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A HUMAN HEALTH RISK ASSESSMENT EQUATIONS

The following equations calculate screening values for the defined media, pathway, and receptor at a cancer risk level of 1E-06 and hazard quotient = 0.2. The equations were obtained from the Environmental Protection Agency’s (EPA) Regional Screening Levels (RSL) website and modified for DEQ purposes when necessary. The screening values are used in Tier 1 of the DEQ risk evaluation process. For Tier 2 risk evaluations, the equation used to derive risk from the screening values and contaminant concentrations is provided at the end of each section.

A.1 SOIL INGESTION PATHWAY

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

Non-Carcinogenic Non-Residential Worker Soil Ingestion

\[ SL_{w-soil-nc-ing} (mg/kg) = \frac{THQ \times AT_{ow} \left( \frac{365 \text{ days}}{\text{year}} \times ED_{ow} \left(25 \text{ years}\right)\right) \times BW_{ow} \left(80 \text{ kg}\right)}{EF_{w} \left(\frac{250 \text{ days}}{\text{year}}\right) \times R_{ow} \left(100 \text{ mg} \times \frac{1}{1 \text{ mg}}\right) \times \text{RfD} \left(\frac{\text{mg}}{\text{kg} \times \text{day}}\right) \times \text{IR} \left(100 \text{ mg/day}\right) \times 10^6 \text{ kg} \]  

\[ SL_{w-soil-nc-ing} = \text{Screening level for non-carcinogenic non-residential worker soil ingestion} \]

\[ THQ = \text{Target hazard quotient} = 0.2 \]

\[ AT = \text{Averaging time} = 365 \text{ days/year} = \text{EPA default} \]

\[ ED = \text{Exposure duration} = 25 \text{ years} = \text{EPA default} \]

\[ BW = \text{Body weight} = 80 \text{ kilograms} = \text{EPA default} \]

\[ EF = \text{Exposure frequency} = 250 \text{ days/year} = \text{EPA default} \]

\[ \text{RfD} = \text{Chronic oral reference dose} = \text{Contaminant specific in mg/kg-day} = \text{EPA default} = \text{See chem-tox database} \]

\[ \text{IR} = \text{Ingestion rate} = 100 \text{ mg/day} = \text{EPA Default} \]

Carcinogenic Non-Residential Worker Soil Ingestion

\[ SL_{w-soil-ca-ing} (mg/kg) = \frac{TR \times AT_{ow} \left( \frac{365 \text{ days}}{\text{year}} \times LT \left(70 \text{ years}\right)\right) \times BW_{ow} \left(80 \text{ kg}\right)}{EF_{w} \left(\frac{250 \text{ days}}{\text{year}}\right) \times ED_{ow} \left(25 \text{ years}\right) \times CSF_{w} \left(\frac{\text{mg}}{\text{kg} \times \text{day}}\right) \times IR_{ow} \left(100 \text{ mg} \times \frac{1}{1 \text{ mg}}\right) \times 10^6 \text{ kg} \]  

\[ SL_{w-soil-ca-ing} = \text{Screening level for carcinogenic non-residential worker soil ingestion} \]

\[ TR = \text{Target risk} = 1\text{E-06} \]

\[ AT = \text{Averaging time} = 365 \text{ days/year} = \text{EPA default} \]

\[ LT = \text{Lifetime} = 70 \text{ years} = \text{EPA default} \]

\[ BW = \text{Body weight} = 80 \text{ kilograms} = \text{EPA default} \]

\[ EF = \text{Exposure frequency} = 250 \text{ days/year} = \text{EPA default} \]

\[ ED = \text{Exposure duration} = 25 \text{ years} = \text{EPA default} \]

\[ \text{CSF} = \text{Oral Cancer Slope Factor} = \text{Contaminant specific in (mg/kg-day)}^{-1} = \text{EPA default} = \text{See chem-tox database} \]

\[ \text{IR} = \text{Ingestion rate} = 100 \text{ mg/day} = \text{EPA default} \]
A.1.b. Resident Soil Ingestion

**Non-Carcinogenic Resident Soil Ingestion**

Child

\[
SL_{res-soil-nc-ing-c} \left( \frac{mg}{kg} \right) = \frac{THQ \times AT \times \left( \frac{365 \text{ days}}{\text{year}} \times ED_c \left( 6 \text{ years} \right) \right) \times BW_c \left( 15 \text{ Kg} \right)}{EF_r \left( \frac{350 \text{ days}}{\text{year}} \right) \times ED_c \left( 6 \text{ years} \right) \times RfD_c \left( \frac{1 \text{ mg}}{\text{Kg-day}} \right) \times IRS_c \left( 200 \text{ mg/day} \right) \times 10^{-6} \text{ Kg/1mg}}
\]

Adult

\[
SL_{res-soil-nc-ing-a} \left( \frac{mg}{kg} \right) = \frac{THQ \times AT \times \left( \frac{365 \text{ days}}{\text{year}} \times ED_r \left( 26 \text{ years} \right) \right) \times BW_a \left( 80 \text{ Kg} \right)}{EF_r \left( \frac{350 \text{ days}}{\text{year}} \right) \times ED_r \left( 26 \text{ years} \right) \times RfD_a \left( \frac{1 \text{ mg}}{\text{Kg-day}} \right) \times IRS_a \left( 100 \text{ mg/day} \right) \times 10^{-6} \text{ Kg/1mg}}
\]

Note: Child and adult equations are the same with exception of body weight (BW), exposure duration (ED), and ingestion rate of soil (IRS). The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA RSLs. However, inputs for both the child and adult equations are provided for reference. Note that the exposure durations cancel out in this equation, so age adjustment is not applicable.

\( SL_{res-soil-nc-ing-c} \) = Screening level for non-carcinogenic residential child soil ingestion
\( SL_{res-soil-nc-ing-a} \) = Screening level for non-carcinogenic residential adult soil ingestion
\( THQ \) = Target hazard quotient = 0.2
\( AT \) = Averaging time = 365 days/year = EPA default
\( ED \) = Exposure duration = 26 years (6 years child + 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
\( RfD \) = Chronic oral reference dose = Contaminant specific in mg/kg-day = EPA default = See chem-tox database
\( IRS \) = Ingestion rate = 200 mg/day child and 100 mg/day adult = EPA default

**Carcinogenic Resident Soil Ingestion**

Note that additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and TCE. 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

\[
SL_{res-soil-ca-ing} (mg/kg) = \frac{TR \times AT \left(365 \text{ days/year} \times LT (70 \text{ years})\right)}{CSF \left(\frac{mg}{Kg \cdot \text{day}}\right) \times IFS_{adj} \left(\frac{36750 \text{ mg}}{Kg}\right) \times 10^{-6} \text{ Kg}}
\]

where:

\[
IFS_{adj} \left(\frac{36750 \text{ mg}}{Kg}\right) = EF_{resco} \left(350 \text{ days/year}\right) \times ED_c (6 \text{ years}) \times IRS_c \left(200 \text{ mg/day}\right) \times EF_{ressa} \left(350 \text{ days/year}\right) \times ED_{24} (20 \text{ years}) \times IRS_{24} \left(100 \text{ mg/day}\right)
\]

\[
BW_c (15 \text{ Kg})
\]

\[
LR = \text{Age adjusted soil ingestion rate} = \text{Calculated via secondary equation in mg/kg} = \text{EPA default}
\]

\[
IFSM_{adj} = \text{Resident mutagenic soil ingestion rate – age-adjusted} = \text{Calculated via secondary equation in mg/kg} = \text{EPA default}
\]

\[
\text{Remaining inputs are the same as the standard equation for carcinogenic resident soil ingestion.}
\]

Mutagenic Carcinogenic Equation for Resident Soil Ingestion

\[
SL_{res-soil-mu-ing} (mg/kg) = \frac{TR \times AT \left(365 \text{ days/year} \times LT (70 \text{ years})\right)}{CSF \left(\frac{mg}{Kg \cdot \text{day}}\right) \times IFSM_{adj} \left(\frac{16666 \text{ mg}}{Kg}\right) \times 10^{-6} \text{ Kg}}
\]

where:

\[
IFS_{adj} = \text{Age adjusted soil ingestion rate} = \text{Calculated via secondary equation in mg/kg} = \text{EPA default}
\]

\[
EF_{resco} \left(350 \text{ days/year}\right) \times ED_c (6 \text{ years}) \times IRS_c \left(200 \text{ mg/day}\right) \times 10 \left(\frac{EF_{ressa} \left(350 \text{ days/year}\right) \times ED_{24} (20 \text{ years}) \times IRS_{24} \left(100 \text{ mg/day}\right)}{10} \right) + \frac{EF_{resco} 2-6 \left(350 \text{ days/year}\right) \times ED_{24} (20 \text{ years}) \times IRS_{24} \left(100 \text{ mg/day}\right) \times 3}{BW_c (15 \text{ Kg})}
\]

\[
BW_c (15 \text{ Kg})
\]

\[
EF_{ressa} 6-16 \left(350 \text{ days/year}\right) \times ED_{24} (20 \text{ years}) \times IRS_{24} \left(100 \text{ mg/day}\right) \times 3 + \frac{EF_{ressa} 6-16 \left(350 \text{ days/year}\right) \times ED_{24} (20 \text{ years}) \times IRS_{24} \left(100 \text{ mg/day}\right) \times 3}{BW_c (15 \text{ Kg})}
\]

For mutagenic compounds where chemical-specific data are not available to directly assess carcinogenic risk during childhood versus adulthood, a default mutagenic equation is used. The mutagenic equation adds an age-dependent adjustment factor (ADAF) to account for increased childhood risk for mutagenic compounds. The adjustment factor is 10-fold for the 0 to 2-year age range, three-fold for the 2 to 6-year age range, three-fold for the 6 to 16-year age range, and there is no adjustment (i.e. one-fold) for the 16 to 26-year age range. The remaining portions of the equation are similar to the standard carcinogenic equation.
Vinyl Chloride Carcinogenic Equation for Resident Soil Ingestion

\[
SL_{\text{res-soil-ca-vc-ing}}(\text{mg/kg}) = \frac{\text{TF}}{\left(\frac{\text{CSF}_0\left(\text{mg} \text{ Kg}^{-1} \text{ day}^{-1}\right)}{\text{Kg} \text{ day}^{-1}} \times \text{IFS}_{\text{adj}}\left(\frac{36750 \text{ mg}}{\text{Kg}}\right) \times 10^{-6} \text{Kg}^{-1} \text{mg}^{-1}\right)} + \\
\left(\frac{\text{AT}_r\left(\frac{365 \text{ days}}{\text{year}}\right) \times \text{LT} (70 \text{ years})}{\text{BW}_c (15 \text{ kg})}\right) \times \left(\frac{\text{CSF}_0\left(\text{mg} \text{ Kg}^{-1} \text{ day}^{-1}\right)}{\text{Kg} \text{ day}^{-1}} \times \text{IRS}_c\left(\frac{200 \text{ mg}}{\text{day}}\right) \times 10^{-6} \text{Kg}^{-1} \text{mg}^{-1}\right)
\]

where:

\[
\text{IFS}_{\text{adj}}\left(\frac{36750 \text{ mg}}{\text{Kg}}\right) = \left(\frac{\text{EF}_{\text{ressc}}\left(\frac{350 \text{ days}}{\text{year}}\right) \times \text{ED}_c (6 \text{ years}) \times \text{IRS}_c \left(\frac{200 \text{ mg}}{\text{day}}\right)}{\text{BW}_c (15 \text{ kg})}\right) + \\
\left(\frac{\text{EF}_{\text{ressa}}\left(\frac{350 \text{ days}}{\text{year}}\right) \times \text{ED}_r - \text{ED}_c (20 \text{ years}) \times \text{IRS}_a \left(\frac{100 \text{ mg}}{\text{day}}\right)}{\text{BW}_a (60 \text{ Kg})}\right)
\]

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.

\[
SL_{\text{res-soil-ca-vc-ing}} = \text{Screening level for carcinogenic resident soil ingestion for vinyl chloride}
\]

Remaining inputs are the same as the standard equation for carcinogenic resident soil ingestion.
TCE Carcinogenic Equation for Resident Soil Ingestion

For TCE, 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).

\[
SL_{\text{res-soil-tce-ing}} (mg/kg) = \frac{TR \times AT_{\text{res}} (365 \text{ days/year}) \times LT (70 \text{ years})}{CSF_o \left( \frac{mg}{kg\text{-day}} \right)^{-1} \times \left( \frac{10^6 \text{ kg}}{mg} \right) \times \left( \frac{37,650 \text{ mg}}{kg} \right) \times \left( \frac{166,833 \text{ mg}}{kg} \right)}
\]

where:

\[
IFS_{\text{res-adj}} \left( \frac{36,750 \text{ mg}}{kg} \right) = \frac{ED_{\text{res-c}} (6 \text{ years}) \times EF_{\text{res-c}} (350 \text{ days/year}) \times IRS_{\text{res-c}} (200 \text{ mg/day})}{BW_{\text{res-c}} (15 \text{ kg})}
\]

\[
IFS_{\text{res-adj}} \left( \frac{166,833 \text{ mg}}{kg} \right) = \frac{ED_{0-2} (2 \text{ years}) \times EF_{0-2} (350 \text{ days/year}) \times IRS_{0-2} (200 \text{ mg/day}) \times 10}{BW_{0-2} (15 \text{ kg})}
\]

\[
IFS_{\text{res-adj}} \left( \frac{166,833 \text{ mg}}{kg} \right) = \frac{ED_{2-6} (4 \text{ years}) \times EF_{2-6} (350 \text{ days/year}) \times IRS_{2-6} (200 \text{ mg/day}) \times 3}{BW_{2-6} (15 \text{ kg})}
\]

\[
IFS_{\text{res-adj}} \left( \frac{166,833 \text{ mg}}{kg} \right) = \frac{ED_{6-16} (10 \text{ years}) \times EF_{6-16} (350 \text{ days/year}) \times IRS_{6-16} (100 \text{ mg/day}) \times 3}{BW_{6-16} (80 \text{ kg})}
\]

\[
IFS_{\text{res-adj}} \left( \frac{166,833 \text{ mg}}{kg} \right) = \frac{ED_{10-26} (10 \text{ years}) \times EF_{10-26} (350 \text{ days/year}) \times IRS_{10-26} (100 \text{ mg/day}) \times 1}{BW_{10-26} (80 \text{ kg})}
\]

For TCE, 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).

\[
SL_{\text{res-soil-tce-ing}} = \text{Screening Level for carcinogenic resident soil ingestion for TCE}
\]

\[
IFS_{\text{adj}} = \text{Resident mutagenic soil ingestion rate – age-adjusted = Calculated via secondary equation in mg/kg = EPA default}
\]

\[
CAF_o = \text{Cancer adjustment factor oral = 0.804 = EPA default}
\]

\[
MAF_o = \text{Mutagenic adjustment factor oral = 0.202 = EPA default}
\]

Remaining inputs are the same as the standard equation for carcinogenic resident soil ingestion.
A.1.c. Construction Worker Soil Ingestion

Non-Carcinogenic Construction Worker Soil Ingestion

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

\( SL_{cw\cdot soil\cdot nc-ing} = \text{Screening level for non-carcinogenic construction worker soil ingestion} \)

\( THQ = \text{Target hazard quotient} = 0.2 \)

\( AT = EW \times 7 \frac{\text{days}}{\text{week}} \times ED = \text{See EW and ED values below} \)

\( EW = \text{Weeks worked} = 50 \frac{\text{weeks}}{\text{year}} = \text{EPA default} \)

\( ED = \text{Exposure duration} = 1 \text{ year} = \text{EPA default} \)

\( BW = \text{Body weight} = 80 \text{ kilograms} = \text{EPA default} \)

\( EF = EW (\text{weeks worked}) \times DW (\text{days worked}) = 250 \frac{\text{days}}{\text{year}} = \text{EPA default} \)

\( RfD = \text{Subchronic oral reference dose} = \text{Contaminant Specific in} \frac{\text{mg}}{\text{kg}\cdot\text{day}} = \text{EPA default} = \text{See chem-tox database} \)

\( IR = \text{Ingestion rate} = 330 \frac{\text{mg}}{\text{day}} = \text{EPA default} \)

Carcinogenic Construction Worker Soil Ingestion

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

\( SL_{cw\cdot soil\cdot ca-ing} = \text{Screening level for carcinogenic construction worker soil ingestion} \)

\( TR = \text{Target risk} = 1 \times 10^{-6} \)

\( AT = 365 \frac{\text{days}}{\text{year}} = \text{EPA default} \)

\( LT = \text{Lifetime} = 70 \text{ years} = \text{EPA default} \)

\( BW = \text{Body weight} = 80 \text{ kilograms} = \text{EPA default} \)

\( EF = EW (\text{weeks worked}) \times DW (\text{days worked}) = 250 \frac{\text{days}}{\text{year}} = \text{EPA default} \)

\( ED = \text{Exposure duration} = 1 \text{ year} = \text{EPA default} \)

\( CSF = \text{Oral Cancer Slope Factor} = \text{Contaminant Specific in} (\frac{\text{mg}}{\text{kg}\cdot\text{day}})^{-1} = \text{EPA default} = \text{See chem-tox database} \)

\( IR = \text{Ingestion rate} = 330 \frac{\text{mg}}{\text{day}} = \text{EPA default} \)
A.1.d. User Defined (Recreator/Trespasser) Soil Ingestion

Non-Carcinogenic Recreator Soil Ingestion

Child

\[
SL_{\text{rec-soil-nc-ing-c}}(\text{mg/kg}) = \frac{THQ \times AT_{\text{rec-c}} \left( \frac{365 \text{ days}}{\text{year}} \right) \times ED_{\text{rec-c}}(\text{years}) \times BW_{\text{rec-c}}(15 \text{ kg})}{EF_{\text{rec-c}}(\text{days/year}) \times ED_{\text{rec-c}}(\text{years}) \times \frac{1}{RfD_{\text{rec-c}}(\text{mg/kg-day})} \times IRS_{\text{rec-c}}(200 \text{ mg/day}) \times 10^{-5} \text{kg/1mg}}
\]

Adult

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

Note: Child and adult equations are the same with exception of body weight (BW), exposure duration (ED), and ingestion rate of soil (IRS). The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA RSLs. However, inputs for both the child and adult equations are provided for reference. Note that the exposure durations cancel out in this equation, so age adjustment is not applicable.

- \( SL_{\text{rec-soil-nc-ing-c}} = \) Screening level for non-carcinogenic recreator (child) soil ingestion
- \( SL_{\text{rec-soil-nc-ing-a}} = \) Screening level for non-carcinogenic recreator adult soil ingestion
- \( THQ = \) Target hazard quotient = 0.2
- \( AT = \) Averaging time = 365 days/year = EPA default
- \( ED = \) Exposure duration recreator = 6 years child and 20 years adult = EPA default
- \( BW = \) Body weight recreator = 15 kilograms child and 80 kilograms adult = EPA default
- \( EF = \) Exposure frequency recreator = 90 days/year = EPA default
- \( EF = \) Exposure frequency trespasser = 195 days/year = NC DEQ default = 5 days/week, 9 months/year
- \( RfD = \) Chronic oral reference dose = Contaminant specific in mg/kg-day = EPA default = See chem-tox database
- \( IRS = \) Ingestion rate = 200 mg/day child and 100 mg/day adult = EPA default
Non-Carcinogenic Trespasser Soil Ingestion

Adolescent

\[
SL_{\text{tres-soil-nc-ing}} (\text{mg/kg}) = \frac{\text{THQ} \times \text{AT}_{\text{tres}}}{\text{EF}_{\text{tres}}} \left( \frac{365 \text{ days}}{\text{year}} \right) \times \left( \frac{\text{ED}_{\text{tres}} \ (\text{years})}{\text{BW}_{\text{tres}} \ (45 \text{ kg})} \right) \times \left( \frac{1}{\text{RfD}_o \left( \frac{\text{mg}}{\text{kg-day}} \right)} \right) \times \left( \frac{\text{IRS}_{\text{tres}} \ (200 \text{ mg/day})}{1 \text{ mg}} \right) \times 10^{-6} \text{kg}
\]

\( SL_{\text{tres-soil-nc-ing}} \) = Screening level for non-carcinogenic adolescent trespasser soil ingestion
\( \text{THQ} \) = Target hazard quotient = 0.2
\( \text{AT} \) = Averaging time = 365 days/year = EPA default
\( \text{ED} \) = Exposure duration trespasser = 10 years adolescent = EPA default
\( \text{BW} \) = Body weight trespasser = 45 kilograms adolescent = EPA default
\( \text{EF} \) = Exposure frequency trespasser = 90 days/year = NC DEQ default
\( \text{RfD} \) = Chronic oral reference dose = Contaminant specific in mg/kg-day = EPA default = See chem-tox database
\( \text{IRS} \) = Ingestion rate = 200 mg/day adolescent = NC DEQ default

Carcinogenic Recreator and Trespasser Soil Ingestion

Standard Carcinogenic Equation for Recreator/Trespasser Soil Ingestion

\[
SL_{\text{rec-soil-ca-ing}} (\text{mg/kg}) = \frac{\text{TR} \times \text{AT}_{\text{rec}} \left( \frac{365 \text{ days}}{\text{year}} \right) \times \text{LT} \ (70 \text{ years})}{\text{CSF}_o \left( \frac{\text{mg}}{\text{kg-day}} \right) \times \text{IFS}_{\text{rec-adj}} (\text{mg/kg})} \times \left( \frac{10^{-6} \text{kg}}{\text{mg}} \right)
\]

where:

\[
\text{IFS}_{\text{rec-adj}} (\text{mg/kg}) = \frac{\text{ED}_{\text{rec-c}} \ (\text{years}) \times \text{EF}_{\text{rec-c}} \ (\text{days/year}) \times \text{IRS}_{\text{rec-c}} (\text{200 mg/day})}{\text{BW}_{\text{rec-c}} \ (15 \text{ kg})} + \frac{\text{ED}_{\text{rec-a}} \ (\text{years}) \times \text{EF}_{\text{rec-a}} \ (\text{days/year}) \times \text{IRS}_{\text{rec-a}} (\text{100 mg/day})}{\text{BW}_{\text{rec-a}} \ (80 \text{ kg})}
\]

\( SL_{\text{rec-soil-ca-ing}} \) = Screening level for carcinogenic recreator/trespasser soil ingestion
\( \text{TR} \) = Target risk = 1E-06
\( \text{AT} \) = Averaging time = 365 days/year = EPA default
\( \text{LT} \) = Lifetime = 70 years = EPA default
\( \text{CSF} \) = Oral Cancer Slope Factor = Contaminant specific in (mg/kg-day)^-1 = EPA default = See chem-tox database
\( \text{IFS}_{\text{adj}} \) = Age adjusted soil ingestion rate = Calculated via secondary equation in mg/kg = EPA default

Use child and adult inputs for recreator scenario, adolescent inputs only for trespasser scenario
\( \text{EF} \) = Exposure frequency = 195 days/year for recreators (child and adult) = NC DEQ default
\( \text{EF} \) = Exposure frequency = 90 days/year for trespassers (adolescent) = NC DEQ default
ED = Exposure duration recreator = 6 years child and 20 years adult = EPA default
ED = Exposure duration trespasser = 10 years (adolescent) = EPA default
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 default

Mutagenic Carcinogenic Equation for Recreator/Trespasser Soil Ingestion

For mutagenic compounds where chemical-specific data are not available to directly assess carcinogenic risk during childhood versus adulthood, a default mutagenic equation is used. The mutagenic equation adds an age-dependent adjustment factor (ADAF) to account for increased childhood risk for mutagenic compounds. The adjustment factor is 10-fold for the 0 to 2-year age range, three-fold for the 2 to 6-year age range, three-fold for the 6 to 16-year age range, and there is no adjustment (i.e. one-fold) for the 16 to 26-year age range. The remaining portions of the equation are similar to the standard carcinogenic equation.

SL_{rec-soil-mu-ing} (mg/kg) = \frac{\text{TR} \times \text{AT}_{rec} \times 365 \text{ days/year} \times \text{LT}(70 \text{ years})}{\text{CSF}_0 \left( \frac{\text{mg}}{\text{kg-day}} \right)^{-1} \times \text{IFSM}_{rec-adj} \left( \frac{\text{mg}}{\text{kg}} \right) \times 10^{-6} \text{kg/mg}}

where:

- ED_{0-2} (years) \times \text{EF}_{0-2} \left( \frac{\text{days}}{\text{year}} \right) \times \text{IRS}_{0-2} \left( \frac{200 \text{ mg}}{\text{day}} \right) \times 10
- ED_{2-6} (years) \times \text{EF}_{2-6} \left( \frac{\text{days}}{\text{year}} \right) \times \text{IRS}_{2-6} \left( \frac{200 \text{ mg}}{\text{day}} \right) \times 3
- ED_{6-16} (years) \times \text{EF}_{6-16} \left( \frac{\text{days}}{\text{year}} \right) \times \text{IRS}_{6-16} \left( \frac{100 \text{ mg}}{\text{day}} \right) \times 3
- ED_{16-26} (years) \times \text{EF}_{16-26} \left( \frac{\text{days}}{\text{year}} \right) \times \text{IRS}_{16-26} \left( \frac{100 \text{ mg}}{\text{day}} \right) \times 1

IFSM_{rec-adj} (mg/kg) = \frac{\text{BW}_{0-2} (15 \text{ kg})}{\text{BW}_{2-6} (15 \text{ kg})} + \frac{\text{BW}_{2-6} (15 \text{ kg})}{\text{BW}_{6-16} (80 \text{ kg})} + \frac{\text{BW}_{6-16} (80 \text{ kg})}{\text{BW}_{16-26} (80 \text{ kg})}

SL_{rec-soil-mu-ing} = \text{Screening level for carcinogenic recreator/trespasser soil ingestion for mutagenic compounds}
IFSM_{rec-adj} = \text{Recreator mutagenic soil ingestion rate – age-adjusted = Calculated via secondary equation in mg/kg = EPA default}

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

\[
SL_{\text{rec-soil-ca-vc-ing}}(\text{mg/kg}) = \frac{T\text{R}}{	ext{CSF}_0 \left( \frac{\text{mg}}{\text{kg-day}} \right)^{-1} \times IFS_{\text{rec-adj}} \left( \frac{\text{mg}}{\text{kg}} \right) \times 10^{-6} \text{kg}}{1 \text{ mg}} + \frac{AT_{\text{rec}} \left( \frac{365 \text{ days}}{\text{year}} \times \text{LT} (70 \text{ years}) \right)}{BW_{\text{rec-c}} (15 \text{ kg})}
\]

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.

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

For TCE, 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-soil-tce-ing} (mg/kg) = \frac{TR \times AT_{rec} \left( \frac{365 \text{ days}}{\text{year}} \times LT (70 \text{ years}) \right)}{CSF_{o} (\text{mg/kg-day})^{-1} \times \left( \frac{10^{-6} \text{ kg}}{\text{mg}} \right) \times \left( \frac{\text{CAF}_{o} (0.804) \times \text{IFS}_{rec-adj} (\text{mg/kg})}{\text{MAF}_{o} (0.202) \times \text{IFS}_{Mrec-adj} (\text{mg/kg})} \right)}

where:

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

where:

IFS_{Mrec-adj} (mg/kg) = \frac{ED_{0-2} (\text{years}) \times EF_{0-2} (\text{days/year}) \times IRS_{0-2} (200 \text{ mg/day}) \times 10}{BW_{0-2} (15 \text{ kg})} + \frac{ED_{2-6} (\text{years}) \times EF_{2-6} (\text{days/year}) \times IRS_{2-6} (200 \text{ mg/day}) \times 3}{BW_{2-6} (15 \text{ kg})} + \frac{ED_{6-16} (\text{years}) \times EF_{6-16} (\text{days/year}) \times IRS_{6-16} (100 \text{ mg/day}) \times 3}{BW_{6-16} (80 \text{ kg})} + \frac{ED_{16-26} (\text{years}) \times EF_{16-26} (\text{days/year}) \times IRS_{16-25} (100 \text{ mg/day}) \times 1}{BW_{16-26} (80 \text{ kg})}

For TCE, 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-soil-tce-ing} = Screening Level for carcinogenic recreator/trespasser soil ingestion for TCE
IFS_{rec-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. DERMAL CONTACT WITH SOIL PATHWAY

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

Non-Carcinogenic Non-Residential Worker Dermal Contact with Soil

\[
SL_{\text{w-soil-nc-der}} (\text{mg/kg}) = \frac{\text{THQ} \times AT \times (\text{ED}_w (25 \text{ years}) \times BW_w (80 \text{ kg}))}{EF \times BW \times \text{AT} \times AF \times \text{ABSd} \times \text{AF}}
\]

\[
= \frac{\text{THQ} \times \frac{365 \text{ days}}{\text{year}} \times \frac{25 \text{ years}}{\text{year}} \times \frac{1}{\text{mg}} \times \frac{365 \text{ cm}^2}{\text{day}} \times \frac{0.12 \text{ mg}}{\text{cm}^2} \times 10^{-6} \text{ kg}}{250 \text{ days/year} \times 80 \text{ kg} \times 365 \text{ days/year} \times (25 \text{ years}) \times 0.12 \text{ mg/cm}^2 \times 10^{-6} \text{ kg}}
\]

\[
SL_{\text{w-soil-nc-der}} = \text{Screening level for non-carcinogenic non-residential worker soil dermal contact}
\]

THQ = Target hazard quotient = 0.2
AT = Averaging time = 365 days/year = 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 = Contaminant specific in mg/kg-day = EPA default = See chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
SA = Worker surface area = 3,527 cm² = EPA default
AF = Soil Adherence Factor = 0.12 mg/cm² = EPA default
ABSd = Dermal absorption fraction = Contaminant specific (unitless) = EPA default = See chem-tox database

Carcinogenic Non-Residential Worker Dermal Contact with Soil

\[
SL_{\text{w-soil-ca-der}} (\text{mg/kg}) = \frac{\text{TR} \times AT \times (\text{ED}_w (25 \text{ years}) \times BW_w (80 \text{ kg}))}{EF \times BW \times \text{AT} \times AF \times \text{ABSd} \times \text{AF}}
\]

\[
= \frac{1 \times 365 \text{ days/year} \times 25 \text{ years} \times 80 \text{ kg}}{225 \text{ days/year} \times 80 \text{ kg} \times 365 \text{ days/year} \times 25 \text{ years} \times 0.12 \text{ mg/cm}^2 \times 10^{-6} \text{ kg}}
\]

\[
SL_{\text{w-soil-ca-der}} = \text{Screening level for carcinogenic non-residential worker soil dermal contact}
\]

TR = Target carcinogenic risk = 1E-6
AT = Averaging time = 365 days/year = EPA default
LT = Lifetime = 70 years = EPA default
BW = Body weight = 80 kilograms = EPA default
EF = Exposure frequency = 225 days/year = EPA default
ED = Exposure duration = 25 years = EPA default
CSF = Oral Cancer Slope Factor = Contaminant specific in (mg/kg-day)^{-1} = EPA default = See chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
SA = Worker surface area = 3,527 cm² = EPA default
AF = Soil Adherence Factor = 0.12 mg/cm² = EPA default
ABSd = Dermal absorption fraction = Contaminant specific (unitless) = EPA default = See chem-tox database

A.2.b. Resident Dermal Contact with Soil

**Non-Carcinogenic Resident Dermal Contact with Soil**

**Child**

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

**Adult**

\[
SL_{\text{res-soil-nc-der-a}} (\text{mg/kg}) = \frac{\text{THQ} \times A_T \times 365 \text{ days/year} \times ED_{\text{res-a}} (26 \text{ years}) \times BW_{\text{res-a}} (80 \text{ kg})}{EF_{\text{res-a}} (350 \text{ days/year}) \times ED_{\text{res-a}} (26 \text{ years}) \times \left( \frac{1}{RfD_{\text{a}}} \right) \times GIABS \times SA_{\text{res-a}} (6932 \text{ cm}^2 \text{/day}) \times AF_{\text{res-a}} (0.07 \text{ mg/cm}^2) \times ABS_{\text{a}} \times 10^{-6} \text{kg/mg}}
\]

Note: Child and adult equations are the same with exception of BW, ED, and IRS. The child calculation yields the most conservative result and is therefore used in both the DSCA risk calculator and the EPA RSLs. However, inputs for both the child and adult equations are provided for reference. Note that the exposure durations cancel out in this equation, so age adjustment is not applicable.

SL_{\text{res-soil-nc-der-c}} = Screening level for non-carcinogenic residential child soil dermal contact
SL_{\text{res-soil-nc-der-a}} = Screening level for non-carcinogenic residential adult soil dermal contact
THQ = Target hazard quotient = 0.2
AT = Averaging time = 365 days/year = 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 = Contaminant specific in mg/kg-day = EPA default = See chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
SA = Skin surface area = 2,373 cm²/day child and 6,032 cm²/day adult = EPA default
AF = Adherence factor = 0.2 mg/cm² child and 0.07 mg/cm² adult = EPA default
ABSd = Dermal absorption fraction = Contaminant specific (unitless) = EPA default = See chem-tox database
Carcinogenic Resident Dermal Contact with Soil

Note that additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and TCE. These equations are only applicable for the residential carcinogenic scenario. The standard equation is listed below, followed by the alternative equations.

**Standard Carcinogenic Equation for Resident Dermal Contact with Soil**

\[
SL_{\text{res-soil-ca-der}} (\text{mg/kg}) = \frac{TR \times \frac{AT}{365 \text{ day/year}} \times LT (70 \text{ years})}{CSF (\text{mg/kg-day})^{-1} \times DFS_{\text{res-adj}} \left( \frac{103.390 \text{ mg/kg}}{10^6 \text{ mg}} \right) \times ABSD_g \times \left( 10^6 \text{ kg} \right)}
\]

where:

\[
DFS_{\text{res-adj}} \left( \frac{103.390 \text{ mg/kg}}{10^6 \text{ kg}} \right) = \frac{EF_{\text{res-c}} \left( \frac{350 \text{ days}}{\text{year}} \right) \times ED_{\text{res-c}} (6 \text{ years}) \times SA_{\text{res-c}} \left( 2373 \text{ cm}^2/\text{day} \right) \times AF_{\text{res-c}} \left( \frac{0.2 \text{ mg}}{\text{cm}^2} \right) + }{BW_{\text{res-c}} (15 \text{ kg})}
\]

\[
EF_{\text{res-c}} \left( \frac{350 \text{ days}}{\text{year}} \right) \times ED_{\text{res-c}} (6 \text{ years}) \times ED_{\text{res-a}} (26 \text{ years}) \times ED_{\text{res-c}} (6 \text{ years}) \times SA_{\text{res-a}} \left( 6032 \text{ cm}^2/\text{day} \right) \times AF_{\text{res-a}} \left( \frac{0.07 \text{ mg}}{\text{cm}^2} \right)
\]

\[
BW_{\text{res-a}} (80 \text{ kg})
\]

SL_{\text{res-soil-ca-der}} = Screening level for carcinogenic residential soil dermal contact
TR = Target carcinogenic risk = 1E-6
AT = Averaging time = 365 days/year = EPA default
LT = Lifetime = 70 years = EPA default
CSF = Oral Cancer Slope Factor = Contaminant specific in (mg/kg-day)^{-1} = EPA default = See chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
DFS = Age adjusted dermal contact factor = Calculated via secondary equation in mg/kg
ABSD = Dermal absorption fraction = Contaminant specific (unitless) = EPA default = 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 cm²/day child and 6,032 cm²/day adult = EPA default
AF = Adherence factor = 0.2 mg/cm² child and 0.07 mg/cm² adult = EPA default
BW = Body weight = 15 kilograms child and 80 kilograms adult = EPA default
**Mutagenic Carcinogenic Equation for Resident Dermal Contact with Soil**

\[
SL_{\text{res-soil-mu-der}} (\text{mg/kg}) = \frac{TR \times AT_{\text{res}} (\text{365 days/year}) \times LT (70 \text{ years})}{CSF_0 (\text{mg/kg-day})^{-1} \times DFSM_{\text{res-adj}} (428,260 \text{ mg/kg}) \times ABS4 \times 10^{-6} \text{kg/mg}}
\]

where:

\[
\text{DFSM}_{\text{res-adj}} (\frac{428,260 \text{ mg}}{\text{kg}}) = \begin{cases} 
\text{EF}_{0.2} (\frac{350 \text{ days}}{\text{year}}) \times \text{ED}_{0.2} (2 \text{ years}) \times \text{AF}_{0.2} (0.2 \text{ mg/cm}^2) \times \text{SA}_{0.2} (\frac{2373 \text{ cm}^2}{\text{day}}) \times 10 \\
\text{EF}_{2.6} (\frac{350 \text{ days}}{\text{year}}) \times \text{ED}_{2.6} (4 \text{ years}) \times \text{AF}_{2.6} (0.2 \text{ mg/cm}^2) \times \text{SA}_{2.6} (\frac{2373 \text{ cm}^2}{\text{day}}) \times 3 \\
\text{EF}_{6.16} (\frac{350 \text{ days}}{\text{year}}) \times \text{ED}_{6.16} (10 \text{ years}) \times \text{AF}_{6.16} (0.07 \text{ mg/cm}^2) \times \text{SA}_{6.16} (\frac{6032 \text{ cm}^2}{\text{day}}) \times 3 \\
\text{EF}_{16.26} (\frac{350 \text{ days}}{\text{year}}) \times \text{ED}_{16.26} (10 \text{ years}) \times \text{AF}_{16.26} (0.07 \text{ mg/cm}^2) \times \text{SA}_{16.26} (\frac{6032 \text{ cm}^2}{\text{day}}) \times 1 \\
\end{cases} 
\]

\[
\text{BSW}_{0.2} (15 \text{ kg}) \\
\text{BSW}_{2.6} (15 \text{ kg}) \\
\text{BSW}_{6.16} (80 \text{ kg}) \\
\text{BSW}_{16.26} (80 \text{ kg}) 
\]

\[
SL_{\text{res-soil-mu-der}} = \text{Screening level for carcinogenic residential soil dermal contact for mutagenic compounds}
\]

\[
\text{DFSM}_{\text{adj}} = \text{Resident mutagenic soil dermal contact factor – age-adjusted} = \text{Calculated via secondary equation in mg/kg}
\]

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

\[
SL_{res-soil-vc-der} (mg/kg) = \frac{CSF_{0} (mg \cdot kg^{-1} \cdot day^{-1})}{GLI\delta_{s}} \times DFS_{res-adj} (103,390 \ mg \ kg^{-1}) \times AB_{d,4} \times 10^{-6} \ kg \ mg^{-1} \ \frac{365 \ days}{year} \times LT (70 \ years) \]

where:
\[
DFS_{res-adj} (103,390 \ mg \ kg^{-1}) = \frac{EF_{res-c} (350 \ days \ year) \times ED_{res-c} (6 \ years) \times SA_{res-c} (2373 \ cm^{2} \ day^{-1}) \times AF_{res-c} (0.2 \ mg \ cm^{2} \ day^{-1}) \times BW_{res-c} (15 \ kg)}{BW_{res-a} (80 \ kg)}
\]

SL_{res-soil-vc-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.

TCE Carcinogenic Equation for Resident Dermal Contact with Soil

\[
SL_{res-soil-tce-der} (mg/kg) = \frac{TR \times AT_{res} (365 \ days \ year) \times LT (70 \ years)}{CSF_{0} (kg^{-1} \ mg^{-1} \ day^{-1}) \times 10^{-6} \ kg \ mg^{-1} \ \frac{365 \ days}{year} \times (MAF_{0} (0.202) \times DFSM_{res-adj} (428,260 \ mg \ kg^{-1}) \times AB_{d,4})}
\]

where:
\[
DFS_{res-adj} (428,260 \ mg \ kg^{-1}) = \frac{ED_{res-c} (6 \ years) \times EF_{res-c} (350 \ days \ year) \times SA_{res-c} (2373 \ cm^{2} \ day^{-1}) \times AF_{res-c} (0.2 \ mg \ cm^{2} \ day^{-1}) \times BW_{res-c} (15 \ kg)}{BW_{res-a} (80 \ kg)}
\]

\[
DFSM_{res-adj} (428,260 \ mg \ kg^{-1}) = \frac{ED_{2-2} (2 \ years) \times EF_{2-2} (350 \ days \ year) \times AF_{2-2} (0.2 \ mg \ cm^{2} \ day^{-1}) \times BW_{2-2} (15 \ kg)}{BW_{2-2} (15 \ kg)} + \frac{ED_{2-6} (4 \ years) \times EF_{2-6} (350 \ days \ year) \times AF_{2-6} (0.2 \ mg \ cm^{2} \ day^{-1}) \times BW_{2-6} (15 \ kg)}{BW_{2-6} (15 \ kg)} + \frac{ED_{6-16} (10 \ years) \times EF_{6-16} (350 \ days \ year) \times AF_{6-16} (0.07 \ mg \ cm^{2} \ day^{-1}) \times BW_{6-16} (60 \ kg)}{BW_{6-16} (60 \ kg)} + \frac{ED_{16-26} (10 \ years) \times EF_{16-26} (350 \ days \ year) \times AF_{16-26} (0.07 \ mg \ cm^{2} \ day^{-1}) \times BW_{16-26} (60 \ kg)}{BW_{16-26} (60 \ kg)}
\]
PRG_{res-soil-tce-der} = Preliminary remediation goal (i.e. screening level) for carcinogenic resident soil dermal contact for TCE
DFSM_{adj} = Resident mutagenic soil dermal contact factor – age-adjusted = Calculated via secondary equation in mg/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 resident soil ingestion.

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

#### Non-Carcinogenic Construction Worker Dermal Contact with Soil

\[
SL_{cw-soil-nc-der} (mg/kg) = \frac{THQ \times AT_{cw-adj} \times 50 \text{ weeks/year} \times 7 \text{ days/week} \times ED_{cw} (1 \text{ year}) \times BW_{cw} (80 \text{ kg})}{EF_{cw} (60 \text{ weeks/year} \times 5 \text{ days/week}) \times ED_{cw} (1 \text{ year}) \times \frac{1}{RF_{o} (\text{mg/kg-day})} \times GIABS} \times SA_{cw} (3627 \text{ cm}^2 \text{ day}) \times AF_{cw} \left(0.3 \text{ mg/cm}^2\right) \times ABSd (10^5 \text{ kg/1 mg})
\]

- \( SL_{cw-soil-nc-der} \) = Screening level for non-carcinogenic construction worker soil dermal contact
- \( THQ \) = Target hazard quotient = 0.2
- \( AT = EW \times 7 \text{ days/week} \times ED \) = See EW and ED values below
- \( EW = \) 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
- \( RF_{o} \) = Subchronic oral reference dose = Contaminant specific in mg/kg-day = EPA default = See chem-tox database
- \( GIABS \) = Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
- \( SA_{cw} = \) Worker surface area = 3,527 cm\(^2\) = EPA default
- \( AF_{cw} \) = Soil Adherence Factor = 0.3 mg/cm\(^2\) = EPA default
- \( ABSd = \) Dermal absorption fraction = Contaminant specific (unitless) = EPA default = See chem-tox database

#### Carcinogenic Construction Worker Dermal Contact with Soil

\[
SL_{cw-soil-ca-der} (mg/kg) = \frac{TR \times AT_{cw} \times 365 \text{ days/year} \times LT(70 \text{ years}) \times BW_{cw} (80 \text{ kg})}{EF_{cw} (60 \text{ weeks/year} \times 5 \text{ days/week}) \times ED_{cw} (1 \text{ year}) \times \left(\frac{CSF_{o} (\text{mg kg-day})}{GIABS}\right)^{1/3} \times SA_{cw} (3572 \text{ cm}^2 \text{ day}) \times AF_{cw} \left(0.3 \text{ mg/cm}^2\right) \times ABSd \times 10^5 \text{ kg/1 mg})
\]

- \( SL_{cw-soil-ca-der} \) = Screening level for carcinogenic construction worker soil dermal contact
TR = Target risk = 1E-06
AT = 365 days/year = 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 = Contaminant Specific in (mg/kg-day)^-1 = EPA default = See chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
SA = Worker surface area = 3,527 cm^2 = EPA default
AF = Soil Adherence Factor = 0.3 mg/cm^2 = EPA default
ABSd = Dermal absorption fraction = Contaminant specific (unitless) = EPA default = See chem-tox database

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

Non-Carcinogenic Recreator Dermal Contact with Soil

Child

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

Adult

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

Note: Child and adult equations are the same with exception of BW, ED, and SA. The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA RSLs. However, inputs for both the child and adult equations are provided for reference. Note that the exposure durations cancel out in this equation, so age adjustment is not applicable.

\( SL_{res-soil-nc-der-c} = \) Screening level for non-carcinogenic recreator child dermal contact with soil
\( SL_{res-soil-nc-der-a} = \) Screening level for non-carcinogenic recreator adult dermal contact with soil
THQ = Target hazard quotient = 0.2
AT = Averaging time = 365 days/year = EPA default
Non-Carcinogenic Trespasser Dermal Contact with Soil

Adolescent

\[
SL_{\text{tres-soil-nc-der}}(\text{mg/kg}) = \frac{\text{THQ} \times \text{AT}_{\text{tres}} \times \left(\frac{365 \text{ days}}{\text{year}}\right) \times \left(\frac{10 \text{ years}}{\text{year}}\right) \times \text{BW}_{\text{tres}} \times \text{ED}_{\text{tres}} \times \left(\frac{1 \text{ year}}{\text{year}}\right) \times \text{EF}_{\text{tres}} \times \left(\frac{90 \text{ days}}{\text{year}}\right) \times \left(\frac{10 \text{ years}}{\text{year}}\right) \times \text{ED}_{\text{tres}} \times \left(\frac{1 \text{ year}}{\text{year}}\right)}{\text{SA}_{\text{tres}} \times \left(\frac{6032 \text{ cm}^2}{\text{day}}\right) \times \text{AF}_{\text{tres}} \times \left(\frac{0.2 \text{ mg}}{\text{cm}^2 \cdot \text{day}}\right) \times \text{ABSd}_{\text{tres}} \times \left(\frac{10^{-6} \text{ kg}}{\text{mg}}\right) \times \left(\frac{1 \text{ year}}{\text{year}}\right) \times \left(\frac{1 \text{ year}}{\text{year}}\right)}
\]

\(SL_{\text{tres-soil-nc-der}}\) = Screening level for non-carcinogenic trespasser adolescent dermal contact with soil

THQ = Target hazard quotient = 0.2

AT = Averaging time = 365 days/year = EPA default

ED = Exposure duration trespasser = 10 years adolescent = EPA default

BW = Body weight trespasser = 45 kilograms adolescent = EPA default

EF = Exposure frequency trespasser = 90 days/year = NC DEQ default

RfD = Chronic oral reference dose = Contaminant specific in mg/kg-day = EPA default = See chem-tox database

SA = Skin surface area trespasser = 6,032 cm²/day adolescent = EPA default

AF = Adherence factor trespasser = 0.2 mg/cm² adolescent = EPA default

ABSd = Dermal absorption fraction = Contaminant specific (unitless) = EPA default = See chem-tox database
Carcinogenic Recreator Dermal Contact with Soil

Note that additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and TCE. These equations are only applicable for the residential carcinogenic scenario. The standard equation is listed below, followed by the alternative equations.

**Standard Carcinogenic Equation for Recreator/Trespasser Dermal Contact with Soil**

\[
SL_{rec-soil-ca-der} (mg/kg) = \frac{TR \times AT_{rec} \left( \frac{365 \ days}{year} \times LT (70 \ years) \right)}{\left( \frac{CSF}{GIABS} \right) \times DFS_{rec-adj} (mg/kg) \times ABS_d \times \left( \frac{10^{-6} kg}{mg} \right)}
\]

where:

\[
DFS_{rec-adj} (mg/kg) = \frac{EP_{rec-c} \ (years) \times EF_{rec-c} \ (days/year) \times SA_{rec-c} \ (2373 \ cm^2/\ day) \times AF_{rec-c} \ (0.2 \ mg/cm^2)}{EW_{rec-c} \ (15 \ kg)}
\]

\[
DFS_{rec-a} (mg/kg) = \frac{EP_{rec-a} \ (years) \times EF_{rec-a} \ (days/year) \times SA_{rec-a} \ (6032 \ cm^2/\ day) \times AF_{rec-a} \ (0.07 \ mg/cm^2)}{BW_{rec-a} \ (80 \ kg)}
\]

**Variables:**
- \( SL_{rec-soil-ca-der} \): Screening level for carcinogenic recreator/trespasser soil dermal contact
- \( TR \): Target carcinogenic risk = 1E-6
- \( AT \): Averaging time = 365 days/year = EPA default
- \( LT \): Lifetime = 70 years = EPA default
- \( CSF \): Oral Cancer Slope Factor = Contaminant specific in (mg/kg-day)^{-1} = EPA default = See chem-tox database
- \( GIABS \): Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
- \( DFS \): Age adjusted dermal contact factor = Calculated via secondary equation in mg/kg
- \( ABS_d \): Dermal absorption fraction = Contaminant specific (unitless) = EPA default = 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 = 195 days/year = NC DEQ default
- \( EF \): Exposure frequency trespasser = 90 days/year = EPA Region 4 guidance
- \( SA \): 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 default
Mutagenic Carcinogenic Equation for Recreator/Trespasser Contact with Soil

\[ SL_{\text{rec-soil-mu-der}} (\text{mg/kg}) = \frac{TR \times AT_{\text{rec}} \left( \frac{365 \text{ days}}{\text{year}} \right) \times LT (70 \text{ years})}{\left( \frac{CSF_0 (\text{mg}}{\text{kg-day}} \right)^{-1} \times DFS_{\text{rec-adj}} (\text{mg/kg}) \times ABS_d \left( \frac{10^6 \text{kg}}{\text{mg}} \right)} \times \left( \frac{\text{BW}_{\text{rec}} (15 \text{ kg})}{15 \text{ kg}} \right) \]

where:

\[ \begin{aligned} DFS_{\text{rec-adj}} (\text{mg/kg}) &= \frac{\text{ED}_{0.2} (\text{year}) \times \text{EF}_{0.2} (\text{day/year}) \times \text{AF}_{0.2} (\text{mg/cm}^2) \times \text{SA}_{0.2} (\text{cm}^2 \text{day}) \times 10}{\text{BW}_{0.2} (15 \text{ kg})} + \\
&\quad \frac{\text{ED}_{2.6} (\text{year}) \times \text{EF}_{2.6} (\text{day/year}) \times \text{AF}_{2.6} (\text{mg/cm}^2) \times \text{SA}_{2.6} (\text{cm}^2 \text{day}) \times 3}{\text{BW}_{2.6} (16 \text{ kg})} + \\
&\quad \frac{\text{ED}_{18} (\text{year}) \times \text{EF}_{18} (\text{day/year}) \times \text{AF}_{18} (\text{mg/cm}^2) \times \text{SA}_{18} (\text{cm}^2 \text{day}) \times 3}{\text{BW}_{18} (28 \text{ kg})} + \\
&\quad \frac{\text{ED}_{26} (\text{year}) \times \text{EF}_{26} (\text{day/year}) \times \text{AF}_{26} (\text{mg/cm}^2) \times \text{SA}_{26} (\text{cm}^2 \text{day}) \times 1}{\text{BW}_{26} (60 \text{ kg})} \end{aligned} \]

SL_{\text{rec-soil-mu-der}} = \text{Screening level for carcinogenic recreator/trespasser soil dermal contact for mutagenic compounds}

DFSM_{\text{adj}} = \text{Recreator/trespasser mutagenic soil dermal contact factor – age-adjusted} = \text{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

\[ SL_{\text{rec-soil-cyc-der}} (\text{mg/kg}) = \frac{TR}{\left( \frac{CSF_0 (\text{mg}}{\text{kg-day}} \right)^{-1} \times DFS_{\text{rec-adj}} (\text{mg/kg}) \times ABS_d \left( \frac{10^6 \text{kg}}{\text{mg}} \right)} \times \left( \frac{\text{BW}_{\text{rec}} (15 \text{ kg})}{15 \text{ kg}} \right) \]

\[ \begin{aligned} DFS_{\text{rec-adj}} (\text{mg/kg}) &= \frac{\text{CSF}_0 (\text{mg}}{\text{kg-day}} \right)^{-1} \times \text{SA}_{\text{rec-c}} (\frac{2373 \text{ cm}^2}{\text{day}}) \times \text{EF}_{\text{rec-c}} (0.2 \text{ mg/cm}^2) \times \text{ABS} \left( \frac{10^6 \text{kg}}{\text{mg}} \right) \end{aligned} \]
SL_{res-soil-ca-vc-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.

**TCE Carcinogenic Equation for Recreator/Trespasser Dermal Contact with Soil**

\[
SL_{tce-soil-der}(mg/kg) = \frac{TR \times AT_{rec} \left(\frac{365 \text{ days}}{\text{year}}\right) \times LT(70 \text{ years})}{\left(\frac{CS_{tce} \left(\frac{mg}{kg \cdot day}\right)}{ABS}\right)^{1.1} \times \left(\frac{EF_{tce}(0.004) \times DFS_{rec-adj} \left(\frac{mg}{kg}\right) \times ABS_{d}}{MAF_{o}(0.202) \times DFSM_{rec-adj} \left(\frac{mg}{kg}\right) \times ABS_{d}}\right)}
\]

where:

\[
DFS_{rec-adj}(mg/kg) = \left(\frac{ED_{tce}(\text{years}) \times EF_{tce}(\text{day/year}) \times SA_{tce} \left(\frac{2373 \text{ cm}^2}{\text{day}}\right) \times AT_{rec} \left(\frac{0.2 \text{ mg}}{\text{cm}^2}\right)}{BS_{tce}(5 \text{ kg})}ight) + \left(\frac{ED_{tce}(\text{years}) - ED_{tce}(\text{years}) \times EF_{tce}(\text{day/year}) \times SA_{tce} \left(\frac{6032 \text{ cm}^2}{\text{day}}\right) \times AF_{rec-adj} \left(\frac{0.07 \text{ mg}}{\text{cm}^2}\right)}{BN_{tce}(50 \text{ kg})}\right)
\]

where:

\[
DFSM_{rec-adj}(mg/kg) = \left(\frac{ED_{tce}(\text{year}) \times EF_{tce}(\text{day/year}) \times AF_{tce} \left(\frac{0.2 \text{ mg}}{\text{cm}^2}\right) \times SA_{tce} \left(\frac{2373 \text{ cm}^2}{\text{day}}\right) \times 10}{BW_{tce}(16 \text{ kg})}\right) + \left(\frac{ED_{tce}(\text{year}) \times EF_{tce}(\text{day/year}) \times AF_{tce} \left(\frac{0.2 \text{ mg}}{\text{cm}^2}\right) \times SA_{tce} \left(\frac{2373 \text{ cm}^2}{\text{day}}\right) \times 9}{BW_{tce}(16 \text{ kg})}\right) + \left(\frac{ED_{tce}(\text{year}) \times EF_{tce}(\text{day/year}) \times AF_{tce} \left(\frac{0.07 \text{ mg}}{\text{cm}^2}\right) \times SA_{tce} \left(\frac{6032 \text{ cm}^2}{\text{day}}\right) \times 3}{BW_{tce}(16 \text{ kg})}\right) + \left(\frac{ED_{tce}(\text{year}) \times EF_{tce}(\text{day/year}) \times AF_{tce} \left(\frac{0.07 \text{ mg}}{\text{cm}^2}\right) \times SA_{tce} \left(\frac{6032 \text{ cm}^2}{\text{day}}\right) \times 1}{BW_{tce}(16 \text{ kg})}\right)
\]

SL_{res-soil-tce-der} = Screening Level for carcinogenic recreator/trespasser soil dermal contact for TCE
DFSM_{rec-adj} = Recreator/trespasser mutagenic soil dermal contact factor – age-adjusted = Calculated via secondary equation in mg/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 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

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

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

\[
SL_{w-soil-nc-inh} = \text{Screening level for non-carcinogenic non-residential worker soil inhalation}
\]

THQ = Target hazard quotient = 0.2

AT = Averaging time = 365 days/year = 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 = Contaminant specific in mg/m$^3$ = EPA default = See chem-tox database

VF = Volatilization factor = See supplemental equation in Section A.3.e. (VF is not applied for non-volatile compounds)

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**

\[
SL_{w-soil-ca-inh} \text{ (mg/kg)} = \frac{TR \times AT_{ow} \left( \frac{365 \text{ days}}{\text{year}} \right) \times LT (70 \text{ years})}{\ EF_{w} \left( \frac{250 \text{ days}}{\text{year}} \right) \times \ EF_{w} (25 \text{ years}) \times ET_{w} \left( \frac{8 \text{ hours}}{\text{day}} \right) \times \left( \frac{1 \text{ day}}{24 \text{ hours}} \right) \times \frac{1}{IUR \text{ (µg/m}^3\text{)}} \times \frac{1}{(1000 \text{ µg})} \times \frac{1}{V_F \left( \frac{\text{m}^3}{\text{kg}} \right)} + \frac{1}{PEF_{w} \left( \frac{\text{m}^3}{\text{kg}} \right)}
\]

\[
SL_{w-soil-ca-inh} = \text{Screening level for carcinogenic non-residential worker soil inhalation}
\]

TR = Target carcinogenic risk = 1E-6

AT = Averaging time = 365 days/year = 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 risk = Compound specific in (µg/m$^3$)$^{-1}$ = EPA default = See chem-tox
A.3.b. Resident Outdoor Inhalation of Volatiles and Particulates from Soil

Non-Carcinogenic Resident Outdoor Inhalation of Volatiles and Particulates from Soil

Child

\[
SL_{\text{res-soil-nc-inh-c}} \text{ (mg/kg)} = \frac{\text{THQ} \times \text{AT} \left( \frac{365 \text{ days}}{\text{year}} \times \text{ED}_c \text{ (6 years)} \right)}{\left(\frac{24 \text{ hours}}{\text{day}} \times \frac{1 \text{ day}}{\text{24 hours}} \times \frac{1}{\text{RfC}} \left(\frac{\text{mg}}{\text{m}^3}\right) \times \frac{1}{\text{VF}} \left(\frac{\text{m}^3}{\text{Kg}}\right) + \frac{1}{\text{PEF}} \left(\frac{\text{m}^3}{\text{Kg}}\right) \right)}
\]

Adult

\[
SL_{\text{res-soil-nc-inh-a}} \text{ (mg/kg)} = \frac{\text{THQ} \times \text{AT} \left( \frac{365 \text{ days}}{\text{year}} \times \text{ED}_a \text{ (26 years)} \right)}{\left(\frac{24 \text{ hours}}{\text{day}} \times \frac{1 \text{ day}}{\text{24 hours}} \times \frac{1}{\text{RfC}} \left(\frac{\text{mg}}{\text{m}^3}\right) \times \frac{1}{\text{VF}} \left(\frac{\text{m}^3}{\text{Kg}}\right) + \frac{1}{\text{PEF}} \left(\frac{\text{m}^3}{\text{Kg}}\right) \right)}
\]

Note: 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.

\( SL_{\text{res-soil-nc-inh-c}} \) = Screening level for non-carcinogenic residential child soil inhalation
\( SL_{\text{res-soil-nc-inh-a}} \) = Screening level for non-carcinogenic residential adult soil inhalation
\( \text{THQ} \) = Target hazard quotient = 0.2
\( \text{AT} \) = Averaging time = 365 days/year = EPA default
\( \text{ED} \) = Exposure duration = 6 years child + 20 years adult = 26 years = EPA default
\( \text{EF} \) = Exposure frequency = 350 days/year = EPA default
\( \text{ET} \) = Exposure time = 24 hours/day = EPA default
\( \text{RfC} \) = Chronic inhalation reference concentration = Contaminant specific in mg/m\(^3\) = EPA default = See chem-tox database
\( \text{VF} \) = Volatilization factor = See supplemental equation in Section A.3.e. (VF is not applied for non-volatile compounds)
\( \text{PEF} \) = Particulate emission factor = 5.93E+10 m\(^3\)/kg. See supplemental equation in Section A.3.f.
Carcinogenic Resident Outdoor Inhalation of Volatiles and Particulates from Soil

Note that additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and TCE. These equations are only applicable for the residential carcinogenic scenario. The standard equation is listed below, followed by the alternative equations.

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

\[
SL_{res-soil-ca-inh} (mg/kg) = \frac{\sum TR \times AT res \times \left(355 \text{ days/year} \times LT (70 \text{ years})\right)}{IUR \left(\frac{\mu g}{m^3}\right)^{-1} \times \left(1000 \frac{mg}{\mu g}\right) \times ED res \times \left(26 \text{ years} \times 24 \text{ hours/day} \times \frac{1 \text{ day}}{24 \text{ hours}}\right) \times \left(\frac{1}{EF_s} \times \frac{1}{PEF_w} \times \left(1000 \frac{\mu g}{mg}\right)\right) + \left(\frac{1}{VF_s} \times \frac{1}{EF_s} \times \frac{1}{PEF_w} \times \left(1000 \frac{\mu g}{mg}\right)\right) \times \left(\frac{1}{VF_s} \times \frac{1}{EF_s} \times \frac{1}{PEF_w} \times \left(1000 \frac{\mu g}{mg}\right)\right) \times \left(\frac{1}{VF_s} \times \frac{1}{EF_s} \times \frac{1}{PEF_w} \times \left(1000 \frac{\mu g}{mg}\right)\right)}
\]

\(SL_{res-soil-ca-inh}\) = Screening level for carcinogenic resident soil inhalation

TR = Target carcinogenic risk = 1E-6
AT = Averaging time = 365 days/year = EPA default
LT = Lifetime = 70 years = EPA default
IUR = Chronic inhalation risk = Compound specific in \((\mu g/m^3)^{-1}\) = EPA default = See chem-tox database
EF = Exposure frequency = 350 days/year = EPA default
VF = Volatilization factor = See supplemental equation in Section A.3.e. (VF is not applied for non-volatile compounds)
PEF = Particulate emission factor = 5.93E+10 m^3/kg. See supplemental equation in 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

\[
SL_{res-soil-mu-inh} (mg/kg) = \frac{\sum TR \times AT res \times \left(355 \text{ days/year} \times LT (70 \text{ years})\right)}{IUR \left(\frac{mg}{m^3}\right)^{-1} \times \left(1000 \frac{\mu g}{mg}\right) \times ED res \times \left(26 \text{ years} \times 24 \text{ hours/day} \times \frac{1 \text{ day}}{24 \text{ hours}}\right) \times \left(\frac{1}{EF_s} \times \frac{1}{PEF_w} \times \left(1000 \frac{\mu g}{mg}\right)\right) + \left(\frac{1}{VF_s} \times \frac{1}{EF_s} \times \frac{1}{PEF_w} \times \left(1000 \frac{\mu g}{mg}\right)\right) \times \left(\frac{1}{VF_s} \times \frac{1}{EF_s} \times \frac{1}{PEF_w} \times \left(1000 \frac{\mu g}{mg}\right)\right) \times \left(\frac{1}{VF_s} \times \frac{1}{EF_s} \times \frac{1}{PEF_w} \times \left(1000 \frac{\mu g}{mg}\right)\right)}
\]

\(SL_{res-soil-mu-inh}\) = Screening level for mutagenic resident soil inhalation
SL_{res-soil-mu-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**

\[
SL_{res-soil-ca-vc-inh} (\text{mg/kg}) = \frac{TR}{IUR \left( \frac{\mu g/m^3}{L} \right)^{-1} \times EF_{r} \left( \frac{350 \text{ days}}{\text{year}} \right) 	imes ED_{(26 \text{ years})} \times ET_{1s} \left( \frac{24 \text{ hours}}{\text{day}} \right) \times \frac{1 \text{ day}}{24 \text{ hours}} \times \left( \frac{1000 \mu g}{\text{mg}} \right)} + \frac{AT_{r} \left( \frac{365 \text{ days}}{\text{year}} \times LT \left( 70 \text{ years} \right) \right) \times VEF \left( \frac{m^3}{kg} \right)}{IUR \left( \frac{\mu g/m^3}{L} \right)^{-1} \times \left( \frac{1000 \mu g}{\text{mg}} \right)} \times \left( \frac{m^3}{kg} \right)}
\]

SL_{res-soil-ca-vc-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.

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

\[
SL_{res-soil-tce-inh} (\text{mg/kg}) = \frac{TR \times AT_{res} \left( \frac{365 \text{ days}}{\text{year}} \times LT \left( 70 \text{ years} \right) \right)}{IUR \left( \frac{\mu g/m^3}{L} \right) \times VEF \left( \frac{m^3}{kg} \right) \times PEF \left( \frac{m^3}{kg} \right)} \times \left( \frac{1 \text{ day}}{24 \text{ hours}} \right) \times \left( \frac{1000 \mu g}{\text{mg}} \right) + \frac{CAF_{i} \left( 0.756 \times EF_{res} \left( \frac{350 \text{ days}}{\text{year}} \right) \times ED_{(26 \text{ years})} \times ET_{res} \left( \frac{24 \text{ hours}}{\text{day}} \right) \times MAF_{i} \left( 0.244 \right) \times 10 \right) + \frac{AT_{c} \left( 365 \text{ days} \times LT \left( 70 \text{ years} \right) \right) \times ET_{2} \left( \frac{24 \text{ hours}}{\text{day}} \right) \times MAF_{i} \left( 0.244 \right) \times 3 \right) + \frac{AT_{c} \left( 365 \text{ days} \times LT \left( 70 \text{ years} \right) \right) \times ET_{6.16} \left( \frac{24 \text{ hours}}{\text{day}} \right) \times MAF_{i} \left( 0.244 \right) \times 3 \right) + \frac{AT_{c} \left( 365 \text{ days} \times LT \left( 70 \text{ years} \right) \right) \times ET_{16.26} \left( \frac{24 \text{ hours}}{\text{day}} \right) \times MAF_{i} \left( 0.244 \right) \times 3 \right) + \frac{AT_{c} \left( 365 \text{ days} \times LT \left( 70 \text{ years} \right) \right) \times ET_{26} \left( \frac{24 \text{ hours}}{\text{day}} \right) \times MAF_{i} \left( 0.244 \right) \times 1 \right)
\]

SL_{res-soil-tce-inh} = Screening Level for carcinogenic resident soil inhalation for TCE

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

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

\[
SL_{cw-soil-nc-inh} \text{(mg/kg)} = \frac{THQ \times AT_{cw} \left( EW_{cw} \cdot 50 \text{ weeks/year} \times 7 \text{ days/week} \times ED_{cw} \cdot 1 \text{ year} \right)}{\left( EW_{cw} \cdot 50 \text{ weeks/year} \times 7 \text{ days/week} \times ED_{cw} \cdot 1 \text{ year} \right) \times \left( 1 \text{ day/24 hours} \times 8 \text{ hours/day} \times 5 \text{ days/week} \right) \times \left( 1 \text{ m$^3$/kg} \times PEF_{sc} \text{ (m$^3$/kg)} \right) + 1}
\]

**Carcinogenic Construction Worker Outdoor Inhalation of Volatiles and Particulates from Soil**

\[
SL_{cw-soil-ca-inh} \text{(mg/kg)} = \frac{TR \times AT_{cw} \left( EW_{cw} \cdot 50 \text{ weeks/year} \times 7 \text{ days/week} \times LT \cdot 70 \text{ years} \right)}{\left( EW_{cw} \cdot 50 \text{ weeks/year} \times 7 \text{ days/week} \times ED_{cw} \cdot 1 \text{ year} \right) \times \left( 1 \text{ day/24 hours} \times 8 \text{ hours/day} \times 5 \text{ days/week} \right) \times \left( 1 \text{ m$^3$/kg} \times PEF_{sc} \text{ (m$^3$/kg)} \right) + 1}
\]

SL_{cw-soil-nc-inh} = Screening level for non-carcinogenic construction worker soil inhalation
THQ = Target hazard quotient = 0.2
AT = EW x ED = See below
EW = Weeks worked = 50 weeks/year = EPA default
ED = Exposure duration = 1 year = EPA default
EF = EW x DW = See below
DW (days worked) of 5 days/week = EPA Default
ET = Exposure time = 8 hours/day = EPA default
RfC = Subchronic inhalation reference concentration = Contaminant specific in mg/m$^3$ = EPA default = See chem-tox database
VF = Volatilization factor = See supplemental equation in Section A.3.e. (VF is not applied for non-volatile compounds)
PEF = Particulate emission factor = See supplemental information in Appendix C.

SL_{cw-soil-ca-inh} = Screening level for carcinogenic construction worker soil inhalation
TR = Target risk = 1E-06
AT = EW x ED = See below
EW = Weeks worked = 50 weeks/year = EPA default
ED = Exposure duration = 1 year = EPA default
LT = Lifetime = 70 years = EPA default
EF = EW x DW = See below
DW (days worked) of 5 days/week = EPA Default
IUR = Subchronic inhalation risk = Compound specific in (µg/m$^3$)$^{-1}$ = EPA default = See chem-tox database
VF = Volatilization factor = See supplemental equation in Section A.3.e. (VF is not applied for...
non-volatile compounds)
PEF = Particulate emission factor = See supplemental information in Appendix C.

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

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

**Child**

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

**Adult**

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

Note: 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_{\text{res-soil-nc-inh-c}}** = Screening level for non-carcinogenic recreator (child) soil inhalation

**SL_{\text{res-soil-nc-inh-a}}** = Screening level for non-carcinogenic recreator (adult) or trespasser (adolescent) soil inhalation

**THQ** = Target hazard quotient = 0.2

**AT** = Averaging time = 365 days/year = EPA default

**ED** = Exposure duration recreator = 6 years child, 20 years adult = EPA default

**ED** = Exposure duration trespasser = 10 years adolescent = EPA Region 4 guidance

**EF** = Exposure frequency recreator = 195 days/year = NC DEQ default

**EF** = Exposure frequency trespasser = 90 days/year = EPA Region 4 guidance

**ET** = Exposure time recreator = 2 hours/day = EPA default

**ET** = Exposure time trespasser = 2 hours/day = NC DEQ default

**RfC** = Chronic inhalation reference concentration = Contaminant specific in mg/m³ = EPA default = See chem-tox database

**VF** = Volatilization factor = See supplemental equation in Section A.3.e. (VF is not applied for non-volatile compounds)
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

Note that additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and TCE. The standard equation is listed below, followed by the alternative equations.

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

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

\( SL_{\text{rec-soil-ca-inh}} \) = Screening level for carcinogenic recreator/trespasser soil inhalation
\( TR = \) Target carcinogenic risk = 1E-6
\( AT = \) Averaging time = 365 days/year = EPA default
\( LT = \) Lifetime = 70 years = EPA default
\( IUR = \) Chronic inhalation risk = Compound specific in (\( \mu g/m^3 \))$^{-1}$ = EPA default = See chem-tox database
\( EF = \) Exposure frequency recreator = 195 days/year = NC DEQ default
\( EF = \) Exposure frequency trespasser = 90 days/year = EPA Region 4 guidance
\( VF = \) Volatilization factor = See supplemental equation in Section A.3.e. (VF is not applied for non-volatile compounds)
\( PEF = \) Particulate emission factor = 5.93E+10 m$^3$/kg. See supplemental equation in 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 = EPA default
\( ET = \) Exposure time trespasser = 2 hours/day = NC DEQ default
Mutagenic Carcinogenic Equation for Recreator/Trespasser Inhalation of Volatiles and Particulates from Soil

\[
SL_{\text{rec-soil-mu-inh}} (\text{mg/kg}) = \frac{TR \times AT_{\text{rec}} \left( \frac{365 \text{ days}}{\text{year}} \times LT \left( \frac{70 \text{ years}}{\text{}} \right) \right)}{IUR \left( \frac{\mu g}{m^3} \right)^{-1} \left( \frac{1}{V_F_S \left( \frac{m^3}{kg} \right)} + \frac{1}{PEF \left( \frac{m^3}{kg} \right)} \right) \times \left( \frac{1000 \mu g}{mg} \right) \times \\
\left( ED_{D-2} \left( \frac{\text{years}}{\text{year}} \right) \times EF_{D-2} \left( \frac{\text{days}}{\text{year}} \right) \times ET_{D-2} \left( \frac{\text{hours}}{\text{day}} \right) \times \left( \frac{1 \text{ day}}{24 \text{ hours}} \right) \times 10 \right) + \\
\left( ED_{2.6} \left( \frac{\text{years}}{\text{year}} \right) \times EF_{2.6} \left( \frac{\text{days}}{\text{year}} \right) \times ET_{2.6} \left( \frac{\text{hours}}{\text{day}} \right) \times \left( \frac{1 \text{ day}}{24 \text{ hours}} \right) \times 3 \right) + \\
\left( ED_{6.16} \left( \frac{\text{years}}{\text{year}} \right) \times EF_{6.16} \left( \frac{\text{days}}{\text{year}} \right) \times ET_{6.16} \left( \frac{\text{hours}}{\text{day}} \right) \times \left( \frac{1 \text{ day}}{24 \text{ hours}} \right) \times 3 \right) + \\
\left( ED_{16.26} \left( \frac{\text{years}}{\text{year}} \right) \times EF_{16.26} \left( \frac{\text{days}}{\text{year}} \right) \times ET_{16.26} \left( \frac{\text{hours}}{\text{day}} \right) \times \left( \frac{1 \text{ day}}{24 \text{ hours}} \right) \times 1 \right)
\]

\( SL_{\text{rec-soil-mu-inh}} = \) 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

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

\( SL_{\text{rec-soil-ca-vc-inh}} = \) 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.
TCE Carcinogenic Equation for Recreator/Trespasser Inhalation of Volatiles and Particulates from Soil

\[
SL_{\text{rec-soil-tce-inh}} [\text{mg/kg}] = \frac{\text{TR} \times \text{AT}_{\text{rec}} \left( \frac{365 \text{ days}}{\text{year}} \times \text{LT} (70 \text{ years}) \right)}{1000 \left( \frac{\mu g}{\text{m}^3} \right) \times \left( \frac{1 \text{ day}}{24 \text{ hours}} \right) \times \left( \frac{1 \text{ m}^3}{\text{kg}} \right) \times \left( \frac{1}{\text{UF}_s} \right) \times \left( \frac{1}{\text{PEF}_w} \right) \times \left( \text{CAF}_i \right) \times \left( \text{MAF}_i \right)}
\]

\[
= \left( \frac{\text{EF}_0.2 \left( \frac{\text{days}}{\text{year}} \right) \times \text{ED}_0.2 \left( \frac{\text{hours}}{\text{day}} \right) \times \text{MAF}_i \left( 0.244 \right) \times 10}{\text{ED}_0.2 \left( \frac{\text{days}}{\text{year}} \right) \times \text{ED}_0.2 \left( \frac{\text{hours}}{\text{day}} \right) \times \text{MAF}_i \left( 0.244 \right) \times 10} \right) \times \left( \frac{\text{ED}_2.5 \left( \frac{\text{days}}{\text{year}} \right) \times \text{ED}_2.5 \left( \frac{\text{hours}}{\text{day}} \right) \times \text{MAF}_i \left( 0.244 \right) \times 3}{\text{ED}_2.5 \left( \frac{\text{days}}{\text{year}} \right) \times \text{ED}_2.5 \left( \frac{\text{hours}}{\text{day}} \right) \times \text{MAF}_i \left( 0.244 \right) \times 3} \right) \times \left( \frac{\text{ED}_6.16 \left( \frac{\text{days}}{\text{year}} \right) \times \text{ED}_6.16 \left( \frac{\text{hours}}{\text{day}} \right) \times \text{MAF}_i \left( 0.244 \right) \times 3}{\text{ED}_6.16 \left( \frac{\text{days}}{\text{year}} \right) \times \text{ED}_6.16 \left( \frac{\text{hours}}{\text{day}} \right) \times \text{MAF}_i \left( 0.244 \right) \times 3} \right) \times \left( \frac{\text{ED}_{16.28} \left( \frac{\text{days}}{\text{year}} \right) \times \text{ED}_{16.28} \left( \frac{\text{hours}}{\text{day}} \right) \times \text{MAF}_i \left( 0.244 \right) \times 1}{\text{ED}_{16.28} \left( \frac{\text{days}}{\text{year}} \right) \times \text{ED}_{16.28} \left( \frac{\text{hours}}{\text{day}} \right) \times \text{MAF}_i \left( 0.244 \right) \times 1} \right)
\]

SL_{\text{rec-soil-tce-inh}} = Screening level for carcinogenic recreator/trespasser soil inhalation for TCE
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 (i.e. lower groundwater screening level) for subsequent modeling calculations.
mass limit model for chronic exposure

\[ VF = \frac{m_{air}^3}{kg_{soil}} = \frac{Q}{C_{vol}} \left( \frac{g}{m^2 \cdot s} \right) \times \left( T \text{ (year)} \times \left( \frac{3.15 \times 10^7 \left( \frac{s}{\text{year}} \right)}{\rho_b \left( \frac{Mg}{m^3} \right) \times d_s (m) \times 10^8 \left( \frac{g}{Mg} \right)} \right) \right) \]

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

**VF** = Volatilization factor = 3,142.13 m³/kg

**Q/C_{vol}** = Calculated with secondary equation in \([(g/m^2 \cdot s)/(kg/m^3)]\)

**T** = Exposure interval = 26 years (Note this value was confirmed with EPA via email; however, note that EPA indicated they may modify this value to be equivalent to the exposure duration [ED] at some point in the future.)

**\( \rho_b \)** = Dry soil bulk density = Site-specific can be entered = EPA default 1.5 g/cm³

\( = 1.5 \times 10^9 \text{ mg/m}^3 \) (Values entered in risk calculator in g/cm³, but are converted to mg/m³ within 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

\[ VF_\text{m} \left( \frac{m^3}{kg_{\text{soil}}} \right) = \frac{Q \cdot \left( \frac{g}{m^2 \cdot s} \right)}{C_{\text{vol}} \cdot \left( \frac{kg}{m^3} \right)} \times \left( 3.14 \times D_A \left( \frac{cm^2}{s} \right) \times T(s) \right)^{1/2} \times 10^{-4} \left( \frac{m^2}{cm^2} \right) \]

where:

\[ \frac{Q}{C_{\text{vol}}} \left( \frac{g}{m^2 \cdot s} \right) = A \times \exp \left( \frac{(lnA_s \cdot (acre \cdot B)^2)}{C} \right) \]

where:

\[ D_A \left( \frac{cm^2}{s} \right) = \left( \frac{\theta_a \left( \frac{L_{\text{air}}}{L_{\text{soil}}} \right)^{10^3} \times D_{\text{soil}} \left( \frac{cm^2}{s} \right) \times H' + \theta_w \left( \frac{0.15 L_{\text{water}}}{L_{\text{soil}}} \right)^{10^3} \times D_{\text{water}} \left( \frac{cm^2}{s} \right) \times H' \right)}{\rho_b \left( \frac{1.5g}{cm^3} \right) \times K_d \left( \frac{cm^3}{g} \right) + \theta_w \left( \frac{0.15 L_{\text{water}}}{L_{\text{soil}}} \right) + \theta_a \left( \frac{L_{\text{air}}}{L_{\text{soil}}} \right) \times H'} \]

where:

\[ \theta_a \left( \frac{L_{\text{air}}}{L_{\text{soil}}} \right) = n \left( \frac{\theta_{\text{soil}}}{L_{\text{soil}}} \right) \theta_{\text{water}} \left( \frac{0.15 L_{\text{water}}}{L_{\text{soil}}} \right) \text{ and } n \left( \frac{\theta_{\text{soil}}}{L_{\text{soil}}} \right) = 1 \cdot \left( \frac{\rho_b \left( \frac{1.5g}{cm^3} \right)}{\rho_s \left( \frac{2.65 g}{cm^3} \right)} \right) \]

where:

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

\[ VF = \text{Volatilization factor} = \text{Calculated in m}^3/\text{kg} \]
\[ Q/C_{\text{vol}} = \text{Calculated with secondary equation in } [(g/m^2-s)/(kg/m^3)] \]
\[ D_A = \text{Apparent diffusivity} = \text{Calculated with secondary equation in } (cm^2/s) \]
\[ T(s) = \text{Exposure interval in seconds} = 26 \text{ years} = 8.20 \times 10^8 \text{ seconds} \text{ (Note this value was confirmed with EPA via email; however, note that EPA indicated they may modify this value to be equivalent to the exposure duration [ED] at some point in the future.)} \]
\[ \rho_b = \text{Dry soil bulk density} = \text{Site-specific can be entered = EPA default 1.5 g/cm}^3 = 1.5E9 \text{ mg/m}^3 \text{ (Values entered in risk calculator in g/cm}^3, \text{ but are converted to mg/m}^3 \text{ within formulas)} \]
\[ A_s = \text{Areal extent of site or contamination} = \text{range 0.5 to 500 = DEQ default 0.5 acres} \]
\[ A = 12.3675 \text{ (unitless)} = \text{EPA dispersion constant for Raleigh, NC Region} \]
\[ B = 18.6337 \text{ (unitless)} = \text{EPA dispersion constant for Raleigh, NC Region} \]
\[ C = 212.7284 \text{ (unitless)} = \text{EPA dispersion constant for Raleigh, NC Region} \]
\[ \theta_a = \text{Air filled soil porosity} = \text{Calculated via secondary equation in L/L or site-specific can be entered = EPA default 0.28 L/L} \]
\[ \theta_w = \text{Water filled soil porosity} = \text{Site-specific can be entered = EPA default 0.15 L/L} \]
\[ n = \text{Total soil porosity} = \text{The EPA provides a secondary equation that can be used to calculate the total soil porosity based on the dry soil bulk density } \rho_b \text{ and the soil particle density } \rho_s. \text{ However, in most cases the DEQ has collected site-specific porosity data, and rarely collects soil particle density data. Therefore, the DSCA risk calculator allows entry of site-specific data. The} \]
default value is 0.43 L/L, which is the same as the EPA default calculated via the secondary equation presented above.

$D_{ia} = \text{Diffusivity in air} = \text{Contaminant specific in in cm}^2/\text{s} = \text{See chem-tox database}$

$D_{iw} = \text{Diffusivity in water} = \text{Contaminant specific in in cm}^2/\text{s} = \text{See chem-tox database}$

$H' = \text{Henry's law constant} = \text{Contaminant specific (unitless)} = \text{See chem-tox database}$

$K_d = \text{Calculated via secondary equation in cm}^3/\text{g}$

$foc = \text{Fraction organic carbon} = \text{Site-specific can be entered} = \text{EPA default 0.006 g/g}$

$K_{oc} = \text{Soil organic carbon-water partition coefficient} = \text{Contaminant specific in L/kg} = \text{See chem-tox database}$

$\rho_s = \text{Soil particle density in g/cm}^3 = \text{The parameter is only used if porosity is calculated based on the soil dry bulk density and soil particle density. The risk calculator allows entry of porosity (n) data directly, which means this parameter is not used in the risk calculator.}$

**Construction Worker VF Equations**

mass limit model for subchronic exposure

$$
\sqrt[3]{F_{oc}} = \left( \frac{m_{ai}}{C_{sa}} \right) = \frac{Q}{C_{sa}} \left( \frac{g}{m^2 \cdot s} \right) \times 1 \times \frac{T (s)}{F_d \times \rho_b \left( \frac{1.5 Mg}{m^3} \right) \times d_s (m) \times 10^8 \left( \frac{g}{Mg} \right)}
$$

where

$$
\frac{Q}{C_{sa}} = A \times \exp \left[ \frac{\left( n \frac{A_s (acres)}{D} \right)^2}{C} \right]
$$

$$
T (302400000 s) = E_{ocw} \left( 1 \text{yr} \times \frac{50 \text{ wks}}{\text{year}} \times \frac{7 \text{ days}}{\text{week}} \times \frac{24 \text{ hrs}}{\text{day}} \times \frac{3600 \text{ s}}{\text{hr}} \right)
$$

$$
F_d (0.16594) = 0.1952 + \left( 5.3537 / t_c \right) + \left( -9.6316 / t_c^2 \right)
$$

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

$VF = \text{Volatileization factor} = \text{Calculated in m}^3/\text{kg}$

$Q/C = \text{Calculated with secondary equation in \([(g/m^2 \cdot s)/(kg/m^3)]\}$

$T(s) = \text{Calculated with secondary equation}$

$F_d = \text{Calculated with secondary equation}$

$t_c = \text{Calculated with secondary equation}$

$\rho_b = \text{Dry soil bulk density} = \text{Site-specific can be entered} = \text{EPA default 1.5 g/cm}^3$

$= 1.5E9 \text{ mg/m}^3 \text{ (Values entered in risk calculators in g/cm}^3, \text{ but are converted to mg/m}^3 \text{ within formulas)}$

$d_s = \text{Depth to base of soil source area} = \text{Site-specific can be entered} = \text{EPA default 12.44 m}$

$A_s = \text{Areal extent of site or contamination} = \text{range 0.5 to 500} = \text{DEQ default 0.5 acres}$

$A = 12.3675 \text{ (unitless)} = \text{EPA dispersion constant for Raleigh, NC Region}$

$B = 18.6337 \text{ (unitless)} = \text{EPA dispersion constant for Raleigh, NC Region}$

$C = 212.7284 \text{ (unitless)} = \text{EPA dispersion constant for Raleigh, NC Region}$

$ED = \text{Exposure duration} = 1 \text{ year} = \text{EPA default}$

$EW = \text{Weeks worked} = 50 \text{ weeks/year} = \text{EPA default}$
unlimited source model for subchronic exposure

\[ VF_{oc} = \frac{C_{sa}}{Q} \left( \frac{1}{F_D} \right) \times \left[ \frac{3.14 \times D_A \left( \frac{cm^2}{s} \right) \times \left( \frac{1.5 g}{cm^3} \right)}{2 \times \rho_b \left( \frac{1.5 g}{cm^3} \right) \times D_A \left( \frac{cm^2}{s} \right)} \right]^{1/2} \times 10^{-4} \left( \frac{m^2}{cm^2} \right) \]

where:

\[ \frac{Q}{C_{sa}} = A \times \exp \left[ \frac{(\ln A_s (acre) - B)}{C} \right] \]

\[ D_A = \frac{\left( \frac{L_{air}}{L_{soil}} \right)^{10/3} \times D_{ia} \left( \frac{cm^2}{s} \right) \times H' + \theta_w \left( \frac{0.15 L_{water}}{L_{soil}} \right)^{10/3} \times D_{iw} \left( \frac{cm^2}{s} \right) \times \rho_s \left( \frac{2.65 g}{cm^3} \right)}{n^2 \left( \frac{L_{pore}}{L_{soil}} \right)} \]

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

\[ K_d = f_{o,c} \left( \frac{g}{g} \right) \times K_{oc} \left( \frac{cm^3}{g} \right) \text{ only for organics.} \]

\[ T = \frac{ED_{cw} (1 yr) \times EW_{cw}}{50 \text{ wks/year}} \times \frac{7 \text{ days/week}}{24 \text{ hrs/day}} \times \frac{3600 \text{ s/hr}}{3.024 \times 10^7 \text{ seconds}} \]

\[ F_D = \left( 0.1852 + \frac{5.3537}{t_c} \right) + \left( -9.6316 / t_c^2 \right) \]

\[ t_c = \frac{ED_{cw} (1 yr) \times EW_{cw}}{50 \text{ wks/year}} \times \frac{7 \text{ days/week}}{24 \text{ hrs/day}} \]

\[ VF = \text{ Volatilization factor = Calculated in m}^3/\text{kg} \]

\[ Q/C_{sa} = \text{ Calculated with secondary equation in } [(g/m^2-s)/(kg/m^3)] \]

\[ F_D = \text{ Calculated with secondary equation} \]

\[ D_A = \text{ Apparent diffusivity = Calculated with secondary equation in } cm^2/s \]

\[ T(s) = \text{ Total time over which construction occurs = 1 yr x 50 wks/yr x 7 days/week x 24 hrs/day x 3600 s/hr = 3.024x10^7 seconds = EPA default} \]

\[ t_c = T(s) \text{ in hours = 8,400 hours} \]

\[ \rho_b = \text{ Dry soil bulk density = Site-specific can be entered = EPA default 1.5 g/cm}^3 \]

\[ = 1.5E9 \text{ mg/m}^3 \text{ (Values entered in risk calculators in g/cm}^3\text{, but are converted to mg/m}^3\text{ within formulas)} \]

\[ A_s = \text{ Areal extent of site or contamination = range 0.5 to 500 = DEQ default 0.5 acres} \]

\[ A = 12.3675 \text{ (unitless) = EPA dispersion constant for Raleigh, NC Region} \]

\[ B = 18.6337 \text{ (unitless) = EPA dispersion constant for Raleigh, NC Region} \]
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. Therefore, the DSCA risk calculators allow entry of site-specific 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

K_d = Calculated via secondary equation in cm^3/g

foc = Fraction organic carbon = Site-specific can be entered = EPA default 0.006 g/g

K_{oc} = 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

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

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

PEF = Particulate Emission factor = Calculated in m^3/kg = 5.93E+10

Q/C_{wind} = Calculated with secondary equation in [(g/m^2-s)/(kg/m^3)]

V = Fraction of vegetative cover = 0.5 (unitless) = EPA default

U_m = Mean annual wind speed (m/s) = 3.44 m/s = EPA default for Raleigh, NC Region

U_t = Equivalent threshold value of wind speed at 7m = 11.32 = 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 Appendix C for description of justification for the default value of 1.06E+06 m³/kg used in the risk calculator.

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**A.4 GROUNDWATER (TAP WATER) INGESTION PATHWAY**

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

**Non-Carcinogenic Non-Residential Worker Groundwater Ingestion**

\[
SL_{\text{water-nc-ing-w}}(\mu g/L) = \frac{\text{THQ} \times \text{AT}_w \times \left(\frac{365\ \text{days}}{\text{year}}\right) \times \text{ED}_w \times (25\ \text{years}) \times \text{BW}_w \times (80\ \text{kg}) \times \left(\frac{1000\ \mu g}{\text{mg}}\right)}{\text{EF}_w \times \left(\frac{250\ \text{days}}{\text{year}}\right) \times \text{ED}_w \times (25\ \text{years}) \times \text{IRW}_w \times (1.25\ L/\text{day}) \times \left(\frac{1}{\text{mg}}\right) \times \left(\frac{\text{mg}}{\text{kg-d}}\right)}
\]

\(SL_{\text{water-nc-ing-w}}\) = Screening level for non-carcinogenic non-residential worker water ingestion of tap water
THQ = Target hazard quotient = 0.2
AT = Averaging time = 365 days/year = 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 = Contaminant specific in mg/kg-day = EPA default = See chem-tox database
IRW = Tap water Ingestion rate = 1.25 L/day = EPA Region 4 default (one half resident intake)

**Carcinogenic Non-Residential Worker Water Ingestion**

\[
SL_{\text{wa-ca-ing}}(\mu g/L) = \frac{\text{TR} \times \text{AT}_w \times \left(\frac{365\ \text{days}}{\text{year}}\right) \times \text{LT} \times (70\ \text{years}) \times \text{BW}_w \times (80\ \text{kg})}{\text{EF}_w \times \left(\frac{250\ \text{days}}{\text{year}}\right) \times \text{ED}_w \times (25\ \text{years}) \times \text{CSF}_w \times (\left(\frac{\text{mg}}{\text{kg-d}}\right) \times \text{IR} \times \left(\frac{1.25\ L}{\text{day}}\right) \times \left(\frac{10^{-3}\ \text{mg}}{\mu g}\right)}
\]

\(SL_{\text{wa-ca-ing}}\) = Screening level for carcinogenic non-residential worker tap water ingestion
TR = Target risk = 1E-06
AT = Averaging time = 365 days/year = 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 = Contaminant specific in (mg/kg-day)^{-1} = EPA default = See chem-tox database  
IR = Tap water Ingestion rate = 1.25 L/day = EPA Region 4 default (one half resident intake)  

A.4.b. Resident Groundwater Ingestion  

Non-Carcinogenic Resident Groundwater Ingestion  

Child  

$$SL_{\text{water-nc-ing-c}} (\mu g/L) = \frac{\text{THQ} \times AT_{\text{res-c}} \left( \frac{365 \text{ days}}{\text{year}} \times ED_{\text{res-c}} (6 \text{ years}) \right) \times BW_{\text{res-c}} (15 \text{ kg}) \times \left( \frac{1000 \mu g}{\text{mg}} \right)}{EF_{\text{res-c}} \left( \frac{350 \text{ days}}{\text{year}} \right) \times ED_{\text{res-c}} (6 \text{ years}) \times \frac{1}{RfD_0 \left( \frac{\text{mg}}{\text{kg-d}} \right) \times IRW_{\text{res-c}} (0.78 \text{ L/day})}}$$  

Adult  

$$SL_{\text{water-nc-ing-a}} (\mu g/L) = \frac{\text{THQ} \times AT_{\text{res-a}} \left( \frac{365 \text{ days}}{\text{year}} \times ED_{\text{res}} (26 \text{ years}) \right) \times BW_{\text{res-a}} (80 \text{ kg}) \times \left( \frac{1000 \mu g}{\text{mg}} \right)}{EF_{\text{res-a}} \left( \frac{350 \text{ days}}{\text{year}} \right) \times ED_{\text{res}} (26 \text{ years}) \times \frac{1}{RfD_0 \left( \frac{\text{mg}}{\text{kg-d}} \right) \times IRW_{\text{res-a}} (2.5 \text{ L/day})}}$$  

Note: Child and adult equations are the same with exception of body weight (BW), exposure duration (ED), and ingestion rate of water (IRW). The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA RSLs. However, inputs for both the child and adult equations are provided for reference. Note that the exposure durations cancel out in this equation, so age adjustment is not applicable.

$SL_{\text{water-nc-ing-c}}$ = Screening level for non-carcinogenic residential child groundwater ingestion  
$SL_{\text{water-nc-ing-a}}$ = Screening level for non-carcinogenic residential adult groundwater ingestion  
THQ = Target hazard quotient = 0.2  
AT = Averaging time = 365 days/year = 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 = Contaminant specific in mg/kg-day = EPA default = See chem-tox database  
IRW = Ingestion rate = 0.78 L/day child and 2.5 L/day adult = EPA default
Carcinogenic Resident Water Ingestion

Note that additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and TCE. 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

\[
\text{SL}_{\text{water-ca-ing}} = \frac{\text{TR} \times \text{AT}_{\text{res}} \left(\frac{365 \text{ days}}{\text{year}} \times \text{LT}(70 \text{ years})\right) \times \left(\frac{1000 \text{ mg}}{\text{mg}}\right)}{\text{CSF}_o \left(\frac{\text{mg}}{\text{kg-day}}\right)^{-1} \times \left[\text{IFW}_{\text{res-adj}} \left(\frac{327.95 \text{ L}}{\text{kg}}\right)\right]},
\]

where:

\[
\text{IFW}_{\text{res-adj}} = \left(\frac{327.95 \text{ L}}{\text{kg}}\right) = \left\{ \begin{array}{l}
\frac{\text{EF}_{\text{res-c}} \left(\frac{350 \text{ days}}{\text{year}}\right) \times \text{ED}_{\text{res-c}} (6 \text{ years}) \times \text{IRW}_{\text{res-c}} (0.78 \text{ L/day}) + \\
\frac{\text{BW}_{\text{res-c}} (15 \text{ kg})}{\text{BW}_{\text{res-a}} (80 \text{ kg})}
\end{array} \right \}
\]

\[
\text{SL}_{\text{water-ca-ing}} = \text{Screening level for carcinogenic resident water ingestion}
\]
\[
\text{TR} = \text{Target risk} = 1E-06
\]
\[
\text{AT} = \text{Averaging time} = 365 \text{ days/year} = \text{EPA default}
\]
\[
\text{LT} = \text{Lifetime} = 70 \text{ years} = \text{EPA default}
\]
\[
\text{CSF} = \text{Oral Cancer Slope Factor} = \text{Contaminant specific in (mg/kg-day)}^{-1} = \text{EPA default} = \text{See chem-tox database}
\]
\[
\text{IFW}_{\text{res-adj}} = \text{Age adjusted water ingestion rate} = \text{Calculated via secondary equation in L/kg} = \text{EPA default}
\]
\[
\text{EF} = \text{Exposure frequency} = 350 \text{ days/year} (\text{same for child and adult}) = \text{EPA default}
\]
\[
\text{ED} = \text{Exposure duration} = 6 \text{ years child and 20 years adult} = \text{EPA default}
\]
\[
\text{IRW} = \text{Ingestion rate} = 0.78 \text{ L/day child and 2.5 L/day adult} = \text{EPA default}
\]
\[
\text{BW} = \text{Body weight} = 15 \text{ kilograms child and 80 kilograms adult} = \text{EPA default}
\]
Mutagenic Carcinogenic Equation for Resident Water Ingestion

\[
SL_{\text{water-mu-ing}}(\mu g/L) = \frac{TR \times AT_{\text{res}} \left( \frac{365 \text{ days}}{\text{year}} \right) \times LT (70 \text{ years}) \times \left( \frac{1000 \mu g}{\text{mg}} \right)}{CSF_0 \left( \frac{\text{mg}}{\text{kg-day}} \right) \times \text{IFWM}_{\text{res-adj}} \left( \frac{1019.9 \text{ L}}{\text{kg}} \right)}
\]

where:

\[
\text{IFWM}_{\text{res-adj}} \left( \frac{1019.9 \text{ L}}{\text{kg}} \right) = \begin{cases} 
EF_{0-2} \left( \frac{350 \text{ days}}{\text{year}} \right) \times ED_{0-2} \left( \text{years} \right) \times IRW_{0-2} \left( \frac{0.78 \text{ L}}{\text{day}} \right) \times 10 
\end{cases} 
\]

For mutagenic compounds where chemical-specific data are not available to directly assess carcinogenic risk during childhood versus adulthood, a default mutagenic equation is used. The mutagenic equation adds an age-dependent adjustment factor (ADAF) to account for increased childhood risk for mutagenic compounds. The adjustment factor is 10-fold for the 0 to 2-year age range, three-fold for the 2 to 6-year age range, three-fold for the 6 to 16-year age range, and there is no adjustment (i.e. one-fold) for the 16 to 26-year age range. The remaining portions of the equation are similar to the standard carcinogenic equation.

\[
SL_{\text{water-mu-ing}} = \text{Screening level for carcinogenic resident water ingestion for mutagenic compounds}
\]

\[
\text{IFWM}_{\text{res-adj}} = \text{Resident mutagenic water ingestion rate – age-adjusted} = \text{Calculated via secondary equation in mg/kg} = \text{EPA default}
\]

Remaining inputs are the same as the standard equation for carcinogenic resident water ingestion.
Vinyl Chloride Carcinogenic Equation for Resident Water Ingestion

\[
SL_{\text{water-ca-vc-ing}} (\mu g/L) = \frac{\text{CSF} \left( \frac{\text{mg}}{\text{kg-day}} \right)^{-1} \cdot \text{IFV}_{\text{res-adj}} \left( \frac{327 \text{ mg L}}{\text{kg}} \right) \cdot \text{AT}_{\text{res}} \left( \frac{365 \text{ days year}}{\text{year \times LT (70 years)} \right)}{\text{BW}_{\text{res-c}} \left( \frac{1.5 \text{ kg}}{\text{kg}} \right) \cdot \text{TR} \cdot \left( \frac{1000 \mu g}{1 \text{ mg}} \right)}
\]

where:

\[
\text{IFV}_{\text{res-adj}} \left( \frac{327 \text{ mg L}}{\text{kg}} \right) = \frac{\left( \frac{\text{EF}_{\text{res-c}} \left( \frac{350 \text{ days year}}{\text{year}} \right) \cdot \text{ED}_{\text{res-c}} \left( \frac{6 \text{ years}}{\text{year}} \right) \cdot \text{IRW}_{\text{res-c}} \left( \frac{0.78 \text{ L}}{\text{day}} \right)}{\text{BW}_{\text{res-c}} \left( \frac{1.5 \text{ kg}}{\text{kg}} \right)} + \left( \frac{\text{ED}_{\text{res-a}} \left( \frac{25 \text{ years}}{\text{year}} \right) \cdot \text{ED}_{\text{res-c}} \left( \frac{6 \text{ years}}{\text{year}} \right) \cdot \text{IRW}_{\text{res-a}} \left( \frac{2.5 \text{ L}}{\text{day}} \right)}{\text{BW}_{\text{res-a}} \left( \frac{90 \text{ kg}}{\text{kg}} \right)} \right) \right)
\]

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.

\[
SL_{\text{water-ca-vc-ing}} = \text{Screening level for carcinogenic resident water ingestion for vinyl chloride}
\]

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

TCE Carcinogenic Equation for Resident Water Ingestion

\[
SL_{\text{water-te-long}} (\mu g/L) = \frac{\text{CSF} \left( \frac{\text{mg}}{\text{kg-day}} \right)^{-1} \cdot \text{IFW}_{\text{res-adj}} \left( \frac{327.96 \text{ L}}{\text{kg}} \right) \cdot \text{AT}_{\text{res}} \left( \frac{365 \text{ days year}}{\text{year \times LT (70 years)} \right)}{\text{BW}_{\text{res-c}} \left( \frac{1.5 \text{ kg}}{\text{kg}} \right) \cdot \text{TR} \cdot \left( \frac{1000 \mu g}{1 \text{ mg}} \right)}
\]

where:

\[
\text{IFW}_{\text{res-adj}} \left( \frac{327.96 \text{ L}}{\text{kg}} \right) = \frac{\left( \frac{\text{ED}_{\text{res-c}} \left( \frac{350 \text{ days year}}{\text{year}} \right) \cdot \text{IRW}_{\text{res-c}} \left( \frac{0.78 \text{ L}}{\text{day}} \right)}{\text{BW}_{\text{res-c}} \left( \frac{1.5 \text{ kg}}{\text{kg}} \right)} + \left( \frac{\text{ED}_{\text{res-a}} \left( \frac{25 \text{ years}}{\text{year}} \right) \cdot \text{ED}_{\text{res-c}} \left( \frac{6 \text{ years}}{\text{year}} \right) \cdot \text{IRW}_{\text{res-a}} \left( \frac{2.5 \text{ L}}{\text{day}} \right)}{\text{BW}_{\text{res-a}} \left( \frac{90 \text{ kg}}{\text{kg}} \right)} \right) \right)
\]

where:

\[
\text{IFW}_{\text{res-adj}} \left( \frac{1019.9 \text{ L}}{\text{kg}} \right) = \frac{\left( \frac{\text{ED}_{0.2} \left( \frac{2 \text{ years}}{\text{year}} \right) \cdot \text{ED}_{0.2} \left( \frac{350 \text{ days year}}{\text{year}} \right) \cdot \text{IRW}_{0.2} \left( \frac{0.78 \text{ L}}{\text{day}} \right) \cdot 10}{\text{BW}_{0.2} \left( \frac{16 \text{ kg}}{\text{kg}} \right)} + \frac{\text{ED}_{0.6} \left( \frac{4 \text{ years}}{\text{year}} \right) \cdot \text{ED}_{0.6} \left( \frac{350 \text{ days year}}{\text{year}} \right) \cdot \text{IRW}_{0.6} \left( \frac{0.78 \text{ L}}{\text{day}} \right) \cdot 3}{\text{BW}_{0.6} \left( \frac{15 \text{ kg}}{\text{kg}} \right)} + \frac{\text{ED}_{0.16} \left( \frac{10 \text{ years}}{\text{year}} \right) \cdot \text{ED}_{0.16} \left( \frac{350 \text{ days year}}{\text{year}} \right) \cdot \text{IRW}_{0.16} \left( \frac{2.5 \text{ L}}{\text{day}} \right) \cdot 3}{\text{BW}_{0.16} \left( \frac{80 \text{ kg}}{\text{kg}} \right)} + \frac{\text{ED}_{0.26} \left( \frac{10 \text{ years}}{\text{year}} \right) \cdot \text{ED}_{0.26} \left( \frac{350 \text{ days year}}{\text{year}} \right) \cdot \text{IRW}_{0.26} \left( \frac{2.5 \text{ L}}{\text{day}} \right) \cdot 1}{\text{BW}_{0.26} \left( \frac{600 \text{ kg}}{\text{kg}} \right)} \right)
\]
For TCE, 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).

\[
\text{SL}_{\text{water-tce-ing}} = \text{Screening Level for carcinogenic resident water ingestion for TCE}
\]

\[
\text{IFWM}_{\text{res-adj}} = \text{Resident mutagenic water ingestion rate – age-adjusted} = \text{Calculated via secondary equation in L/kg} = \text{EPA default}
\]

\[
\text{CAF}_o = \text{Cancer adjustment factor oral} = 0.804 = \text{EPA default}
\]

\[
\text{MAF}_o = \text{Mutagenic adjustment factor oral} = 0.202 = \text{EPA default}
\]

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

**Non-Carcinogenic Non-Residential Worker Dermal Contact with Groundwater**

\[
\text{DA}_{\text{event}} \left( \frac{\text{ug}}{\text{cm}^2 \cdot \text{event}} \right) = \frac{\text{THQ} \times AT_w \left( \frac{1000 \text{ cm}^3}{\text{year}} \right) \times \text{ED}_{w} \left( \frac{1 \text{ event}}{\text{day}} \right) \times \text{EF}_{w} \left( \frac{250 \text{ days}}{\text{year}} \right) \times \text{SA}_{w} \left( \frac{19652 \text{ cm}^2}{\text{kg}} \right) \times \text{BW}_{w} \left( \frac{86 \text{ kg}}{\text{mg}} \right) \times \text{ET}_{\text{event}} \left( \frac{\text{hours}}{\text{event}} \right) \times \text{K}_p \left( \frac{\text{cm}}{\text{hour}} \right) \times \text{ET}_{\text{event}} \left( \frac{\text{hours}}{\text{event}} \right) \times \text{0.71 hours} \left( \frac{\text{hours}}{\text{event}} \right) }{\text{1 + B} \left( \frac{1}{\text{1 + B}} \right)^2}
\]

\[
\text{SL}_{\text{water-nc-der-w}} = \text{Screening level for tap water, non-carcinogenic worker, dermal contact}
\]

\[
\text{DA}_{\text{event}} = \text{Absorbed Dose per Event (ug-cm}^2/\text{event)}
\]

\[
\text{K}_p = \text{Dermal Permeability Constant (cm/hr) = EPA default = See chem-tox database}
\]

\[
\text{ET}_{\text{event}} = \text{Exposure Time (hr/event) = EPA default}
\]
\( t^* \) = Time to Reach Steady State (hr) = EPA default = See chem-tox database
\( FA \) = Fraction Absorbed in Water (unitless) = EPA default = See chem-tox database
\( \tau_{\text{event}} \) = Lag Time (hr/d) = EPA default = See chem-tox database
\( B \) = Relative Contribution of Permeability Coefficient = EPA default = See chem-tox database
\( \text{THQ} \) = Target hazard quotient = 0.2
\( AT \) = Averaging time = 365 days/year = EPA default
\( ED \) = Exposure duration = 25 years = EPA default
\( BW \) = Body weight = 80 kilograms = EPA default
\( \text{RfD} \) = Chronic oral reference dose = Contaminant specific in mg/kg-day = EPA default = See chem-tox database
\( \text{GIABS} \) = Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
\( \text{EV} \) = Worker events (events/day)
\( \text{EF} \) = Exposure frequency = 250 days/year = EPA default
\( \text{SA} \) = Skin surface area = 19,652 cm\(^2\)/day = EPA default

**Carcinogenic Non-Residential Worker Dermal Contact with Groundwater**

\[
\text{SL}_{\text{water-ca-der-w}} = \frac{DA_{\text{event}} \cdot \frac{\mu g}{cm^2 \cdot \text{event}} \cdot \frac{1000 \, cm^3}{L}}{K_p \cdot \frac{cm}{\text{hour}} \cdot ET_{\text{event-w}}} \left( \frac{0.71 \, \text{hours}}{\text{event}} \right)
\]

or,

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

where:

\[
DA_{\text{event}} = \frac{\text{TR} \times AT \cdot \left( 365 \, \text{days} \times ED_W \left( 70 \, \text{years} \right) \right) \cdot \left( 1000 \, \mu g \cdot \text{mg}^{-1} \right) \times BW_W \left( 50 \, \text{kg} \right)}{\text{CFS} \left( mg/kg \cdot \text{d} \right) \times \text{GIABS} \times ED_W \left( 1 \, \text{event} \right) \times ED_W \left( 25 \, \text{years} \right) \times EF_W \left( 250 \, \text{days} \right) \times SA_W \left( 19,652 \, cm^2 \right)}
\]

\( \text{SL}_{\text{water-ca-der-w}} \) = Screening level for tap water, carcinogenic non-residential worker, dermal contact
\( DA_{\text{event}} \) = Absorbed Dose per Event (µg·cm\(^2\)/event)
\( K_p \) = Dermal Permeability Constant (cm/hr) = EPA default = See chem-tox database
\( ET_{\text{event}} \) = Exposure Time (hr/event) = 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
\( \tau_{\text{event}} = \text{Lag Time (hr/d)} = \text{EPA default} = \text{See chem-tox database} \)

B = Relative Contribution of Permeability Coefficient = EPA default = See chem-tox database

TR = Target carcinogenic risk = 1E-6

AT = Averaging time = 365 days/year = EPA default

ED = Exposure duration = 25 adult = EPA default

BW = Body weight = 80 kilograms adult = EPA default

CSF = Oral Cancer Slope Factor = Contaminant specific in (mg/kg-day\(^{-1}\)) = EPA default = See chem-tox database

GIABS = Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database

EV = Worker events (events/day)

EF = Exposure frequency = 250 days/year = EPA default

SA = Skin surface area = 19,652 cm\(^2\)/day adult = EPA default

**A.5.b. Resident Dermal Contact with Groundwater**

*Non-Carcinogenic Resident Dermal Contact with Groundwater*

**Child**

**FOR INORGANICS:**

\[
S_{\text{water-ac-deal}} (\mu g/L) = \frac{DA_{\text{event}} \left( \frac{\mu g}{cm^2 \cdot \text{event}} \right) \times 1000 \text{ cm}^2}{K_p \left( \frac{\text{cm}}{\text{hour}} \right) \times ET_{\text{event-resc}} \left( \frac{0.54 \text{ hours}}{\text{event}} \right)}
\]

**FOR ORGANICS:**

\[
\begin{align*}
\text{IF } ET_{\text{event-res-c}} \left( \frac{0.54 \text{ hours}}{\text{event}} \right) & \leq 1^* \text{ (hours)}, \text{ then } S_{\text{water-ac-deal}} (\mu g/L) = \\
& \frac{DA_{\text{event}} \left( \frac{\mu g}{cm^2 \cdot \text{event}} \right) \times 1000 \text{ cm}^2}{2 \times FA \times K_p \left( \frac{cm}{\text{hour}} \right) \times ET_{\text{event-res-c}} \left( \frac{0.54 \text{ hours}}{\text{event}} \right)}
\end{align*}
\]

or,

\[
\begin{align*}
\text{IF } ET_{\text{event-res-c}} \left( \frac{0.54 \text{ hours}}{\text{event}} \right) & > 1^* \text{ (hours)}, \text{ then } S_{\text{water-ac-deal}} (\mu g/L) = \\
& \frac{DA_{\text{event}} \left( \frac{\mu g}{cm^2 \cdot \text{event}} \right) \times 1000 \text{ cm}^2}{FA \times K_p \left( \frac{cm}{\text{hour}} \right) \times \sqrt{\frac{ET_{\text{event-res-c}} \left( \frac{0.54 \text{ hours}}{\text{event}} \right) \times 0.54 \text{ hours}}{1 + B} + 2 \times \tau_{\text{event}} \left( \frac{\text{hours}}{\text{event}} \right) \left( \frac{1 + 3B + 3B^2}{1 + B} \right)}
\end{align*}
\]

where:

\[
DA_{\text{event}} \left( \frac{\mu g}{cm^2 \cdot \text{event}} \right) = \frac{\text{THQ} \times AT_{\text{res-c}} \left( \frac{365 \text{ days}}{\text{year}} \right) \times ED_{\text{res-c}} (6 \text{ years}) \times 1000 \text{ mg} \times BW_{\text{res-c}} (15 \text{ kg})}{1 \left( \frac{\text{mg}}{\text{kg/day}} \right) \times ET_{\text{res-c}} \left( \frac{1 \text{ events}}{\text{day}} \right) \times EV_{\text{res-c}} (6 \text{ years}) \times EF_{\text{res-c}} \left( \frac{360 \text{ days}}{\text{year}} \right) \times SA_{\text{res-c}} (6365 \text{ cm}^2)}
\]
Adult

**FOR INORGANICS:**

\[
SL_{\text{water-nc-der-a}}(\mu g/L) = \frac{DA_{\text{event}} \cdot \frac{ug}{cm^2 \cdot \text{event}} \cdot \frac{1000 \ cm^2}{L}}{K_p \ cm \ \text{hour} \cdot ET_{\text{event-res-a}} \ \frac{0.71 \ \text{hours}}{\text{event}}}
\]

**FOR ORGANICS**

If \( ET_{\text{event-res-a}} \cdot \frac{0.71 \ \text{hours}}{\text{event}} \cdot t^* \ \text{(hours)} \) then \( SL_{\text{water-nc-der-a}}(\mu g/L) = \)

\[
\frac{DA_{\text{event}} \cdot \frac{ug}{cm^2 \cdot \text{event}} \cdot \frac{1000 \ cm^2}{L}}{2 \cdot FA \cdot \left( \frac{cm}{\text{hour}} \right) \cdot \frac{ET_{\text{event-res-a}} \ \frac{0.71 \ \text{hours}}{\text{event}}}{a}}
\]

Where:

\[
DA_{\text{event}} = \frac{\frac{1}{RfD} \ \left( \frac{mg}{kg \cdot \text{day}} \right) \cdot GIABS \cdot \frac{1}{\text{events-day}} \cdot \frac{1}{\text{ED}} \cdot (26 \ \text{years}) \cdot \frac{1000 \ ugg}{mg} \cdot BW_{\text{res-a}} \cdot (80 \ kg)}{365 \ \text{days/year} \cdot \frac{3650 \ \text{days}}{26 \ \text{years}} \cdot \frac{1}{\text{ED}} \cdot (26 \ \text{years}) \cdot \frac{350 \ \text{days/year}}{\text{EF}} \cdot \frac{19652 \ \text{cm}^2}{1} \cdot \frac{350 \ \text{days/year}}{\text{EF}} \cdot \frac{19652 \ \text{cm}^2}{1}
\]

Note: Child and adult equations are the same with exception of BW, ED, and IRS. The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA RSLs. However, inputs for both the child and adult equations are provided for reference. Note that the exposure durations cancel out in this equation, so age adjustment is not applicable.

\( SL_{\text{water-nc-der-c}} \) = Screening level for non-carcinogenic residential child water dermal contact
\( SL_{\text{water-nc-der-a}} \) = Screening level for non-carcinogenic residential adult water dermal contact
\( DA_{\text{event}} \) = Absorbed Dose per Event (µg-cm²/event)
\( K_p \) = Dermal Permeability Constant (cm/hr) = EPA default = See chem-tox database
\( ET_{\text{event}} \) = Exposure Time (hr/event) = 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
\( \tau_{\text{event}} \) = 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 = 1E-6
\( AT \) = Averaging time = 365 days/year = 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
\( RfD \) = Chronic oral reference dose = Contaminant specific in mg/kg-day = EPA default = See chem-tox database
\( GIABS \) = Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
\( EV \) = Resident events (events/day)
\( EF \) = Exposure frequency (events/year) = EPA default
\[
SA = \text{Skin surface area} = 6,365 \, \text{cm}^2/\text{day child and 19,652 cm}^2/\text{day adult} = \text{EPA default}
\]

**Carcinogenic Resident Dermal Contact with Groundwater**

Note that additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and TCE. These equations are only applicable for the residential carcinogenic scenario. The standard equation is listed below, followed by the alternative equations. Refer to Appendix A.2b. for a discussion of how the alternative equations differ from the standard equation.

**Standard Carcinogenic Equation for Resident Dermal Contact with Tap Water**

\[
\begin{align*}
\text{SL}_{\text{water-derm}} & = \frac{\text{DA}_{\text{event}} \times \left( \frac{\text{ug}}{\text{cm}^2 \cdot \text{event}} \right) \times 1000 \, \text{cm}^2 \times \left( \frac{1}{\text{L}} \right)}{K_p \times \text{cm} / \text{hour} \times \text{ET}_{\text{event-res-adj}} \times \left( \frac{\text{hours}}{\text{event}} \right)} \\
\text{DA}_{\text{event}} & = \text{Absorbed Dose per Event (ug/cm}^2/\text{event)} \\
K_p & = \text{Dermal Permeability Constant (cm/hr) = EPA default} \quad \text{See chem-tox database} \\
\text{ET}_{\text{event-res-adj}} & = \text{Exposure Time (hr/event) = EPA default} \\
\tau^* & = \text{Time to Reach Steady State (hr) = EPA default} \quad \text{See chem-tox database} \\
\text{FA} & = \text{Fraction Absorbed in Water (unitless) = EPA default} \quad \text{See chem-tox database} \\
\text{B} & = \text{Relative Contribution of Permeability Coefficient = EPA default} \quad \text{See chem-tox database}
\end{align*}
\]

\[
\text{SL}_{\text{water-nc-derm}} = \text{Screening level for tap water, carcinogenic resident, dermal contact} \quad \text{FA} = \text{Fraction Absorbed in Water (unitless) = EPA default} \quad \text{See chem-tox database}
\]

\[
\begin{align*}
\text{DA}_{\text{event}} & = \frac{\text{TR} \times \text{AT}_{\text{res-adj}} \times 365 \, \text{days} \times \text{LT} \left( \frac{\text{years}}{\text{years}} \right) \times \left( \frac{\text{1000 mg}}{\text{mg}} \right) \times \left( \frac{\text{1 cm}^2}{\text{cm}^2} \right)}{\text{CSF} \times \text{mg/day} \times \text{w/d}} \times \text{DFW}_{\text{res-adj}} \times \left( \frac{\text{2,610,650 events/cm}^2}{\text{kg}} \right)
\end{align*}
\]

\[
\begin{align*}
\text{DFW}_{\text{res-adj}} &= \left( \frac{\text{2,610,650 events/cm}^2}{\text{kg}} \right) \\
\text{EF}_{\text{res-adj}} &= \left( \frac{\text{365 days/year}}{\text{year}} \right) \times \text{EV}_{\text{res-adj}} \left( \frac{\text{1 event/day}}{\text{day}} \right) \times \text{ED}_{\text{res-adj}} \left( \text{6 year} \right) \times \text{SA}_{\text{res-adj}} \left( \text{6,365 cm}^2 \right) \\
\text{B}_{\text{res-adj}} &= \left( \frac{\text{15 kg}}{\text{kg}} \right) \\
\text{ET}_{\text{event-res-adj}} &= \left( \frac{\text{0.9708 hours/event}}{\text{event}} \right) \\
\text{DFW}_{\text{res-adj}} &= \left( \frac{\text{2,610,650 events/cm}^2}{\text{kg}} \right) \\
\text{EF}_{\text{res-adj}} &= \left( \frac{\text{365 days/year}}{\text{year}} \right) \times \text{EV}_{\text{res-adj}} \left( \frac{\text{1 event/day}}{\text{day}} \right) \times \text{ED}_{\text{res-adj}} \left( \text{6 year} \right) \times \text{SA}_{\text{res-adj}} \left( \text{6,365 cm}^2 \right) \\
\text{B}_{\text{res-adj}} &= \left( \frac{\text{15 kg}}{\text{kg}} \right) \\
\text{ET}_{\text{event-res-adj}} &= \left( \frac{\text{0.9708 hours/event}}{\text{event}} \right) \\
\end{align*}
\]

\[
\text{SL}_{\text{water-nc-derm}} = \text{Screening level for tap water, carcinogenic resident, dermal contact} \\
\text{DA}_{\text{event}} = \text{Absorbed Dose per Event (µg-cm}^2/\text{event)} \\
K_p = \text{Dermal Permeability Constant (cm/hr) = EPA default = See chem-tox database} \\
\text{ET}_{\text{event}} = \text{Exposure Time (hr/event) = EPA default} \\
\tau^* = \text{Time to Reach Steady State (hr) = EPA default = See chem-tox database} \\
\text{FA} = \text{Fraction Absorbed in Water (unitless) = EPA default = See chem-tox database} \\
\text{B} = \text{Relative Contribution of Permeability Coefficient = EPA default = See chem-tox database} \\
\text{DFW}_{\text{res-adj}} = \text{Resident water dermal contact factor- age-adjusted (cm}^2 - \text{event/kg)}
TR = Target carcinogenic risk = 1E-6
AT = Averaging time = 365 days/year = 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 = Contaminant specific in (mg/kg-day)^-1 = EPA default = See chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
EV = Resident events (events/day)
EF = Exposure frequency = 350 days/year = EPA default
SA = Skin surface area = 6,365 cm^2/day child and 19,652 cm^2/day adult = EPA default

Mutagenic Carcinogenic Equation for Resident Dermal Contact with Tap Water

\[
SL_{\text{water-mu-de}} (\mu g/L) = \frac{DA_{\text{event}} \left( \frac{ug}{cm^2 \cdot \text{event}} \right) \cdot \left( \frac{1000 \text{ cm}^3}{L} \right)}{k_p \left( \frac{cm^2}{hour} \right) \cdot k_{ET, \text{event-mu-de}} \left( \frac{10.608 \text{ hours}}{\text{event}} \right)}
\]

or,

\[
SL_{\text{water-mu-de}} (\mu g/L) = \frac{DA_{\text{event}} \left( \frac{ug}{cm^2 \cdot \text{event}} \right) \cdot \left( \frac{1000 \text{ cm}^3}{L} \right)}{2 \cdot FA \cdot \left( \frac{cm}{hour} \right) \cdot \left( \frac{10.608 \text{ hours}}{\text{event}} \right) \cdot \left( \frac{1 + \beta}{1 - \beta^2} \right)}
\]

where:

\[
DA_{\text{event}} \left( \frac{ug}{cm^2 \cdot \text{event}} \right) = \frac{TR \cdot AT \cdot ED \cdot BW \cdot CSF \cdot GIABS (\text{unitless}) \cdot DPWM_{\text{res-ad}} \left( \frac{8,191,633 \text{ events} \cdot \text{cm}^2}{\text{kg}} \right)}{1100 \text{ day/year}}
\]

and

\[
ET_{\text{event-res-mad}} \left( \frac{0.6708 \text{ hours}}{\text{event}} \right) = \frac{ET_{\text{event-res-mad}} \left( \frac{0.54 \text{ hours}}{\text{event}} \right) + ET_{\text{event-res-mad}} \left( \frac{0.21 \text{ hours}}{\text{event}} \right)}{ET_{\text{event-res-mad}} \left( \frac{0.54 \text{ hours}}{\text{event}} \right) + ET_{\text{event-res-mad}} \left( \frac{0.21 \text{ hours}}{\text{event}} \right)}
\]
SL_{res-soil-mu-der} = Screening level for carcinogenic residential water dermal contact for mutagenic compounds
DFW_{res-adj} = Resident mutagenic water dermal contact factor – age-adjusted = Calculated via secondary equation in events-cm²/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

\[
\text{IF ET}_{\text{event-res-adj}} \left( \frac{0.6708 \text{ hours}}{\text{ event}} \right) \leq t \text{ (hours)} \text{ then } \text{SL}_{\text{water-vc-der}(\mu g/L)} = \frac{\text{DA}_{\text{event}} \left( \frac{\mu g}{\text{cm}^2 \cdot \text{ event}} \right) \left( 1000 \text{ cm}^2 /L \right)}{2 \times f' \left( \frac{\text{cm}}{\text{hour}} \right) \left( \frac{6 \times \text{event}}{\text{hours}} \right) \times \text{ET}_{\text{event-res-adj}} \left( \frac{0.6708 \text{ hours}}{\text{ event}} \right)}
\]

\[
\text{or, if ET}_{\text{event-res-adj}} \left( \frac{0.6708 \text{ hours}}{\text{ event}} \right) > t \text{ (hours)} \text{ then } \text{SL}_{\text{water-vc-der}(\mu g/L)} = \frac{\text{DA}_{\text{event}} \left( \frac{\mu g}{\text{cm}^2 \cdot \text{ event}} \right) \left( 1000 \text{ cm}^2 /L \right)}{2 \times f' \left( \frac{\text{cm}}{\text{hour}} \right) \left( \frac{6 \times \text{event}}{\text{hours}} \right) \times \text{ET}_{\text{event-res-adj}} \left( \frac{0.6708 \text{ hours}}{\text{ event}} \right) \left( 1 + 6 \times 30^2 \right)}
\]

where:

\[
\text{DA}_{\text{event}} \left( \frac{\mu g}{\text{cm}^2 \cdot \text{ event}} \right) = \frac{\text{CSF} \left( \frac{\text{mg}}{\text{kg day}} \right) \times \text{DFW}_{\text{res-adj}} \left( 2.610 \times 10^6 \text{ events-cm}^2 /\text{kg} \right)}{\text{AT}_{\text{res}} \left( 365 \text{ days} \times 15 \text{ years} \right) \times 1000 \text{ mg} / \text{kg}}
\]

\[
\text{TP} = \frac{0.8F_{\text{res}c} \left( \frac{\text{mg}}{\text{kg day}} \right) \times \text{EV}_{\text{res}c} \left( 1 \text{ event day} \right) \times \text{SA}_{\text{res}c} \left( 6365 \text{ cm}^2 \right)}{\text{EF}_{\text{res}c} \left( 350 \text{ days year} \right) + \text{EF}_{\text{res}c} \left( 1 \text{ event day} \right) \times \text{ET}_{\text{res}c} \left( 6 \text{ years} \right) + \text{SA}_{\text{res}c} \left( 6365 \text{ cm}^2 \right)}
\]

where:

\[
\text{DFW}_{\text{res-adj}} \left( 2.610 \times 10^6 \text{ events-cm}^2 /\text{kg} \right) = \frac{\text{EF}_{\text{res}c} \left( 350 \text{ days year} \right) + \text{EF}_{\text{res}c} \left( 1 \text{ event day} \right) \times \text{ET}_{\text{res}c} \left( 6 \text{ years} \right) + \text{SA}_{\text{res}c} \left( 6365 \text{ cm}^2 \right)}{\text{EF}_{\text{res}c} \left( 1 \text{ event day} \right) \times \text{ET}_{\text{res}c} \left( 30 \text{ years} \right) + \text{SA}_{\text{res}c} \left( 10652 \text{ cm}^2 \right)}
\]

and

\[
\text{ET}_{\text{event-res-adj}} \left( \frac{0.6708 \text{ hours}}{\text{ event}} \right) = \left( \frac{\text{ET}_{\text{event-res-adj}} \left( 0.54 \text{ hours event} \right) + \text{ET}_{\text{event-res-adj}} \left( 0.71 \text{ hours event} \right) \times \text{ET}_{\text{event-res-adj}} \left( 26 \text{ years} \right)}{\text{ET}_{\text{res}c} \left( 26 \text{ years} \right)} \right)
\]

SL_{water-vc-der} = Screening Level for carcinogenic resident tap water dermal contact for vinyl chloride
DFW_{res-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.
TCE Carcinogenic Equation for Resident Dermal Contact with Water

For Organics

\[
\text{IF } ET_{\text{event-res}} \text{ (hours/\text{event})} \leq (\text{hours/\text{event}}) \text{ then } \text{SL}_{\text{water-tce-der (\mu g/L)}} = \frac{\text{DA}_{\text{toe-event}} \text{ (ug/cm}^2\text{-event)}}{\text{cm}^2\text{-event}} \times \frac{1000 \text{ cm}^2}{\text{L}} \times \frac{\text{tau}_{\text{event}} \text{ (hours/\text{event})}}{\pi} \times \frac{2 + \tau_{\text{event}} \text{ (hours/\text{event})}}{1 + \tau_{\text{event}} \text{ (hours/\text{event})} + \frac{0.6700 \text{ hours/\text{event}}}{(1 + \tau_{\text{event}} \text{ (hours/\text{event})})}}
\]

or,

\[
\text{IF } ET_{\text{event-res}} > (\text{hours/\text{event}}) \text{ then } \text{SL}_{\text{water-tce-der (\mu g/L)}} = \frac{\text{DA}_{\text{toe-event}} \text{ (ug/cm}^2\text{-event)}}{\text{cm}^2\text{-event}} \times \frac{1000 \text{ cm}^2}{\text{L}} \times \frac{\text{FA} \times K_4 \text{ (cm/hour)}}{\text{ET}_{\text{sub-res}} \text{ (hours/\text{event})}} \times \frac{1 + 2\times \tau_{\text{event}} \text{ (hours/\text{event})}}{1 + 2\times \tau_{\text{event}} \text{ (hours/\text{event})} + \frac{0.6700 \text{ hours/\text{event}}}{(1 + 2\times \tau_{\text{event}} \text{ (hours/\text{event})})}}
\]

where:

\[
\text{DA}_{\text{toe-event}} \text{ (ug/cm}^2\text{-event)} = \frac{\text{TR} \times \text{AT}_{\text{Res} (365 \text{ days/yr} \times \text{LT (70 years)}}}{\text{CF}_{\text{Res} (\text{mg/kg})} \times \text{DFWM}_{\text{Res-adj}} \times \text{CAF}_0 \text{ (0.804)} \times \text{DFWM}_{\text{Res-adj}} \times \text{MAF}_0 \text{ (0.202)} \times \text{DFWM}_{\text{Res-adj}} \times \text{CSF}_\text{GAB} \times \text{GF}_{\text{CS}} \times \text{GF}_{\text{CS}}}
\]

\[
\text{DFWM}_{\text{Res-adj}} \text{ (events/cm}^2\text{-year)} = \frac{\text{ET}_{\text{event-res}} \text{ (hours/\text{event})} \times \text{EF}_{\text{adj} \text{ (2 \text{ years/\text{year})}}} \times \text{EF}_{\text{adj} \text{ (4 \text{ years/\text{year})}}} \times \text{EF}_{\text{adj} \text{ (10 \text{ years/\text{year})}}} \times \text{SA}_{\text{adj} \text{ (6156 cm}^2\text{)}} \times \text{SA}_{\text{adj} \text{ (1956 cm}^2\text{)}}}{\text{BW}_{\text{Res} \text{ (15 kg)}}}
\]

\[
\text{DFWM}_{\text{Res-adj}} \text{ (events/kg)} = \frac{\text{BW}_{\text{Res} \text{ (50 kg)}}}{\text{BW}_{\text{Res} \text{ (15 kg)}}}
\]

\[
\text{SL}_{\text{water-tce-der (\mu g/L)}} = \text{Screening Level for carcinogetic resident tap water dermal contact for TCE}
\]

\[
\text{DFWM}_{\text{Res-adj}} = \text{Residential mutagenic tap water contact factor for carcinogetic resident dermal contact for trichloroethylene}
\]

\[
\text{CAF}_0 = \text{Cancer adjustment factor oral (0.804) = EPA default}
\]

\[
\text{MAF}_0 = \text{Mutagenic adjustment factor oral (0.202) = EPA default}
\]

Remaining inputs are the same as the standard equation for carcinogetic 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

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

\[
SL_{\text{water-nc-inh-w}}(\mu g/L) = \frac{\text{THQ} \times \text{AT}_w \times (365 \text{ days/year}) \times \text{ED}_w \times (25 \text{ years}) \times \text{ET}_w \times (8 \text{ hours/day}) \times \frac{1000 \mu g}{\text{mg}} \times \frac{1}{\text{mg}} \times K}{\text{EF}_w \times (250 \text{ days/year}) \times \text{ED}_w \times (25 \text{ years}) \times \text{ET}_w \times (1 \text{ day/24 hours}) \times \frac{1 \text{ day/24 hours}}{24 \text{ hours}} \times \frac{1 \text{ L}}{0.5 \text{ L}}}\]

\(SL_{\text{water-nc-inh-w}}\) = Screening level for non-carcinogenic non-residential worker exposure to vapors from tap water use

THQ = Target hazard quotient = 0.2

AT = Averaging time = 365 days/year = 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 = Contaminant specific in mg/m\(^3\) = EPA default = See chem-tox database

K = Andelman Volatilization Factor (L/m\(^3\))

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

\[
SL_{\text{water-ca-inh}}(\mu g/L) = \frac{\text{TR} \times \text{AT}_w \times (365 \text{ days/year}) \times \text{LT} \times (70 \text{ years})}{\text{EF}_w \times (250 \text{ days/year}) \times \text{ED}_w \times (25 \text{ years}) \times \text{ET}_w \times (8 \text{ hours/day}) \times \frac{1 \text{ day/24 hours}}{24 \text{ hours}} \times \text{IUR} \times (\mu g/m^3)^{-1} \times K \times \frac{0.5 \text{ L}}{m^3}}\]

\(SL_{\text{water-ca-inh}}\) = Screening level for carcinogenic non-residential worker tap water vapor exposure

TR = Target carcinogenic risk = 1E-06

AT = Averaging time = 365 days/year = 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 = Contaminant specific in mg/m\(^3\) = EPA default = See chem-tox database

K = Andelman Volatilization Factor (L/m\(^3\))
A.6.b. Residential Indoor Groundwater (tap water) Vapor Inhalation

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

**Child**

\[
SL_{\text{water-nc-inh-c}}(\mu g/L) = \frac{\text{THQ} \times \text{AT}_{\text{res-c}} \left(365 \text{ days/ year} \times \text{ED}_{\text{res-c}} \left(6 \text{ years}\right) \times \frac{1000 \mu g}{mg}\right)}{\text{EF}_{\text{res-c}} \left(365 \text{ days/ year}\right) \times \text{ED}_{\text{res-c}} \left(6 \text{ years}\right) \times \frac{24 \text{ hours/d}}{24 \text{ hours}} \times \frac{1 \text{ day}}{24 \text{ hours}} \times \frac{1}{\text{RfC} \left(\frac{mg}{m^3}\right)} \times K \left(\frac{0.5 L}{m^3}\right)}
\]

**Adult**

\[
SL_{\text{water-nc-inh-a}}(\mu g/L) = \frac{\text{THQ} \times \text{AT}_{\text{res-a}} \left(365 \text{ days/ year} \times \text{ED}_{\text{res-a}} \left(26 \text{ years}\right) \times \frac{1000 \mu g}{mg}\right)}{\text{EF}_{\text{res-a}} \left(365 \text{ days/ year}\right) \times \text{ED}_{\text{res-a}} \left(26 \text{ years}\right) \times \frac{24 \text{ hours/d}}{24 \text{ hours}} \times \frac{1 \text{ day}}{24 \text{ hours}} \times \frac{1}{\text{RfC} \left(\frac{mg}{m^3}\right)} \times K \left(\frac{0.5 L}{m^3}\right)}
\]

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

**Carcinogenic Residential Indoor Groundwater (tap water) Vapor Inhalation**

\[
SL_{\text{water-ca-inh}}(\mu g/L) = \frac{\text{TR} \times \text{AT}_{\text{res}} \left(365 \text{ days/ year} \times \text{LT} \left(70 \text{ years}\right)\right)}{\text{EF} \left(365 \text{ days/ year}\right) \times \text{ED} \left(26 \text{ years}\right) \times \frac{24 \text{ hours/d}}{24 \text{ hours}} \times \frac{1 \text{ day}}{24 \text{ hours}} \times \frac{1}{\text{UR} \left(\frac{mg}{m^3}\right)^{-1}} \times K \left(\frac{0.5 L}{m^3}\right)}
\]

**SL_{\text{water-ca-inh}}** = Screening level for carcinogenic resident tap water to indoor air

**SL_{\text{water-nc-inh-c}}** = Screening level for non-carcinogenic resident child tap water to indoor air

**THQ** = Target hazard quotient = 0.2

**AT** = Averaging time = 365 days/year = 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 = Contaminant specific in mg/m³ = EPA default = See chem-tox database

**K** = Andelman Volatilization Factor (L/m³)

**Target carcinogenic risk** = 1E-06

**AT** = Averaging time = 365 days/year = 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 = Contaminant specific in mg/m³ = EPA default  

K = Andelman Volatilization Factor (L/m³)  

Note that additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and TCE. These equations are only applicable for the residential carcinogenic scenario.

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

\[
\text{SL}_{\text{water-mu-inh}}(\mu g/L) = \frac{\text{TR} \times \text{AT}_{\text{res}} \left(\frac{365 \text{ days}}{\text{year}}\right) \times \text{LT}(70 \text{ years})}{\text{IUR} \left(\frac{\mu g}{m^3}\right)^{-1} \times K \left(\frac{0.5 \text{ L}}{m^3}\right) \times \left(\frac{\text{EF}_0.2 \left(\frac{350 \text{ days}}{\text{year}}\right) \times \text{ED}_0.2 \left(\frac{24 \text{ hours}}{\text{day}}\right) \times \left(\frac{1 \text{ day}}{24 \text{ hours}}\right) \times \text{ED}_0.2 \left(\text{years} \times 10\right) + \right) \right)}
\]

SL\text{water-mu-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

\[
\text{SL}_{\text{water-ca-vc-inh}}(\mu g/L) = \frac{\text{TR}}{\left(\text{IUR} \left(\frac{\mu g}{m^3}\right)^{-1} \times \text{AT}_{\text{res}} \left(\frac{365 \text{ days}}{\text{year}}\right) \times \text{LT}(70 \text{ years}) \times K \left(\frac{0.5 \text{ L}}{m^3}\right) \right) + \left(\text{IUR} \left(\frac{\mu g}{m^3}\right)^{-1} \times K \left(\frac{0.5 \text{ L}}{m^3}\right) \times \left(\frac{\text{EF}_2.6 \left(\frac{350 \text{ days}}{\text{year}}\right) \times \text{ET}_2.6 \left(\frac{24 \text{ hours}}{\text{day}}\right) \times \left(\frac{1 \text{ day}}{24 \text{ hours}}\right) \times \text{ED}_2.6 \left(\text{years} \times 3\right) + \right) \right) \right)}
\]

SL\text{water-ca-vc-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.
**TCE Carcinogenic Equation for Resident Groundwater (tap water) Vapor Inhalation**

\[
SL\text{\textsubscript{water-tec-inh}}(\mu \text{g/L}) = \frac{TR \times AT_{\text{res}} \left(\frac{365 \text{ days}}{\text{year}}\right) \times LT(70 \text{ years})}{\text{UR}\left(\frac{\mu \text{g}}{\text{m}^3}\right) \times K\left(\frac{1}{\text{m}^3}\right) \times \left(\left[\left(\text{EF}_{\text{res}} \left(\frac{350 \text{ days}}{\text{year}}\right) \times \text{ED}_{\text{res}} \left(26 \text{ years}\right) \times \text{ET}_{\text{res}} \left(\frac{24 \text{ hours}}{\text{day}}\right) \times \left(\frac{1 \text{ day}}{24 \text{ hours}}\right) \times \text{CAF}_i(0.756)\right) + \left(\left(\text{ED}_{1-2}(2 \text{ years}) \times \text{EF}_{1-2} \left(\frac{350 \text{ days}}{\text{year}}\right) \times \text{ET}_{1-2} \left(\frac{24 \text{ hours}}{\text{day}}\right) \times \left(\frac{1 \text{ day}}{24 \text{ hours}}\right) \times \text{MAF}_i(0.244) \times 10\right) + \left(\left(\text{ED}_{2-6}(4 \text{ years}) \times \text{EF}_{2-6} \left(\frac{360 \text{ days}}{\text{year}}\right) \times \text{ET}_{2-6} \left(\frac{24 \text{ hours}}{\text{day}}\right) \times \left(\frac{1 \text{ day}}{24 \text{ hours}}\right) \times \text{MAF}_i(0.244) \times 3\right) + \left(\left(\text{ED}_{5-16}(10 \text{ years}) \times \text{EF}_{5-16} \left(\frac{350 \text{ days}}{\text{year}}\right) \times \text{ET}_{5-16} \left(\frac{24 \text{ hours}}{\text{day}}\right) \times \left(\frac{1 \text{ day}}{24 \text{ hours}}\right) \times \text{MAF}_i(0.244) \times 3\right) + \left(\left(\text{ED}_{16-26}(10 \text{ years}) \times \text{EF}_{16-26} \left(\frac{350 \text{ days}}{\text{year}}\right) \times \text{ET}_{16-26} \left(\frac{24 \text{ hours}}{\text{day}}\right) \times \left(\frac{1 \text{ day}}{24 \text{ hours}}\right) \times \text{MAF}_i(0.124) \times 1\right)\right)\right)\right)\right)}
\]

\(SL\text{\textsubscript{water-tec-inh}} = \) 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.

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**A.7 SURFACE WATER INGESTION PATHWAY**

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

**Non-Carcinogenic Recreator Surface Water Ingestion**

\[
SL\text{\textsubscript{rec-water-nc-ing-c}}(\mu \text{g/L}) = \frac{THQ \times AT_{\text{rec-c}} \left(\frac{365 \text{ days}}{\text{year}}\right) \times \text{ED}_{\text{rec-c}} \left(\text{years}\right) \times \text{BW}_{\text{rec-c}}(15 \text{ kg}) \times \frac{1000 \mu \text{g}}{\text{mg}}}{\text{EF}_{\text{rec-c}} \left(\frac{\text{days}}{\text{year}}\right) \times \text{IRW}_{\text{rec-c}} \left(\text{mg kg-d}\right) \times \frac{1}{\text{RIF}_0 \left(\text{mg kg-d}\right)} \times \frac{1}{\text{IRW}_{\text{rec-c}} \left(\text{mg kg-d}\right)} \times \text{EV}_{\text{rec-c}} \left(\text{events day}\right) \times \text{ET}_{\text{rec-c}} \left(\text{hours event}\right) + \text{events day} \times \text{ET}_{\text{rec-c}} \left(\text{hours event}\right)}
\]

**Child**

\[
SL\text{\textsubscript{rec-water-nc-ing-c}}(\mu \text{g/L}) = \text{THQ} \times \frac{\text{AT}_{\text{rec-c}} \left(\frac{365 \text{ days}}{\text{year}}\right) \times \text{ED}_{\text{rec-c}} \left(\text{years}\right) \times \text{BW}_{\text{rec-c}}(15 \text{ kg}) \times 1000 \mu \text{g}}{\text{EF}_{\text{rec-c}} \left(\frac{\text{days}}{\text{year}}\right) \times \text{IRW}_{\text{rec-c}} \left(\text{mg kg-d}\right) \times \frac{1}{\text{RIF}_0 \left(\text{mg kg-d}\right)} \times \frac{1}{\text{IRW}_{\text{rec-c}} \left(\text{mg kg-d}\right)} \times \text{EV}_{\text{rec-c}} \left(\text{events day}\right) \times \text{ET}_{\text{rec-c}} \left(\text{hours event}\right) \times \text{events day} \times \text{ET}_{\text{rec-c}} \left(\text{hours event}\right)}
\]

**Adult**

\[
SL\text{\textsubscript{rec-water-nc-ing-a}}(\mu \text{g/L}) = \frac{\text{THQ} \times \text{AT}_{\text{rec-a}} \left(\frac{365 \text{ days}}{\text{year}}\right) \times \text{ED}_{\text{rec-a}} \left(\text{years}\right) \times \text{BW}_{\text{rec-a}}(80 \text{ kg}) \times 1000 \mu \text{g}}{\text{EF}_{\text{rec-a}} \left(\frac{\text{days}}{\text{year}}\right) \times \text{IRW}_{\text{rec-a}} \left(\text{mg kg-d}\right) \times \frac{1}{\text{RIF}_0 \left(\text{mg kg-d}\right)} \times \frac{1}{\text{IRW}_{\text{rec-a}} \left(\text{mg kg-d}\right)} \times \text{EV}_{\text{rec-a}} \left(\text{events day}\right) \times \text{ET}_{\text{rec-a}} \left(\text{hours event}\right) \times \text{events day} \times \text{ET}_{\text{rec-a}} \left(\text{hours event}\right)}
\]
Note: Child and adult equations are the same. Inputs vary as noted below. The child calculation yields the most conservative result and is therefore used in both the DEQ risk calculator and the EPA calculator. However, inputs for both the child and adult equations are provided for reference. Note that the exposure durations cancel out in this equation, so age adjustment is not applicable.

\[ \text{SL}_{\text{rec-water-nc-ing-c}} = \text{Screening level for non-carcinogenic recreator child surface water ingestion} \]
\[ \text{SL}_{\text{rec-water-nc-ing-a}} = \text{Screening level for non-carcinogenic recreator adult surface water ingestion} \]
\[ \text{THQ} = \text{Target hazard quotient} = 0.2 \]
\[ \text{AT} = \text{Averaging time} = 365 \text{ days/year} = \text{EPA default} \]
\[ \text{ED} = \text{Exposure duration recreator} = 6 \text{ years child, 20 years adult} = \text{NC DEQ default} \]
\[ \text{BW} = \text{Body weight} = 15 \text{ kilograms child, 80 kilograms adult} = \text{EPA default} \]
\[ \text{EF} = \text{Exposure frequency recreator} = 195 \text{ days/year} = \text{NC DEQ default} \]
\[ \text{RfD} = \text{Chronic oral reference dose} = \text{Contaminant specific in mg/kg-day} = \text{EPA default} = \text{See chem-tox database} \]
\[ \text{IRW} = \text{Ingestion rate surface water} = 0.05 \text{ L/hr} = \text{EPA default} \]
\[ \text{EV} = \text{Events Frequency} = 1 \text{ event/day} = \text{EPA default} \]
\[ \text{ET} = \text{Exposure Time} = 2 \text{ hour/event} = \text{EPA default} \]

**Non-Carcinogenic Trespasser Surface Water Ingestion**

**Adolescent**

\[
\text{SL}_{\text{rec-water-nc-ing-a}} = \text{Screening level for non-carcinogenic trespasser adolescent surface water ingestion} \\
\text{THQ} = \text{Target hazard quotient} = 0.2 \\
\text{AT} = \text{Averaging time} = 365 \text{ days/year} = \text{EPA default} \\
\text{ED} = \text{Exposure duration trespasser} = 10 \text{ years adolescent} = \text{NC DEQ default} \\
\text{BW} = \text{Body weight} = 45 \text{ kilograms adolescent} = \text{EPA default} \\
\text{EF} = \text{Exposure frequency trespasser} = 90 \text{ days/year} = \text{NC DEQ default} \\
\text{RfD} = \text{Chronic oral reference dose} = \text{Contaminant specific in mg/kg-day} = \text{EPA default} = \text{See chem-tox database} \\
\text{IRW} = \text{Ingestion rate surface water} = 0.05 \text{ L/hr} = \text{EPA default} \\
\text{EV} = \text{Events Frequency} = 1 \text{ event/day} = \text{EPA default} \\
\text{ET} = \text{Exposure Time} = 2 \text{ hour/event} = \text{EPA default} \]
Carcinogenic Recreator/Trespasser Surface Water Ingestion

Standard Carcinogenic Equation for Recreator/Trespasser Surface Water Ingestion

\[
SL_{\text{rec-water-ca-ing}} \, (\mu g/L) = \frac{TR \times AT \times LT \times SL_{\text{rec-waterr-ca-ing}}}{CSF \times \text{IFW}_{\text{rec-adj}}}
\]

where:

\[
\text{IFW}_{\text{rec-adj}} = \frac{EV \times ED \times EF \times ET \times IRW}{BW}
\]

\(SL_{\text{rec-water-ca-ing}} = \) Screening level for carcinogenic recreator/trespasser surface water ingestion
\(TR = \) Target risk = 1E-06
\(AT = \) Averaging time = 365 days/year = EPA default
\(LT = \) Lifetime = 70 years = EPA default
\(CSF = \) Oral Cancer Slope Factor = Contaminant specific in (mg/kg-day)
\(\text{IFW}_{\text{rec-adj}} = \) Age adjusted surface water ingestion rate = Calculated via secondary equation in L/kg
\(EV = \) Events Frequency = 1 event/day = EPA default
\(ED = \) Exposure duration recreator = 6 years child and 20 years adult = EPA default
\(ED = \) Exposure duration trespasser = 10 years (adolescent) = EPA default
\(EF = \) Exposure frequency = 195 days/year for child and adult recreators = NC DEQ default
\(EF = \) Exposure frequency = 90 days/year for adolescent trespasser = NC DEQ defalut
\(ET = \) Exposure Time = 2 hour/event = EPA default
\(IRW = \) Ingestion rate surface water = 0.05 L/hr = EPA default
\(BW = \) Body weight = 15 kilograms child and 80 kilograms adult recreators = EPA default
\(BW = \) Body weight = 45 kilograms adolescent trespasser = EPA default
For mutagenic compounds where chemical-specific data are not available to directly assess carcinogenic risk during childhood versus adulthood, a default mutagenic equation is used. The mutagenic equation adds an age-dependent adjustment factor (ADAF) to account for increased childhood risk for mutagenic compounds. The adjustment factor is 10-fold for the 0 to 2-year age range, three-fold for the 2 to 6-year age range, three-fold for the 6 to 16-year age range, and there is no adjustment (i.e. one-fold) for the 16 to 26-year age range. The remaining portions of the equation are similar to the standard carcinogenic equation.

\[ SL_{\text{rec-water-mu-ing}} = \frac{\text{TR} \times \text{AT}_{\text{rec}} \times \left( \frac{365 \text{ days}}{\text{year}} \times \text{LT (70 years)} \times \left( \frac{1000 \mu g}{\text{mg}} \right) \right)}{\text{CSF}_{0} \left( \frac{\text{mg}}{\text{kg-day}} \right)^{1} \times \text{IFWM}_{\text{rec-adj}} \left( \frac{\text{L}}{\text{kg}} \right)} \]

where:

\[
\text{IFWM}_{\text{rec-adj}} \left( \frac{\text{L}}{\text{kg}} \right) = \begin{cases} \frac{\text{ED}_{0-2} \left( \text{years} \right) \times \text{EF}_{0-2} \left( \text{days/year} \right) \times \text{IRW}_{0-2} \left( \text{L/hour} \right) \times \text{EV}_{0-2} \left( \text{events/day} \right) \times \text{ET}_{0-2} \left( \text{hours/event} \right) \times 10}{\text{BW}_{0-2} \left( \text{15 kg} \right)} & \text{if 0 to 2-year age range} \\ \frac{\text{ED}_{2-6} \left( \text{years} \right) \times \text{EF}_{2-6} \left( \text{days/year} \right) \times \text{IRW}_{2-6} \left( \text{L/hour} \right) \times \text{EV}_{2-6} \left( \text{events/day} \right) \times \text{ET}_{2-6} \left( \text{hours/event} \right) \times 3}{\text{BW}_{2-6} \left( \text{15 kg} \right)} & \text{if 2 to 6-year age range} \\ \frac{\text{ED}_{6-16} \left( \text{years} \right) \times \text{EF}_{6-16} \left( \text{days/year} \right) \times \text{IRW}_{6-16} \left( \text{L/hour} \right) \times \text{EV}_{6-16} \left( \text{events/day} \right) \times \text{ET}_{6-16} \left( \text{hours/event} \right) \times 3}{\text{BW}_{6-16} \left( \text{80 kg} \right)} & \text{if 6 to 16-year age range} \\ \frac{\text{ED}_{16-26} \left( \text{years} \right) \times \text{EF}_{16-26} \left( \text{days/year} \right) \times \text{IRW}_{16-26} \left( \text{L/hour} \right) \times \text{EV}_{16-26} \left( \text{events/day} \right) \times \text{ET}_{16-26} \left( \text{hours/event} \right)}{\text{BW}_{16-26} \left( \text{80 kg} \right)} & \text{if 16 to 26-year age range} \end{cases} \]

**Equation Variables:**
- **SL<sub>rec-water-mu-ing</sub>** = Screening level for carcinogenic recreator/trespasser surface water ingestion for mutagenic compounds
- **IFWM<sub>rec-adj</sub>** = Recreator/trespasser mutagenic surface water ingestion rate – age-adjusted = Calculated via secondary equation in L/kg = EPA default
- Remaining inputs are the same as the standard equation for carcinogenic surface water ingestion.
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.

\[
SL_{\text{rec-water-ca-vc-ing}} (\mu g/L) = \frac{CSF_0 \left( \frac{mg}{kg-day} \right)^1 \times IFW_{\text{rec-adj}} \left( \frac{L}{kg} \right) \times IRW_{\text{rec-c}} \left( \frac{mg}{0.05 L} \times 1000 \mu g \right)}{AT_{\text{rec}} \left( \frac{365 \text{ days} \times LT (70 \text{ years})}{\text{year}} \right) + CSF_0 \left( \frac{mg}{kg-day} \right) \times ET_{\text{rec-c}} \left( \frac{hr}{day} \right) \times IRW_{\text{rec-c}} \left( \frac{mg}{0.05 L} \times 1000 \mu g \right)}
\]

where:

\[
IFW_{\text{rec-adj}} \left( \frac{L}{kg} \right) = \frac{EV_{\text{rec-c}} \left( \frac{event}{day} \right) \times ED_{\text{rec-c}} \left( \frac{years}{(years)} \right) \times EF_{\text{rec-c}} \left( \frac{day}{year} \right) \times ET_{\text{rec-c}} \left( \frac{hours}{event} \right) \times IRW_{\text{rec-c}} \left( \frac{0.05 L}{hour} \right)}{BW_{\text{rec-c}} (15 \text{ kg})}
\]

\[
IFW_{\text{rec-a}} \left( \frac{L}{kg} \right) = \frac{EV_{\text{rec-a}} \left( \frac{event}{day} \right) \times ED_{\text{rec-a}} \left( \frac{years}{(years)} \right) \times EF_{\text{rec-a}} \left( \frac{day}{year} \right) \times ET_{\text{rec-a}} \left( \frac{hours}{event} \right) \times IRW_{\text{rec-a}} \left( \frac{0.05 L}{hour} \right)}{BW_{\text{rec-a}} (80 \text{ kg})}
\]

**Vinyl Chloride Carcinogenic Equation for Recreator/Trespasser Soil Ingestion**

\[
SL_{\text{rec-water-ca-vc-ing}} = \text{Screening level for carcinogenic recreator/trespasser surface water ingestion for vinyl chloride}
\]

Remaining inputs are the same as the standard equation for carcinogenic resident surface water ingestion.
TCE Carcinogenic Equation for Recreational Surface Water Ingestion

For TCE, 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).

\[
\begin{align*}
SL_{rec-water-tce-ing} (\mu g/L) &= \frac{TR^{AT}_{rec} \left( \frac{365 \text{ days}}{\text{year}} \right) \times LT(70 \text{ years}) \times (1000 \mu g \text{ mg}^{-1})}{CSF_0 \left( \frac{\text{mg}}{\text{kg \cdot day}} \right) \times \left( \frac{\text{CAF}_0 (0.804) \times IFW_{rec-adj} (\frac{L}{kg})}{\text{MAF}_0 (0.202) \times IFWM_{rec-adj} (\frac{L}{kg})} \right)} \\
\text{where:} & \\
IFW_{rec-adj} (\frac{L}{kg}) &= \left( \frac{EV_{rec-c} (\text{events day}^{-1}) \times ED_{rec-c} (\text{days year}^{-1}) \times EF_{rec-c} (\text{days year}^{-1}) \times ET_{rec-c} (\text{hours event}^{-1}) \times IRW_{rec-c} (\frac{0.05 \text{ L}}{\text{hour}})}{BW_{rec-c} (15 \text{ kg})} \right) + \left( \frac{EV_{rec-a} (\text{events day}^{-1}) \times ED_{rec-a} (\text{days year}^{-1}) \times EF_{rec-a} (\text{days year}^{-1}) \times ET_{rec-a} (\text{hours event}^{-1}) \times IRW_{rec-a} (\frac{0.05 \text{ L}}{\text{hour}})}{BW_{rec-a} (80 \text{ kg})} \right) \\
IFWM_{rec-adj} (\frac{L}{kg}) &= \left( \frac{ED_{0-2} (\text{years}) \times EF_{0-2} (\text{days year}^{-1}) \times IRW_{0-2} (\frac{0.05 \text{ L}}{\text{hour}}) \times EV_{0-2} (\text{events day}^{-1}) \times ET_{0-2} (\text{hours event}^{-1}) \times 10}{BW_{0-2} (15 \text{ kg})} \right) + \left( \frac{ED_{2-6} (\text{years}) \times EF_{2-6} (\text{days year}^{-1}) \times IRW_{2-6} (\frac{0.05 \text{ L}}{\text{hour}}) \times EV_{2-6} (\text{events day}^{-1}) \times ET_{2-6} (\text{hours event}^{-1}) \times 3}{BW_{2-6} (15 \text{ kg})} \right) + \left( \frac{ED_{6-16} (\text{years}) \times EF_{6-16} (\text{days year}^{-1}) \times IRW_{6-16} (\frac{0.05 \text{ L}}{\text{hour}}) \times EV_{6-16} (\text{events day}^{-1}) \times ET_{6-16} (\text{hours event}^{-1}) \times 3}{BW_{6-16} (80 \text{ kg})} \right) + \left( \frac{ED_{16-26} (\text{years}) \times EF_{16-26} (\text{days year}^{-1}) \times IRW_{16-26} (\frac{0.05 \text{ L}}{\text{hour}}) \times EV_{16-26} (\text{events day}^{-1}) \times ET_{16-26} (\text{hours event}^{-1}) \times 1}{BW_{16-26} (80 \text{ kg})} \right)
\end{align*}
\]

For TCE, 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).

\[
SL_{rec-water-tce-ing} = \text{Screening Level for carcinogenic recreator/trespasser surface water ingestion for TCE} \\
IFW_{rec-adj} = \text{Recreator/trespasser mutagenic surface water ingestion rate – age-adjusted} = \text{Calculated via secondary equation in L/kgt} \\
\text{CAF}_0 = \text{Cancer adjustment factor oral} = 0.804 = \text{EPA default} \\
\text{MAF}_0 = \text{Mutagenic adjustment factor oral} = 0.202 = \text{EPA default} \\
\text{Remaining inputs are the same as the standard equation for carcinogenic recreator/trespasser surface water ingestion}
\]
A.8 DERMAL CONTACT WITH SURFACE WATER PATHWAY

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

Non-Carcinogenic Dermal Contact with Surface Water

Child

FOR INORGANICS:

\[
S_{\text{rec-water-nc-der-c}} (\mu g/L) = \frac{DA_{\text{event}} (ug/cm^2 \cdot \text{event}) \times 1000 \text{ cm}^3}{K \cdot \text{cm/\text{hour}} \times \frac{ET_{\text{event-rec-c}}}{\text{hours/\text{event}}}}
\]

FOR ORGANICS:

IF \( \frac{ET_{\text{event-rec-c}}}{\text{hours/\text{event}}} \leq 1^* \) (hour), then \( S_{\text{rec-water-nc-der-c}} (\mu g/L) = \)

\[
\left( \frac{DA_{\text{event}} (ug/cm^2 \cdot \text{event}) \times 1000 \text{ cm}^3}{2 \times FA \times K \cdot \text{cm/\text{hour}} \times \frac{ET_{\text{event-rec-c}}}{\text{hours/\text{event}}} \times \frac{6 \times \text{revent}}{\pi}} \right)
\]

or,

IF \( \frac{ET_{\text{event-rec-c}}}{\text{hours/\text{event}}} > 1^* \) (hour), then \( S_{\text{rec-water-nc-der-c}} (\mu g/L) = \)

\[
\left( \frac{DA_{\text{event}} (ug/cm^2 \cdot \text{event}) \times 1000 \text{ cm}^3}{FA \times K \cdot \text{cm/\text{hour}} \times \left( \frac{ET_{\text{event-rec-c}}}{\text{hours/\text{event}}} \right)} \times \frac{2 \times \text{revent}}{(1 + B) \left( \frac{1 + 3B + 3B^2}{(1 + B)^2} \right)} \right)\]

where:

\[
DA_{\text{event}} (ug/cm^2 \cdot \text{event}) = \frac{THQ \times AT_{\text{rec-c}} \times 365 \text{ days/year} \times ED_{\text{rec-c}} \text{ (years)} \times 1000 \mu g/mg \times BW_{\text{rec-c}} \text{ (15 kg)}}{R\text{D}_{\text{c}} \text{ mg/kg-day} \times \text{GIABSS} \times EV_{\text{rec-c}} \text{ (events/day)} \times ED_{\text{rec-c}} \text{ (years)} \times EF_{\text{rec-c}} \text{ (days/year)} \times SA_{\text{rec-c}} \text{ (6365 cm^2)}}
\]
**Adult/Adolescent**

**FOR INORGANICS:**

\[
SL_{\text{rec-water-nc-der-c}}(\mu g/L) = \frac{DA_{\text{event}}(\mu g/cm^2 \cdot \text{event}) \times 1000 \text{ cm}^3}{\frac{K_p}{\text{cm/hr}} \cdot ET_{\text{event-rec-c}} \times \text{hours} \text{ per event}}
\]

**FOR ORGANICS:**

\[
IF \ ET_{\text{event-rec-c}}(\text{hours} \text{ per event}) \leq t^* \text{ (hour)}, \text{then } SL_{\text{rec-water-nc-der-c}}(\mu g/L) = \frac{DA_{\text{event}}(\mu g/cm^2 \cdot \text{event}) \times 1000 \text{ cm}^3}{\frac{2 \times \pi}{r_{\text{event}}} \times \frac{6 \times \pi}{r_{\text{event}}} \times \frac{ET_{\text{event-rec-c}} \times \text{hours} \text{ per event}}{\pi}}
\]

or,

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

where:

\[
DA_{\text{event}}(\mu g/cm^2 \cdot \text{event}) = \frac{THQ \times AT_{\text{rec-c}}}{ET_{\text{rec-c}} \times \text{ED}_{\text{rec-c}}(\text{years}) \times 1000 \mu g \text{ mg}^{-1} \times BW_{\text{rec-c}}(80 \text{ kg})}
\]

\[
DK_o(\text{mg kg}^{-1} \text{ day}^{-1}) \times GIABS
\]

\[
\frac{1}{EV_{\text{rec-c}} \times \text{days} \text{ per year}} \times ED_{\text{rec-c}}(\text{years}) \times EF_{\text{rec-c}} \times 365 \text{ days/year} \times SA_{\text{rec-c}}(19662 \text{ cm}^2)
\]

Note: 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. Inputs for the child and adult equations are provided for reference. Note that the exposure durations cancel out in this equation, so age adjustment is not applicable.

\[
SL_{\text{rec-water-nc-der-c}} = \text{Screening level for surface water, recreator, non-carcinogenic child, dermal contact}
\]

\[
SL_{\text{rec-water-nc-der-a}} = \text{Screening level, surface water, for non-carcinogenic adult recreator dermal contact or adolescent trespasser}
\]

\[
DA_{\text{event}} = \text{Absorbed Dose per Event (µg-cm}^2/\text{event})
\]

\[
K_p = \text{Dermal Permeability Constant (cm/hr) = EPA default = See chem-tox database}
\]

\[
ET_{\text{event}} = \text{Exposure Time (hr/event) = EPA default}
\]

\[
t^* = \text{Time to Reach Steady State (hr) = EPA default = See chem-tox database}
\]

\[
FA = \text{Fraction Absorbed in Water (unitless) = EPA default = See chem-tox database}
\]

\[
\tau_{\text{event}} = \text{Lag Time (hr/d) = EPA default = See chem-tox database}
\]

\[
B = \text{Relative Contribution of Permeability Coefficient = EPA default = See chem-tox database}
\]

\[
THQ = \text{Target hazard quotient = 0.2}
\]

\[
AT = \text{Averaging time = 365 days/year = EPA default}
\]

\[
ED = \text{Exposure duration = 20 years adult = EPA default}
\]

\[
BW = \text{Body weight = 15 kilograms child, 45 kilograms adolescent, and 80 kilograms adult = EPA default}
\]
RfD = Chronic oral reference dose = Contaminant specific in mg/kg-day = EPA default = See chem-tox database
GIABS = Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
EV = Recreator events (events/day)
EF = Exposure frequency = 195 days/year for recreators, 90 days/year trespasser = NC DEQ default
SA = Skin surface area = 6,365 cm²/day child and 19,652 cm²/day adult and trespasser = EPA default

Carcinogenic Dermal Contact with Surface Water

Note: 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 TCE. These equations are only applicable for the recreational/trespasser carcinogetic dermal contact scenario. The standard equation is listed below, followed by the alternative equations.

FOR INORGANICS:

\[
\text{SL}_{\text{rec-water-ca-der}} \left( \text{ug/mL} \right) = \frac{D_A}{K_p} \frac{\text{ug/cm}^2 \cdot \text{event}}{\text{cm}^3 \cdot \text{event}} \times \frac{1000 \text{ cm}^3}{\text{L}}
\]

FOR ORGANICS:

\[
\text{IF } \frac{ET_{\text{event-rec-adj}}}{\text{hours \ event}} \leq \frac{1}{\text{hour, then SL}_{\text{rec-water-ca-der}} (\text{ug/mL}) = \frac{D_A}{K_p} \frac{\text{ug/cm}^2 \cdot \text{event}}{\text{cm}^3 \cdot \text{event}} \times \frac{1000 \text{ cm}^3}{\text{L}}}{2 \times FA \times K_p \left( \frac{\text{cm}^2 \cdot \text{event}}{\text{cm}^3 \cdot \text{event}} \right) \times \frac{1000 \text{ cm}^3}{\text{L}}}
\]

or,

\[
\text{IF } \frac{ET_{\text{event-rec-adj}}}{\text{hours \ event}} > \frac{1}{\text{hour, then SL}_{\text{rec-water-ca-der}} (\text{ug/mL}) = \frac{D_A}{K_p} \frac{\text{ug/cm}^2 \cdot \text{event}}{\text{cm}^3 \cdot \text{event}} \times \frac{1000 \text{ cm}^3}{\text{L}}}{FA \times K_p \left( \frac{\text{cm}^2 \cdot \text{event}}{\text{cm}^3 \cdot \text{event}} \right) \times \frac{1000 \text{ cm}^3}{\text{L}}}
\]

where:

\[
D_A \left( \frac{\text{ug/cm}^2 \cdot \text{event}}{\text{cm}^3 \cdot \text{event}} \right) = \frac{\text{TR} \times AT_{\text{rec}}}{365 \text{ days} \cdot 1 \text{LT} \cdot (70 \text{ years})} \times \frac{1000 \text{ ug}}{\text{mg}}
\]

where:

\[
\text{CSF} \left( \frac{\text{mg/kg \cdot day}}{\text{GIABS}} \right) \times \text{DPW}_{\text{rec-a}} \left( \frac{\text{events-cm}^2}{\text{kg}} \right)
\]

\[
\text{DPW}_{\text{rec-a}} \left( \frac{\text{events-cm}^2}{\text{kg}} \right) = \frac{\text{EV}_{\text{rec-a}} \left( \text{events/day} \right) \times \text{ED}_{\text{rec-a}} \left( \text{days/year} \right) \times \text{SA}_{\text{rec-a}} \left( 19,652 \text{ cm}^2 \right)}{\text{BW}_{\text{rec-a}} \left( 80 \text{ kg} \right)}
\]

and:

\[
\text{ET}_{\text{event-rec-adj}} \left( \text{hours \ event} \right) = \frac{\text{ET}_{\text{event-rec-a}} \left( \text{hours \ event} \right) \times \text{ED}_{\text{rec-a}} \left( \text{years} \right) \times \text{ED}_{\text{rec-a}} \left( \text{years} \right)}{\text{ED}_{\text{rec-a}} \left( \text{years} \right) \times \text{ED}_{\text{rec-a}} \left( \text{years} \right)}
\]
\( SL_{\text{rec-water-ca-der}} = \) Screening level for carcinogenic recreator/trespasser surface water dermal contact
\( DA_{\text{event}} = \) Absorbed Dose per Event (\( \mu g \cdot cm^2/\text{event} \))
\( K_p = \) Dermal Permeability Constant (cm/hr) = EPA default = See chem-tox database
\( ET_{\text{event}} = \) Exposure Time (hr/event) = 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
\( \tau_{\text{event}} = \) 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 = 1E-6
\( AT = \) Averaging time = 365 days/year = EPA default
\( ED = \) Exposure duration = 6 years child, 10 years adolescent, 20 years adult = EPA default
\( BW = \) Body weight = 15 kilograms child, 45 kilograms adolescent, and 80 kilograms adult = EPA default
\( GIABS = \) Fraction of contaminant absorbed in intestinal tract = Contaminant specific (unitless) = EPA default = See chem-tox database
\( EV = \) Recreator events (events/day)
\( EF = \) Exposure frequency = 195 days/year for recreators, 90 days/year trespasser = NC DEQ default
\( SA = \) Skin surface area = 6,365 \( cm^2/\text{day} \) child, and 19,652 \( cm^2/\text{day} \) adult and trespasser = EPA default
Mutagenic Carcinogenic Equation for User Defined (Recreator/Trespasser) Contact with Surface Water

\[
\text{SL}_{\text{rec-water-mu-der}} = \text{Screening level for user defined (recreator/trespasser) surface water dermal contact for mutagenic compounds}
\]

\[
\text{DFWM}_{\text{rec-adj}} = \text{Recreator/trespasser mutagenic water dermal contact factor – age-adjusted = Calculated via secondary equation in events-cm}^2/\text{kg}
\]

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

\[
\text{IF } ET_{\text{event-rec-adj}} \leq \tau \text{ (hours), then } \text{ST}_{\text{rec-water-voc-dec}} (\mu g/L) = \frac{DA_{\text{event}} \left( \frac{\text{ug}}{\text{cm}^2 \cdot \text{event}} \right) \left( \frac{1000 \text{ cm}^3}{L} \right)}{2 \times FA \times K_p (\text{cm/hour})^{n} \left( \frac{\text{cm}^{2}}{\text{hour}} \right) \sqrt{1 + 3B + 3B^2 \left( \frac{1}{1 + B} \right)^2}}
\]

or,

\[
\text{IF } ET_{\text{event-rec-adj}} > \tau \text{ (hours), then } \text{ST}_{\text{rec-water-voc-dec}} (\mu g/L) = \frac{DA_{\text{event}} \left( \frac{\text{ug}}{\text{cm}^2 \cdot \text{event}} \right) \left( \frac{1000 \text{ cm}^3}{L} \right)}{FA \times K_p (\text{cm/hour})^{n} \left( \frac{\text{cm}^{2}}{\text{hour}} \right) \sqrt{1 + 3B + 3B^2 \left( \frac{1}{1 + B} \right)^2}}
\]

where:

\[
DA_{\text{event}} = \left( \frac{\text{mg}}{\text{kg} \cdot \text{day}} \right) \times \text{DFW}_{\text{rec-adj}} \left( \frac{\text{events}}{\text{kg}} \right)
\]

\[
TR = \left( \frac{\text{mg}}{\text{kg} \cdot \text{day}} \right) \times \left( \frac{\text{EV}_{\text{rec-c}} \left( \frac{\text{events}}{\text{day}} \right)}{\text{BW}_{\text{rec-c}} (15 \text{ kg})} \right) \times \left( \frac{\text{SA}_{\text{rec-c}} (6365 \text{ cm}^2)}{1000 \text{ ug/mg}} \right)
\]

where:

\[
\text{DFW}_{\text{rec-adj}} = \text{DFW}_{\text{rec-a}} (19652 \text{ cm}^2)
\]

and:

\[
\text{ET}_{\text{event-rec-adj}} = \left( \frac{\text{ET}_{\text{event-rec-c}} (\text{hours}) \times \text{ED}_{\text{rec-c}} (\text{years}) + \text{ET}_{\text{event-rec-a}} (\text{hours}) \times \text{ED}_{\text{rec-a}} (\text{years})}{\text{ED}_{\text{rec-c}} (\text{years}) + \text{ED}_{\text{rec-a}} (\text{years})} \right)
\]

DFW_{rec-adj} = \text{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.
DFW_{rec-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

Non-Carcinogenic Non-Residential Worker Indoor Air Vapor Inhalation

\[
SL_{w-air-nc} \left( \mu g/m^3 \right) = \frac{\text{THQ} \times \text{AT}_w \left( \frac{365 \text{ days}}{\text{year}} \times \text{ED}_w \ (25 \text{ years}) \right) \times \left( \frac{1000 \mu g}{\text{mg}} \right)}{\text{EF}_w \left( \frac{250 \text{ days}}{\text{year}} \right) \times \text{ED}_w \ (25 \text{ years}) \times \text{ET}_w \left( \frac{8 \text{ hr}}{24 \text{ hr}} \right) \times \frac{1}{\text{RfC} \left( \frac{\text{mg}}{\text{m}^3} \right)}}
\]

\( SL_{w-air-nc} \) = Screening level for non-carcinogenic non-residential worker indoor air
\( \text{THQ} \) = Target hazard quotient = 0.2
\( \text{AT} \) = Averaging time = 365 days/year = EPA default
\( \text{ED} \) = Exposure duration = 25 years = EPA default
\( \text{EF} \) = Exposure frequency = 250 days/year = EPA default
\( \text{ET} \) = Exposure time = 8 hours/day = EPA default
\( \text{RfC} \) = Chronic inhalation reference concentration = Contaminant specific in mg/m³ = EPA default = See chem-tox database

Carcinogenic Non-Residential Worker Indoor Air Vapor Inhalation

\[
SL_{w-air-ca} \left( \mu g/m^3 \right) = \frac{\text{TR} \times \text{AT}_w \left( \frac{365 \text{ days}}{\text{year}} \times \text{LT} \ (70 \text{ years}) \right)}{\text{EF}_w \left( \frac{250 \text{ days}}{\text{year}} \right) \times \text{ED}_w \ (25 \text{ years}) \times \text{ET}_w \left( \frac{8 \text{ hr}}{24 \text{ hr}} \right) \times \text{IUR} \left( \frac{\mu g}{\text{m}^3} \right)^{-1}}
\]

\( SL_{w-air-ca} \) = Screening level for carcinogenic non-residential worker indoor air
\( \text{TR} \) = Target carcinogenic risk = 1E-06
\( \text{AT} \) = Averaging time = 365 days/year = EPA default
\( \text{LT} \) = Lifetime = 70 years = EPA default
\( \text{EF} \) = Exposure frequency = 250 days/year = EPA default
\( \text{ED} \) = Exposure duration = 25 years = EPA default
\( \text{ET} \) = Exposure time = 8 hours/day = EPA default
\( \text{IUR} \) = Chronic inhalation unit risk = Contaminant specific in mg/m³ = EPA default = See chem-tox database
A.9.b. Residential Indoor Air Vapor Inhalation

Non-Carcinogenic Residential Indoor Air Vapor Inhalation

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

\( SL_{\text{res-air-nc}} \) = Screening level for non-carcinogenic resident indoor air
\( THQ \) = Target hazard quotient \( = 0.2 \)
\( AT \) = Averaging time \( = 365 \text{ days/year} \) = EPA default
\( ED \) = Exposure duration \( = 26 \text{ years} \) = EPA default
\( EF \) = Exposure frequency \( = 350 \text{ days/year} \) = EPA default
\( ET \) = Exposure time \( = 24 \text{ hours/day} \) = EPA default
\( RfC \) = Chronic inhalation reference concentration = Contaminant specific in mg/m^3 = EPA default

Carcinogenic Residential Indoor Air Vapor Inhalation

Note that additional equations are applicable for carcinogenic risk for mutagens, vinyl chloride, and TCE. These equations are only applicable for the residential carcinogenic scenario. The standard equation is listed below, followed by the alternative equations.

Standard Carcinogenic Equation for Resident Indoor Air Vapor Inhalation

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

\( SL_{\text{res-air-ca}} \) = Screening level for carcinogenic resident indoor air
\( TR \) = Target carcinogenic risk \( = 1E-06 \)
\( AT \) = Averaging time \( = 365 \text{ days/year} \) = EPA default
\( LT \) = Lifetime \( = 70 \text{ years} \) = EPA default
\( EF \) = Exposure frequency \( = 350 \text{ days/year} \) = EPA default
\( ED \) = Exposure duration \( = 26 \text{ years} \) = EPA default
\( ET \) = Exposure time \( = 24 \text{ hours/day} \) = EPA default
\( IUR \) = Chronic inhalation unit risk = Contaminant specific in mg/m^3 = EPA default
Mutagenic Carcinogenic Equation for Resident Indoor Air Vapor Inhalation

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

\( SL_{\text{res-air-mu}} \) = 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

\[ SL_{\text{res-air-ca-vinyl chloride}} \left( \mu g/m^3 \right) = \frac{TR \times AT_{\text{res}} \left( \frac{365 \text{ days}}{\text{year}} \right) \times LT (70 \text{ years})}{IUR \left( \mu g/m^3 \right)^{-1} \times \left( \frac{1 \text{ day}}{24 \text{ hours}} \right) \times \left( \frac{24 \text{ hours}}{\text{day}} \right) \times \left( \frac{350 \text{ days}}{\text{year}} \right) \times ET_{0-2} + ET_{2-6} + ET_{6-16} \times \left( \frac{24 \text{ hours}}{\text{day}} \right) \times 10 + \left( \frac{10 \text{ years}}{\text{year}} \right) \times ET_{16-26} \times \left( \frac{24 \text{ hours}}{\text{day}} \right) \times 1} \]

\( SL_{\text{res-air-ca-vinyl chloride}} \) = Screening level for carcinogenic resident indoor air for vinyl chloride
Remaining inputs are the same as the standard equation for carcinogenic resident indoor air.
TCE Carcinogenic Equation for Resident Indoor Air Vapor Inhalation

\[ SL_{\text{res-air-tce}} \left( \mu g/m^3 \right) = \frac{TR \times AT_{\text{res}} \left( \frac{365 \text{ days}}{\text{year}} \right) \times LT \left( 70 \text{ years} \right)}{IUR \left( \mu g/m^3 \right) \times \left( \frac{1 \text{ day}}{24 \text{ hours}} \right) \times \left( \frac{1}{\text{res}} \right) \times \left( \frac{1}{\text{air}} \right) \times \left( \frac{1}{\text{ca-tce}} \right) + \left( \frac{ED_{\text{res}} \left( 26 \text{ years} \right) \times EF_{\text{res}} \left( \frac{365 \text{ days}}{\text{year}} \right) \times ET_{\text{res}} \left( \frac{24 \text{ hours}}{\text{day}} \right) \times CAF_i \left( 0.756 \right) \right) + \left( \frac{ED_{0-2} \left( 2 \text{ years} \right) \times EF_{0-2} \left( \frac{365 \text{ days}}{\text{year}} \right) \times ET_{0-2} \left( \frac{24 \text{ hours}}{\text{day}} \right) \times MAF_i \left( 0.244 \right) \times 10 \right) + \left( \frac{ED_{2-6} \left( 4 \text{ years} \right) \times EF_{2-6} \left( \frac{365 \text{ days}}{\text{year}} \right) \times ET_{2-6} \left( \frac{24 \text{ hours}}{\text{day}} \right) \times MAF_i \left( 0.244 \right) \times 3 \right) + \left( \frac{ED_{6-16} \left( 10 \text{ years} \right) \times EF_{6-16} \left( \frac{365 \text{ days}}{\text{year}} \right) \times ET_{6-16} \left( \frac{24 \text{ hours}}{\text{day}} \right) \times MAF_i \left( 0.244 \right) \times 3 \right) + \left( \frac{ED_{16-25} \left( 10 \text{ years} \right) \times EF_{16-26} \left( \frac{365 \text{ days}}{\text{year}} \right) \times ET_{16-26} \left( \frac{24 \text{ hours}}{\text{day}} \right) \times MAF_i \left( 0.244 \right) \times 1 \right) \]  

\( SL_{\text{res-air-ca-tce}} = \) Screening level for carcinogenic resident indoor air for TCE  
\( CAF_i = \) 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 based on the factors specified in the DEQ Vapor Intrusion Guidance Document (DEQ, 2014).

**Non-Residential Soil Gas to Indoor Air Equation**

\[ SGSL_{\text{nr}} = IASL_{\text{nr}} \times 1/AF_{\text{sgnr}} \]

\( SGSL_{\text{nr}} = \) Non-residential soil gas screening level (µg/m³)  
\( IASL_{\text{nr}} = \) Non-residential indoor air screening level (µg/m³)  
\( AF_{\text{sgnr}} = \) Non-residential soil gas to indoor air attenuation factor = 0.01

Note: 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:

\[ IASL_{\text{nr}} = SGSL_{\text{nr}} \times AF_{\text{sgnr}} \]
Residential Soil Gas to Indoor Air Equation

\[ \text{SGSL}_r = \text{IASL}_r \times \frac{1}{\text{AF}_{\text{sgr}}} \]

\( \text{SGSL}_r \) = Residential soil gas screening level (µg/m\(^3\))
\( \text{IASL}_r \) = Residential indoor air screening level (µg/m\(^3\))
\( \text{AF}_{\text{sgr}} \) = Residential soil gas to indoor air attenuation factor = 0.03

Note: 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:

\[ \text{IASL}_r = \text{SGSL}_r \times \text{AF}_{\text{sgr}} \]

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

\[ \text{GWSL}_{\text{nr}} = \text{IASL}_{\text{nr}} \times \frac{1}{H'} \times \text{CF} \times \frac{1}{\text{AF}_{\text{gwnr}}} \]

\( \text{GWSL}_{\text{nr}} \) = Non-residential groundwater screening level (µg/L\(^3\))
\( \text{IASL}_{\text{nr}} \) = Non-residential indoor air screening level (µg/m\(^3\))
\( H' \) = Henry’s law constant = Chemical specific = See chem-tox database
\( \text{CF} \) = Conversion factor = 0.001 m\(^3\)/L
\( \text{AF}_{\text{gwnr}} \) = Non-residential groundwater to indoor air attenuation factor = 0.001

Note: 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:

\[ \text{IASL}_{\text{nr}} = \text{GWSL}_{\text{nr}} \times H' \times \frac{1}{\text{CF}} \times \text{AF}_{\text{gwnr}} \]

Residential Groundwater to Indoor Air Equation

\[ \text{GWSL}_r = \text{IASL}_r \times H' \times \text{CF} \times \frac{1}{\text{AF}_{\text{gwr}}} \]

\( \text{GWSL}_r \) = Residential groundwater screening level (µg/L\(^3\))
\( \text{IASL}_r \) = Residential indoor air screening level (µg/m\(^3\))
H’ = Henry’s law constant = Chemical specific = See chem-tox database
CF = Conversion factor = 0.001 m³/L
AF_{gwr} = Residential groundwater to indoor air attenuation factor = 0.001

Note: 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

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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Default Values</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_{\text{soil}} )</td>
<td>Calculated Source Concentration for soil</td>
<td>not applicable</td>
</tr>
<tr>
<td>( C_{\text{gw}} )</td>
<td>Applicable Groundwater Target Concentration (NC GW Std)</td>
<td>chemical-specific</td>
</tr>
<tr>
<td>( d_f )</td>
<td>Dilution factor</td>
<td>20 (0.5 acre source size)</td>
</tr>
<tr>
<td>( K_s )</td>
<td>Soil-water partition coefficient for organic constituents ( k_s = k_{oc} f_{oc} ) for inorganic constituents ( k_s = k_d )</td>
<td>chemical-specific</td>
</tr>
<tr>
<td>( k_{oc} )</td>
<td>Soil organic carbon-water partition coefficient</td>
<td>chemical-specific</td>
</tr>
<tr>
<td>( F_{oc} )</td>
<td>Fraction of organic carbon in subsurface vadose soils</td>
<td>0.001 (0.1%)</td>
</tr>
<tr>
<td>( K_d )</td>
<td>Soil-water partition coefficient for inorganics</td>
<td>chemical-specific (pH=5.5)</td>
</tr>
<tr>
<td>( \theta_w )</td>
<td>Water-filled soil porosity-vadose soils</td>
<td>0.3</td>
</tr>
<tr>
<td>( \theta_a )</td>
<td>Air-filled soil porosity-vadose soils</td>
<td>0.13</td>
</tr>
<tr>
<td>( P_b )</td>
<td>Dry bulk density</td>
<td>1.5</td>
</tr>
<tr>
<td>( H' )</td>
<td>Henry's Law constant-dimensionless where: ( H' = \frac{H}{41} )</td>
<td>chemical-specific</td>
</tr>
</tbody>
</table>

1. From the USEPA 1996 Soil Screening Guidance
2. Default value from 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). As discussed in Section 4.5.1, 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:

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

- **Cs** = Soil concentration (mg/kg)
- **Cw** = Groundwater concentration (mg/L)
- **ρb** = Dry soil bulk density (kg/L) = Site-specific or default = Default 1.5 kg/L
- **Ks** = Soil-water partition coefficient (L/kg) = Koc x foc (Note this equation is valid for organics only. The risk calculator is not currently set up to correctly run inorganics for this pathway.)
- **Koc** = Soil organic carbon/water partition coefficient (L/kg) = Chemical specific = Defined in chem-tox database
- **foc** = Fraction organic carbon in soil (g/g) = Site-specific or default = Default is 0.002
- **θw** = Water-filled soil porosity (L\text{water}/L\text{soil}) = Site-specific or default = Default is 0.3
- **θa** = Air-filled soil porosity (L\text{air}/L\text{soil}) = Site-specific or default = Default is 0.13
- **H’** = Henry’s law constant (dimensionless) = Chemical specific = Defined in chem-tox database
- **df** = Dilution factor = See secondary equation below

*Secondary Equation #1 – Dilution Factor*

\[ df = 1 + \frac{K_id}{IL} \]

**df** = Dilution factor
**K** = Aquifer hydraulic conductivity (m/yr) = Site-specific or default = Default is 2,519 m/y (690 cm/d)
i = Hydraulic gradient (m/m) = Site-specific or default = Default is 0.01

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 or default = Default is 5 m (500 cm)

---

**Secondary Equation #2 – Mixing Zone Depth**

\[ d = (0.0112L^2)^{0.5} da \{1 - \exp\left[\frac{(-LI)}{(Kd_a)}\right]\} \]

\( d \) = Mixing zone depth (m), calculated default is 0.66 m

\( L \) = Length of source area parallel to groundwater flow (m) = Site-specific or default = Default is 5 m (500 cm)

\( I \) = 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 or default = Default is 2,519 m/y (690 cm/d)

\( i \) = Hydraulic gradient (m/m) = Site-specific or default = Default is 0.01

\( d_a \) = Aquifer thickness = Site-specific or default = Default is 15 m (49.2 feet)

---

**Mass-Limit Equation**

\[ C_s = \frac{(C_w)(I)(ED)}{(\rho_b)(d_s)} \]

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

\[ C_w = \frac{(C_s)(\rho_b)(d_s)}{(I)(ED)} \]

\( C_s \) = Soil concentration (mg/kg)

\( C_w \) = Groundwater concentration (mg/L)

\( \rho_b \) = 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

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**B.1.b. Groundwater Migration to POE**

Groundwater migration to 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.
\[ C_{\text{POE}} = C_{\text{si}} \left\{ \text{erf} \left( \frac{S_w}{\sqrt{\alpha_x x}} \right) \right\} \left\{ \text{erf} \left( \frac{S_d}{2\sqrt{\alpha_x x}} \right) \right\} \]

\( C_{\text{POE}} \) = Groundwater concentration (mg/L) along the plume centerline at the point of exposure (POE)
\( C_{\text{si}} \) = Source groundwater concentration (mg/L)
\( x \) = Distance to POE (cm)
\( S_w \) = Groundwater source width (cm) = Site-specific or default = Default is 4,500 cm (150 feet)
\( S_d \) = Groundwater source thickness (cm) = Site-specific or default = Default is 200 cm (6.5 feet)
\( \alpha_x \) = Longitudinal Dispersivity (cm) = See equation below
\( \alpha_y \) = Transverse Dispersivity (cm) = See equation below
\( \alpha_z \) = Vertical Dispersivity (cm) = See equation below
\( \alpha_x = 0.1*x \)
\( \alpha_y = 0.33* \alpha_x \)
\( \alpha_z = 0.05* \alpha_x \)

Note: 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.

\[ D_{\text{Fgwsw}} = \left[ 1 + \frac{Q_{\text{sw}}}{K_i \delta_{\text{sw}} W_{\text{gwsw}}} \right]^{-1} \]

\( D_{\text{Fgwsw}} \) = Dilution Factor for groundwater to surface water
\( Q_{\text{sw}} \) = Surface water flow rate (cm/s) = No default established by EPA, DEQ default is 0 cm/s
\( K \) = Aquifer hydraulic conductivity (m/yr) = No default established by EPA, DEQ default is 2,519 m/y (690 cm/d)
\( i \) = Hydraulic gradient (m/m) = No default established by EPA, DEQ default is 0.01
\( \delta_{\text{sw}} \) = Thickness of groundwater plume at surface water interface (cm) = No default established by EPA, DEQ default is 200 cm
\( W_{\text{gwsw}} \) = 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/m$^3$). The PEF is the inverse of the standard adjusted for unit conversions:

- $\text{PEF} = \frac{1}{\text{NAAQS}} (150 \, \mu g/m^3) = 6.7E-03 \, m^3/\mu g \times 1E+09 \, ug/kg = 6.7E+06 \, m^3/kg$

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.