First Interim Report

Mercury Emissions and Mercury Controls For Coal-fired Electrical Utility Boilers

Volume One Of Two
September 1, 2003

NCDENR

North Carolina
Department of Environment and Natural Resources
Division of Air Quality

Requirement For This Report

Excerpted from the *North Carolina Clean Smokestacks Act*

[**Title**: An Act to Improve Air Quality in the State by Imposing Limits on the Emission of Certain Pollutants from Certain Facilities that Burn Coal to Generate Electricity and to Provide for Recovery by Electric Utilities of the Costs of Achieving Compliance with Those Limits]

SECTION 12. The General Assembly anticipates that measures implemented to achieve the reductions in emissions of oxides of nitrogen (NO_x) and sulfur dioxide (SO2) required by G.S. 143-215.107D, as enacted by Section 1 of this act, will also result in significant reductions in the emissions of mercury from coal-fired generating units. The Division of Air Quality of the Department of Environment and Natural Resources shall study issues related to monitoring emissions of mercury and the development and implementation of standards and plans to implement programs to control emissions of mercury from coal-fired generating units. The Division shall evaluate available control technologies and shall estimate the benefits and costs of alternative strategies to reduce emissions of mercury. The Division shall annually report its interim findings and recommendations to the Environmental Management Commission and the Environmental Review Commission beginning 1 September 2003. The Division shall report its final findings and recommendations to the Environmental Management Commission and the Environmental Review Commission no later than 1 September 2005. The costs of implementing any air quality standards and plans to reduce the emission of mercury from coal-fired generating units below the standards in effect on the date this act becomes effective, except to the extent that the emission of mercury is reduced as a result of the reductions in the emissions of oxides of nitrogen (NO_x) and sulfur dioxide (SO2) required to achieve the emissions limitations set out in G.S. 143-215.107D, as enacted by Section 1 of this act, shall not be recoverable pursuant to G.S. 62-133.6, as enacted by Section 9 of this act.

GENERAL ASSEMBLY OF NORTH CAROLINA - SESSION 2001 – (SENATE BILL 1078)
Ratified the 19th day of June 2002. (Ch. SL 2002-4 S.13)
Marc Basnight - President Pro Tempore of the Senate
James B. Black - Speaker of the House of Representatives
Michael F. Easley- Governor

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NCDENR

Michael F. Easley, Governor William G. Ross, Jr., Secretary

September 1, 2003

TO: Environmental Review Commission
Environmental Management Commission

FROM: William G. Ross Jr.

SUBJECT: Mercury and CO_2 Reports Required by Clean Smokestacks Act

When the North Carolina General Assembly passed, and Governor Easley signed the Clean Smokestacks Act in June of 2002, our State took two crucial steps toward addressing several of the most pressing environmental and public health issues of our time. One step was highly visible, the other less so.

The visible step was to attack the problems of ozone, smog and pollution from fine particles by requiring North Carolina's fourteen coal-fired power plants to make deep cuts in sulfur dioxide and nitrogen oxides, and to do so quickly. The utility companies swung into action and are on schedule to achieve the required reductions.

The less visible, but nonetheless crucial, steps that North Carolina took under the leadership of the General Assembly and Governor Easley was to call for our state to address the issues related to the emissions of carbon dioxide from coal-fired power plants and other stationary sources also related to the emissions of mercury from power plants. Under the new law, our department, through our Division of Air Quality, will study and make findings and recommendations on both subjects in reports due in September 2003, 2004 and 2005. We are this week issuing the 2003 reports on CO_2 and mercury.

Why is it crucial that North Carolina address emissions of CO_2 and mercury? In my view it is crucial that we focus on the biggest problems facing us, and mercury and carbon dioxide emissions seem clearly to be among our biggest problems. With mercury, there is a growing concern about its impacts on public health. With carbon dioxide, there is the concern that we are changing the climate in a manner and pace that are unprecedented.

In his 2002 book, The Earth Remains Forever, Professor Rob Jackson of Duke University frames the question this way:

> "Based on current scientific evidence, I believe that by the end of the twenty-first century:

I. There will be at least nine billion people on earth.
II. Annual global energy use will be at least fifty percent higher per capita than at the end of the twentieth century, and total energy consumption will triple.
III. Atmospheric carbon dioxide concentrations will be more than five hundred parts per million, double the pre-industrial levels and higher than at any time in the past forty million years. In consequence, the average temperature of the earth will be at least 5° F warmer.
IV. Thousands, perhaps millions, of species will be extinct.
V. The demographic and economic momentum behind these changes is immense." (p 129)

> "Most of all, I want to know that we did our best, that we tried everything we could to preserve the quality of life for people today and tomorrow and saved as much room as possible for the rest of life on earth. Who doesn't want this? The moral, the practical, the ultimate question is what we do about it, what we will give up today so that we and our descendants and the rest of life on earth may have their tomorrow." (p.132)

Thanks to the leadership of the General Assembly and Governor Easley, our state is a national leader in reducing emissions of SO_2 and NOx from coal-fired power plants. To answer Professor Jackson's question, we are doing our best as a state on these two issues.

What will we do about mercury and carbon dioxide? Thanks again to our legislators and the Governor, we also have a chance to answer Professor Jackson's question, this time for mercury and carbon dioxide in a similar, positive way.

We appreciate your attention to these two reports. We look forward to your comments and questions about them.

Thank you.

Preface

This report has been produced by a working group within the North Carolina Division of Air Quality. Stakeholders from industry, environmental and other organizations were also invited to provide their insights, comments and other input. The Division appreciates the efforts of all the stakeholders and other individuals who committed their time and effort to the development of this preliminary report. This open process will continue in the development of subsequent and final reports on this topic.

Many portions of this document were taken directly from other government (non-copyrighted) documents in the interest of time and completeness. Some of these sections may have only minor wording changes from the original documents. Quotations are not strictly used to identify these parts, but a strong effort has been made to reference these documents and acknowledge them. The purpose has not been to claim credit for original work of others, but to provide as much detail and accuracy as possible within a limited time.

This report consists of two volumes. Volume One includes technical information that has been condensed and summarized from technical reports and Volume Two contains background information. The objective of this first interim report is to provide a technical background and provide results or summaries of investigations and studies.

List of Acronyms Used in This Report

BAF - Bioaccumulation factors
CAA – Clean Air Act – Primary federal clean air statute
CAPA – Clean Air Planning Act – Carper Bill
CEM – Continuous Emission Measurement
CPA – Clean Power Act – Jeffords-Waxman Bill
CSI – Clear Skies Initiative – Proposal for revised CAA legislation by the Bush Administration (also recently referred to as Clean Skies Act, though not yet an actual Act)
CSA – NC Clean Smokestacks Act
DAQ – NC Division of Air Quality
DEHNR - Former NC Department of Environment, Health, and Natural Resources, now DENR and DHHS
DENR – NC Department of Environment and Natural Resources
DENOX – A selective catalytic named DENOX®
DHHS - NC Department of Health and Human Services
DMF - Division of Marine Fisheries
DWQ - Division of Water Quality
EMC - NC Environmental Management Commission
EPA – US Environmental Protection Agency
EPRI – EPRI Journal Online
FGD – flue gas desulfurization
Hg^0 – elemental mercury
Hg^+ – inorganic mercury compounds (e.g., mercuric chloride)
Hg^{++} – organic mercury compounds (primarily methylmercury)
Hg^P – elemental mercury attached to particulate
HAP – hazardous air pollutant
HCl – hydrochloric acid
$HgCl_2$ – mercury chloride
HgS – mercuric sulfide
MACT – Maximum Achievable Control Technology
MDN - Mercury Deposition Network
N_2 – nitrogen
NAAQS – National Ambient Air Quality Standards
NAS - National Academy of Science
NC – North Carolina
NCSU – North Carolina State University
NHANES -National Health and Nutrition Examination Survey
NO - nitric oxide
NO_x – Oxides of Nitrogen, including NO_2, the primary nitrogen species from combustion.
OH – The Canadian Ontario-Hydro (OH) utility company
RELMAP – the Regional Lagrangian Model of Air Pollution
RGM - Reactive Gaseous Mercury
SCR - Selective Catalytic Reduction

SIP - State Implementation Plan
SNCR - Selective Non-Catalytic Reduction
SO_2 – Sulfur Dioxide
SO_3 – Sulfur Trioxide
SO_x – Oxides of Sulfur, including SO_2, the primary combustion product of sulfur
TGM - Total Gaseous Mercury
TMDL - Total Maximum Daily Load
TRI – Toxic Release Inventory

EXECUTIVE SUMMARY

SUMMARY OF STATUTE

The *Clean Smokestacks Act* (CSA) directs the Department of Environment and Natural Resources, Division of Air Quality (DENR-DAQ) to:

- ✓ study issues related to monitoring emissions of mercury and the development and implementation of standards and plans to implement programs to control emissions of mercury from coal-fired generating units,
- ✓ evaluate available control technologies,
- ✓ estimate the benefits and costs of alternative strategies to reduce emissions of mercury,
- ✓ annually report its interim findings and recommendations to the Environmental Management Commission and the Environmental Review Commission beginning 1 September 2003, and
- ✓ report its final findings and recommendations to the Environmental Management Commission and the Environmental Review Commission no later than 1 September 2005.

SCOPE & OBJECTIVES

Purpose of the Report

This report provides a background understanding of the properties of mercury and its compounds, health effects of methylmercury, mercury emissions, the effects of various air pollution control devices on mercury emissions, and estimated reductions of mercury emissions in North Carolina as a result of controls to be installed for other pollutants under requirements of the CSA. Information presented herein is largely a result of a literature search and summary of several pertinent and recent publications of the U.S. Environmental Protection Agency (EPA), U.S. Department of Energy (DOE), and other similar documents and their supporting scientific studies.

Expectations For Future Reports

This 2003 report will be supplemented each year for the next two years to include more technical detail gained over time, results of related federal and state regulations, and recommendations for any new standards based on further knowledge and implementation of standards resulting from the CSA and other legislation.

Summary of Scope of Problem

Mercury has been found in fish tissue, primarily in Eastern North Carolina, and fish advisories have been in effect for some time. Determination of the sources and routes by which mercury may reach this food chain are thus of concern. In North Carolina, coal-fired power plants are one of the likely suspects. Other suspects for large contributions have been a now closed chlor- alkali plant in southeastern NC and many smaller emission sources. Many localized sources (e.g., incineration, mercury battery disposal, fluorescent tube disposal, etc.) are much smaller in terms of emission quantity, but they may have a significant impact on their immediate surroundings. The focus of this report is coal-fired power plants, as directed by the CSA.

Mercury is a naturally occurring metallic mineral contaminant in coal. Air emissions of mercury result from burning coal in coal-fired electric power generating units. Elemental mercury is the only form of this metal found in the actual boiler firebox exhaust. Inorganic mercury compounds are formed when the stack gases begin to cool in the presence of chlorine and fly ash. After these transitions, the only forms of mercury at the exit of the smoke stack remain elemental mercury and inorganic mercury compounds. Although these compounds can represent a health risk if directly ingested, adsorbed through the skin, or inhaled as fine particulate, their impact potential is minimal compared to methylmercury, which is the harmful form of mercury.

Methylmercury (an organic or carbon-containing compound) does not form until inorganic mercury compounds are deposited in water, and soil (with subsequent physical transport to water bodies) and exposed to waterborne bacteria. Methylmercury compounds can then bioaccumulate in the food chain of fish, animals and eventually humans. Human exposure to methylmercury comes primarily from consumption of contaminated fish. Methylmercury has a relatively long biological half-life in humans; estimates ranging from 44 to 80 days before one half of the intake of this compound is exhausted from the human body. Methylmercury compounds break down readily when exposed to the atmosphere. They then may undergo complex chemical reactions, many of which are believed to be reversible in typical environments.

The United States Environmental Protection Agency (EPA) and DENR information indicate that approximately 1.5 tons/year of inorganic mercury are emitted to the air of NC from coal-fired power plants in NC. A recently closed chlor-alkali plant in the eastern part of the state is strongly implicated as a significant contributor to localized mercury emissions and residues. Some unknown portion of this atmospheric mercury is deposited on the land and waters of North Carolina. The deposits that occur on land are fairly fixed to the deposit site (non-transient), but some can be washed into the waters where they can combine with those deposited in the water and be converted to methylmercury**.** At the same time, a large quantity of mercury exists in the "global" air that enters North Carolina, from both natural and man-made sources. Some small portion (again, not well quantified or quantifiable) of this mercury is likely deposited within the state boundaries. A portion of the deposited mercury from all these sources is likely to again be re-emitted into the air. Thus, the quantified realities are complex and elusive. If one makes a gross assumption that *all* (probably at least a factor of 10 to 100 too high) of the 1.5 tons per year is deposited within the state and equally spread throughout the 53,821 square miles of the state, this would equate to roughly 0.0569 pounds per square mile per year, or about 0.000000002 pounds/ft^2.

ACTIONS CURRENTLY BEING TAKEN IN NC

Coal-fired generating units currently account for approximately 75 percent of mercury emissions estimated to be emitted into the air in North Carolina. Emission control equipment planned and proposed for installation to meet the *North Carolina Clean Smokestacks Act* (CSA) is estimated to capture about 55 percent of current mercury emissions from coal-fired generating units in North Carolina. Though the Act does not prescribe mercury-specific controls, these substantial mercury emission reductions are achieved as a secondary benefit. The proposed addition of wet scrubbers to control sulfur oxides (SO_x) is expected to reduce total mercury emissions from coal-fired electrical generating units from an estimated 3,052 pounds per year (ppy) to about 1,363 ppy.

ACTIONS CURRENTLY BEING TAKEN BY THE FEDERAL GOVERNMENT

The EPA has already regulated mercury emissions from sources other than utilities combustion sources. EPA has proposed a regulation to limit mercury emissions from industrial boilers, which must be finalized by early 2004, under the terms of a consent decree. Also under the terms of a settlement agreement EPA has agreed to propose a standard for utility boilers by December 15, 2003, and to finalize it by December 15, 2004. Maximum Achievable Control Technology (MACT) requirements will have major impact and implications regarding the ultimate recommendations regarding mercury under Section 12 of the CSA. These MACT standards, consistent with other schedules under CSA, are currently scheduled to be met by December 15, 2007.

Nationally, mercury from industrial sources, municipal waste combustors and medical waste incinerators has been reduced by 90 percent from 1995 levels. Additionally, the intentional use of mercury in commercial products in the United States has declined by more than 75 percent from 1988 to 1996. This national finding is believed to be an accurate description of reductions in North Carolina also.

PRELIMINARY FINDINGS AND ANTICIPATED FUTURE ACTION

From studies to date, several basic findings can be made on emissions, effects, and control of mercury:

- Mercury is a potential threat to human health and well-being.

- Coal-fired power plants release both elemental and inorganic mercury compounds, but not methylmercury. Coal-fired power plants emit approximately 66 percent of the mercury that is omitted to the sky from NC sources.

- There are numerous ongoing studies of the impact of mercury emissions from the various sources, both natural and anthropogenic (created by human activity).

- Scientific study is underway to establish a quantitative relationship between reduced mercury emissions into the air in North Carolina and reduced methylmercury levels in fish tissues.

- Various types of air pollution controls on coal-fired power plants that are added primarily to control other pollutants (e.g., sulfur dioxide (SO_2) and oxides of nitrogen (NO_x) –pursuant to the *North Carolina Clean Smokestacks Act*) are expected to also reduce mercury emissions by approximately 55 percent.

- Mercury compounds reach the proper conditions (pH, sulfur concentrations, biological activity, etc.) in a water body, methylmercury forms.

In light of these basic findings, DAQ believes it important to pursue the following steps:

- ✓ Study the issues as directed by the CSA.

- ✓ Refine the estimated effects on mercury emissions of projected SO_2 and NO_x controls on electric utility emissions, and refine the estimates of levels and fate of mercury emissions that remain.

- ✓ Monitor changes in plans for application of control devices by the utility companies and adjust emission estimates and analysis accordingly.

- ✓ Monitor and evaluate outside influences and regulatory developments at the federal level, and with other states involved in similar efforts.

- ✓ Provide support for efforts to refine health effects and trends of mercury levels in fish and other potential routes of exposure.

- ✓ Determine funding needs to identify and study more closely the distribution of humans who are at risk of fish contaminated fish.

- ✓ Evaluate whether and to what extent global reductions in mercury emissions are causing changes in mercury depositions in NC.

- ✓ Evaluate and refine information on other potential sources of mercury in North Carolina.

- ✓ Address and respond to specific questions generated by this 2003 report.

- ✓ Assemble economic data and models to reflect multiple risk scenarios and costs of implementation of further controls.

MERCURY PROBLEMS

The species of mercury (elemental and inorganic mercury) and their ratio in coal-fired boiler emissions are important when devising capture and control techniques. The chemical species of mercury emitted from utility boilers vary significantly from one plant to another. Removal effectiveness depends on the species of mercury present. Elemental mercury passes through control devices. Capture efficiency is dependent on converting elemental mercury into inorganic mercury. To date, no single control technology has been identified that removes any elemental mercury and all inorganic mercury.

Elemental mercury passes readily through the body. Inorganic mercury compounds take several days to transit out of the body. Organic mercury (primarily methylmercury) has a strong propensity to be stored in the body (fatty tissues such as the brain) and is slowly removed from the body over a period of months. Methylmercury exposure to humans is dependent on the amount of fish consumed and the methylmercury concentration in the fish. Groups susceptible to the effects of methylmercury are children up to the age of six (developing neurological systems), women of child-bearing age, sports fishermen, and subsistence fishermen.

Mercury cycles through the environment as a result of both natural and human activity. Most of the mercury in the atmosphere is elemental mercury vapor, that circulates in the atmosphere for up to a year, and can be transported thousands of miles from the source. Mercury that is deposited to soil and terrestrial vegetation does not result in exposures likely to be detrimental to health.

CHEMICAL AND PHYSICAL ATTRIBUTES OF MERCURY

Elemental mercury is a heavy (weighing 13.53 times as much as water per unit volume) silver-white metal with an atomic weight of 200.59 grams per mole. By comparison, the atomic weight of iron is 55.847. At room temperature, mercury is a liquid and has a vapor pressure of 0.002 mm mercury at 25 degrees Centigrade (0.038 psi at 77 degrees Fahrenheit).[1]

Mercury is used widely in industrial applications. It conducts electricity, responds to temperature and pressure changes, and forms an alloy with almost all metals. In the electrical industry, mercury is used in florescent lights, in switches as part of wiring devices, and with instruments that measure temperatures and pressures. It is also a component of dental amalgams used in restoring teeth. In addition to its use in specific products, mercury is used in numerous industrial processes. The largest manufacturing use of mercury in the United States is associated with the production of chlorine and caustic soda by mercury-cell ‘chlor-alkali’ plants. Mercury has also been used in amalgamation with other metals (e.g., gold) and as an antifungal agent in vaccines and wood preserving.[2] Many of these uses have shrunk in recent years due to concerns over

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human exposures to mercury, and in many cases, due to regulations that did not previously exist.

ELEMENTAL MERCURY, INORGANIC MERCURY, AND METHYLMERCURY

The elemental and inorganic mercury that exits the smoke stack becomes part of the global pool of mercury in the atmosphere or falling on land or water. Elemental and inorganic mercury are not health hazards. However, when waterborne bacteria modify inorganic mercury, an organic mercury molecule is produced. Organic mercury, primarily methylmercury, accumulates in long-lived animals. Predatory fish at the top of the food chain accumulate increasing concentrations of methylmercury in their body tissues (i.e., bioaccumulation), which is a health threat to humans who eat quantities of these fish.

Mercury exists in three forms (species): elemental mercury (Hg^0), inorganic mercury compounds (Hg^+) (e.g., mercuric chloride), and organic mercury (Hg^{++}) compounds (primarily methylmercury).[3] Organic species of mercury (methylmercury) are harmful to humans. Elemental mercury passes rapidly through the body. Inorganic mercury compounds may take several days to transit out of the body, but like elemental mercury, causes no harm. Organic mercury has a strong propensity to be stored in the body's fatty tissues, such as the brain, but does slowly leave the body over a period of months.

Speciation is a term used to denote the relative amounts of elemental mercury, oxidized mercury, and mercury attached to particulate in flue gas. No methylmercury is emitted from the stacks of coal-fired boilers. The rate of conversion of the gaseous mercury is dependent on temperature, flue gas composition, and the amount and properties of entrained particles (fly ash and sorbents). Mercury speciation is a particularly important variable for flue gas cleaning as it directly impacts the capture of mercury. For example, mercury chloride ($HgCl_2$) is water-soluble and readily reacts with alkali metal oxides in an acid-base reaction; therefore, conventional acid gas scrubbers used for sulfur dioxide (SO_2) control are effective in controlling $HgCl_2$. However, elemental mercury Hg^0 is insoluble water and must be adsorbed onto a sorbent or converted to a soluble form that can be collected in a wet scrubber. In coal-fired combustion units, where concentrations of chlorine are low and SO_2 is present, mercury may remain predominantly in the elemental form.[4]

MERCURY CYCLES IN THE ENVIRONMENT

General Assumptions And Efforts To Date

Mercury moves about the environment because of both natural and human activity. Most mercury in the atmosphere is elemental mercury vapor, which circulates in the atmosphere for up to a year, and hence can be transported thousands of miles from the

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source.[5] Recent modeling indicates that the rate of oxidation of elemental mercury in the atmosphere may be occurring twice as fast as previously thought (half-life of six months instead of one year). If substantiated, this means that either there are unknown sources of elemental mercury contributing mercury to the global pool or the calculated release of elemental mercury vapor as a result of natural and human activity is understated by a factor of two.

Mercury modeling efforts initially made an assumption that all inorganic mercury compounds that settled on the ground would eventually enter the surface water drainage system and accumulate in rivers, streams, and lakes. Contrary to that assumption, inorganic mercury compounds have a strong propensity to attach to and remain on leafy vegetation and soil particles. The majority of inorganic mercury compounds found in water bodies arrived by way of atmospheric transport. However, mercury that is deposited to soil and terrestrial vegetation does not result in exposures likely to be detrimental to health through terrestrial exposure pathways.[6]

Mercury in the atmosphere comes both from natural resources and from human activities. Scientists continue to work to define the total and contributory amounts. Studies by Nriagu and Pacyna (1988) estimate global natural emissions at 3,000 tons per year (tpy) and the medium for global emissions from human activities at 3,560 tpy. A more recent critical review by Jackson (1997) estimates that 2,000 tpy from natural resources, while 4,000 tpy are emitted from sources attributed to human activities e.g., combustion of fossil fuel and solid waste.[7]

Anthropogenic mercury released directly to land or water bodies, or deposited on them from the atmosphere, undergoes transformations that are not fully understood. The amount of mercury transformed to methylmercury varies greatly from one water body to another. According to Krabbenholf, et al., (1999), many factors influence methylmercury production beyond mercury loading. These factors include environmental setting (e.g., climate, geology, land use, land cover), water chemistry, and wetland density. The latter is the most important basin-scale factor controlling methylmercury production.[8]

PATH FROM COAL-FIRED BOILERS TO BIOACCUMULATION OF METHYLMERCURY

Nearly all mercury that accumulates in fish tissue is methylmercury (an organic mercury compound). The EPA has found a plausible link between anthropogenic releases of mercury and methylmercury in fish tissue.[9] To transition from mercury in coal to methylmercury in fish, is a complex path.

To be converted to organic mercury, elemental mercury must combine with another element (such as sulfur, chlorine or oxygen) or combine with other compounds to

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form inorganic mercury compounds. Either a living organism must act on this inorganic mercury compound or an organic compound must react with it to obtain organic mercury. Coal-fired electric utility boilers produce no organic mercury compounds directly. Mercury that is deposited to soil and terrestrial vegetation does not result in exposures likely to be detrimental to health through terrestrial exposure pathways.[10]

The main pathway of introducing methylated mercury forms into aquatic systems is via *in situ* (natural) production, mediated by sulfate-reducing bacteria. Recent investigations suggest that a substantial portion of what is often considered "dissolved" mercury is actually mercury associated with macromolecular colloidal organic matter (submicroscopic particles that do not settle out). Focusing predominately on loading or abundance of inorganic mercury as the dominant controlling factor is often given excessive weight in assessing methylmercury concentrations and production in aquatic systems. While the amount of inorganic mercury is indeed an important factor, it is not the only important factor; nor is it necessarily the controlling factor. A number of parameters have been identified as important in influencing the production and abundance of methylmercury in aquatic systems. They include mercury loading, the chemical form of mercury (chemical speciation), temperature, the availability of organic substrate for sulfate-reducing bacteria (i.e., a food source), mercury de-methylation activity (by bacteria), natural reduction-oxidation conditions, and in some cases photo-demethylation (light induced).[11] To complicate the issue further, many of these parameters vary temporally and spatially in aquatic systems. Any of these parameters can potentially limit the abundance of bio-available methylmercury in an aquatic system.[12]

Other Uncertainty Factors

Additional factors influence the bioaccumulation of mercury in aquatic biota. They include the acidity (pH) of the water, length of the aquatic food chain, temperature, and dissolved organic material. Physical and chemical characteristics of a watershed, such as soil type and erosion or proportion of area that is wetlands, can affect the amount of mercury that is transported from soils to water bodies. Interrelationships among these factors are poorly understood and are likely to be site-specific. No single factor (including pH) has been correlated with extent of mercury bioaccumulation in all cases examined. Two lakes that are similar biologically, physically, and chemically can have different methylmercury concentrations in water, fish, and other aquatic organisms.[13]

Benoit, Gilmour, Mason, and colleagues have recently proposed that sulfide levels in aquatic systems can be very important in controlling methylmercury production by sulfate-reducing bacteria. This influence arises from the strong interaction between inorganic mercury and sulfide to form mercury-sulfide complexes and the bioavailability of these complexes to sulfate-reducing bacteria. They hypothesize that only neutrally charged mercury complexes (e.g., elemental mercury, mercuric sulfide [HgS^0] or

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mercuric chloride [$HgCl_2^0$]) are capable of readily passing bacterial membranes for intra-cellular mercury methylation. Hence, the in situ chemical speciation of mercury is very important in controlling mercury methylation.[14] If this proposal is proven correct, then waters with high sulfide levels and low oxygen will have low methylmercury levels.

Not all mercury compounds entering an aquatic ecosystem are methylated (converted to methylmercury). Demethylation reactions (conversion of methylmercury into mercury compounds), as well as volatilization of dimethylmercury, decrease the amount of methylmercury available in the aquatic environment. In other words, physical and chemical forces are in action at various rates to deduce methylmercury concentrations in aquatic ecosystems. There is substantial scientific certainty regarding the rate at which these reactions take place.[15]

Additionally, scientific understanding of the environmental fate and transport of mercury is limited. Quantifying the contribution of United States anthropogenic emissions relative to other sources of mercury, including natural sources and re-emissions from the global pool (natural and anthropogenic), on methylmercury levels in fish consumed by the U.S. population is not possible at this time. Mercury methylation and subsequent uptake in fish is complex and not yet well understood. As a result, a change in total mercury emissions cannot be firmly established as being linearly related to any resulting change in methylmercury in fish. The time over which these changes will occur is also uncertain. This is an area of ongoing study.[16]

MERCURY IN WATER

Mercury In Drinking Water and Scrubber Blow Down

The EPA drinking water standard is 0.002 mg/liter for mercury. While this is on the basis of total mercury (elemental mercury and mercury compounds), it is not specific to or limited to methylmercury, which would not exist in scrubber blow down. Levels of mercury in scrubber blow down from coal fired utility boilers would likely be many times over the drinking water standard. Obviously, it would be ill advised to remove mercury from stack exhaust and then allow these emissions to be discharged into surface or other drinking water sources (where it could potentially interact with the biological mechanisms to form methylmercury). At time this document was prepared, insufficient information had been collected by DAQ to enable a reasonable determination of what the industry norm and expectations would be for collection and treatment of the blow down water to prevent it from being a water quality problem. This is an important potential issue and will be researched and addressed in the next subsequent report update.

Additional detailed discussions of mercury in North Carolina's waters are presented in Chapter 3 and Volume 2 of this report.

MERCURY IN SOIL

Mercury dispersion simulation modeling efforts initially followed an assumption that all inorganic mercury compounds that settled on the ground would eventually enter the surface water drainage system and accumulate in rivers, streams, and lakes. Contrary to that assumption, inorganic mercury compounds have a strong propensity to attach to leafy vegetation and soil particles. The majority of inorganic mercury compounds found in water bodies are believed to have arrived by way of atmospheric transport and not from local drainage.

One study shows the estimated release of mercury vapors from 200,000 tons of fly ash per year has a maximum potential release of 0.0044 pounds, or 2 grams of mercury per year.[17] Therefore, land disposal of fly ash does not appear to be a significant source of mercury contamination or emission.

MERCURY IN AIR

Mercury in the atmosphere comes both from natural sources and from global emissions from human activities. Most of the mercury in the atmosphere is elemental mercury vapor, which may circulate in the atmosphere for years ("global pool") in a dynamic deposition/re-emission state of flux, and hence, can be transported thousand of miles from the source.[18] Modeling studies recently have suggested that the rate of oxidation of elemental mercury in the atmosphere may be occurring twice as fast (half-life of six months instead of one year) as previously believed. If true, either undefined sources of elemental mercury exist or the release of elemental mercury vapor because of natural and human activity may be in error by a factor of two, meaning total annual mercury emission rates might be up to two times greater than currently estimated.

However, recent experiments using plume chemistry in a static plume dilution chamber, developed by the Electric Power Research Institute, may change the interpretation of chemistry used to calculate percentages of elemental mercury and oxidized (inorganic) mercury transported in the plume. [19] This study suggests that oxidized mercury rapidly converts to elemental mercury near the stack. This finding may explain measurements made near a large coal-fired power plant in Georgia. Based on mercury concentrations in coal burned at the plant, scientists predicted that the stack gases would contain 60 percent oxidized mercury and 40 percent elemental mercury. Mercury measured in air 15 miles downwind was found to be 9 percent oxidized mercury and 91 percent elemental mercury.[19]

These two concepts - (that the oxidation of mercury occurs twice as fast as previously believed, and that oxidized mercury rapidly converts to elemental mercury near the stack) conflict and further demonstrate the need to further understand the science of mercury speciation in the atmosphere.

MERCURY CONCERNS SPECIFIC TO NC

HISTORY: MERCURY IN NORTH CAROLINA

Biologists suspected for many years that freshwater fish in the black water systems of eastern North Carolina would be prone to mercury contamination as found in other parts of the country sharing similar environmental conditions. In 1970 the Federal Water Quality Administration issued a report on mercury pollution that mentioned mercury contamination found in fish caught in the lower Cape Fear River basin. Industrial discharges of mercury to local waterways and mercurial pesticide use were scrutinized at that time, but no study was made of atmospheric contributions. Past studies of mercury levels in eastern North Carolina peat deposits discussed the possible contribution of atmospheric deposition of mercury to local waterways. However, no information was available on atmospheric mercury trends in the areas surrounding eastern North Carolina's sensitive waterways

Mercury in Fish Tissue

The rate and degree to which methylmercury bioaccumulates within a system is dependent on a number of factors. The most significant of these includes the water's pH, food chain length and composition (productivity), water temperature, water body chemistry, and the form and structure of the organisms present. Methyl mercury, the toxic and most bioaccumulative form of mercury in fish, can be concentrated in top predator species.

The Environmental Sciences Branch (fisheries programs) of the North Carolina Division of Water Quality (DWQ) conducts fish community assessments, fish tissue monitoring, fish kill data assessment, and supports special projects. In 1992, the DWQ conducted an intensive fish mercury survey in the vicinity of Lake Waccamaw, situated in the Lumber River Basin of southeastern North Carolina (Figure 3-1). In that study, 60 percent of largemouth bass samples from Big Creek and the Waccamaw River were found to contain mercury levels above one part per million (ppm), the threshold level for issuance of fish consumption NCDEHNR advisories at that time.

The DWQ's efforts from 1995 to 1999 consisted of monitoring for mercury and other contaminants under basin-wide assessments, sampling statewide, verification of the high levels of mercury in eastern piscivores (fish-eaters), and the king mackerel mercury survey (1998-1999) with the Division of Marine Fisheries (DMF). From 1998 to 1999, DWQ assisted with

Figure 3-1

Southeastern North Carolina

Including Lake Waccamaw and Surrounding Environs

the analyses of 112 king mackerel and Spanish mackerel samples that were collected by the DMF from recreational and commercial sources. The fish tissues were collected from a range of fish sizes and seasonal populations.

The Spanish mackerel samples contained low mercury levels. However, regression models using king mackerel tissue data demonstrates a strong relationship exists between king mackerel size and mercury concentration. From these regression curves, a mercury level over 1ppm is predicted for king mackerel over 13 pounds or 37 inches.

Human Mercury Burden

Mercury compounds can be converted in some aquatic environments into a more toxic form, methylmercury. The NC Department of Health and Human Services (DHHS) found that this is the form of mercury that is incorporated into the food chain. Fish consumption is the primary way that both humans and wildlife are exposed to methylmercury. Methylmercury can accumulate to harmful concentrations in predatory fish.

In North Carolina, high levels of methylmercury (levels at 0.4 mg/kg or greater) have been found in ocean fish like shark, swordfish, king mackerel, and tilefish, and in freshwater fish like largemouth bass, bowfin, and chain pickerel south and east of Interstate 85 (see Figures 3-2 and 3-3). Women of childbearing age and children have been notified through advisories to not eat the four ocean fish and the three freshwater fish south and east of Interstate 85. These advisories have been issued to protect the most sensitive population, the developing child. The developing human nervous system is particularly sensitive to methylmercury. Several studies have reported increasing effects on the developing nervous system of an unborn child with increasing maternal methylmercury exposure from routine fish and whale consumption. Neurological processes in the areas of language, attention, and memory have been most affected.

The NC DHHS is seeking funding from the Centers for Disease Control and Prevention to conduct biomonitoring in seven counties including Columbus, Brunswick, Bladen, Moore, Scotland, Duplin, and Martin Counties. The largemouth bass and bowfin in these counties have some of the highest methylmercury fish tissue concentrations in the state. Based on consultation with local residents from these counties and with the NC Wildlife Resources Commission, there are recreational and subsistence fishermen in these counties. The potential for exposure to high levels of methylmercury exists for individuals living in these counties. Even though there are advisories in these areas, the people may not be aware of the advisories or may choose to ignore them.

An epidemiological study consisting of blood and hair methylmercury analysis was completed in 1990 after discovering elevated fish tissue levels in largemouth bass and bowfin for Columbus and Brunswick Counties. Some of the highest levels of methylmercury in human hair and blood ever recorded in the United States have been identified among residents living in Columbus and Brunswick Counties. The purpose of this study was to determine if the subsistence fishermen in these counties had elevated methylmercury blood or hair levels. A total of 64 blood samples and 77 hair samples were collected for 81 residents living in these two counties. There was a positive correlation between residents with high rates of fish consumption from the waters under advisory and elevated methylmercury hair and blood levels. The blood levels ranged from non detect to 141 ug/L (well above 5 percent effect level of 58 ug/L associated with abnormal neurodevelopmental scores above background). The hair levels ranged from non detect to 33.5 mg/kg (well above 5 percent effect level of 10 mg/kg associated with abnormal neurodevelopmental scores above background).

Additional biomonitoring is needed to prevent illness and improve public health through the following:

- To determine awareness of the fish advisories pertaining to methylmercury and to also communicate the fish advisories.

- To modify and/or expand approach for communicating fish advisories if decreased awareness or individuals are not following advice.

- To determine methylmercury body burden levels among women of childbearing age and children within the counties that have some of the highest methylmercury fish tissue levels in the state and to recommend low methylmercury fish choices.

- To determine methylmercury body burden levels among women of childbearing age and children within the counties that have some of the highest methylmercury fish tissue levels in the state and to recommend low methylmercury fish choices.

The results of the study will benefit women of childbearing age and their offspring. The program will obtain information about the proportion of women who are aware of the advisory and how to successfully distribute advisory information to women who are not getting the message. By increasing the proportion of women who are aware of the advisory, the program will decrease methylmercury exposure to the women and their offspring. In addition, the intervention design will be shared with other states so that their advisory information will be distributed successfully to this subpopulation. The end result is to ensure that women of childbearing age are getting the advisory information so that they will limit their exposure to methylmercury and other contaminants through consumption of fish.

Estimated Risk to Newborns in North Carolina

The potential number of newborns in North Carolina at risk from maternal exposure to methylmercury is calculated using data from the 1999 National Health and Nutrition Examination Survey (NHANES). This survey reported blood and hair methylmercury sample results for women ages 16 to 49. Approximately 10 percent of the women surveyed had hair methylmercury levels above the EPA-recommended hair level of 1 mg/kg to protect developing fetuses (corresponds to reference dose of 0.1 ug/kg-day). According to the Centers for Disease Control and Prevention, this indicates a narrow margin of safety for some fetuses. [20] EPA estimates that at or below the reference dose of 0.1 ug/kg-day or maternal hair level of 1 mg/kg, chronic non-cancer health effects

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are not likely to occur. But as the exposure dose increases above the EPA reference dose, the probability of adverse health effects also increases.

Using this information, one may extrapolate to find the number of newborn infants in North Carolina that may potentially be at risk. This extrapolation assumes that the NHANES population surveyed is representative of a cross section of North Carolina and that women in North Carolina have methylmercury levels similar to levels found in the NHANES survey.

Based on the 1995 national fecundity rates for women ages 15 to 44 and the population data for North Carolina, it is estimated that there are 1,105,045 fertile women in North Carolina. [21] Using the North Carolina fertility rate of live births of 67.5 per 1,000 fertile women for 1999, one can expect 74,590 live births.[22] If one assumes that 10 percent of the maternal hair levels for the 74,590 births are greater than 1 mg/kg as reported in the national survey, then 7,459 North Carolina fetuses annually may be at a dose higher than that recommended by EPA. EPA estimates that chronic non-cancer health effects are not likely to occur at or below the reference dose. But as the exposure dose increases above the EPA reference dose, the probability of adverse health effects also increases.

HEALTH EFFECTS

Human methylmercury contamination occurs primarily through diet. Fish and fish products are the predominate source.[23] Consumption of fish and marine birds and mammals represent 95 percent of the human intake of methylmercury. Within the United States, individual consumption of fish and seafood is highly variable. Approximately one to two percent of the U.S. population report eating fish daily, whereas about 10 percent rarely consume fish.[24]

Susceptible populations include people consuming above average amounts (greater than ten grams) of methylmercury contaminated fish on a regular basis. Ten grams per day is equivalent to 8 pounds of fish per year. Higher than average consumption of fish and other seafood is found among people of Asian and American Indian ethnicity and recreational anglers and their families. People who are subsistence fishers may be particularly important population with respect to methylmercury contamination. Methylmercury contamination depends on the amount of fish consumed and on the methylmercury concentrations in the fish.[25]

Methylmercury adversely affects the developing nervous system at lower exposure than it affects adult neurological functioning. Consequently, women of childbearing age, maternal and fetal pairs, nursing mother and infant pairs, and young

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children (up to age six) are all susceptible populations.[26] An analysis of dietary surveys led the EPA to conclude that between one and three percent of women of childbearing age (i.e., between 15 and 44) eat significant amounts of fish to be at risk from mercury exposure.[27]

The EPA has found mercury residuals in fish in 92 percent of 374 surface water bodies tested in the U.S. Eighty-five percent of the sites were found to have 0.0 to 0.5 ppm mercury levels. Mercury levels above 1 ppm were found in at least one fish at two percent of the sites surveyed, and above 0.5 ppm were found in at least one fish at 15 percent of the sites. The national average for freshwater fish is 0.3 ppm.[28] In humans, methylmercury has an estimated biological half-life of between 44 and 80 days.[29] Inorganic mercury, which is less efficiently absorbed and more readily eliminated from the body than methylmercury, does not tend to bioaccumulate.[30]

Findings By The NC Department of Health and Human Services

Consumption of fish can be beneficial for both pregnant and breastfeeding women, and their developing children. The developing retina and nervous system of an unborn child may benefit from maternal consumption of fish during pregnancy. Additionally, fish consumption has been associated with a decreased risk of heart attack and coronary artery disease in adults.[31,32,33] However, a form of mercury known as methylmercury can accumulate to harmful concentrations in predatory fish.[34] Consumption of these fish by pregnant and/or nursing women and by children poses a health risk to children and fetuses.

The developing human nervous system is particularly sensitive to methylmercury. Several studies have reported increasing effects on the developing nervous system of an unborn child with increasing maternal methylmercury exposure from routine fish and whale consumption. Neurological processes in the areas of language, attention, and memory were most affected. According to the National Academy of Sciences, studies conducted in the New Zealand and Faroe Islands show that the deficits observed can be considered predictive of problems in cognitive and academic performance associated

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with methylmercury exposure, or can affect the way the children may think, learn, and problem solve. These studies have shown the developing fetus to be at least three times more sensitive than adults.[35]

Routine consumption of fish containing concentrations of 0.4 mg/kg or greater of methylmercury poses an increased risk of neuro-developmental effects for the developing fetus and children under 15 years of age.[36] The EPA reference dose for methylmercury is 0.1 ug/kg-day (corresponds to maternal hair level of 1 mg/kg and blood level of 5.8 ug/L). This is the dose that is not likely to be associated with health effects for the developing fetus and child. Routine consumption of fish containing 0.4 mg/kg of methylmercury can result in exceedances of the US EPA reference dose for methylmercury.

To derive the reference dose of 0.1 ug/kg-day, EPA calculated benchmark doses (BMD) or doses associated with a 5 percent incremental risk above background (background associated with 5 percent risk) of having abnormal neuropsychological test scores for children from the Faroe Islands located in the North Sea between Scotland and Iceland. These test scores provide a measure of the way children learn, think, and problem solve. The mothers of these children consumed three fish meals per week and less than one pilot whale meal per month.

The benchmark dose, based on EPA and National Academy of Science review was 85 ppb in cord blood, corresponds to 15 mg/kg in hair. At these blood and hair levels, there is an estimated 5 percent incremental risk above background of having abnormal neuropsychological test scores. EPA determined the 95 percent confidence interval or the range of doses that would be expected to be associated with a total 10 percent risk of having abnormal scores or 5 percent incremental risk above background. The lowest dose of this interval was 58 ppb in cord blood or 10 mg/kg in maternal hair and is designated as the Benchmark Dose Limit (BMDL). This corresponds to an intake of 1.081 ug/kg-day. An uncertainty factor of 10 was applied to the 1.081 ug/kg-day to account for variability in susceptibility within the study cohort, variability in pharmacokinetic parameters for methylmercury, and lack of data on long term sequelae of in utero exposure. The resulting reference dose is 0.1 ug/kg-day or 0.0001 mg/kg-day corresponding to hair level of 1.0 mg/kg.[37]

The Center for Disease Control and Prevention's 1999 National Health and Nutrition Examination Survey (NHANES) reported blood and hair methylmercury

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sample results for women ages 16 to 49. Approximately 10 percent of the women surveyed had hair methylmercury levels above the EPA-recommended hair level of 1 mg/kg to protect developing fetuses (corresponds to reference dose of 0.1 ug/kg-day). According to the Centers for Disease Control and Prevention, this indicates a narrow margin of safety for some fetuses.[38] EPA estimates that at or below the reference dose of 0.1 ug/kg-day or maternal hair level of 1 mg/kg, chronic non-cancer health effects are not likely to occur. But as the exposure dose increases above the EPA reference dose, the probability of adverse health effects also increases.

North Carolina Safe Fish Eating Guidelines

The most recent safe fish eating guidelines issued by DHHS were prepared by the Medical Evaluation and Risk Assessment Unit (MERAU) and dated August 29, 2001. Women of childbearing age (15-44 years), pregnant women, nursing women, and children under 15 years may eat two meals per week of fish low in methylmercury, like farm-raised fish, canned tuna and other canned fish, fish sticks, shrimp, crab, lobster, clams, oysters, scallops, salmon, trout, cod, whitefish, pollock, mahi-mahi, ocean perch, halibut, haddock, flounder, croaker, herring, crappie, sunfish, white perch, yellow perch, and bream.[39] They should not eat shark, swordfish, tilefish, or king mackerel.[40] Also, they should not eat bowfin (blackfish), chain pickerel (jack fish) or largemouth bass caught in North Carolina waters south and east of Interstate 85.

Other women, men, and children over 15 years may eat four meals per week of fish low in methylmercury, like farm-raised fish, canned tuna and other canned fish, fish sticks, shrimp, crab, lobster, clams, oysters, scallops, salmon, trout, cod, whitefish, pollock, mahi-mahi, ocean perch, halibut, haddock, flounder, croaker, herring, crappie, sunfish, white perch, yellow perch, and bream.[41] They should eat no more than one meal per week of shark, swordfish, tilefish, or king mackerel. Also, they should eat no more than one meal per week of bowfin (blackfish), chain pickerel (jack fish), or largemouth bass caught in North Carolina waters south and east of Interstate 85 see Figures 3-2 and 3-3).

MONITORING FOR ATMOSPHERIC MERCURY

The following discussion on monitoring North Carolina atmosphere and water mercury concentrations represents a condensed version of highlights from major scientific studies that are available for review in Volume 2 of this report.

Very little historical data are available describing typical atmospheric mercury levels in North Carolina. Stopford anecdotally reported levels between 1.7 and 8.9 ng/m^3 in Durham, NC in 1978, with a short-term peak of approximately 400 ng/m^3 during a plume fumigation event arising from a nearby coal-fired power plant. Between 1998 and 2001, periodic measurements of TGM taken at a site in Research Triangle Park, NC indicated that levels rarely exceeded 2 ng/m^3, with values typically in a range between 1.4 - 1.7 ng/m^3.[41] TGM was measured over a 3-month period between June and August of 1996 at Phelps Lake, a remote site in northeastern North Carolina; 15-minute readings were consistently between 1 and 2 ng/m^3 and never exceeded 6 ng/m^3.

Mercury, in its various forms, is transported into and out of the atmosphere by several different means. Mercury can be absorbed by cloud formations and deposited to the earth's surface in rainwater or as dew. This is known as "wet deposition". Mercury can also adhere to particulate matter and settle out onto vegetation and the earth's surface. This mechanism is known as "dry deposition". Levels of mercury in rainwater and adhered to particulate matter can both be measured. North Carolina has been measuring mercury in rainwater since 1996. Mercury that is not deposited out of the atmosphere remains suspended in the ambient air and exists either in its elemental form, *elemental mercury*, or its reactive form, which is referred to as reactive gaseous mercury (RGM). Together, elemental mercury and RGM comprise what is referred to as Total Gaseous Mercury (TGM). North Carolina has the ability to measure these two forms of mercury while still suspended in the air and can distinguish one from the other.

MERCURY WET DEPOSITION

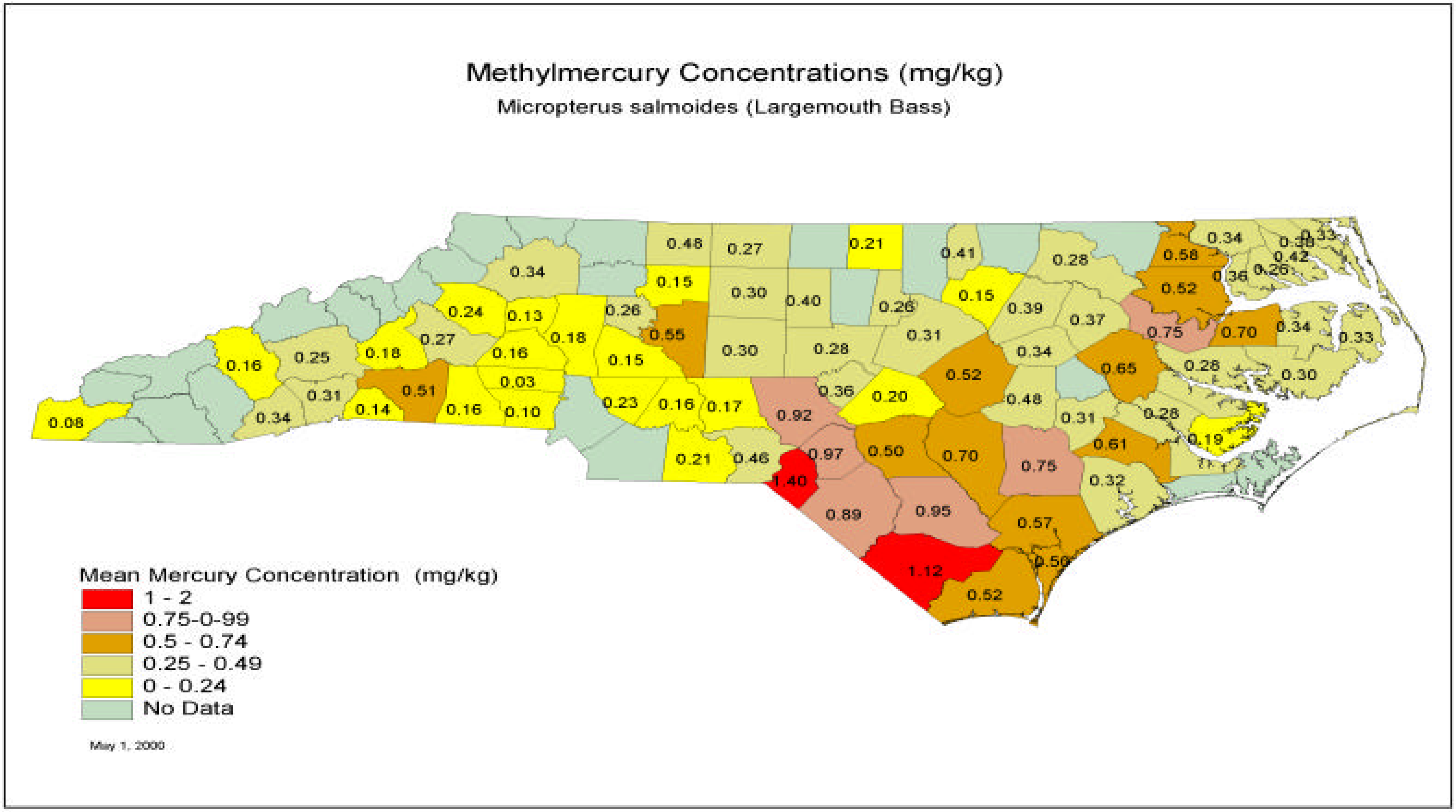
Mercury wet deposition involves the transfer of mercury from the atmosphere to land or surface waters in precipitation or condensation of water vapor. Water-soluble species of gaseous or particulate mercury may be scavenged from the atmosphere by cloud water, rain, snowfall or water vapor. For many surface waters, atmospheric deposition is the most significant route of mercury loading. Dry deposition of particulate mercury or RGM also contributes to the overall rate of atmospheric deposition. Together, these phenomena contribute to raise methylmercury levels in fish residing in mercury-sensitive waters.

Mercury Wet Deposition Sites

Shortly after the discovery of widespread mercury contamination in Lumber River basin fish, the Division of Air Quality (DAQ) stationed air monitoring instruments at Lake Waccamaw and Pettigrew State Parks to measure mercury levels in rainfall.

Figure 3-2

Contaminated Largemouth Bass



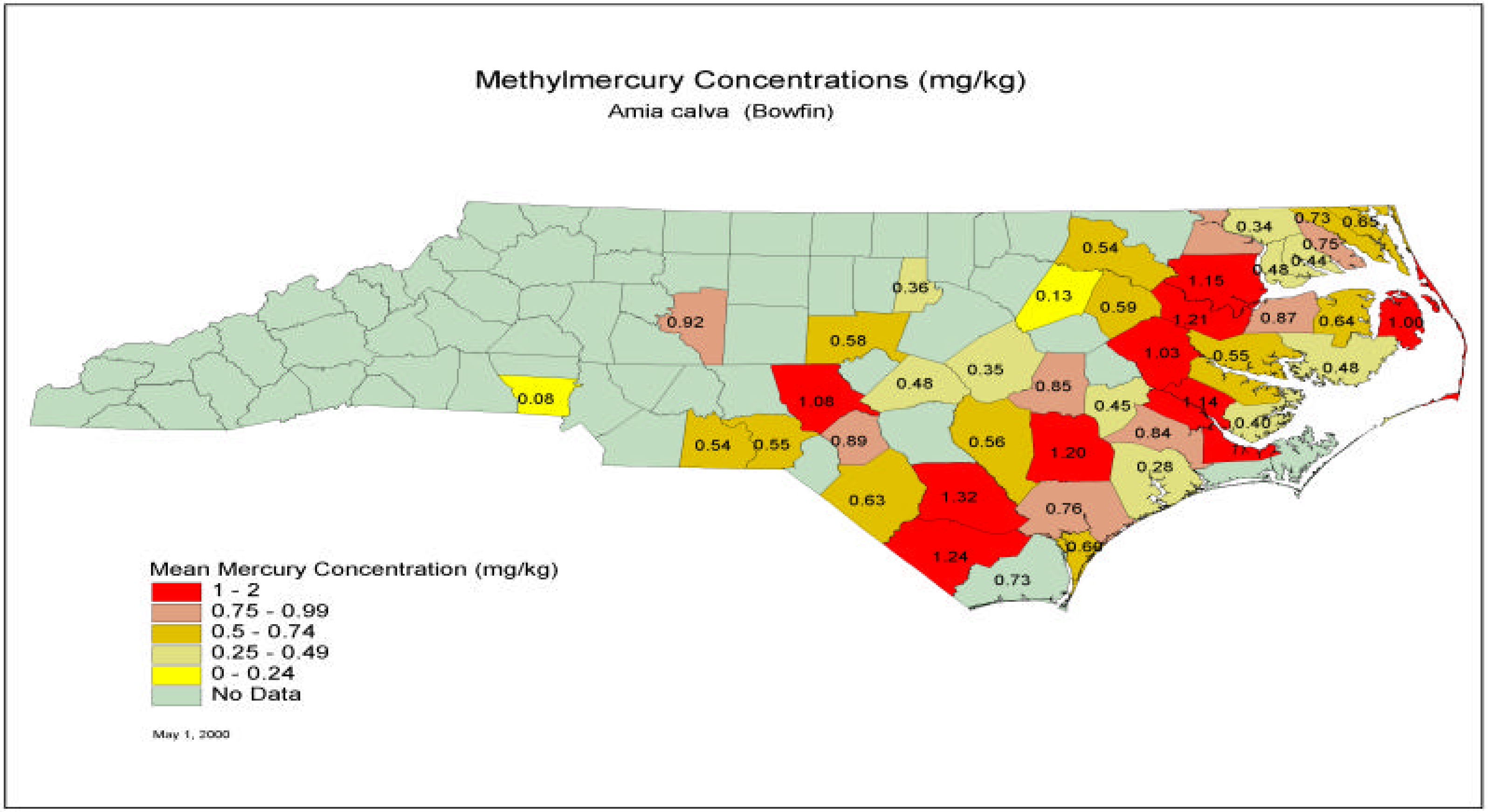
Methylmercury Concentrations (mg/kg)

Micropterus salmoides (Largemouth Bass)

May 1, 2000

Figure 3-3

Contaminated Bowfin



Measurement of mercury in rainwater can provide an estimated rate of atmospheric deposition and loading to local waters. The Waccamaw and Pettigrew stations were among the earliest sites in the National Atmospheric Deposition Network's Mercury Deposition Network (MDN). Composite rainwater samples were collected and analyzed weekly for total mercury content beginning in late 1995.

Recent data from both sites during 1999 and 2000 suggested that mercury levels in precipitation may be declining in these areas. The most dramatic drop occurred between 1998 and 1999 at Lake Waccamaw State Park, when levels declined to values typical of the more remote location at Pettigrew State Park. Since 1998 however, the levels have crept back up. The current theory of cause and effect for mercury levels increasing may be cleanup activities at the closed chlor-alkali facility.

There was a reduction in mercury deposition (a 30 percent drop compared to the previous three year average) at the Waccamaw site starting in 1999. This reduction coincides with the closure of the HoltraChem mercury cell chlor-alkali plant. However, concentrations increased in 2000 and 2001, possibly due to plant clean-up efforts at the closed plant. The weighted concentration levels in 2000 and 2001 do not reach the magnitude of pre-1999 concentrations. Data from the Pettigrew site generally follow the same curve, but with lower weighted concentrations.

The Mercury Deposition Network

The National Atmospheric Deposition Program's Mercury Deposition Network (MDN) was designed to identify geographical and temporal trends in mercury deposition across North America. As of 2002 more than 50 sites were operating in more than 20 states and Canadian provinces. Precipitation levels, total mercury concentration, and mercury wet deposition rate are reported weekly. Volume-weighted mercury concentration is calculated on a quarterly and annual basis.

AMBIENT GASEOUS MERCURY

In recent years, ultra-sensitive techniques have been developed to measure and speciate mercury in ambient air and rainwater, allowing for the determination of temporal and spatial trends in atmospheric mercury. Mercury vapor analyzers are not dependent on precipitation events. They collect and record mercury concentrations 24-hours per day. The vast majority of these readings showed total gaseous mercury levels at or below 2 ng/m^3, which is in the range of concentrations considered "background" for this type of site. However, fluctuations of mercury vapor concentrations, up to twice background values, were periodically seen. Mercury data were matched to concurrent wind direction data to illustrate an association between elevated total gaseous mercury and winds originating from the east-northeast. This evidence suggested a fixed upwind source might be impacting atmospheric mercury levels at Lake Waccamaw State Park.

Atmospheric monitoring for total gaseous mercury was carried out concurrently at the Riegelwood and Lake Waccamaw locations during 1999 and 2000. The study, known as the Waccamaw Atmospheric Mercury Study, also involved chemical speciation of elemental and reactive gaseous mercury during 2000 at one of the Riegelwood sites.

Total Gaseous Mercury Summary

This section presents summation information on total atmospheric mercury levels collected over a three-year period between 1997 and 2000. Findings include:

- Data collected during 1998 at Lake Waccamaw State Park suggested that periodic spikes of total gaseous mercury exceeding 50 ng/m^3 were typical for this area during this time, but atypical for such a remote/rural location.

- On-site meteorology identified a relationship between elevations in total gaseous mercury and winds originating from the east-northeast.

- Beginning in early 1999, levels of atmospheric mercury at Lake Waccamaw state park returned to typical “background” levels (1.5 – 2.0 ng/m^3).

- Reduced atmospheric levels of total gaseous mercury were observed simultaneous with the cessation of chlorine production at a mercury cell chlor-alkali plant located approximately 25 kilometers to the east-northeast of Lake Waccamaw State Park.

- In Riegelwood, NC, measurements of atmospheric mercury included periodic spikes in total gaseous mercury throughout 1999 and 2000.

- Quarterly average total gaseous mercury levels during 1999 and 2000 were up to 166 percent higher at the Riegelwood monitoring locations versus coincident readings from Lake Waccamaw State Park. However, average values appeared to decline in Riegelwood over the course of this study and at one site decreased by roughly 40 percent between 1999 and 2000.

- Total gaseous mercury levels did not exceed 300 ng/m^3 (NC Acceptable Ambient Level and EPA inhalation reference concentration) at the Riegelwood sites for an extended period of time, suggesting that health risks from non-occupational inhalation of mercury were minimal for local citizens during the study period.

- Long-term continuous measurement of atmospheric mercury can be successfully achieved, even at the low levels found in the atmosphere. Data from these types of studies can be used in combination with on-site meteorological data to identify possible source-receptor relationships.

Reactive Gaseous Mercury Findings

Meaningful findings for reactive gaseous mercury include**:**

- Levels of atmospheric reactive gaseous mercury fluctuated significantly in the Riegelwood area throughout the last half of 2000.
- Short-term increases in reactive gaseous mercury frequently occurred in tandem with increases in elemental mercury when the monitoring site was downwind of the chlor-alkali plant and pulp and paper mill, suggesting that mercury emissions included both elemental and reactive gaseous mercury.
- In addition to source-related increases in reactive gaseous mercury, smaller scale increases also frequently occurred during afternoon hours, particularly on low humidity days, suggesting a natural diurnal cycle for reactive gaseous mercury.
- Meteorological conditions such as wind direction, precipitation, humidity and temperature appear to affect ambient air reactive gaseous mercury levels.
- New methods to measure and distinguish reactive gaseous mercury and elemental mercury performed well over extended periods of time; however, some modifications to the instrument assembly may be needed to maintain gold trap integrity over extended sampling periods.

Future DAQ Monitoring Efforts

The MDN sites at Lake Waccamaw and Pettigrew State Park will continue to collect data. If improvements in source emissions and total gaseous mercury at Lake Waccamaw in fact are related to declining mercury levels in regional precipitation, then rainwater data from this site should be comparable to results from Pettigrew State Park in future years. More data, collected over several years is needed to determine whether trends seen over the past three years support evidence for a relationship between regional anthropogenic activities and total gaseous mercury levels, or instead represent normal year-to-year variability in mercury wet deposition.

MONITORING MERCURY IN WATER

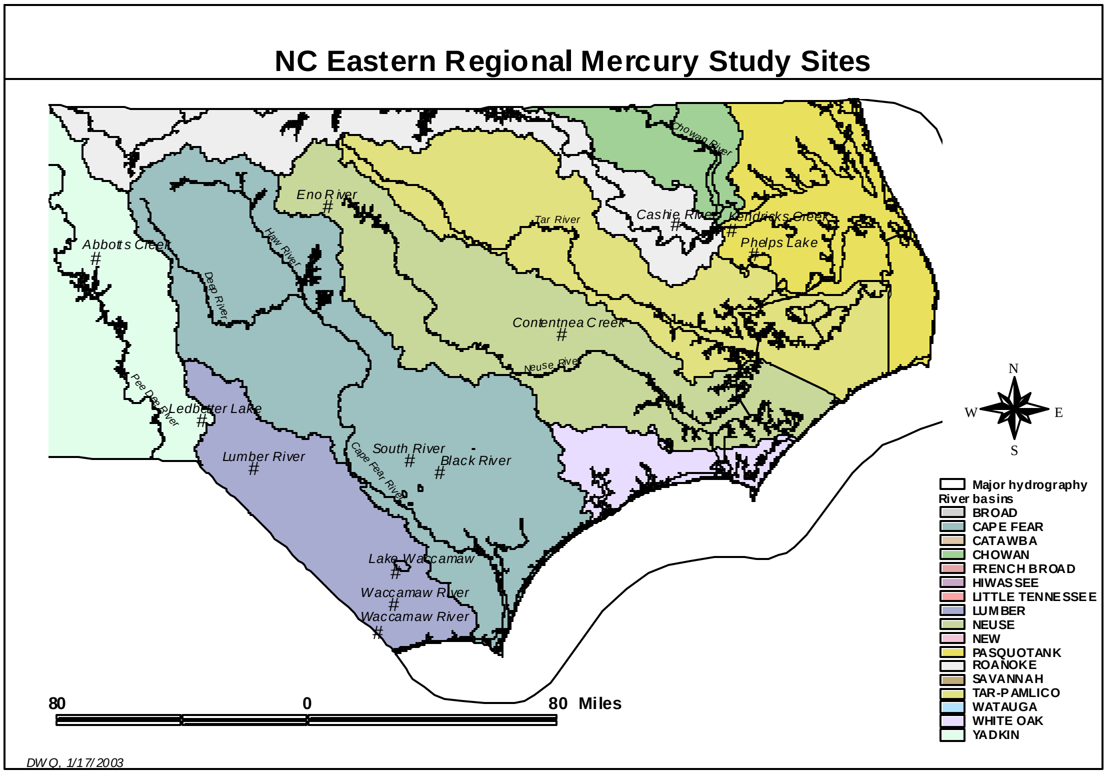
Waters affected by fish advisories by the DHHS are considered to be impaired by the DWQ. Therefore, DWQ is required to perform Total Maximum Daily Load (TMDL) studies. The TMDL is the amount of a given pollutant that a waterbody can assimilate while maintaining its designated uses (the current water quality standard for mercury of 0.12 ug/L). This allowable pollutant load must be allocated to the various point and area sources within the watershed. To establish a TMDL, the current level of contamination must be determined.

The DWQ has identified 4 major goals for this study. They are:

1. To determine levels of ambient mercury in the surface water system.
2. To estimate site-specific total mercury methylmercury translators to evaluate water quality criteria.
3. To develop site-specific water to fish bioaccumulation factors (BAFs).
4. To determine levels of mercury in treatment plant effluent.

Figure 3-4

Location of Water Study Areas



Future DWQ Monitoring Efforts

The DWQ will continue to monitor mercury in fish across North Carolina and has several studies in the works:

- Continue low-level waterborne mercury study in eastern NC.
- Monitor tissue analysis in marine species after removal of known atmospheric source.
- Operate six stations around the defunct Riegelwood chlor-alkali plant (begun in 2001 and will continue as resources allow for the foreseeable future).
- Monitor 12 sites for low-level ambient mercury.
- Determine ambient levels of mercury in surface water.
- Develop site specific BAF's with fish.
- Continue methylmercury analysis of marine species (Spot, Croaker, Speckled Trout, and Bluefish, with more species as resources allow) jointly with the DAQ, DHHS, and DMF.

NC MERCURY EMISSIONS RESULTING FROM PLANNED SO_2 AND NO_X CONTROLS

The two main North Carolina electrical utility companies are mandated to significantly reduce NO_x and SO_2 emissions by the amounts and schedule stated in the North Carolina. *Clean Smokestacks Act* (CSA). Each of the two major utility companies has submitted their plans identifying the boilers getting retrofitted with NO_x and SO_2 control technologies and the corresponding retrofit schedules. In contrast to the definitive CSA provisions and the definitive NO_x and SO_2 technology choices already made by the utilities, the new State law does not contain any specific requirements and technology choices for mercury emission reductions. Instead, mercury emission reductions are expected as side benefits to the specific reductions of NO_x and SO_2 emissions.

Coal-fired utility boilers produce the largest share of mercury emissions. The CSA is estimated to reduce current mercury emissions of 3,052 pounds to 1,363 pounds per year, based on the utilities initial compliance plans for NO_x and SO_2.

STATE-WIDE MERCURY EMISSION SOURCES

In 1998, sources in North Carolina reported a cumulative total mercury emission of 4,626 pounds. The 500 sources represent an estimated 95 percent of statewide mercury emissions. Table 4-1 displays the industrial categories of mercury source as a percent of total mercury emissions in North Carolina. The primary sources of mercury emissions in North Carolina are coal-fired electric utility boilers.

Table 4-1

Cumulative North Carolina Mercury Emissions

Industrial Category	Percent of NC Mercury Emissions
Manufacturing Processes	1
Municipal Waste Combustion	8
Medical/Hazardous Waste Incineration	11
Industrial Boilers	18
Electric Utility	62

Source: 1998-99 DAQ and Local Program Emissions Inventories, 1999 EPA Information Collection Request.

According to the EPA's 1997 *Mercury Study Report to Congress*, coal-fired electric utilities are the largest source of human-caused mercury air emissions in the United States. Nationally, utilities are followed by municipal waste combustors (19 percent), medical waste incinerators (ten percent), and hazardous waste combustors (four plus percent). The largest remaining identified source of mercury emissions are from coal-fired utility boilers.[42] Additionally, the intentional use of mercury in commercial products in the United States declined by more than 75 percent from 1988 to 1996.[43]

Coal-fired Utilities Boilers

In 1999, the U.S. Environmental Protection Agency (EPA) conducted the Electric Utility Steam Generating Unit Mercury Information Collection Effort (EU/ICE) to gather information about mercury emissions from the coal-fired electric utility industry**.** This effort led to the collection of stack test and coal mercury content reports on 80 furnace or boiler units. Information collected during the stack testing included operating control device configurations. Research Triangle Institute used this collected data to build the tool "Electric Power", "*EUCFF*" (Version 3.0.1). The tool was developed in June 2001 for estimating mercury emissions from coal combustion at electrical utilities in the United States.

Electric Power allows permitting authorities and others to evaluate the impact on mercury emissions if certain parameters including type of coal, boiler, or pollution control device are changed.[44] This program, does not account for any additional mercury capture if selective catalytic reduction (SCR) equipment is installed in the flue gas stream. Therefore, if an SCR is installed, the actual mercury emissions may be lower (more captured) than emissions reported in Table 4-2.

Table 4-2 shows three estimated mercury annual emission rates from each coal-fired electric utility boiler: mercury emissions based on mercury content in coal, current mercury emissions (total of 3,052 pounds per year), and the estimated mercury emissions after additional air pollution controls are operational to meet the NO_x and SO_2 emissions pollutant caps of the CSA.

The mercury emission data presented in Chapter 4 are characterized as *preliminary estimates*. This caveat was used because there is a limited database of speciated mercury emission measurements not only nationwide, but also here in NC. The emission data presented in this report was not based on individual measurements made on each NC boiler, but rather on correlations statistically.

Other Point Sources

Chlor-Alkali Plant

The only chlor-alkali plant operating in North Carolina has been shut down for approximately three years. Since the plant discontinued production, area air and water sampling are showing reduced mercury concentrations.

Table 4-2

Mercury Emissions from Coal Fired Electrical Utility Boilers

Comparison of Estimated Mercury Emissions

Before and After the Clean Stacks Act

North Carolina Coal-fired Electrical Utility Facilities			Total Mercury In Coal [a]	Existing Mercury Emissions		Clean Stacks Mercury Emissions	
Plant	**Unit**	**Location**	**lbs/year**	**Percent Reduced**	**lbs/ year**	**Percent Reduced**	**lbs/ year**
Duke Energy							
Allen	1	Belmont	43.42	29.1	30.77	77.7	9.67
Allen	2	Belmont	20.01	29.1	14.18	77.7	4.46
Allen	3	Belmont	79.64	29.1	56.44	77.7	17.74
Allen	4	Belmont	82.42	29.1	58.41	77.7	18.36
Allen	5	Belmont	82.16	29.1	58.22	77.7	18.3
		TOTAL	**307.65**		**218.02**		**68.53**
Belews Creek	1	Walnut Cove	419.95	29.1	297.6	77.9	93.55
Belews Creek	2	Walnut Cove	313.66	29.1	222.28	77.9	69.87
		TOTAL	**733.61**		**519.88**		**163.42**
Buck**	3	Salisbury	5.68	10.7	5.23	0.0	5.23
Buck	4	Salisbury	7.06	10.7	7.06	0.0	7.06
Buck	5	Salisbury	42.54	10.7	38.01	0.0	38.01
Buck	6	Salisbury	43.28	10.7	38.67	0.0	38.67
		TOTAL	**98.56**		**88.97**		**88.97**
Cliffside	1	Cliffside	3.22	10.7	2.88	0.0	2.88
Cliffside	2	Cliffside	3.4	10.7	3.04	0.0	3.04
Cliffside	3	Cliffside	6.52	10.7	5.83	0.0	5.83
Cliffside	4	Cliffside	7.24	10.7	6.47	0.0	6.47
Cliffside	5	Cliffside	120.91	29.1	85.69	77.7	26.93
		TOTAL	**141.29**		**103.91**		**45.15**
Dan River	1	Eden	9.12	10.7	8.15	0.0	8.15
Dan River	2	Eden	9.44	10.7	8.43	0.0	8.43
Dan River	3	Eden	22.38	29.1	15.86	0.0	15.86
		TOTAL	**40.94**		**32.44**		**32.44**
Marshall	1	Terrell	18.65	29.1	84.08	77.7	26.43
Marshall	2	Terrell	131.65	29.1	93.29	77.7	29.33
Marshall	3	Terrell	172.41	29.1	122.18	77.7	38.41

North Carolina Coal-fired Electrical Utility Facilities			**Total Mercury In Coal [a]**	**Existing Mercury Emissions**		**Clean Stacks Mercury Emissions**	
Plant	**Unit**	**Location**	**lbs/year**	**Percent Reduced**	**lbs/ year**	**Percent Reduced**	**lbs/ year**
Marshall	4	Terrell	219.02	29.1	155.21	77.7	48.79
		TOTAL	**541.73**		**454.76**		**142.96**
Riverbend	4	Mount Holly	31.66	10.7	28.29	0.0	28.29
Riverbend	5	Mount Holly	11.04	10.7	9.87	0.0	9.87
Riverbend	6	Mount Holly	11.36	10.7	10.15	0.0	10.15
Riverbend	7	Mount Holly	30.29	10.7	27.07	0.0	27.07
		TOTAL	**84.35**		**75.38**		**75.38**
Progress Energy							
Ashville	1	Arden	91.27	29.1	64.68	77.7	20.33
Ashville	2	Arden	104.52	29.1	74.07	77.7	23.28
		TOTAL	**195.79**		**138.75**		**43.61**
Cape Fear	5	Moncure	53.24	29.1	37.73	77.7	11.86
Cape Fear	6	Moncure	72.51	29.1	51.38	77.7	16.15
		TOTAL	**125.75**		**89.11**		**28.01**
Lee	1	Goldsboro	25.27	29.1	17.91	0.0	17.91
Lee	2	Goldsboro	23.66	10.7	21.14	0.0	21.14
Lee	3	Goldsboro	88.67	29.1	62.84	77.7	62.84
		TOTAL	**137.6**		**101.89**		**101.89**
Mayo	1A	Roxboro	128.31	10.7	114.67	77.7	28.58
Mayo	1B	Roxboro	128.31	10.7	114.64	39.2	78.03
		TOTAL	**256.62**		**229.31**		**106.61**
Roxborro	1	Semora	171.03	29.1	121.2	77.7	38.2
Roxborro	2	Semora	295.73	29.1	209.58	77.7	65.88
Roxborro	3A	Semora	162.62	29.1	115.24	77.7	36.22
Roxborro	3B	Semora	162.62	29.1	115.24	77.7	36.22
Roxborro	4A	Semora	131.9	10.7	117.85	39.2	80.21
Roxborro	4B	Semora	131.9	10.7	117.85	39.2	80.21
		TOTAL	**1055.8**		**796.96**		**336.94**
L V Sutton	1	Wilmington	33.08	10.7	29.55	0.0	29.55
L V Sutton	2	Wilmington	30.98	10.7	27.68	0.0	27.68
L V Sutton	3	Wilmington	152.08	29.1	107.78	77.7	33.88
		TOTAL	**216.14**		**165.01**		**91.11**
Weatherspoon	1	Lumberton	15.07	29.1	10.68	0.0	10.68
Weatherspoon	2	Lumberton	15.29	29.1	10.84	0.0	10.84

North Carolina Coal-fired Electrical Utility Facilities			Total Mercury In Coal [a]	Existing Mercury Emissions		Clean Stacks Mercury Emissions	
Plant	**Unit**	**Location**	**lbs/year**	**Percent Reduced**	**lbs/ year**	**Percent Reduced**	**lbs/ year**
Weatherspoon	3	Lumberton	22.53	29.1	15.97	0.0	15.97
		TOTAL	**52.89**		**37.49**		**37.49**
		State Totals lbs/year	**3,989**		**3,052**		**1,363**

[a] This numerical value represents the mercury in coal that is burned. However, a percentage of the mercury is converted from elemental to oxidized mercury, and a percentage of the oxidized mercury attaches to fly ash and is removed from the exhaust gas by electrostatic precipitators as it captures the fly ash.

Medical And Municipal Waste

The EPA already has taken action to reduce mercury emissions from three significant industrial sources. In 1995, EPA issued final regulations cutting mercury emissions from municipal waste combustors, and in 1998, from medical waste incinerators. The same year, the EPA announced a final rule to reduce mercury emissions from hazardous waste combustion. These actions, once fully implemented, will reduce mercury emissions caused by human activities by over 50 percent of the 1990 levels.[45]

Nucor Steel

A new source in North Carolina that recently started full-scale operations is Nucor Steel in Cofield, North Carolina. This facility is basically a steel making facility that uses primarily scrap steel to recycle into new steel products. Recently, the facility was required to do some stack tests to determine levels of a number of pollutants as a result of their permit. The tests resulted in unexpectedly high levels of mercury being measured. These emissions, along with the refinement and lowering of emissions from several coal-fired utility units has given Nucor Steel the distinction of reporting the most mercury emissions from a single facility in the state for Calendar Year 2001. This came as a surprise to the company and to the DAQ. There is a strong possibility that mercury emissions originate from mercury switches that remained intact during automobile shredding as scrap.

These results have reportedly started a new, industry-wide reevaluation as to why the emissions were so high and whether the data are valid. More work continues on this and the situation will be watched very closely, but for now there is reason to believe these high mercury emission test results and estimates may be valid.

GENERAL BACKGROUND FOR EMISSION CONTROLS

Because the ratio of the two chemical species of mercury emitted from boilers varies from plant to plant, no single control technology removes all mercury. [46] Elemental mercury passes through control equipment. When elemental mercury is changed to inorganic mercury compounds, control equipment can capture the mercury. The ratio of the chemical species of mercury emissions also varies from boiler to boiler due to boiler design, power plant configuration (including controls), and the type and source of the coal burned. These variables affect flue gas chemical and particulate properties, increasing or reducing the percentage of inorganic mercury compounds.

Recent field tests indicate that significant mercury capture is being achieved at coal-fired electric utility boilers through inherent fly ash sorption and collection in existing particulate matter (PM) collectors. These data also show that even more substantial capture occurs for systems using sulfur dioxide (SO_2) scrubbers and post-combustion nitrogen oxide (NO_x) controls. Even greater mercury reductions will be achieved through implementation of advanced controls and strategies for compliance with fine PM, ozone non-attainment, regional haze, and new source review requirements.

The country's first full-scale program to test advanced mercury control technologies was completed in early 2002 by the Department of Energy (DOE) at Unit 3 of Alabama Power's Gaston plant. Testing results demonstrated that mercury can be removed at rates between 80 and 90 percent when activated carbon is injected ahead of the existing bag house ash collection system. Unit 3 is unusual in that it burns low sulfur bituminous coal and controls particulate with an electrostatic precipitator and a baghouse in series.[47]

Generally, the most important conclusions from the assessment of flue gas treatment technologies include:

1. Control devices operating at relatively low temperatures (300 to 400 ° Fahrenheit).
2. The presence of an effective mercury sorbent and a method to collect the sorbent (e.g., high levels of carbon in the fly ash enhance mercury sorption onto particulate matter, which is subsequently removed by the particulate control device).
3. Hydrogen chloride (HCl) presence in the flue gas stream, which can result in the formation of mercury chloride ($HgCl_2$), is readily adsorbed onto carbon-containing particulate matter, or can be efficiently scrubbed.

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4. Conversely, sulfur dioxide (SO_2) in flue gas can act as a reducing agent to convert oxidized mercury into elemental mercury, which is more difficult to capture.[48]

All mercury leaving the furnace (before the preheater and controls) is elemental mercury (Hg^0), and its subsequent oxidation under typical exhaust-flue conditions is kinetically limited, so the abundance of oxidized mercury expected under thermochemical equilibrium does not materialize in the actual exhaust system. However, the predominate oxidized species, mercury chloride ($HgCl_2$), is water-soluble and, therefore, dissolves in scrubber solutions, whereas Hg^0 is insoluble and passes through the scrubber. In total, 102 elementary chemical reactions are included in the homogeneous Hg^0 oxidation mechanism.[49]

Over the last 22 years in the Netherlands, the behavior of mercury in coal-fired power plants has been studied extensively. On average, the fate of mercury entering the power station in the coal was as follows: less than 1 percent in the bottom ash, 49 percent in the pulverized fuel ash (ash collected by the electrostatic precipitator (ESP), 16.6 percent in the wet flue gas desulfurization (FGD) gypsum, 9 percent in the sludge of the wastewater treatment plant, 0.04 percent in the effluent of the wastewater treatment plant, 0.07 percent in the fly dust (leaving the stack), and greater than 24 percent as gaseous mercury in the flue gas and emitted into the air. DENOX® selective catalytic reduction (SCR) favors the formation of oxidized mercury (influencing oxidation of 2 to 12 percent of elemental mercury). Dutch electrostatic precipitators (ESPs) are operated at lower temperatures (lower temperatures encourage mercury oxidation) than in the United State because of lower sulfur concentrations in the Dutch coal. Higher concentrations of coal sulfur creates more sulfur dioxide (SO_2) in flue gas, which can act as a reducing agent to convert oxidized mercury back into elemental mercury. Additionally, higher concentrations of coal sulfur in the United States requires American ESPs to be operated at higher stack exhaust temperatures to prevent the condensation of sulfuric acid (H_2SO_4).[50]

Results show that some commercial SCR catalysts are capable of oxidizing elemental mercury in flue gas.[51] Recent results indicate that up to 60 percent of elemental mercury present in flue gas may be oxidized across an SCR.[52] Mercury oxidation by an SCR catalyst decreases as flue gas temperature increases from 650 to 800 °F. The addition of ammonia to the flue gas immediately upstream of the catalyst tends to decrease mercury oxidation.[53] However, when no absorber is present downstream from

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an SCR, increased levels of oxidized mercury may be emitted from the plant, creating a localized mercury deposition problem.[54]

Demonstrations of activated carbon injection for utility boilers have been conducted in the United States. Based on limited testing, using activated carbon injection to control of mercury for utility boilers varies greatly. The same technology might capture 20 percent of mercury at one plant and 80 percent at another. The addition of activated carbon to utility flue gas for mercury control would significantly increase the amount of particulate matter requiring disposal.[55]

The most important factors affecting mercury control on utility boilers include:[56]

1. flue gas volume,
2. flue gas temperature,
3. chloride content,
4. the mercury concentration, and
5. the mercury chemical form.

CONTROLLING COAL-FIRED UTILITIES MERCURY EMISSIONS

The issue of cost-effective control of mercury emissions from coal-fired utilities is indeed complex and in need of greater understanding. The issue facing the utility industry, its federal and state regulators, and the public is not merely the simple question of what is the single best add-on mercury emission control technology industry wide, but rather a multifaceted set of questions on what are the best candidate technologies for each boiler individually, including:

> How much of each species of mercury is emitted from the existing boiler combustion process?
>
> How much control of each mercury species is achieved by existing air pollution control equipment?
>
> How much control of each mercury species will be achieved by installing new air pollution control equipment for NO_x, and the similar question for SO_2?
>
> Is additional mercury control warranted to protect human health and the environment, and if so, how much further control is needed, what are the

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costs and level of control for each option, and can the cost/benefit of the selected option be justified?

What and when will the new federal standards be set for mercury?

An example of a multi-pollutant emission issue was experienced in the late 1970s / early 1980s when many utilities switched to low sulfur coal in order to reduce SO_2 emissions. What some utilities discovered was that while lowering SO_2 emissions, the low sulfur coal switch inadvertently increased particulate emissions on many cold-side ESPs due to high resistivity hard-to-collect flyash. To restore previous particulate emission levels, utilities had to further invest in enlarging their ESPs, installing flue gas conditioning systems to lower resistivity, reconfiguring their cold-side ESPs-to become hot-side units, or replacing their ESPs with fabric filters.

EXISTING MERCURY CONTROLS AND CONTROL PERFORMANCE

Certain fly ashes have been shown to promote oxidation of elemental gaseous mercury more than others. The difference in oxidation appears to be attributable to fly ash composition and flue gas composition. Trace levels of iron in the fly ash and the surface area of fly ash are also indicated to influence oxidation levels. Given this complexity of mercury speciation and behavior, the science of understanding how to best capture mercury with existing emission control equipment and emerging control technologies is actually in its early stages. The following discussion is an attempt to present engineering material on the details and characteristics of mercury emission control performance, with emphasis given to parameters and conditions specific to NC coal-fired utility boilers.

Table 4-3 presents characteristics of each coal-fired utility boiler and its corresponding emission control equipment currently operating in NC. As shown, NC has approximately 50 coal-fired utility boilers burning eastern bituminous low sulfur (at or below 1 percent sulfur) coal belonging to two utility companies. Duke Power owns and operates 27 boilers and Progress Energy owns and operates 18 boilers for a combined total generating capacity of 13,308 megawatts (MW). Currently there are primarily two types of stand-alone particulate air pollution control systems on the Duke Power and Progress Energy NC utility boilers: Cold-side electrostatic precipitators (ESPs), and Hot-side ESPs. Other smaller industrial and utilities own and operate 4 cogeneration facilities with a total capacity of 465 MW, or 3 percent of the electricity produced in NC (Dwayne Collier Battle in Battleboro, Tobaccoville Plant in Tobaccoville, and Westmoreland-LG&E Partners Roanoke Valley I and II in Weldon). The cogeneration boiler facilities are controlled with spray dryer / fabric filters and a stand-alone fabric filter. The allocation of air pollution control systems in NC is not dissimilar from the national average, where ESPs are installed on 84 percent of the boilers nationwide (with most being stand-alone cold-side ESPs) and spray dryer / fabric filters are installed on just 4 percent of the units.

Table 4-4 is intended to show that the majority of the state's utility generating capacity will have NO_x and SO_2 emission controls installed. Table 4-4 summarizes each utility's generating capacity with controls and their percent of generating capacity with controls for NO_x and SO_2. The percent controlled is the percent of the utility's mega watt generating capacity, not the percent of controlled NO_x and SO_2.

EXISTING CONTROLS AND MERCURY CONTROL PERFORMANCE

Electrostatic Precipitators

Electrostatic Precipitators (ESPs) are very effective particulate emission control devices. While they remove a large percentage (98-99 percent) of fly ash and other particulate from the boiler combustion exhaust gas stream, they are ineffective in removing any gas phase pollutants, such as SO_2, NO_x, or gaseous elemental mercury. ESPs use high voltages on the order of 30,000 volts applied to wires or tubes to electrically charge particles that will cause them to be attracted to ESP collection plates. Periodic rapping removes the particles from the collection plates into hoppers located below where the dust is conveyed and either disposed of in an acceptable manner or recycled into useful products, such as cement or road material.

Typical “cold side ESPs” generally operate in the temperature range of 280 - 320 °F; the term cold side denotes the ESP is installed downstream (on the colder-side) of the air pre-heater. An air pre-heater is a heat exchange device downstream of the boiler furnace where thermal energy is extracted from the flue gas. The air preheater transfers thermal heat from the boiler exhaust gas stream at a temperature near 750 °F to preheat relatively cool combustion (ambient) air entering the boiler firebox. Preheating combustion air saves fuel and makes the boiler more efficient. The acronym for a cold side ESP is ESP-CS. For this study, cold-side ESPs treating bituminous coal-fired boilers remove 29.1 percent of the total mercury emissions entrained in the boiler exhaust gas stream. In comparison to other air pollution controls in use at utility boilers, cold-side ESPs exhibit mediocre efficiencies for mercury removal, as its temperature favor the mercury being in both the ionic and elemental gaseous forms. This allows the ionic mercury fraction to be absorbed onto the particulate for subsequent removal by the cold-side ESP. [EPRI 2000, p. 3-21 & 22] Roughly 60 percent of the state’s utility boilers are controlled with cold-side ESPs.

A "hot side ESP" normally operates in the 700 - 800 °F temperature range; the term hot side denotes the ESP is installed upstream (on the hot-side) from the air pre-heater. Hot-side ESPs were intended to be an alternative solution to cold-side ESPs treating flue gas from boilers burning low sulfur coal producing high resistivity hard-to-collect flyash. The acronym for a hot side ESP is ESP-HS. For this study it is assumed that hot-side ESPs treating bituminous coal-fired boilers remove only 10.7 percent of the total mercury emissions contained in the boiler exhaust. In comparison to other air pollution controls, hot-side ESPs are among the least efficient mercury-removal air pollution control devices in use at utility boilers, as the high temperature favors mercury being in the elemental gaseous mercury, a form uncollectable by ESPs. [EPRI 2000, p. 3-21] Nearly 40 percent of the state’s utility boilers are controlled with hot-side ESPs.

Table 4-3

Boiler and Emission Control System Characteristics and Plans

For NC Coal Fired Electrical Utility Boilers

NC Coal-fired Electrical Utility Facilities			Boiler Rating	Existing Particulate Control	NO_x Control Plan		SO_2 Control Plan	
Plant	**Unit**		**MW**	**Technology**	**Technology**	**Year**	**Technology**	**Year**
Duke Energy								
Allen	1		165	ESP-CS	SNCR / LNB	2003	Wet scrubber	2013
Allen	2		165	ESP-CS	SNCR / LNB	2007	Wet scrubber	2013
Allen	3		275	ESP-CS	SNCR / LNB	2006	Wet scrubber	2009
Allen	4		275	ESP-CS	SNCR / LNB	2005	Wet scrubber	2010
Allen	5		275	ESP-CS	SNCR / LNB	2006	Wet scrubber	2011
		Subtotal	**1155**					
Belews Creek	1		1246	ESP-CS	SCR	2004	Wet scrubber	2008
Belews Creek	2		1246	ESP-CS	SCR / LNB	2004	Wet scrubber	2008
		Subtotal	**2492**					
Buck**	3		40	ESP-HS	SNCR / LNB	2009	None	NA
Buck	4		40	ESP-HS	SNCR / LNB	2008	None	NA
Buck	5		125	ESP-HS	SNCR / LNB	2007	None	NA
Buck	6		125	ESP-HS	SNCR / LNB	2007	None	NA
		Subtotal	**330**					
Cliffside	1		40	ESP-HS	SNCR / LNB	2008	None	NA
Cliffside	2		40	ESP-HS	SNCR / LNB	2008	None	NA
Cliffside	3		65	ESP-HS	SNCR / LNB	2009	None	NA
Cliffside	4		65	ESP-HS	SNCR / LNB	2009	None	NA

NC Coal-fired Electrical Utility Facilities			Boiler Rating	Existing Particulate Control	NO$_x$ Control Plan			SO$_2$ Control Plan	
Plant	**Unit**		**MW**	**Technology**		**Technology**	**Year**	**Technology**	**Year**
Cliffside	5		571	ESP-CS		SCR	2002	Wet scrubber	2009
		Subtotal	**781**						
Dan River	1		70	ESP-HS		SNCR / LNB	2009	None	NA
Dan River	2		70	ESP-HS		SNCR / LNB	2009	None	NA
Dan River	3		326	ESP-CS		SNCR / LNB	2007	None	NA
		Subtotal	**466**						
Marshall	1		350	ESP-CS		SNCR / LNB	2007	Wet scrubber	2007
Marshall	2		350	ESP-CS		SNCR / LNB	2008	Wet scrubber	2007
Marshall	3		648	ESP-CS		SNCR / LNB	2008	Wet scrubber	2006
Marshall	4		648	ESP-CS		SNCR / LNB	2008	Wet scrubber	2006
		Subtotal	**1996**						
Riverbend	4		220	ESP-HS		SNCR / LNB	2007	None	NA
Riverbend	5		220	ESP-HS		SNCR / LNB	2008	None	NA
Riverbend	6		266	ESP-HS		SNCR / LNB	2008	None	NA
Riverbend	7		266	ESP-HS		SNCR / LNB	2007	None	NA
		Subtotal	**972**						
Duke Energy		**TOTAL**	**8,192**						
Progress Energy									
Asheville	1		198	ESP-CS		LNB/AEFLGR/SCR	2012	Wet or dry scrubber	2005
Asheville	2		194	ESP-CS		LNB/OFA/SCR		Wet or dry scrubber	2006
		Subtotal	**392**						
Cape Fear	5		143	ESP-CS		ROFA/ROTAMIX		Wet or dry scrubber	2012
Cape Fear	6		173	ESP-CS		ROFA/ROTAMI		Wet or dry scrubber	2011

NC Coal-fired Electrical Utility Facilities			Boiler Rating	Existing Particulate Control	NO$_x$ Control Plan			SO$_2$ Control Plan	
Plant	**Unit**		**MW**	**Technology**		**Technology**	**Year**	**Technology**	**Year**
						X			
		Subtotal	**316**						
Lee	1		79	ESP-CS		WIR		None	NA
Lee	2		76	ESP-HS		ROFA	2007	None	NA
Lee	3		252	ESP-CS		LNB/OFA/SCR	2010	Wet or dry scrubber	2010
		Subtotal	**407**						
Mayo	1A		375	ESP-HS		LNB/OFA/SCR		Wet or dry scrubber	2007
Mayo	1B		375	ESP-HS		LNB/OFA/SCR		Wet or dry scrubber	2007
		Subtotal	**750**						
Roxboro	1		385	ESP-CS		LNB/OFA/SCR		Wet or dry scrubber	2009
Roxboro	2		670	ESP-CS		TFS2000/SCR		Wet or dry scrubber	2005
Roxboro	3A		354	ESP-CS		LNB/OFA/SCR		Wet or dry scrubber	2007
Roxboro	3B		353	ESP-CS		LNB/OFA/SCR		Wet or dry scrubber	2007
Roxboro	4A		350	ESP-HS		LNB/OFA/SCR		Wet or dry scrubber	2008
Roxboro	4B		350	ESP-HS		LNB/OFA/SCR		Wet or dry scrubber	2008
		Subtotal	**2462**						
L V Sutton	1		97	ESP-HS		SAS			
L V Sutton	2		106	ESP-HS		ROFA	2010	None	NA
L V Sutton	3		410	ESP-CS		LNB/ROFA		Wet or dry scrubber	2013
		Subtotal	**613**						
Weatherspoon	1		49	ESP-CS				None	NA
Weatherspoon	2		49	ESP-CS				None	NA
Weatherspoon	3		78	ESP-CS		WIR		None	NA

NC Coal-fired Electrical Utility Facilities			Boiler Rating	Existing Particulate Control		NO_x Control Plan		SO_2 Control Plan	
Plant	**Unit**		**MW**	**Technology**		**Technology**	**Year**	**Technology**	**Year**
		Subtotal	**176**						
Progress Energy		**TOTAL**	**5,116**						
Cogeneration Facilities									
Dwayne Collier	1, 2, 3, and 4		150 total	FF		SC		Dry scrubber	Existing
Tobaccoville	1 and 2		80 total	FF		LNB		None	NA
Westmoreland	1		183	FF		LNB/OFA		Dry scrubber	Existing
Westmoreland	2		52	FF		LNB/OFA/SNCR		Dry scrubber	Existing
Total Cogeneration		**Subtotal**	**465**						
NC Statewide		**TOTAL**	**13,773**						

Particulate controls acronyms
ESP-CS = Cold side ESP
ESP-HS = Hot side ESP
FF = Fabric filter
SD = Spray dryer (dry scrubber)

NOx controls acronyms
AEFLGR = Amine enhanced flue gas reburn
LNB = Low NOx burners

NOx controls acronyms (continued)
ROFA = Rotating opposed-fired air
Rotamix = Ammonia injection to further reduce NOx (used with ROFA)
SC = Staged combustion
SCR = Selective catalytic reduction
SNCR = Selective non-catalytic reduction
WIR = Underfire air
TFS2000 = Combination Low-NOx burner / Overfire air
SAS = Separated air staging and OFA = Overfire air

Table 4-4

Total Generating Capacity and Percent Capacity with Control of NO_x and SO_2 For NC Coal Fired Electrical Utility Boilers

Utility	NO_x Control	Generating Capacity and Percent Capacity with NO_x Control	SO_2 Control	Generating Capacity and Percent Capacity with SO_2 Control
Duke Energy Statistics	Total MW with SCR, SNCR, or NH3 injection	8192 MW	Total MW with Scrubbers	6,214 MW
	Percent MW with SCR, SNCR, or NH3 injection	100 Percent	Percent MW with Scrubbers	76 Percent
Progress Energy Statistics	Total MW with SCR, SNCR, or NH3 injection	4512 MW	Total MW with Scrubbers	4,582 MW
	Percent MW with SCR, SNCR, or NH3 injection	88 Percent	Percent MW with Scrubbers	90 Percent
Cogeneration Statistics	Total MW with SCR, SNCR, or NH3 injection	52 MW	Total MW with Scrubbers	385 MW
	Percent MW with SCR, SNCR, or NH3 injection	11 Percent	Percent MW with Scrubbers	83 Percent
Statewide Statistics	Total MW with SCR, SNCR, or NH3 injection	12756 MW	Total MW with Scrubbers	11,181 MW
	Percent MW with SCR, SNCR, or NH3 injection	93 Percent	Percent MW with Scrubbers	81 Percent

Fabric filters

Fabric filters have similar collection and operating concepts to household vacuum cleaners, except they are a great deal bigger, use industrial strength bag materials, and have automatic bag cleaning mechanisms to remove collected dust. Fabric filters normally operate in the low 300 °F temperature range and are very efficient in particulate removal, usually at or above 99 percent for well designed and operated units. Like ESPs, as stand-alone devices they are primarily designed for particulate removal and usually ineffective in removing gaseous pollutants. However, when used in combination with sorbent injection systems, fabric filters become effective in removing gaseous pollutants as these pollutants come into close contact with the dust / sorbent collected on the bag surface and absorbed onto the sorbent. The average removal performance by existing fabric filters tested on bituminous coal-fired boilers in the EU/ICR was 90 percent of total mercury emissions. Fabric filters are installed on only 9 percent of utility boilers nationwide, and 16 percent of NC utility boilers. Average mercury capture by spray dryers / fabric filters was 98 percent. Relative to other air pollution controls, spray dryers and fabric filters show excellent mercury removal performance because of the additional gas–particle contact afforded by the filter dust cake along with its low temperature and oxidizing conditions favoring mercury speciation in the oxidized form. (EU/ICR data)

Spray Dryer and Fabric filters

Spray dryers use an alkaline (typically lime) solution that is atomized into small droplets when sprayed into the boiler exhaust gas stream for SO_2 control. They are also referred to as dry scrubbers or dry flue gas desulfurization (FGD) scrubbers. The hot gas stream vaporizes the droplets into small particles that are then collected downstream in a fabric filter. The alkaline droplets / particles absorb SO_2 while being transported in the ducting. Fabric filters offer an advantage because additional SO_2 is collected on the fabric filter bags, making fabric filters the particulate air pollution control method of choice with sprayed or injected sorbents. Spray dryer / fabric filters normally achieve a SO_2 control efficiency of 90+ percent. The average mercury capture by existing spray dryers / fabric filters tested on bituminous coal boilers in the EU/ICR was 98 percent of total mercury emissions. One major spray dryer manufacturer cites as one if its benefits is "inherent oxidized mercury emission reductions." [B&W Dry FGD brochure] Spray dryers are installed on less than 5 percent of utility boilers nationwide and on 6 percent of the NC boilers, with all of the NC units operating on the relatively small co-generation plants. (EU/ICR data)

Fabric filters downstream of spray dryers are designed and operated similar to stand-alone fabric filters. The biggest difference is that the particulate loading is roughly twice as much due to the increase in entrained solids produced from the spray dryer. The average mercury capture by existing spray dryers / fabric filters was 98 percent. Relative to other air pollution controls, spray dryers / fabric filters show excellent mercury removal performance because of the additional gas–particle contact afforded by the filter dust cake along with its low temperature and oxidizing conditions favoring mercury speciation and collection in the oxidized form. (EU/ICR data)

In summary, the EU/ICR data show that existing controls to meet particulate emission standards do capture some of the mercury emissions. However, the controls currently used at most NC power plants are not highly effective in capturing mercury. While fabric filters and spray dryer adsorbers remove 90 percent or more of the mercury released by burning coal in NC, Table 4-1 shows that these two systems only control 3.4 percent of the states generating capacity. The remaining 96+ percent of the states electrical generating capacity is controlled by less effective mercury control technologies: cold-side ESPs with about 30 percent removal and hot-side ESPs with only 10 percent removal. The last column in Table 4-1 provides a mass balance of the mercury released from NC coal-fired utility boilers, showing that roughly:

- four percent is collected by stand-alone hot-side ESPs,
- 17 percent is collected by stand-alone cold-side ESPs,
- 0.5 percent is collected by stand-alone fabric filters,
- three percent is collected by spray dryer / fabric filters,
- a total of 24 percent is collected by all the above control systems, and
- 76 percent is emitted to the atmosphere.

PLANNED SO_2 AND NO_X CONTROLS AND MERCURY CONTROL PERFORMANCE

In response to the Clean Smokestack Act of 2002, the utility companies are required to reduce their NO_x emissions 78 percent by 2009 and their SO_2 emissions 73 percent by 2013. In order to achieve these requirements, Duke Energy and Progress Energy plan to install flue gas desulfurization (FGD) wet and/or dry scrubbers to reduce SO_2 emissions, and combustion controls and post-combustion controls to lower NO_x emissions.

Wet SO_2 Scrubbers

Wet scrubbers are similar to dry scrubbers in that both use an alkaline solution to collect SO_2 and both are located downstream of a particulate air pollution control. However, wet scrubbers saturate the flue gas stream with water, as the complete scrubbing process, including by-products, remains liquid or in a slurry form. They are also referred to as wet FGD scrubbers and normally achieve a SO_2 control efficiency of 90+ percent. In this study it was estimated that wet scrubbers downstream of cold-side ESPs would remove almost 80 percent of total mercury emissions and wet scrubbers downstream of hot-side ESPs would remove nearly 40 percent of total mercury emissions. This decrease in mercury control performance in hot-side ESP is due to the relatively lower amount of mercury oxidized at elevated temperatures. Relative to other air pollution controls, wet scrubbers downstream of cold-ESPs show higher mercury removal performance because the gas temperature favors more oxidized mercury, with the oxidized fraction being more effectively removed in the scrubber. The challenge to improve performance of mercury capture in wet FGD is to find a way to oxidize the elemental mercury vapor before it reaches the scrubber or to modify the liquid phase of the scrubber to cause oxidation to occur. Wet FGD scrubbers are installed on about 15 percent of utility boilers nationwide, most of which are on the larger boilers, as these scrubbers control roughly 25 percent of the US power generating capacity. No wet FGDs are currently installed on any NC boilers. (EU/ICR data)

Consistent with this national profile, both NC utility companies plan to install 23 wet and dry FGD scrubbers on their largest units in response to the CSA requirements of reducing SO_2 emissions by 73 percent by 2013. Duke Energy is preparing to install wet scrubbers on its 12 largest boilers, representing 75 percent of its generating capacity. All of Duke Energy scrubber will be located downstream of cold-side ESPs. Progress Energy plans to install a combination of wet and dry FGD scrubbers on their 11 largest units, as both are proven technologies and provide greater than 90 percent SO_2 removal efficiencies. The Progress Energy scrubbers will control 90 percent of its generating capacity. However, FGDs will be installed on two of Progress Energy's largest units downstream of hot-side ESPs (700 MW or more at Mayo 1 and Roxboro 4); the remaining eleven FGDs will be installed on other large units downstream of cold-side ESPs.

Progress Energy recently contracted with McDermott Technologies / Babcock Wilcox to supply wet and dry FGDs on its NC coal-fired boilers. Two sets of experiments on a 10 MW test facility representative of utility boilers indicated 80+ percent mercury control with a McDermott proprietary reagent added to the FGD scrubber slurry; cost prediction for such a reagent is less than 5 percent of normal FGD cost. Another test on this 10 MW – FGD test facility showed an increase in the oxidized mercury species across a SCR, suggesting that improved mercury control would occur for FGDs and particulate control systems downstream of a SCR. Follow-up tests at full-scale utility boilers are scheduled on enhanced mercury control with FGD and SCR. (Reference: "Wet FGD Enhanced Mercury Control for Coal-Fired boilers" by M.G. Milobowski, B&W, et al with McDermott Technologies.)

Nitrogen Oxides Controls

Cost effective control techniques to reduce nitrogen oxides (NO_x) formation are typically accomplished by combustion and post-combustion control measures. Combustion measures consist of operating and equipment modifications that reduce the peak temperature and excess air in the boiler furnace. These modification / control practices generally consist of improvements known as low NO_x burners, overfire air, underfire air, rotating opposed-fired air, staged combustion, and various forms of gas reburn usually with natural gas. Low NO_x burners can lower NO_x emissions by about 25 – 55 percent. Overfire air can reduce NO_x emissions by about 15 – 50 percent. In combination, reductions up to 60 percent may result. The actual reduction achieved with a given combustion control measure can vary with boiler and fuel characteristics. Almost 60 percent of the US boilers were equipped with some form of combustion modification / controls to reduce NO_x emissions, according to the 1999 EU/ICR database. Combustion controls typically reduce coal-fired boiler NO_x emissions from uncontrolled levels near 0.7 – 0.8 down to 0.2 – 0.3 lb/MMBtu.

In order to achieve further reductions greater than 60 percent and below 0.2 – 0.3 lb/MMBtu (as is the case for NC CSA requirements), post-combustion controls for coal-fired utility boilers are necessary. The two predominant post-combustion control technologies are selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR). With both of these methods, a reducing agent such as ammonia (NH_3) or urea is injected into the duct to reduce NO_x to nitrogen (N_2). While the application of post-combustion NO_x controls is becoming more prevalent, less than four percent of boilers nationwide used either SCR or SNCR systems in 1999.

Selective Catalytic Reduction

The SCR process uses a catalyst with ammonia gas to reduce the nitric oxide (NO) and NO_2 in the flue gas to molecular nitrogen and water. Ammonia gas is diluted with air or steam, and this mixture is injected into the flue gas stream upstream of a metallic catalyst bed composed of vanadium, titanium, platinum, or zeolite. In the reactor, the reduction reactions occur at the catalytic surface. The SCR catalyst bed reactor is usually located between the economizer outlet and the air heater inlet, where temperatures range from 450 – 750 °F. Recent data suggests that SCRs tend to promote additional mercury oxidation, thereby enhancing mercury removal with most existing and emerging particulate / SO_2 control technologies.

Selective Non-Catalytic Reduction

The SNCR process is based on the same basic chemistry as SCR but does not require the use of a catalyst to produce the reactions. Instead, the reducing agent is injected into the flue gas stream at a point where the flue gas temperature is maintained with a specific temperature range. In the two most common SNCR processes, either ammonia or aqueous urea is injected upstream of the economizer where the temperature is in the range of 1600 – 2000 °F. If the flue gas temperature at the injection location gets above this range, the ammonia will oxidize and form more NO_x; if the temperature drops below this range, the effectiveness of the process drops significantly.

In summary, the estimated data in Table 4-3 show that the planned controls to meet the new SO_2 and NO_x emission requirements are expected to also significantly reduce mercury emissions. More than 50 percent of the statewide utility mercury emissions are estimated to be controlled by cold-side ESP / FGD configuration. Each of the remaining five types of emission control configurations is expected to account for nominal reductions individually (less than 5 percent). However, collectively it is expected that at least 63 percent of the potential mercury emissions will be captured by the planned and unchanged existing controls. This means that the coincidental reductions in mercury emissions approach the CSA required reduction levels of 73 percent and 77 percent for SO_2 and NO_x, respectively. This fact demonstrates the rationale and benefits of applying a multi-pollutant contained in the Bush administration proposed Clear Skies Bill and the other bills under consideration by the US Congress. Selection and deployment of new SO_2, NO_x, and fine particulate controls, which also control or contribute to the control of gaseous mercury in coal combustion, may reduce or eliminate the need for mercury-specific controls.

The last column in Table 4-3 depicts a mass balance of the mercury released from NC coal-fired utility boilers, showing that roughly:

- 1.5 percent collected by stand-alone hot-side ESPs,
- 1.2 percent collected by stand-alone cold-side ESPs,
- 0.5 percent collected by stand-alone fabric filters,
- three percent collected by spray dryer / fabric filters,
- 53 percent collected by cold-side ESPs / FGD,
- three percent collected by hot-side ESPs / FGD,
- a sum of 63 percent collected by all the above control systems, and
- 37 percent emitted to the atmosphere.

Figure 4-1 presents statewide data for the existing and planned scenarios, comparing the uncontrolled (released to the atmosphere) mercury emission levels before and after adding FGD scrubbers to the 26 largest boilers statewide. This figure illustrates that the majority of estimated mercury emissions are emitted prior to the installation of FGD scrubbers. The majority of the mercury will be controlled after the installation FGD scrubbers.

Note it is possible that further mercury emission reductions could be realized from the planned SO_2 / NO_x controls than what is presented above. There are two mercury control enhancements suggested by certain testing that have not been considered in the above calculations because of the lack of hard data. These possible enhancements are:

> Additional oxidation of gaseous elemental mercury afforded by SCRs for NO_x controls that could elevate mercury capture in the downstream new SO_2 controls and/or the existing particulate controls; certain data indicate that 90+ percent of the total mercury from bituminous coal-fired boilers is oxidized by SCRs. And

78 percent level currently estimated in this report. Likewise, it is possible that levels above the 40 percent assumption are achievable by wet FGDs following hot-side ESPs.

Additional capture by wet FGD downstream of cold-side ESPs and/or hot-side ESPs; certain data indicate that 90+ percent mercury control is achievable by wet FGD following cold-side ESPs, notably above the 40 percent assumption are achievable by wet FGDs following hot-side ESPs.

POTENTIAL RETROFIT MERCURY CONTROL TECHNOLOGIES

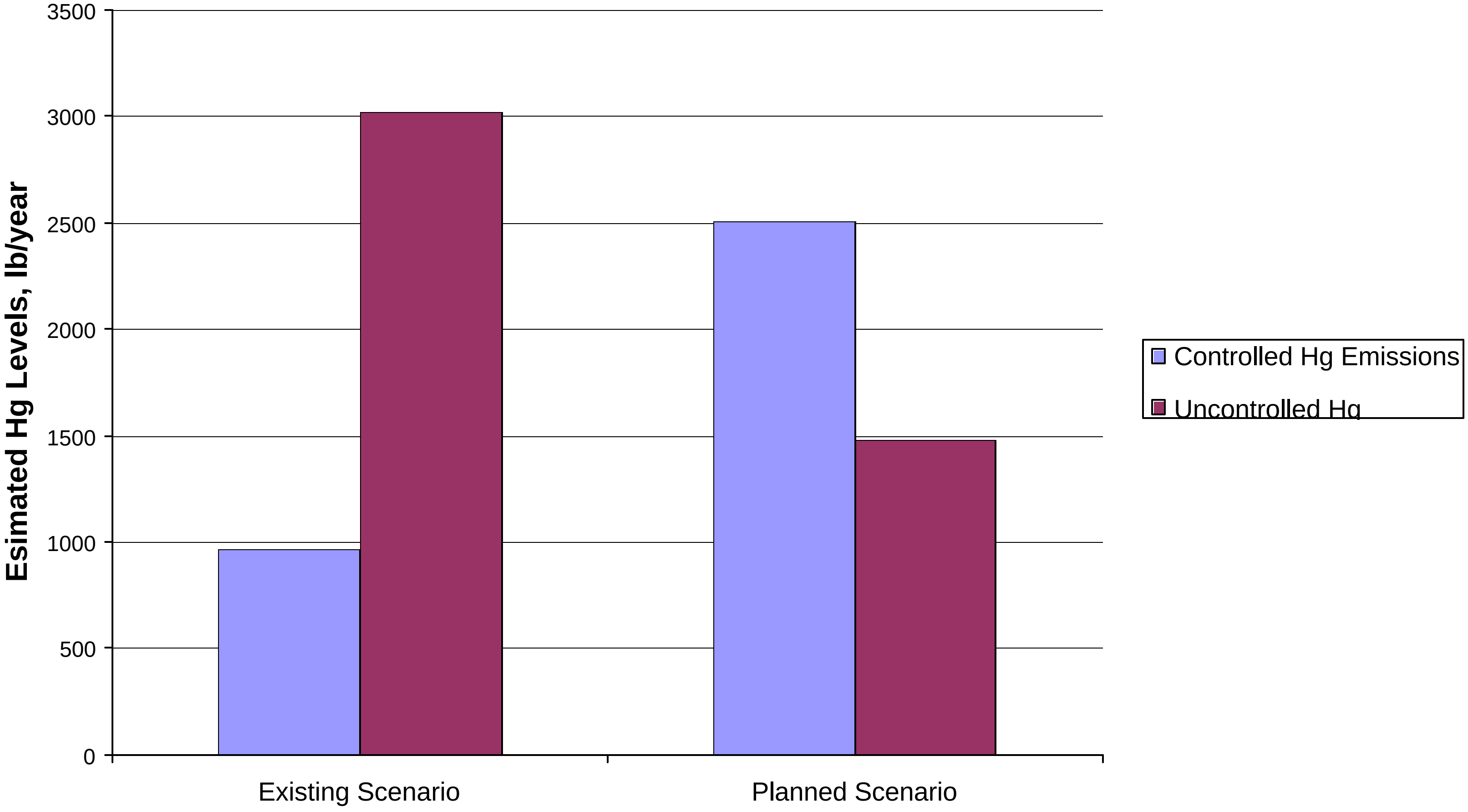
In the event that additional mercury control is found warranted on any NC coal-fired boiler, it is worthwhile to identify and study the performance and cost of potential cost-effective retrofit mercury control technologies. Most retrofit controls are a modification of, or distinct from, the existing and planned controls already discussed in this section.

Reducing Mercury In Coal

A data collection effort by the EPA showed that mercury levels could vary appreciably from one coal type to another, as well as within a particular coal type. Further, mercury levels in coal from the same coal seam at a mine can vary. [57]

Data are available from pilot and lab studies on the mercury concentrations in raw coal and cleaned coal and on the percent reduction of mercury reduction achieved by cleaning. These data, which includes a number of different coal seams in four states (Illinois, Pennsylvania, Kentucky, and Alabama), show that mercury reductions from 0 to 64 percent, with an overall average reduction of 21 percent. Conventional cleaning and column froth floatation (bench-scale) reduced mercury concentrations from raw coal by 40 to over 57 percent, with an average of 55 percent. Conventional cleaning and selective agglomeration (bench-scale) reduced mercury concentrations from the raw coal by 63 percent to 82 percent, with an average of 68 percent. In a second bench-scale study, in which three types of coal were cleaned with a heavy media cyclone (a conventional cleaning methods), followed by a water only cyclone and a floatation system, mercury concentrations in the raw coal were reduced by as much as 63 to 65 percent. The DOE is also carrying out bench-scale testing to investigate the use of naturally occurring microbes to reduce mercury (and other trace elements) from coal. Approximately 77 percent of the eastern and midwestern bituminous coal shipments are cleaned in order to meet customer specifications for heating, ash content, and sulfur content, but not for mercury reduction.[58]

Figure 4-1. Existing vs Planned Hg Control Scenario for NC Coal-Fired Utility Boilers



Parallel to switching to low sulfur coal for SO_2 emission reductions, some may consider it a viable candidate control strategy to switch to a lower mercury coal. While coal type is a dominant factor for FGD and all other secondary mercury controls, changing suppliers of the low sulfur eastern bituminous coal burned in NC utility boilers appears to offer limited benefit. First, bituminous coal affords the best mercury capture fly ash properties relative to the other two common US coal types, sub-bituminous and lignite coals. Second, the NC utility boilers were designed for bituminous coal and, as a result of over 30 years of operating experience, their operation and maintenance has been maximized for bituminous coal. Third, from a near-term perspective, some reduction of the mercury content in certain coals burning at existing utility boilers can be achieved by physical coal cleaning processes. However, there is no easily identifiable coal deposits or coal types that will reliably benefit from cleaning with respect to reducing mercury content. In addition, even with use of widespread coal cleaning for mercury emission control, significant quantities of mercury will remain in the coal after cleaning, and thus require other control technologies be used to achieve additional mercury emission reductions.

Consideration for retrofitting controls to further improve mercury emission reduction would include several site specific factors, including coal properties, age and size of the boilers, condition and type of existing emission control configuration, facility's geographic location, state regulatory requirements, and preferences of the facility owner or operator. Additionally, there are other *caveats* and complicating factors to be considered, including:

> The relative novelty of the various options encompassing mercury specific control technologies and modifications should be measured; the status and progress of each of these 'emerging' technologies or modifications should be monitored carefully; such inexperience should be cautiously addressed.
>
> The identified options may not be technically feasible or economically practical to install and operate at all facilities. Networking among utilities is being practiced to share information on success and failure.

Control discussion is not necessarily in order of applicability, cost-effectiveness, or least-capital requirement.

Cold-Side ESP Retrofit Options

Add Flue Gas Cooling

Lowering the flue gas temperature entering the ESP assists natural fly ash sorption of mercury, improves the performance of any sorbents injected upstream for mercury control, and inherently enhances particulate control performance by reducing gas velocity and lengthening residence time. However, the acid dew point temperature limits the extent of gas cooling when the flue gas has significant formation potential of hydrochloric acid or sulfuric acid.

Add Sorbent Injection

Gaseous mercury can be converted to particle–bound mercury by adsorption onto solid particles in the flue gas. Injecting suitable sorbents into the flue gas upstream of the ESP increases the amount of mercury captured. This modification may also require additional ducting between the injection location and the ESP inlet, and adding a gas absorber / humidifier upstream of the ESP. This approach may be limited to ESPs with a wide compliance margin, as boilers with marginally performing ESPs may have difficulty meeting existing particulate-related emission requirements due to the increased loading and likely high resistivity levels.

Add Downstream Fabric Filter with Sorbent Injection

Installing a fabric filter after the ESP allows most of the native collected fly ash in the ESP without reacted sorbent and enhances overall particulate control for marginally performing ESPs. Furthermore, due to the low particulate loading, the filter dust cake porosity is reduced, allowing use of a smaller, less expensive fabric filter with long cleaning cycles and high sorbent and bag life performance.

COHPAC Option

There is a patented variation of adding a downstream fabric filter (baghouse) to a cold- or hot-side ESP known as COHPAC (Compact Hybrid Particulate Collector) developed by the Electric Power Research Institute. It involves retrofitting a baghouse either in the space of the last field (or section) of an ESP or in a separate housing downstream of an ESP with a precharger located immediately upstream of the baghouse. In either case, the residual or induced charge on the particulate produces a marked effect in lowering the porosity of the filter dust cake. Such an arrangement allows use of a much smaller, less expensive fabric filter with long cleaning cycles and high sorbent and bag life performance. For example, COHPAC units are designed with filtration velocities of 8-12 feet per minute (fpm) as compared to the filtration velocities of 3-5 fpm typically used for pulse-jet fabric filters on coal-fired utility boilers.

Hot-side ESP Retrofit Option.

This entails conversion of a hot-side ESP to a cold-side ESP, and could then include any of the other cold-side ESP retrofit options mentioned above. Several hot-side ESPs in the US, including a few in NC (such as Duke Energy Allen Units 3-5), have been converted to cold-sides to improve particulate collection performance and ESP reliability. Depending on plant layout and design, this may be possible by reconfiguring the ducting, retuning the ESP to operate at lower temperatures, and perhaps installing a SO_3 or NH_3 gas conditioning system to restore performance.

Wet FGD Scrubber Retrofit Options

Previous research has shown that much of the mercury released during coal combustion is either removed with the flyash or can be absorbed in FGD units, if it is in the oxidized form. Oxidation of the gaseous elemental mercury is more readily captured by wet FGDs than gaseous elemental mercury. Several flue gas additives and scrubbing liquid additives are being developed to oxidize more of the gaseous elemental mercury and to prevent any re-conversion of oxidized mercury to gaseous elemental mercury. However, there is the caution that increasing oxidants in the flue gas or in the scrubbing liquid may also oxidize other species such as SO_2 and NO_x to sulfuric acid and nitric acid aerosols. Other options under development include use of oxidizing catalysts upstream of scrubbers, higher scrubber liquid-to-gas ratios, and scrubber tower design changes.

Dry Sorbent Injection.

For boilers with dry air pollution controls without FGD, injection of dry sorbents (such as powdered activated carbon [PAC] or less costly alternatives) offer a candidate control technology. Because of the added contact on the filter dust cake, it is estimated that FFs would require 1/10 of the sorbent rate as ESPs. Full scale tests with a small FF downstream of a hot-side ESP showed 90 percent mercury control with PAC injection. Such performance was achieved with a significant increase in bag cleaning frequency (a reliable surrogate indicator for a decrease in bag life and increase in bag replacement cost) with the suggestion of rather high overall cost for the PAC injection system. Further full scale tests have been performed at a Wisconsin electric utility. [Reference: “Full Scale Evaluation of Mercury Control with Sorbent Injection and COHPAC…”] Other tests have/ are being performed with Darco FGD™ carbon injection upstream of ESPs. Results with low sulfur bituminous coal show total mercury capture vary from 20 – 80 percent depending on ESP operating temperature ranging from 220 – 275 °F.

Sorbent collection performance for mercury is expected to depend on 5 key parameters, including sorbent size, sorbent capacity, residence time, type of dry air pollution control, and mercury level. Predicted costs for PAC using representative values for these parameters range from $4-12 million/year for ESPs and from $4-6 million/year for FFs for a 500 MW boiler. (Since these levels are considered prohibitive by some, many other candidate technologies target cost levels as ¼ to ½ of PAC costs.). Title: “Predicted Cost of Mercury Control at Electric Utilities Using Sorbent Injection”

Calcium-based Sorbent Injection

An alternative to PAC is calcium-based sorbent, such as limestone. EPA laboratory tests indicated that injection of calcium-based sorbents into flue gas could result in significant mercury removal and a small amount of SO_2 and SO_3 removal. Further testing by McDermott Technology, Inc. produced results slightly above 50 percent mercury capture. Comparison of these results with PAC results indicate that while PAC is a more effective sorbent than limestone on a mass basis, limestone is a more effective sorbent than PAC on a cost basis.

In summary, there are several emerging potential retrofit mercury control technologies at various stages of investigation and development. Further efforts to study and validate full-scale performance are underway, but it appears premature to obtain a complete set of definitive cost data for performing a robust cost analysis for many/most of the competing mercury control technologies.

FLUE GAS MEASUREMENT METHOD FOR SPECIATED MERCURY

Accurate measurements of the various forms of mercury present in coal combustion flue gas are important:

- To determine and characterize facility and/or fuel-type emissions,
- to understand the behavior of mercury in combustion processes and equipment configurations, and
- to evaluate the removal efficiency of mercury control technologies.

Generally, EPA develops manual reference test methods as a formal, accurate means of determining source emissions over a few-hour time period providing a “snap-shot” of emissions. Manual methods typically consist of a probe and nozzle inserted into the stack for extracting a representative sample, a filter to collect the particulate, and series of impingers with pollutant-specific liquid solutions to capture gaseous pollutants. In the case of speciated mercury, separate impinger solutions are used to collect the gaseous oxidized mercury fraction and the gaseous elemental mercury.

Formal manual reference methods are well established for measuring total mercury emissions from combustion systems. The EPA Method 101A and Method 29 were developed and validated to measure total mercury emissions (particulate phase and gas phase) for coal and waste combustors. These reference methods were developed and used to support total mercury regulatory needs. A reference method for speciated mercury measurements does not currently exist because there are no regulations requiring speciated mercury emission measurements. However, a valid methodology was needed to characterize coal combustion speciated mercury emissions to better understand the performance variability in emission controls as well as to better assess the risk from this industry's contribution.

The Canadian Ontario-Hydro (OH) utility company developed a manual method known as the OH Method that is the manual test method currently designated as the method of choice by the EPA and the utility industry for the collection of speciated mercury emission data from coal combustion. The EPA first endorsed it in 1999, just prior to the start of their EU/ICR testing program. The OH Method has been submitted to the American Society for Testing and Materials (ASTM) for acceptance as a standard reference method. Since data collected with other methods are not considered valid and the OH Method has only been recently approved, there is limited database on valid, speciated mercury flue gas measurements on coal-fired boilers.

The precision of the OH Method has been recently demonstrated by paired train measurements at a DOE hazardous waste incinerator. In this evaluation consisting of 18 runs, correlation of the paired OH Method train measurements showed acceptable relative standard deviation (RSD) results, including:

- six percent RSD for elemental mercury in range of 0.2-180 ug/dscm,
- 21 percent RSD for oxidized mercury in range of 0.2-15 ug/dscm,
- five percent RSD for total mercury in range of 0.4-200 ug/dscm, and
- in relation to an target 20 percent RSD specification.

Such a high degree of precision across wide ranges in mercury concentration increases the confidence, and tends to rule out significant errors, in OH Method measurements.[59]

Continuous emission monitors (CEMs) are preferred because they have advantages over manual methods. A CEM can produce real-time or near real-time emission data over long periods of time. CEMs produce data that illustrates any short- and long-term emission variability, which in turn provides the opportunity to evaluate and gain insight on the effects of variations in process operating conditions, fuel properties, etc. Ultimately, the use of CEMs leads to a better understanding on how to minimize emissions. Given the benefits, EPA, DOE, and the utility industry are supporting the development of mercury CEMs.

A limited number of CEMs exist and are currently undergoing evaluation for the measurement of *total* gas-phase mercury and, to a lesser extent, *speciated* gas-phase mercury. Recent EPA and DOE sponsored mercury CEMS tests at the Progress Energy Cape Fear Power Plant and at the U.S. DOE TSCA Incinerator showed mixed results.

Out of 5 mercury CEMS at the Cape Fear Plant, only one produced data meeting EPA CEMS data quality standards. However, at the TSCA Incinerator, 3 of 6 mercury CEMS produced data meeting EPA data quality standards. While experts use mercury CEMs as a research tool, mercury CEMs are not currently suitable for routine use on US power plants.

As an mercury CEMS alternative, the Electric Power Research Institute is in the process of developing a semi-continuous method known as the "Quick CEMS." This method collects a low-flow rate continuous sample into an activated carbon tube that can be removed intermittently (e.g., after a day or week) and then analyzed. The sponsor believes that this method would be suitable as a backup system when a mercury CEMS is not working or as the primary compliance method for smaller boilers operating only during peak demand periods.

Note that the mercury emission data presented in this section is characterized as *preliminary estimates*. This caveat was used because there is a limited database of speciated mercury emission measurements not only nationwide, but also here in NC. The emission data presented in this report was not based on individual measurements made on each NC boiler, but rather on correlations statistically derived from the available national database on speciated mercury emissions, largely stemming from the EU/ICR emission data. The known speciated mercury emission measurement database for NC coal-fired utility boilers consists of the following three plants:

Two plants were randomly selected by US EPA for the EU/ICR testing:

a. Duke Energy's Cliffside facility with its hot-side ESPs, and

b. Dwayne Collier Battle Cogeneration Facility with its spray dyer / fabric filter.

2. Progress Energy's Cape Fear facility with its cold-side ESPs hosted a several-month US EPA-sponsored mercury CEMS demonstration in 2002, including several sets of paired OH Method tests to evaluate the accuracy and reliability of five candidate mercury CEMs.

Preliminary estimate of mercury capture by *existing* controls for NC coal-fired utility boilers is shown in Table 4-5. For a comparison, Table 4-6 shows preliminary estimates of mercury capture for *planned* controls for NC coal-fired utility boilers

Table 4-5

Preliminary Estimate of Mercury Capture by Existing Controls For NC Coal-Fired Utility Boilers[60]

Existing Controls	Control Configuration	Percent of NC Utility Boilers	Estimated Total Hg Capture	Percent of NC Utility Hg Emissions
PM Control Only	Hot-side ESP	38.6	10.7[a]	4.1 % captured
	Cold-side ESP	58	29.1 [a]	16.9 % captured
	Fabric filter (FF)	0.6	90 [b]	0.5 % captured
PM and Dry FGD	Spray dryer adsorber and FF	2.8	98[b]	2.7 % captured
Totals		100		24.3 % captured
				75.7% emitted

a. Based on modeling performed by Research Triangle Institute for DAQ using best available data; note that estimates are subject to change.

b. Reference: US EPA, "Control of Mercury Emissions from Coal-Fired Electric Utility Boilers: Interim Report," April 2002, EPA-600/R-01-109, Research Triangle Park, NC,

Table 4-6

Preliminary Estimates of Mercury Capture for Planned Controls For NC Coal-Fired Utility Boilers[61]

Planned Controls	Control Configuration	Percent of NC Generating Capacity (MW basis)	Estimated Total Hg Percent Capture	Estimated Percent of NC Utility Hg Emissions (Percent Captured)
PM Control Only	Hot-side ESP	14.0	27	1.5
	Cold-side ESP	4.2	46-48[a]	1.2
	Fabric filter (FF)	0.6	=90 %[b]	0.5
PM and FGD	Spray dryer adsorber + FF	2.8	>90[b]	2.7
	Cold-side ESP + FGD	67.9	65-70[a]	52.7
	Hot-side ESP + FGD	10.5	65[a]	4.1
Totals		100		**62.8 Captured** **37.2 Emitted**

a. Based on modeling performed by Research Triangle Institute for DAQ using best available data; note that estimates are subject to change.

b. Reference: US EPA, "Control of Mercury Emissions from Coal-Fired Electric Utility Boilers: Interim Report," April 2002, EPA-600/R-01-109, Research Triangle Park, NC,

STATE AND NATIONAL LEGISLATION AND REGULATION

CLEAN AIR ACT REPORT TO CONGRESS

The Act required the EPA to address the toxic air pollutants from utilities. This report indicates that the vast majority of coal-fired plants (424 of the 426 plants) in the United States were likely to pose lifetime cancer risks (i.e., increased probability of an exposed person getting cancer during a lifetime) of less than one in a million due to inhalation exposure to utility hazardous air pollutant (HAP) emissions (which includes mercury). However, when the EPA conducted long-range transport analysis, using the Regional Lagrangian Model of Air Pollution (RELMAP) (a computer simulation of long-range transport of emissions), the results show that a significant percentage of the population exposure exists outside a 50 km radius. The EPA's 1997 Mercury Study Report to Congress suggests that approximately 52 tons of the 158 tons per year (tpy) of U.S. anthropogenic (human activities) emissions are deposited within the lower 48 states. The remaining two-thirds (107 tons) are transported outside of U.S. borders where they diffuse into the global reservoir. Additionally, the computer simulation suggests that another 35 tons of mercury from the global pool are deposited for a total deposition of roughly 87 tpy in the U.S. This type of modeling has a high level of uncertainty, but additional emissions to air will certainly contribute to levels in the global reservoir and increase deposition into water bodies.[62]

Furthermore, this study suggested an increased cancer incidence to be up to 1.3 cases per year. Thus, these efforts indicate that both local and distant sources, through long-range transport, contribute to increases in incidence of cancer. Mercury was included in the local (50 km) study, but was not included with arsenic, cadmium, chromium, and nickel in the RELMAP study.[63]

NORTH CAROLINA STATE REGULATION AND LEGISLATION

NC Clean Smokestacks Act

The CSA requires a 77 percent reduction in NO_x and a 73 percent reduction in SO_2, but does not specify any limits or specific control devices on specific plants. That management and trade off process is left to the utility to determined, based on technologies, costs and other plant specific factors. The plants do have to keep DENR informed and will have to apply for specific permit changes in each case. Both companies in NC that are affected by the requirements have provided lists of general types of devices that they are considering that will provide initial plans regarding which units will

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receive certain control devices. Their planning maybe subject to revisions over time as design, cost and other factors become more specific and final decisions are made.

North Carolina's NO_X State Implementation Plan

On October 27, 1998, the EPA promulgated rules requiring certain states, which included North Carolina, to adopt rules to control the emissions of nitrogen oxides (NO_X) from large stationary combustion sources. These rules cover (1) fossil fuel-fired stationary boilers, combustion turbines, and combined cycle systems serving a generator with a nameplate capacity greater than 25 megawatts electrical and selling any amount of electricity, (2) fossil fuel-fired stationary boilers, combustion turbines, and combined cycle systems having a maximum design heat input greater than 250 million Btu per hour, and (3) reciprocating stationary internal combustion engines rated at equal or greater than 2400 brake horsepower (3000 brake horsepower for diesel engines and 4400 brake horsepower for dual fuel engines).

The EPA promulgated this requirement because it found that controls for NO_X emissions from large combustion sources in North Carolina and other states were not adequate to prohibit these sources and other activities from emitting NO_X in amounts that contribute significantly to nonattainment in one or more other states with respect to the one-hour ozone national ambient air quality standard. It also found controls for NO_X in North Carolina were not adequate to prohibit these sources and other activities from emitting NO_X in amounts that contribute significantly to nonattainment in one or more other states with respect to the eight-hour ozone national ambient air quality standard.

The EPA rules established a NO_X budget for sources in North Carolina and other states. The budgets were later revised and published in the March 2, 2000 Federal Register. North Carolina has a Phase II budget of 165,022 tons per ozone season. The EPA rules require continuous emission monitors to be used and allows compliance to be achieved through interstate trading.

Besides amending existing NO_X rules and adopting new NO_X rules specifically to address the EPA NO_X state implementation plan (SIP) call, the North Carolina rules also require new sources to control emissions of NO_X. The objective of this requirement is (1) to aid in meeting the NO_X budget for North Carolina for minor sources and (2) to aid in attaining and maintaining the ambient air quality standard for ozone in North Carolina.

The amended and new rules are in Section 15A NCAC 2D .1400, Nitrogen Oxide. Rules in this Section cover three types of programs. They are:

1. contingency plan for the three ozone maintenance areas,
2. the NO_X SIP call in 40 CFR Part 51, Subpart G, and
3. new sources of nitrogen oxides not covered under the NO_X SIP call.

The Environmental Management Commission (EMC) approved taking permanent rules to public hearing to satisfy the EPA's NO_X SIP call. After the EPA reviewed the submittal, it recommended several changes to the rules submitted. These recommended changes were incorporated in the rules taken to public hearing. Additionally, as a result of stakeholders meetings, several more changes have been included in the rules. Some important changes are:

1. specific allocations of NO_X for the boilers at the CP&L and Duke plants;
2. requiring all sources covered under the NO_X SIP call to use Part 75 continuous emission monitor systems;
3. changing emission allocations for 2004 from May 1 through September to May 31 through September 30 and reducing the 2004 allowable allocations to 80% of that allowed by the EPA for this period (thus, creating more than 8000 tons credit to be used in 2005);
4. extending full compliance for non-utility electric generating units (EGU), affected non-EGU, and internal combustion engines (ICE) from 2005 to 2006;
5. clarifying that if a source is replaced, the new source receives the old source's allocations;
6. adding criteria for the EMC to consider when deciding whether to reallocate emission allocations;
7. revising the reallocation calculation procedures to give credit to lower emitting sources; and
8. revising the procedures for allocating emission allocation from the new source set aside pool (a pro rata method is used instead of the first-come-first-receive approach in current rule).

FEDERAL LEGISLATION

In addition to the North Carolina's CSA and the NC NO_X SIP, the EPA (CAA) will propose the *Utility MACT*. Additionally, there are at least three federal legislative proposals that could affect coal-fired electric utility plants if one or more are passed. They are on parallel courses and have not been enacted (i.e., discussions, review, and proposed legislative activities continue).

EPA's Utility MACT

The *Utility MACT*, with the proposal of emission standards to be announced on or before December 15, 2003, and promulgation by December 15, 2004. The EPA has announced its finding that regulation of HAP emissions from oil- and coal-fired electric utility steam generating units is necessary and appropriate. This finding is based on the mandate given to EPA by Congress in Section (112)(n)(1)(A) of the CCA, that the EPA perform a study of the hazards to the public health reasonably anticipated to occur as a result of HAP emissions by electric utility steam generating units. The study was performed using data collected from power plants across the country, including those in North Carolina. The results of the study were released in a Report to Congress on February 24, 1998. The EPA was also required to determine whether, based on the results of the study and any other applicable information, regulation of HAP emissions from the industry was appropriate and necessary. On December 14, 2000, the EPA announced that it had found that such regulation is warranted. A project to develop emission regulations under section 112 consequentially is underway.

Since the determination to regulate utility boilers, EPA has conducted a series of public meetings of the Mercury MACT Workgroup, a Federal Advisory Committee under the Clean Air Act Advisory Committee. This workgroup included stakeholders from industry, states and the environmental community. The group evaluate data collected by EPA to determine the best performing plants, the most appropriate monitoring methods, etc. While no consensus was reached among the stakeholders, a variety of options (proposing 73-90 percent control of mercury) were presented to EPA for regulating emissions from utility boilers.

EPA is currently in the process of developing a draft regulation for proposal in December 2003. It is impossible to know at this time what form the standard will take, but the CAA requires that MACT standards "require the maximum degree of reduction in emissions" and shall not be less stringent than the average emission limitation achieved by the best performing 12 percent of existing sources. Once promulgated, sources will have three years to comply with the requirements of the MACT standard. This standard is expected to apply to every major source in the United States with a coal-fired electric utility steam-generating unit, presumable to include units not currently being affected by the CSA.

Bush Administration's Initiative *Clear Skies Act*

A potential legislature impact on control of mercury emissions from coal-fired electric utility plants comes from the proposed *Clear Skies Act* (CSA), which has been drafted by the Bush Administration. This act proposes to amend Title IV of the CAA to establish new "cap-and trade" programs and reducing SO_2, NO_x, and mercury emissions. However, Some analyses indicate net reductions, but the predominant analyses indicate that this proposal would result in reduced control pressures on mercury emissions. The act calls for the specific reductions from electric generating facilities of:

1. SO_2 emissions by 73 percent, from year 2000 emissions of 11 million tons to a cap of 4.5 million tons in 2010 and to a cap of 3 million tons in 2018;

2. NO_X emissions by 67 percent, from year 2000 emissions of 5 million tons to a cap of 2.1 million tons in 2008 and to a cap of 1.7 million tons in 2018; and

3. reduce mercury emissions by 69 percent - the first-ever national cap on mercury emissions. Emissions would be cut from 1999 emissions of 48 tons to a cap of 26 tons in 2010 and to a cap of 15 tons in 2018.

Other Federal Initiatives

Other legislative initiatives have been proposed in both the US House and in the Senate. There has been debate as to whether any legislation would be three pollutants (SO_x, NO_x and Mercury) or four pollutants (add CO_2). All contain provisions for mercury control. The main legislative initiatives to date, in addition to the Clear Skies Act (CSA), are the Jeffords-Waxman Bills and the Carper Clean Air Planning Act (CAPA - **S**3135). Neither of the bills introduced to date has made significant progress toward full consideration by the Senate and House. Debate and behind the scene efforts remain quite active, however. The discussion below is not intended to encompass all actions and discussions underway, but to provide some major points.

Jeffords-Waxman Bills

The Senate Environment and Public Works Committee has held several hearings to date, and in June of 2002 narrowly passed the "Clean Power Act" (S.556, aka "CPA") proposed by Sen. James Jeffords. The House companion, Henry Waxman's "Clean Smokestacks Act" (H.R. 1256), has not been passed in committee or on the House floor. The final CPA, if passed generally as proposed, would establish new controls on power plant emissions of SO_2, NO_x, mercury and CO_2. It would limit, by 2009, national emissions from all electricity generating facilities to not more than 2,250,000 tons of sulfur dioxide, 1,510,000 tons of nitrogen oxides, 2,050,000,000 tons of carbon dioxide, and reduce by 2008, the annual national emissions of mercury from electricity generating facilities to not more than 5 tons. Opponents say that these bills would abandon that common-sense approach and attempt to reduce pollution indirectly, by suppressing energy use.

Carper Bill

The Carper Bill, or CAPA, was introduced by Senator Thomas Carper during the last days of the 107th Congress. Primarily, it appeared because the CSA and CPA were so far apart. The proposal was a bipartisan effort, has not yet received full consideration in neither Committee nor the full Senate.

Legislative impacts could be influenced by information currently in a DOE report titled *Analysis Of Emissions Reduction Options For The Electric Power Industry*, March 1999 (Report#:SR/OIAF/2000-05).[64] This report is a continuation of multiple pollutant

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analysis for the electric power industry and is considered the basis for possible future actions. It proposes that if control of multiple pollutants is planned concurrently, the control cost tends to be less than if separately planning for the individual control of pollutants.

ACTIONS TAKEN BY OTHER STATE

Almost every state has mercury rules of some sort. However, most all of them relate to municipal or medical waste incinerators, battery and fluorescent bulb recycling, limits for disposal or mercury content in products. Many states seem to have taken the "wait and see" attitude for coal fired power plants, knowing that federal actions (whether from MACT or new legislation) are eminent. The potential for inconsistent overlapping requirements or confusion from different approaches is a concern. However, a limited few have taken individual action. This section is not intended to be complete nor to represent the activities in all other states, but as examples of what has happened in some selected states where information is readily available.

Connecticut

The Senate and House of Representatives passed a new law in Connecticut on June 3, 2003 in their General Assembly. This may be the only law specific to mercury from coal-fired power plants, of which the state has only one. This Act is aimed entirely at coal-fired utilities (any unit that generates electricity in the state and combusts coal in an amount greater than ten percent of its total heat input on a rolling twelve-month basis) mercury emissions and contains the main points listed below:

- "Mercury" means mercury and mercury compounds in either a gaseous or particulate form.

- On and after July 1, 2008, the owner or operator of an affected unit or units must meet an emissions rate of equal to or less than 0. 6 pounds of mercury per TBtu, or meet a mercury emissions rate equal to a ninety per cent reduction of mercury from the measured inlet conditions for the affected unit, whichever is more readily achievable.

- Interim alternative limits (with quarterly testing of emissions) are allowed and to be established by the Commissioner of Environmental Protection if the initial technology fails to perform to expectation, no later than April 1, 2010.

- Thereafter, upon any application for renewal of such Title V permit, the Commissioner of Environmental Protection shall conduct a review of such affected unit's alternative emissions limit and may impose a more stringent alternative emissions limit based upon any new data regarding the demonstrated control capabilities of the type of control technology installed and operated at such affected unit.

- Stack tests used to demonstrate compliance with the mercury emissions rate requirements or used in the establishment or compliance with an alternative emissions limit - based on the average of the stack tests conducted during the two most recent calendar quarters for an affected unit and conducted on a calendar quarter basis in accordance with the EPA Method 29 for the determination of metal emissions from stationary sources, as set forth in 40 CFR 60, Appendix A, as amended from time to time, or any other alternative method approved by the EPA or the Commissioner of Environmental Protection. Such stack tests must be conducted while combusting coal or coal blends that are representative of the coal or coal blends combusted at such affected unit during the calendar quarter represented by such stack test. CEMS may be allowed under approved situations.

- On or before July 1, 2012, the Commissioner of Environmental Protection must conduct a review of the mercury emission limits applicable to all affected units in the state and may adopt regulations imposing mercury emission limits that are more stringent the initial requirements established in the beginning.

Title: AN ACT CONCERNING MERCURY EMISSIONS FROM COAL-FIRED ELECTRICITY GENERATORS – passed into law June 3, 2003.[65]

New Hampshire

The New Hampshire legislation is more typical of several states, which may also have other acts or rules within the same state for other components. The law for municipal combustors was passed May 15, 2002. This act set time frames within which certain municipal waste combustors must comply with mercury emission limits, and provides alternate compliance provisions, and extends the reporting date of an ash landfill study to May 30, 2002. The addresses mercury air emissions, but not from coal fired power plants. Title: CHAPTER 172 HB 253-FN - FINAL VERSION 4/10/02 3246s 2002 SESSION 01-035 08/10 HOUSE BILL 253-FN.[66]

Oregon

The Oregon Environmental Council (OEC) has petitioned Oregon to regulate mercury. The petition calls for Oregon DEQ to monitor mercury air emissions and set permit limits for mercury from any facility that discharges more than a pound of mercury in a year. In addition to the petition, OEC is also asking the Commission to take three other specific steps to reduce the discharge of mercury and other persistent pollutants, including:

1) The adoption of specific mercury reduction goals as a matter of state policy,

2) Directing DEQ to use its storm water rules to limit the discharge of mercury and other persistent pollutants, and

3) Eliminating “mixing zones” for persistent pollutants.

Reference: Oregon Environmental Council Petitions State to Regulate Mercury Pollution; *OEC Calls on Environmental Quality Commission to Take “Leadership Role”*[67]

Wisconsin

Wisconsin may be more typical of states that has activity and may pass legislation, but it has not been accomplished, yet. A petition in 2000 was circulated trying to get state to control mercury from utilities. In response, in order to reduce the amount of mercury entering the environment, the WDNR proposed new mercury emission limits on coal-fueled power plants and other large sources in Wisconsin. Following this proposal, the Public Service Commission of Wisconsin (PSCW) began investigating the potential rule impacts on electric reliability, cost and fuel impacts.

Also, the state has an agreement with the utilities known as the “Multi Emission Cooperative Agreement: Commitments”-This agreement was signed on September 30, 2002 for the Wisconsin coal-fueled electric generation fleet. The utilities agreed to meet all legislative provisions of the Environmental Cooperation Pilot Program. The 10 year agreement commits them to invest $400 million to $600 million in environmental improvements to reduce sulfur dioxide, nitrogen oxide and mercury from their power plants by 45-50, 60-65 and 50 percent, respectively.[68]

ECONOMIC IMPACTS

COST OF ADDITIONAL CONTROLS

An approximation of control costs for controlling mercury emissions from utility boilers is reported in *Performance and Costs of Mercury Emission Control Technology Applications On Electrical Utility Boilers*, EPA-600/R-00-083, September 2000. [69] However, costs are base on limited data and the results of pilot projects. Stated assumptions are clear, but they are not yet scientifically documented. Therefore, in light of uncertainty and broad cost ranges, capital and operational control cost discussions will be addressed later.

Recently, the Department of Energy estimated that reducing mercury emissions by 90 percent could add $5 billion to $8 billion a year to the nation's utility bill.[70]

The EPA estimates that the implementation of the new fine particle standard for ambient air quality through regional control strategy that significantly reduces sulfur dioxide (SO_2) below the requirements of Title IV of the federal Clean Air Act can indirectly lower forecasted mercury emissions in 2010 by about 11 tons from power generation by units burning fossil fuel.[71] However, Duke Energy and Progress Energy's planned air pollution control equipment to meet the CSA should reduce North Carolina's mercury emissions by 55 percent instead of the 21 percent estimated by the EPA for the rest of the country.

There are no published studies, specific to North Carolina, which provides information on costs of implementing further mercury controls. However, work is being done at the EPA in regard to the mercury MACT that are due to be released in the near future. Additionally, the air agency in New York has studies underway that promise to provide substantial economic information that may be transferable to North Carolina. This report cannot as yet address this issue. However, efforts to develop such information are being undertaken within DAQ.

HEALTH COSTS

COST ON FISHING

OTHER COSTS AND BENEFITS

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