

E.12 MODELS/EQUATIONS FOR ESTIMATING DTLs and TIER 1 RISK-BASED TARGET LEVELS WITHIN THE MRBCA PROCESS

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AIR Risk-Based Target Levels (Residential and Non-Residential Worker)

NON-CARCINOGENIC (child, adult, and age-adjusted resident and non-resident worker)

$$RBTL = \frac{THQ \times AT_{nc} \times 1000 \left(\frac{\mu g}{mg}\right)}{\left(\frac{1}{RfC}\right) \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)}\right) \times EF \times ED}$$

CARCINOGENIC (child, adult, and age-adjusted resident and non-resident worker)

$$RBTL = \frac{TR \times AT_c}{UR_i \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)}\right) \times EF \times ED}$$

MUTAGENIC (residential only – child, adult, and age-adjusted resident)

Child Resident:

$$RBTL = \frac{TR \times AT_c}{UR_i \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)}\right) \times EF \times [(ED_{0-2} \times ADAF_{0-2}) + (ED_{2-6} \times ADAF_{2-6})]}$$

Adult Resident:

$$RBTL = \frac{TR \times AT_c}{UR_i \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)}\right) \times EF \times [(ED_{6-16} \times ADAF_{6-16}) + (ED_{16-26} \times ADAF_{16-26})]}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c}{UR_i \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)}\right) \times EF \times [(ED_{0-2} \times ADAF_{0-2}) + (ED_{2-6} \times ADAF_{2-6}) + (ED_{6-16} \times ADAF_{6-16}) + (ED_{16-26} \times ADAF_{16-26})]}$$

TRICHLOROETHYLENE (TCE) – MUTAGENIC (residential only – child, adult, and age-adjusted resident)

$$RBTL = \frac{1}{\left(\left(\frac{1}{TCE \text{ Carcinogenic } RBTL}\right) + \left(\frac{1}{TCE \text{ Mutagenic } RBTL}\right)\right)}$$

AIR Risk-Based Target Levels (Residential and Non-Residential Worker) CONTINUED

VINYL CHLORIDE (VC) - MUTAGENIC (residential only - child and age-adjusted resident only)

$$RBTL = \frac{TR}{UR_i + \left(\frac{UR_i \times \left(\frac{ET}{24 \left(\frac{hr}{d} \right)} \right) \times EF \times ED}{AT_c} \right)}$$

Where:

RBTL = Risk Based Target Level ($\mu\text{g}/\text{m}^3$)

THQ = Target Hazard Quotient (unitless)

TR = Target Cancer Risk (unitless)

AT_{nc} = Averaging Time for Non-Carcinogens (days)

AT_c = Averaging Time for Carcinogens (days)

RfC = Chronic Inhalation Reference Concentration (mg/m^3)

UR_i = Chronic Inhalation Unit Risk ($\mu\text{g}/\text{m}^3$)⁻¹

ET = Exposure Time for Inhalation (hours/day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (years)

ED₀₋₂ = Mutagenic Exposure Duration - age segment 0-2 (years)

ED₂₋₆ = Mutagenic Exposure Duration - age segment 2-6 (years)

ED₆₋₁₆ = Mutagenic Exposure Duration - age segment 6-16 (years)

ED₁₆₋₂₆ = Mutagenic Exposure Duration - age segment 16-26 (years)

ADAF₀₋₂ = Mutagenic Age-Dependent Adjustment Factor 0-2 years (unitless)

ADAF₂₋₆ = Mutagenic Age-Dependent Adjustment Factor 2-6 years (unitless)

ADAF₆₋₁₆ = Mutagenic Age-Dependent Adjustment Factor 6-16 years (unitless)

ADAF₁₆₋₂₆ = Mutagenic Age-Dependent Adjustment Factor 16-26 years (unitless)

VAPOR INTRUSION Risk-Based Target Levels (Residential and Non-Residential Worker)

Note: Volatile chemicals are defined as chemicals with a Henry's Law Constant $\geq 1 \times 10^{-5}$ atm-m³/mole or a Vapor Pressure ≥ 1 mm Hg.

Target Crawlspace Air Concentration Corresponding to Target Residential or Non-Residential Air Concentration

$$RBTL = \frac{RBTL_{target\ air}}{AF_c}$$

Target Sub-Slab Soil Gas Concentration Corresponding to Target Residential or Non-Residential Air Concentration

$$RBTL = \frac{RBTL_{target\ air}}{AF_{ss}}$$

Target Exterior Soil Gas Concentration Corresponding to Target Residential or Non-Residential Air Concentration

$$RBTL = \frac{RBTL_{target\ air}}{AF_{sg}}$$

Target Groundwater Concentration Corresponding to Target Residential or Non-Residential Air Concentration

$$RBTL = \frac{RBTL_{target\ air}}{AF_{gw} \times H' \times 1000 \left(\frac{L}{m^3}\right)}$$

Where:

$RBTL$ = Risk Based Target Level ($\mu\text{g}/\text{m}^3$)

$RBTL_{target\ air}$ = Target Residential or Non-Residential Air Concentration ($\mu\text{g}/\text{m}^3$)

AF_c = Crawlspace Attenuation Factor (unitless)

AF_{ss} = Sub-Slab Soil Gas Attenuation Factor (unitless)

AF_{sg} = Exterior Soil Gas Attenuation Factor (unitless)

AF_{gw} = Groundwater Attenuation Factor (unitless)

H' = Henry's Law Constant (unitless)

GROUNDWATER - Domestic Water Use Risk-Based Target Levels (Residential)

NON-CARCINOGENIC (child, adult, and age-adjusted resident)

Ingestion of Water

Child and Adult Resident:

$$RBTL = \frac{THQ \times AT_{nc} \times BW \times 1000 \left(\frac{\mu g}{mg}\right)}{\left(\frac{1}{RfD_o}\right) \times IRW \times EF \times ED}$$

Age-Adjusted Resident:

$$RBTL = \frac{THQ \times AT_{nc,age-adjusted} \times 1000 \left(\frac{\mu g}{mg}\right)}{\left(\frac{1}{RfD_o}\right) \times EF \times \left[\left(\frac{IRW_{child} \times ED_{child}}{BW_{child}}\right) + \left(\frac{IRW_{adult} \times ED_{adult}}{BW_{adult}}\right)\right]}$$

Dermal Absorption

Child and Adult Resident:

$$RBTL = \frac{THQ \times AT_{nc} \times BW \times 1000 \left(\frac{\mu g}{mg}\right) \times 1000 \left(\frac{cm^3}{L}\right)}{\left(\frac{1}{RfD_d}\right) \times DA_{event} \times SA_{water} \times F_{event} \times EF \times ED}$$

Age-Adjusted Resident:

$$RBTL = \frac{THQ \times AT_{nc,age-adjusted} \times 1000 \left(\frac{\mu g}{mg}\right) \times 1000 \left(\frac{cm^3}{L}\right)}{\left(\frac{1}{RfD_o}\right) \times DA_{event,age-adjusted} \times F_{event} \times EF \times \left[\left(\frac{SA_{water,child} \times ED_{child}}{BW_{child}}\right) + \left(\frac{SA_{water,adult} \times ED_{adult}}{BW_{adult}}\right)\right]}$$

Inhalation of Volatiles

Child, Adult, and Age-Adjusted Resident:

$$RBTL = \frac{THQ \times AT_{nc} \times 1000 \left(\frac{\mu g}{mg}\right)}{\left(\frac{1}{RfC}\right) \times K \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)}\right) \times EF \times ED}$$

Total RBTL

$$RBTL = \frac{1}{\left(\left(\frac{1}{RBTL_{GWingestion}}\right) + \left(\frac{1}{RBTL_{GWdermal}}\right) + \left(\frac{1}{RBTL_{GWinhalation}}\right)\right)}$$

GROUNDWATER - Domestic Water Use Risk-Based Target Levels (Residential) CONTINUED

CARCINOGENIC (child, adult, and age-adjusted resident)

Ingestion of Water

Child and Adult Resident:

$$RBTL = \frac{TR \times AT_c \times BW \times 1000 \left(\frac{\mu g}{mg}\right)}{SF_o \times IRW \times EF \times ED}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c \times 1000 \left(\frac{\mu g}{mg}\right)}{SF_o \times EF \times \left[\left(\frac{IRW_{child} \times ED_{child}}{BW_{child}} \right) + \left(\frac{IRW_{adult} \times ED_{adult}}{BW_{adult}} \right) \right]}$$

Dermal Absorption

Child and Adult Resident:

$$RBTL = \frac{TR \times AT_c \times BW \times 1000 \left(\frac{\mu g}{mg}\right) \times 1000 \left(\frac{cm^3}{L}\right)}{SF_d \times DA_{event} \times SA \times F_{event} \times EF \times ED}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c \times 1000 \left(\frac{\mu g}{mg}\right) \times 1000 \left(\frac{cm^3}{L}\right)}{SF_d \times DA_{event,age-adjusted} \times F_{event} \times EF \times \left[\left(\frac{SA_{water,child} \times ED_{child}}{BW_{child}} \right) + \left(\frac{SA_{water,adult} \times ED_{adult}}{BW_{adult}} \right) \right]}$$

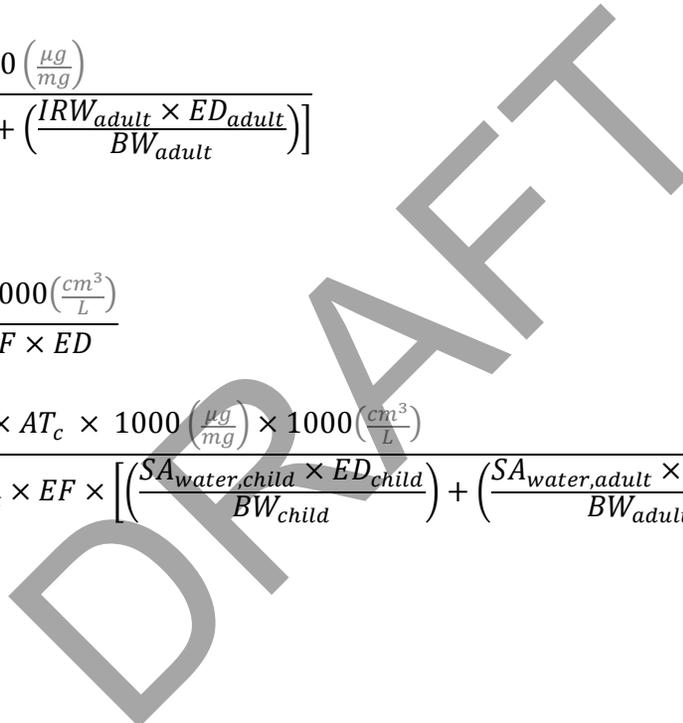
Inhalation of Volatiles

Child, Adult, and Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c}{UR_i \times K \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)} \right) \times EF \times ED}$$

Total RBTL

$$RBTL = \frac{1}{\left(\left(\frac{1}{RBTL_{GWingestion}} \right) + \left(\frac{1}{RBTL_{GWdermal}} \right) + \left(\frac{1}{RBTL_{GWinhalation}} \right) \right)}$$



GROUNDWATER - Domestic Water Use Risk-Based Target Levels (Residential) CONTINUED

MUTAGENIC (child, adult, and age-adjusted resident)

Ingestion of Water

Child Resident:

$$RBTL = \frac{TR \times AT_c \times 1000 \left(\frac{\mu g}{mg}\right)}{SF_o \times EF \times \left[\left(\frac{IRW_{child} \times ED_{0-2} \times ADAF_{0-2}}{BW_{child}} \right) + \left(\frac{IRW_{child} \times ED_{2-6} \times ADAF_{2-6}}{BW_{child}} \right) \right]}$$

Adult Resident:

$$RBTL = \frac{TR \times AT_c \times 1000 \left(\frac{\mu g}{mg}\right)}{SF_o \times EF \times \left[\left(\frac{IRW_{adult} \times ED_{6-16} \times ADAF_{6-16}}{BW_{adult}} \right) + \left(\frac{IRW_{adult} \times ED_{16-26} \times ADAF_{16-26}}{BW_{adult}} \right) \right]}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c \times 1000 \left(\frac{\mu g}{mg}\right)}{SF_o \times EF \times \left[\left(\frac{IRW_{child} \times ED_{0-2} \times ADAF_{0-2}}{BW_{child}} \right) + \left(\frac{IRW_{child} \times ED_{2-6} \times ADAF_{2-6}}{BW_{child}} \right) + \left(\frac{IRW_{adult} \times ED_{6-16} \times ADAF_{6-16}}{BW_{adult}} \right) + \left(\frac{IRW_{adult} \times ED_{16-26} \times ADAF_{16-26}}{BW_{adult}} \right) \right]}$$

Dermal Absorption

Child Resident:

$$RBTL = \frac{TR \times AT_c \times 1000 \left(\frac{\mu g}{mg}\right) \times 1000 \left(\frac{cm^3}{L}\right)}{SF_d \times DA_{event,child} \times F_{event} \times EF \times \left[\left(\frac{SA_{child} \times ED_{0-2} \times ADAF_{0-2}}{BW_{child}} \right) + \left(\frac{SA_{child} \times ED_{2-6} \times ADAF_{2-6}}{BW_{child}} \right) \right]}$$

Adult Resident:

$$RBTL = \frac{TR \times AT_c \times 1000 \left(\frac{\mu g}{mg}\right) \times 1000 \left(\frac{cm^3}{L}\right)}{SF_d \times DA_{event,adult} \times F_{event} \times EF \times \left[\left(\frac{SA_{adult} \times ED_{6-16} \times ADAF_{6-16}}{BW_{adult}} \right) + \left(\frac{SA_{adult} \times ED_{16-26} \times ADAF_{16-26}}{BW_{adult}} \right) \right]}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c \times 1000 \left(\frac{\mu g}{mg}\right) \times 1000 \left(\frac{cm^3}{L}\right)}{SF_d \times DA_{event,age-adjusted} \times F_{event} \times EF \times \left[\left(\frac{SA_{child} \times ED_{0-2} \times ADAF_{0-2}}{BW_{child}} \right) + \left(\frac{SA_{child} \times ED_{2-6} \times ADAF_{2-6}}{BW_{child}} \right) + \left(\frac{SA_{adult} \times ED_{6-16} \times ADAF_{6-16}}{BW_{adult}} \right) + \left(\frac{SA_{adult} \times ED_{16-26} \times ADAF_{16-26}}{BW_{adult}} \right) \right]}$$

Inhalation of Volatiles

Child Resident:

$$RBTL = \frac{TR \times AT_c}{UR_i \times K \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)} \right) \times EF \times [(ED_{0-2} \times ADAF_{0-2}) + (ED_{2-6} \times ADAF_{2-6})]}$$

GROUNDWATER - Domestic Water Use Risk-Based Target Levels (Residential) CONTINUED

Adult Resident:

$$RBTL = \frac{TR \times AT_c}{UR_i \times K \times \left(\frac{ET}{24 \left(\frac{hr}{d} \right)} \right) \times EF \times [(ED_{6-16} \times ADAF_{6-16}) + (ED_{16-26} \times ADAF_{16-26})]}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c}{UR_i \times K \times \left(\frac{ET}{24 \left(\frac{hr}{d} \right)} \right) \times EF \times [(ED_{0-2} \times ADAF_{0-2}) + (ED_{2-6} \times ADAF_{2-6}) + (ED_{6-16} \times ADAF_{6-16}) + (ED_{16-26} \times ADAF_{16-26})]}$$

Total RBTL

$$RBTL = \frac{1}{\left(\left(\frac{1}{RBTL_{GWingestion}} \right) + \left(\frac{1}{RBTL_{GWdermal}} \right) + \left(\frac{1}{RBTL_{GWinhalation}} \right) \right)}$$

TRICHLOROETHYLENE (TCE) – MUTAGENIC (child, adult, and age-adjusted resident)

$$RBTL = \frac{1}{\left(\left(\frac{1}{Total\ TCE\ Carcinogenic\ RBTL} \right) + \left(\frac{1}{Total\ TCE\ Mutagenic\ RBTL} \right) \right)}$$

VINYL CHLORIDE (VC) - MUTAGENIC (child and age-adjusted resident only)

Ingestion of Water

Child Resident:

$$RBTL = \frac{TR}{\left(\frac{SF_o \times IRW_{child} \times EF \times ED_{child} \times 10^{-4} \left(\frac{mg}{\mu g} \right)}{AT_c \times BW_{child}} \right) + \left(\frac{SF_o \times IRW_{child} \times 10^{-4} \left(\frac{mg}{\mu g} \right)}{BW_{child}} \right)}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR}{\left(SF_o \times EF \times 10^{-4} \left(\frac{mg}{\mu g} \right) \times \left[\left(\frac{IRW_{child} \times ED_{child}}{BW_{child}} \right) + \left(\frac{IRW_{adult} \times ED_{adult}}{BW_{adult}} \right) \right] \times \left(\frac{1}{AT_c} \right) \right) + \left(\frac{SF_o \times IRW_{child} \times 10^{-4} \left(\frac{mg}{\mu g} \right)}{BW_{child}} \right)}$$

GROUNDWATER - Domestic Water Use Risk-Based Target Levels (Residential) CONTINUED

Dermal Absorption

Child Resident:

$$RBTL = \frac{TR \times 1000 \left(\frac{cm^3}{L}\right)}{\left(\frac{SF_d \times DA_{event,child} \times SA_{water,child} \times F_{event} \times EF \times ED_{child}}{AT_c \times BW_{chld} \times 1000 \left(\frac{\mu g}{mg}\right)}\right) + \left(\frac{SF_d \times DA_{event,child} \times SA_{water,child} \times F_{event}}{BW_{chld} \times 1000 \left(\frac{\mu g}{mg}\right)}\right)}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times \left(\frac{1000 cm^3}{L}\right)}{(SF_d \times DA_{event,age-adjusted} \times F_{event} \times EF \times 10^{-4} \left(\frac{mg}{\mu g}\right) \times \left[\left(\frac{SA_{water,child} \times ED_{child}}{BW_{chld}}\right) + \left(\frac{SA_{water,adult} \times ED_{adult}}{BW_{adult}}\right)\right] \times \left(\frac{1}{AT_c}\right)) + \left(\frac{SF_d \times DA_{event(age-adjusted)} \times SA_{child} \times F_{event}}{BW_{chld} \times \left(\frac{1000 \mu g}{mg}\right)}\right)}$$

Inhalation of Volatiles

Child and Age-Adjusted Resident:

$$RBTL = \frac{TR}{\left(\frac{UR_i \times K \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)}\right) \times EF \times ED}{AT_c}\right) + (UR_i \times K)}$$

Total RBTL

$$RBTL = \frac{1}{\left(\frac{1}{(VC RBTL_{GWingestion})}\right) + \left(\frac{1}{(VC RBTL_{GWdermal})}\right) + \left(\frac{1}{(VC RBTL_{GWinhalation})}\right)}$$

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GROUNDWATER - Domestic Water Use Risk-Based Target Levels (Residential) CONTINUED

Where:

$RBTL$ = Risk Based Target Level ($\mu\text{g/L}$)

THQ = Target Hazard Quotient (unitless)

TR = Target Cancer Risk (unitless)

AT_{nc} = Averaging Time for Non-Carcinogens (days)

AT_c = Averaging Time for Carcinogens (days)

BW = Body Weight (kg)

RfD_o = Chronic Oral Reference Dose (mg/kg-day)

SF_o = Oral Slope Factor (mg/kg-day)⁻¹

RfD_d = Chronic Dermal Reference Dose (mg/kg-day)

SF_d = Dermal Slope Factor (mg/kg-day)⁻¹

RfC = Chronic Inhalation Reference Concentration (mg/m³)

UR_i = Inhalation Unit Risk ($\mu\text{g/m}^3$)⁻¹

IRW = Water Ingestion Rate (L/day)

DA_{event} = Dermal Absorbed Dose per Event (cm/event)

SA_{water} = Skin Surface Area Available for Water Contact (cm²)

F_{event} = Event Frequency for Dermal Contact with Water (events/day)

K = Volatilization Constant for Domestic Water Use (L/m³)

ET = Exposure Time (hours/day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (years)

ED_{0-2} = Mutagenic Exposure Duration - age segment 0-2 (years)

ED_{2-6} = Mutagenic Exposure Duration - age segment 2-6 (years)

ED_{6-16} = Mutagenic Exposure Duration - age segment 6-16 (years)

ED_{16-26} = Mutagenic Exposure Duration - age segment 16-26 (years)

$ADAF_{0-2}$ = Mutagenic Age-Dependent Adjustment Factor 0-2 years (unitless)

$ADAF_{2-6}$ = Mutagenic Age-Dependent Adjustment Factor 2-6 years (unitless)

$ADAF_{6-16}$ = Mutagenic Age-Dependent Adjustment Factor 6-16 years (unitless)

$ADAF_{16-26}$ = Mutagenic Age-Dependent Adjustment Factor 16-26 years (unitless)

Note: For K , volatile chemicals are defined as chemicals with a Henry's Law Constant $\geq 1 \times 10^{-5}$ atm-m³/mole or a Vapor Pressure ≥ 1 mm Hg.

GROUNDWATER Trench Exposure Risk-Based Target Levels (Construction Worker)

NON-CARCINOGENIC (construction worker only)

Dermal Absorption

$$RBTL = \frac{THQ \times AT_{nc} \times BW \times 1000 \left(\frac{\mu g}{mg}\right) \times 1000 \left(\frac{cm^3}{L}\right)}{\left(\frac{1}{RfD_d}\right) \times DA_{event} \times SA_{water} \times F_{event} \times EF \times ED}$$

Inhalation of Volatiles

$$RBTL = \left(\frac{THQ \times AT_{nc} \times 1000 \left(\frac{\mu g}{mg}\right)}{\left(\frac{1}{RfC}\right) \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)}\right) \times EF \times ED} \right) \div VF_{trench}$$

Total RBTL

$$RBTL = \frac{1}{\left(\left(\frac{1}{RBTL_{GWdermal}}\right) + \left(\frac{1}{RBTL_{GWinhalation}}\right) \right)}$$

CARCINOGENIC (construction worker only)

Dermal Absorption

$$RBTL = \frac{TR \times AT_c \times BW \times 1000 \left(\frac{\mu g}{mg}\right) \times 1000 \left(\frac{cm^3}{L}\right)}{SF_d \times DA_{event} \times SA \times F_{event} \times EF \times ED}$$

Inhalation of Volatiles

$$RBTL = \left(\frac{TR \times AT_c}{UR_i \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)}\right) \times EF \times ED} \right) \div VF_{trench}$$

GROUNDWATER Trench Exposure Risk-Based Target Levels (Construction Worker) CONTINUED

Total RBTL

$$RBTL = \frac{1}{\left(\left(\frac{1}{RBTL_{GWdermal}} \right) + \left(\frac{1}{RBTL_{GWinhalation}} \right) \right)}$$

Where:

$RBTL$ = Risk Based Target Level ($\mu\text{g/L}$)

THQ = Target Hazard Quotient (unitless)

TR = Target Cancer Risk (unitless)

AT_{nc} = Averaging Time for Non-Carcinogens (days)

AT_c = Averaging Time for Carcinogens (days)

BW = Body Weight (kg)

RfD_d = Chronic Dermal Reference Dose (mg/kg-day)

SF_d = Dermal Slope Factor (mg/kg-day)⁻¹

RfC = Chronic Inhalation Reference Concentration (mg/m³)

UR_i = Inhalation Unit Risk ($\mu\text{g/m}^3$)⁻¹

DA_{event} = Dermally Absorbed Dose per Event (cm/event)

SA_{water} = Skin Surface Area Available for Water Contact (cm²)

F_{event} = Event Frequency for Dermal Contact with Water (events/day)

VF_{trench} = Trench Air Volatilization Factor (L/m³)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (years)

Note: For VF_{trench} , volatile chemicals are defined as chemicals with a Henry's Law Constant $\geq 1 \times 10^{-5}$ atm-m³/mole or a Vapor Pressure ≥ 1 mm Hg.

GROUNDWATER – Dermal Absorbed Dose per Event (Residential and Construction Worker)

DA_{event} (cm/event) - Inorganics

$$DA_{event} = K_p \times t_{event}$$

DA_{event} (cm/event) - Organics

$$\text{If } t_{event} \leq t^* \text{ (hr), then } DA_{event} = 2 \times FA \times K_p \times \sqrt{\frac{6 \times \tau_{event} \times t_{event}}{\pi}}$$

or

$$\text{If } t_{event} > t^* \text{ (hr), then } DA_{event} = FA \times K_p \times \left[\frac{t_{event}}{1+B} + 2 \times \tau_{event} \times \left(\frac{1+3B+3B^2}{(1+B)^2} \right) \right]$$

DA_{event} Supporting Equations

$$\text{If } B \leq 0.6, \text{ then } t^* \text{ (hr)} = 2.4 \times \tau_{event}$$

OR

$$\text{If } B > 0.6, \text{ then } t^* \text{ (hr)} = 6 \times \tau_{event} \times (b - \sqrt{b^2 - c^2})$$

where:

$$b = \frac{2 \times (1+B)^2}{\pi} - c \text{ and } c = \frac{1+3B+3B^2}{3 \times (1+B)}$$

$$B = K_p \times \frac{\sqrt{MW} \left(\frac{g}{mole} \right)}{2.6}$$

$$\tau_{event} = \frac{I_{sc}^2 \text{ (cm)}}{6 \times D_{sc} \left(\frac{cm^2}{hr} \right)}$$

where:

$$\log \frac{D_{sc} \left(\frac{cm^2}{hr} \right)}{I_{sc} \text{ (cm)}} = -2.80 - 0.0056 \times MW \left(\frac{g}{mole} \right) \text{ or } \frac{D_{sc} \left(\frac{cm^2}{hr} \right)}{I_{sc} \text{ (cm)}} = 10^{(-2.80 - 0.0056 \times MW \left(\frac{g}{mole} \right))}$$

thus:

$$I_{sc} = 10^{-3} \text{ and } D_{sc} \left(\frac{cm^2}{hr} \right) = I_{sc} \text{ (cm)} \times 10^{(-2.8 - 0.0056 \times MW \left(\frac{g}{mole} \right))}$$

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GROUNDWATER – Dermal Absorbed Dose per Event (Residential and Construction Worker) CONTINUED

Where:

DA_{event} = Dermal Absorbed Dose per Event (cm/event)

t_{event} = Exposure Time for Dermal Contact with Water (hours/event)

t^* = Time to Reach Steady-State (hours)

FA = Fraction Absorbed Water (unitless)

K_p = Dermal Permeability Coefficient of compound in water (cm/hour)

τ_{event} = Lag Time per Event (hours/event)

B = Ratio of the Permeability Coefficient of a Compound through the Stratum Corneum Relative to its Permeability Coefficient Across the Viable Epidermis (unitless)

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GROUNDWATER – Trench Volatilization Factor (Construction Worker)

Note: Volatile chemicals are defined as chemicals with a Henry's Law Constant $\geq 1 \times 10^{-5}$ atm-m³/mole or a Vapor Pressure ≥ 1 mm Hg.

VF_{trench} (L/m³)

$$VF_{trench} = \frac{K_i \times A \times F \times 10^{-3} \left(\frac{L}{cm^3}\right) \times 10,000 \left(\frac{cm^2}{m^2}\right) \times 3600 \left(\frac{s}{hr}\right)}{ACH \times V}$$

VF_{trench} Supporting Equations

$$K_i = \frac{1}{\left(\frac{1}{K_{iL}}\right) + \left[\frac{R \times T}{H' \times K_{iG}}\right]}$$

$$A = L_{trench} \times W_{trench}$$

$$V = L_{trench} \times W_{trench} \times D_{trench}$$

$$K_{iL} = \left(\frac{MW_{O_2}}{MW}\right)^{0.5} \times \left(\frac{T}{298}\right) \times K_{i,O_2}$$

$$K_{iG} = \left(\frac{MW_{H_2O}}{MW}\right)^{0.335} \times \left(\frac{T}{298}\right)^{1.005} \times K_{iG,H_2O}$$

Where:

VF_{trench} = Trench Air Volatilization Factor (L/m³)

K_i = Overall mass transfer coefficient (cm/s)

A = Area of Trench (m²)

F = Fraction of floor through which contaminant can enter (unitless)

ACH = Air changes per hour (h⁻¹)

V = Volume of Trench (m³) = $L_{trench} * W_{trench} * D_{trench}$

L_{trench} = Length of Trench (m)

W_{trench} = Width of Trench (m)

D_{trench} = Depth of Trench (m)

K_{iL} = Liquid-phase mass transfer coefficient (cm/s)

R = Ideal gas constant (8.2E-05 atm-m³/mol-K)

T = Average system absolute temperature (K)

H' = Henry's Law Constant (atm-m³/mol)

K_{iG} = Gas-phase mass transfer coefficient (cm/s)

MW_{O_2} = Molecular Weight of O₂ (32 g/mol)

MW = Molecular Weight (g/mol)

K_{i,O_2} = Liquid-phase mass transfer coefficient of O₂ at 25°C (cm/s)

MW_{H_2O} = Molecular Weight of Water (18 g/mol)

K_{iG,H_2O} = Gas-phase mass transfer coefficient of water vapor at 25°C (0.833 cm/s)

SOIL Direct Contact Risk-Based Target Levels (Residential, Non-Residential Worker, and Construction Worker)

NON-CARCINOGENIC (child, adult, and age-adjusted resident, non-resident worker, and construction worker)

Incidental Ingestion of Soil

Child and Adult Resident, Non-Residential Worker, and Construction Worker:

$$RBTL = \frac{THQ \times AT_{nc} \times BW}{\left(\frac{1}{RfD_o}\right) \times IRS \times RBA \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times ED}$$

Age-Adjusted Resident:

$$RBTL = \frac{THQ \times AT_{nc,age-adjusted}}{\left(\frac{1}{RfD_o}\right) \times RBA \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times \left[\left(\frac{IRS_{child} \times ED_{child}}{BW_{child}}\right) + \left(\frac{IRS_{adult} \times ED_{adult}}{BW_{adult}}\right)\right]}$$

Dermal Contact with Soil

Child and Adult Resident, Non-Residential Worker, and Construction Worker:

$$RBTL = \frac{THQ \times AT_{nc} \times BW}{\left(\frac{1}{RfD_d}\right) \times SA \times AF \times ABS \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times ED}$$

Age-Adjusted Resident:

$$RBTL = \frac{THQ \times AT_{nc,age-adjusted}}{\left(\frac{1}{RfD_d}\right) \times ABS \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times \left[\left(\frac{SA_{child} \times AF_{child} \times ED_{child}}{BW_{child}}\right) + \left(\frac{SA_{adult} \times AF_{adult} \times ED_{adult}}{BW_{adult}}\right)\right]}$$

Inhalation of Volatiles and Particulates Emitted from Soil

Child, Adult, and Age-Adjusted Resident, Non-Residential Worker, and Construction Worker:

$$RBTL = \frac{THQ \times AT_{nc}}{\left(\frac{1}{RfC}\right) \times \left(\frac{1}{VF} + \frac{1}{PEF}\right) \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)}\right) \times EF \times ED}$$

Total RBTL

$$RBTL = \frac{1}{\left(\left(\frac{1}{RBTL_{SOILingestion}}\right) + \left(\frac{1}{RBTL_{SOILdermal}}\right) + \left(\frac{1}{RBTL_{SOILinhalation}}\right)\right)}$$

SOIL Direct Contact Risk-Based Target Levels (Residential, Non-Residential Worker, and Construction Worker) CONTINUED

CARCINOGENIC (child, adult, and age-adjusted resident, non-resident worker, and construction worker)

Incidental Ingestion of Soil

Child and Adult Resident, Non-Residential Worker, and Construction Worker:

$$RBTL = \frac{TR \times AT_c \times BW}{SF_o \times IRS \times RBA \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times ED}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c}{SF_o \times RBA \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times \left[\left(\frac{IRS_{child} \times ED_{child}}{BW_{child}} \right) + \left(\frac{IRS_{adult} \times ED_{adult}}{BW_{adult}} \right) \right]}$$

Dermal Contact with Soil

Child and Adult Resident, Non-Residential Worker, and Construction Worker:

$$RBTL = \frac{TR \times AT_c \times BW}{SF_d \times SA \times AF \times ABS \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times ED}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c}{SF_d \times ABS \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times \left[\left(\frac{SA_{child} \times AF_{child} \times ED_{child}}{BW_{child}} \right) + \left(\frac{SA_{adult} \times AF_{adult} \times ED_{adult}}{BW_{adult}} \right) \right]}$$

Inhalation of Volatiles and Particulates Emitted from Soil

Child, Adult, and Age-Adjusted Resident, Non-Residential Worker, and Construction Worker:

$$RBTL = \frac{TR \times AT_c}{UR_i \times \left(\frac{1}{VF} + \frac{1}{PEF} \right) \times 1000 \left(\frac{\mu g}{mg}\right) \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)} \right) \times EF \times ED}$$

Total RBTL

$$RBTL = \frac{1}{\left(\left(\frac{1}{RBTL_{SOILingestion}} \right) + \left(\frac{1}{RBTL_{SOILdermal}} \right) + \left(\frac{1}{RBTL_{SOILinhalation}} \right) \right)}$$

SOIL Direct Contact Risk-Based Target Levels (Residential, Non-Residential Worker, and Construction Worker) CONTINUED

MUTAGENIC (child, adult, and age-adjusted resident)

Incidental Ingestion of Soil

Child Resident:

$$RBTL = \frac{TR \times AT_c}{SF_o \times RBA \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times \left[\left(\frac{IRS_{child} \times ED_{0-2} \times ADAF_{0-2}}{BW_{child}} \right) + \left(\frac{IRS_{child} \times ED_{2-6} \times ADAF_{2-6}}{BW_{child}} \right) \right]}$$

Adult Resident:

$$RBTL = \frac{TR \times AT_c}{SF_o \times RBA \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times \left[\left(\frac{IRS_{adult} \times ED_{6-16} \times ADAF_{6-16}}{BW_{adult}} \right) + \left(\frac{IRS_{adult} \times ED_{16-26} \times ADAF_{16-26}}{BW_{adult}} \right) \right]}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c}{SF_o \times RBA \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times \left[\left(\frac{IRS_{child} \times ED_{0-2} \times ADAF_{0-2}}{BW_{child}} \right) + \left(\frac{IRS_{child} \times ED_{2-6} \times ADAF_{2-6}}{BW_{child}} \right) + \left(\frac{IRS_{adult} \times ED_{6-16} \times ADAF_{6-16}}{BW_{adult}} \right) + \left(\frac{IRS_{adult} \times ED_{16-26} \times ADAF_{16-26}}{BW_{adult}} \right) \right]}$$

Dermal Contact with Soil

Child Resident:

$$RBTL = \frac{TR \times AT_c}{SF_d \times ABS \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times \left[\left(\frac{SA_{child} \times AF_{child} \times ED_{0-2} \times ADAF_{0-2}}{BW_{child}} \right) + \left(\frac{SA_{child} \times AF_{child} \times ED_{2-6} \times ADAF_{2-6}}{BW_{child}} \right) \right]}$$

Adult Resident:

$$RBTL = \frac{TR \times AT_c}{SF_d \times ABS \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times \left[\left(\frac{SA_{adult} \times AF_{adult} \times ED_{6-16} \times ADAF_{6-16}}{BW_{adult}} \right) + \left(\frac{SA_{adult} \times AF_{adult} \times ED_{16-26} \times ADAF_{16-26}}{BW_{adult}} \right) \right]}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c}{SF_d \times ABS \times 10^{-6} \left(\frac{kg}{mg}\right) \times EF \times \left[\left(\frac{SA_{child} \times AF_{child} \times ED_{0-2} \times ADAF_{0-2}}{BW_{child}} \right) + \left(\frac{SA_{child} \times AF_{child} \times ED_{2-6} \times ADAF_{2-6}}{BW_{child}} \right) + \left(\frac{SA_{adult} \times AF_{adult} \times ED_{6-16} \times ADAF_{6-16}}{BW_{adult}} \right) + \left(\frac{SA_{adult} \times AF_{adult} \times ED_{16-26} \times ADAF_{16-26}}{BW_{adult}} \right) \right]}$$

Inhalation of Volatiles and Particulates Emitted from Soil

Child Resident:

$$RBTL = \frac{TR \times AT_c}{UR_i \times \left(\frac{1}{VF} + \frac{1}{PEF} \right) \times 1000 \left(\frac{\mu g}{mg}\right) \times \left(\frac{ET}{24 \left(\frac{hr}{d}\right)} \right) \times EF \times \left[(ED_{0-2} \times ADAF_{0-2}) + (ED_{2-6} \times ADAF_{2-6}) \right]}$$

SOIL Direct Contact Risk-Based Target Levels (Residential, Non-Residential Worker, and Construction Worker) CONTINUED

Adult Resident:

$$RBTL = \frac{TR \times AT_c}{UR_i \times \left(\frac{1}{VF} + \frac{1}{PEF} \right) \times 1000 \left(\frac{\mu g}{mg} \right) \times \left(\frac{ET}{24 \left(\frac{hr}{d} \right)} \right) \times EF \times [(ED_{6-16} \times ADAF_{6-16}) + (ED_{16-26} \times ADAF_{16-26})]}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR \times AT_c}{UR_i \times \left(\frac{1}{VF} + \frac{1}{PEF} \right) \times 1000 \left(\frac{\mu g}{mg} \right) \times \left(\frac{ET}{24 \left(\frac{hr}{d} \right)} \right) \times EF \times [(ED_{0-2} \times ADAF_{0-2}) + (ED_{2-6} \times ADAF_{2-6}) + (ED_{6-16} \times ADAF_{6-16}) + (ED_{16-26} \times ADAF_{16-26})]}$$

Total RBTL

$$RBTL = \frac{1}{\left(\left(\frac{1}{RBTL_{SOILingestion}} \right) + \left(\frac{1}{RBTL_{SOILdermal}} \right) + \left(\frac{1}{RBTL_{SOILinhalation}} \right) \right)}$$

TRICHLOROETHYLENE (TCE) – MUTAGENIC (child, adult, and age-adjusted resident)

$$RBTL = \frac{1}{\left(\left(\frac{1}{Total\ TCE\ Carcinogenic\ RBTL} \right) + \left(\frac{1}{Total\ TCE\ Mutagenic\ RBTL} \right) \right)}$$

VINYL CHLORIDE (VC) - MUTAGENIC (child and age-adjusted resident only)

Incidental Ingestion of Soil

Child Resident:

$$RBTL = \frac{TR}{\left(\frac{SF_o \times IRS_{child} \times RBA \times 10^{-6} \left(\frac{kg}{mg} \right) \times EF \times ED_{child}}{AT_c \times BW_{child}} \right) + \left(\frac{SF_o \times IRS_{child} \times RBA \times 10^{-6} \left(\frac{kg}{mg} \right)}{BW_{child}} \right)}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR}{\left(SF_o \times RBA \times 10^{-6} \left(\frac{kg}{mg} \right) \times EF \times \left[\left(\frac{IRS_{child} \times ED_{child}}{BW_{child}} \right) + \left(\frac{IRS_{adult} \times ED_{adult}}{BW_{adult}} \right) \right] \times \left(\frac{1}{AT_c} \right) \right) + \left(\frac{SF_o \times IRS_{child} \times RBA \times 10^{-6} \left(\frac{kg}{mg} \right)}{BW_{child}} \right)}$$

SOIL Direct Contact Risk-Based Target Levels (Residential, Non-Residential Worker, and Construction Worker) CONTINUED

Dermal Contact with Soil

Child Resident:

$$RBTL = \frac{TR}{\left(\frac{SF_d \times SA_{soil,child} \times AF_{child} \times ABS \times 10^{-6} \left(\frac{kg}{mg} \right) \times EF \times ED_{child}}{AT_c \times BW_{child}} \right) + \left(\frac{SF_d \times SA_{soil,child} \times AF_{child} \times ABS \times 10^{-6} \left(\frac{kg}{mg} \right)}{BW_{child}} \right)}$$

Age-Adjusted Resident:

$$RBTL = \frac{TR}{\left(SF_d \times ABS \times 10^{-6} \left(\frac{kg}{mg} \right) \times EF \times \left[\left(\frac{SA_{soil,child} \times AF_{child} \times ED_{child}}{BW_{child}} \right) + \left(\frac{SA_{soil,adult} \times AF_{adult} \times ED_{adult}}{BW_{adult}} \right) \right] \times \left(\frac{1}{AT_c} \right) \right) + \left(\frac{SF_d \times SA_{soil,child} \times AF_{child} \times ABS \times 10^{-6} \left(\frac{kg}{mg} \right)}{BW_{child}} \right)}$$

Inhalation of Volatiles and Particulates Emitted from Soil

Child and Age-Adjusted Resident:

$$RBTL = \frac{TR}{\left(\frac{UR_i \times 1000 \left(\frac{\mu g}{mg} \right) \times \left(\frac{1}{VF} + \frac{1}{PEF} \right) \times \left(\frac{ET}{24 \left(\frac{hr}{d} \right)} \right) \times EF \times ED}{AT_c} \right) + \left(UR_i \times 1000 \left(\frac{\mu g}{mg} \right) \times \left(\frac{1}{VF} + \frac{1}{PEF} \right) \right)}$$

Total RBTL

$$RBTL = \frac{1}{\left(\frac{1}{VC \ RBTL_{SOILingestion}} \right) + \left(\frac{1}{VC \ RBTL_{SOILdermal}} \right) + \left(\frac{1}{VC \ RBTL_{SOILinhalation}} \right)}$$

SOIL Direct Contact Risk-Based Target Levels (Residential, Non-Residential Worker, and Construction Worker) CONTINUED

Where:

THQ = Target Hazard Quotient (unitless)

TR = Target Cancer Risk (unitless)

AT_{nc} = Averaging Time for Non-Carcinogens (days)

AT_c = Averaging Time for Carcinogens (days)

BW = Body Weight (kg)

RfD_o = Chronic Oral Reference Dose (mg/kg-day)

SF_o = Oral Slope Factor (mg/kg-day)⁻¹

RfD_d = Chronic Dermal Reference Dose (mg/kg-day)

SF_d = Dermal Slope Factor (mg/kg-day)⁻¹

RfC = Chronic Inhalation Reference Concentration (mg/m³)

UR_i = Inhalation Unit Risk (μg/m³)⁻¹

IRS = Soil Ingestion Rate (mg/day)

RBA = Oral Relative Bioavailability (unitless)

SA_{soil} = Skin Surface Area Available for Dermal Contact with Soil (cm²)

AF = Adherence Factor of Soil to Skin (mg/cm²)

ABS = Soil Absorption Fraction (unitless)

VF = Soil to Air Volatilization Factor (m³/kg)

PEF = Soil Particulate Emission Factor (m³/kg)

ET = Exposure Time (hours/day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (years)

ED_{0-2} = Mutagenic Exposure Duration - age segment 0-2 (years)

ED_{2-6} = Mutagenic Exposure Duration - age segment 2-6 (years)

ED_{6-16} = Mutagenic Exposure Duration - age segment 6-16 (years)

ED_{16-26} = Mutagenic Exposure Duration - age segment 16-26 (years)

$ADAF_{0-2}$ = Mutagenic Age-Dependent Adjustment Factor 0-2 years (unitless)

$ADAF_{2-6}$ = Mutagenic Age-Dependent Adjustment Factor 2-6 years (unitless)

$ADAF_{6-16}$ = Mutagenic Age-Dependent Adjustment Factor 6-16 years (unitless)

$ADAF_{16-26}$ = Mutagenic Age-Dependent Adjustment Factor 16-26 years (unitless)

Note: For VF, volatile chemicals are defined as chemicals with a Henry's Law Constant $\geq 1 \times 10^{-5}$ atm-m³/mole or a Vapor Pressure ≥ 1 mm Hg.

SOIL - Volatilization Factor (Residential and Non-Residential Worker)

Note: Volatile chemicals are defined as chemicals with a Henry's Law Constant $\geq 1 \times 10^{-5}$ atm-m³/mole or a Vapor Pressure ≥ 1 mm Hg.

Volatilization Factor (residential and non-residential worker only)

$$VF = \frac{Q/C_{vol} \times (3.14 \times D_A \times T)^{\frac{1}{2}} \times 10^{-4} \left(\frac{m^2}{cm^2}\right)}{2 \times \rho_b \times D_A}$$

VF Supporting Equations

$$D_A = \frac{\left[\left(\theta_a^{10/3} \times D_{ia} \times H' + \theta_w^{10/3} \times D_{iw} \right) / n^2 \right]}{\rho_b \times K_d + \theta_w + \theta_a \times H'}$$

$$\theta_a = n - \theta_w$$

$$n = 1 - \left(\frac{\rho_b}{\rho_s} \right)$$

$$K_d (\text{organics}) = K_{oc} \times f_{oc}; K_d (\text{inorganics}) = \text{default values}$$

Where:

VF = Soil to Air Volatilization Factor (m³/kg)

Q/C_{vol} = Inverse of the Ratio of the Geometric Mean Air Concentration to the Volatilization Flux at the Center of a Square Source (g/m²-s kg/m³)

D_A = Apparent Diffusivity (cm²/s)

T = Exposure Interval (s)

ρ_b = Dry Soil Bulk Density (g/cm³)

θ_a = Air-Filled Soil Porosity (L_{air}/L_{soil})

n = Total Soil Porosity (L_{pore}/L_{soil})

θ_w = Water-Filled Soil Porosity (L_{water}/L_{soil})

ρ_s = Soil particle density (g/cm³)

D_{ia} = Diffusivity in Air (cm²/s)

H' = Dimensionless Henry's Law Constant (unitless)

D_{iw} = Diffusivity in Water (cm²/g)

K_d = Soil-Water Partition Coefficient (cm³/g)

K_{oc} = Soil Organic Carbon Partition Coefficient (cm³/g)

f_{oc} = Fraction Organic Carbon in Soil (g/g)

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SOIL - Subchronic Volatilization Factor (Construction Worker)

Note: Volatile chemicals are defined as chemicals with a Henry's Law Constant $\geq 1 \times 10^{-5}$ atm-m³/mole or a Vapor Pressure ≥ 1 mm Hg.

Subchronic Volatilization Factor (construction worker only)

$$VF_{sc} = \left[\frac{(3.14 \times D_A \times T)^{1/2}}{2 \times \rho_b \times D_A} \right] \times 10^{-4} \left(\frac{m^2}{cm^2} \right) \times Q/C_{sa} \times \frac{1}{F_D}$$

VF_{sc} Supporting Equations

$$D_A = \frac{[(\theta_a^{10/3} \times D_{ia} \times H' + \theta_w^{10/3} \times D_{iw})/n^2]}{\rho_b \times K_d + \theta_w + \theta_a \times H'}$$

$$\theta_a = n - \theta_w$$

$$n = 1 - \left(\frac{\rho_b}{\rho_s} \right)$$

$$K_d (\text{organics}) = K_{oc} \times f_{oc}; K_d (\text{inorganics}) = \text{default values}$$

Where:

VF_{sc} = Subchronic Soil to Air Volatilization Factor (m³/kg)

D_A = Apparent Diffusivity (cm²/s)

T = Total Time Over Which Construction Occurs (s)

ρ_b = Dry Soil Bulk Density (g/cm³)

Q/C_{sa} = Inverse of the ratio of the 1-h geometric mean air concentration to the volatilization flux at the center of a square site (g/m²-s kg/m³)

F_D = Dispersion Correction Factor (unitless)

θ_a = Air-Filled Soil Porosity (L_{air}/L_{soil})

n = Total Soil Porosity (L_{pore}/L_{soil})

θ_w = Water-Filled Soil Porosity (L_{water}/L_{soil})

ρ_s = Soil particle density (g/cm³)

D_{ia} = Diffusivity in Air (cm²/s)

H' = Dimensionless Henry's Law Constant (unitless)

D_{iw} = Diffusivity in Water (cm²/g)

K_d = Soil-Water Partition Coefficient (cm³/g)

K_{oc} = Soil Organic Carbon Partition Coefficient (cm³/g)

f_{oc} = Fraction Organic Carbon in Soil (g/g)

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SOIL - Particulate Emission Factor-Wind (Residential and Non-Residential Worker)

Soil Particulate Emission Factor-Wind (residential and non-residential only)

$$PEF_w = Q/C_{wind} \times \left[\frac{3600 \left(\frac{s}{hr} \right)}{0.036 \times (1 - V) \times \left(\frac{U_m}{U_t} \right)^3 \times F_{(x)}} \right]$$

Where:

PEF_w = Soil Particulate Emission Factor for Wind-Blown Dust (m^3/kg)

Q/C_{wind} = Inverse of the Ratio of the Geometric Mean Air Concentration to the Emission Flux at the Center of a Square Source (g/m^2 -s per kg/m^3)

V = Fraction of Vegetative Cover (unitless)

U_m = Mean Annual Windspeed (m/s)

U_t = Equivalent Threshold Value of Windspeed at 7m (m/s)

$F_{(x)}$ = Function Dependent on U_m/U_t (unitless)

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SOIL - Subchronic Particulate Emission Factor-Vehicle Traffic (Construction Worker)

Subchronic Soil Particulate Emission Factor-Vehicle Traffic (construction worker only)

$$PEF_{sc} = Q/C_{sr} \times \frac{1}{F_D} \times \left[\frac{T \times A_R}{556 \times \left(\frac{W}{3}\right)^{0.4} \times \frac{\left(365 \left(\frac{d}{yr}\right) - p\right)}{365 \left(\frac{d}{yr}\right)} \times \Sigma VKT} \right]$$

Where:

PEF_{sc} = Subchronic Soil Particulate Emission Factor for Construction Traffic on an Unpaved Road (m^3/kg)

Q/C_{sr} = Inverse of the Ratio of the 1-h Geometric Mean Air Concentration to the Emission Flux Along a Straight Road Segment Bisecting a Square Site ($g/m^2 \cdot s$ per kg/m^3)

F_D = Dispersion Correction Factor (unitless)

T = Total Time Over Which Construction Occurs (s)

A_R = Surface Area of Contaminated Road Segment (m^2)

W = Mean Vehicle Weight (tons)

p = Number of Days with at Least 0.01 inches of Precipitation (days/year)

ΣVKT = Sum of Fleet Vehicle Kilometers Traveled During the Exposure Duration (km)

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SOIL - Protection Of Groundwater Risk-Based Target Level (Soil Migration to Groundwater)

Soil Migration to Groundwater

$$RBTL = C_w \times \left[K_d + \left(\frac{\theta_w + \theta_a \times H'}{\rho_b} \right) \right]$$

Soil Migration to Groundwater Supporting Equations

$$C_w = \text{Risk - Based Groundwater Concentration or MCL} \left(\frac{\mu\text{g}}{\text{L}} \right) \times 10^{-4} \left(\frac{\text{mg}}{\mu\text{g}} \right) \times DAF$$

$$K_d (\text{organics}) = K_{oc} \times f_{oc}; K_d (\text{inorganics}) = \text{default values}$$

$$\theta_a = n - \theta_w$$

$$n = 1 - \left(\frac{\rho_b}{\rho_s} \right)$$

Where:

Protection of Groundwater RBTL (mg/kg)

C_w = Target Soil Leachate Concentration (mg/L)

DAF = Dilution Attenuation Factor (unitless)

K_d = Soil-Water Partition Coefficient (cm^3/g)

K_{oc} = Soil Organic Carbon Partition Coefficient (cm^3/g)

f_{oc} = Fraction Organic Carbon in Soil (g/g)

θ_w = Water-Filled Soil Porosity ($L_{\text{water}}/L_{\text{soil}}$)

θ_a = Air-Filled Soil Porosity ($L_{\text{air}}/L_{\text{soil}}$)

ρ_b = Dry Soil Bulk Density (g/cm^3)

n = Total Soil Porosity ($L_{\text{pore}}/L_{\text{soil}}$)

ρ_s = Soil Particle Density (kg/L)

H' = Dimensionless Henry's Law Constant (unitless)

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SOIL Saturation Limit

Soil Saturation Limit

$$C_{sat} = \frac{S}{\rho_b} \times [(K_d \times \rho_b) + \theta_w + (H' \times \theta_a)]$$

C_{sat} Supporting Equations

K_d (organics) = $K_{oc} \times f_{oc}$; K_d (inorganics) = default values

$$\theta_a = n - \theta_w$$

$$n = 1 - \left(\frac{\rho_b}{\rho_s}\right)$$

Where:

C_{sat} = Soil Saturation Concentration (mg/kg)

S = Solubility in Water (mg/L_{water})

ρ_b = Dry Soil Bulk Density (kg/L)

K_d = Soil-Water Partition Coefficient (L/kg)

K_{oc} = Soil Organic Carbon Partition Coefficient (L/kg)

f_{oc} = Fraction Organic Carbon in Soil (g/g)

θ_w = Water-Filled Soil Porosity (L_{water}/L_{soil})

H' = Dimensionless Henry's Law Constant (unitless)

θ_a = Air-Filled Soil Porosity (L_{air}/L_{soil})

n = Total Soil Porosity (L_{pore}/L_{soil})

ρ_s = Soil Particle Density (kg/L)

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