Risk Evaluation Equations and Calculations

July 2024

NORTH CAROLINA

DEPARTMENTAL QUALITY

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A Human Health Risk Assessment Equations

The following equations calculate screening levels for the defined media, receptor, and pathway at a cancer risk level of 1.0E-06 and hazard quotient = 0.2. The equations were obtained from the United States Environmental Protection Agency's (US EPA) Regional Screening Levels (RSL) website and modified when necessary. The screening levels are used in Tier 1 of the North Carolina Department of Environmental Quality (NC DEQ) risk evaluation process.

A.1 SOIL INGESTION PATHWAY

A.1.a. Non-Residential Worker Soil Ingestion

Noncarcinogenic Non-Residential Worker Soil Ingestion

$$SL_{W\text{-}soil\text{-}nc\text{-}ing}(mg/kg) = \frac{THQ \times AT_W \left(\frac{365\ days}{year} \times ED_W\ (25\ years)\right) \times BW_W\ (80\ kg)}{EF_W \left(250\ \frac{days}{year}\right) \times ED_W\ (25\ years) \times \frac{RBA}{RfD_O \left(\frac{mg}{kg\text{-}day}\right)} \times IR_W \left(100\ \frac{mg}{day}\right) \times \left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

$SL_{W\text{-}soil\text{-}nc\text{-}ing}$ = Screening level for noncarcinogenic non-residential worker soil ingestion
THQ = Target hazard quotient = 0.2
AT = Averaging time = 9,125 days = EPA default
ED = Exposure duration = 25 years = EPA default
BW = Body weight = 80 kilograms = EPA default
EF = Exposure frequency = 250 days/year = EPA default
RBA = Relative Bioavailability Factor = 0.6 for arsenic, all others = 1
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
IR = Ingestion rate = 100 mg/day = EPA Default

Carcinogenic Non-Residential Worker Soil Ingestion

$$SL_{W\text{-}soil\text{-}ca\text{-}ing}(mg/kg) = \frac{TR \times AT_W \left(\frac{365\ days}{year} \times LT\ (70\ years)\right) \times BW_W\ (80\ kg)}{EF_W \left(250\ \frac{days}{year}\right) \times ED_W\ (25\ years) \times CSF_O \left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IR_W \left(100\ \frac{mg}{day}\right) \times \left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

$SL_{W\text{-}soil\text{-}ca\text{-}ing}$ = Screening level for carcinogenic non-residential worker soil ingestion
TR = Target risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
BW = Body weight = 80 kilograms = EPA default
EF = Exposure frequency = 250 days/year = EPA default
RBA = Relative Bioavailability Factor = 0.6 for arsenic, all others = 1
ED = Exposure duration = 25 years = EPA default
CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
IR = Ingestion rate = 100 mg/day = EPA default

A.1.b. Resident Soil Ingestion

Noncarcinogenic Resident Soil Ingestion

Child

$$SL_{res\text{-}soil\text{-}nc\text{-}ing\text{-}c}\,(mg/kg) = \frac{THQ \times AT_{res\text{-}c}\left(\frac{365\ days}{year} \times ED_{res\text{-}c}\,(6\ years)\right) \times BW_{res\text{-}c}\,(15\ kg)}{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\,(6\ years) \times \frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)} \times IRS_{res\text{-}c}\left(\frac{200\ mg}{day}\right) \times \frac{10^{-6}kg}{1mg}}$$

Adult

$$SL_{res\text{-}soil\text{-}nc\text{-}ing\text{-}a}\,(mg/kg) = \frac{THQ \times AT_{res\text{-}a}\left(\frac{365\ days}{year} \times ED_{res}\,(26\ years)\right) \times BW_{res\text{-}a}\,(80\ kg)}{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times ED_{res}\,(26\ years) \times \frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)} \times IRS_{res\text{-}a}\left(\frac{100\ mg}{day}\right) \times \frac{10^{-6}kg}{1mg}}$$

The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA RSLs. The exposure durations cancel out in this equation, so age adjustment is not applicable.

$SL_{res\text{-}soil\text{-}nc\text{-}ing\text{-}c}$ = Screening level for noncarcinogenic residential child soil ingestion
$SL_{res\text{-}soil\text{-}nc\text{-}ing\text{-}a}$ = Screening level for noncarcinogenic residential adult soil ingestion
THQ = Target hazard quotient = 0.2
AT = Averaging time = 2,190 days child and 9,490 days adult = EPA default
ED = Exposure duration = 26 years (6 years child and 20 years adult) = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default
EF = Exposure frequency = 350 days/year = EPA default
RBA = Relative Bioavailability Factor = 0.6 for arsenic, all others = 1
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
IRS = Ingestion rate = 200 mg/day child and 100 mg/day adult = EPA default

Carcinogenic Resident Soil Ingestion

Additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and trichloroethylene. The standard equation is listed below, followed by the alternative equations and a discussion of how the alternative equations differ from the standard equation.

Standard Carcinogenic Equation for Resident Soil Ingestion

$$SL_{res\text{-}soil\text{-}ca\text{-}ing}\,(mg/kg) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IFS_{res\text{-}adj}\left(\frac{36{,}750\ mg}{kg}\right) \times \left(\frac{10^{-6}\,kg}{mg}\right)}$$

where:

$$IFS_{res\text{-}adj}\left(\frac{36{,}750\ mg}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\,(6\ years) \times IRS_{res\text{-}c}\left(\frac{200\ mg}{day}\right)}{BW_{res\text{-}c}\,(15\ kg)} + \frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times \left(ED_{res}\,(26\ years) - ED_{res\text{-}c}\,(6\ years)\right) \times IRS_{res\text{-}a}\left(\frac{100\ mg}{day}\right)}{BW_{res\text{-}a}\,(80\ kg)}\right)$$

$SL_{res\text{-}soil\text{-}ca\text{-}ing}$ = Screening level for carcinogenic resident soil ingestion
TR = Target risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
$IFS_{res\text{-}adj}$ = Age adjusted soil ingestion rate (mg/kg). Calculated via secondary equation.
EF = Exposure frequency = 350 days/year (same for child and adult) = EPA default
RBA = Relative Bioavailability Factor = 0.6 for arsenic, all others = 1
ED = Exposure duration = 6 years child and 20 years adult = EPA default
IRS = Ingestion rate = 200 mg/day child and 100 mg/day adult = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default

Mutagenic Carcinogenic Equation for Resident Soil Ingestion

$$SL_{res\text{-}soil\text{-}mu\text{-}ing}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IFSM_{res\text{-}adj}\left(\frac{166{,}833\ mg}{kg}\right) \times \left(\frac{10^{-6} kg}{mg}\right)}$$

where:

$$IFSM_{res\text{-}adj}\left(\frac{166{,}833\ mg}{kg}\right) = \left(\begin{array}{l} \frac{EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ED_{0\text{-}2}\left(2\ years\right) \times IRS_{0\text{-}2}\left(\frac{200\ mg}{day}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \\ \frac{EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ED_{2\text{-}6}\left(4\ years\right) \times IRS_{2\text{-}6}\left(\frac{200\ mg}{day}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \\ \frac{EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ED_{6\text{-}16}\left(10\ years\right) \times IRS_{6\text{-}16}\left(\frac{100\ mg}{day}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \\ \frac{EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ED_{16\text{-}26}\left(10\ years\right) \times IRS_{16\text{-}26}\left(\frac{100\ mg}{day}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)} \end{array}\right)$$

Some cancer-causing chemicals operate by a mutagenic mode of action which would exhibit a greater effect in early-life exposure. To account for this difference, a separate equation is used to calculate cancer risk posed by mutagens. The mutagenic equation adds an age-dependent adjustment factor (ADAF) to account for increased childhood risk for mutagenic compounds. The adjustment factor is ten for the 0 to 2-year age range, three for the 2 to 6-year age range, three for the 6 to 16-year age range, and one for the 16 to 26-year age range. The remaining portions of the equation are similar to the standard carcinogenic equation.

$SL_{res\text{-}soil\text{-}mu\text{-}ing}$ = Screening level for carcinogenic resident soil ingestion for mutagenic compounds
$IFSM_{res\text{-}adj}$ = Age-adjusted Resident mutagenic soil ingestion rate (mg/kg). Calculated via secondary equation.
Remaining inputs are the same as the standard equation for carcinogenic resident soil ingestion.

Vinyl Chloride Carcinogenic Equation for Resident Soil Ingestion

$$SL_{res\text{-}soil\text{-}ca\text{-}vc\text{-}ing}\left(\frac{mg}{kg}\right) = \frac{TR}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IFS_{res\text{-}adj}\left(\frac{36{,}750\ mg}{kg}\right) \times \frac{10^{-6}\ kg}{1\ mg}}{AT_{res}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}\right) + \left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IRS_{res\text{-}c}\left(\frac{200\ mg}{day}\right) \times \frac{10^{-6}\ kg}{1\ mg}}{BW_{res\text{-}c}(15\ kg)}\right)}$$

where:

$$IFS_{res\text{-}adj}\left(\frac{36{,}750\ mg}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}(6\ years) \times IRS_{res\text{-}c}\left(\frac{200\ mg}{day}\right)}{BW_{res\text{-}c}(15\ kg)} + \frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times \left(ED_{res}(26\ years) - ED_{res\text{-}c}(6\ years)\right) \times IRS_{res\text{-}a}\left(\frac{100\ mg}{day}\right)}{BW_{res\text{-}a}(80\ kg)}\right)$$

Vinyl chloride is a mutagenic compound with sufficient chemical-specific data to directly evaluate carcinogenic exposure through a mutagenic mode of action, in contrast to compounds with insufficient chemical-specific data which are assessed using the default mutagenic equation. Therefore, vinyl chloride has a unique set of equations for residential carcinogenic risk.

$SL_{res\text{-}soil\text{-}ca\text{-}vc\text{-}ing}$ = Screening level for carcinogenic resident soil ingestion for vinyl chloride
Remaining inputs are the same as the standard equation for carcinogenic resident soil ingestion.

Trichloroethylene Carcinogenic Equation for Resident Soil Ingestion

$$SL_{res\text{-}soil\text{-}tce\text{-}ing}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times \left(\frac{10^{-6}\,kg}{mg}\right) \times \left(\left(CAF_o(0.804) \times IFS_{res\text{-}adj}\left(\frac{37{,}650\ mg}{kg}\right)\right) + \left(MAF_o(0.202) \times IFSM_{res\text{-}adj}\left(\frac{166{,}833\ mg}{kg}\right)\right)\right)}$$

where:

$$IFS_{res\text{-}adj}\left(\frac{36{,}750\ mg}{kg}\right) = \left(\frac{ED_{res\text{-}c}(6\ years) \times EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times IRS_{res\text{-}c}\left(\frac{200\ mg}{day}\right)}{BW_{res\text{-}c}(15\ kg)} + \frac{\left(ED_{res}(26\ years) - ED_{res\text{-}c}(6\ years)\right) \times EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times IRS_{res\text{-}a}\left(\frac{100\ mg}{day}\right)}{BW_{res\text{-}a}(80\ kg)}\right)$$

where:

$$IFSM_{res\text{-}adj}\left(\frac{166{,}833\ mg}{kg}\right) = \left(\frac{ED_{0\text{-}2}(2\ years) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times IRS_{0\text{-}2}\left(\frac{200\ mg}{day}\right) \times 10}{BW_{0\text{-}2}(15\ kg)} + \frac{ED_{2\text{-}6}(4\ years) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times IRS_{2\text{-}6}\left(\frac{200\ mg}{day}\right) \times 3}{BW_{2\text{-}6}(15\ kg)} + \frac{ED_{6\text{-}16}(10\ years) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times IRS_{6\text{-}16}\left(\frac{100\ mg}{day}\right) \times 3}{BW_{6\text{-}16}(80\ kg)} + \frac{ED_{16\text{-}26}(10\ years) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times IRS_{16\text{-}26}\left(\frac{100\ mg}{day}\right) \times 1}{BW_{16\text{-}26}(80\ kg)}\right)$$

For trichloroethylene, EPA recommends that kidney risk be assessed using a mutagenic equation and that liver and non-Hodgkin lymphoma (NHL) risk be assessed using the standard cancer equations. EPA has developed adjustment factors that account for the different toxicity factors. The liver and NHL risks are evaluated using the standard cancer equations and a cancer adjustment factor (CAF). The kidney risk is evaluated using the mutagenic cancer equations and a mutagenic adjustment factor (MAF).

$SL_{res\text{-}soil\text{-}tce\text{-}ing}$ = Screening Level for carcinogenic resident soil ingestion for trichloroethylene
$IFSM_{res\text{-}adj}$ = Age-adjusted Resident mutagenic soil ingestion rate (mg/kg). Calculated via secondary equation.
CAF_o = Cancer adjustment factor oral = 0.804 = EPA default
MAF_o = Mutagenic adjustment factor oral = 0.202 = EPA default
Remaining inputs are the same as the standard equation for carcinogenic resident soil ingestion.

A.1.c. Construction Worker Soil Ingestion

Noncarcinogenic Construction Worker Soil Ingestion

$$SL_{cw\text{-}soil\text{-}nc\text{-}ing}\,(mg/kg) = \frac{THQ \times AT_{cw}\left(EW_{cw}\frac{50\ weeks}{year}\times\frac{7\ days}{week}\times ED_{cw}\,(1\ year)\right)\times BW_{cw}\,(80\ kg)}{EF_{cw}\left(EW_{cw}\frac{50\ weeks}{year}\times DW_{cw}\,\frac{5\ days}{week}\right)\times ED_{cw}\,(1\ year)\times\frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)}\times IR_{cw}\left(330\frac{mg}{day}\right)\times\left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

$SL_{cw\text{-}soil\text{-}nc\text{-}ing}$ = Screening level for noncarcinogenic construction worker soil ingestion
THQ = Target hazard quotient = 0.2
AT = Averaging time = 350 days = EPA default
EW = Weeks worked = 50 weeks/year = EPA default
ED = Exposure duration = 1 year = EPA default
BW = Body weight = 80 kilograms = EPA default
EF = EW (weeks worked) of 50 weeks/year x DW (days worked) of 5 days/week = 250 days/year = EPA default
RBA = Relative Bioavailability Factor = 0.6 for arsenic, all others = 1
RfD = Subchronic oral reference dose (mg/kg-day), see chem-tox database
IR = Ingestion rate = 330 mg/day = EPA default

Carcinogenic Construction Worker Soil Ingestion

$$SL_{cw\text{-}soil\text{-}ca\text{-}ing}\,(mg/kg) = \frac{TR \times AT_{cw}\left(\frac{365\ days}{year}\times LT\,(70\ years)\right)\times BW_{cw}\,(80\ kg)}{EF_{cw}\left(EW_{cw}\frac{50\ weeks}{year}\times DW_{cw}\,\frac{5\ days}{week}\right)\times ED_{cw}\,(1\ year)\times CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}\ RBA\times IR_{cw}\left(330\frac{mg}{day}\right)\times\left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

$SL_{cw\text{-}soil\text{-}ca\text{-}ing}$ = Screening level for carcinogenic construction worker soil ingestion
TR = Target risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
BW = Body weight = 80 kilograms = EPA default
EF = EW (weeks worked) of 50 weeks/year x DW (days worked) of 5 days/week = 250 days/year
ED = Exposure duration = 1 year = EPA default
CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
RBA = Relative Bioavailability Factor = 0.6 for arsenic, all others = 1
IR = Ingestion rate = 330 mg/day = EPA default

A.1.d. User Defined (Recreator/Trespasser) Soil Ingestion

Noncarcinogenic Recreator Soil Ingestion

Child

$$SL_{rec\text{-}soil\text{-}nc\text{-}ing\text{-}c}\,(mg/kg) = \frac{THQ \times AT_{rec\text{-}c}\left(\frac{365\ days}{year} \times ED_{rec\text{-}c}\,(years)\right) \times BW_{rec\text{-}c}\,(15\ kg)}{EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ED_{rec\text{-}c}\,(years) \times \frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)} \times IRS_{rec\text{-}c}\left(\frac{200\ mg}{day}\right) \times \frac{10^{-6}kg}{1mg}}$$

Adult

$$SL_{rec\text{-}soil\text{-}nc\text{-}ing\text{-}a}(mg/kg) = \frac{THQ \times AT_{rec\text{-}a}\left(\frac{365\ days}{year} \times ED_{rec\text{-}a}\,(years)\right) \times BW_{rec\text{-}a}\,(80\ kg)}{EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ED_{rec\text{-}a}\,(years) \times \frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)} \times IRS_{rec\text{-}a}\left(\frac{100\ mg}{day}\right) \times \frac{10^{-6}kg}{1mg}}$$

The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA RSLs. The exposure durations cancel out in this equation, so age adjustment is not applicable.

$SL_{rec\text{-}soil\text{-}nc\text{-}ing\text{-}c}$ = Screening level for noncarcinogenic recreator (child) soil ingestion
$SL_{rec\text{-}soil\text{-}nc\text{-}ing\text{-}a}$ = Screening level for noncarcinogenic recreator adult soil ingestion
THQ = Target hazard quotient = 0.2
AT = Averaging time = 2,190 days child and 9,490 days adult = EPA default
ED = Exposure duration = 6 years child and 26 years adult = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default
EF = Exposure frequency = 150 days/year = NC DEQ default
RBA = Relative Bioavailability Factor = 0.6 for arsenic, all others = 1
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
IRS = Ingestion rate = 200 mg/day child and 100 mg/day adult = EPA default

Noncarcinogenic Trespasser Soil Ingestion

Adolescent

$$SL_{tres\text{-}soil\text{-}nc\text{-}ing}\,(mg/kg) = \frac{THQ \times AT_{tres}\left(\frac{365\ days}{year} \times ED_{tres}\ (years)\right) \times BW_{tres}\ (45\ kg)}{EF_{tres}\left(\frac{days}{year}\right) \times ED_{tres}\,(years) \times \frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)} \times IRS_{tres}\left(\frac{200\ mg}{day}\right) \times \frac{10^{-6}\,kg}{1\,mg}}$$

$SL_{tres\text{-}soil\text{-}nc\text{-}ing}$ = Screening level for noncarcinogenic adolescent trespasser soil ingestion
THQ = Target hazard quotient = 0.2
AT = Averaging time = 3,650 days = EPA Region 4 Guidance
ED = Exposure duration = 10 years adolescent = EPA Region 4 Guidance
BW = Body weight = 45 kilograms adolescent = EPA Region 4 Guidance
EF = Exposure frequency = 90 days/year = EPA Region 4 Guidance
RBA = Relative Bioavailability Factor = 0.6 for arsenic, all others = 1
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
IRS = Ingestion rate = 200 mg/day adolescent = NC DEQ default

Carcinogenic Recreator and Trespasser Soil Ingestion

Standard Carcinogenic Equation for Recreator/Trespasser Soil Ingestion

$$SL_{rec\text{-}soil\text{-}ca\text{-}ing}\,(mg/kg) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}\ RBA \times IFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times \left(\frac{10^{-6}\,kg}{mg}\right)}$$

where:

$$IFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\frac{ED_{rec\text{-}c}\,(years) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times IRS_{rec\text{-}c}\left(\frac{200\ mg}{day}\right)}{BW_{rec\text{-}c}\,(15\ kg)} + \frac{ED_{rec\text{-}a}\,(years) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times IRS_{rec\text{-}a}\left(\frac{100\ mg}{day}\right)}{BW_{rec\text{-}a}\,(80\ kg)}\right)$$

Use child and adult inputs for recreator scenario, adolescent inputs only for trespasser scenario
$SL_{rec\text{-}soil\text{-}ca\text{-}ing}$ = Screening level for carcinogenic recreator/trespasser soil ingestion
TR = Target risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
RBA = Relative Bioavailability Factor = 0.6 for arsenic, all others = 1
$IFS_{rec\text{-}adj}$ = Age-adjusted soil ingestion rate (mg/kg). Calculated via secondary equation.
EF = Exposure frequency = 150 days/year for recreators (child and adult) = NC DEQ default
EF = Exposure frequency = 90 days/year for trespassers (adolescent) = EPA Region 4 Guidance
ED = Exposure duration recreator = 6 years child and 20 years adult = EPA default
ED = Exposure duration trespasser = 10 years (adolescent) = EPA Region 4 Guidance IRS =

Ingestion rate = 200 mg/day child and 100 mg/day adult = EPA default
IRS = Ingestion rate = 200 mg/day adolescent = NC DEQ default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default
BW = Body weight = 45 kilograms adolescent trespasser = EPA Region 4 Guidance

Mutagenic Carcinogenic Equation for Recreator/Trespasser Soil Ingestion

$$SL_{rec\text{-}soil\text{-}mu\text{-}ing}\left(mg/kg\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} RBA \times IFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times \left(\frac{10^{-6} kg}{mg}\right)}$$

where:

$$IFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\begin{array}{l} \frac{ED_{0\text{-}2}\left(years\right) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times IRS_{0\text{-}2}\left(\frac{200\ mg}{day}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \\ \frac{ED_{2\text{-}6}\left(years\right) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times IRS_{2\text{-}6}\left(\frac{200\ mg}{day}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \\ \frac{ED_{6\text{-}16}\left(years\right) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times IRS_{6\text{-}16}\left(\frac{100\ mg}{day}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \\ \frac{ED_{16\text{-}26}\left(years\right) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times IRS_{16\text{-}26}\left(\frac{100\ mg}{day}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)} \end{array}\right)$$

Some cancer-causing chemicals operate by a mutagenic mode of action which would exhibit a greater effect in early-life exposure. To account for this difference, a separate equation is used to calculate cancer risk posed by mutagens. The mutagenic equation adds an age-dependent adjustment factor (ADAF) to account for increased childhood risk for mutagenic compounds. The adjustment factor is ten for the 0 to 2-year age range, three for the 2 to 6-year age range, three for the 6 to 16-year age range, and one for the 16 to 26-year age range. The remaining portions of the equation are similar to the standard carcinogenic equation.

$SL_{rec\text{-}soil\text{-}mu\text{-}ing}$ = Screening level for carcinogenic recreator/trespasser soil ingestion for mutagenic compounds
$IFSM_{rec\text{-}adj}$ = Age-adjusted Recreator Mutagenic Soil Ingestion Rate (mg/kg). Calculated via secondary equation.

Remaining inputs are the same as the standard equation for carcinogenic recreator soil ingestion as defined above.

Trespasser inputs only (ED = 10 years, EF = 90 days/year, IRS = 200 mg/day, and BW = 45 kg) are used in the 6 -16 year portion of the IFSM calculation when calculating risks under the trespasser scenario.

Vinyl Chloride Carcinogenic Equation for Recreator/Trespasser Soil Ingestion

$$SL_{rec\text{-}soil\text{-}ca\text{-}vc\text{-}ing}\,(mg/kg) = \frac{TR}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times IFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times \frac{10^{-6}kg}{1\ mg}}{AT_{rec}\left(\frac{365\ days}{year} \times LT\ (70\ years)\right)}\right) + \left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times IRS_{rec\text{-}c}\left(\frac{200\ mg}{day}\right) \times \frac{10^{-6}kg}{1\ mg}}{BW_{rec\text{-}c}\,(15\ kg)}\right)}$$

Vinyl chloride is a mutagenic compound with sufficient chemical-specific data to directly evaluate carcinogenic exposure through a mutagenic mode of action, in contrast to compounds with insufficient chemical-specific data which are assessed using the default mutagenic equation. Therefore, vinyl chloride has a unique set of equations for residential carcinogenic risk.

$SL_{rec\text{-}soil\text{-}ca\text{-}vc\text{-}ing}$ = Screening level for carcinogenic recreator/trespasser soil ingestion for vinyl chloride
Recreator: $IFS_{rec\text{-}adj} = IFSM_{rec\text{-}adj}$ (equation above) for the sum of $ED_{6\text{-}16}$ and $ED_{16\text{-}26}$ = 9,751 mg/kg
Trespasser: $IFS_{rec\text{-}adj} = IFSM_{rec\text{-}adj}$ (equation above) for the $ED_{6\text{-}16}$ = 4,000 mg/kg, child portion = 0
Remaining inputs are the same as the standard equation for carcinogenic recreator/trespasser soil ingestion.

Trichloroethylene Carcinogenic Equation for Recreator/Trespasser Soil Ingestion

$$SL_{rec\text{-}soil\text{-}tce\text{-}ing}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times \left(\frac{10^{-6}\ kg}{mg}\right) \times \left(\left(CAF_o\left(0.804\right) \times IFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right)\right) + \left(MAF_o\left(0.202\right) \times IFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right)\right)\right)}$$

where:

$$IFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\frac{ED_{rec\text{-}c}\left(years\right) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times IRS_{rec\text{-}c}\left(\frac{200\ mg}{day}\right)}{BW_{rec\text{-}c}\left(15\ kg\right)} + \frac{\left(ED_{rec}\left(years\right) - ED_{rec\text{-}c}\left(years\right)\right) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times IRS_{rec\text{-}a}\left(\frac{100\ mg}{day}\right)}{BW_{rec\text{-}a}\left(80\ kg\right)}\right)$$

where:

$$IFSM_{rec\text{-}adj\text{-}}\left(\frac{mg}{kg}\right) = \left(\begin{array}{l} \frac{ED_{0\text{-}2}\left(years\right) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times IRS_{0\text{-}2}\left(\frac{200\ mg}{day}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \\ \frac{ED_{2\text{-}6}\left(years\right) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times IRS_{2\text{-}6}\left(\frac{200\ mg}{day}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \\ \frac{ED_{6\text{-}16}\left(years\right) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times IRS_{6\text{-}16}\left(\frac{100\ mg}{day}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \\ \frac{ED_{16\text{-}26}\left(years\right) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times IRS_{16\text{-}26}\left(\frac{100\ mg}{day}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)} \end{array}\right)$$

For trichloroethylene, EPA recommends that kidney risk be assessed using a mutagenic equation and that liver and non-Hodgkin lymphoma (NHL) risk be assessed using the standard cancer equations. EPA has developed adjustment factors that account for the different toxicity factors. The liver and NHL risks are evaluated using the standard cancer equations and a cancer adjustment factor (CAF). The kidney risk is evaluated using the mutagenic cancer equations and a mutagenic adjustment factor (MAF).

$SL_{rec\text{-}soil\text{-}tce\text{-}ing}$ = Screening Level for carcinogenic recreator/trespasser soil ingestion for trichloroethylene
$IFSM_{rec\text{-}adj}$ = Recreator/trespasser mutagenic soil ingestion rate – age-adjusted = Calculated via secondary equation in mg/kg = EPA default
CAF_o = Cancer adjustment factor oral = 0.804 = EPA default
MAF_o = Mutagenic adjustment factor oral = 0.202 = EPA default
Remaining inputs are the same as the standard equation for carcinogenic recreator/trespasser soil ingestion

A.2. SOIL DERMAL CONTACT PATHWAY

A.2.a. Non-Residential Worker Dermal Contact with Soil

Noncarcinogenic Non-Residential Worker Dermal Contact with Soil

$$SL_{w\text{-}soil\text{-}nc\text{-}der}\,(mg/kg) = \frac{THQ \times AT_w \left(\frac{365\ days}{year} \times ED_w\,(25\ years)\right) \times BW_w\,(80\ kg)}{EF_w\left(250\ \frac{days}{year}\right) \times ED_w\,(25\ years) \times \left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS}\right) \times SA_w\left(\frac{3527\ cm^2}{day}\right) \times AF_w\left(\frac{0.12\ mg}{cm^2}\right) \times ABS_d \times \left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

$SL_{w\text{-}soil\text{-}nc\text{-}der}$ = Screening level for noncarcinogenic non-residential worker soil dermal contact
THQ = Target hazard quotient = 0.2
AT = Averaging time = 9,125 days = EPA default
BW = Body weight = 80 kilograms = EPA default
EF = Exposure frequency = 250 days/year = EPA default
ED = Exposure duration = 25 years = EPA default
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
SA = Worker skin surface area = 3,527 cm^2/day = EPA default
AF = Soil Adherence Factor = 0.12 mg/cm^2 = EPA default
ABS_d = Dermal absorption fraction (unitless). Contaminant specific, see chem-tox database

Carcinogenic Non-Residential Worker Dermal Contact with Soil

$$SL_{w\text{-}soil\text{-}ca\text{-}der}\,(mg/kg) = \frac{TR \times AT_w \left(\frac{365\ days}{year} \times LT\,(70\ years)\right) \times BW_w\ (80\ kg)}{EF_w\ \left(250\ \frac{days}{year}\right) \times ED_w\,(25\ years) \times \left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times SA_w\ \left(\frac{3527\ cm^2}{day}\right) \times AF_w\ \left(\frac{0.12\ mg}{cm^2}\right) \times ABS_d \times \left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

$SL_{ow\text{-}soil\text{-}ca\text{-}der}$ = Screening level for carcinogenic non-residential worker soil dermal contact
TR = Target carcinogenic risk = 1.0E-6
LT = Lifetime = 70 years = EPA default
BW = Body weight = 80 kilograms = EPA default
EF = Exposure frequency = 250 days/year = EPA default
ED = Exposure duration = 25 years = EPA default
CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
SA = Worker skin surface area = 3,527 cm^2/day = EPA default
AF = Soil Adherence Factor = 0.12 mg/cm^2 = EPA default
ABS_d = Dermal absorption fraction (unitless). Contaminant specific, see chem-tox database

A.2.b. Resident Dermal Contact with Soil

Noncarcinogenic Resident Dermal Contact with Soil

Child

$$SL_{res\text{-}soil\text{-}nc\text{-}der\text{-}c}\,(mg/kg) = \frac{THQ \times AT_{res\text{-}c}\left(\frac{365\ days}{year}\right) \times ED_{res\text{-}c}\,(6\ years) \times BW_{res\text{-}c}\,(15\ kg)}{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\,(6\ years) \times \frac{1}{\left(RfD_O\left(\frac{mg}{kg\text{-}day}\right) \times GIABS\right)} \times SA_{res\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{res\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right) \times ABS_d \times \frac{10^{-6}kg}{1mg}}$$

Adult

$$SL_{res\text{-}soil\text{-}nc\text{-}der\text{-}a}\,(mg/kg) = \frac{THQ \times AT_{res\text{-}a}\left(\frac{365\ days}{year}\right) \times ED_{res}\,(26\ years) \times BW_{res\text{-}a}\,(80\ kg)}{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times ED_{res}\,(26\ years) \times \frac{1}{\left(RfD_O\left(\frac{mg}{kg\text{-}day}\right) \times GIABS\right)} \times SA_{res\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{res\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right) \times ABS_d \times \frac{10^{-6}kg}{1mg}}$$

The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA RSLs. The exposure durations cancel out in this equation, so age adjustment is not applicable.

$SL_{res\text{-}soil\text{-}nc\text{-}der\text{-}c}$ = Screening level for noncarcinogenic residential child soil dermal contact
$SL_{res\text{-}soil\text{-}nc\text{-}der\text{-}a}$ = Screening level for noncarcinogenic residential adult soil dermal contact
THQ = Target hazard quotient = 0.2
AT = Averaging time = 2,190 days child and 9,490 days adult = EPA default
ED = Exposure duration = 6 years child and 26 years adult = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default
EF = Exposure frequency = 350 days/year = EPA default
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
SA = Skin surface area = 2,373 cm^2/day child and 6,032 cm^2/day adult = EPA default
AF = Adherence factor = 0.2 mg/cm^2 child and 0.07 mg/cm^2 adult = EPA default
ABS_d = Dermal absorption fraction (unitless). Contaminant specific, see chem-tox database

Carcinogenic Resident Dermal Contact with Soil

Additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and trichloroethylene. The standard equation is listed below, followed by the alternative equations.

Standard Carcinogenic Equation for Resident Dermal Contact with Soil

$$SL_{res\text{-}soil\text{-}ca\text{-}der}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) \times ABS_d \times \left(\frac{10^{-6} kg}{mg}\right)}$$

where:

$$DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\left(6\ years\right) \times SA_{res\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{res\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right)}{BW_{res\text{-}c}\left(15\ kg\right)} + \frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times \left(ED_{res}\left(26\ years\right) - ED_{res\text{-}c}\left(6\ years\right)\right) \times SA_{res\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{res\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right)}{BW_{res\text{-}a}\left(80\ kg\right)}\right)$$

$SL_{res\text{-}soil\text{-}ca\text{-}der}$ = Screening level for carcinogenic residential soil dermal contact
TR = Target carcinogenic risk = 1.0E-6
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
DFS = Age adjusted dermal contact factor (mg/kg). Calculated via secondary equation.
ABS_d = Dermal absorption fraction (unitless). Contaminant specific, see chem-tox database
EF = Exposure frequency = 350 days/year (same for child and adult) = EPA default
ED = Exposure duration = 6 years child and 20 years adult = EPA default
SA = Skin surface area = 2,373 cm^2/day child and 6,032 cm^2/day adult = EPA default
AF = Adherence factor = 0.2 mg/cm^2 child and 0.07 mg/cm^2 adult = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default

Mutagenic Carcinogenic Equation for Resident Dermal Contact with Soil

$$SL_{res\text{-}soil\text{-}mu\text{-}der}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times DFSM_{res\text{-}adj}\left(\frac{428{,}260\ mg}{kg}\right) \times ABS_d \times \left(\frac{10^{-6} kg}{mg}\right)}$$

where:

$$DFSM_{res\text{-}adj}\left(\frac{428{,}260\ mg}{kg}\right) = \left(\begin{array}{l} \frac{EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ED_{0\text{-}2}\left(2\ years\right) \times AF_{0\text{-}2}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{0\text{-}2}\left(\frac{2373\ cm^2}{day}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \\ \frac{EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ED_{2\text{-}6}\left(4\ years\right) \times AF_{2\text{-}6}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{2\text{-}6}\left(\frac{2373\ cm^2}{day}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \\ \frac{EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ED_{6\text{-}16}\left(10\ years\right) \times AF_{6\text{-}16}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{6\text{-}16}\left(\frac{6032\ cm^2}{day}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \\ \frac{EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ED_{16\text{-}26}\left(10\ years\right) \times AF_{16\text{-}26}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{16\text{-}26}\left(\frac{6032\ cm^2}{day}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)} \end{array}\right)$$

$SL_{res\text{-}soil\text{-}mu\text{-}der}$ = Screening level for carcinogenic residential soil dermal contact for mutagenic compounds
$DFSM_{adj}$ = Age-adjusted resident mutagenic soil dermal contact factor (mg/kg). Calculated via secondary equation.
Remaining inputs are the same as the standard equation for carcinogenic resident soil dermal contact.

Vinyl Chloride Carcinogenic Equation for Resident Dermal Contact with Soil

$$SL_{res\text{-}soil\text{-}ca\text{-}vc\text{-}der}\left(\frac{mg}{kg}\right) = \frac{TR}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS} \times DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) \times ABS_d \times \frac{10^{-6}\ kg}{1\ mg}\right) + \left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS} \times SA_{res\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{res\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right) \times ABS \times \frac{10^{-6}\ kg}{1\ mg}\right)}$$

$$AT_{res}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right) \qquad BW_{res\text{-}c}\,(15\ kg)$$

where:

$$DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\,(6\ years) \times SA_{res\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{res\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right)}{BW_{res\text{-}c}\,(15\ kg)} + \frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times \left(ED_{res}\,(26\ years) - ED_{res\text{-}c}\,(6\ years)\right) \times SA_{res\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{res\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right)}{BW_{res\text{-}a}\,(80\ kg)}\right)$$

$SL_{res\text{-}soil\text{-}ca\text{-}vc\text{-}der}$ = Screening level for carcinogenic resident soil dermal contact for vinyl chloride Remaining inputs are the same as the standard equation for carcinogenic resident soil dermal contact.

Trichloroethylene Carcinogenic Equation for Resident Dermal Contact with Soil

$$SL_{res\text{-}soil\text{-}tce\text{-}der}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times \left(\frac{10^{-6}\ kg}{mg}\right) \times \left(\left(CAF_o\,(0.804) \times DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) \times ABS_d\right) + \left(MAF_o\,(0.202) \times DFSM_{res\text{-}adj}\left(\frac{428{,}260\ mg}{kg}\right) \times ABS_d\right)\right)}$$

where:

$$DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) = \left(\frac{ED_{res\text{-}c}\,(6\ years) \times EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times SA_{res\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{res\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right)}{BW_{res\text{-}c}\,(15\ kg)} + \frac{\left(ED_{res}\,(26\ years) - ED_{res\text{-}c}\,(6\ years)\right) \times EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times SA_{res\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{res\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right)}{BW_{res\text{-}a}\,(80\ kg)}\right)$$

where:

$$DFSM_{res\text{-}adj}\left(\frac{428{,}260\ mg}{kg}\right) = \left(\begin{array}{l} \frac{ED_{0\text{-}2}\,(2\ years) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times AF_{0\text{-}2}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{0\text{-}2}\left(\frac{2373\ cm^2}{day}\right) \times 10}{BW_{0\text{-}2}\,(15\ kg)} + \\ \frac{ED_{2\text{-}6}\,(4\ years) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times AF_{2\text{-}6}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{2\text{-}6}\left(\frac{2373\ cm^2}{day}\right) \times 3}{BW_{2\text{-}6}\,(15\ kg)} + \\ \frac{ED_{6\text{-}16}\,(10\ years) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times AF_{6\text{-}16}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{6\text{-}16}\left(\frac{6032\ cm^2}{day}\right) \times 3}{BW_{6\text{-}16}\,(80\ kg)} + \\ \frac{ED_{16\text{-}26}\,(10\ years) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times AF_{16\text{-}26}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{16\text{-}26}\left(\frac{6032\ cm^2}{day}\right) \times 1}{BW_{16\text{-}26}\,(80\ kg)} \end{array}\right)$$

$SL_{res\text{-}soil\text{-}tce\text{-}der}$ = Screening level for carcinogenic resident soil dermal contact for trichloroethylene
$DFSM_{adj}$ = Age-adjusted resident mutagenic soil dermal contact factor (mg/kg). Calculated via secondary equation.
CAF_o = Cancer adjustment factor oral = 0.804 = EPA default
MAF_o = Mutagenic adjustment factor oral = 0.202 = EPA default
Remaining inputs are the same as the standard equation for carcinogenic resident soil ingestion.

A.2.c. Construction Worker Dermal Contact with Soil

Noncarcinogenic Construction Worker Dermal Contact with Soil

$$SL_{cw\text{-}soil\text{-}nc\text{-}der}\,(mg/kg) = \frac{THQ \times AT_{cw\text{-}a}\left(EW_{cw}\,\frac{50\ weeks}{year} \times \frac{7\ days}{week} \times ED_{cw}\,(1\ year)\right) \times BW_{cw}\,(80\ kg)}{EF_{cw}\left(EW_{cw}\,\frac{50\ weeks}{year} \times DW_{cw}\,\frac{5\ days}{week}\right) \times ED_{cw}\,(1\ year) \times \left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS}\right) \times SA_{cw}\left(\frac{3527\ cm^2}{day}\right) \times AF_{cw}\left(\frac{0.3\ mg}{cm^2}\right) \times ABS_d \times \left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

$SL_{cw\text{-}soil\text{-}nc\text{-}der}$ = Screening level for noncarcinogenic construction worker soil dermal contact
THQ = Target hazard quotient = 0.2
AT = Averaging time = 350 days/year = EPA default
EW = Weeks worked = 50 weeks/year = EPA default
ED = Exposure duration = 1 year = EPA default
BW = Body weight = 80 kilograms = EPA default
EF = EW (weeks worked) of 50 weeks/year x DW (days worked) of 5 days/week = 250 days/year = EPA default
RfD = Subchronic oral reference dose (mg/kg-day), see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
SA = Worker skin surface area = 3,527 cm^2/day = EPA default
AF = Soil Adherence Factor = 0.3 mg/cm^2 = EPA default
ABS_d = Dermal absorption fraction (unitless). Contaminant specific, see chem-tox database

Carcinogenic Construction Worker Dermal Contact with Soil

$$SL_{cw\text{-}soil\text{-}ca\text{-}der}\,(mg/kg) = \frac{TR \times AT_{cw}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right) \times BW_{cw}\,(80\ kg)}{EF_{cw}\left(EW_{cw}\,\frac{50\ weeks}{year} \times DW_{cw}\,\frac{5\ days}{week}\right) \times ED_{cw}\,(1\ year) \times \left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times SA_{cw}\left(\frac{3527\ cm^2}{day}\right) \times AF_{cw}\left(\frac{0.3\ mg}{cm^2}\right) \times ABS_d \times \left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

$SL_{cw\text{-}soil\text{-}ca\text{-}der}$ = Screening level for carcinogenic construction worker soil dermal contact
TR = Target risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default

BW = Body weight = 80 kilograms = EPA default
EF = EW (weeks worked) of 50 weeks/year x DW (days worked) of 5 days/week = 250 days/year = EPA default
ED = Exposure duration = 1 year = EPA default
CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
SA = Worker skin surface area = 3,527 cm^2/day = EPA default
AF = Soil Adherence Factor = 0.3 mg/cm^2 = EPA default
ABS_d = Dermal absorption fraction (unitless). Contaminant specific, see chem-tox database

A.2.d. User Defined (Recreator/Trespasser) Dermal Contact with Soil

Noncarcinogenic Recreator Dermal Contact with Soil

Child

$$SL_{rec\text{-}soil\text{-}nc\text{-}der\text{-}c}\,(mg/kg) = \frac{THQ \times AT_{rec\text{-}c}\left(\frac{365\ days}{year}\right) \times ED_{rec\text{-}c}\,(years) \times BW_{rec\text{-}c}\,(15\ kg)}{EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ED_{rec\text{-}c}\,(years) \times \frac{1}{\left(RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS\right)} \times SA_{rec\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{rec\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right) \times ABS_d \times \frac{10^{-6} kg}{1mg}}$$

Adult

$$SL_{rec\text{-}soil\text{-}nc\text{-}der\text{-}a}\,(mg/kg) = \frac{THQ \times AT_{rec\text{-}a}\left(\frac{365\ days}{year}\right) \times ED_{rec\text{-}a}\,(years) \times BW_{rec\text{-}a}\,(80\ kg)}{EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ED_{rec\text{-}a}\,(years) \times \frac{1}{\left(RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS\right)} \times SA_{rec\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{rec\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right) \times ABS_d \times \frac{10^{-6} kg}{1mg}}$$

The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA RSLs. The exposure durations cancel out in this equation, so age adjustment is not applicable.

$SL_{res\text{-}soil\text{-}nc\text{-}der\text{-}c}$ = Screening level for noncarcinogenic recreator child dermal contact with soil
$SL_{res\text{-}soil\text{-}nc\text{-}der\text{-}a}$ = Screening level for noncarcinogenic recreator adult dermal contact with soil
THQ = Target hazard quotient = 0.2
AT = Averaging time = 2,190 days child and 9,490 days adult = EPA default
ED = Exposure duration = 6 years child, 26 years adult = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default
EF = Exposure frequency = 150 days/year = NC DEQ default
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database

GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database

SA = Skin surface area = 2,373 cm^2/day child and 6,032 cm^2/day adult = EPA default
AF = Adherence factor = 0.2 mg/cm^2 child and 0.07 mg/cm^2 adult = EPA default
ABS_d = Dermal absorption fraction (unitless). Contaminant specific, see chem-tox database

Noncarcinogenic Trespasser Dermal Contact with Soil

Adolescent

$$SL_{tres\text{-}soil\text{-}nc\text{-}der}\,(mg/kg) = \frac{THQ \times AT_{tres}\left(\frac{365\ days}{year}\right) \times ED_{tres}\ (10\ year) \times BW_{tres}\ (45\ kg)}{EF_{tres}\left(\frac{90\ days}{year}\right) \times ED_{tres}\,(10\ years) \times \frac{1}{\left(RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS\right)} \times SA_{tres}\left(\frac{6032\ cm^2}{day}\right) \times AF_{tres}\left(\frac{0.2\ mg}{cm^2}\right) \times ABS_d \times \frac{10^{-6} kg}{1 mg}}$$

$SL_{tres\text{-}soil\text{-}nc\text{-}ing}$ = Screening level for noncarcinogenic trespasser adolescent dermal contact with soil
THQ = Target hazard quotient = 0.2
AT = Averaging time = 3,650 days = EPA Region 4 Guidance
ED = Exposure duration = 10 years adolescent = EPA Region 4 Guidance
BW = Body weight = 45 kilograms adolescent = EPA Region 4 Guidance
EF = Exposure frequency = 90 days/year = EPA Region 4 Guidance
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
SA = Skin surface area = 6,032 cm^2/day adolescent = EPA default for adult used for adolescent
AF = Adherence factor = 0.2 mg/cm^2 adolescent = EPA default
ABS_d = Dermal absorption fraction (unitless). Contaminant specific, see chem-tox database

Carcinogenic Recreator Dermal Contact with Soil

Additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and trichloroethylene. The standard equation is listed below, followed by the alternative equations.

Standard Carcinogenic Equation for Recreator/Trespasser Dermal Contact with Soil

$$SL_{rec\text{-}soil\text{-}ca\text{-}der}\left(mg/kg\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times DFS_{rec\text{-}adj}\left(\frac{mg}{Kg}\right) \times ABS_d \times \left(\frac{10^{-6} kg}{mg}\right)}$$

where:

$$DFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\frac{ED_{rec\text{-}c}\left(years\right) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times SA_{rec\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{rec\text{-}c}\left(\frac{0.2 mg}{cm^2}\right)}{BW_{rec\text{-}c}\left(15\ kg\right)} + \frac{ED_{rec\text{-}a}\left(years\right) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times SA_{rec\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{rec\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right)}{BW_{rec\text{-}a}\left(80\ kg\right)}\right)$$

$SL_{res\text{-}soil\text{-}ca\text{-}der}$ = Screening level for carcinogenic recreator/trespasser soil dermal contact
TR = Target carcinogenic risk = 1.0E-6
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
DFS = Age adjusted dermal contact factor (mg/kg). Calculated via secondary equation.
ABS_d = Dermal absorption fraction (unitless). Contaminant specific, see chem-tox database
ED = Exposure duration recreator = 6 years child and 20 years adult = EPA default
ED = Exposure duration trespasser = 10 years adolescent = EPA Region 4 Guidance
EF = Exposure frequency recreator = 150 days/year = NC DEQ default
EF = Exposure frequency trespasser = 90 days/year = NC DEQ default
SA = Skin surface area recreator = 2,373 cm^2/day child and 6,032 cm^2/day adult = EPA default
SA = Skin surface area trespasser = 6,032 cm^2/day adolescent = EPA default for adult used for adolescent
AF = Adherence factor recreator = 0.2 mg/cm^2 child and 0.07 mg/cm^2 adult = EPA default
AF = Adherence factor trespasser = 0.2 mg/cm^2 = EPA default for child used for adolescent
BW = Body weight recreator = 15 kilograms child and 80 kilograms adult = EPA default
BW = Body weight trespasser = 45 kilograms adolescent = EPA Region 4 Guidance

Mutagenic Carcinogenic Equation for Recreator/Trespasser Contact with Soil

$$SL_{rec\text{-}soil\text{-}mu\text{-}der}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times DFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times ABS_d \times \left(\frac{10^{-6}kg}{mg}\right)}$$

where:

$$DFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\begin{array}{l} \frac{ED_{0\text{-}2}\left(years\right) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times AF_{0\text{-}2}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{0\text{-}2}\left(\frac{2373\ cm^2}{day}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \\ \frac{ED_{2\text{-}6}\left(years\right) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times AF_{2\text{-}6}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{2\text{-}6}\left(\frac{2373\ cm^2}{day}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \\ \frac{ED_{6\text{-}16}\left(years\right) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times AF_{6\text{-}16}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{6\text{-}16}\left(\frac{6032\ cm^2}{day}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \\ \frac{ED_{16\text{-}26}\left(years\right) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times AF_{16\text{-}26}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{16\text{-}26}\left(\frac{6032\ cm^2}{day}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)} \end{array}\right)$$

$SL_{res\text{-}soil\text{-}mu\text{-}der}$ = Screening level for carcinogenic recreator/trespasser soil dermal contact for mutagenic compounds
$DFSM_{adj}$ = Age-adjusted recreator/trespasser mutagenic soil dermal contact factor (mg/kg). Calculated via secondary equation in mg/kg
Remaining inputs are the same as the standard equation for carcinogenic recreator/trespasser soil dermal contact.

Vinyl Chloride Carcinogenic Equation for Recreator/Trespasser Dermal Contact with Soil

$$SL_{rec\text{-}soil\text{-}ca\text{-}vc\text{-}der}\left(\frac{mg}{kg}\right) = \frac{TR}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS} \times DFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times ABS_d \times \frac{10^{-6}kg}{1\ mg}}{AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}\right) + \left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS} \times SA_{rec\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{rec\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right) \times ABS \times \frac{10^{-6}kg}{1\ mg}}{BW_{rec\text{-}c}\left(15\ kg\right)}\right)$$

$SL_{res\text{-}soil\text{-}ca\text{-}vc\text{-}der}$ = Screening level for carcinogenic recreator/trespasser soil dermal contact for vinyl chloride
Remaining inputs are the same as the standard equation for carcinogenic recreator/trespasser soil dermal contact.

Trichloroethylene Carcinogenic Equation for Recreator/Trespasser Dermal Contact with Soil

$$SL_{rec\text{-}soil\text{-}tce\text{-}der}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times \left(\frac{10^{-6}\,kg}{mg}\right) \times \left(\left(CAF_o\left(0.804\right) \times DFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times ABS_d\right) + \left(MAF_o\left(0.202\right) \times DFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times ABS_d\right)\right)}$$

where:

$$DFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\frac{ED_{rec\text{-}c}\left(years\right) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times SA_{rec\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{rec\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right)}{BW_{rec\text{-}c}\left(15\ kg\right)} + \frac{\left(ED_{rec}\left(years\right) - ED_{rec\text{-}c}\left(years\right)\right) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times SA_{rec\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{rec\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right)}{BW_{rec\text{-}a}\left(80\ kg\right)}\right)$$

where:

$$DFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\begin{array}{l} \frac{ED_{0\text{-}2}\left(years\right) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times AF_{0\text{-}2}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{0\text{-}2}\left(\frac{2373\ cm^2}{day}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \\ \frac{ED_{2\text{-}6}\left(years\right) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times AF_{2\text{-}6}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{2\text{-}6}\left(\frac{2373\ cm^2}{day}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \\ \frac{ED_{6\text{-}16}\left(years\right) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times AF_{6\text{-}16}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{6\text{-}16}\left(\frac{6032\ cm^2}{day}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \\ \frac{ED_{16\text{-}26}\left(years\right) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times AF_{16\text{-}26}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{16\text{-}26}\left(\frac{6032\ cm^2}{day}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)} \end{array}\right)$$

$SL_{res\text{-}soil\text{-}tce\text{-}der}$ = Screening Level for carcinogenic recreator/trespasser soil dermal contact for trichloroethylene
$DFSM_{rec\text{-}adj}$ = Age-adjusted recreator/trespasser mutagenic soil dermal contact factor (mg/kg). Calculated via secondary equation.
CAF_o = Cancer adjustment factor oral = 0.804 = EPA default
MAF_o = Mutagenic adjustment factor oral = 0.202 = EPA default
Remaining inputs are the same as the standard equation for carcinogenic recreator/trespasser soil dermal.

A.3 OUTDOOR INHALATION OF VOLATILES AND PARTICULATES FROM SOIL

A.3.a. Non-Residential Worker Outdoor Inhalation of Volatiles and Particulates from Soil

Noncarcinogenic Non-Residential Worker Outdoor Inhalation of Volatiles and Particulates from Soil

$$SL_{w\text{-}soil\text{-}nc\text{-}inh}\,(mg/kg) = \frac{THQ \times AT_{ow}\left(\frac{365\ days}{year} \times ED_{ow}\,(25\ years)\right)}{EF_{iw}\left(250\ \frac{days}{year}\right) \times ED_{ow}\,(25\ years) \times ET_{ws}\left(\frac{8\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(\frac{mg}{m^3}\right)} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)}$$

$SL_{w\text{-}soil\text{-}nc\text{-}inh}$ = Screening level for noncarcinogenic non-residential worker soil inhalation
THQ = Target hazard quotient = 0.2
AT = Averaging time = 9,125 days = EPA default
ED = Exposure duration = 25 years = EPA default
EF = Exposure frequency = 250 days/year = EPA default
ET = Exposure time = 8 hours/day = EPA default
RfC = Chronic inhalation reference concentration (mg/m^3), see chem-tox database
VF = Volatilization factor = See supplemental equation in Section A.3.e.
PEF = Particulate emission factor = 5.93E+10 m^3/kg. See supplemental equation in Section A.3.f.

Carcinogenic Non-Residential Worker Outdoor Inhalation of Volatiles and Particulates from Soil

$$SL_{w\text{-}soil\text{-}ca\text{-}inh}\,(mg/kg) = \frac{TR \times AT_{W}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{EF_{W}\left(250\ \frac{days}{year}\right) \times ED_{W}\,(25\ years) \times ET_{W}\left(\frac{8\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1000\ \mu g}{mg}\right) \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_W\left(\frac{m^3}{kg}\right)}\right)}$$

$SL_{w\text{-}soil\text{-}ca\text{-}inh}$ = Screening level for carcinogenic non-residential worker soil inhalation
TR = Target carcinogenic risk = 1.0E-6
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
EF = Exposure frequency = 250 days/year = EPA default
ED = Exposure duration = 25 years = EPA default
ET = Exposure time = 8 hours/day = EPA default
IUR = Chronic inhalation unit risk $(\mu g/m^3)^{-1}$, see chem-tox database
VF = Volatilization factor = See supplemental equation in Section A.3.e.
PEF = Particulate emission factor = 5.93E+10 m^3/kg. See supplemental equation, Section A.3.f.

A.3.b. Resident Outdoor Inhalation of Volatiles and Particulates from Soil

Noncarcinogenic Resident Outdoor Inhalation of Volatiles and Particulates from Soil

Child

$$SL_{res\text{-}soil\text{-}nc\text{-}inh\text{-}c}\left(mg/kg\right)=\frac{THQ\times AT_r\left(\frac{365\ days}{year}\times ED_c\left(6\ years\right)\right)}{EF_r\left(\frac{350\ days}{year}\right)\times ED_c\left(6\ year\right)\times ET_{rs}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times\frac{1}{RfC\left(\frac{mg}{m^3}\right)}\times\left(\frac{1}{VF_s\left(\frac{m^3}{Kg}\right)}+\frac{1}{PEF_w\left(\frac{m^3}{Kg}\right)}\right)}$$

Adult

$$SL_{res\text{-}soil\text{-}nc\text{-}inh\text{-}a}\left(mg/kg\right)=\frac{THQ\times AT_r\left(\frac{365\ days}{year}\times ED_r\left(26\ years\right)\right)}{EF_r\left(\frac{350\ days}{year}\right)\times ED_r\left(26\ year\right)\times ET_{rs}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times\frac{1}{RfC\left(\frac{mg}{m^3}\right)}\times\left(\frac{1}{VF_s\left(\frac{m^3}{Kg}\right)}+\frac{1}{PEF_w\left(\frac{m^3}{Kg}\right)}\right)}$$

Child and adult formulas are the same with exception of ED. The ED values cancel out, so the results are the same regardless of which formula is used.

$SL_{res\text{-}soil\text{-}nc\text{-}inh\text{-}c}$ = Screening level for noncarcinogenic residential child soil inhalation
$SL_{res\text{-}soil\text{-}nc\text{-}inh\text{-}a}$ = Screening level for noncarcinogenic residential adult soil inhalation
THQ = Target hazard quotient = 0.2
AT = Averaging time = 2,190 days child and 9,490 days adult = EPA default
ED = Exposure duration = 26 years (6 years child and 20 years adult) = EPA default
EF = Exposure frequency = 350 days/year = EPA default
ET = Exposure time = 24 hours/day = EPA default
RfC = Chronic inhalation reference concentration (mg/m^3), see chem-tox database
VF = Volatilization factor = See supplemental equation in Section A.3.e.
PEF = Particulate emission factor = 5.93E+10 m^3/kg. See supplemental equation, Section A.3.f.

Carcinogenic Resident Outdoor Inhalation of Volatiles and Particulates from Soil

Additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and trichloroethylene. The standard equation is listed below, followed by the alternative equations.

Standard Carcinogenic Equation for Resident Outdoor Inhalation of Volatiles and Particulates from Soil

$$SL_{res\text{-}soil\text{-}ca\text{-}inh}\left(mg/kg\right)=\frac{TR\times AT_r\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1}\times\left(\frac{1000\ \mu g}{mg}\right)\times EF_r\left(\frac{350\ days}{year}\right)\times\left(\frac{1}{VF_s\left(\frac{m^3}{Kg}\right)}+\frac{1}{PEF_w\left(\frac{m^3}{Kg}\right)}\right)\times ED_r\left(26\ years\right)\times ET_{rs}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)}$$

$SL_{res\text{-}soil\text{-}ca\text{-}inh}$ = Screening level for carcinogenic resident soil inhalation
TR = Target carcinogenic risk = 1.0E-6
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
IUR = Chronic inhalation unit risk $(\mu g/m^3)^{-1}$, see chem-tox database
EF = Exposure frequency = 350 days/year = EPA default
VF = Volatilization factor = See supplemental equation in Section A.3.e.
PEF = Particulate emission factor = 5.93E+10 m^3/kg. See supplemental equation, Section A.3.f.
ED = Exposure duration = 26 years = EPA default
ET = Exposure time = 24 hours/day = EPA default

Mutagenic Carcinogenic Equation for Resident Outdoor Inhalation of Volatiles and Particulates from Soil

$$SL_{res\text{-}soil\text{-}mu\text{-}inh}\left(mg/kg\right)=\frac{TR\times AT_{res}\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1}\times\left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)}+\frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)\times\left(\frac{1000\ \mu g}{mg}\right)\times\left(\begin{array}{l}\left(ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right)\times ED_{0\text{-}2}\left(2\ years\right)\times 10\right)+\\ \left(ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right)\times ED_{2\text{-}6}\left(4\ years\right)\times 3\right)+\\ \left(ET_{6\text{-}16}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right)\times ED_{6\text{-}16}\left(10\ years\right)\times 3\right)+\\ \left(ET_{16\text{-}26}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right)\times ED_{16\text{-}26}\left(10\ years\right)\times 1\right)\end{array}\right)}$$

$SL_{res\text{-}soil\text{-}mu\text{-}inh}$ = Screening level for carcinogenic resident soil inhalation for mutagenic compounds.
Remaining inputs are the same as the standard equation for carcinogenic resident soil inhalation.

Vinyl Chloride Carcinogenic Equation for Resident Outdoor Inhalation of Volatiles and Particulates from Soil

$$SL_{res\text{-}soil\text{-}ca\text{-}vc\text{-}inh}\left(mg/kg\right)=\frac{TR}{\left(\frac{IUR\left(\frac{\mu g}{m^3}\right)^{-1}\times EF_r\left(\frac{350\ days}{year}\right)\times ED\left(26\ years\right)\times ET_{rs}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{AT_r\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)\times VF_s\left(\frac{m^3}{kg}\right)}\right)+\left(\frac{IUR\left(\frac{\mu g}{m^3}\right)^{-1}}{VF_s\left(\frac{m^3}{kg}\right)}\times\left(\frac{1000\ \mu g}{mg}\right)\right)}$$

$SL_{res\text{-}soil\text{-}ca\text{-}vc\text{-}inh}$ = Screening level for carcinogenic resident soil inhalation for vinyl chloride.
Remaining inputs are the same as the standard equation for carcinogenic resident soil inhalation.

Trichloroethylene Carcinogenic Equation for Resident Outdoor Inhalation of Volatiles and Particulates from Soil

$$SL_{res\text{-}soil\text{-}tce\text{-}inh}\left(mg/kg\right)=\frac{TR\times AT_{res}\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1}\times\left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)}+\frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)\times\left(\frac{1000\ \mu g}{mg}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times\left(\begin{array}{l}\left(CAF_i\left(0.756\right)\times EF_{res}\left(\frac{350\ days}{year}\right)\times\right.\\\left.ED_{res}\left(26\ years\right)\times ET_{res}\left(\frac{24\ hours}{day}\right)\right)+\end{array}\left(\begin{array}{l}\left(ED_{0\text{-}2}\left(2\ years\right)\times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right)\times ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right)\times MAF_i\left(0.244\right)\times 10\right)+\\\left(ED_{2\text{-}6}\left(4\ years\right)\times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right)\times ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right)\times MAF_i\left(0.244\right)\times 3\right)+\\\left(ED_{6\text{-}16}\left(10\ years\right)\times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right)\times ET_{6\text{-}16}\left(\frac{24\ hours}{day}\right)\times MAF_i\left(0.244\right)\times 3\right)+\\\left(ED_{16\text{-}26}\left(10\ years\right)\times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right)\times ET_{16\text{-}26}\left(\frac{24\ hours}{day}\right)\times MAF_i\left(0.244\right)\times 1\right)\end{array}\right)$$

$SL_{res\text{-}soil\text{-}tce\text{-}inh}$ = Screening Level for carcinogenic resident soil inhalation for trichloroethylene
CAF_i = Cancer adjustment factor inhalation = 0.756 = EPA default
MAF_i = Mutagenic adjustment factor oral = 0.244 = EPA default
Remaining inputs are the same as the standard equation for carcinogenic resident soil inhalation.

A.3.c. Construction Worker Outdoor Inhalation of Volatiles and Particulates from Soil

Noncarcinogenic Construction Worker Outdoor Inhalation of Volatiles and Particulates from Soil

$$SL_{cw\text{-}soil\text{-}nc\text{-}inh}\,(mg/kg) = \frac{THQ \times AT_{cw}\left(EW_{cw}\frac{50\ weeks}{year} \times \frac{7\ days}{week} \times ED_{cw}\,(1\ year)\right)}{EF_{cw}\left(EW_{cw}\frac{50\ weeks}{year} \times DW_{cw}\ \frac{5\ days}{week}\right) \times ED_{cw}\,(1\ year) \times ET_{ws}\left(\frac{8\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(\frac{mg}{m^3}\right)} \times \left(\frac{1}{VF_{sc}\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF'_{sc}\left(\frac{m^3}{kg}\right)}\right)}$$

$SL_{cw\text{-}soil\text{-}nc\text{-}inh}$ = Screening level for noncarcinogenic construction worker soil inhalation
THQ = Target hazard quotient = 0.2
AT = Averaging time = 350 days = EPA default
EW = Weeks worked = 50 weeks/year = EPA default
ED = Exposure duration = 1 year = EPA default
EF = EW (weeks worked) of 50 weeks/year x DW (days worked) of 5 days/week = 250 days/year = EPA default
ET = Exposure time = 8 hours/day = EPA default
RfC = Subchronic inhalation reference concentration (mg/m^3), see chem-tox database
VF = Volatilization factor = See supplemental equation in Section A.3.e.
PEF = Particulate emission factor (m^3/kg) = See supplemental information in Section C.

Carcinogenic Construction Worker Outdoor Inhalation of Volatiles and Particulates from Soil

$$SL_{cw\text{-}soil\text{-}ca\text{-}inh}\,(mg/kg) = \frac{TR \times AT_{cw}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{EF_{cw}\left(EW_{cw}\frac{50\ weeks}{year} \times DW_{cw}\ \frac{5\ days}{week}\right) \times ED_{cw}\,(1\ year) \times ET_{cw}\left(\frac{8\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1000\ \mu g}{mg}\right) \times \left(\frac{1}{VF_{sc}\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_{sc}\left(\frac{m^3}{kg}\right)}\right)}$$

$SL_{cw\text{-}soil\text{-}ca\text{-}inh}$ = Screening level for carcinogenic construction worker soil inhalation
TR = Target risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
EW = Weeks worked = 50 weeks/year = EPA default
LT = Lifetime = 70 years = EPA default
EF = EW (weeks worked) of 50 weeks/year x DW (days worked) of 5 days/week = 250 days/year
IUR = Subchronic inhalation risk $(\mu g/m^3)^{-1}$, see chem-tox database
VF = Volatilization factor = See supplemental equation in Section A.3.e.
PEF = Particulate emission factor = See supplemental information in Section C.

A.3.d. User Defined (Recreator/Trespasser) Outdoor Inhalation of Volatiles and Particulates from Soil

Noncarcinogenic Recreator/Trespasser Outdoor Inhalation of Volatiles and Particulates from Soil

Child

$$SL_{rec\text{-}soil\text{-}nc\text{-}inh\text{-}c}\left(mg/kg\right) = \frac{THQ \times AT_{rec\text{-}c}\left(\frac{365\ days}{year} \times ED_{rec\text{-}c}\left(years\right)\right)}{EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ED_{rec\text{-}c}\left(years\right) \times ET_{rec\text{-}c}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(\frac{mg}{m^3}\right)} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)}$$

Adult

$$SL_{rec\text{-}soil\text{-}nc\text{-}inh\text{-}a}\left(mg/kg\right) = \frac{THQ \times AT_{rec\text{-}a}\left(\frac{365\ days}{year} \times ED_{rec\text{-}a}\left(years\right)\right)}{EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ED_{rec\text{-}a}\left(years\right) \times ET_{rec\text{-}a}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(\frac{mg}{m^3}\right)} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)}$$

Child, and adult formulas are the same with exception of ED. The ED values cancel out, so the results are the same regardless of which formula is used.
$SL_{res\text{-}soil\text{-}nc\text{-}inh\text{-}c}$ = Screening level for noncarcinogenic recreator (child) soil inhalation
$SL_{res\text{-}soil\text{-}nc\text{-}inh\text{-}a}$ = Screening level for noncarcinogenic recreator (adult) or trespasser (adolescent) soil inhalation
THQ = Target hazard quotient = 0.2
AT = Averaging time = 2,190 days child and 9,490 days adult = EPA default
ED = Exposure duration recreator = 6 years child, 26 years adult = EPA default
ED = Exposure duration trespasser = 10 years adolescent = EPA Region 4 Guidance
EF = Exposure frequency recreator = 150 days/year = NC DEQ default
EF = Exposure frequency trespasser = 90 days/year = NC DEQ default
ET = Exposure time recreator = 2 hours/day = NC DEQ default
ET = Exposure time trespasser = 2 hours/day = NC DEQ default
RfC = Chronic inhalation reference concentration (mg/m^3), see chem-tox database
VF = Volatilization factor = See supplemental equation in Section A.3.e.
PEF = Particulate emission factor = 5.93E+10 m^3/kg. See supplemental equation in Section A.3.f.

Carcinogenic Recreator/Trespasser Outdoor Inhalation of Volatiles and Particulates from Soil

Additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and trichloroethylene. The standard equation is listed below, followed by the alternative equations

Standard Carcinogenic Equation for Recreator/Trespasser Inhalation of Volatiles and Particulates from Soil

$$SL_{rec\text{-}soil\text{-}ca\text{-}inh}\,(mg/kg) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1000\ \mu g}{mg}\right) \times EF_{rec}\left(\frac{days}{year}\right) \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times ED_{rec}\,(years) \times ET_{rec}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right)}$$

$SL_{rec\text{-}soil\text{-}ca\text{-}inh}$ = Screening level for carcinogenic recreator/trespasser soil inhalation
TR = Target carcinogenic risk = 1.0E-6
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
IUR = Chronic inhalation unit risk $(\mu g/m^3)^{-1}$, see chem-tox database
EF = Exposure frequency recreator = 150 days/year = NC DEQ default
EF = Exposure frequency trespasser = 90 days/year = NC DEQ default
VF = Volatilization factor = See supplemental equation in Section A.3.e.
PEF = Particulate emission factor = 5.93E+10 m^3/kg. See supplemental equation, Section A.3.f.
ED = Exposure duration recreator = 6 years child, 20 years adult = EPA default
ED = Exposure duration trespasser = 10 years adolescent = EPA Region 4 Guidance
ET = Exposure time recreator = 2 hours/day = NC DEQ default
ET = Exposure time trespasser = 2 hours/day = NC DEQ default

Mutagenic Carcinogenic Equation for Recreator/Trespasser Inhalation of Volatiles and Particulates from Soil

$$SL_{rec\text{-}soil\text{-}mu\text{-}inh}\,(mg/kg) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times \left(\frac{1000\ \mu g}{mg}\right) \times \left(\begin{array}{l} \left(ED_{0\text{-}2}\,(years) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times ET_{0\text{-}2}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 10\right) + \\ \left(ED_{2\text{-}6}\,(years) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times ET_{2\text{-}6}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 3\right) + \\ \left(ED_{6\text{-}16}\,(years) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times ET_{6\text{-}16}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 3\right) + \\ \left(ED_{16\text{-}26}\,(years) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times ET_{16\text{-}26}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 1\right) \end{array}\right)}$$

$SL_{rec\text{-}soil\text{-}mu\text{-}inh}$ = Screening level for carcinogenic recreator/trespasser soil inhalation for mutagenic compounds
Remaining inputs are the same as the standard equation for carcinogenic recreator/trespasser soil inhalation.

Vinyl Chloride Carcinogenic Equation for Recreator/Trespasser Inhalation of Volatiles and Particulates from Soil

$$SL_{rec\text{-}soil\text{-}ca\text{-}vc\text{-}inh}\,(mg/kg) = \frac{TR}{\left(\frac{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times EF_{rec}\left(\frac{days}{year}\right) \times ED_{rec}\,(years) \times ET_{rec}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{AT_{rec}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right) \times VF_s\left(\frac{m^3}{kg}\right)}\right) + \left(\frac{IUR\left(\frac{\mu g}{m^3}\right)^{-1}}{VF_s\left(\frac{m^3}{kg}\right)} \times \left(\frac{1000\ \mu g}{mg}\right)\right)}$$

$SL_{rec\text{-}soil\text{-}ca\text{-}vc\text{-}inh}$ = Screening level for carcinogenic recreator/trespasser soil inhalation for vinyl chloride
Remaining inputs are the same as the standard equation for carcinogenic recreator/trespasser soil inhalation.

Trichloroethylene Carcinogenic Equation for Recreator/Trespasser Inhalation of Volatiles and Particulates from Soil

$$SL_{rec\text{-}soil\text{-}tce\text{-}inh}\left(mg/kg\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times \left(\frac{1000\ \mu g}{mg}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \left(\begin{array}{l} \left(CAF_i\left(0.756\right) \times EF_{rec}\left(\frac{days}{year}\right) \times \right. \\ \left. ED_{rec}\left(years\right) \times ET_{rec}\left(\frac{hours}{day}\right)\right) + \left(\begin{array}{l} \left(ED_{0\text{-}2}\left(years\right) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times ET_{0\text{-}2}\left(\frac{hours}{day}\right) \times MAF_i\left(0.244\right) \times 10\right) + \\ \left(ED_{2\text{-}6}\left(years\right) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times ET_{2\text{-}6}\left(\frac{hours}{day}\right) \times MAF_i\left(0.244\right) \times 3\right) + \\ \left(ED_{6\text{-}16}\left(years\right) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times ET_{6\text{-}16}\left(\frac{hours}{day}\right) \times MAF_i\left(0.244\right) \times 3\right) + \\ \left(ED_{16\text{-}26}\left(years\right) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times ET_{16\text{-}26}\left(\frac{hours}{day}\right) \times MAF_i\left(0.244\right) \times 1\right) \end{array}\right) \end{array}\right)}$$

$SL_{rec\text{-}soil\text{-}tce\text{-}inh}$ = Screening level for carcinogenic recreator/trespasser soil inhalation for trichloroethylene
CAF_i = Cancer adjustment factor inhalation = 0.756 = EPA default
MAF_i = Mutagenic adjustment factor oral = 0.244 = EPA default
Remaining inputs are the same as the standard equation for carcinogenic recreator/trespasser soil inhalation.

A.3.e. Supplemental Volatilization Factor (VF) Equation for Outdoor Inhalation of Volatiles from Soil

Non-Residential Worker, Residential, Recreational User, and Trespasser VF Equations

The risk calculator calculates volatilization factors via two equations, (1) unlimited source model for chronic exposure and (2) mass limit model for chronic exposure. The risk calculator then selects the equation that provides the higher soil screening level (lower groundwater screening level) for subsequent modeling calculations.

mass limit model for chronic exposure

$$VF_s\left(\frac{m^3_{air}}{kg_{soil}}\right)=\frac{Q}{C_{vol}}\left(\frac{\left(\frac{g}{m^2\text{-}s}\right)}{\left(\frac{kg}{m^3}\right)}\right)\times\frac{\left[T\,(year)\times\left(3.15\times10^7\left(\frac{s}{year}\right)\right)\right]}{\rho_b\left(\frac{Mg}{m^3}\right)\times d_s\,(m)\times10^6\left(\frac{g}{Mg}\right)}$$

$$\text{where: }\frac{Q}{C_{vol}}\left(\frac{\left(\frac{g}{m^2\text{-}s}\right)}{\left(\frac{kg}{m^3}\right)}\right)=A\times\exp\left[\frac{\left(\ln A_s\,(acre)\text{-}B\right)^2}{C}\right]$$

VF = Volatilization factor = 3,142.13 m^3/kg
Q/C_{vol} = Calculated with secondary equation in $[(g/m^2\text{-}s)/(kg/m^3)]$
T = Exposure interval = 26 years (This value was confirmed with EPA via email. EPA indicated they may modify this value to be equivalent to the exposure duration [ED] at some point in the future.)
ρ_b = Dry soil bulk density = Site-specific can be entered = EPA default 1.5 g/cm^3
= 1.5E+09 mg/m^3 (ρ_b entered as g/cm^3 and converted to mg/m^3 in formulas)
d_s = Depth to base of soil source area = Site-specific can be entered = EPA default 12.44 m
A_s = Areal extent of site or contamination = range 0.5 to 500 = DEQ default 0.5 acres
A = 12.3675 (unitless) = EPA dispersion constant for Raleigh, NC Region
B = 18.6337 (unitless) = EPA dispersion constant for Raleigh, NC Region
C = 212.7284 (unitless) = EPA dispersion constant for Raleigh, NC Region

unlimited source model for chronic exposure

$$VF_s\left(\frac{m^3_{air}}{kg_{soil}}\right) = \frac{\frac{Q}{C_{vol}}\left(\frac{\left(\frac{g}{m^2\text{-}s}\right)}{\left(\frac{kg}{m^3}\right)}\right) \times \left(3.14 \times D_A\left(\frac{cm^2}{s}\right) \times T(s)\right)^{1/2} \times 10^{-4}\left(\frac{m^2}{cm^2}\right)}{2 \times \rho_b\left(\frac{g}{cm^3}\right) \times D_A\left(\frac{cm^2}{s}\right)}$$

$$\text{where: } \frac{Q}{C_{vol}}\left(\frac{\left(\frac{g}{m^2\text{-}s}\right)}{\left(\frac{kg}{m^3}\right)}\right) = A \times \exp\left[\frac{\left(\ln A_s\,(acre) - B\right)^2}{C}\right]$$

$$\text{where: } D_A\left(\frac{cm^2}{s}\right) = \frac{\left(\theta_a\left(\frac{L_{air}}{L_{soil}}\right)^{10/3} \times D_{ia}\left(\frac{cm^2}{s}\right) \times H' + \theta_w\left(\frac{0.15\ L_{water}}{L_{soil}}\right)^{10/3} \times D_{iw}\left(\frac{cm^2}{s}\right)\right) \Big/ n^2\left(\frac{L_{pore}}{L_{soil}}\right)}{\rho_b\left(\frac{1.5g}{cm^3}\right) \times K_d\left(\frac{cm^3}{g}\right) + \theta_w\left(\frac{0.15\ L_{water}}{L_{soil}}\right) + \theta_a\left(\frac{L_{air}}{L_{soil}}\right) \times H'}$$

$$\text{where: } \theta_a\left(\frac{L_{air}}{L_{soil}}\right) = n\left(\frac{L_{pore}}{L_{soil}}\right) - \theta_w\left(\frac{0.15\ L_{water}}{L_{soil}}\right) \text{ and } n\left(\frac{L_{pore}}{L_{soil}}\right) = 1 - \left(\rho_b\left(\frac{1.5g}{cm^3}\right) \Big/ \rho_s\left(\frac{2.65\ g}{cm^3}\right)\right)$$

$$\text{where: } K_d\left(\frac{cm^3}{g}\right) = f_{oc}\left(\frac{g}{g}\right) \times K_{oc}\left(\frac{cm^3}{g}\right) \text{ only for organics.}$$

VF = Volatilization factor (m^3/kg)
Q/C_{vol} = Calculated with secondary equation in [$(g/m^2\text{-}s)/(kg/m^3)$]
D_A = Apparent diffusivity = Calculated with secondary equation in (cm^2/s)
T(s) = Exposure interval in seconds = 26 years = 8.20E+08 seconds (This value was confirmed with EPA via email. EPA indicated they may modify this value to be equivalent to the exposure duration [ED] at some point in the future.)
ρ_b = Dry soil bulk density = Site-specific can be entered = EPA default 1.5 g/cm^3
= 1.5E+09 mg/m^3 (ρ_b entered as g/cm^3 and converted to mg/m^3 in formulas)
A_s = Areal extent of site or contamination = range 0.5 to 500 = DEQ default 0.5 acres
A = 12.3675 (unitless) = EPA dispersion constant for Raleigh, NC Region
B = 18.6337 (unitless) = EPA dispersion constant for Raleigh, NC Region
C = 212.7284 (unitless) = EPA dispersion constant for Raleigh, NC Region
θ_a = Air filled soil porosity = Calculated via secondary equation in L/L or site-specific can be entered = EPA default 0.28 L/L
θ_w = Water filled soil porosity = Site-specific can be entered = EPA default 0.15 L/L
n = Total soil porosity = The EPA provides a secondary equation that can be used to calculate the total soil porosity based on the dry soil bulk density ρ_b and the soil particle density ρ_s. However, in most cases the DEQ has collected site-specific porosity data, and rarely collects soil particle density data. The default value is 0.43 L/L, which is the same as the EPA default calculated via the secondary equation presented above.

D_{ia} = Diffusivity in air = Contaminant specific in in cm^2/s = See chem-tox database
D_{iw} = Diffusivity in water = Contaminant specific in in cm^2/s = See chem-tox database
H' = Henry's law constant = Contaminant specific (unitless) = See chem-tox database
Kd = Calculated via secondary equation in cm^3/g
foc = Fraction organic carbon = Site-specific can be entered = EPA default 0.006 g/g
Koc = Soil organic carbon-water partition coefficient = Contaminant specific in L/kg = See chem-tox database
ρ_s =Soil particle density in g/cm^3 = The parameter is only used if porosity is calculated based on the soil dry bulk density and soil particle density. The risk calculator allows entry of porosity (n) data directly, which means this parameter is not used in the risk calculator.

Construction Worker VF Equations

mass limit model for subchronic exposure

$$VF_{sc}\left(\frac{m^3_{air}}{kg_{soil}}\right)=\frac{Q}{C_{sa}}\left(\frac{\left(\frac{g}{m^2\text{- }s}\right)}{\left(\frac{kg}{m^3}\right)}\right)\times\frac{1}{F_D}\times\frac{T\,(s)}{\rho_b\left(\frac{1.5\ Mg}{m^3}\right)\times d_s\,(m)\times 10^6\left(\frac{g}{Mg}\right)}$$

$$\text{where: }\frac{Q}{C_{sa}}\left(\frac{\left(\frac{g}{m^2\text{- }s}\right)}{\left(\frac{kg}{m^3}\right)}\right)=A\times\exp\left[\frac{\left(\ln A_s\,(acre)-B\right)^2}{C}\right]$$

$$T\ (30240000\ s)=ED_{cw}\,(1\ yr)\times EW_{cw}\left(\frac{50\ wks}{year}\right)\times\left(\frac{7\ days}{week}\right)\times\left(\frac{24\ hrs}{day}\right)\times\left(\frac{3600\ s}{hr}\right)$$

$$F_D\,(0.18584)=0.1852+\left(5.3537/t_c\right)+\left(-9.6318/t_c^{\,2}\right)$$

$$t_c\,(8400\ hr)=ED_{cw}\,(1\ yr)\times EW_{cw}\left(\frac{50\ wks}{year}\right)\times\left(\frac{7\ days}{week}\right)\times\left(\frac{24\ hrs}{day}\right)$$

VF = Volatilization factor = Calculated in m^3/kg
Q/C = Calculated with secondary equation in $[(g/m^2\text{-}s)/(kg/m^3)]$
T(s) = Calculated with secondary equation
F_d = Calculated with secondary equation
t_c = Calculated with secondary equation
ρ_b = Dry soil bulk density = Site-specific can be entered = EPA default 1.5 g/cm^3
= 1.5E+09 mg/m^3 (ρ_b entered as g/cm^3 and converted to mg/m^3 in formulas)
d_s = Depth to base of soil source area = Site-specific can be entered = EPA default 12.44 m
A_s = Areal extent of site or contamination = range 0.5 to 500 = DEQ default 0.5 acres
A = 12.3675 (unitless) = EPA dispersion constant for Raleigh, NC Region
B = 18.6337 (unitless) = EPA dispersion constant for Raleigh, NC Region
C = 212.7284 (unitless) = EPA dispersion constant for Raleigh, NC Region
ED = Exposure duration = 1 year = EPA default
EW = Weeks worked = 50 weeks/year = EPA default

unlimited source model for subchronic exposure

$$VF_{sc}\left(\frac{m^3_{air}}{kg_{soil}}\right) = \frac{Q}{C_{sa}}\left(\frac{\left(\frac{g}{m^2\text{-}s}\right)}{\left(\frac{kg}{m^3}\right)}\right) \times \frac{1}{F_D} \times \left[\frac{\left(3.14 \times D_A\left(\frac{cm^2}{s}\right) \times T(s)\right)^{1/2}}{2 \times \rho_b\left(\frac{1.5g}{cm^3}\right) \times D_A\left(\frac{cm^2}{s}\right)}\right] \times 10^{-4}\left(\frac{m^2}{cm^2}\right)$$

$$\text{where: } \frac{Q}{C_{sa}}\left(\frac{\left(\frac{g}{m^2\text{-}s}\right)}{\left(\frac{kg}{m^3}\right)}\right) = A \times \exp\left[\frac{\left(\ln A_s(acre) - B\right)^2}{C}\right]$$

$$D_A\left(\frac{cm^2}{s}\right) = \frac{\left(\theta_a\left(\frac{L_{air}}{L_{soil}}\right)^{10/3} \times D_{ia}\left(\frac{cm^2}{s}\right) \times H' + \theta_w\left(\frac{0.15\ L_{water}}{L_{soil}}\right)^{10/3} \times D_{iw}\left(\frac{cm^2}{s}\right)\right) \Big/ n^2\left(\frac{L_{pore}}{L_{soil}}\right)}{\rho_b\left(\frac{1.5g}{cm^3}\right) \times K_d\left(\frac{cm^3}{g}\right) + \theta_w\left(\frac{0.15\ L_{water}}{L_{soil}}\right) + \theta_a\left(\frac{L_{air}}{L_{soil}}\right) \times H'}$$

$$\theta_a\left(\frac{L_{air}}{L_{soil}}\right) = n\left(\frac{L_{pore}}{L_{soil}}\right) - \theta_w\left(\frac{0.15\ L_{water}}{L_{soil}}\right) \text{ and } n\left(\frac{L_{pore}}{L_{soil}}\right) = 1 - \left(\rho_b\left(\frac{1.5\ g}{cm^3}\right) \Big/ \rho_s\left(\frac{2.65\ g}{cm^3}\right)\right)$$

$$K_d\left(\frac{cm^3}{g}\right) = f_{oc}\left(\frac{g}{g}\right) \times K_{oc}\left(\frac{cm^3}{g}\right) \text{ only for organics.}$$

$$T\ (30240000\ s) = ED_{cw}(1\ yr) \times EW_{cw}\left(\frac{50\ wks}{year}\right) \times \left(\frac{7\ days}{week}\right) \times \left(\frac{24\ hrs}{day}\right) \times \left(\frac{3600\ s}{hr}\right)$$

$$F_D\ (0.18584) = 0.1852 + \left(5.3537 / t_c\right) + \left(-9.6318 / t_c^{\,2}\right)$$

$$t_c\ (8400\ hr) = ED_{cw}(1\ yr) \times EW_{cw}\left(\frac{50\ wks}{year}\right) \times \left(\frac{7\ days}{week}\right) \times \left(\frac{24\ hrs}{day}\right)$$

VF = Volatilization factor = Calculated in m^3/kg
Q/C_{sa} = Calculated with secondary equation in $[(g/m^2\text{-}s)/(kg/m^3)]$
Fd = Calculated with secondary equation
D_A = Apparent diffusivity = Calculated with secondary equation in cm^2/s
T(s) = Total time over which construction occurs = 1 yr x 50 wks/yr x 7 days/week x 24 hrs/day x 3600 s/hr = 3.024E+07 seconds = EPA default
t_c = T(s) in hours = 8,400 hours
ρ_b = Dry soil bulk density = Site-specific can be entered = EPA default 1.5 g/cm^3
= 1.5E+09 mg/m^3 (ρ_b entered as g/cm^3 and converted to mg/m^3 in formulas)
A_s = Areal extent of site or contamination = range 0.5 to 500 = DEQ default 0.5 acres
A = 12.3675 (unitless) = EPA dispersion constant for Raleigh, NC Region
B = 18.6337 (unitless) = EPA dispersion constant for Raleigh, NC Region
C = 212.7284 (unitless) = EPA dispersion constant for Raleigh, NC Region

θ_a = Air filled soil porosity = Calculated via secondary equation in L/L or site-specific can be entered = EPA default 0.28 L/L
θ_w = Water filled soil porosity = Site-specific can be entered = EPA default 0.15 L/L
n = Total soil porosity = The EPA provides a secondary equation that can be used to calculate the total soil porosity based on the dry soil bulk density ρ_b and the soil particle density ρ_s. However, in most cases the DEQ has collected site-specific porosity data, and rarely collects soil particle density data. The default value is 0.43 L/L, which is the same as the EPA default calculated via the secondary equation presented above.
D_{ia} = Diffusivity in air = Contaminant specific in in cm^2/s = See chem-tox database
D_{iw} = Diffusivity in water = Contaminant specific in in cm^2/s = See chem-tox database
H' = Henry's law constant = Contaminant specific (unitless) = See chem-tox database
Kd = Calculated via secondary equation in cm^3/g
foc = Fraction organic carbon = Site-specific can be entered = EPA default 0.006 g/g
Koc = Soil organic carbon-water partition coefficient = Contaminant specific in L/kg = See chem-tox database
ρ_s =Soil particle density in g/cm^3 = The parameter is only used if porosity is calculated based on the soil dry bulk density and soil particle density. The risk calculators allow entry of porosity (n) data directly, which means this parameter is not used in the risk calculators.

A.3.f. Supplemental Particulate Emission Factor (PEF) Equation for Outdoor Inhalation of Particulates from Soil

Non-Residential Worker, Residential, Recreational User, and Trespasser PEF Equations

$$PEF_w\left(\frac{m^3_{air}}{kg_{soil}}\right)=\frac{Q}{C_{wind}}\left(\frac{\left(\frac{g}{m^2\text{-}s}\right)}{\left(\frac{kg}{m^3}\right)}\right)\times\frac{3{,}600\left(\frac{s}{hour}\right)}{0.036\times(1\text{-}V)\times\left(\frac{U_m\left(\frac{m}{s}\right)}{U_t\left(\frac{m}{s}\right)}\right)^3\times F(x)}$$

$$\text{and: }\frac{Q}{C_{wind}}=A\times\exp\left[\frac{\left(\ln A_s\,(acre)\text{-}B\right)^2}{C}\right]$$

PEF = Particulate Emission factor = 5.93E+10 m^3/kg
Q/C_{wind} = Calculated with secondary equation in $[(g/m^2\text{-}s)/(kg/m^3)]$
V = Fraction of vegetative cover = 0.5 (unitless) = EPA default
U_m = Mean annual wind speed = 3.44 m/s = EPA default for Raleigh, NC Region
U_t = Equivalent threshold value of wind speed at 7m = 11.32 m/s = EPA default for Raleigh, NC Region
F(x) = Function depending on Um/Ut = 0.0086 (unitless) = EPA default for Raleigh, NC Region
A_s = Areal extent of site or contamination = range 0.5 to 500 = DEQ default 0.5 acres
A = 12.3675 (unitless) = EPA dispersion constant for Raleigh, NC Region
B = 18.6337 (unitless) = EPA dispersion constant for Raleigh, NC Region
C = 212.7284 (unitless) = EPA dispersion constant for Raleigh, NC Region

Construction Worker PEF Equations

Calculation of a PEF for a construction worker is significantly more complex than for other receptors due to the increased potential for particulates generated from heavy vehicle traffic, grading, dozing, tilling, and excavation during construction activities. See Section C for description of justification for the default value of 1.06E+06 m^3/kg used in the risk calculator.

A.4 GROUNDWATER (TAP WATER) INGESTION PATHWAY

A.4.a. Non-Residential Worker Groundwater Ingestion

Noncarcinogenic Non-Residential Worker Groundwater Ingestion

$$SL_{water\text{-}nc\text{-}ing\text{-}w}(\mu g/L) = \frac{THQ \times AT_w \left(\frac{365\ days}{year} \times ED_w\ (25\ years)\right) \times BW_w\ (80\ kg) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_w \left(250\ \frac{days}{year}\right) \times ED_w\ (25\ years) \times \frac{1}{RfD_o\left(\frac{mg}{kg\text{-}d}\right)} \times IRW_w \left(\frac{0.83\ L}{day}\right)}$$

$SL_{water\text{-}nc\text{-}ing\text{-}w}$ = Screening level for noncarcinogenic non-residential worker water ingestion of tap water
THQ = Target hazard quotient = 0.2
AT = Averaging time = 9,125 days = EPA default
ED = Exposure duration = 25 years = EPA default
BW = Body weight = 80 kilograms = EPA default
EF = Exposure frequency = 250 days/year = EPA default
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
IRW = Tap water Ingestion rate = 0.83 L/day = NC DEQ default

Carcinogenic Non-Residential Worker Water Ingestion

$$SL_{w\text{-}wa\text{-}ca\text{-}ing}\ (\mu g/L) = \frac{TR \times AT_w \left(\frac{365\ days}{year} \times LT\ (70\ years)\right) \times BW_w\ (80\ kg)}{EF_w \left(250\ \frac{days}{year}\right) \times ED_w\ (25\ years) \times CSF_o \left(\frac{mg}{kg\text{-}day}\right)^{-1} \times IR_w \left(0.83 \frac{L}{day}\right) \times \left(\frac{10^{-3}\ mg}{\mu g}\right)}$$

$SL_{w\text{-}wa\text{-}ca\text{-}ing}$ = Screening level for carcinogenic non-residential worker tap water ingestion
TR = Target risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
BW = Body weight = 80 kilograms = EPA default
EF = Exposure frequency = 250 days/year = EPA default
ED = Exposure duration = 25 years = EPA default

CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
IR = Tap water Ingestion rate = 0.83 L/day = NC DEQ Default

A.4.b. Resident Groundwater Ingestion

Noncarcinogenic Resident Groundwater Ingestion

Child

$$SL_{water\text{-}nc\text{-}ing\text{-}c}\left(\mu g/L\right) = \frac{THQ \times AT_{res\text{-}c}\left(\frac{365\ days}{year} \times ED_{res\text{-}c}\left(6\ years\right)\right) \times BW_{res\text{-}c}\left(15\ kg\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\left(6\ years\right) \times \frac{1}{RfD_o\left(\frac{mg}{kg\text{-}d}\right)} \times IRW_{res\text{-}c}\left(\frac{0.78\ L}{day}\right)}$$

Adult

$$SL_{water\text{-}nc\text{-}ing\text{-}a}\left(\mu g/L\right) = \frac{THQ \times AT_{res\text{-}a}\left(\frac{365\ days}{year} \times ED_{res}\left(26\ years\right)\right) \times BW_{res\text{-}a}\left(80\ kg\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{res\text{-}a}\left(350\ \frac{days}{year}\right) \times ED_{res}\left(26\ years\right) \times \frac{1}{RfD_o\left(\frac{mg}{kg\text{-}d}\right)} \times IRW_{res\text{-}a}\left(\frac{2.5\ L}{day}\right)}$$

The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA RSLs. The exposure durations cancel out in this equation, so age adjustment is not applicable.

$SL_{water\text{-}nc\text{-}ing\text{-}c}$ = Screening level for noncarcinogenic residential child groundwater ingestion
$SL_{water\text{-}nc\text{-}ing\text{-}a}$ = Screening level for noncarcinogenic residential adult groundwater ingestion
THQ = Target hazard quotient = 0.2
AT = Averaging time = 2,190 days child and 9,490 days adult = EPA default
ED = Exposure duration = 6 years child and 26 years adult = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default
EF = Exposure frequency = 350 days/year = EPA default
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
IRW = Ingestion rate = 0.78 L/day child and 2.5 L/day adult = EPA default

Carcinogenic Resident Water Ingestion

Additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and trichloroethylene. The standard equation is listed below, followed by the alternative equations and a discussion of how the alternative equations differ from the standard equation.

Standard Carcinogenic Equation for Resident Water Ingestion

$$SL_{water\text{-}ca\text{-}ing}\left(\mu g/L\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times \left(IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right)\right)}$$

where:

$$IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\left(6\ years\right) \times IRW_{res\text{-}c}\left(\frac{0.78\ L}{day}\right)}{BW_{res\text{-}c}\left(15\ kg\right)} + \frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times \left(ED_{res}\left(26\ years\right) - ED_{res\text{-}c}\left(6\ years\right)\right) \times IRW_{res\text{-}a}\left(\frac{2.5\ L}{day}\right)}{BW_{res\text{-}a}\left(80\ kg\right)}\right)$$

$SL_{water\text{-}ca\text{-}ing}$ = Screening level for carcinogenic resident water ingestion
TR = Target risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
$IFW_{res\text{-}adj}$ = Age-adjusted water ingestion rate (L/kg). Calculated via secondary equation.
EF = Exposure frequency = 350 days/year (same for child and adult) = EPA default
ED = Exposure duration = 6 years child and 20 years adult = EPA default
IRW = Ingestion rate = 0.78 L/day child and 2.5 L/day adult = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default

Mutagenic Carcinogenic Equation for Resident Water Ingestion

$$SL_{water\text{-}mu\text{-}ing}\left(\mu g/L\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times IFWM_{res\text{-}adj}\left(\frac{1019.9\ L}{kg}\right)}$$

where:

$$IFWM_{res\text{-}adj}\left(\frac{1019.9\ L}{kg}\right) = \left(\begin{array}{l} \frac{EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ED_{0\text{-}2}\left(years\right) \times IRW_{0\text{-}2}\left(\frac{0.78\ L}{day}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \\ \frac{EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ED_{2\text{-}6}\left(years\right) \times IRW_{2\text{-}6}\left(\frac{0.78\ L}{day}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \\ \frac{EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ED_{6\text{-}16}\left(years\right) \times IRW_{6\text{-}16}\left(\frac{2.5\ L}{day}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \\ \frac{EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ED_{16\text{-}26}\left(years\right) \times IRW_{16\text{-}26}\left(\frac{2.5\ L}{day}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)} \end{array}\right)$$

Some cancer-causing chemicals operate by a mutagenic mode of action which would exhibit a greater effect in early-life exposure. To account for this difference, a separate equation is used to calculate cancer risk posed by mutagens. The mutagenic equation adds an age-dependent adjustment factor (ADAF) to account for increased childhood risk for mutagenic compounds. The adjustment factor is ten for the 0 to 2-year age range, three for the 2 to 6-year age range, three for the 6 to 16-year age range, and one for the 16 to 26-year age range. The remaining portions of the equation are similar to the standard carcinogenic equation.

$SL_{water\text{-}mu\text{-}ing}$ = Screening level for carcinogenic resident water ingestion for mutagenic compounds
$IFWM_{res\text{-}adj}$ = Age-adjusted resident mutagenic water ingestion rate (L/kg), calculated via secondary equation.
Remaining inputs are the same as the standard equation for carcinogenic resident water ingestion.

Vinyl Chloride Carcinogenic Equation for Resident Water Ingestion

$$SL_{water\text{-}ca\text{-}vc\text{-}ing}\left(\mu g/L\right) = \frac{TR}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right) \times \left(\frac{mg}{1000\ \mu g}\right)}{AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}\right) + \left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times IRW_{res\text{-}c}\left(\frac{0.78\ L}{day}\right) \times \left(\frac{mg}{1000\ \mu g}\right)}{BW_{res\text{-}c}\left(15\ kg\right)}\right)}$$

where:

$$IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\left(6\ years\right) \times IRW_{res\text{-}c}\left(\frac{0.78\ L}{day}\right)}{BW_{res\text{-}c}\left(15\ kg\right)} + \frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times \left(ED_{res}\left(26\ years\right) - ED_{res\text{-}c}\left(6\ years\right)\right) \times IRW_{res\text{-}a}\left(\frac{2.5\ L}{day}\right)}{BW_{res\text{-}a}\left(80\ kg\right)}\right)$$

Vinyl chloride is a mutagenic compound with sufficient chemical-specific data to directly evaluate carcinogenic exposure through a mutagenic mode of action, in contrast to compounds with insufficient chemical-specific data which are assessed using the default mutagenic equation. Therefore, vinyl chloride has a unique set of equations for residential carcinogenic risk.

$SL_{water\text{-}ca\text{-}vc\text{-}ing}$ = Screening level for carcinogenic resident water ingestion for vinyl chloride. Remaining inputs are the same as the standard equation for carcinogenic resident water ingestion.

Trichloroethylene Carcinogenic Equation for Resident Water Ingestion

$$SL_{water\text{-}tce\text{-}ing}\left(\mu g/L\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times \left(\left(CAF_o\left(0.804\right) \times IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right)\right) + \left(MAF_o\left(0.202\right) \times IFWM_{res\text{-}adj}\left(\frac{1019.9\ L}{kg}\right)\right)\right)}$$

where:

$$IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right) = \left(\frac{ED_{res\text{-}c}\left(6\ years\right) \times EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times IRW_{res\text{-}c}\left(\frac{0.78\ L}{day}\right)}{BW_{res\text{-}c}\left(15\ kg\right)} + \frac{\left(ED_{res}\left(26\ years\right) - ED_{res\text{-}c}\left(6\ years\right)\right) \times EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times IRW_{res\text{-}a}\left(\frac{2.5\ L}{day}\right)}{BW_{res\text{-}a}\left(80\ kg\right)}\right)$$

where:

$$IFWM_{res\text{-}adj}\left(\frac{1019.9\ L}{kg}\right) = \left(\frac{ED_{0\text{-}2}\left(2\ years\right) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times IRW_{0\text{-}2}\left(\frac{0.78\ L}{day}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \frac{ED_{2\text{-}6}\left(4\ years\right) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times IRW_{2\text{-}6}\left(\frac{0.78\ L}{day}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \frac{ED_{6\text{-}16}\left(10\ years\right) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times IRW_{6\text{-}16}\left(\frac{2.5\ L}{day}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \frac{ED_{16\text{-}26}\left(10\ years\right) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times IRW_{16\text{-}26}\left(\frac{2.5\ L}{day}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)}\right)$$

For trichloroethylene, EPA recommends that kidney risk be assessed using a mutagenic equation and that liver and non-Hodgkin lymphoma (NHL) risk be assessed using the standard cancer equations. EPA has developed adjustment factors that account for the different toxicity factors. The liver and NHL risks are evaluated using the standard cancer equations and a cancer adjustment factor (CAF). The kidney risk is evaluated using the mutagenic cancer equations and a mutagenic adjustment factor (MAF).

$SL_{water\text{-}tce\text{-}ing}$ = Screening Level for carcinogenic resident water ingestion for trichloroethylene
$IFWM_{res\text{-}adj}$ = Age-adjusted resident mutagenic water ingestion rate (L/kg), calculated via secondary equation.
CAF_o = Cancer adjustment factor oral = 0.804 = EPA default
MAF_o = Mutagenic adjustment factor oral = 0.202 = EPA default
Remaining inputs are the same as the standard equation for carcinogenic resident water ingestion.

A.5 GROUNDWATER (TAP WATER) DERMAL PATHWAY

A.5.a. Non-Residential Worker Dermal Contact with Groundwater

Noncarcinogenic Non-Residential Worker Dermal Contact with Groundwater

FOR INORGANICS:

$$SL_{water\text{-}nc\text{-}der\text{-}w}(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}w}\left(\frac{0.71\ hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}w}\left(\frac{0.71\ hours}{event}\right) \le t^*\ (hours), \text{then } SL_{water\text{-}nc\text{-}der}(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}w}\left(\frac{0.71\ hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}w}\left(\frac{0.71\ hours}{event}\right) > t^*\ (hours), \text{then } SL_{water\text{-}nc\text{-}der\text{-}w}(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}w}\left(\frac{0.71\ hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right) = \frac{THQ\times AT_w\left(\frac{365\ days}{year}\times ED_w\ (25\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)\times BW_w\ (80\ kg)}{\left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)\times GIABS}\right)\times EV_w\left(\frac{1\ events}{day}\right)\times ED_w\ (25\ years)\times EF_w\left(\frac{250\ \underline{days}}{year}\right)\times SA_w\ (19652\ cm^2)}$$

$SL_{water\text{-}nc\text{-}der\text{-}w}$ = Screening level for tap water, noncarcinogenic worker, dermal contact
DA_{event} = Absorbed Dose per Event ($\mu g/cm^2$-event)
K_p = Dermal Permeability Constant (cm/hr), see chem-tox database
ET_{event} = Exposure Time = 0.67 hr/event = NC DEQ default

t* = Time to Reach Steady State (hr) = EPA default = See chem-tox database
FA = Fraction Absorbed in Water (unitless) = EPA default = See chem-tox database
τ_{event} = Lag Time (hr/d) = EPA default = See chem-tox database
B = Relative Contribution of Permeability Coefficient = EPA default = See chem-tox database
THQ = Target hazard quotient = 0.2
AT = Averaging time = 9,125 days = EPA default
ED = Exposure duration = 25 years = EPA default
BW = Body weight = 80 kilograms = EPA default
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
EV = Worker events = 1 event/day, NC DEQ default
EF = Exposure frequency = 250 days/year = EPA default
SA = Skin surface area = 19,652 cm^2 = EPA default

Carcinogenic Non-Residential Worker Dermal Contact with Groundwater

FOR INORGANICS:

$$SL_{water\text{-}ca\text{-}der\text{-}w}(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}w}\left(\frac{0.71\ hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}w}\left(\frac{0.71\ hours}{event}\right) \le t^*\ (hours), \text{then } SL_{water\text{-}ca\text{-}der}(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}w}\left(\frac{0.71\ hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}w}\left(\frac{0.71\ hours}{event}\right) > t^*\ (hours), \text{then } SL_{water\text{-}nc\text{-}der\text{-}w}(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}w}\left(\frac{0.71\ hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right) = \frac{TR\times AT_w\ \left(\frac{365\ days}{year}\right)\times ED_w\ (70\ years)\times\left(\frac{1000\ \mu g}{mg}\right)\times BW_w\ (80\ kg)}{\left(\frac{CFS\ (mg/kg\text{-}d)^{-1}}{GIABS}\right)\times EV_w\ \left(\frac{1\ events}{day}\right)\times ED_w\ (25\ years)\times EF_w\ \left(\frac{250\ days}{year}\right)\times SA_w\ \left(19652\ cm^2\right)}$$

$SL_{water\text{-}ca\text{-}der\text{-}w}$ = Screening level for tap water, carcinogenic non-residential worker, dermal contact
DA_{event} = Absorbed Dose per Event ($\mu g/cm^2$-event)
K_p = Dermal Permeability Constant (cm/hr), see chem-tox database
ET_{event} = Exposure Time = 0.67 hr/event = NC DEQ default
t* = Time to Reach Steady State (hr) = EPA default = See chem-tox database
FA = Fraction Absorbed in Water (unitless) = EPA default = See chem-tox database
τ_{event} = Lag Time (hr/d) = EPA default = See chem-tox database

B = Relative Contribution of Permeability Coefficient = EPA default = See chem-tox database
TR = Target carcinogenic risk = 1.0E-6
AT = Averaging time = 25,550 days = EPA default
ED = Exposure duration = 25 years = EPA default
BW = Body weight = 80 kilograms adult = EPA default
CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
EV = Worker events = 1event/day NC DEQ default
EF = Exposure frequency = 250 days/year = EPA default
SA = Skin surface area = 19,652 cm^2 adult = EPA default

A.5.b. Resident Dermal Contact with Groundwater

Noncarcinogenic Resident Dermal Contact with Groundwater

<u>Child</u>

FOR INORGANICS:

$$SL_{water\text{-}nc\text{-}der\text{-}c}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\ event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right) \le t^*\ (hours), \text{then } SL_{water\text{-}nc\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\ event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right) > t^*\ (hours), \text{then } SL_{water\text{-}nc\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\ event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}\ event}\right) = \frac{THQ\times AT_{res\text{-}c}\left(\frac{365\ days}{year}\times ED_{res\text{-}c}\left(6\ years\right)\right)\times\left(\frac{1000\ \mu g}{mg}\right)\times BW_{res\text{-}c}\left(15\ kg\right)}{\left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)\times GIABS}\right)\times EV_{res\text{-}c}\left(\frac{1\ events}{day}\right)\times ED_{res\text{-}c}\left(6\ years\right)\times EF_{res\text{-}c}\left(\frac{350\ days}{year}\right)\times SA_{res\text{-}c}\left(6365\ cm^2\right)}$$

Adult

FOR INORGANICS:

$$SL_{water\text{-}nc\text{-}der\text{-}a}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\ event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right) \le t^*\ (hours), \text{then } SL_{water\text{-}nc\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\ event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right) > t^*\ (hours), \text{then } SL_{water\text{-}nc\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\ event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}\ event}\right) = \frac{THQ\times AT_{res\text{-}a}\left(\frac{365\ days}{year}\times ED_{res}\left(26\ years\right)\right)\times\left(\frac{1000\ \mu g}{mg}\right)\times BW_{res\text{-}a}\left(80\ kg\right)}{\left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)\times GIABS}\right)\times EV_{res\text{-}a}\left(\frac{1\ events}{day}\right)\times ED_{res}\left(26\ years\right)\times EF_{res\text{-}a}\left(\frac{350\ days}{year}\right)\times SA_{res\text{-}a}\left(19652\ cm^2\right)}$$

The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA RSLs. The exposure durations cancel out in this equation, so age adjustment is not applicable.

$SL_{water\text{-}nc\text{-}der\text{-}c}$ = Screening level for noncarcinogenic residential child water dermal contact
$SL_{water\text{-}nc\text{-}der\text{-}a}$ = Screening level for noncarcinogenic residential adult water dermal contact
DA_{event} = Absorbed Dose per Event ($\mu g/cm^2$-event)
K_p = Dermal Permeability Constant (cm/hr), see chem-tox database
ET_{event} = Exposure Time = 0.54 hr/event child and 0.71 hr/event adult = EPA default
t* = Time to Reach Steady State (hr) = EPA default = See chem-tox database
FA = Fraction Absorbed in Water (unitless) = EPA default = See chem-tox database
τ_{event} = Lag Time (hr/d) = EPA default = See chem-tox database
B = Relative Contribution of Permeability Coefficient = EPA default = See chem-tox database
TR = Target carcinogenic risk = 1.0E-6
AT = Averaging time = 2,190 days child and 9,490 days adult = EPA default
ED = Exposure duration = 6 years child and 26 years adult = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
EV = Resident events = 1 event/day = NC DEQ default
EF = Exposure frequency = 350 days/year = EPA default
SA = Skin surface area = 6,365 cm^2 child and 19,652 cm^2 adult = EPA default

Carcinogenic Resident Dermal Contact with Groundwater

Additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and trichloroethylene. The standard equation is listed below, followed by the alternative equations.

Standard Carcinogenic Equation for Resident Dermal Contact with Tap Water

FOR INORGANICS:

$$SL_{water\text{-}ca\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}$$

FOR ORGANICS:

$$IF\ ET_{event\text{-}res\text{-}adj}\left(\frac{hours}{event}\right) \le t^*\ (hours), then\ SL_{water\text{-}ca\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}{\pi}}}$$

or,

$$IF\ ET_{event\text{-}res\text{-}adj}\left(\frac{hours}{event}\right) > t^*\ (hours), then\ SL_{water\text{-}ca\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{- event}}\right) = \frac{TR\times AT_{res}\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right)\times DFW_{res\text{-}adj}\left(\frac{2{,}610{,}650\ events\text{-}cm^2}{kg}\right)}$$

where:

$$DFW_{res\text{-}adj}\left(\frac{2{,}610{,}650\ events\text{-}cm^2}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right)\times EV_{res\text{-}c}\left(\frac{1\ events}{day}\right)\times ED_{res\text{-}c}\left(6\ years\right)\times SA_{res\text{-}c}\left(6365\ cm^2\right)}{BW_{reswc}\left(15\ kg\right)}+\frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right)\times EV_{res\text{-}a}\left(\frac{1\ events}{day}\right)\times\left(ED_{res}\left(26\ years\right)-ED_{res\text{-}c}\left(6\ years\right)\right)\times SA_{res\text{-}a}\left(19652\ cm^2\right)}{BW_{res\text{-}a}\left(80\ kg\right)}\right)$$

and:

$$ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right) = \left(\frac{\left(ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right)\times ED_{res\text{-}c}\left(6\ years\right)+ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right)\times\left(ED_{res}\left(26\ years\right)-ED_{res\text{-}c}\left(6\ years\right)\right)\right)}{ED_{res}\left(26\ years\right)}\right)$$

$SL_{water\text{-}nc\text{-}der\text{-}w}$ = Screening level for tap water, carcinogenic resident, dermal contact
DA_{event} = Absorbed Dose per Event ($\mu g/cm^2$-event)
K_p = Dermal Permeability Constant (cm/hr), see chem-tox database
ET_{event} = Exposure Time = 0.54 hr/event child and 0.71 hr/event adult = EPA default
t* = Time to Reach Steady State (hr) = EPA default = See chem-tox database
FA = Fraction Absorbed in Water (unitless) = EPA default = See chem-tox database
τ_{event} = Lag Time (hr/d) = EPA default = See chem-tox database
B = Relative Contribution of Permeability Coefficient = EPA default = See chem-tox database
$DFW_{res\text{-}adj}$ = Resident water dermal contact factor- age-adjusted (cm^2 - event/kg)
TR = Target carcinogenic risk = 1.0E-6
AT = Averaging time = 25,550 days = EPA default
ED = Exposure duration = 6 years child and 20 years adult = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default

CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
EV = Resident events = 1 event/day = NC DEQ default
EF = Exposure frequency = 350 days/year = EPA default
SA = Skin surface area = 6,365 cm^2 child and 19,652 cm^2 adult = EPA default

Mutagenic Carcinogenic Equation for Resident Dermal Contact with Tap Water

FOR INORGANICS:

$$SL_{water\text{-}mu\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}res\text{-}madj}\left(\frac{0.6708\ hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}res\text{-}madj}\left(\frac{0.6708\ hours}{event}\right) \le t^*\ (hours), \text{then } SL_{water\text{-}mu\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}res\text{-}madj}\left(\frac{hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}res\text{-}madj}\left(\frac{0.6708\ hours}{event}\right) > t^*\ (hours), \text{then } SL_{water\text{-}mu\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}res\text{-}madj}\left(\frac{hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = \frac{TR\times AT_{res}\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right)\times DFWM_{res\text{-}adj}\left(\frac{8{,}191{,}633\ events\text{-}cm^2}{kg}\right)}$$

where:

$$DFWM_{res\text{-}adj}\left(\frac{8{,}191{,}633\ events\text{-}cm^2}{kg}\right) = \left[\begin{array}{l}\left(\frac{EV_{0\text{-}2}\left(\frac{1\ events}{day}\right)\times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right)\times ED_{0\text{-}2}\left(years\right)\times SA_{0\text{-}2}\left(6365\ cm^2\right)\times 10}{BW_{0\text{-}2}\left(15\ kg\right)}\right)+\\ \left(\frac{EV_{2\text{-}6}\left(\frac{1\ events}{day}\right)\times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right)\times ED_{2\text{-}6}\left(years\right)\times SA_{2\text{-}6}\left(6365\ cm^2\right)\times 3}{BW_{2\text{-}6}\left(15\ kg\right)}\right)+\\ \left(\frac{EV_{6\text{-}16}\left(\frac{1\ events}{day}\right)\times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right)\times ED_{6\text{-}16}\left(years\right)\times SA_{6\text{-}16}\left(19652\ cm^2\right)\times 3}{BW_{6\text{-}16}\left(80\ kg\right)}\right)+\\ \left(\frac{EV_{16\text{-}26}\left(\frac{1\ events}{day}\right)\times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right)\times ED_{16\text{-}26}\left(years\right)\times SA_{16\text{-}26}\left(19652\ cm^2\right)\times 1}{BW_{16\text{-}26}\left(80\ kg\right)}\right)\end{array}\right]$$

and:

$$ET_{event\text{-}res\text{-}madj}\left(\frac{0.6708\ hours}{event}\right) = \frac{\left(\begin{array}{l}ET_{event\text{-}res(0\text{-}2)}\left(\frac{0.54\ hours}{event}\right)\times ED_{0\text{-}2}\left(2\ years\right)+ET_{\ event\text{-}res(2\text{-}6)}\left(\frac{0.54\ hours}{event}\right)\times ED_{2\text{-}6}\left(4\ years\right)+\\ ET_{event\text{-}res(6\text{-}16)}\left(\frac{0.71\ hours}{event}\right)\times ED_{6\text{-}16}\left(10\ years\right)+ET_{\ event\text{-}res(16\text{-}26)}\left(\frac{0.71\ hours}{event}\right)\times ED_{16\text{-}26}\left(10\ years\right)\end{array}\right)}{ED_{0\text{-}2}\left(2\ years\right)+ED_{2\text{-}6}\left(4\ years\right)+ED_{6\text{-}16}\left(10\ years\right)+ED_{16\text{-}26}\left(10\ years\right)}$$

$SL_{res\text{-}soil\text{-}mu\text{-}der}$ = Screening level for carcinogenic residential water dermal contact for mutagenic compounds
$DFWM_{res\text{-}adj}$ = Age-adjusted resident mutagenic water dermal contact factor (events-cm^2/kg). Calculated via secondary equation in events-cm^2/kg
Remaining inputs are the same as the standard equation for carcinogenic resident tap water dermal contact.

Vinyl Chloride Carcinogenic Equation for Resident Dermal Contact with Tap water

$$\text{IF } ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right) \le t^{*}\ (hours), \text{then } SL_{water\text{-}vc\text{-}der}\ (\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\ event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right) > t^{*}\ (hours), \text{then } SL_{water\text{-}vc\text{-}der}\ (\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\ event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}\ event}\right) = \frac{TR}{\left(\frac{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right)\times DFW_{res\text{-}adj}\left(\frac{2{,}610{,}650\ events\text{-}cm^2}{kg}\right)}{AT_{res}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}\right)+\left(\frac{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right)\times EV_{res\text{-}c}\left(\frac{1\ events}{day}\right)\times SA_{res\text{-}c}\left(6365\ cm^2\right)}{BW_{res\text{-}c}\ (15\ kg)\times\left(\frac{1000\ \mu g}{mg}\right)}\right)}$$

where:

$$DFW_{res\text{-}adj}\left(\frac{2{,}610{,}650\ events\text{-}cm^2}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right)\times EV_{res\text{-}c}\left(\frac{1\ events}{day}\right)\times ED_{res\text{-}c}\ (6\ years)\times SA_{res\text{-}c}\left(6365\ cm^2\right)}{BW_{res\text{-}c}\ (15\ kg)}+\frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right)\times EV_{res\text{-}a}\left(\frac{1\ events}{day}\right)\times ED_{res\text{-}a}\ (20\ years)\times SA_{res\text{-}a}\left(19652\ cm^2\right)}{BW_{res\text{-}a}\ (80\ kg)}\right)$$

and:

$$ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right) = \left(\frac{\left(ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right)\times ED_{res\text{-}c}\ (6\ years)+ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right)\times\left(ED_{res}\ (26\ years)-ED_{res\text{-}c}\ (6\ years)\right)\right)}{ED_{res}\ (26\ years)}\right)$$

$SL_{water\text{-}vc\text{-}der}$ = Screening Level for carcinogenic resident tap water dermal contact for vinyl chloride
$DFW_{res\text{-}adj}$ = Residential mutagenic water contact factor for carcinogenic resident dermal contact for vinyl chloride
Remaining inputs are the same as the standard equation for carcinogenic resident tap water dermal contact.

Trichloroethylene Carinogenic Equation for Resident Dermal Contact with Water

FOR ORGANICS:

$$\text{IF } ET_{\text{event-res-adj}}\left(\frac{\text{hours}}{\text{event}}\right) \le t^{*}\ (\text{hours}), \text{then } SL_{\text{water-tce-der}}\ (\mu g/L) = \frac{DA_{\text{tce-event}}\left(\frac{ug}{cm^2\text{- event}}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{2 \times FA \times K_p\left(\frac{cm}{hour}\right) \sqrt{\frac{6 \times \tau_{\text{event}}\left(\frac{\text{hours}}{\text{event}}\right) \times ET_{\text{event-res-adj}}\left(\frac{0.6708\ \text{hours}}{\text{event}}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{\text{event-res-adj}}\left(\frac{\text{hours}}{\text{event}}\right) > t^{*}\ (\text{hours}), \text{then } SL_{\text{water-tce-der}}\ (\mu g/L) = \frac{DA_{\text{tce-event}}\left(\frac{ug}{cm^2\text{- event}}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{FA \times K_p\left(\frac{cm}{hour}\right) \times \left[\frac{ET_{\text{event-res-adj}}\left(\frac{0.6708\ \text{hours}}{\text{event}}\right)}{1+B} + 2 \times \tau_{\text{event}}\left(\frac{\text{hours}}{\text{event}}\right) \times \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{\text{tce-event}}\left(\frac{ug}{cm^2\text{- event}}\right) = \frac{TR \times AT_{\text{res}}\left(\frac{365\ \text{days}}{\text{year}} \times LT\ (70\ \text{years})\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{\frac{CSF_o\left(\frac{mg}{kg\text{-day}}\right)^{-1}}{GIABS} \times \left(\left(CAF_o\ (0.804) \times DFW_{\text{res-adj}}\left(\frac{2{,}610{,}650\ \text{events - } cm^2}{kg}\right)\right) + \left(MAF_o\ (0.202) \times DFWM_{\text{res-adj}}\left(\frac{8{,}191{,}633\ \text{events - } cm^2}{kg}\right)\right)\right)}$$

where:

$$DFW_{\text{res-adj}}\left(\frac{2{,}610{,}650\ \text{events - } cm^2}{kg}\right) = \left(\frac{EV_{\text{res-c}}\left(\frac{1\ \text{events}}{\text{day}}\right) \times ED_{\text{res-c}}\ (6\ \text{years}) \times EF_{\text{res-c}}\left(\frac{350\ \text{days}}{\text{year}}\right) \times SA_{\text{res-c}}\left(6365\ cm^2\right)}{BW_{\text{res-c}}\ (15\ kg)} + \frac{EV_{\text{res-a}}\left(\frac{1\ \text{events}}{\text{day}}\right) \times ED_{\text{res-a}}\ (20\ \text{years}) \times EF_{\text{res-a}}\left(\frac{350\ \text{days}}{\text{year}}\right) \times SA_{\text{res-a}}\left(19652\ cm^2\right)}{BW_{\text{res-a}}\ (80\ kg)}\right)$$

where:

$$DFWM_{\text{res-adj}}\left(\frac{8{,}191{,}633\ \text{events - } cm^2}{kg}\right) = \left[\begin{array}{l} \left(\frac{EV_{0\text{-}2}\left(\frac{1\ \text{events}}{\text{day}}\right) \times ED_{0\text{-}2}\ (2\ \text{years}) \times EF_{0\text{-}2}\left(\frac{350\ \text{days}}{\text{year}}\right) \times SA_{0\text{-}2}\left(6365\ cm^2\right) \times 10}{BW_{0\text{-}2}\ (15\ kg)}\right) + \\ \left(\frac{EV_{2\text{-}6}\left(\frac{1\ \text{events}}{\text{day}}\right) \times ED_{2\text{-}6}\ (4\ \text{years}) \times EF_{2\text{-}6}\left(\frac{350\ \text{days}}{\text{year}}\right) \times SA_{2\text{-}6}\left(6365\ cm^2\right) \times 3}{BW_{2\text{-}6}\ (15\ kg)}\right) + \\ \left(\frac{EV_{6\text{-}16}\left(\frac{1\ \text{events}}{\text{day}}\right) \times ED_{6\text{-}16}\ (10\ \text{years}) \times EF_{6\text{-}16}\left(\frac{350\ \text{days}}{\text{year}}\right) \times SA_{6\text{-}16}\left(19652\ cm^2\right) \times 3}{BW_{6\text{-}16}\ (80\ kg)}\right) + \\ \left(\frac{EV_{16\text{-}26}\left(\frac{1\ \text{events}}{\text{day}}\right) \times ED_{16\text{-}26}\ (10\ \text{years}) \times EF_{16\text{-}26}\left(\frac{350\ \text{days}}{\text{year}}\right) \times SA_{16\text{-}26}\left(19652\ cm^2\right) \times 1}{BW_{16\text{-}26}\ (80\ kg)}\right) \end{array}\right]$$

and:

$$ET_{\text{event-res-adj}}\left(\frac{0.6708\ \text{hours}}{\text{event}}\right) = \frac{\left(\begin{array}{l} ET_{\text{event-res}(0\text{-}2)}\left(\frac{0.54\ \text{hours}}{\text{event}}\right) \times ED_{0\text{-}2}\ (2\ \text{years}) + ET_{\text{event-res}(2\text{-}6)}\left(\frac{0.54\ \text{hours}}{\text{event}}\right) \times ED_{2\text{-}6}\ (4\ \text{years}) + \\ ET_{\text{event-res}(6\text{-}16)}\left(\frac{0.71\ \text{hours}}{\text{event}}\right) \times ED_{6\text{-}16}\ (10\ \text{years}) + ET_{\text{event-res}(16\text{-}26)}\left(\frac{0.71\ \text{hours}}{\text{event}}\right) \times ED_{16\text{-}26}\ (10\ \text{years}) \end{array}\right)}{ED_{0\text{-}2}\ (2\ \text{years}) + ED_{2\text{-}6}\ (4\ \text{years}) + ED_{6\text{-}16}\ (10\ \text{years}) + ED_{16\text{-}26}\ (10\ \text{years})}$$

$SL_{\text{es-soil-tce-der}}$ = Screening Level for carcinogenic resident tap water dermal contact for trichloroethylene
$DFWM_{\text{res-adj}}$ = Residential mutagenic tap water contact factor for carcinogenic resident dermal contact for trichloroethylene
CAF_o = Cancer adjustment factor oral = 0.804 = EPA default
MAF_o = Mutagenic adjustment factor oral = 0.202 = EPA default
Remaining inputs are the same as the standard equation for carcinogenic resident tap water dermal contact.

A.6 GROUNDWATER (TAP WATER) VAPOR INHALATION PATHWAY

A.6.a. Non-Residential Worker Groundwater (tap water) Vapor Indoor Inhalation

Noncarcinogenic Non-Residential Worker Groundwater (tap water) Vapor Indoor Inhalation

$$SL_{water\text{-}nc\text{-}inh\text{-}w}(\mu g/L) = \frac{THQ \times AT_W \left(\frac{365\ days}{year} \times ED_W\ (25\ years)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_W \left(\frac{250\ days}{year}\right) \times ED_W\ (25\ years) \times ET_W \left(\frac{8\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(\frac{mg}{m^3}\right)} \times K\left(\frac{0.5\ L}{m^3}\right)}$$

$SL_{water\text{-}nc\text{-}inh\text{-}w}$ = Screening level for noncarcinogenic non-residential worker exposure to vapors from tap water use
THQ = Target hazard quotient = 0.2
AT = Averaging time = 9,125 days = EPA default
ED = Exposure duration = 25 years = EPA default
EF = Exposure frequency = 250 days/year = EPA default
ET = Exposure time = 8 hours/day = EPA default
RfC = Chronic inhalation reference concentration (mg/m^3), see chem-tox database
K = Andelman Volatiliztion Factor = 0.5 L/m^3

Carcinogenic Non-Residential Worker Groundwater (tap water) Vapor Indoor Inhalation

$$SL_{water\text{-}ca\text{-}inh}(\mu g/L) = \frac{TR \times AT_W \left(\frac{365\ days}{year} \times LT\ (70\ years)\right)}{EF_W \left(\frac{250\ days}{year}\right) \times ED_W\ (25\ years) \times ET_W \left(\frac{8\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times K\left(\frac{0.5\ L}{m^3}\right)}$$

$SL_{water\text{-}ca\text{-}inh}$ = Screening level for carcinogenic non-residential worker tap water vapor exposure
TR = Target carcinogenic risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
EF = Exposure frequency = 250 days/year = EPA default
ED = Exposure duration = 25 years = EPA default
ET = Exposure time = 8 hours/day = EPA default
IUR = Chronic inhalation unit risk (mg/m^3), see chem-tox database
K = Andelman Volatiliztion Factor = 0.5 L/m^3

A.6.b. Residential Indoor Groundwater (tap water) Vapor Inhalation

Noncarcinogenic Residential Indoor Groundwater (tap water) Vapor Inhalation

Child

$$SL_{water\text{-}nc\text{-}inh\text{-}c}\left(\mu g/L\right) = \frac{THQ \times AT_{res\text{-}c}\left(\frac{365\ days}{year} \times ED_{res\text{-}c}\left(6\ years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\left(6\ years\right) \times ET_{res\text{-}c}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(\frac{mg}{m^3}\right)} \times K\left(\frac{0.5\ L}{m^3}\right)}$$

Adult

$$SL_{water\text{-}nc\text{-}inh\text{-}a}\left(\mu g/L\right) = \frac{THQ \times AT_{res\text{-}a}\left(\frac{365\ days}{year} \times ED_{res}\left(26\ years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times ED_{res}\left(26\ years\right) \times ET_{res\text{-}a}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(\frac{mg}{m^3}\right)} \times K\left(\frac{0.5\ L}{m^3}\right)}$$

Since the only difference in the child and adult equations is the exposure duration and that cancels out, these equations are the same.

$SL_{water\text{-}nc\text{-}inh\text{-}c}$ = Screening level for noncarcinogenic resident child tap water to indoor air
$SL_{water\text{-}nc\text{-}inh\text{-}a}$ = Screening level for noncarcinogenic resident adult tap water to indoor air
THQ = Target hazard quotient = 0.2
AT = Averaging time = 2,190 days child and 9,490 days adult = EPA default
ED = Exposure duration = 6 years child, 26 years adult = EPA default
EF = Exposure frequency = 350 days/year = EPA default
ET = Exposure time = 24 hours/day = EPA default
RfC = Chronic inhalation reference concentration (mg/m^3), see chem-tox database
K = Andelman Volatiliztion Factor = $0.5L/m^3$

Carcinogenic Residential Indoor Groundwater (tap water) Vapor Inhalation

$$SL_{water\text{-}ca\text{-}inh}\left(\mu g/L\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{EF_{res}\left(\frac{350\ days}{year}\right) \times ED_{res}\left(26\ years\right) \times ET_{res}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times K\left(\frac{0.5\ L}{m^3}\right)}$$

$SL_{water\text{-}ca\text{-}inh}$ = Screening level for carcinogenic resident tap water to indoor air
TR = Target carcinogenic risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
EF = Exposure frequency = 350 days/year = EPA default

ED = Exposure duration = 26 years = EPA default
ET = Exposure time = 24 hours/day = EPA default
IUR = Chronic inhalation unit risk (mg/m^3), see chem-tox database
K = Andelman Volatiliztion Factor = 0.5 L/m^3

Additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and trichloroethylene.

Mutagenic Carcinogenic Equation for Resident Groundwater (tap water) Vapor Inhalation

$$SL_{water\text{-}mu\text{-}inh}\,(\mu g/L) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times K\left(\frac{0.5\ L}{m^3}\right) \times \left(\begin{array}{l}\left(EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times ED_{0\text{-}2}\,(years) \times 10\right) + \\ \left(EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times ED_{2\text{-}6}\,(years) \times 3\right) + \\ \left(EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ET_{6\text{-}16}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times ED_{6\text{-}16}\,(years) \times 3\right) + \\ \left(EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ET_{16\text{-}26}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times ED_{16\text{-}26}\,(years) \times 1\right)\end{array}\right)}$$

$SL_{water\text{-}mu\text{-}inh}$ = Screening level for carcinogenic resident tap water to indoor air for mutagens
Remaining inputs are the same as the standard equation for carcinogenic resident indoor air.

Vinyl Chloride Equation for Resident Groundwater (tap water) Vapor Inhalation

$$SL_{water\text{-}ca\text{-}vc\text{-}inh}\,(\mu g/L) = \frac{TR}{\left(\frac{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times EF_{res}\left(\frac{350\ days}{year}\right) \times ED_{res}\,(26\ years) \times ET_{res}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times K\left(\frac{0.5\ L}{m^3}\right)}{AT_{res}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}\right) + \left(IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times K\left(\frac{0.5\ L}{m^3}\right)\right)}$$

$SL_{water\text{-}ca\text{-}vc\text{-}inh}$ = Screening level for carcinogenic resident tap water to indoor air for vinyl chloride
Remaining inputs are the same as the standard equation for carcinogenic resident indoor air.

Trichloroethylene Carcinogenic Equation for Resident Groundwater (tap water) Vapor Inhalation

$$SL_{water\text{-}tce\text{-}inh}\left(\mu g/L\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times K\left(\frac{0.5\ L}{m^3}\right) \times \left(\left(EF_{res}\left(\frac{350\ days}{year}\right) \times ED_{res}\left(26\ years\right) \times ET_{res}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times CAF_i\left(0.756\right)\right) + \left(\left(\left(ED_{0\text{-}2}\left(2\ years\right) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times MAF_i\left(0.244\right) \times 10\right) + \left(ED_{2\text{-}6}\left(4\ years\right) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times MAF_i\left(0.244\right) \times 3\right) + \left(ED_{6\text{-}16}\left(10\ years\right) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ET_{6\text{-}16}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times MAF_i\left(0.244\right) \times 3\right) + \left(ED_{16\text{-}26}\left(10\ years\right) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ET_{16\text{-}26}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times MAF_i\left(0.244\right) \times 1\right)\right)\right)\right)}$$

$SL_{water\text{-}tce\text{-}inh}$ = Screening level for carcinogenic resident tap water to indoor air for trichloroethylene
CAF_i = Cancer adjustment factor inhalation = 0.756 = EPA default
MAF_i = Mutagenic adjustment factor oral = 0.244 = EPA default
Remaining inputs are the same as the standard equation for carcinogenic resident indoor air.

A.7 SURFACE WATER INGESTION PATHWAY

A.7.a. User Defined (Recreator/Trespasser) Surface Water Ingestion

Noncarcinogenic Recreator Surface Water Ingestion

Child

$$SL_{rec\text{-}water\text{-}nc\text{-}ing\text{-}c}\left(\mu g/L\right) = \frac{THQ \times AT_{rec\text{-}c}\left(\frac{365\ days}{year} \times ED_{rec\text{-}c}\left(years\right)\right) \times BW_{rec\text{-}c}\left(15\ kg\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ED_{rec\text{-}c}\left(years\right) \times \frac{1}{RfD_o\left(\frac{mg}{kg\text{-}d}\right)} \times IRW_{rec\text{-}c}\left(\frac{0.12\ L}{hour}\right) \times EV_{rec\text{-}c}\left(\frac{events}{day}\right) \times ET_{rec\text{-}c}\left(\frac{hours}{event}\right)}$$

Adult

$$SL_{rec\text{-}water\text{-}nc\text{-}ing\text{-}a}\left(\mu g/L\right) = \frac{THQ \times AT_{rec\text{-}a}\left(\frac{365\ days}{year} \times ED_{rec\text{-}a}\left(years\right)\right) \times BW_{rec\text{-}a}\left(80\ kg\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ED_{rec\text{-}a}\left(years\right) \times \frac{1}{RfD_o\left(\frac{mg}{kg\text{-}d}\right)} \times IRW_{rec\text{-}a}\left(\frac{0.11\ L}{hour}\right) \times EV_{rec\text{-}a}\left(\frac{events}{day}\right) \times ET_{rec\text{-}a}\left(\frac{hours}{event}\right)}$$

The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA calculator. The exposure durations cancel out in this equation, so age adjustment is not applicable.

$SL_{rec\text{-}water\text{-}nc\text{-}ing\text{-}c}$ = Screening level for noncarcinogenic recreator child surface water ingestion
$SL_{rec\text{-}water\text{-}nc\text{-}ing\text{-}a}$ = Screening level for noncarcinogenic recreator adult surface water ingestion
THQ = Target hazard quotient = 0.2
AT = Averaging time = 2,190 days child and 9,490 days adult = EPA default
ED = Exposure duration = 6 years child, 26 years adult = EPA default
BW = Body weight = 15 kilograms child, 80 kilograms adult = EPA default
EF = Exposure frequency recreator = 90 days/year = NC DEQ default
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
IRW = Ingestion rate surface water = 0.12 L/hr child, 0.11 L/hr adult = EPA default
EV = Events Frequency = 1 event/day = NC DEQ default
ET = Exposure Time = 2 hour/event = NC DEQ default

Noncarcinogenic Trespasser Surface Water Ingestion

Adolescent

$$SL_{rec\text{-}water\text{-}nc\text{-}ing\text{-}a}\left(\mu g/L\right) = \frac{THQ \times AT_{rec\text{-}a}\left(\frac{365\ days}{year} \times ED_{rec\text{-}a}\left(years\right)\right) \times BW_{rec\text{-}a}\left(45\ kg\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ED_{rec\text{-}a}\left(years\right) \times \frac{1}{RfD_o\left(\frac{mg}{kg\text{-}d}\right)} \times IRW_{rec\text{-}a}\left(\frac{0.124\ L}{hour}\right) \times EV_{rec\text{-}a}\left(\frac{events}{day}\right) \times ET_{rec\text{-}a}\left(\frac{hours}{event}\right)}$$

$SL_{rec\text{-}water\text{-}nc\text{-}ing\text{-}a}$ = Screening level for noncarcinogenic trespasser adolescent surface water ingestion
THQ = Target hazard quotient = 0.2
AT = Averaging time = 3,650 days = EPA Region 4 Guidance
ED = Exposure duration = 10 years adolescent = EPA Region 4 Guidance
BW = Body weight = 45 kilograms adolescent = EPA Region 4 Guidance
EF = Exposure frequency trespasser = 45 days/year = NC DEQ default
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
IRW = Ingestion rate surface water = 0.124 L/hr = EPA default
EV = Events Frequency = 1 event/day = NC DEQ default
ET = Exposure Time = 2 hour/event = NC DEQ default

Carcinogenic Recreator/Trespasser Surface Water Ingestion

Standard Carcinogenic Equation for Recreator/Trespasser Surface Water Ingestion

$$SL_{rec\text{-}water\text{-}ca\text{-}ing}\left(\mu g/L\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right)}$$

where:

$$IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right) = \left(\frac{EV_{rec\text{-}c}\left(\frac{events}{day}\right) \times ED_{rec\text{-}c}\left(years\right) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ET_{rec\text{-}c}\left(\frac{hours}{event}\right) \times IRW_{rec\text{-}c}\left(\frac{0.12\ L}{hour}\right)}{BW_{rec\text{-}c}\left(15\ kg\right)} + \frac{EV_{rec\text{-}a}\left(\frac{events}{day}\right) \times ED_{rec\text{-}a}\left(years\right) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ET_{rec\text{-}a}\left(\frac{hours}{event}\right) \times IRW_{rec\text{-}a}\left(\frac{0.11\ L}{hour}\right)}{BW_{rec\text{-}a}\left(80\ kg\right)}\right)$$

$SL_{rec\text{-}waterr\text{-}ca\text{-}ing}$ = Screening level for carcinogenic recreator/trespasser surface water ingestion
TR = Target risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
CSF = Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$, see chem-tox database

$IFW_{rec\text{-}adj}$ = Age adjusted surface water ingestion rate (L/kg), calculated via secondary equation
EV = Events Frequency = 1 event/day = NC DEQ default
ED = Exposure duration recreator = 6 years child and 20 years adult = EPA default
ED = Exposure duration trespasser = 10 years (adolescent) = NC DEQ default
EF = Exposure frequency = 90 days/year for child and adult recreators = NC DEQ default
EF = Exposure frequency = 45 days/year for trespasser (adolescent) = EPA DEQ default
ET = Exposure Time = 2 hour/event = NC DEQ default
IRW = Ingestion rate surface water = 0.12 L/hr child, 0.11 L/hr adult = EPA default, 0.11 L/hr adolescent = NC DEQ default
BW = Body weight = 15 kilograms child and 80 kilograms adult recreators = EPA default
BW = Body weight = 45 kilograms adolescent trespasser = EPA Region 4 Guidance

Mutagenic Carcinogenic Equation for Recreator/Trespasser Surface Water Ingestion

$$SL_{rec\text{-}water\text{-}mu\text{-}ing}(\mu g/L) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT(70\ years)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times IFWM_{rec\text{-}adj}\left(\frac{L}{kg}\right)}$$

where:

$$IFWM_{rec\text{-}adj}\left(\frac{L}{kg}\right) = \left(\frac{ED_{0\text{-}2}(years) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times IRW_{0\text{-}2}\left(\frac{0.12\ L}{hour}\right) \times EV_{0\text{-}2}\left(\frac{events}{day}\right) \times ET_{0\text{-}2}\left(\frac{hours}{event}\right) \times 10}{BW_{0\text{-}2}(15\ kg)} + \frac{ED_{2\text{-}6}(years) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times IRW_{2\text{-}6}\left(\frac{0.12\ L}{hour}\right) \times EV_{2\text{-}6}\left(\frac{events}{day}\right) \times ET_{2\text{-}6}\left(\frac{hours}{event}\right) \times 3}{BW_{2\text{-}6}(15\ kg)} + \frac{ED_{6\text{-}16}(years) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times IRW_{6\text{-}16}\left(\frac{0.11\ L}{hour}\right) \times EV_{6\text{-}16}\left(\frac{events}{day}\right) \times ET_{6\text{-}16}\left(\frac{hours}{event}\right) \times 3}{BW_{6\text{-}16}(80\ kg)} + \frac{ED_{16\text{-}26}(years) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times IRW_{16\text{-}26}\left(\frac{0.11\ L}{hour}\right) \times EV_{16\text{-}26}\left(\frac{events}{day}\right) \times ET_{16\text{-}26}\left(\frac{hours}{event}\right) \times 1}{BW_{16\text{-}26}(80\ kg)}\right)$$

Some cancer-causing chemicals operate by a mutagenic mode of action which would exhibit a greater effect in early-life exposure. To account for this difference, a separate equation is used to calculate cancer risk posed by mutagens. The mutagenic equation adds an age-dependent adjustment factor (ADAF) to account for increased childhood risk for mutagenic compounds. The adjustment factor is ten for the 0 to 2-year age range, three for the 2 to 6-year age range, three for the 6 to 16-year age range, and one for the 16 to 26-year age range. The remaining portions of the equation are similar to the standard carcinogenic equation.

$SL_{rec\text{-}water\text{-}mu\text{-}ing}$ = Screening level for carcinogenic recreator/trespasser surface water ingestion for mutagenic compounds
$IFWM_{rec\text{-}adj}$ = Age-adjusted recreator/trespasser mutagenic surface water ingestion rate, calculated via secondary equation
Remaining inputs are the same as the standard equation for carcinogenic surface water ingestion.

Vinyl Chloride Carcinogenic Equation for Recreator/Trespasser Soil Ingestion

$$SL_{rec\text{-}water\text{-}ca\text{-}vc\text{-}ing}\left(\mu g/L\right)=\frac{TR}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}\times IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right)\times\left(\frac{mg}{1000\ \mu g}\right)}{AT_{rec}\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)}\right)+\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}\times ET_{rec\text{-}c}\left(\frac{hr}{day}\right)\times IRW_{rec\text{-}c}\ \frac{0.12\ L}{hour}\times\left(\frac{mg}{1000\ \mu g}\right)}{BW_{rec\text{-}c}\left(15\ kg\right)}\right)}$$

where:

$$IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right)=\left(\frac{EV_{rec\text{-}c}\left(\frac{events}{day}\right)\times ED_{rec\text{-}c}\left(years\right)\times EF_{rec\text{-}c}\left(\frac{days}{year}\right)\times ET_{rec\text{-}c}\left(\frac{hours}{event}\right)\times IRW_{rec\text{-}c}\left(\frac{0.12\ L}{hour}\right)}{BW_{rec\text{-}c}\left(15\ kg\right)}+\frac{EV_{rec\text{-}a}\left(\frac{events}{day}\right)\times ED_{rec\text{-}a}\left(years\right)\times EF_{rec\text{-}a}\left(\frac{days}{year}\right)\times ET_{rec\text{-}a}\left(\frac{hours}{event}\right)\times IRW_{rec\text{-}a}\left(\frac{0.11\ L}{hour}\right)}{BW_{rec\text{-}a}\left(80\ kg\right)}\right)$$

Vinyl chloride is a mutagenic compound with sufficient chemical-specific data to directly evaluate carcinogenic exposure through a mutagenic mode of action, in contrast to compounds with insufficient chemical-specific data which are assessed using the default mutagenic equation. Therefore, vinyl chloride has a unique set of equations for residential carcinogenic risk.

$SL_{rec\text{-}water\text{-}ca\text{-}vc\text{-}ing}$ = Screening level for carcinogenic recreator/trespasser surface water ingestion for vinyl chloride
Remaining inputs are the same as the standard equation for carcinogenic resident surface water ingestion.

Trichloroethylene Carcinogenic Equation for Recreational Surface Water Ingestion

$$\text{water-tce-ing}\left(\mu g/L\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} x \left(\left(CAF_o\ (0.804) \times IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right)\right)\right) + \left(MAF_o\ (0.202) \times IFWM_{rec\text{-}adj}\left(\frac{L}{kg}\right)\right)}$$

where:

$$IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right) = \left(\frac{EV_{rec\text{-}c}\left(\frac{events}{day}\right) \times ED_{rec\text{-}c}\left(years\right) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ET_{rec\text{-}c}\left(\frac{hours}{event}\right) \times IRW_{rec\text{-}c}\left(\frac{0.12\ L}{hour}\right)}{BW_{rec\text{-}c}\left(15\ kg\right)} + \frac{EV_{rec\text{-}a}\left(\frac{events}{day}\right) \times ED_{rec\text{-}a}\left(years\right) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ET_{rec\text{-}a}\left(\frac{hours}{event}\right) \times IRW_{rec\text{-}a}\left(\frac{0.11\ L}{hour}\right)}{BW_{rec\text{-}a}\left(80\ kg\right)}\right)$$

where:

$$IFWM_{rec\text{-}adj}\left(\frac{L}{kg}\right) = \left(\begin{array}{l} \frac{ED_{0\text{-}2}\left(years\right) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times IRW_{0\text{-}2}\left(\frac{0.12\ L}{hour}\right) \times EV_{0\text{-}2}\left(\frac{events}{day}\right) \times ET_{0\text{-}2}\left(\frac{hours}{event}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \\ \frac{ED_{2\text{-}6}\left(years\right) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times IRW_{2\text{-}6}\left(\frac{0.12\ L}{hour}\right) \times EV_{2\text{-}6}\left(\frac{events}{day}\right) \times ET_{2\text{-}6}\left(\frac{hours}{event}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \\ \frac{ED_{6\text{-}16}\left(years\right) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times IRW_{6\text{-}16}\left(\frac{0.11\ L}{hour}\right) \times EV_{6\text{-}16}\left(\frac{events}{day}\right) \times ET_{6\text{-}16}\left(\frac{hours}{event}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \\ \frac{ED_{16\text{-}26}\left(years\right) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times IRW_{16\text{-}26}\left(\frac{0.11\ L}{hour}\right) \times EV_{16\text{-}26}\left(\frac{events}{day}\right) \times ET_{16\text{-}26}\left(\frac{hours}{event}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)} \end{array}\right)$$

For trichloroethylene, EPA recommends that kidney risk be assessed using a mutagenic equation and that liver and non-Hodgkin lymphoma (NHL) risk be assessed using the standard cancer equations. EPA has developed adjustment factors that account for the different toxicity factors. The liver and NHL risks are evaluated using the standard cancer equations and a cancer adjustment factor (CAF). The kidney risk is evaluated using the mutagenic cancer equations and a mutagenic adjustment factor (MAF).

$SL_{rec\text{-}water\text{-}tce\text{-}ing}$ = Screening Level for carcinogenic recreator/trespasser surface water ingestion for trichloroethylene
$IFW_{rec\text{-}adj}$ = Age-adjusted recreator/trespasser mutagenic surface water ingestion rate, calculated via secondary equation in L/kg
CAF_o = Cancer adjustment factor oral = 0.804 = EPA default
MAF_o = Mutagenic adjustment factor oral = 0.202 = EPA default
Remaining inputs are the same as the standard equation for carcinogenic recreator/trespasser surface water ingestion

A.8 DERMAL CONTACT WITH SURAFCE WATER PATHWAY

A.8.a. User Defined (Recreator/Trespasser) Dermal Contact with Surface Water

Noncarcinogenic Dermal Contact with Surface Water

Child

FOR INORGANICS:

$$SL_{rec\text{-}water\text{-}nc\text{-}der\text{-}c}\left(\mu g/L\right)=\frac{DA_{event}\left(\frac{ug}{cm^2\text{- }event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}rec\text{-}c}\left(\frac{hours}{event}\right)}$$

FOR ORGANICS:

$$IF\ ET_{event\text{-}rec\text{-}c}\left(\frac{hours}{event}\right)\le t^*\left(hour\right),then\ SL_{rec\text{-}water\text{-}nc\text{-}der}\left(\mu g/L\right)=\frac{DA_{event}\left(\frac{ug}{cm^2\text{- }event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times\tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}rec\text{-}c}\left(\frac{hours}{event}\right)}{\pi}}}$$

or,

$$IF\ ET_{event\text{-}rec\text{-}c}\left(\frac{hours}{event}\right)>t^*\left(hour\right),then\ SL_{rec\text{-}water\text{-}nc\text{-}der}\left(\mu g/L\right)=\frac{DA_{event}\left(\frac{ug}{cm^2\text{- }event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}rec\text{-}c}\left(\frac{hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{\left(1+B\right)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{- }event}\right)=\frac{THQ\times AT_{rec\text{-}c}\left(\frac{365\ days}{year}\times ED_{rec\text{-}c}\left(years\right)\right)\times\left(\frac{1000\ \mu g}{mg}\right)\times BW_{rec\text{-}c}\left(15\ kg\right)}{\left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)\times GIABS}\right)\times EV_{rec\text{-}c}\left(\frac{events}{day}\right)\times ED_{rec\text{-}c}\left(years\right)\times EF_{rec\text{-}c}\left(\frac{days}{year}\right)\times SA_{rec\text{-}c}\left(6365\ cm^2\right)}$$

Adult/Adolescent

FOR INORGANICS:

$$SL_{rec\text{-}water\text{-}nc\text{-}der\text{-}a}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}rec\text{-}c}\left(\frac{hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}rec\text{-}a}\left(\frac{hours}{event}\right) \le t^*\,(hour), \text{then } SL_{rec\text{-}water\text{-}nc\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times\tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}rec\text{-}a}\left(\frac{hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}rec\text{-}a}\left(\frac{hours}{event}\right) > t^*\,(hour), \text{then } SL_{rec\text{-}water\text{-}nc\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}rec\text{-}a}\left(\frac{hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = \frac{THQ\times AT_{rec\text{-}a}\left(\frac{365\ days}{year}\times ED_{rec\text{-}a}\,(years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)\times BW_{rec\text{-}a}\,(80\ kg)}{\left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)\times GIABS}\right)\times EV_{rec\text{-}a}\left(\frac{events}{day}\right)\times ED_{rec\text{-}a}\,(years)\times EF_{rec\text{-}a}\left(\frac{days}{year}\right)\times SA_{rec\text{-}a}\left(19652\ cm^2\right)}$$

The child and adult recreator, and the adolescent trespasser equations are the same. Inputs vary as noted below. For the recreators, the child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA calculator. The exposure durations cancel out in this equation, so age adjustment is not applicable.

$SL_{rec\text{-}water\text{-}nc\text{-}der\text{-}c}$ = Screening level for surface water, recreator, noncarcinogenic child, dermal contact
$SL_{rec\text{-}water\text{-}nc\text{-}der\text{-}a}$ = Screening level, surface water, for noncarcinogenic adult recreator dermal contact or adolescent trespasser
DA_{event} = Absorbed Dose per Event ($\mu g/cm^2$-event)
K_p = Dermal Permeability Constant (cm/hr), see chem-tox database
ET_{event} = Exposure Time = 2 hr/event = NC DEQ default
t* = Time to Reach Steady State (hr) = EPA default = See chem-tox database
FA = Fraction Absorbed in Water (unitless) = EPA default = See chem-tox database
τ_{event} = Lag Time (hr/d) = EPA default = See chem-tox database
B = Relative Contribution of Permeability Coefficient = EPA default = See chem-tox database
THQ = Target hazard quotient = 0.2
AT = Averaging time = 2,190 days child and 9,490 days adult = EPA default
AT = Averaging time = 3,650 days adolescent = EPA Region 4 Guidance
ED = Exposure duration = 6 years child, 26 years adult = EPA default
ED = Exposure duration = 10 years adolescent = EPA Region 4 Guidance

BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default
BW = Body weight = 45 kilograms adolescent = EPA Region 4 Guidance
RfD = Chronic oral reference dose (mg/kg-day), see chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
EV = Recreator events = 1 event/day NC DEQ default
EF = Exposure frequency = 90 days/year for recreators, 45 days/year trespasser = NC DEQ default
SA = Skin surface area = 6,365 cm^2 child and 19,652 cm^2 adult and trespasser = EPA default

Carcinogenic Dermal Contact with Surface Water

Child and adult recreator, and the adolescent trespasser equations are the same. Inputs vary as noted. Additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and trichloroethylene. The standard equation is listed below, followed by the alternative equations.

FOR INORGANICS:

$$SL_{rec\text{-}water\text{-}ca\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right)}$$

FOR ORGANICS:

$$IF\ ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right) \le t^*\ (hour), then\ SL_{rec\text{-}water\text{-}ca\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right)}{\pi}}}$$

or,

$$IF\ ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right) > t^*\ (hour), then\ SL_{rec\text{-}water\text{-}ca\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = \frac{TR\times AT_{rec}\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right)\times DFW_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right)}$$

where:

$$DFW_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right) = \left(\frac{EV_{rec\text{-}c}\left(\frac{events}{day}\right)\times ED_{rec\text{-}c}\left(years\right)\times EF_{rec\text{-}c}\left(\frac{days}{year}\right)\times SA_{rec\text{-}c}\left(6365\ cm^2\right)}{BW_{rec\text{-}c}\left(15\ kg\right)}+\frac{EV_{rec\text{-}a}\left(\frac{events}{day}\right)\times ED_{rec\text{-}a}\left(years\right)\times EF_{rec\text{-}a}\left(\frac{days}{year}\right)\times SA_{rec\text{-}a}\left(19652\ cm^2\right)}{BW_{rec\text{-}a}\left(80\ kg\right)}\right)$$

and:

$$ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right) = \left(\frac{\left(ET_{event\text{-}rec\text{-}c}\left(\frac{hours}{event}\right)\times ED_{rec\text{-}c}\left(years\right)+ET_{event\text{-}rec\text{-}a}\left(\frac{hours}{event}\right)\times ED_{rec\text{-}a}\left(years\right)\right)}{ED_{rec\text{-}c}\left(years\right)+ED_{rec\text{-}a}\left(years\right)}\right)$$

$SL_{rec\text{-}water\text{-}ca\text{-}der}$ = Screening level for carcinogenic recreator/trespasser surface water dermal contact
DA_{event} = Absorbed Dose per Event ($\mu g/cm^2$-event)
K_p = Dermal Permeability Constant (cm/hr), see chem-tox database
ET_{event} = Exposure Time = 2 hr/event = NC DEQ default
t* = Time to Reach Steady State (hr) = EPA default = See chem-tox database
FA = Fraction Absorbed in Water (unitless) = EPA default = See chem-tox database
τ_{event} = Lag Time (hr/d) = EPA default = See chem-tox database
B = Relative Contribution of Permeability Coefficient = EPA default = See chem-tox database
TR = Target carcinogenic risk = 1.0E-6
AT = Averaging time = 25,550 days = EPA default
ED = Exposure duration = 6 years child, 20 years adult = EPA default
ED = Exposure duration = 10 years adolescent = EPA Region 4 Guidance
LT = Lifetime = 70 years = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default
BW = Body weight = 45 kilograms adolescent = EPA Region 4 Guidance
GIABS = Fraction of contaminant absorbed in intestinal tract (unitless). Contaminant specific, see chem-tox database
EV = Recreator events = 1 event/day = NC DEQ default
EF = Exposure frequency = 90 days/year for recreators, 45 days/year trespasser = NC DEQ default
SA = Skin surface area = 6,365 cm^2 child, and 19,652 cm^2 adult and trespasser = EPA default

Mutagenic Carcinogenic Equation for User Defined (Recreator/Trespasser) Contact with Surface Water

FOR INORGANICS:

$$SL_{rec\text{-}water\text{-}mu\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}rec\text{-}madj}\left(\frac{hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}rec\text{-}madj}\left(\frac{hours}{event}\right) \le t^*\ (hours), \text{then } SL_{rec\text{-}water\text{-}mu\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}rec\text{-}madj}\left(\frac{hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}rec\text{-}madj}\left(\frac{hours}{event}\right) > t^*\ (hours), \text{then } SL_{rec\text{-}water\text{-}mu\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}rec\text{-}madj}\left(\frac{hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = \frac{TR\times AT_{rec}\left(\frac{365\ days}{year}\right)\times LT\ (70\ years)\times\left(\frac{1000\ \mu g}{mg}\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right)\times DFWM_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right)}$$

where:

$$DFWM_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right) = \left[\begin{array}{l}\left(\frac{EV_{0\text{-}2}\left(\frac{events}{day}\right)\times ED_{0\text{-}2}\ (years)\times EF_{0\text{-}2}\left(\frac{days}{year}\right)\times SA_{0\text{-}2}\left(6365\ cm^2\right)\times 10}{BW_{0\text{-}2}\ (15\ kg)}\right)+\\ \left(\frac{EV_{2\text{-}6}\left(\frac{events}{day}\right)\times ED_{2\text{-}6}\ (years)\times EF_{2\text{-}6}\left(\frac{days}{year}\right)\times SA_{2\text{-}6}\left(6365\ cm^2\right)\times 3}{BW_{2\text{-}6}\ (15\ kg)}\right)+\\ \left(\frac{EV_{6\text{-}16}\left(\frac{events}{day}\right)\times ED_{6\text{-}16}\ (years)\times EF_{6\text{-}16}\left(\frac{days}{year}\right)\times SA_{6\text{-}16}\left(19652\ cm^2\right)\times 3}{BW_{6\text{-}16}\ (80\ kg)}\right)+\\ \left(\frac{EV_{16\text{-}26}\left(\frac{events}{day}\right)\times ED_{16\text{-}26}\ (years)\times EF_{16\text{-}26}\left(\frac{days}{year}\right)\times SA_{16\text{-}26}\left(19652\ cm^2\right)\times 1}{BW_{16\text{-}26}\ (80\ kg)}\right)\end{array}\right]$$

and:

$$ET_{event\text{-}rec\text{-}madj}\left(\frac{hours}{event}\right) = \frac{\left(\begin{array}{l}ET_{event\text{-}rec\ (0\text{-}2)}\left(\frac{hours}{event}\right)\times ED_{0\text{-}2}\ (years)+ET_{event\text{-}rec\ (2\text{-}6)}\left(\frac{hours}{event}\right)\times ED_{2\text{-}6}\ (years)+\\ ET_{event\text{-}rec\ (6\text{-}16)}\left(\frac{hours}{event}\right)\times ED_{6\text{-}16}\ (years)+ET_{event\text{-}rec\ (16\text{-}26)}\left(\frac{hours}{event}\right)\times ED_{16\text{-}26}\ (years)\end{array}\right)}{ED_{0\text{-}2}\ (years)+ED_{2\text{-}6}\ (years)+ED_{6\text{-}16}\ (years)+ED_{16\text{-}26}\ (years)}$$

$SL_{rec\text{-}water\text{-}mu\text{-}der}$ = Screening level for user defined (recreator/trespasser) surface water dermal contact for mutagenic compounds
$DFWM_{rec\text{-}adj}$ = Recreator/trespasser mutagenic water dermal contact factor – age-adjusted = Calculated via secondary equation in events-cm^2/kg
Remaining inputs are the same as the standard equation for carcinogenic recreator surface water dermal contact.

Vinyl Chloride Mutagenic Carcinogenic Equation for User Defined (Recreator/Trespasser) Dermal Contact with Surface Water

$$\text{IF } ET_{\text{event-rec-adj}}\left(\frac{\text{hours}}{\text{event}}\right) \le t^{*}\ (\text{hours}), \text{then } SL_{\text{rec-water-vc-der}}\ (\mu g/L) = \frac{DA_{\text{event}}\left(\frac{ug}{cm^2\text{- event}}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{2 \times FA \times K_p\left(\frac{cm}{hour}\right) \sqrt{\frac{6 \times \tau_{\text{event}}\left(\frac{\text{hours}}{\text{event}}\right) \times ET_{\text{event-rec-adj}}\left(\frac{\text{hours}}{\text{event}}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{\text{event-rec-adj}}\left(\frac{\text{hours}}{\text{event}}\right) > t^{*}\ (\text{hours}), \text{then } SL_{\text{rec-water-vc-der}}\ (\mu g/L) = \frac{DA_{\text{event}}\left(\frac{ug}{cm^2\text{- event}}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{FA \times K_p\left(\frac{cm}{hour}\right) \times \left[\frac{ET_{\text{event-rec-adj}}\left(\frac{\text{hours}}{\text{event}}\right)}{1+B} + 2 \times \tau_{\text{event}}\left(\frac{\text{hours}}{\text{event}}\right) \times \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{\text{event}}\left(\frac{ug}{cm^2\text{- event}}\right) = \frac{TR}{\left(\frac{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-day}}\right)^{-1}}{GIABS}\right) \times DFW_{\text{rec-adj}}\left(\frac{\text{events-cm}^2}{kg}\right)}{AT_{\text{rec}}\left(\frac{365\ \text{days}}{\text{year}} \times LT\ (70\ \text{years})\right) \times \left(\frac{1000\ \mu g}{mg}\right)}\right) + \left(\frac{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-day}}\right)^{-1}}{GIABS}\right) \times EV_{\text{rec-c}}\left(\frac{\text{events}}{\text{day}}\right) \times SA_{\text{rec-c}}\left(6365\ cm^2\right)}{BW_{\text{rec-c}}\ (15\ kg) \times \left(\frac{1000\ \mu g}{mg}\right)}\right)}$$

where:

$$DFW_{\text{rec-adj}}\left(\frac{\text{events-cm}^2}{kg}\right) = \left(\frac{EV_{\text{rec-c}}\left(\frac{\text{events}}{\text{day}}\right) \times ED_{\text{rec-c}}\ (\text{years}) \times EF_{\text{rec-c}}\left(\frac{\text{days}}{\text{year}}\right) \times SA_{\text{rec-c}}\left(6365\ cm^2\right)}{BW_{\text{rec-c}}\ (15\ kg)} + \frac{EV_{\text{rec-a}}\left(\frac{\text{events}}{\text{day}}\right) \times ED_{\text{rec-a}}\ (\text{years}) \times EF_{\text{rec-a}}\left(\frac{\text{days}}{\text{year}}\right) \times SA_{\text{rec-a}}\left(19652\ cm^2\right)}{BW_{\text{rec-a}}\ (80\ kg)}\right)$$

and:

$$ET_{\text{event-rec-adj}}\left(\frac{\text{hours}}{\text{event}}\right) = \left(\frac{\left(ET_{\text{event-rec-c}}\left(\frac{\text{hours}}{\text{event}}\right) \times ED_{\text{rec-c}}\ (\text{years})\right) + \left(ET_{\text{event-rec-a}}\left(\frac{\text{hours}}{\text{event}}\right) \times ED_{\text{rec-a}}\ (\text{years})\right)}{ED_{\text{rec-c}}\ (\text{years}) + ED_{\text{rec-a}}\ (\text{years})}\right)$$

$DFW_{rec\text{-}adj}$ = Residential mutagenic water contact factor for carcinogenic resident dermal contact for vinyl chloride

Remaining inputs are the same as the standard equation for carcinogenic recreator surface water dermal contact.

Trichloroethylene Carcinogenic Equation for Resident Dermal Contact with Water

FOR ORGANICS:

$$\text{IF } ET_{\text{event-rec-madj}}\left(\frac{1\text{ hour}}{\text{event}}\right) \le t^{*}\ (\text{hours}),\text{then } SL_{\text{rec-water-tce-der}}(\mu g/L) = \frac{DA_{\text{tce-event}}\left(\frac{ug}{cm^2\text{- event}}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{\text{event-rec-madj}}\left(\frac{hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{\text{event-rec-madj}}\left(\frac{hours}{event}\right) > t^{*}\ (\text{hours}),\text{then } PRG_{\text{rec-water-tce-der}}(\mu g/L) = \frac{DA_{\text{tce-event}}\left(\frac{ug}{cm^2\text{- event}}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{\text{event-rec-madj}}\left(\frac{hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{\text{tce-event}}\left(\frac{ug}{cm^2\text{- event}}\right) = \frac{TR\times AT_{rec}\left(\frac{365\text{ days}}{year}\times LT(70\text{ years})\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{\frac{CSF_o\left(\frac{mg}{kg\text{-day}}\right)^{-1}}{GIABS}\times\left(\left(AF_o(0.804)\times DFW_{\text{rec-adj}}\left(\frac{events\text{ - }cm^2}{kg}\right)\right)+\left(MAF_o(0.202)\times DFWM_{\text{rec-adj}}\left(\frac{events\text{ - }cm^2}{kg}\right)\right)\right)}$$

where:

$$DFW_{\text{rec-adj}}\left(\frac{events\text{ - }cm^2}{kg}\right) = \left(\frac{EV_{\text{rec-c}}\left(\frac{events}{day}\right)\times ED_{\text{rec-c}}(\text{years})\times EF_{\text{rec-c}}\left(\frac{days}{year}\right)\times SA_{\text{rec-c}}\left(6365\ cm^2\right)}{BW_{\text{rec-c}}(15\text{ kg})}+\frac{EV_{\text{rec-a}}\left(\frac{events}{day}\right)\times ED_{\text{rec-a}}(\text{years})\times EF_{\text{rec-a}}\left(\frac{days}{year}\right)\times SA_{\text{rec-a}}\left(19652\ cm^2\right)}{BW_{\text{rec-a}}(80\text{ kg})}\right)$$

where:

$$DFWM_{\text{rec-adj}}\left(\frac{events\text{ - }cm^2}{kg}\right) = \left[\begin{array}{l}\left(\frac{EV_{0\text{-}2}\left(\frac{events}{day}\right)\times ED_{0\text{-}2}(\text{years})\times EF_{0\text{-}2}\left(\frac{days}{year}\right)\times SA_{0\text{-}2}\left(6365\ cm^2\right)\times 10}{BW_{0\text{-}2}(15\text{ kg})}\right)+\\ \left(\frac{EV_{2\text{-}6}\left(\frac{events}{day}\right)\times ED_{2\text{-}6}(\text{years})\times EF_{2\text{-}6}\left(\frac{days}{year}\right)\times SA_{2\text{-}6}\left(6365\ cm^2\right)\times 3}{BW_{2\text{-}6}(15\text{ kg})}\right)+\\ \left(\frac{EV_{6\text{-}16}\left(\frac{events}{day}\right)\times ED_{6\text{-}16}(\text{years})\times EF_{6\text{-}16}\left(\frac{days}{year}\right)\times SA_{6\text{-}16}\left(19652\ cm^2\right)\times 3}{BW_{6\text{-}16}(80\text{ kg})}\right)+\\ \left(\frac{EV_{16\text{-}26}\left(\frac{events}{day}\right)\times ED_{16\text{-}26}(\text{years})\times EF_{16\text{-}26}\left(\frac{days}{year}\right)\times SA_{16\text{-}26}\left(19652\ cm^2\right)\times 1}{BW_{16\text{-}26}(80\text{ kg})}\right)\end{array}\right]$$

and:

$$ET_{\text{event-rec-madj}}\left(\frac{hours}{event}\right) = \frac{\left(\begin{array}{l}ET_{\text{event-rec}(0\text{-}2)}\left(\frac{hours}{event}\right)\times ED_{0\text{-}2}(\text{years})+ET_{\text{event-rec}(2\text{-}6)}\left(\frac{hours}{event}\right)\times ED_{2\text{-}6}(\text{years})+\\ ET_{\text{event-rec}(6\text{-}16)}\left(\frac{hours}{event}\right)\times ED_{6\text{-}16}(\text{years})+ET_{\text{event-rec}(16\text{-}26)}\left(\frac{hours}{event}\right)\times ED_{16\text{-}26}(\text{years})\end{array}\right)}{ED_{0\text{-}2}(\text{years})+ED_{2\text{-}6}(\text{years})+ED_{6\text{-}16}(\text{years})+ED_{16\text{-}26}(\text{years})}$$

$DFW_{rec\text{-}adj}$ = Residential mutagenic water contact factor for carcinogenic resident dermal contact for vinyl chloride

Remaining inputs are the same as the standard equation for carcinogenic resident water dermal contact.

A.9 VAPOR INTRUSION

A.9.a. Non-Residential Worker Indoor Air Vapor Inhalation

Noncarcinogenic Non-Residential Worker Indoor Air Vapor Inhalation

$$SL_{w\text{-}air\text{-}nc}\left(\mu g/m^3\right)=\frac{THQ\times AT_w\left(\frac{365\ days}{year}\times ED_w\left(25\ years\right)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{EF_w\left(\frac{250\ days}{year}\right)\times ED_w\left(25\ years\right)\times ET_w\left(\frac{8\ hr}{24\ hr}\right)\times\frac{1}{RfC\left(\frac{mg}{m^3}\right)}}$$

$SL_{w\text{-}air\text{-}nc}$ = Screening level for noncarcinogenic non-residential worker indoor air
THQ = Target hazard quotient = 0.2
AT = Averaging time = 9,125 days = EPA default
ED = Exposure duration = 25 years = EPA default
EF = Exposure frequency = 250 days/year = EPA default
ET = Exposure time = 8 hours/day = EPA default
RfC = Chronic inhalation reference concentration (mg/m^3), see chem-tox database

Carcinogenic Non-Residential Worker Indoor Air Vapor Inhalation

$$SL_{w\text{-}air\text{-}ca}\left(\mu g/m^3\right)=\frac{TR\times AT_w\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)}{EF_w\left(\frac{250\ days}{year}\right)\times ED_w\left(25\ years\right)\times ET_w\left(\frac{8\ hr}{24\ hr}\right)\times IUR\left(\frac{\mu g}{m^3}\right)^{-1}}$$

$SL_{w\text{-}air\text{-}ca}$ = Screening level for carcinogenic non-residential worker indoor air
TR = Target carcinogenic risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
EF = Exposure frequency = 250 days/year = EPA default
ED = Exposure duration = 25 years = EPA default
ET = Exposure time = 8 hours/day = EPA default
IUR = Chronic inhalation unit risk (mg/m^3), see chem-tox database

A.9.b. Residential Indoor Air Vapor Inhalation

Noncarcinogenic Residential Indoor Air Vapor Inhalation

$$SL_{res\text{-}air\text{-}nc}\left(\mu g/m^3\right)=\frac{THQ\times AT_r\left(\frac{365\ days}{year}\times ED_r\left(26\ years\right)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{EF_r\left(\frac{350\ days}{year}\right)\times ED_r\left(26\ years\right)\times ET_{ra}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times\frac{1}{RfC\left(\frac{mg}{m^3}\right)}}$$

$SL_{res\text{-}air\text{-}nc}$ = Screening level for noncarcinogenic resident indoor air
THQ = Target hazard quotient = 0.2
AT = Averaging time = 9,490 days = EPA default
ED = Exposure duration = 26 years = EPA default
EF = Exposure frequency = 350 days/year = EPA default
ET = Exposure time = 24 hours/day = EPA default
RfC = Chronic inhalation reference concentration (mg/m^3), see chem-tox database

Carcinogenic Residential Indoor Air Vapor Inhalation

Additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and trichloroethylene. The standard equation is listed below, followed by the alternative equations.

<u>Standard Carcinogenic Equation for Resident Indoor Air Vapor Inhalation</u>

$$SL_{res\text{-}air\text{-}ca}\left(\mu g/m^3\right)=\frac{TR\times AT_r\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)}{EF_r\left(\frac{350\ days}{year}\right)\times ED_r\left(26\ years\right)\times ET_{ra}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times IUR\left(\frac{\mu g}{m^3}\right)^{-1}}$$

$SL_{res\text{-}air\text{-}ca}$ = Screening level for carcinogenic resident indoor air
TR = Target carcinogenic risk = 1.0E-06
AT = Averaging time = 25,550 days = EPA default
LT = Lifetime = 70 years = EPA default
EF = Exposure frequency = 350 days/year = EPA default
ED = Exposure duration = 26 years = EPA default
ET = Exposure time = 24 hours/day = EPA default
IUR = Chronic inhalation unit risk (mg/m^3), see chem-tox database

Mutagenic Carcinogenic Equation for Resident Indoor Air Vapor Inhalation

$$SL_{res\text{-}air\text{-}mu}\left(\mu g/m^3\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1\ day}{24\ hours}\right) \times \left(\begin{array}{l}\left(ED_{0\text{-}2}\left(2\ years\right) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right) \times 10\right) + \\ \left(ED_{2\text{-}6}\left(4\ years\right) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right) \times 3\right) + \\ \left(ED_{6\text{-}16}\left(10\ years\right) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ET_{6\text{-}16}\left(\frac{24\ hours}{day}\right) \times 3\right) + \\ \left(ED_{16\text{-}26}\left(10\ years\right) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ET_{16\text{-}26}\left(\frac{24\ hours}{day}\right) \times 1\right)\end{array}\right)}$$

$SL_{res\text{-}air\text{-}mu}$ = Screening level for carcinogenic resident indoor air for mutagenic equations
Remaining inputs are the same as the standard equation for carcinogenic resident indoor air.

Vinyl Chloride Equation for Resident Indoor Air Vapor Inhalation

$$SL_{res\text{-}air\text{-}ca\text{-}vinyl\ chloride}\left(\mu g/m^3\right) = \frac{TR}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} + \left(\frac{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times EF_r\left(\frac{350\ days}{year}\right) \times ED_r\left(26\ years\right) \times ET_{ra}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right)}{AT_r\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}\right)}$$

$SL_{res\text{-}air\text{-}ca\text{-}vinyl\ chloride}$ = Screening level for carcinogenic resident indoor air for vinyl chloride
Remaining inputs are the same as the standard equation for carcinogenic resident indoor air.

Trichloroethylene Carcinogenic Equation for Resident Indoor Air Vapor Inhalation

$$SL_{res\text{-}air\text{-}tce}\left(\mu g/m^3\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1\ day}{24\ hours}\right) \times \left(\begin{array}{l} \left(ED_{res}\left(26\ years\right) \times EF_{res}\left(\frac{350\ days}{year}\right) \times ET_{res}\left(\frac{24\ hours}{day}\right) \times CAF_i\left(0.756\right)\right) + \\ \left(\left(ED_{0\text{-}2}\left(2\ years\right) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right) \times MAF_i\left(0.244\right) \times 10\right) + \right. \\ \left(ED_{2\text{-}6}\left(4\ years\right) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right) \times MAF_i\left(0.244\right) \times 3\right) + \\ \left(ED_{6\text{-}16}\left(10\ years\right) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ET_{6\text{-}16}\left(\frac{24\ hours}{day}\right) \times MAF_i\left(0.244\right) \times 3\right) + \\ \left.\left(ED_{16\text{-}26}\left(10\ years\right) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ET_{16\text{-}26}\left(\frac{24\ hours}{day}\right) \times MAF_i\left(0.244\right) \times 1\right)\right) \end{array}\right)}$$

$SL_{res\text{-}air\text{-}ca\text{-}tce}$ = Screening level for carcinogenic resident indoor air for trichloroethylene
CAF_i = Cancer adjustment factor inhalation = 0.756 = EPA default
MAF_i = Mutagenic adjustment factor oral = 0.244 = EPA default
Remaining inputs are the same as the standard equation for carcinogenic resident indoor air.

A.9.c. Soil Gas to Indoor Air Equations

The soil gas to indoor air equations calculate a screening level by applying an attenuation factor to the indoor air concentration, as further described below. The attenuation factors are the based on the factors specified in the DEQ Vapor Intrusion Guidance Document (DEQ, March 2018).

Non-Residential Soil Gas to Indoor Air Equation

$$SGSL_{nr} = IASL_{nr} \times 1/AF_{sgnr}$$

$SGSL_{nr}$ = Non-residential soil gas screening level ($\mu g/m^3$)
$IASL_{nr}$ = Non-residential indoor air screening level ($\mu g/m^3$)
AF_{sgnr} = Non-residential soil gas to indoor air attenuation factor = 0.01

The risk calculator takes the entered soil gas concentration, converts it to a predicted indoor air concentration, then calculates risk based on the predicted indoor air concentration as specified in Sections A.9.a. and A.9.b. above. This process entails modification of the above equation as follows:

$$IASL_{nr} = SGSL_{nr} \times AF_{sgnr}$$

Residential Soil Gas to Indoor Air Equation

$$SGSL_r = IASL_r \times 1/AF_{sgr}$$

$SGSL_r$ = Residential soil gas screening level ($\mu g/m^3$)
$IASL_r$ = Residential indoor air screening level ($\mu g/m^3$)
AF_{sgr} = Residential soil gas to indoor air attenuation factor = 0.03

The risk calculator takes the entered soil gas concentration, converts it to a predicted indoor air concentration, then calculates risk based on the predicted indoor air concentration as specified in Sections A.9.a. and A.9.b. above. This process entails modification of the above equation as follows:

$$IASL_r = SGSL_r \times AF_{sgr}$$

A.9.d. Groundwater to Indoor Air Equations

The groundwater to indoor air equations calculate a screening level by applying an attenuation factor to the indoor air concentration, then converting the estimated soil gas concentration to a groundwater concentration using Henry's Law, as further described below.

Non-Residential Groundwater to Indoor Air Equation

$$GWSL_{nr} = IASL_{nr} \times 1/H' \times CF \times 1/AF_{gwnr}$$

$GWSL_{nr}$ = Non-residential groundwater screening level ($\mu g/L$)
$IASL_{nr}$ = Non-residential indoor air screening level ($\mu g/m^3$)
H' = Henry's law constant (unitless), chemical specific, see chem-tox database
CF = Conversion factor = 0.001 m^3/L
AF_{gwnr} = Non-residential groundwater to indoor air attenuation factor = 0.001

The risk calculator takes the entered groundwater concentration, converts it to a predicted indoor air concentration, then calculates risk based on the predicted indoor air concentration as specified in Sections A.9.a. and A.9.b. above. This process entails modification of the above equation as follows:

$$IASL_{nr} = GWSL_{nr} \times H' \times 1/CF \times AF_{gwnr}$$

Residential Groundwater to Indoor Air Equation

$$GWSL_r = IASL_r \times 1/H' \times CF \times 1/AF_{gwr}$$

$GWSL_r$ = Residential groundwater screening level (µg/L)
$IASL_r$ = Residential indoor air screening level (µg/m^3)
H' = Henry's law constant (unitless), chemical specific, see chem-tox database
CF = Conversion factor = 0.001 m^3/L
AF_{gwr} = Residential groundwater to indoor air attenuation factor = 0.001

The risk calculator takes the entered groundwater concentration, converts it to a predicted indoor air concentration, then calculates risk based on the predicted indoor air concentration as specified in Sections A.9.a. and A.9.b. above. This process entails modification of the above equation as follows:

$$IASL_r = GWSL_r \times H' \times 1/CF \times AF_{gwr}$$

B Contaminant Migration Equations

Transport Model to Calculate the Protection of Groundwater Remediation Goals

$$C_{soil} = C_{gw}\left[k_s + \frac{(\theta_w + \theta_a H')}{P_b}\right]df$$

	Parameters	Default Values	Units
C_{soil}	Calculated Source Concentration for soil	not applicable	mg/kg - soil
C_{gw}	Applicable Groundwater Target Concentration (NC GW Std)	chemical-specific	mg/L - water
df	Dilution factor	20 (0.5-acre source size)	unitless
k_s	Soil-water partition coefficient for organic constituents ks = koc x foc (for inorganic constituents ks = kd)	chemical-specific	L/kg
k_{oc}	Soil organic carbon-water partition coefficient	chemical-specific	L/kg
f_{oc}	Fraction of organic carbon in subsurface vadose soils	0.002 (0.2%)	kg/kg
k_d	Soil-water partition coefficient for inorganics	chemical-specific (pH=5.5)	L/kg
θ_w	Water-filled soil porosity-vadose soils	0.3	Lwater/Lsoil
θ_a	Air-filled soil porosity-vadose soils	0.13	Lair/Lsoil
P_b	Dry bulk density	1.5	kg/L
H'	Henry's Law constant-dimensionless where: H' = Henry's Law constant (atm- m3/mole) x conversion factor of 41	chemical-specific	unitless

Equation and Parameters are from the USEPA 1996 Soil Screening Guidance and the USEPA 1996 Soil Screening Guidance

B.1.a. Soil Leaching to Groundwater

Soil leaching to groundwater calculations are based on the methodology presented in the EPA Soil Screening Guidance (EPA, 1996) and EPA Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (EPA, 2002). The risk calculator calculates soil leaching to groundwater via two equations, (1) unlimited source model for chronic exposure and (2) mass limit model for chronic exposure. The risk calculator then selects the equation that provides the higher soil screening level (i.e. lower groundwater screening level) for subsequent modeling calculations.

Unlimited Source Equation

Primary Equation

$$C_s = C_w \left[K_s + \frac{(\theta_{w+}\theta_a H')}{\rho_b}\right] df$$

The equation rearranged to calculate the groundwater concentration based on entry of the soil concentration is as follows:

$$C_w = \frac{C_s}{\left\{K_s + \left(\frac{\theta_{w+}\theta_a H'}{\rho_b}\right)\right\} df}$$

C_s = Soil concentration (mg/kg)
C_w = Groundwater concentration (mg/L)
ρ_b = Dry soil bulk density (kg/L) = Site-specific or default = Default 1.5 kg/L
K_s = Soil-water partition coefficient (L/kg) = K_{oc} x f_{oc} (This equation is valid for organics only. The risk calculator is not currently set up to correctly run inorganics for this pathway.)
K_{oc} = Soil organic carbon/water partition coefficient (L/kg) = Chemical specific = Defined in chem-tox database
f_{oc} = Fraction organic carbon in soil (g/g) = Site-specific or default = Default is 0.002
θ_w = Water-filled soil porosity (L_{water}/L_{soil}) = Site-specific or default = Default is 0.3
θ_a = Air-filled soil porosity (L_{air}/L_{soil}) = Site-specific or default = Default is 0.13
H' = Henry's law constant (dimensionless), chemical specific, see chem-tox database
df = Dilution factor = See secondary equation below

Secondary Equation #1 – Dilution Factor

$$df = 1 + \frac{Kid}{IL}$$

df = Dilution factor
K = Aquifer hydraulic conductivity (m/yr) = Site-specific
i = Hydraulic gradient (m/m) = Site-specific
d = Mixing zone depth (m) = See supplemental equation below, calculated default is 0.66 m

I = Infiltration rate (m/yr) = Site-specific or default = Default is 66 cm/yr (26 in/yr)
L = Length of source area parallel to groundwater flow (m) = Site-specific

Secondary Equation #2 – Mixing Zone Depth

$$d = (0.0112L^2)^{0.5}\, d_a\{1 - \exp\,[\frac{(-LI)}{(Kid_a)}]$$

d = Mixing zone depth (m), calculated default is 0.66 m
L = Length of source area parallel to groundwater flow (m) = Site-specific
I = Infiltration rate (m/yr) = Site-specific or default = Default is 0.66 m/yr (26 in/yr)
K = Aquifer hydraulic conductivity (m/yr) = Site-specific
i = Hydraulic gradient (m/m) = Site-specific
d_a = Aquifer thickness = Site-specific

Mass-Limit Equation

$$\mathrm{C_s} = \frac{(\mathrm{C_w})(\mathrm{I})(\mathrm{ED})}{(\rho_\mathrm{b})(\mathrm{d_s})}$$

The equation rearranged to calculate the groundwater concentration based on entry of the soil concentration is as follows:

$$\mathrm{C_w} = \frac{(\mathrm{C_s})(\rho_\mathrm{b})(\mathrm{d}_s)}{(\mathrm{I})(\mathrm{ED})}$$

C_s = Soil concentration (mg/kg)
C_w = Groundwater concentration (mg/L)
ρ_b = Dry soil bulk density (kg/L) = Site-specific or default = Default is 1.5 kg/L
d_s = Depth to base of soil source area (cm) = Site-specific or default = Default is 1,244 cm
I = Infiltration rate (m/yr) = Site-specific or default = Default is 0.66 m/yr (26 in/yr)
ED = Exposure duration (yr) = EPA default = 70 years

B.1.b. Groundwater Migration to the Point of Exposure

Groundwater migration to the point of exposure (POE) calculations are based on the methodology presented in Domenico and Robbins (1985) and Domenico (1987). Chemical degradation may be incorporated into the equation, but the risk calculator conservatively assumes no chemical degradation.

$$C_{POE} = C_{si}\left\{\mathrm{erf}\left(\frac{S_w}{4\sqrt{\alpha_y \mathrm{x}}}\right)\right\}\left\{\mathrm{erf}\left(\frac{S_d}{2\sqrt{\alpha_z \mathrm{x}}}\right)\right\}$$

C_{POE} = Groundwater concentration (mg/L) along the plume centerline at the point of exposure (POE)
C_{si} = Source groundwater concentration (mg/L)
x = Distance to POE (cm)
S_w = Groundwater source width (cm) = Site-specific
S_d = Groundwater source thickness (cm) = Site-specific
α_x = Longitudinal Dispersivity (cm) = See equation below
α_y = Transverse Dispersivity (cm) = See equation below
α_z = Vertical Dispersivity (cm) = See equation below
$\alpha_x = 0.1*x$
$\alpha_y = 0.33* \alpha_x$
$\alpha_z = 0.05* \alpha_x$

The dispersion equations listed above are based on the methodology employed in ASTM E-1739 (2002).

B.1.c. Surface Water Dilution

The surface water calculations apply an additional dilution factor to determine the surface water concentration based on the groundwater concentration at the surface water body.

$$DFgwsw = \left[1 + \frac{Q_{sw}}{Ki\delta_{sw}W_{gwsw}}\right]^{-1}$$

DF_{gwsw} = Dilution Factor for groundwater to surface water
Q_{sw} = Surface water flow rate (cm^3/s) = No default established by EPA, DEQ default is 0 cm^3/s
K = Aquifer hydraulic conductivity (m/yr) = Site-specific = Hydraulic gradient (m/m) = Site-specific
δ_{sw} = Thickness of groundwater plume at surface water interface (cm) = Site Specific
W_{gwsw} = Width of groundwater plume at surface water interface (cm) = No default established

C Construction Worker Particulate Emission Factor (PEF) Calculations

The particulate emission factor (PEF) calculations for residential and non-residential land-use scenarios model generation of particulates due to wind erosion. However, these PEF values may not be sufficiently conservative for a construction worker scenario due to the increased potential for particulates generated from heavy vehicle traffic, grading, dozing, tilling, and excavation during construction activities. The EPA Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (EPA, 2002) provides a detailed method for calculating PEF for the two construction worker scenarios, (1) standard vehicle traffic, and (2) Other than standard vehicle traffic (grading, dozing, tilling, and excavation). However, default values are not provided for many of the input parameters, and these parameters are difficult to estimate due to the wide variety of different potential construction scenarios. Therefore, the PEF value for a construction worker was evaluated using two methods as detailed further below.

First, the EPA on-line risk calculator was run using EPA defaults, where available, or conservative estimated inputs where EPA defaults are not available. A summary of the values and justification for each value is shown in the attached table. The risk calculator input and output sheets are also attached. The results of the EPA risk calculator indicated the following PEF values:

- Construction Worker PEF for standard vehicle traffic – 1.06E+06 m^3/kg
- Construction worker PEF for other than standard vehicle traffic (grading, dozing, tilling, and excavation) – 1.96E+07 m^3/kg

As a further check of the estimated PEF, a calculation was performed based on the EPA's National Ambient Air Quality Standard (NAAQS) established under 40 CFR Part 50 for particle pollution. Particles typical of soil generated during construction are classified as PM10 (coarse dust particles between 2.5 and 10 micrometers in diameter). The NAAQS for PM10 is 150 micrograms per cubic meter (µg/m3). The PEF is the inverse of the standard adjusted for unit conversions:

- PEF = 1/NAAQS (150 $\mu g/m^3$) = 6.7E-03 $m^3/$ µg x 1E+09 ug/kg = 6.7E+06 m^3/kg

The calculated PEF values range from a low of 1.06E+06 m^3/kg to a high of 1.96E+07 m^3/kg. A lower PEF value yields lower standards/higher risk. Therefore, the lowest estimated value of 1.06E+06 m^3/kg is the default selected by the DEQ. It should be noted that if this PEF generates unacceptable risk levels, remediation is not necessarily required. A Tier 3 could be performed to further evaluate the site-specific PEF, or measures to minimize construction worker contact with impacted soil could be incorporated into land-use controls for the site.

D List of Parameters

Receptor	Parameter	Name	Default Value	Location for Data Entry in Calculator	Justification for Default Value
Resident	AF_{resa}	Resident Adult Soil Adherence Factor (mg/cm^2)	0.07	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	AF_{resc}	Resident Child Soil Adherence Factor (mg/cm^2)	0.2	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	AT_{resa}	Resident Averaging Time (d)	9,490	Exposure Factors and Target Risk tab	ED x 365 d/yr
Resident	AT_{resc}	Resident Child Averaging Time (d)	2,190	Exposure Factors and Target Risk tab	ED x 365 d/yr
Resident	AT_{res}	Resident Age Adjusted Averaging Time (d)	25,550	Exposure Factors and Target Risk tab	ED x 365 d/yr
Resident	BW_{resa}	Resident Adult Body Weight (kg)	80	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	BW_{resc}	Resident Child Body Weight (kg)	15	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	ED_{res}	Resident Exposure Duration (yr)	26	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	ED_{resa}	Resident Adult Exposure Duration (yr)	20	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	ED_{resc}	Resident Child Exposure Duration (yr)	6	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	EF_{res}	Resident Exposure Frequency (d/yr)	350	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	EF_{resa}	Resident Adult Exposure Frequency (d/yr)	350	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	EF_{resc}	Resident Child Exposure Frequency (d/yr)	350	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	$ET_{eventresa}$	Resident Adult Water Exposure Time (hr/event)	0.71	Exposure Factors and Target Risk tab	EPA RSL[1], showering
Resident	$ET_{eventresc}$	Resident Child Water Exposure Time (hr/event)	0.54	Exposure Factors and Target Risk tab	EPA RSL[1], bathing
Resident	ET_{resa}	Resident Adult Exposure Time (hr/d)	24	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	ET_{res}	Resident Child Exposure Time (hr/d)	24	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	EV_{resa}	Resident Adult Event Frequency (events/day)	1	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	EV_{resa}	Resident Adult Event Frequency (events/day)	1	Exposure Factors and Target Risk tab	EPA RSL[1]

Receptor	Parameter	Name	Default Value	Location for Data Entry in Calculator	Justification for Default Value
Resident	IRS_{resa}	Resident Adult Ingestion Rate of Soil (mg/d)	100	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	IRS_{resc}	Resident Child Ingestion Rate of Soil (mg/d)	200	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	IRW_{resa}	Resident Adult Ingestion Rate of Water (L/d)	2.5	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	IRW_{resc}	Resident Child Ingestion Rate of Water (L/d)	0.78	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	SA_{resas}	Resident Adult Skin Surface Area Soil (cm^2/day)	6,032	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	SA_{rescs}	Resident Child Skin Surface Area Soil (cm^2/day)	2,373	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	SA_{resaw}	Resident Adult Skin Surface Area Water (cm^2)	19,652	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	SA_{rescw}	Resident Child Skin Surface Area Water (cm^2)	6,365	Exposure Factors and Target Risk tab	EPA RSL[1]
Resident	α_{rgw}	Residential Groundwater to Indoor Air Attenuation Factor	0.001	Individual calculator tabs	NCDEQ
Resident	α_{rsg}	Residential Soil Gas to Indoor Air Attenuation Factor	0.03	Individual calculator tabs	NCDEQ
Non-Residential Worker	AF_w	Non-Residential Worker Soil Adherence Factor (mg/cm^2)	0.12	Exposure Factors and Target Risk tab	EPA RSL[1]
Non-Residential Worker	AT_w	Non-Residential Worker Carcinogenic Averaging Time (d)	25,550	Exposure Factors and Target Risk tab	LT x 365 d/yr
Non-Residential Worker	AT_{wa}	Non-Residential Worker Noncarcinogenic Averaging Time (d)	9,125	Exposure Factors and Target Risk tab	ED x 365 d/yr
Non-Residential Worker	BW_w	Non-Residential Worker Body Weight (kg)	80	Exposure Factors and Target Risk tab	EPA RSL[1]
Non-Residential Worker	ED_w	Non-Residential Worker Exposure Duration (yr)	25	Exposure Factors and Target Risk tab	EPA RSL[1]
Non-Residential Worker	EF_w	Non-Residential Worker Exposure Frequency (d/yr)	250	Exposure Factors and Target Risk tab	EPA RSL[1]
Non-Residential Worker	ET_w	Non-Residential Worker Exposure Time (hr/d)	8	Exposure Factors and Target Risk tab	EPA RSL[1]
Non-Residential Worker	ET_{eventw}	Non-Residential Worker Water Exposure Time (hr/event)	0.67	Exposure Factors and Target Risk tab	NC DEQ

Receptor	Parameter	Name	Default Value	Location for Data Entry in Calculator	Justification for Default Value
Non-Residential Worker	EV_w	Non-Residential Worker Event Frequency (events/day)	1	Exposure Factors and Target Risk tab	NC DEQ, same as residential adult.
Non-Residential Worker	IR_w	Non-Residential Worker Ingestion Rate of Soil (mg/d)	100	Exposure Factors and Target Risk tab	EPA RSL[1]
Non-Residential Worker	IRW_w	Non-Residential Worker Ingestion Rate of Water (L/d)	0.83	Exposure Factors and Target Risk tab	NC DEQ, 2.5 L/d x 8 hr/24 hr = 0.83 L/d.
Non-Residential Worker	SA_{ws}	Non-Residential Worker Skin Surface Area Soil (cm^2/day)	3,527	Exposure Factors and Target Risk tab	EPA RSL[1]
Non-Residential Worker	SA_{ww}	Non-Residential Worker Skin Surface Area Water (cm^2)	19,652	Exposure Factors and Target Risk tab	EPA RSL[1]
Non-Residential Worker	α_{wgw}	Non-residential Groundwater to Indoor Air Attenuation Factor	0.001	Individual calculator tabs	NCDEQ
Non-Residential Worker	α_{wsg}	Non-residential Soil Gas to Indoor Air Attenuation Factor	0.01	Individual calculator tabs	NCDEQ
Construction Worker	AF_{cw}	Construction Worker Soil Adherence Factor (mg/cm^2)	0.3	Exposure Factors and Target Risk tab	EPA RSL[1]
Construction Worker	AT_{cw}	Construction Worker Carcinogenic Averaging Time (d)	25,550	Exposure Factors and Target Risk tab	LT x 365 d/yr
Construction Worker	AT_{cwa}	Construction Worker Noncarcinogenic Averaging Time (d)	350	NA	ED x EW x 7 d/wk
Construction Worker	BW_{cw}	Construction Worker Body Weight (kg)	80	Exposure Factors and Target Risk tab	EPA RSL[1]
Construction Worker	ED_{cw}	Construction Worker Exposure Duration (yr)	1	Exposure Factors and Target Risk tab	EPA RSL[1]
Construction Worker	EF_{cw}	Construction Worker Exposure Frequency (d/yr)	250	Exposure Factors and Target Risk tab	EPA RSL[1]
Construction Worker	ET_{cw}	Construction Worker Exposure Time (hr/d)	8	Exposure Factors and Target Risk tab	EPA RSL[1]
Construction Worker	EW_{cw}	Construction Worker Weeks Worked (weeks)	50	Exposure Factors and Target Risk tab	EPA RSL[1]
Construction Worker	IR_{cw}	Construction Worker Ingestion Rate of Soil (mg/d)	330	Exposure Factors and Target Risk tab	EPA RSL[1]
Construction Worker	IRW_{cw}	Construction Worker Ingestion Rate of Water (L/d)	0.83	Exposure Factors and Target Risk tab	NC DEQ, 2.5 L/d x 8 hr/24 hr = 0.83 L/d.

Receptor	Parameter	Name	Default Value	Location for Data Entry in Calculator	Justification for Default Value
Construction Worker	SA_{cws}	Construction Worker Skin Surface Area Soil (cm^2/day)	3,527	Exposure Factors and Target Risk tab	EPA RSL[1]
Recreator	AF_{reca}	Recreator Adult Soil Adherence Factor (mg/cm^2)	0.07	Exposure Factors and Target Risk tab	NC DEQ
Recreator	AF_{recc}	Recreator Child Soil Adherence Factor (mg/cm^2)	0.2	Exposure Factors and Target Risk tab	NC DEQ
Recreator	AT_{rec}	Recreator Carcinogenic Averaging Time (d)	25,550	Exposure Factors and Target Risk tab	ED x 365 d/yr
Recreator	AT_{reca}	Recreator Adult Noncarcinogenic Averaging Time (d)	9,490	Exposure Factors and Target Risk tab	ED x 365 d/yr
Recreator	AT_{recc}	Recreator Child Noncarcinogenic Averaging Time (d)	2,190	Exposure Factors and Target Risk tab	ED x 365 d/yr
Recreator	BW_{reca}	Recreator Adult Body Weight (kg)	80	Exposure Factors and Target Risk tab	EPA RSL[1]
Recreator	BW_{recc}	Recreator Child Body Weight (kg)	15	Exposure Factors and Target Risk tab	EPA RSL[1]
Recreator	ED_{reca}	Recreator Exposure Duration (yr)	26	Exposure Factors and Target Risk tab	NC DEQ
Recreator	ED_{reca}	Recreator Adult Exposure Duration (yr)	20	Exposure Factors and Target Risk tab	NC DEQ
Recreator	ED_{recc}	Recreator Child Exposure Duration (yr)	6	Exposure Factors and Target Risk tab	NC DEQ
Recreator	EF_{rec}	Recreator Soil Exposure Frequency (d/yr)	150	Exposure Factors and Target Risk tab	NC DEQ
Recreator	EF_{reca}	Recreator Adult Soil Exposure Frequency (d/yr)	150	Exposure Factors and Target Risk tab	NC DEQ
Recreator	EF_{recc}	Recreator Child Soil Exposure Frequency (d/yr)	150	Exposure Factors and Target Risk tab	NC DEQ
Recreator	EF_{rec}	Recreator Surface Water Exposure Frequency (d/yr)	90	Exposure Factors and Target Risk tab	NC DEQ
Recreator	EF_{reca}	Recreator Adult Surface Water Exposure Frequency (d/yr)	90	Exposure Factors and Target Risk tab	NC DEQ
Recreator	EF_{recc}	Recreator Child Surface Water Exposure Frequency (d/yr)	90	Exposure Factors and Target Risk tab	NC DEQ
Recreator	$ET_{eventreca}$	Recreator Adult Water Exposure Time (hr/event)	2	Exposure Factors and Target Risk tab	Virginia Guidance[3]

Receptor	Parameter	Name	Default Value	Location for Data Entry in Calculator	Justification for Default Value
Recreator	$ET_{eventrecadj}$	Recreator Age Adjusted Water Exposure Time (hr/event)	2	Exposure Factors and Target Risk tab	Virginia Guidance[3]
Recreator	$ET_{eventrecc}$	Recreator Child Water Exposure Time (hr/event)	2	Exposure Factors and Target Risk tab	Virginia Guidance[3]
Recreator	ET_{rec}	Recreator Adult Exposure Time (hr/event)	2	Exposure Factors and Target Risk tab	Virginia Guidance[3].
Recreator	ET_{reca}	Recreator Child Exposure Time (hr/event)	2	Exposure Factors and Target Risk tab	Virginia Guidance[3].
Recreator	EV_{reca}	Recreator Adult Event Frequency (events/day)	1	Exposure Factors and Target Risk tab	Virginia Guidance[3].
Recreator	EV_{recc}	Recreator Child Event Frequency (events/day)	1	Exposure Factors and Target Risk tab	Virginia Guidance[3].
Recreator	IRS_{reca}	Recreator Adult Soil Ingestion Rate (mg/d)	100	Exposure Factors and Target Risk tab	EPA RSL[1]
Recreator	IRS_{recc}	Recreator Child Soil Ingestion Rate (mg/d)	200	Exposure Factors and Target Risk tab	EPA RSL[1]
Recreator	IRW_{reca}	Adult Recreator Ingestion Rate Surface Water (L/d)	0.11	Exposure Factors and Target Risk tab	EPA RSL[1]
Recreator	IRW_{recc}	Child Recreator Ingestion Rate Surface Water (L/d)	0.12	Exposure Factors and Target Risk tab	EPA RSL[1]
Recreator	$IRW_{rec\ 0\text{-}2}$	Child Recreator (0-2 yrs) Ingestion Rate Surface Water (L/d)	0.12	Exposure Factors and Target Risk tab	EPA RSL[1]
Recreator	$IRW_{rec\ 2\text{-}6}$	Child Recreator (2-6 yrs) Ingestion Rate Surface Water (L/d)	0.12	Exposure Factors and Target Risk tab	EPA RSL[1]
Recreator	$IRW_{rec\ 6\text{-}16}$	Adolescent Recreator (6-16 yrs) Ingestion Rate Surface Water (L/d)	0.11	Exposure Factors and Target Risk tab	NC DEQ
Recreator	$IRW_{rec\ 16\text{-}26}$	Adult Recreator (16-26 yrs) Ingestion Rate Surface Water (L/d)	0.11	Exposure Factors and Target Risk tab	NC DEQ
Recreator	SA_{recas}	Recreator Adult Skin Surface Area Soil (cm^2/day)	6,032	Exposure Factors and Target Risk tab	NC DEQ
Recreator	SA_{reccs}	Recreator Child Skin Surface Area Soil (cm^2/day)	2,373	Exposure Factors and Target Risk tab	NC DEQ
Recreator	SA_{reca}	Recreator Adult Skin Surface Area Water (cm^2)	19,652	Exposure Factors and Target Risk tab	EPA RSL[1]
Recreator	SA_{recc}	Recreator Child Skin Surface Area Water (cm^2)	6,365	Exposure Factors and Target Risk tab	EPA RSL[1]
Trespasser	AF_t	Trespasser Skin Soil Adherence Factor (mg/cm^2)	0.2	Exposure Factors and Target Risk tab	NC DEQ

Receptor	Parameter	Name	Default Value	Location for Data Entry in Calculator	Justification for Default Value
Trespasser	AT_t	Trespasser Noncarcinogenic Averaging Time (d)	3,650	NA	ED x 365 d/yr
Trespasser	BW_t	Trespasser Body Weight (kg)	45	Exposure Factors and Target Risk tab	EPA Region 4 Guidance[2].
Trespasser	ED_t	Trespasser Exposure Duration (yr)	10	Exposure Factors and Target Risk tab	EPA Region 4 Guidance[2].
Trespasser	EF_t	Trespasser Surface Water Exposure Frequency (d/yr)	45	Exposure Factors and Target Risk tab	NC DEQ
Trespasser	ET_{event}	Trespasser Water Exposure Time (hr/event)	2	Exposure Factors and Target Risk tab	Virginia Guidance[3]
Trespasser	ET_t	Trespasser Exposure Time (hr/d)	2	Exposure Factors and Target Risk tab	Virginia Guidance[3].
Trespasser	EV_{rect}	Trespasser Event Frequency (events/day)	1	Exposure Factors and Target Risk tab	EPA Region 4 Guidance[2].
Trespasser	IR_t	Trespasser Ingestion Rate of Soil (mg/d)	200	Exposure Factors and Target Risk tab	NC DEQ
Trespasser	IRW_t	Trespasser Surface Water Ingestion Rate (L/d)	0.124	Exposure Factors and Target Risk tab	EPA RSL[1]
Trespasser	SA_{ts}	Trespasser Skin Surface Area Soil (cm^2/day)	6,032	Exposure Factors and Target Risk tab	NC DEQ
Trespasser	SA_{tw}	Trespasser Skin Surface Area Water (cm^2)	19,652	Exposure Factors and Target Risk tab	NC DEQ
NA	CSF_o	Oral Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$	chemical specific	Chemical Database tab	EPA RSL[1]
NA	RfD_o	Oral Reference Dose (mg/kg-d)	chemical specific	Chemical Database tab	EPA RSL[1]
NA	IUR	Inhalation Unit Risk $(ug/m^3)^{-1}$	chemical specific	Chemical Database tab	EPA RSL[1]
NA	RfC	Reference Concentration (mg/m^3)	chemical specific	Chemical Database tab	EPA RSL[1]
NA	ABS_d	Dermal Absorption Fraction (unitless)	chemical specific	Chemical Database tab	EPA RSL[1]
NA	B	Relative Contribution of Permeability Coefficient	chemical specific	Chemical Database tab	EPA RSL[1]
NA	D_{ia}	Diffusivity in Air (cm^2/s)	chemical specific	Chemical Database tab	EPA RSL[1]
NA	D_{iw}	Diffusivity in Water (cm^2/s)	chemical specific	Chemical Database tab	EPA RSL[1]
NA	FA	Fraction Absorbed in Water (unitless)	chemical specific	Chemical Database tab	EPA RSL[1]
NA	GIABS	Fraction of Contaminant Absorbed in Intestinal Tract (unitless)	chemical specific	Chemical Database tab	EPA RSL[1]

Receptor	Parameter	Name	Default Value	Location for Data Entry in Calculator	Justification for Default Value
NA	H'	Henry's Constant (unitless)	chemical specific	Chemical Database tab	EPA RSL[1]
NA	K_d or K_s	Soil-Water Partition Coefficient (L/kg)	K_d is for inorganics, K_s is for organics and calculated as K_{oc} x f_{oc}	Chemical Database tab	EPA RSL[1]
NA	K_{oc}	Soil Organic Carbon-Water Partition Coefficient	chemical specific	Chemical Database tab	EPA RSL[1]
NA	Kp	Dermal Permeability Constant (cm/hr)	chemical specific	Chemical Database tab	EPA RSL[1]
NA	RBA	Relative Bioavailability Factor (unitless)	chemical specific	Chemical Database tab	EPA RSL[1]
NA	t*	Time to Reach Steady State (hr)	chemical specific	Chemical Database tab	EPA RSL[1]
NA	τ_{event}	Lag Time (hr/event)	chemical specific	Chemical Database tab	EPA RSL[1]
NA	THQ	Target Hazard Quotient (unitless)	0.2 individual, 1 cumulative	Exposure Factors and Target Risk tab	NC DEQ
NA	TR	Target Carcinogenic Risk (unitless)	1.0E-06 individual, 1.0E-04 cumulative	Exposure Factors and Target Risk tab	NC DEQ
NA	ED_{ml}	Exposure Duration for Soil Leaching to Groundwater Mass Limit Equation (yrs)	70	Individual calculator tabs	EPA RSL[1]
NA	K	Andelman Volatilization Factor (L/m^3)	0.5	Individual calculator tabs	EPA RSL[1]
NA	POE_{gw}	Distance to Protection of Surface Water POE (ft)	0	Parameters tab	NCDEQ
NA	POE_{sw}	Distance to Protection of Groundwater Use POE (ft)	0	Parameters tab	NCDEQ
NA	d_a	Aquifer Thickness (cm)	no default/site specific	Parameters tab	Site Specific
NA	d_s	Depth to Base of Soil Source Area (cm)	1,244	Parameters tab	NC DEQ
NA	f_{oc}	Fraction Organic Carbon (unitless)	0.006/0.002	Parameters tab	EPA RSL[1]. The two values shown reflect the defaults for (1) VF & PEF equations / (2) Soil to Groundwater equations.

Receptor	Parameter	Name	Default Value	Location for Data Entry in Calculator	Justification for Default Value
NA	I	Infiltration Rate (cm/yr)	66	Parameters tab	DSCA Program previously established default infiltration for different geographic regions: 30% of precipitation in Mountain Zone, 25% of precipitation in Piedmont Zone, and 45% of precipitation in Coastal Plain Zone (DSCA, 2013). The default is based on the most conservative geographic zone (Coastal Zone) and typical rainfall in that region.
NA	i	Hydraulic Gradient (unitless)	no default/ site specific	Parameters tab	Site Specific
NA	T_{gw}	Average Groundwater Temperature (^oC)	25	Parameters tab	EPA RSL[1]
NA	K	Aquifer Hydraulic Conductivity (cm/d)	no default/site specific	Parameters tab	Site Specific
NA	L	Length of Soil Source Area Parallel to Groundwater Flow (cm)	no default/site specific	Parameters tab	NC DEQ default. Equivalent to 16 ft. (No EPA or ASTM defaults established).
NA	LT	Lifetime (years)	70	Parameters tab	EPA RSL[1]
NA	n	Total Soil Porosity (unitless)	0.43	Parameters tab	EPA RSL[1]
NA	Q_{sw}	Surface Water Flow Rate (cm^3/d)	0	Parameters tab	NCDEQ, conservatively assumes no surface water flow.
NA	S_d	Groundwater Source Thickness (cm)	no default/site specific	Parameters tab	Site Specific
NA	S_w	Groundwater Source Width (cm)	no default/site specific	Parameters tab	Site Specific
NA	W_{gwsw}	Width of Groundwater Plume at Surface Water Interface (cm)	no default/site specific	Parameters tab	Site Specific
NA	δ_{sw}	Thickness of Groundwater Plume at Surface Water Interface (cm)	no default/site specific	Parameters tab	Site Specific

Receptor	Parameter	Name	Default Value	Location for Data Entry in Calculator	Justification for Default Value
NA	θ_a	Air Filled Soil Porosity (unitless)	0.28/0.13	Parameters tab	EPA RSL [1]. The two values shown reflect the defaults for (1) VF & PEF equations / (2) Soil to Groundwater equations.
NA	θ_w	Water Filled Soil Porosity (unitless)	0.15/0.3	Parameters tab	EPA RSL [1]. The two values shown reflect the defaults for (1) VF & PEF equations / (2) Soil to Groundwater equations.
NA	ρ_b	Dry Soil Bulk Density (g/cm^3)	1.5	Parameters tab	EPA RSL[1]
NA	V	Fraction of Vegetative Cover (unitless)	0.5	Parameters tab	EPA RSL[1]
NA	A_s	Areal Extent of Site or Soil Contamination (acres)	0.5	Parameters tab	EPA RSL default[1]. Only values between 0.5 and 500 are valid.
NA	A	EPA Dispersion Constant (unitless)	12.3675	Supplemental Equations tab	EPA RSL[1] for Raleigh, NC region.
NA	B	EPA Dispersion Constant (unitless)	18.6337	Supplemental Equations tab	EPA RSL[1] for Raleigh, NC region.
NA	C	EPA Dispersion Constant (unitless)	212.7284	Supplemental Equations tab	EPA RSL[1] for Raleigh, NC region.
NA	F(x)	Function Depending on Um/Ut (unitless)	0.0086	Supplemental Equations tab	EPA RSL[1] for Raleigh, NC region.
NA	T	Exposure Interval for All Receptors Except Construction Worker (years)	26	Supplemental Equations tab	EPA RSL[1].
NA	T(s)	Exposure Interval for All Receptors Except Construction Worker (seconds)	820,000,000	Supplemental Equations tab	EPA RSL[1]
NA	t_c	Construction Worker Exposure Interval (hours)	8,400	Supplemental Equations tab	EPA RSL[1]
NA	U_m	Mean Annual Wind Speed (m/s)	3.44	Supplemental Equations tab	EPA RSL[1] for Raleigh, NC region.
NA	U_t	Equivalent Threshold Value of Wind Speed at 7m	11.32	Supplemental Equations tab	EPA RSL[1] for Raleigh, NC region.
NA	$T(s)_{cw}$	Construction Worker Exposure Interval (seconds)	30,240,000	Supplemental Equations tab	EPA RSL[1]

NA – Not Applicable

ASTM - American Society for Testing and Materials. Standard Guide for Risk-Based Corrective Action, E2081-11. 2000.

References:

1. Environmental Protection Agency. Regional Screening Levels (RSLs) website: https://www.epa.gov/risk/regional-screening-levels-rsls
2. Environmental Protection Agency. Region 4 Human Health Risk Assessment Supplemental Guidance. March 2018 Update.
3. Virginia Department of Environmental Quality. Voluntary Remediation Program - Risk Assessment Guidance website: http://www.deq.virginia.gov/Programs/LandProtectionRevitalization/RemediationProgram/VoluntaryRemediationProgram/VRPRiskAssessmentGuidance/Contents.aspx. May 2016.

E Significant Figures

The North Carolina Preliminary Soil Remediation Goals (NC PSRGs) are obtained using the United States Environmental Protection Agency's Regional Screening Levels (US EPA RSLs). RSLs are provided with 2 significant figures. Users of the PSRGs have the option of using them as screening levels, or, in the case of the residential PSRGs, using them as unrestricted use remediation standards. NC General Statute 143b-279.9(d)(1) states "Unrestricted use standards" are generally applicable standards, guidance, or established methods of governing contaminants that are established by statute or adopted, published, or implemented by the Environmental Management Commission, the Commission for Public Health, or the Department". NC General Statute 130A-310.68(a)(1) lists "unrestricted use standards" as an option for "remediation standards".

The Inactive Hazardous Sites Branch *Guidelines for Assessment and Cleanup of Contaminated Sites* states that the residential PSRGs were established for unrestricted (residential) use and should be used when no limit on site use is desired. The North Carolina Department of Environmental Quality *Revised Technical Guide for Risk-Based Environmental Remediation of Sites* (Technical Guide) also refers to the residential PSRGs as unrestricted use standards, and states that "the extent of soil contamination must be defined in all directions to the residential health-based preliminary soil remediation goals (PSRGs) to determine the appropriate placement of institutional controls".

Remediating parties have the option of using PSRGs as screening levels, and NC statute allows for their use as remediation standards. Because of this dual function as both screening levels and remediation standards, the 2 significant figures from the RSL table are maintained in the PSRG table.

Final remediation standards can be obtained directly from the PSRG table or calculated. The Technical Guide outlines a procedure for using the NC Department of Environmental Quality Risk Calculator to determine cleanup levels. The target risk and output of the calculator incorporates 2 significant figures. In a Tier 3 Baseline Risk Assessment, site-specific risks are calculated for all chemicals of concern, and cleanup levels are backcalculated using a chemical's calculated risk value. To maintain consistency in cleanups in NC, these calculated risk values shall incorporate 2 significant figures.