomato are the main vegetables produced in China. About 1,157,000 ha are cultivated with cucumbers with a total yield of nearly 52 million tonnes. The area grown with tomatoes is 949,500 ha with total yield of about 5 million tonnes (Ministry of Agriculture, 2013). Both crops are grown both in protected and open field environments, but greenhouse cultivation is becoming increasingly important.

Cucumbers and tomatoes are grown in fixed plastic tunnels where it is difficult to rotate with low value crops like wheat, maize or cotton. The conventional rotation model is tomato (or cucumber in autumn), followed by a short-term vegetable such as leaf oil rape in winter and then cucumber (or tomato) in spring. The occurrence of nematodes and soil-borne diseases has become more and more severe, and seriously affect yield and quality after 3-5 years cultivation.

MB was mainly used in cucumber and tomato in the Shandong and Hebei Provinces, in the Beijing and Tianjing municipalities. The total MB consumption in these sectors was about 55 tonnes. MB was applied at rates of 40-50 g/m2to control root knot nematodes (Meloidogyne spp), damping off *(Rhizoctonia* sp. and *Pythium* sp.), *Fusarium* wilt (*Fusarium oxysporum* f.sp. *lycopersici*) and *Phytophthora* spp.

Chemical alternatives, such as dazomet, metham sodium, chloropicrin, Avermectin, sulfuryl fluoride are registered in China but 1,3-D is not registered.

Description of the alternative (s) implemented

Cucumber grafting is an old technology in China, used by many farmers. The rootstock is pumpkin with white or black seeds, resistant to *Fusarium oxysporum* f.sp. *lycopersici* and with some tolerance to nematodes. Resistant tomato cultivars contain the Mi gene and are resistant to rootknot nematodes. Farmers are using grafting without any change in the cropping system.

Avermectins are produced by Streptomyces avermitilis and have broad-spectrum activity against a large number of nematodes and arthropods so are widely used in veterinary and agriculture.(Putter, 1981; Sasser et al., 1982; Carabedian and Gundy, 1983; Bull et al., 1984; Cao, 1994; Cao, 1999).When nematodes are the main soil pest, a combination of resistant tomato or grafted cucumber and avermectin is recommended. When fungal or bacterial diseases are present in addition to nematodes, dazomet and metham sodium are used.

Metham sodium (35-42%) is applied through the drip irrigation system under PE film at a rate of 50-100g/m2. Some farmers apply it as a drench or with flood irrigation water, particularly in plastic tunnels (Carabedian and Gundy, 1983).

Actions for alternative (s) implementation

Complete MB phase-out was supported between 2009 and 2012 by the MLF in Beijing, Shandong and Hebei Provinces and with UNIDO as international implementing agency, in cooperation with Ministries of Environmental Protection and Agriculture.

Crop yields and soil borne pests control

Nematode control with avermectin is as effective as with MB (Table 1). A combination of avermectin with grafting, resistant cultivars or fungicides controls *Fusarium* wilt, damping off, *Phytophthora, Alternaria* and other root rots and nematodes.

Table 1 Crop yields from MB and avermectin in Beijing in 1998-1999

Crop	Yield using MB (t / ha)	Yield using avermectin (t / ha)
Autumn Tomato	116.3	109.6
Spring cucumber	63.0	57.0

Costs and profitability

Avermectin costs are almost 90% lower than those of MB and since yields are similar, avermectin is more profitable for tomato and cucumber. It is also easier to use than MB and does not cause phytotoxicity or plant-back delays, thus it is the preferred option for many tomato and cucumber growers in plastic tunnels. Resistant tomato cultivars and grafted plants (cucumber and tomato) are generally produced directly by the farmers, but some also buy commercial grafted seedlings. The cost is 0.08-0.24 USD/seedling.

Dazomet costs 2,419 USD/ha, metham sodium 973-1,945 USD/ha and plastic film USD 1,354/ha.MB cost is 3,592 USD/ha. Since alternatives are cheaper than MB, farmers accepted the alternatives quickly in cucumber and tomato.

References

Bull Don L, Ivie G Wayne, MacConnell John G, Gruber Virginia F, Ku Chia C, Arison Byron H, Stevenson James M, VandenHeuvel William JA (1984) Fate of avermectin B1a in soil and plants. Journal of Agricultural and Food Chemistry 32. (1):94-102.

Cao Aocheng (1999) The new alternative of methyl bromide--avermectin. In: Research Progress in Plant Protection and Plant Nutrition China Agriculture Press, pp 327-328.

Cao Yuxin (1994) Control of cucumber root knot nematode by using avermectin 1.8EC (in Chinese). Chinese Agricultural Science Bulletin 10:16-18.

Carabedian H., Gundy S.D. (1983) Use of avermectine for the control of Meloidogyne incognite on tomatoes. Journal of Nematology 15 (4):503-510.

Putter I (1981) New insecticides and acaricides and nemaericide-avermectins. Experientia 37:963-964.

Qiao Kang, Liu Xia, Wang Hongyan, Xia Xiaoming, Ji Xiaoxue, Wang Kaiyun (2012) Effect of abamectin on root‐knot nematodes and tomato yield. Pest management science 68. (6):853-857.

Sasser JN, Kirkpatrick TL, Dybas RA (1982) Efficacy of avermectins for root-knot control in tobacco. Plant Disease 66:691-693.

Tomlin CDS (1997) The pesticide manual, 1997. British Crop Protection Council 49.

Prepared by Aocheng Cao, MBTOC member Department of Pesticides, Institute for Plant Protection, Chinese Academy of Agricultural Sciences. Beijing 100193, P. R. China. Phone:+86 10 62815940; Fax:+86 10 62894863 Email: aochengcao@ippcaas.cn

2. *Alternatives for preplant (soils) uses in non-Article 5 Parties*

Case Study 1. Soil biodisinfection and agroecological basis for vegetables in Spain

Initial situation

Spain is the second largest vegetable producer in Europe, and used to be one of the highest consumers of MB, with reported consumption at 5,157 tons in 1998 (Barres *et al*., 2006). Ten years later, Spain managed to reduce and shortly thereafter phase-out its use through different alternatives. Limited access to chemical alternatives, high prices of some non-chemical systems, emergence of virulent soil borne pathogens, and other factors, led to focusing on agro-ecological options, for example organic by-products used for soil biodisinfection which reduce populations of soilborne pathogens, and may be combined with most of the non-chemical alternatives (Bello *et al*., 2008, 2010).

Description of the alternative (s) implemented

A change in the production model was proposed, based on agronomic criteria. Organicmaterials, which emit gases and other compounds with biocidal or biostatic effect that can regulate pest populations during decomposition are used. This is the basis of the concept of soil biodisinfection, which is used within a biological and environmental diversity approach (Barres *et al.,*2006, Bello *et al.,* 2010, López-Pérez *et al.,*2010, Castro Lizazo *et al*., 2011, Díez Rojo *et al*., 2011).

Actions for alternative implementation

Nematodes were chosen as a model for developing soil biodisinfection since this group includes both phytoparasitic and predatory species, which are of interest in the decomposition and assimilation of organic matter in the soil. Biodisinfectants used include solid products such as manures and crop residues, or liquids such as vinasses derived from the alcohol industry, alpechins from the olive industry and slurry from livestock systems. Initial work was aimed at establishing appropriate dosages and duration of the process *in vitro* and in soil under laboratory conditions and later the results were transferred to the field, in protected vegetable crops, ornamentals, strawberries and extensive systems in various productive regions around Spain. Research focused on nematodes of the genus *Meloidogyne*, and established their biogeographical structure, races and biotypes, as a basis for management protocols.,The effects of biodisinfectants on saprophytes, predators and soil bio-indicators were also studied, as well as on soil fertility and crop production are also been taken into account (Bello *et al*.. 2008, 2010; Melero-Vara *et al*..2012; Núñez-Zofio *et al*..2013).

Crop yields, and control of soil borne pests

Soil biodisinfection with organic matter in a C / N ratio of 8:20 was effective, using both solid and liquid products, generating gases. Effectiveness increases when the treatment is combined with solarisation (biosolarisation) ensuring appropriate humidity levels to facilitate organic matter decomposition diffusion of the substances emitted through the soil profilr (Martínez *et al*..2009; Núñez-Zofio *et al.* 2011, 2012). The effect is generally biostatic, so gases must be retained in contact with the soil, where they exert a selective action increasing the number of saprophytic organisms. Soil biodisinfection is more effective when physical, chemical and biological properties of are also considered and can lead to reductions in water and fertilizer consumption.

Costs and profitability

Biodesinfection has been extended to different areas of Spain, and has been found to be economically feasible, with. the main limiting factor being the transportation cost of the biodisinfectants. Using local resources is thus important (Piedra Buena *et al.,*2007;Díez Rojo *et al*.. 2011), as well as the connecton between agriculture and livestock as complementary resources (Bello and González 2012).

Current situation'

Several years after the last CUEs were approved for peppers, cut flowers and strawberries (the last crops using MB for controlled uses in 2010) these sectors have completely and successfully replaced MB. Production systems now rely heavily on agronomic criteria, which are used to manage pests and diseases (Barres *et al.,*2006;Zanón and Jordá 2008;García Ruíz *et al*., 2009; Díez Rojo *et al*., 2011;Bello *et al*., 2011, 2013;González *et al.,*2013a,b; González Ruiz *et al*.,2014).

Selected references

Barres MT, Bello A, Jordá C, Tello JC. 2006. La Eliminación del Bromuro de Metilo en la Protección de Cultivos como Modelo Mundial para la Conservación del Medio Ambiente. MAPA, Madrid, 515 pp.

Bello A, Díez Rojo MA, López Pérez JA. 2013. Biodesinfección de suelos, investigación participativa y desarrollo rural. Cambio climático, destrucción de la capa de ozono. XXI Jornadas Técnicas Estatales SEAE. Desarrollo Rural, Innovación Agroecológica y Agricultura Ecológica en la PAC. Alcalá de Henares, Madrid, 26-27 septiembre, 15 pp.

Bello A, Díez Rojo MA, López Pérez JA, Castro I, Gallego A. 2011. Biodesinfección de Suelos. Sociedad Española de Agricultura Ecológica (SEAE), Ministerio de Medio Ambiente, Medio Rural y Marino, Madrid.(http://vimeo.com/18675250)

Bello A, González JC. 2012. Agroecología y Complementariedad Agraria. 250 pp. http://www.agroecologia.net/recursos/publicaciones/publicaciones-online/2012/libro-agroecologia-bello/libro-agroecologia-bello-sec.pdf

Bello A, Jordá C, Tello JC. 2010.Agroecología y Producción Ecológica**.** CSIC, Catarata, 77 pp.

Bello A, Porter I, Díez Rojo MA, Rodríguez Kabana R. 2008. Soil biodisinfection for the management of soil-borne pathogens and weeds. 3rd Int. Biofumigation Symposium, 21 – 25 Jul., CSIRO Discovery Centre, Canberra, 35 p.

Castro Lizazo I, Díez Rojo MA, López Pérez JA, Díaz Viruliche L, Bello A. 2011. Biodesinfección de Suelos en Producción Ecológica.Dossier SEAE. Valencia. 56 pp. http://www.agroecologia.net/recursos/publicaciones/dossiers/dossier-biodesinfeccion.pdf

Díez Rojo MA, López-Pérez JA, Urbano Terrón P, Bello Pérez A. 2011. Biodesinfección de Suelos y Manejo Agronómico. Ministerio de Medio Ambiente, Medio Rural y Marino, Madrid, Spain, 414 pp. (http://www.magrama.gob.es/es/calidad-y-evaluacion-ambiental/publicaciones/libro_de_biodesinfección_tcm7-156245.pdf)

García Ruíz A, Tello JC, Avilés Guerrero M, Ordovás Ascaso J. 2009. Fusariosis del Clavel. Fusarium oxysporum f.sp. dianthi. Últimos Avances en su Control. Edit. Agrotécnicas, 275 pp.

González JC, González Ruiz J, Domínguez M, Afonso R, Domínguez E, Domínguez K, Hernández M, López Cepero J, Piedra Buena A, López Pérez JA, Arias Mª, Tello JC, Bello A. 2013a. Diversidad y complementaridad en la gestión agroecológica. *XXI Jornadas Técnicas Estatales SEAE: Desarrollo Rural, Innovación Agroecológica y Agricultura Ecológica en la PAC.* Alcalá de Henares, Madrid, 26-27 septiembre, 39 pp. https://docs.google.com/file/d/0B-jLDCjL-kpxWFQ5NDVuNzRmbDg/edit.

González JC, González Ruiz J, Domínguez M, Alfonso R, Domínguez E, Domínguez K, Hernández M, López Cepero J, Piedra Buena A, López Pérez JA, Arias Mª, Tello JC, Bello A. 2013b. Diversidad y complementaridad en la gestión agroecológica. Investigación participativa y desarrollo rural. Ae 14, 48-49.

González Ruiz J, Domínguez M, Afonso R, Domínguez E, Domínguez K, Hernández M, González JC, Ballester J, Gallego A, López Cepero J, Piedra Buena A, López Pérez JA, Torres Nieto JM, García Ruiz A, Arias M, Lacasa A, Tello JC, Gonzálvez V, Bello A. 2014. Agricultura familiar, investigación agroecológica participativa y formación. *Simposium Agricultura Familiar Agroecológica*, SEAE. Lugo, 18 - 20 junio, 15 pp.

López Pérez JA, Roubtsova T, García M de Cara, Ploeg A. 2010. The potential of five winter-grown crops to reduce root-knot nematode damage and increase yield of tomato. *J. Nematol.* 42, 120-127.

Martínez MA, Martínez MC, Bielza P, Tello J, Lacasa A. 2009. Effect of biofumigation with manure amendments and repeated biosolarisation on *Fusarium* densities in pepper crops. *J. Ind. Microbiol. Biot.*38, 3-11.

Melero-Vara JM, Lopez-Herrera CJ, Basallote-Ureba MJ, Prados AM, Vela MD, Macias, FJ, Flor-Peregrin E, Talavera M. 2012. Use of poultry manure combined with soil solarisation as a control method for *Meloidogyne incognita* in carnation. *Plant Dis.* 96, 990-996.

Nuñez-Zofio M, Larregla S, Garbisu C. 2011. Application of organic amendments followed by soil plastic mulching reduces the incidence of Phytophthoracapsici in pepper crops under temperate climate. Crop Prot. 30, 1563-1572.

Nuñez-Zofio M, Larregla S, Garbisu C. 2012. Repeated biodisinfection controls the incidence of Phytophthora root and crown rot of pepper while improving soil quality. Spanish J. Agricultural Research 10, 794-805.

Nuñez-Zofio M, Larregla S, Garbisu C, Guerrero MM, Lacasa CM, Lacasa A. 2013. Application of sugar beet vinasse followed by solarisation reduces the incidence of Meloidogyne incognita in pepper crops while improving soil quality.Phytoparasitica 41, 181-191.

Piedra Buena A, García-Alvarez A, Díez-Rojo MA, Ros C, Fernández P, Lacasa A, Bello A. 2007. Use of pepper crop residues for the control of root-knot nematodes. BioresourTechnol. 98, 2846-2851.

Zanón MJ, Jordá C. 2008. Eradication of Clavibacter michiganensis subsp. michiganensis by incorporating fresh crop debris into soil: preeliminary evaluations under controlled conditions. Crop Prot. 27, 1511-1518.

Provided by Jose Antonio López-Pérez, Miguel A. Díez-Rojo, J.M. Torres and Antonio Bello. Centro Agrario Marchamalo (JCCM)

Case Study 2. Alternatives to methyl bromide for strawberry runner production in Japan

Initial situation

The most important strawberry soilborne diseases in Japan are fusarium wilt (*Fusarium oxysporum,* f. sp. *fragariae*), anthracnose (*Collectotrichum gloeosporioides*), root lesion nematode (*Pratylenchus vulnus*) and root knot nematode (*Meloidogyne hapla*). Since all current varieties are susceptible to these pathogens, pest-free certification for strawberry runners is not required. Growers obtain virus-free mother plant seedlings from the growers associations and use them for runner production.

Actions for replacing MB

Japan has phasedout controlled uses of MB entirely, including strawberry runners production. Agricultural research and plant protection technology extension centers were encouraged to develop chemical and non-chemical alternatives, and pesticide industries were urged to cooperate in this effort. Currently, available alternative technologies have been widely adopted by growers in many strawberry runner production regions.

Description of the implemented alternatives

Mother stock is grown in pots, in soil or substrate . Soil is treated with chloropicrin (liquid, tape or capsule) or dazomet (granules). Substrates (peat moss, coconut hull, bark manure, saw dust, vermiculite, rice hull, sand etc.) are used only for mother stock and nursery stock production, and are bought from specialized companies providing clean materials.

Non-chemical alternatives, including solarisation and anaerobic soil disinfestation are available for strawberry fruit field production (Ueno *et al.*. 2006; Yamada *et al.,* 2003; Yonemoto *et al.,* 2006). Available chemical treatments include Pic, dazomet, 1,3-D/Pic, and a mixture of MITC and 1,3-D.

Current situation

Strawberry stock production takes place in protected houses to help decrease incidence and severity of *Collectortichum gloeosporioides* which is encouraged by free water (rain). Two types of production systems are used: A raised rack type setup, where plant plugs are placed, and ground beds, directly in the field. Racks have become increasingly popular.

References

Department of Agriculture and Forestry of Nagasaki Prefecture (2009) Establishment of standard technology on strawberry production. Nagasaki Standard Technology of Agriculture and Forestry.

Shinozaki Tsuyoshi, Matsuzaki Yukihiro and Yasunaga Tadamiti (2003). Control of Fusarium Wilt by Methyl Bromide Substitution in Strawberry. *Annual Report of Ehime Agricultural Research Institute* 37,27-34

Ueno Kiyoshi, Kaneko Katsuhiro, Taniguchi Enosuke and Nagasawa Sayuri (2006). Control of Fusarium Wilt and Nematode on Strawberry by Soil Reduction in Yamagata Prefecture. *Ann. Rept. Plant Prot. North Japan* 57:62-64

Yamada, K., *et al*. (2003). Control of Fusarium wilt on strawberry by Soil Reduction. *Annual Report of the Kanto-Tosan Plant Protection Society* 50, 49-52

Yonemoto Kengo, Hirota Keisuke, Mizuguchi Shoko and Sakaguchi Kenji (2006). Utlilization of the sterilization by soil reduction in an open air field and its efficacy against Fusarium wilt of strawberry. *Proc. Assoc. Pl. Protec. Shikoku.* No 41:15-24

Provided by Akio Teteya (akio.tateya@nifty.com), Tokyo Japan, member of MBTOC

3. Alternatives to MB use for QPS purposes

Case Study: Minimum use of methyl bromide for quarantine treatment in Japan

This case study describes the measures that Japan has implemented to reduce the amount of MB for the treatment of imported goods in response to Decision VI/11(c) and XX/6 urging Parties to minimize the use and emissions of methyl bromide (MB) for QPS (Table 1, Anonymous 2014). Such measures include updating Japan's non-quarantine pest list, and improved pest identification on entry. Further, all fumigation chambers now require official control and approval by MAFF to ensure a high gas retention capability and appropriate air tightness and correct labeling of MB cylinders. No repeat MB treatments are allowed, and dosage rates for grain have been optimized to ensure fumigation effectiveness (Table 2, Anonymous 2011). Heat treatment of wood packaging for ISPM 15 is now required, to minimize MB use and emissions.

Import plant inspection

When plant products arrive at the Japanese point of entry, the consignee submits the import plant inspection application form No. 4 to the plant quarantine inspector (PQI) who then inspects the consignment. If quarantine pests are intercepted, the respective pest names are entered into the form by the PQI and the consignee is required to follow phytosanitary measures for custom clearance.

Phytosanitary treatment

The pest control operator (PCO), hired by the consignee, submits the phytosanitary treatment plan for the approval of a PQI, and the consignment is loaded into the fumigation chamber (which in turn needs approval from Japan's MAFF). Treatment efefctiveness is checked by the PQI on the basis of survival of the test insects and/or the level of the remaining gas concentration. When the fumigation treatment is considered successful the PQI clears the consignment.

Efforts to minimise use and emission of methyl bromide

MB fumigation as a phytosanitary treatment must strictly and exclusively be applied for those consignments in which quarantine pest insects had been found.

Updating the list of non-quarantine pests

Non-quarantine pests of 334 species have been listed (Anonymous 2014) as of February 24th 2014 by pest risk analysis (PRA) based on ISPM-2. In the future, as progress with PRA is made, the number of non-quarantine pests will most probably increase. Many species of grain pests are now included in this list and as a result MB use has been significantly reduced. In recent years the number of plant commodities in which quarantine pests are found has decreased. Further, the volume of log imports that is subject to quarantine inspection and frequent treatment with MB, has significantly decreased.

Improving pest identification skills of plant quarantine inspectors

PQIs have attended training sessions on pest identification, whether these are classified asquarantine or non-quarantine pests and if treatment of the consignment is or not required. Unnecessary MB use against non-quarantine pests is thus avoided.

Registration of methyl bromide for exclusive quarantine use

MB was registered in December 24th 1994 for exclusive use as a quarantine treatment, independent of the generally regulated use. Therefore, MB for quarantine treatment is not allowed for soil or post harvest treatment. It is been clearly identified with a red label on the cylinder for easy recognition. The PCO engaged in quarantine treatment is strictly instructed to use MB exclusively for quarantine pests no other circumstances.

Optimization of dose rates in grain fumigation schedule

MB dose rates are prescribed in the fumigation schedule to ensure complete disinfestation under various fumigation conditions as shown in table 2 (Anonymous 2011), whilst ensuring minimum use and emissions. They are respectively set under consideration of various fumigation factors:

(1) *Gas retention capability and air tightness of the fumigation chamber*, which should be optimum. Fumigation chambers for quarantine use are designated by Japan MAFF as category class super A, class A, class B and class C according to the quality of these parameters. The higher the gas retention capability of the chamber, the lower the dose applied.
(2) *Fumigation duration*: Dose rates vary depending on whether the fumigation lasts 24 h, 48 h or 72 h. The longer the fumigation, the smaller dose rate is applied. A 48 h fumigation period is presently preferred in view of reduced fumigation costs.
(3) *Grain loading of bagged grain in a warehouse or bulk grain in a silo*: The fumigant penetrates and spreads easier throughout the grain when it is treated in bags rather than in bulk. The dose rate for grain in bags is thus lower than for bulk grain in silos.
(4) *Plant products with gas absorption*: The dose rate is set in consideration of the level of MB absorption by plant products, being lower for products with lower absorption. For example, dose rates for soybeans are higher than for wheat because the former tend to absorb more MB due to their higher protein content. Dose rates for wheat flour are higher than for wheat grain because flour absorbs more MB than grain.
(5) *Grain temperature*: Pests are more sensitive to MB at higher temperatures. Dose rates are thus set depending on the grain temperature - whether < 10°C, between 10°C-20°C or > 20°C.
(6) *Loading rate of the consignment in the chamber*: The loading rate (LR) is expressed in terms of tonnes/m³. High volumes of grain absorb more MB so a higher dose rate is necessary for effective insect disinfestation. Dose rates may thus vary between LR<0.3

t/m^3, LR 0.3 - 0.5 t/m^3 and LR>0.5 t/m^3 for flat fumigation chambers and between LR<0.3 t/m3 and LR>0.3 t/m3 for silos. The LR is not differentiated for different types of chambers (silo of concrete, stainless steel bin or warehouse fumigation).

(7) *Circulation system in the fumigation facility*: Lower dose rates can be used if appropriate air circulation systems are used within the chamber, ensuring easier and more uniform fumigant distribution. Currently, circulation systems are installed in the majority of fumigation chambers in Japan.

Categorisation of fumigation chamber for quarantine use

Fumigation chambers for plant quarantine treatment are categorised by Japan MAFF according to their gas retention capability. Accordingly, they are ranked as class Super A, class A, class B or class C. The gas retention capability is determined by gas concentration remaining inside the empty chambers 48 hours after MB application. If this is higher than 85% of the initial dose rate, the chamber is categorized as class Super A; if over 70%, the chamber is categorized as class A; a chamber with a concentration above 55% is categorized as class B and over 40% as class C. Chambers with a gas concentration below 40% are not allowed for quarantine fumigation treatments. Chamber owners are required to improve the gas tightness to category super A or class A and currently, 99.8 % of the chambers comply with this rule. No Class C chambers are used for phytosanitary fumigation treatment (Table 3, Anonymous 2014).

Determination of air tightness of fumigation chamber

PQI conducts air tightness tests to determine whether a chamber is fit for quarantine treatments. This is done at the owner's expense.

In the case of a warehouse, air is introduced into an empty premise until an air pressure of 55 mm Aq is reached. The warehouse is then sealed and left to sit until the pressure goes down to 50 mm Aq. If the time necessary for a further pressure drop from 50 mm Aq. to to 45 mm Aq. is longer than five minutes, the chamber is categorized as class Super A. If that time is between 5 and 45 mm Aq., the warehouse is classified as class A.
For silos, the air pressure is raised up to 550 mm Aq. by introducing air into the empty silo. Once sealed, the pressure decline is observed until it reaches 500 mm Aq. If after 20 minutes the pressure remains above 400 mm Aq., the silo is lassified as class Super A; if the pressure difference is between 200 and 400 mm Aq., then it is classified as class A.

Other measures for minimizing MB use and emissions

Various additional measures have been taken to minimize the use and emission of MB when it is applied for quarantine purposes as follows:

(1) *Efforts to avoid fumigation failure*: If according to PQI a fumigation treatment with MB has failed (ie by the presence of surviving pests or the gas concentration remaining after treatment), it will not be repeated. Rather, aluminum phosphide or carbon dioxide which take a longer time and are more costly are indicated. The PCOs must follow this instruction or custom clearance is denied and re-shipment to another country or destruction of the consignment is the only option.

(2) *Encourage the use of fumigation chambers in accordance to the size of the commodity consignment*: The MB application dose is set in accordance with the size of the fumigation chamber, not the volume of the consignment.

(3) *No mixed loading of commodities with different absorption rates*: If plant products with different MB absorption rates are loaded together, the dose rate is set according to the plant category with higher absorption rate no matter how small the proportion of product

with higher absorption rate is. To avoid this partial overdosing, it is strongly recommended to fumigate mixed consignments in separate chambers.

(4) *Encourage use of heat treatment for wood packing materials instead of MB*: Plant protection authorities suggest applying heat treatment to wood packing materials taking into account the most recent version of ISPM 15 (IPPC, 2013, Sela et al., 2014). Methyl bromide fumigation is only carried out when the consignment is already packed. Therefore, in Japan heat treatment is used for the majority of disinfestations of wood packing material and methyl bromide fumigation rarely used.

Table 1. Consumption of MB for Quarantine treatments (ref 1)

	Year						
	2007	2008	2009	2010	2011	2012	2013
Amount (t)	867	706	542	511	547	499	503

Table 2. Extract of methyl bromide dose rates in fumigation schedules (ref 2)

Fumigation facility	**Commodity**	**Loading rate (LR) of the commodity in the chamber with forced air circulation tonnes/m3**	**MB dose rate (g/m³) for 48 h treatment at >20°C for the respective category of designated gas retention capability of the fumigation chamber**			
			Super A	**A**	**B**	**C**
Warehouse	Bagged rice, wheat and coffee bean	0.3> LR 0.3≦LR <0.5 LR□0.5	8 10 12	9 11 13	10 13 15	12 15 18
	Bagged maize and millet	0.3> LR 0.3≦LR <0.5 LR□0.5	10 12 15	11 13 17	13 15 21	15 18 24
	Bagged soybean, kidney bean, pea nuts	0.3< LR 0.3≦LR <0.5 LR□0.5	12 13 19	13 15 21	15 18 26	18 21 30
Silo	Bulk rice and wheat	0.3< LR 0.3□LR	11 16	12 18	14 21	17 25
	Bulk maize and millet	0.3< LR 0.3□LR	14 22	15 24	17 28	21 34
	Bulk soybean, kidney bean, peanuts	0.3< LR 0.3□LR	15 23	17 25	20 29	24 35

Dimension of LR: Ratio between the volume of the consignment (tons) and the chamber volume (m³)

Table 3. Numbers of designated fumigation chambers for quarantine treatment as of August 1st 2014 (ref 4)

Location of the treatment	Number of chambers in each gas tightness classification				Total
	Super A	A	B	C	
Warehouses	587	661	19	0	1,267
Silos	2,622	7,060	5	0	9,687
Total	3,209	7,721	15	0	10,945
Number of chambers in % of the total number	29.3	70.5	0.2	0	100
Size of chamber space (m^3) in percent of the total	38.9	60.8	0.3	0	100

References

Anonymous 2014. Delivery amount of methyl bromide and major alternatives. Japan Fumigation Technology Association. Nikkunkyo Dayori of the volume of March 31st 2014. No.115, page 6.

Anonymous 2011. Methyl bromide dose rate in quarantine treatment. The Quarantine Guideline for Grain Import. Attached table. No. 2628, February 6th, 1971. Latest revised version as of September 7th. 2011. Ministry of Agriculture, Forestry, and Fisheries. http://www.pps.go.jp/law_active/Notification/basis/8/53/html/53.html

Anonymous. 2014. List of non-quarantine pest insect and disease. Ministry of Agriculture, Forestry and Fisheries Announcement, No. 296, February 24th 2014, page 13-16 and 28. Ministry of Agriculture, Forestry and Fisheries. http://www.pps.go.jp/law_active/Notification/basis/5/245/html/245.html

Anonymous 2014. Statistics on fumigation chambers for the use of quarantine treatment designated by Plant Protection Stations MAFF. Text on safe use of fumigants for quarantine treatment. Edited by Japan Fumigation Technology Association 2014, page 25.

FAO 2013. Revision of International Standards for Phytosanitary Measures No. 15. Regulation of wood packing material in international trade. Annex 1. Page ISPM 15-14.

Sela, S., Schröder, T., Mamoru M. and Ormsby, M. 2014. Explanatory document for ISPM 15:2009 (Regulation of wood packaging material in international trade), International Plant Protection Convention (IPPC), online: https://www.ippc.int/sites/default/files/documents/20140430/ispm_15_ed_withannexes_2014-04-30_201404300908--1.44%20MB.pdf, 45 pp

Provided by Akio Tateya (akio.tateya@nifty.com), Tokyo Japan, MBTOC member

Annex 2

Annex 2. Methyl Bromide Technical Options Committee - Committee Structure

---

MBTOC structure as at 31 December 2014

Co chairs

Mohamed Besri	Institut Agronomique et Vétérinaire Hassan II Morocco
Ian Porter	La Trobe University Australia
Marta Pizano	Consultant Colombia

Subcommittee chairs, chapter lead authors for this Assessment

Chapter 1 - Executive summary
Chapter 2 - Introduction to the assessment - lead author, *Marta Pizano.*
Chapter 3 - Methyl Bromide production and consumption (controlled uses) **-** lead authors, *Marta Pizano, Alejandro Valeiro, Eduardo Willink.*
Chapter 4 -Alternatives to Methyl Bromide for soil treatment –*Mohamed Besri, Ian Porter*.
Chapter 5 - Alternatives for Treatment of Post-Harvest Commodities and Structures – *Christoph Reichmuth.*
Chapter 6 – Quarantine and Pre-shipment **-** *Marta Pizano, Cristoph Reichmuth*
Chapter 7 – Progress in Methyl Bromide phase-out. Lead authors, *Marta Pizano*.
Chapter 8 - Economic Issues Related to Methyl Bromide Phaseout. Lead author *Nick Vink*
Chapter 9 - Methyl Bromide emissions. Lead authors *Ian Porter, Jonathan Banks*

Committee contact details and Disclosure of Interest
To assure public confidence in the objectivity and competence of TEAP, TOC, and TSB members who guide the Montreal Protocol, Parties to the Protocol have asked that each member to disclose proprietary, financial, and other interests. Disclosures of Interest (DOI) are posted at the Ozone Secretariat website and are updated as necessary, once a year at minimum. They can be accessed at
http://ozone.unep.org/en/disclosure_of_interest.php?body_id=6&committee_id=6

Table A-1 below contains the lists of MBTOC members at December 31st, 2014. As indicated in Chapter 2, as of 1st January 2015, MBTOC membership has been reduced to twenty members.

TABLE A-1.MBTOC MEMBERS AS AT DECEMBER, 2014

Chairs		Affiliation	Time of service	Country
1. Prof. Mohamed Besri	M	Department of Plant Pathology, Institut Agronomique et Vétérinaire Hassan II	A	Morocco, A5
2. Ms. Marta Pizano	F	Consultant, Hortitecnia Ltda.	A	Colombia, A5
3. Dr. Ian Porter	M	La Trobe University	A	Australia, Non-A5
Members		**Affiliation**	**Time of service**	**Country**
4. Dr. Cao Aocheng	M	Institute for Plant Protection, Chinese Academy for Agricultural Sciences	A	China, A 5
5. Dr. Jonathan Banks	M	Consultant	A	Australia Non-A5
6. Dr. Chris Bell*	M	Consultant, retired from Central Science Laboratory (Government research)	A	UK Non-A5
7. Mr. Fred Bergwerff	M	Eco2, Netherlands	B	Netherlands Non-A5
8. Dr. Peter Caulkins*	M	Associate Director, Special Review & Reregistration Division US EPA	B	USA, non-A 5
9. Mr. Ricardo Deang*	M	Consultant	A	Philippines A5
10. Dr. Raquel Ghini	F	EMBRAPA Meio Ambiente – Jaguariúna Sao Paulo	B	Brasil, A5
11. Mr. Ken Glassey	M	Senior Advisor Operational Standards Biosecurity New Zealand, Ministry of Agriculture and Forestry Wellington	B	New Zealand Non- A5
12. Mr. Alfredo Gonzalez	M	Fumigator	A	Philippines A5
13. Ms. Michelle Marcotte*	F	Consultant	A	Canada Non-A5
14. Mr. Takashi Misumi	M	Quarantine Disinfestation Technology Section, Ministry of Agriculture, Forestry and Fisheries MAFF	B	Japan Non A5
15. Dr. David Okioga*	M	Kenya Ozone Office. Min. of Environment	A	Kenya A5
16. Prof. Christoph Reichmuth	M	In transition to Professor at Humboldt University Berlin. Retired from JKI Germany (Government research) (October 2010)	B	Germany Non-A5
17. Mr. Jordi Riudavets	M	IRTA-Department of Plant Protection. (Government Research)	B	Spain Non-A5
18. Mr. John Sansone*	M	SCC Products (Fumigator)	A	US Non-A5
19. Dr. Sally Schneider*	F	National Program Leader – Horticulture, Pathogens & Germplasm, USDA	A	USA, non=A5
20. Dr. JL Staphorst	M	Consultant, Plant Protection Research Institute (PPRI), Agriculture Research Council (ARC)	A	South Africa, -A5
21. Mr. Akio Tateya	M	Technical Adviser, Syngenta Japan	A	Japan, non-A5
22. Mr. Robert Taylor*	M	Consultant, retired from UK research institute	A	UK Non-A5
23. Mr. Chris Watson*	M	Consultant, retired from IGROX Ltd (Fumigator)	A	UK Non-A5
24. Mr. Jim Wells*	M	Environmental Solutions Group, LLC, Sacramento, CA	A	USA, non-A5
25. Mr. Alejandro Valeiro	M	National Project Coordinator, National Institute for Agriculture and Technology,Tucumán	A	Argentina, A 5
26. Dr. Ken Vick	M	Consultant, USDA	A	United States

				Non-A5
27. Prof. Nick Vink	M	University of Stellenbosch, Department of Agricultural Economics	A	South Africa, A 5
28. Mr. Eduardo Willink	M	Estación Experimental Agroindustrial Obispo Colombrés, Tucumán	A	Argentina A5
29. Dr. Suat Yilmaz	M	West Mediterranean Agricultural Research Institute – BATEM, Antalya	B	Turkey, A 5
TOTALS			A= more than 10 yrs; B= 5-10 yrs; C= 0-5 yrs	F= 4 M = 25 A5= 12 non A5 = 17

* Retired from MBTOC on 31 December 2014.

Attachment 10

Coastal Review Online
A Daily News Service Covering North Carolina's Coast

Company Drops Fumigation Plan

09/18/2013 by Mark Hibbs

Text Size: + –

Reprinted from the Carteret County News-Times

MOREHEAD CITY — Cogent Fibre has abandoned a controversial proposal to fumigate logs for export from the state port here.

Robert Mantrop, a partner with Cogent Fibre, said last week that the decision was based on public opposition, expressed during an informational meeting held Aug. 28 at the Crystal Coast Civic Center, to the use of a toxic pesticide to treat the log.

“As a company, we’ve thought long and hard and weighed our options,” Mantrop said.

About 150 attended the public forum at the civic center on the plan and the recently filed state air quality permit application to use the pesticide methyl bromide. Many who spoke at the city-sponsored meeting said the plan is dangerous and incompatible with the surrounding area.

Because it is considered an ozone-depleting substance, methyl bromide was phased out by the Environmental Protection Agency in 2005, except for allowable “critical use exemptions” – cases in which there are no technically and economically feasible alternatives or substitutes available that are acceptable from the standpoint of environment and public health, according to the EPA.

The pesticide is still allowed to fumigate logs, and many countries require that imported logs first be treated with the pesticide. The EPA also allows strawberry growers and some food producers to also use methyl bromide.

News & Features

- News & Features
- Beach & Inlet Management
- Climate Change
- Coastal Policy
- Energy
- Habitat Restoration
- Legislature
- Stormwater
- Terminal Groins
- Transportation

Logs are covered in tarps and readied for fumigation. Photo: Capital Pest Control, India

Cogent Fibre had planned to contract the fumigation work out to Royal Pest Solutions Inc., also known as Royal Fumigation, of New Castle, Del., the company that applied earlier this summer for an air quality permit for the operation at the State Port in Morehead City.

Mantrop said the public's questions and concerns, along with concerns of some company officials, led to the decision to scrap the plan.

The project was in its "exploratory stages," he said.

"We were just going through the process to see if it (the log-export business) was something that could be done," Mantrop said. "The (Aug. 28) meeting was preemptive but it made us step back."

He said Cogent Fibre also researched methyl bromide, and officials with the company didn't like the results.

"We want to be viewed as a company that has a positive impact in the community," he said.

Cogent Fibre also released a statement on the decision, saying the company's primary "mandate" is to operate its business in a socially and environmentally responsible manner.

"To date Cogent has continually adhered to this mandate with its existing wood chip operation in Morehead City, N.C., since 2011 and its operation in Savannah, Ga., since 2005. The bulk log- exporting business that is of concern represented a new and unique export opportunity for the Port of Morehead City and Cogent Fibre that was worthwhile exploring," according to the statement.

The company stated that the first step of any new agricultural trade is to determine regulations and requirements for the product between the exporting and importing countries.

In this case of exporting Southern yellow pine logs to India and China, both countries require the use of methyl bromide as a fumigant before shipping and do not allow for any other method of fumigation.

Cogent had contacted the N.C. State Ports Authority to determine if methyl bromide fumigation was allowed at the port here.

"We were instructed that the current air permit did not allow for such fumigation at the Port of Morehead City but that there is a permitting process conducted by the North Carolina Department of Natural Resources and Air Quality to determine if the activity would be permitted or not," according to the statement.

Royal Pest Solutions' permit application was received at the N.C. Division of Air Quality on July 1. The permitting process was expected to take nine to 12 months, according to Cogent.

"However, it was clear from the meeting that there is significant public concern regarding the potential project and more specifically the use of methyl bromide," Cogent said in the statement.

"As a company it is of great importance to the partners and employees of Cogent Fibre to continue to represent a positive impact on the local community and environment. With this in mind, Cogent Fibre would like to

Recent Articles

Utility Board Set to Consider Filtering Options

Panel to Advise DEQ on Environmental Justice

Beaufort Hears Public Concerns Over Harbor

Sections

Select Category ▾

Archives by Date

announce that it has listened to the concerns put forward during the meeting and has concluded that those concerns are significant enough to discontinue the pursuit of this project any further."

The company stated that it will continue with its existing wood chip operations and "continue to develop new opportunities that are in accordance with our mandate."

Join the conversation on our Facebook Page

Winner of 12 North Carolina Press Association awards in 2018

Prev:
The Federation's Party by the Water

Next:
Pelican Award: Dana Edgren

About the Author
Mark Hibbs

Mark Hibbs is editor of Coastal Review Online, working out of our main office in Ocean, A native of coastal North Carolina, Mark joined the federation June 1, 2015, after more than 20 years with the Carteret County News-Times, where he served as a staff writer and photographer, business editor and assistant to the editor. Mark has won numerous awards for his reporting, including various N.C. Press Association awards and the U.S. Small Business Administration's 2009 Small Business Journalist of the Year Award for the Southeast Region. Mark is a graduate of the University of North Carolina at Wilmington.

Related entries

Attachment 11

Coastal Review Online
A Daily News Service Covering North Carolina's Coast

Coastal Review Online
A Daily News Service Covering North Carolina's Coast

Companies To Halt Fumigation Operations

03/29/2018 by Staff Report

RALEIGH – The state Division of Air Quality was notified Thursday that fumigation operations will come to an end at the Wilmington site of Tima Capital Inc., a hardwood distributor.

According to a release Thursday from the state Department of Environmental Quality, letters from Royal Pest Solutions, currently operating at 800 and 810 Sunnyvale Drive, Wilmington, and Tima Capital, the company that applied for a permit to change the facility to its name and increase the use of the fumigant methyl bromide, are seeking state approval to withdraw the draft air permit and cease fumigation operations at the Wilmington location by April 10, after the current inventory of logs is fumigated.

Division officials began Thursday to make arrangements to withdraw Tima's draft air quality permit and rescind Royal Pest's current air quality permit for the facility.

"At the request of our landowner, Tima Capital Inc. will not be fumigating on this property after Royal Pest Solutions Synthetic Minor Permit cessation of operations and rescission of their permit effective April 10," said Tima Capital President Timurlan Aitaly in a letter to William Willets, the Division of Air Quality's permitting chief, and Brad Newland, the division's regional supervisor. "Therefore, no further permits will be needed by Tima Capital Inc. for the sites of 800 and 810 Sunnyvale Drive."

The hardwood distributor had asked for a permit to dramatically increase its use of the chemical insecticide methyl bromide, also called bromomethane. The facility's current permit expires at the end of May. The company applied to take over the permit originally issued to Royal Pest Solutions, the company that performs the methyl bromide spraying at the Tima log-preparation facility.

Tima Capital's request for a modified permit required a public comment period, which ran from Feb. 23 to March 25. While the new comment period had not been announced, DAQ officials have continued to receive comments about Tima's proposed permit and most of 1,100 comments received since Feb. 23 were opposed to issuing the permit.

Last week, the division issued a news release announcing its plans to hold a new public comment period and public hearing to enable additional input for the Tima Capital's draft air quality permit. The new public comment period came in response to heightened public interest in the permits.

A second fumigation company, Malec Brothers Transport, LLC, is requesting a new air quality permit to start a fumigation facility in Columbus County. Malec is also proposing the use of methyl bromide. As stated in last week's news release, the state plans soon to announce a new public comment period and new public hearing for the Malec Brothers draft air quality permit.

Morehead City residents in 2013 overwhelmingly opposed a proposal for a similar operation, presented by Cogent Fibre with insecticide fumigation of bulk logs for export that would have been provided by Royal Pest Solutions. The company ultimately scrapped its plans to seek a state air quality permit.

Methyl bromide was phased out by the Environmental Protection Agency in 2005 because it's an ozone-depleting substance. Its use is allowed only in cases where there are no technically and economically feasible alternatives or substitutes available that are acceptable from the standpoint of environment and public health, according to the EPA.

Learn More

- Methyl Bromide Phaseout

Join the conversation on our Facebook Page

Like This Story?

It costs about $500 to produce this and all other stories on *CRO*. You can help pay some of the cost by sponsoring a day on *CRO* for as little as $100 or by donating any amount you're comfortable with. All sponsorships and donations are tax-deductible.

SUPPORT US

Prev:
Whale of a Symposium April 6 In Beaufort

Next:
Ocracoke Readies For Trams, Passenger F…

About the Author
Staff Report

The story was compiled by staff members of Coastal Review Online.

Related entries

Recent Articles

Utility Board Set to Consider Filtering Options

Panel to Advise DEQ on Environmental Justice

Beaufort Hears Public Concerns Over Harbor

Sections

Select Category

Archives by Date

Attachment 12

TOP STORIES FROM NCPW

News Commentary

Duke U. scientists to focus on radon, coal ash, flame retardants in Iredell thyroid cancer cluster probe

Something is changing the genetic code in the cells of young girls in Iredell County. Duke Universit [...]

RECENT BLOG POSTS

Lawmakers move forward with anti-immigration measure forcing sheriffs to work with ICE

House Bill 337 could bring major changes to the way North Carolina's school children are tested

Editorial: What Richard Burr must do next in Russia investigation

Partisan gerrymandering and the fight for reproductive freedom

New bill seeks "red flag" court orders to prevent gun violence, suicide

Bill to give academic growth, achievement equal weight marches forward

ENVIRONMENT

BREAKING: Malec Brothers withdraws air permit application to use methyl bromide

By Lisa Sorg January 30, 2019 In Environment

NC gerrymandering opponents to Supreme Court: "Anything would be better than what we do now"

Malec Brothers has formally withdrawn its application for an air permit to emit methyl bromide in Columbus County, the NC Department of Environmental Quality announced Wednesday afternoon. The Australian company had planned to emit up to 140 tons of the toxic compound for its log fumigation operations near Delco and Riegelwood. However, vehement public opposition halted the plan while state officials petitioned the Environmental Management Commission for a new rule to add methyl bromide to the state's list of air toxics.

Methyl bromide has been banned internationally for most uses because of its toxicity and ozone-depleting properties, but log fumigation is exempt from the prohibition. China reportedly will accept only exported logs that have been fumigated, in order to prevent invasive pests from entering the country. But Malec Brothers has decided to debark the logs instead of fumigating them. An air permit is not required for that activity, a DEQ spokesperson said.

Originally, Malec Brothers proposed to place logs timbered from North Carolina forests into shipping containers, which would be infused with methyl bromide. After the logs had been gassed, which could take up to 72 hours, the doors to the containers would be opened, allowing the rest of the methyl bromide to enter the air. If, during fumigation, the container leaked an unacceptable amount of the gas, the solution, according to the company's air permit request, was to seal it off with sand bags and duct tape. The fumigation would have been conducted about a mile from a school.

DEQ has placed any applications for methyl bromide use on hold while the EMC and the Science Advisory Board formulate a permanent rule, a DEQ spokesperson said, "as the use of this hazardous air pollutant is a matter of public concern."

Possibly related posts:

1. **Methyl bromide: So toxic that DEQ proposes first-ever cap on air levels**
2. **Thousands of people live near log fumigation operations; Royal Pest Solutions fined for methyl bromide emissions violations**

MALEC BROTHERS   METHYL BROMIDE   NC DEPARTMENT OF ENVIRONMENTAL QUALITY

Previous Post
In a non-denial denial, EPA says reports that it won't regulate PFAS is "premature"

Next Post
Cooper administration takes a welcome stand on Medicaid expansion

Attachment 13

ENVIRONMENT

Thousands of people live near log fumigation operations; Royal Pest Solutions fined for methyl bromide emissions violations

By Lisa Sorg November 8, 2018 2 Comments In Environment

A log fumigation facility operated by Flowers Timber in Seven Springs is just 220 feet — less than a length of a football field — from the nearest home. (Photo: Google Earth via DEQ)

1500 words, 8 minute read

More than 4,000 people live within a mile and a half of North Carolina's four log fumigation facilities, and some are just 220 to 630 feet away – equivalent to the length of one to two football fields.

NC gerrymandering opponents to Supreme Court: "Anything would be better than what we do now"

These residents would be the highest at risk of chronic exposure to methyl bromide that drifted onto their property. And there are no state or federal regulations to protect the neighbors and the general public from methyl bromide in ambient air.

"We don't want adverse effects happening to people at that fence line," Division of Air Quality Director Mike Abraczinskas told the Environmental Management Commission's Air Quality Committee yesterday. The committee discussed temporary rules to set levels of the toxic compound escaping beyond the property lines of log fumigation operations. *Update: The commission voted 4-3 not to adopt temporary rules. Instead the proposal will undergo a lengthier process in permanent rule-making, which delays DEQ's ability to implement enforceable limits on ambient air levels.*

Methyl bromide can harm human health, including neurological, reproductive, respiratory, kidney, liver and esophageal damage, as well as nasal lesions. Because of those effects and its damage to the ozone layer, methyl bromide has been largely banned internationally. However, there are a few "critical exemptions" to kill pests, including the fumigation of some fruits and logs for export, as well as dried country ham, which can contain mites.

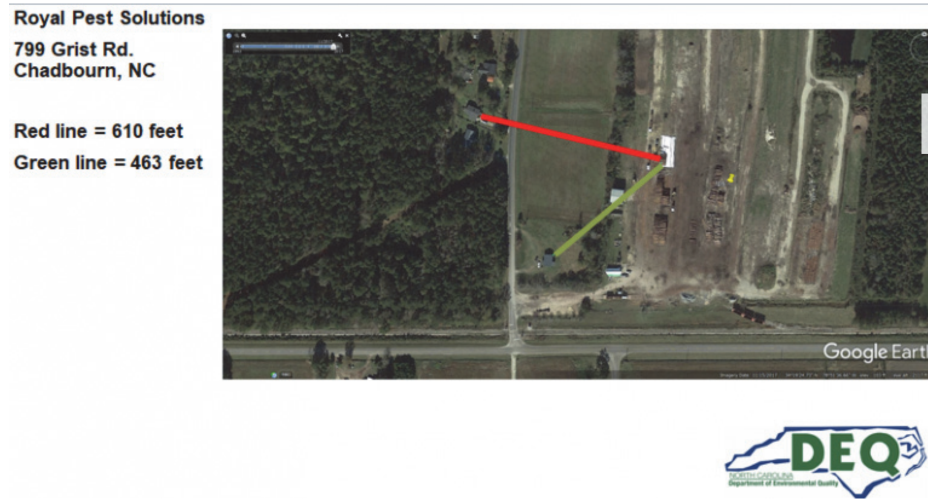
In log fumigation, the wood is placed inside shipping containers, which are then pumped with methyl bromide gas. After 16 to 72 hours, the containers are opened, and the gas escapes into the air. Facilities in North Carolina don't use pollution controls on the containers, although that technology is available.

> We don't want adverse effects happening to people at that fence line
>
> CLICK TO TWEET

While temporary rules would at least buy the Division of Air Quality and the EMC time to craft permanent ones, there is already resistance from the NC Department of Agriculture. According to state documents, agriculture officials told DAQ that "logs are a big export business" and the department "would be concerned if this approach ended it."

The Department of Commerce also questioned whether the proposed rules would regulate the wood pellet industry. Since those operations don't use methyl bromide, they would not be subject to them.

Current North Carolina air permits do limit emissions of methyl bromide from the facilities themselves. But DAQ is asking the EMC to temporarily establish ambient air level limits at .005 parts milligrams per cubic meter for a chronic exposure. (This is also listed in some documents as the equivalent of 1.3 parts per billion.)



Nearly half of the 529 people living within 1.5 miles of the Chadbourn facility are Black. Two homes lie even closer.

This is a minimum risk level at which no adverse health effects can be expected in the general public if they were exposed every day, all day. State regulators said the level was calculated based on the EPA's best available science, but that it needs updated.

The proposed temporary rule is intended to protect the general public and doesn't include occupational exposures, although permanent regulations could do so.

This .005 ppm threshold is the same as adopted by South Carolina, Minnesota and Massachusetts. Six other states' chronic exposure levels are not as stringent. They use annual, eight-hour or one-hour exposures to set their limits, which the industry prefers. Using annual calculations could dilute the actual daily exposures, while shorter time frames would constitute acute exposures, more applicable to workers onsite.

DAQ staff used computer modeling to estimate ambient air levels at the fenceline of four existing log fumigation facilities. Based on the amount of methyl bromide used and the type of logs fumigated (hardwoods require more gas than softwoods, like pine), none of the current facilities would comply with the proposed .005 ppm level — even if they aerated just one container per day.

Malec Brothers, which is proposing to operate a facility in Columbus County, stated in its air permit

TAG CLOUD

ACA AFFORDABLE CARE ACT BUDGET CHARTER SCHOOLS COAL ASH CRUCIAL CONVERSATION DUKE ENERGY ECONOMY EDUCATION ENVIRONMENT GERRYMANDERING GOV. PAT MCCRORY GOV. ROY COOPER GUN VIOLENCE HB2 HEALTH CARE HIGHER EDUCATION IMMIGRATION JOBS LEGISLATURE LGBT RIGHTS MEDICAID MEDICAID EXPANSION N.C. GENERAL ASSEMBLY NC DEPARTMENT OF ENVIRONMENTAL QUALITY NCGA NORTH CAROLINA OBAMACARE PHIL BERGER POVERTY PUBLIC EDUCATION PUBLIC SCHOOLS REDISTRICTING RIGHT-WING STATE BUDGET TAX CUTS TAXES TEACHER PAY THOM TILLIS TRUMP ADMINISTRATION U.S.SUPREME COURT UNC UNEMPLOYMENT VOTER SUPPRESSION WHY COURTS MATTER

WEB LINKS

Blue NC

NC blogs for ReproRights

NC Coalition for Alternatives to the Death Penalty blog

NC Conservation Network

NC Council of Churches Blog

NCCapitol (WRAL)

Off the Charts (Center on Budget and Policy Priorities)

Orange Politics

Policy Points (South by North Strategies)

PoliticsNC

Public Policy Polling

QNotes

Under the Dome (News & Observer)

Watauga Watch

Women AdvaNCe

DAQ has asked Royal Pest Solutions, the primary log fumigation company in the Southeast, for feedback on the draft rules and preliminary modeling. State officials have received no response, Abraczinskas said.

Two of the current facilities are located in predominantly communities of color: Royal Pest Solutions in Chadbourn and Flowers Timber in Seven Springs.

Nearly half of the 529 people living within 1.5 miles of the Chadbourn operation in Columbus County are Black. Three percent are Latinx and 1 percent are American Indian, according to the EPA's Environmental Justice Screen.

Nearly 800 people live within that distance of the Flowers Timber operation in Seven Springs. A third are Latinx; 23 percent are Black.

Two Wilmington facilities operated by RPS — one at 3701 River Road and another at 2200 Burnett Road — are not in large communities of color. However, some of the 3,600 people who live nearby might get a double dose: Parts of the 1.5-mile buffers for each operation overlap.

Other than routine air permitting and reviews, the state paid little attention to methyl bromide until earlier this year. That's when Malec Brothers applied for an air permit for a fumigation facility in Columbus County, near the small towns of Delco and Riegelwood. Residents packed public hearings, objecting to the permit. DAQ, in turn, put that permit, and other pending applications, on hold.

At the time, Malec Brothers officials — who are Australian — said there was no economically feasible technology to control methyl bromide emissions. They suggested using sandbags and duct tape to control errant emissions. But now the company is importing equipment by Mebrom — an Australian company — for a test to be conducted at the proposed facility in Delco. DAQ and the state Department of Agriculture will oversee the tests, said Michael Pjetraj, DAQ deputy director.

Mebrom uses scrubbers and thermal destruction — which would also be subject to air emissions rules — to capture and reduce methyl bromide emissions. The technology has yet to be launched commercially.

Value Recovery and Nordiko, the latter of which is also Australian, use carbon-based technology. These methods are used in the US and internationally. Cost ranges from $35 to $270 per aerated container. The number of containers fluctuates, depending on market demand.

Concurrently, DAQ and the EMC would deliberate on permanent rules, which would be open to public comment and hearings. Those regulations also require an economic impact analysis.

"We want to protect the public from methyl bromide and maintain our market position," Abraczinskas said.

The NC Department of Environmental Quality has fined Royal Pest Solutions $6,700 for emitting more than 10 tons of methyl bromide at its two log fumigation facilities in New Hanover County, a violation of their air permits.

According to state documents, Royal Pest Solutions's facility at the Port of Wilmington exceeded its pollutant limits earlier this year by a total of 1,348 pounds — more than a half ton. Anne Bookout, general counsel for RPS, told state regulators that the exceedances occurred from January through March because unaerated containers had been loaded onto ships bound for China; containers are not air-tight and have a leak rate of 20 percent.

The containers were not aerated because the company's fumigation area at the port had been moved to a "more cramped location," Bookout said. As a safety measure, RPS did not aerate the containers after fumigation. By April, RPS had been assigned a new area at the port, and it began aerating the containers again.

DAQ fined the company $4,904 — 6 percent of the maximum penalty allowed under state law. The facility had no prior air quality violations.

A second Royal Pest Solutions operation at 800/810 Sunnyvale Drive miscalculated the 12-month rolling use for methyl bromide in 2017. Under its permit, RPS's methyl bromide emissions are capped at 10 tons for any consecutive 12-month period. The company exceeded that amount by 832 pounds, or 4 percent of the allowable total.

The company explained the error as a result of manual calculations, and said it use an Excel spreadsheet and formulas in the future, according to the documents.

DAQ fined RPS $1,829, including investigative costs, which is 6 percent of the maximum penalty allowed by state law. However, RPS has stopped fumigating logs at the Sunnyvale Drive location. Its air permit was up for renewal in May, but the company requested a rescission, or cancelation, in late March.

The facility began fumigating logs since 2015, two years after receiving a permit to do so in May 2013. Since then, DAQ issued a notice of deficiency for a late report in 2015, and a notice of violation in 2016 for two late reports.

RPS has compiled several violations related to its fumigation operations in Virginia. That state's regulators fined the company $33,000 last year, for violations at its Chesapeake facility, and forced the company to stop fumigation in Suffolk in 2016.

RPS has filed for an air permit for a proposed fumigation facility north of Scotland Neck in Halifax County. However, like the other proposed permits, including one filed by Malec Brothers for an operation in Columbus County, it is on hold during EMC rule-making.

NOV Royal Pest by on Scribd

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
MICHAEL ABRACZINSKAS
Director

NORTH CAROLINA
Environmental Quality

August 24, 2018

Certified Mail 7016 0910 0000 6171 3084
RETURN RECEIPT REQUESTED

Mr. John Achzet, VP Operations
Royal Pest Solutions, Inc., dba Royal Fumigation
53 McCullough Drive
New Castle, DE 19720

SUBJECT: **Notice of Violation / Notice of Recommendation for Enforcement**
Facility ID No. 6500356
County: New Hanover
Air Permit No. 10313R01 (Permit Class: Synthetic Minor)
Permittee: Royal Pest Solutions, Inc.

VIOLATION: **Exceedance of the 10-ton HAP limit during the months of May, June, and July 2018**

Dear Mr. Achzet,

Wilmington Regional Office Division of Air Quality (DAQ) Compliance Inspector (Linda Willis) requested the methyl bromide use for the fumigation facility located at the Port of Wilmington (Facility ID No. 6500356) from the Royal Pest Solutions, Inc. Regional Manager (James Fealey) for the months of January, February and March (2018). Mr. Fealey provided the requested information and indicated that the aeration process typically used for fumigated shipping containers was not performed and that the unaerated containers were loaded for export. Subsequently, Royal Pest Solutions, Inc. representatives (Jim Fealey and Anne Bookout) were notified by the DAQ Compliance Inspector (Linda Willis) that a leak rate would need to be applied to determine the methyl bromide emissions for recordkeeping and reporting purposes.

The Royal Pest Solutions, Inc. representatives (Jim Fealey and Anne Bookout) provided data for each of the containers fumigated during the months of January, February and March (2018). Data included the amount of methyl bromide charged to each container (ounces) and the amount measured in the air space inside the containers (after an unspecified amount of time had elapsed, but prior to export) using a Fumiscope. The difference between the two were calculated with the average being approximately 20%.

North Carolina Department of Environmental Quality | Division of Air Quality
Wilmington Regional Office | 127 Cardinal Drive Extension | Wilmington, North Carolina 28405
910.796.7215 T | 910.350.2004 F

1 of 10

[Notice of Violation Royal P…] by on Scribd

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

MICHAEL A. ABRACZINSKAS
Director

Certified Mail No. 7013 2630 0002 1133 5429
Return Receipt Requested

February 7, 2018

Mr. John Achzet
VP Operations
Royal Pest Solutions, Inc.
53 McCullough Drive
New Castle, DE 19720

Subject: Notice of Violation
Facility ID No. 6500355

Violation: Exceedance of the 10-ton HAP limit, and
Inaccurate recordkeeping and reporting for the 12-month rolling total methyl bromide usage from January 2017 through January 2018

Dear Mr. Achzet,

In accordance with the Synthetic Minor Facilities operations restrictions (Specific Condition A.6.a.i.), recordkeeping (Specific Condition A.6.b.i.B.) and reporting (Specific Condition A.6.c.ii.) requirements specified in your Air Quality Permit No. 10302R00, you are required to remain below the 10-ton methyl bromide use limit and calculate the 12-month rolling total methyl bromide usage. These requirements are pursuant to 15A North Carolina Administrative Code 2Q .0315 to avoid the applicability of 15A NCAC 2Q .0501 "Purpose of Section and Requirement for a Title V Permit".

It has been determined by this office that the monthly 12-month rolling total usage of methyl bromide, based upon the monthly usage of methyl bromide from January 2017 through January 2018 was not calculated correctly and that during the month of June 2017, the facility exceeded the 10-ton methyl bromide limitation.

You are hereby required to resubmit corrected copies for each monthly report from January 2017 through January 2018 with the appropriate 12-month rolling totals. The corrected reports are due in this office within 15 business days of receipt of this notification. If you have any questions concerning this letter, please contact Linda Willis or myself at (910) 796-7215.

Sincerely,

Brad Newland
Wilmington Regional Supervisor, DAQ

Cc: WiRO

State of North Carolina | Environmental Quality | Air Quality
Wilmington Regional Office | 127 Cardinal Drive Extension | Wilmington, North Carolina 28405
910 796 7215 T | 910 350 2004 F

Show me more about this topic

1 of 1

Possibly related posts:

1. **Methyl bromide: So toxic that DEQ proposes first-ever cap on air levels**
2. **BREAKING: Malec Brothers withdraws air permit application to use methyl bromide**

AIR EMISSIONS ENVIRONMENTAL JUSTICE LOG FUMIGATION METHYL BROMIDE NC DEPARTMENT OF ENVIRONMENTAL QUALITY

Previous Post
Damning new report: NC General Assembly is forcing state judges to "criminalize poverty"

Next Post
Higher rates of birth defects found in four southeastern counties; link to PFAS uncertain

2 COMMENTS

ELIZABETH O'NAN

November 9, 2018 at 6:15 pm

We should not be allowing Austrialians to export trees with current climate change problems and no one should be allowed to make a dime off of poisoning citizens. The DAQ would not delay if their family was being poisoned. Their failure to regulate or even levy maximum fines (6% is not even a slap on the hand) amounts to premeditated random homicide. They know people will die (mostly black people) just not exactly who will die. DAQ should learn that black lives matter.

PETER JOYCE

November 10, 2018 at 8:28 pm

Commercial scale emissions controls for methyl bromide have been demonstrated in Nipomo, CA and the Port of Miami. These facilities have been running for over 5 years and have destroyed over 100,000 lbs of methyl bromide. There is no reason that emissions controls could be enforced, today, like they were in Virginia where Royal Pest Solutions was fined and stopped from directly emitting methyl bromide. There is a cost to emissions controls, not unlike the 'cost' of putting catalytic converters in cars or keeping acid rain out of the air by employing scrubbers in power plants.
The DEQ and the EPA are also at fault for not following their own regulations. And environmental consultants and lawyers are just as guilty for spending tax payers money on modeling, monitoring, hearings and delays. If a commercial solution is available, what is the justification for not requiring it. And what is the justification for allowing for endless meetings that puts the public at risk and hurts the environment. Who or what allows this to occur?

Attachment 14

NACAA
national association of clean air agencies

March 21, 2016

Janet McCabe
Acting Assistant Administrator
Office of Air and Radiation
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Dear Janet:

We are writing to you on behalf of the National Association of Clean Air Agencies (NACAA) to express concern that there are sources emitting major amounts of hazardous air pollutants (HAPs) – substances that are listed under Section 112(b) of the Clean Air Act – that are currently unregulated and for which there are no applicable source categories listed under Section 112(c) and, consequently, no national Maximum Achievable Control Technology (MACT) standards. For the reasons we articulate below, we are requesting that EPA formally evaluate the completeness of the source category list under Section 112(c) and, further, that the agency develop a MACT standard for a category of special concern – the methyl bromide fumigation source category.

NACAA is a national, non-partisan, non-profit association of air pollution control agencies in 40 states, the District of Columbia, four territories and 116 metropolitan areas. The air quality professionals in our member agencies have vast experience dedicated to improving air quality in the United States. These comments are based upon that experience. The views expressed in this document do not necessarily represent the positions of every state and local air pollution control agency in the country.

In order to assess the magnitude of this problem, NACAA recently collected information from its members about sources located throughout the country that emit major amounts of HAPs for which there are no applicable source categories under Section 112 and compiled it in a document available at http://www.4cleanair.org/sites/default/files/Documents/MajorHAPSourcesNoMACT-update-3-14-16.pdf. While many agencies provided information, this should not be considered an exhaustive and comprehensive list of every source in the United States.

Section 112(c)(1) calls for EPA to publish a list of all categories and subcategories of major sources and area sources of HAPs listed in the Clean Air Act, which EPA did for the first time on July 16, 1992. However, the language of the subsection also states that the Administrator should not only publish the list but, "shall from time to time, but no less often than every 8 years, revise, if appropriate, in response to public comment or new information, a list of all categories and subcategories of major sources and areas sources." Section 112(c)(5) also states that the Administrator "may at any time list additional categories and subcategories of sources of hazardous air pollutants according to the same criteria for listing applicable under such paragraphs" and provides a timeline for establishing standards for the new categories. Clearly Congress intended for EPA to evaluate new information and consider the need for additional categories at least every eight years.

To our knowledge, EPA has very infrequently added new source categories to the list and has never published a review of the unregulated major source population. Accordingly, we request that EPA now undertake a formal evaluation of the completeness of the source category list, taking into consideration the information we have collected, among other data.

After compiling and analyzing the list of sources emitting major amounts of HAPs that are in the source categories EPA has not addressed, NACAA identified the categories of greatest concern to our members. The first and most critical is the category of fumigation facilities that emit methyl bromide. While EPA should evaluate all of the source categories on the list NACAA has compiled, the members recommend that EPA place a high priority on this category. To further emphasize the importance of this source category, NACAA offers the following additional information for EPA's consideration.

Fumigation with Methyl Bromide

Methyl bromide, a HAP as well as a volatile organic compound (VOC), is a colorless, odorless nonflammable gas. As a fumigant, methyl bromide is used to control a number of pests, including rodents, insects, and fungi, in warehouses, agricultural fields and shipping containers. Inhalation of methyl bromide can cause headaches, dizziness, fainting, apathy, weakness, confusion, speech impairment, visual effects and numbness. Inhalation of higher concentrations of methyl bromide can cause paralysis, lung injury, kidney damage and injury to the heart[1]. At high concentrations, methyl bromide is dangerous and life-threatening, as evidenced by a recent episode in which an American family vacationing in St. John was severely injured by exposures to high levels of the substance. Although methyl bromide is a banned ozone-depleting substance, unlimited exemptions for its manufacture and use during fumigation activities continue.

Fumigation is an activity that has generally been performed at ports across the nation. There are various methods to conduct these operations, such as fumigating the commodity with only a tarp cover in a parking lot, fumigating the commodity while in a closed-door shipping container, fumigating under tarps in a building and fumigating in a closed chamber designed for this purpose. During the fumigation period, the fumigant concentration must remain above certain commodity-specific thresholds. Aeration, or the exhaust of the fumigation vapor space, frequently occurs at ground level. Facilities can be located on and off port property in warehouses near public populations.

[1] http://www3.epa.gov/airtoxics/hlthef/methylbr.html

Currently, United States Department of Agriculture fumigation regulations address exposures to workers. However, there are not adequate federal measures in place under the Clean Air Act to protect the general public from methyl bromide emissions. Considering the ground-level exhaust, combined with the heavier-than-air vapor density of methyl bromide, the increasing number of these facilities located in proximity to the public and the increasing risk of adverse health effects on the population, EPA should expeditiously develop a MACT standard for methyl bromide fumigation.

Currently states and localities in various areas of the country are faced with commodity fumigation facilities that are major sources of HAPs (over 10 tons per year of methyl bromide emissions). The facilities in operation have been constructed both before and after the implementation deadlines for case-by-case MACT under Section 112(g). At least one fumigation case-by-case MACT permit has been issued since 2005, with several more applications having been submitted in various states. This disparate regulatory regime for new and existing sources creates uneven public health protections for the residents of these jurisdictions, which should be addressed through a national measure.

Additionally, this patchwork approach results in a competitive disadvantage for areas where new sources are subject to case-by-case MACT permitting, as compared to jurisdictions with existing sources that may be exempt from all federal HAP regulation. Some states that investigate and propose methyl bromide controls have been informed that operations will simply be transferred to fumigation locations in other states. Not only do some regulatory agencies spend extensive resources on case-by-case MACT reviews, they risk losing the economic benefits of trade, jobs and taxes simply because they are taking the necessary steps to protect public health from exposure to methyl bromide. The current situation creates regulatory inconsistency and an interstate commerce issue that can be remedied by a single national rule regarding commodity fumigation.

With respect to available controls for methyl bromide commodity fumigation operations, some NACAA members have conducted significant research on this topic. Control technology is currently in use and has been demonstrated to reduce emissions of fumigation HAPs by about 90 percent. These agencies can share their information with EPA.

Finally, EPA's recently announced National Enforcement Initiatives for FY 2017-2019, issued on February 18, 2016, include a focus on reducing hazardous air pollutants, especially in overburdened areas. We believe addressing methyl bromide fumigation operations is consistent with this goal.

Given the potential public health dangers posed by continued operation and expansion of uncontrolled or under controlled on-port or off-port facilities, the interstate economic imbalances resulting from a patchwork approach and the fact that there are viable control measures in operation, NACAA recommends that EPA add methyl bromide fumigation operations to the list of source categories for regulation pursuant to Section 112(c). Further, EPA should then propose and promulgate a MACT standard as expeditiously as possible.

Thank you for this opportunity to provide you with this information. We look forward to working with EPA as you pursue listing appropriate additional source categories. Please contact us or Mary Sullivan Douglas, NACAA's Senior Staff Associate, if we can provide additional information or if you wish to discuss this issue further.

Sincerely,

Robert H. Colby
Chattanooga, TN
Co-Chair
NACAA Air Toxics Committee

William O'Sullivan
New Jersey
Co-Chair
NACAA Air Toxics Committee