

ATTACHMENT C

**STANDARDIZED EQUATIONS FOR CALCULATING THE
VCP REMEDIATION GOALS**

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STANDARDIZED EQUATIONS FOR CALCULATING THE VCP REMEDATION GOALS

The equations used to calculate the Nebraska Voluntary Cleanup Program (VCP) remediation goals (RG) for carcinogenic risks and noncarcinogenic effects are presented herein. Note: the VCP RG lookup tables also include pathway-specific VCP RGs if the user decides against combining specific exposure pathways or if the user wants to identify the relative contribution of each pathway to exposure.

To calculate VCP RGs for volatile contaminants in soil, a chemical-specific volatilization factor is calculated per the volatilization factor (VF_s) equation presented here. Because of its reliance on Henry's law, the VF_s model applies only when the contaminant concentration in soil is at or below saturation (i.e., no free-phase contaminant is present). Soil saturation ("sat") corresponds to the contaminant concentration in soil at which the adsorptive limits of the soil particles and the solubility limits of the available soil moisture have been reached. Above this point, pure liquid-phase contaminant is expected in the soil. If the VCP RG calculated using VF_s exceeds the calculated "sat," the VCP RG was set equal to "sat," in accordance with the "Soil Screening Guidance" (U.S. EPA 1996a, 1996b). The equation for deriving "sat" is presented in this attachment.

VCP RG Equations

All terms within the equations are defined in the text or in Table C-1 at the end of the attachment. Consistent with U.S. Environmental Protection Agency (U.S. EPA) guidance, there are separate equations for the various types of chemicals – those that are carcinogenic, noncarcinogenic, and mutagenic (with specific equations for vinyl chloride) – and the equations are grouped by media (U.S. EPA 2010). Those compounds that are mutagenic are noted in Table A-1. For mutagenic compounds, the exposure rates take into account age-specific susceptibility to mutagens through the use of an age dependent adjustment factor (ADAF). For the inhalation pathway, exposure durations were adjusted to account for mutagenic potential.

Soil Equations: For soils, equations were based on three exposure routes (incidental ingestion, dermal contact, and inhalation).

Residential Soils

Carcinogenic

Residential Soil Incidental Ingestion – Carcinogenic Risks

$$C_{res\ soil\ ingestion-ca} (mg / kg) = \frac{TR_r \times AT_c}{EF_r \times \left(\frac{IFS_{adj} \times SF_o}{1E + 06\ mg / kg} \right)}$$

where:

$$IFS_{adj} \left(\frac{mg - Year}{Kg - day} \right) = \left(\frac{ED_c \times IRS_c}{BW_c} \right) + \left(\frac{ED_r - ED_c \times IRS_a}{BW_a} \right)$$

Residential Dermal Exposure to Soil – Carcinogenic Risks

$$C_{res\ soil\ dermal-ca} (mg / kg) = \frac{TR_r \times AT_c}{EF_r \times \left(\frac{DCF_{adj} \times ABS_d \times [SF_o / ABS_{GI}]}{1E + 06\ mg / kg} \right)}$$

where:

$$DFS_{adj} \left(\frac{mg - Year}{Kg - day} \right) = \frac{ED_c \times SA_c \times AF_c}{BW_c} + \frac{ED_r - ED_c \times SA_a \times AF_a}{BW_a}$$

Residential Soil Inhalation– Carcinogenic Risks

$$C_{res\ soil\ inhalation-ca} (mg / kg) = \frac{TR_r \times AT_{c-inh}}{EF_r \times ED_a \left(\frac{1000\ \mu g / mg \times IUR}{VF_s} \right)}$$

or

$$C_{res\ soil\ inhalation-ca} (mg / kg) = \frac{TR_r \times AT_{c-inh}}{EF_r \times ED_a \left(\frac{1000\ \mu g / mg \times IUR}{PEF_s} \right)}$$

Note: VF_s values are calculated for volatile contaminants (defined as having a Henry's Law Constant greater than 1×10^{-5} atm-m³/mole and a molecular weight less than 200 grams/mole). Alternatively, a default PEF is used for non-volatile contaminants.

Combined Residential Soil Equation - Carcinogenic Risks

$$\frac{1}{\frac{1}{C_{res\ soil\ ingestion-ca}} + \frac{1}{C_{res\ soil\ dermal-ca}} + \frac{1}{C_{res\ soil\ inhalation-ca}}}$$

Note: The above reciprocal of the sum of the reciprocals of the pathway-specific VCP RGs was taken from the U.S. EPA Regional Screening Levels approach. Background documentation listing the equation is available on-line at http://www.epa.gov/reg3hwm/risk/human/rb-concentration_table/usersguide.htm

Noncancer

Residential Soil Incidental Ingestion – Noncarcinogenic Effects

$$C_{res\ soil\ ingestion-nc} (mg / kg) = \frac{THQ_r \times BW_c \times AT_n}{EF_r \times ED_c * \left(\frac{1}{RfD_o} \times \frac{IRS_c}{1E + 06\ mg / kg} \right)}$$

Residential Dermal Exposure to Soil – Noncarcinogenic Effects

$$C_{res\ soil\ dermal-nc} (mg / kg) = \frac{THQ_r \times BW_c \times AT_n}{EF_r \times ED_c \times \left(\frac{1}{[RfD_o \times ABS_{GI}]} \times \frac{SA_c \times AF_c \times ABS_d}{1E + 06\ mg / kg} \right)}$$

Residential Soil Inhalation– Noncarcinogenic Effects

$$C_{res\ soil\ inhalation-nc} (mg / kg) = \frac{THQ_r \times RfC \times AT_{n-inh}}{EF_r \times ED_a \times \left(\frac{1}{VF_s} \right)} \quad \text{or}$$

$$C_{res\ soil\ inhalation-nc} (mg / kg) = \frac{THQ_r \times RfC \times AT_{n-inh}}{EF_r \times ED_a \times \left(\frac{1}{PEF_s} \right)}$$

Note: VF_s values are calculated for volatile contaminants (defined as having a Henry's Law Constant greater than 1 x 10⁻⁵ atm-m³/mole and a molecular weight less than 200 grams/mole). Alternatively, a default PEF is used for non-volatile contaminants.

Combined Residential Soil Equation - Noncarcinogenic Effects

$$\frac{1}{\frac{1}{C_{res\ soil\ ingestion-nc}} + \frac{1}{C_{res\ soil\ dermal-nc}} + \frac{1}{C_{res\ soil\ inhalation-nc}}}$$

Note: The above reciprocal of the sum of the reciprocals of the pathway-specific VCP RGs was taken from the U.S. EPA Regional Screening Level approach. User Guide documentation listing the equation is available on-line at

http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

Mutagenic

Residential Soil Incidental Ingestion – Mutagenic Risks

$$C_{res\ soil\ ingestion-m} (mg / kg) = \frac{TR_r \times AT_c}{EF_r \times \left(\frac{IFS(M)_{adj} \times SF_o}{1E + 06\ mg / kg} \right)}$$

where:

$$IRS(M)_{adj} = \frac{ED_{0-2} \times IRS_{child} \times ADAF_{0-2}}{BW_{child}} + \frac{ED_{2-6} \times IRS_{child} \times ADAF_{2-6}}{BW_{child}} + \frac{ED_{6-16} \times IRS_{adult} \times ADAF_{6-16}}{BW_{adult}} + \frac{ED_{16-30} \times IRS_{adult} \times ADAF_{16-30}}{BW_{adult}}$$

Residential Dermal Exposure to Soil – Mutagenic Risks

$$C_{res\ soil\ dermal-m} (mg / kg) = \frac{TR_r \times AT_c}{EF_r \times \left(\frac{DCF(M)_{adj} \times ABS_d \times [SF_o / ABS_{GI}]}{1E + 06\ mg / kg} \right)}$$

where:

$$DFS(M)_{adj} = \frac{ED_{0-2} \times SA_{child} \times AF_{child} \times 10}{BW_{child}} + \frac{ED_{2-6} \times SA_{child} \times AF_{child} \times 3}{BW_{child}} + \frac{ED_{6-16} \times SA_{adult} \times AF_{adult} \times 3}{BW_{adult}} + \frac{ED_{16-30} \times SA_{adult} \times AF_{adult} \times 1}{BW_{adult}}$$

Residential Soil Inhalation– Mutagenic Risks

$$C_{res\ soil\ inhalation-m} (mg / kg) = \frac{TR_r \times AT_{c-inh}}{EF_r \times ET_r \times 1000\ \mu g / mg \times ((ED_{0-2} \times IUR \times 10) + (ED_{2-6} \times IUR \times 3) + (ED_{6-16} \times IUR \times 3) + (ED_{16-30} \times IUR \times 1)) \times \left(\frac{1}{V_{F_s}} + \frac{1}{PEF_w} \right)}$$

Combined Residential Soil Equation - Mutagenic Risks

$$\frac{1}{\frac{1}{C_{res\ soil\ ingestion-m}} + \frac{1}{C_{res\ soil\ dermal-m}} + \frac{1}{C_{res\ soil\ inhalation-m}}}$$

Note: The above reciprocal of the sum of the reciprocals of the pathway-specific VCP RGs was taken from the U.S. EPA Regional Screening Level approach. User Guide documentation listing the equation is available on-line at

http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

Vinyl Chloride

Residential Soil Incidental Ingestion – Vinyl Chloride Risks

$$C_{res\ soil\ ingestion-vc} (mg / kg) = \frac{TR_r}{\left(EF_r \times \left(\frac{IFS_{adj} \times SF_o}{1E + 06\ mg / kg} \right) \frac{1}{AT_r} \right) + \left(\frac{SF_o \times IRS_c}{BW_c} \right)}$$

Residential Dermal Exposure to Soil – Vinyl Chloride Risks

$$C_{res\ soil\ dermal-vc} (mg / kg) = \frac{TR_r}{\left(EF_r \times \left(\frac{DCF_{adj} \times ABS_d \times [SF_o / ABS_{Gl}]}{1E + 06\ mg / kg} \right) \frac{1}{AT_c} \right) + \left(\frac{[SF_o / ABS_{Gl}] \times SA_c \times AF_c \times ABS \times 1E - 06\ kg / mg}{BW_c} \right)}$$

Residential Soil Inhalation – Vinyl Chloride Risks

$$C_{res\ soil\ inhalation-vc} (mg / kg) = \frac{TR_r}{\left(EF_r \times ED_a \left(\frac{1000\ \mu g / mg \times IUR}{VF_s \times AT_{c-inh}} \right) \right) + \left(\frac{1000\ \mu g / mg \times IUR}{VF_s} \right)}$$

or

$$C_{res\ soil\ inhalation-vc} (mg / kg) = \frac{TR_r}{\left(EF_r \times ED_a \left(\frac{1000\ \mu g / mg \times IUR}{PEF_s \times AT_{c-inh}} \right) \right) + \left(\frac{1000\ \mu g / mg \times IUR}{PEF_s} \right)}$$

Combined Residential Soil Equation – Vinyl Chloride Effects

$$\frac{1}{C_{res\ soil\ ingestion-vc}} + \frac{1}{C_{res\ soil\ dermal-vc}} + \frac{1}{C_{res\ soil\ inhalation-vc}}$$

Note: The above reciprocal of the sum of the reciprocals of the pathway-specific VCP RGs was taken from the U.S. EPA Regional Screening Level approach. User Guide documentation listing the equation is available on-line at

http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

Industrial Soil

Carcinogenic

Industrial Soil Incidental Ingestion – Carcinogenic Risks

$$C_{ind\ soil\ ingestion-ca} (mg / kg) = \frac{TR_w \times BW_a \times AT_c}{EF_w \times ED_w \times \left(\frac{IRS_w \times SF_o}{1E + 06\ mg / kg} \right)}$$

Industrial Dermal Exposure to Soil – Carcinogenic Risks

$$C_{ind\ soil\ dermal-ca} (mg / kg) = \frac{TR_w \times BW_a \times AT_c}{EF_w \times ED_w \times \left(\frac{SA_{a-w} \times AF_{a-w} \times ABS_d \times SF_o / ABS_{GI}}{1E + 06\ mg / kg} \right)}$$

Industrial Soil Inhalation– Carcinogenic Risks

$$C_{ind\ soil\ inhalation-ca} (mg / kg) = \frac{TR_w \times AT_{c-inh}}{EF_w \times ED_w \times ET_w \times \left(\frac{1000\ \mu g / mg \times IUR}{VF_s} \right)}$$

or

$$C_{ind\ soil\ inhalation-ca} (mg / kg) = \frac{TR_w \times AT_{c-inh}}{EF_w \times ED_w \times ET_w \times \left(\frac{1000\ \mu g / mg \times IUR}{PEF_s} \right)}$$

Note: VF_s values are calculated for volatile contaminants (defined as having a Henry's Law Constant greater than 1×10^{-5} atm-m³/mole and a molecular weight less than 200 grams/mole). Alternatively, a default PEF is used for non-volatile contaminants.

Combined Industrial Soil Equation – Carcinogenic Risks

$$\frac{1}{C_{ind\ soil\ ingestion-ca}} + \frac{1}{C_{ind\ soil\ dermal-ca}} + \frac{1}{C_{ind\ soil\ inhalation-ca}}$$

Note: The above reciprocal of the sum of the reciprocals of the pathway-specific VCP RGs was taken from the U.S. EPA Regional Screening Level approach. User Guide documentation listing the equation is available on-line at

http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

Noncancer

Industrial Soil Incidental Ingestion – Noncarcinogenic Effects

$$C_{ind\ soil\ ingestion-nc} (mg / kg) = \frac{THQ_w \times BW_a \times AT_n}{EF_w \times ED_w \times \left(\frac{1}{RfD_o} \times \frac{IRS_w}{1E + 06\ mg / kg} \right)}$$

Industrial Dermal Exposure to Soil – Noncarcinogenic Effects

$$C_{ind\ soil\ dermal-nc} (mg / kg) = \frac{THQ_w \times BW_a \times AT_n}{EF_w \times ED_w \times \left(\frac{1}{[RfD_o \times ABS_{GI}]} \times \frac{SA_{a-w} \times AF_{a-w} \times ABS_d}{1E + 06\ mg / kg} \right)}$$

Industrial Soil Inhalation– Noncarcinogenic Effects

$$C_{ind\ soil\ ingestion-nc} (mg / kg) = \frac{THQ_w \times RfC \times AT_{n-inh}}{EF_w \times ED_w \times ET_w \times \left(\frac{1}{VF_s} \right)}$$

or

$$C_{ind\ soil\ ingestion-nc} (mg / kg) = \frac{THQ_w \times RfC \times AT_{n-inh}}{EF_w \times ED_w \times ET_w \times \left(\frac{1}{PEF_s} \right)}$$

Note: VF_s values are calculated for volatile contaminants (defined as having a Henry's Law Constant greater than 1×10^{-5} atm-m³/mole and a molecular weight less than 200 grams/mole). Alternatively, a default PEF is used for non-volatile contaminants.

Combined Industrial Soil Equation - Noncarcinogenic Effects

$$\frac{1}{C_{ind\ soil\ ingestion-nc}} + \frac{1}{C_{ind\ soil\ dermal-nc}} + \frac{1}{C_{ind\ soil\ inhalation-nc}}$$

Note: The above reciprocal of the sum of the reciprocals of the pathway-specific VCP RGs was taken from the U.S. EPA Regional Screening Level approach. User Guide documentation listing the equation is available on-line at

http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

Groundwater Equations: For groundwater, equations were based on two exposure routes (incidental ingestion and inhalation).

Carcinogenic

Groundwater Ingestion – Carcinogenic Risks

$$C_{\text{wat ingestion-ca}} (\mu\text{g} / \text{L}) = \frac{TR_r \times AT_c \times 1000 \mu\text{g} / \text{mg}}{EF_r \times IFW_{adj} \times SF_o}$$

where:

$$IFW_{adj} = \frac{ED_c \times IRW_c}{BW_c} + \frac{ED_r - ED_c \times IRW_a}{BW_a}$$

Groundwater Inhalation – Carcinogenic Risks

$$C_{\text{wat inhalation-ca}} (\mu\text{g} / \text{L}) = \frac{TR_r \times AT_c}{EF_r \times ED_a \times ET_a \times VF_w \times CF_i \times IUR}$$

Note: VF_w is used for volatile contaminants (defined as having a Henry's Law Constant greater than 1×10^{-5} atm-m³/mole and a molecular weight less than 200 grams/mole. No groundwater inhalation value is calculated for non-volatiles.

Combined Groundwater Equation – Carcinogenic Contaminants

$$\frac{1}{C_{\text{wat ingestion-ca}}} + \frac{1}{C_{\text{wat inhalation-ca}}}$$

Noncancer

Groundwater Ingestion – Noncarcinogenic Effects

$$C_{\text{wat ingestion-nc}} (\mu\text{g} / \text{L}) = \frac{THQ_r \times BW_a \times AT_{n-inh} \times 1000 \mu\text{g} / \text{mg}}{EF_r \times ED_a \times \left(\frac{IRW_a}{RfD_o} \right)}$$

Groundwater Inhalation – Noncarcinogenic Effects

$$C_{\text{wat inhalation-nc}} (\mu\text{g} / \text{L}) = \frac{THQ_r \times RfC \times AT_{n-inh} \times 1000 \mu\text{g} / \text{mg}}{EF_r \times ED_a \times ET_a \times VF_w}$$

Note: VF_w is used for volatile contaminants (defined as having a Henry's Law Constant greater than 1×10^{-5} atm-m³/mole and a molecular weight less than 200 grams/mole. No ground water inhalation value is calculated for non-volatiles.

Combined Groundwater Equation – Noncarcinogenic Contaminants

$$\frac{1}{\frac{1}{C_{\text{wat ingestion-nc}}} + \frac{1}{C_{\text{wat inhalation-nc}}}}$$

Note: The above reciprocal of the sum of the reciprocals of the pathway-specific VCP RGs was taken from the U.S. EPA Regional Screening Level approach. User Guide documentation listing the equation is available on-line at

http://www.epa.gov/reg3hwm/risk/human/rb-concentration_table/usersguide.htm

Mutagenic

Groundwater Ingestion – Mutagenic Risks

$$C_{\text{wat ingestion-ca}} (\mu\text{g} / \text{L}) = \frac{TR_r \times AT_c \times 1000 \mu\text{g} / \text{mg}}{EF_r \times IFW(M)_{\text{adj}} \times SF_o}$$

where:

$$IFW(M)_{\text{adj}} = \frac{ED_{0-2} \times IFW_{\text{child}} \times ADAF_{0-2}}{BW_{\text{child}}} + \frac{ED_{2-6} \times IFW_{\text{child}} \times ADAF_{2-6}}{BW_{\text{child}}} + \frac{ED_{6-16} \times IFW_{\text{adult}} \times ADAF_{6-16}}{BW_{\text{adult}}} + \frac{ED_{16-30} \times IFW_{\text{adult}} \times ADAF_{16-30}}{BW_{\text{adult}}}$$

Groundwater Inhalation – Mutagenic Risks

$$C_{\text{wat inhalation-ca}} (\mu\text{g} / \text{L}) = \frac{TR_r \times AT_c}{EF_r \times ED_a \times ET_a \times VF_w \times CF_i \times IUR}$$

Vinyl Chloride

Groundwater Ingestion – Vinyl Chloride Risks

$$C_{\text{wat ingestion-vc}} (\mu\text{g} / \text{L}) = \frac{TR_r \times 1000 \mu\text{g} / \text{mg}}{\left((EF_r \times IFW_{\text{adj}} \times SF_o) \frac{1}{AT_c} \right) + \left(\frac{SF_o \times IRW_c}{BW_c} \right)}$$

Groundwater Inhalation – Vinyl Chloride Risks

$$C_{\text{wat inhalation-vc}} (\mu\text{g} / \text{L}) = \frac{TR_r}{\left((EF_r \times ED_a \times ET_a \times VF_w \times CF_i \times IUR) \frac{1}{AT_{c-inh}} \right) + (IUR \times VF_w)}$$

Note: VF_w is used for volatile contaminants (defined as having a Henry's Law Constant greater than 1×10^{-5} atm-m³/mole and a molecular weight less than 200 grams/mole. No ground water inhalation value is calculated for non-volatiles.

Combined Groundwater Equation – Vinyl Chloride

$$\frac{1}{C_{wat\ ingestion-vc}} + \frac{1}{C_{wat\ inhalation-vc}}$$

SUPPORTING EQUATIONS

Soil-to-Air Volatilization Factor (VF_s)

Derivation of the Volatilization Factor

$$VF_s (m^3 / kg) = Q / C \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 1E-04 m^2 / cm^2$$

Where:

$$D_A (cm^2 / sec) = \frac{[(\theta_a^{10/3} \times D_i \times H' + \theta_w^{10/3} \times D_w) / n^2]}{\rho_b \times K_d + \theta_w + \theta_a \times H'}$$

Where:

Parameter	Definition	Units	Default Value
D _A	Apparent diffusivity	cm ² /sec	Chemical-specific (calculated)
D _i	Diffusivity in air	cm ² /sec	Chemical-specific
D _w	Diffusivity in water	cm ² /sec	Chemical-specific
f _{oc}	Fraction organic carbon in soil	g/g	0.006 (0.6%)
H	Henry's Law Constant	atm-m ³ /mole	Chemical-specific
H'	Dimensionless Henry's Law Constant, = H x 41	unitless	Chemical-specific (calculated)
K _d	Soil-water partition coefficient, = K _{oc} x f _{oc}	cm ³ /g	Chemical-specific (calculated for organics)
K _{oc}	Soil-organic carbon-water partition coefficient	cm ³ /g	Chemical-specific
n	Total soil porosity	(L _{pore} /L _{soil})	0.43 or 1-(ρ _b /ρ _s)
Q/C	Inverse of the mean contaminant conc. at the center of a 0.5-acre square source	g/m ² -sec/kg-m ³	81.64 (value for Lincoln, NE)
T	Exposure interval	sec	9.5E+08
VF _s	Volatilization factor	m ³ /kg	Chemical-specific (calculated)
θ _a	Air-filled soil porosity	(L _{air} /L _{soil})	0.28 or n-θ _w
θ _w	Water-filled soil porosity	(L _{water} /L _{soil})	0.15
ρ _b	Dry soil bulk density	g/cm ³	1.5
ρ _s	Soil particle density	g/cm ³	2.65

Soil-to-Air Particulate Emission Factor (PEF)

Derivation of the Particulate Emission Factor

$$PEF \text{ m}^3 / \text{kg} = Q / C \times \left(\frac{[3600 \text{ sec/hr}]}{[0.036 \times (1 - V) \times (U_m / U_t)^3 \times F(x)]} \right)$$

Where:

Parameter	Definition	Units	Default Value
F(x)	Function dependent on U_m/U_t derived using Cowherd and others (1985)	unitless	0.194
PEF	Particulate emission factor	m ³ /kg	1.2E+09 (calculated)
Q/C	Inverse of the mean contaminant conc. at the center of a 0.5-acre square source	g/m ² -sec/kg-m ³	81.64 (value for Lincoln, NE)
U_m	Mean annual windspeed	m/sec	4.69
U_t	Equivalent threshold value of windspeed at 7 m	m/sec	11.32
V	Fraction of vegetative cover	unitless	0.5

Soil Saturation Concentration (sat)

Derivation of the Soil Saturation Limit

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

Where:

Parameter	Definition	Units	Default Value
sat	Soil saturation concentration	mg/kg	Chemical-specific (calculated)
S	Solubility in water	mg/L-water	Chemical-specific
ρ_b	Dry soil bulk density	kg/L	1.5
n	Total soil porosity	$L_{\text{pore}}/L_{\text{soil}}$	0.43 or $1 - \rho_b/\rho_s$
ρ_s	Soil particle density	kg/L	2.65
K_d	Soil-water partition coefficient, = $K_{oc} \times f_{oc}$	L/kg	Chemical-specific (calculated for organics)
K_{oc}	Soil-organic carbon-water partition coefficient	L/kg	Chemical-specific
f_{oc}	Fraction organic carbon content of soil	g/g	0.006 (0.6%)
θ_w	Water-filled soil porosity	$L_{\text{water}}/L_{\text{soil}}$	0.15
θ_a	Air-filled soil porosity	$L_{\text{air}}/L_{\text{soil}}$	0.28 or $n - \theta_w$
w	Average soil moisture content	$\text{kg}_{\text{water}}/\text{kg}_{\text{soil}}$ or $L_{\text{water}}/\text{kg}_{\text{soil}}$	0.1
H	Henry's Law Constant	atm-m ³ /mole	Chemical-specific
H'	Dimensionless Henry's Law Constant, = H x 41	unitless	Chemical-specific (calculated)

Soil-to-Groundwater RG

Derivation of the Soil-to-Groundwater RG

$$RG(\text{mg} / \text{kg}) = C_w \times DAF \times \left[K_d + \frac{(\theta_w + \theta_a \times H')}{\rho_b} \right]$$

Where:

Parameter	Definition	Units	Default Value
C_w	Target soil leachate concentration	mg/L	Chemical-specific (MCL, or calculated groundwater combined value if no MCL available)
DAF	Dilution attenuation factor	unitless	20
f_{oc}	Fraction organic carbon content of soil	g/g	0.002 (0.2%)
H	Henry's Law Constant	atm-m ³ /mole	Chemical-specific
H'	Dimensionless Henry's Law Constant = H x 41	unitless	Chemical-specific (calculated)
K_d	Soil-organic carbon/water partition coefficient, = $K_{oc} \times f_{oc}$	L/kg	Chemical-specific (calculated for organics)
n	Total soil porosity	L_{pore}/L_{soil}	0.43 or $1 - \rho_b/\rho_s$
θ_a	Air-filled soil porosity	L_{air}/L_{soil}	0.13 or $n - \theta_w$
θ_w	Water-filled soil porosity	L_{water}/L_{soil}	0.3
ρ_b	Dry soil bulk density	kg/L	1.5
ρ_s	Soil particle density	kg/L	2.65

TABLE C-1

STANDARD DEFAULT FACTORS

Symbol	Definition	Units	Default Value	Reference
ABS _d	Dermal absorption factors	unitless	Chemical-specific	
	Semi-volatile organics	unitless	0.1	Dermal Assessment, U.S. EPA 2001a (U.S. EPA/540/R-99/005)
	Volatile organics	unitless	---	Dermal Assessment, U.S. EPA 2001a (U.S. EPA/540/R-99/005)
	Inorganics	unitless	---	Dermal Assessment, U.S. EPA 2001a (U.S. EPA/540/R-99/005)
AF _{a-r}	Adherence factor for soils, adult resident	mg/cm ²	0.07	Dermal Assessment, U.S. EPA 2001a (U.S. EPA/540/R-99/005)
AF _{a-w}	Adherence factor for soils, adult worker	mg/cm ²	0.2	Dermal Assessment, U.S. EPA 2001a (U.S. EPA/540/R-99/005)
AF _c	Adherence factor for soils, child	mg/cm ²	0.2	Dermal Assessment, U.S. EPA 2001a (U.S. EPA/540/R-99/005)
AT _c	Averaging time, carcinogens	days	25,550	RAGS (Part A), U.S. EPA 1989 (U.S. EPA/540/1-89/002)
AT _n	Averaging time, noncarcinogens	days	ED x 365	RAGS (Part A), U.S. EPA 1989 (U.S. EPA/540/1-89/002)
AT _{c-inh}	Averaging time, carcinogens	hours	25,550 x 24	RAGS (Part A), U.S. EPA 1989 (U.S. EPA/540/1-89/002)
AT _{n-inh}	Averaging time, noncarcinogens	hours	ED x 365 x 24	RAGS (Part A), U.S. EPA 1989 (U.S. EPA/540/1-89/002)
BW _a	Body weight, adult	kg	70	RAGS (Part A), U.S. EPA 1989 (U.S. EPA/540/1-89/002)
BW _c	Body weight, child	kg	15	Exposure Factors, U.S. EPA 1991b (OSWER No. 9285.6-03)
DCF _{adj}	Age-adjusted dermal factor	mg-year/kg-day	361 (calculated)	By analogy to RAGS (Part B)
DCF(M) _{adj}	Age-adjusted dermal factor	mg-year/kg-day	361 (calculated)	U.S. EPA 2005
ED _c	Exposure duration, child	years	6	Exposure Factors, U.S. EPA 1991b (OSWER No. 9285.6-03)
ED _a	Exposure duration, adult resident	years	30 ^a	Exposure Factors, U.S. EPA 1991b (OSWER No. 9285.6-03)
ED _w	Exposure duration, industrial	years	25	Exposure Factors, U.S. EPA 1991b (OSWER No. 9285.6-03)
EF _r	Exposure frequency, residential	days/year	350	Exposure Factors, U.S. EPA 1991b (OSWER No. 9285.6-03)
EF _w	Exposure frequency, industrial	days/year	250	Exposure Factors, U.S. EPA 1991b (OSWER No. 9285.6-03)
IFS _{adj}	Age-adjusted soil ingestion factor	mg-year/kg-day	114 (calculated)	RAGS (Part B), U.S. EPA 1991b (OSWER No. 9285.7-01B)
IFS(M) _{adj}	Age-adjusted soil ingestion factor - mutagenic	mg-year/kg-day	calculated	U.S. EPA 2005
IFW _{adj}	Age-adjusted water ingestion factor	L-year/kg-day	1.1 (calculated)	By analogy to RAGS (Part B)
IFW(M) _{adj}	Age-adjusted water ingestion factor - mutagenic	L-year/kg-day	calculated	U.S. EPA 2005
IRS _a	Soil ingestion rate, adult	mg/day	100	Exposure Factors, U.S. EPA 1991b (OSWER No. 9285.6-03)

TABLE C-1 (Continued)
STANDARD DEFAULT FACTORS

Symbol	Definition	Units	Default Value	Reference
IRS _c	Soil ingestion rate, child	mg/day	200	Exposure Factors, U.S. EPA 1991b (OSWER No. 9285.6-03)
IRS _w	Soil ingestion rate, industrial	mg/day	100	Soil Screening Guidance, U.S. EPA 2002b
IRW _a	Drinking water ingestion rate, adult	L/day	2	RAGS (Part A), U.S. EPA 1989 (U.S. EPA/540/1-89/002)
IRW _c	Drinking water ingestion rate, child	L/day	1	RAGS (Part A), U.S. EPA 1989 (U.S. EPA/540/1-89/002)
IUR	Inhalation unit risk factor	(μg/m ³) ⁻¹	Chemical-specific	IRIS, HEAST, or PPRTV ^b
PEF	Particulate emission factor	m ³ /kg	1.2E+09 (calculated)	Soil Screening Guidance, U.S. EPA 1996a; and 1996b
RfC	Inhalation reference concentration	mg/m ³	Chemical-specific	IRIS, HEAST, or PPRTV ^b
RfD _o	Reference dose, oral	mg/kg-day	Chemical-specific	IRIS, HEAST, or PPRTV ^b
SA _{a-r}	Exposed surface area for soil/dust, adult resident	cm ² /day	5,700	Dermal Assessment, U.S. EPA 2001a (U.S. EPA/540/R-99/005)
SA _{a-w}	Exposed surface area for soil/dust, adult worker	cm ² /day	3,300	Dermal Assessment, U.S. EPA 2001a (U.S. EPA/540/R-99/005)
SA _c	Exposed surface area for child in soil	cm ² /day	2,800	Dermal Assessment, U.S. EPA 2001a (U.S. EPA/540/R-99/005)
Sat	Soil saturation concentration	mg/kg	Chemical-specific (calculated)	Soil Screening Guidance, U.S. EPA 1996a; and 1996b
SF _o	Oral cancer slope factor	(mg/kg-day) ⁻¹	Chemical-specific	IRIS, HEAST, or PPRTV ^b
THQ _r	Target hazard quotient, residential	unitless	0.25	Nebraska Department of Environmental Quality
THQ _w	Target hazard quotient, industrial	unitless	1	Nebraska Department of Environmental Quality
TR _r	Target cancer risk, residential	unitless	1E-06	Nebraska Department of Environmental Quality
TR _w	Target cancer risk, industrial	unitless	1E-05	Nebraska Department of Environmental Quality
VF _s	Volatilization factor for soil	m ³ /kg	Chemical-specific (calculated)	Soil Screening Guidance, U.S. EPA 1996a; 1996b
VF _w	Volatilization factor for water	L/m ³	0.5	RAGS (Part B), U.S. EPA 1991a (Publication 9285.7-01B)

Footnotes:

- ^a Exposure duration for lifetime residents is assumed to be 30 years total. For carcinogens, exposures are combined for children (6 years) and adults (24 years).
- ^b IRIS – Integrated Risk Information System (U.S. EPA 2011), HEAST – Health Effects Assessment Tables (U.S. EPA 1997), and PPRTV Provisional Peer Reviewed Toxicity Values derived by U.S. EPA’s Superfund Health Risk Technical Support Center.

cm²/day square centimeters per day
kg kilogram
L/day liter per day
L/m³ liter per cubic meter
m³-year/kg-day cubic meter year per kilogram per day
m³/day cubic meter per day
m³/kg cubic meter per kilogram
mg/cm² milligram per cubic centimeter
mg/day milligram per day
mg/kg milligram per kilogram
mg/kg-day milligram per kilogram body weight per day
mg/m³ milligram per cubic meter
mg-year/kg-day milligram year per kilogram per day
μg/m³ microgram per cubic meter

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