USEPA Risk-Based Standards for Controlling Contaminated Sites – Soil Screening Levels (SSLs)

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Relevant United States Environmental Laws

- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) – Superfund

- Safe Drinking Water Act (SDWA)

CERCLA

- CERCLA, commonly known as Superfund, was enacted by Congress on December 11, 1980
- Enabled the revision of the National Contingency Plan (NCP).
- Amended by the Superfund Amendments and Reauthorization Act (SARA) on October 17, 1986.

CERCLA (cont'd)

- Created a tax on the chemical and petroleum industries.
- Provided Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment.

CERCLA (cont'd)

- Established prohibitions and requirements concerning closed and abandoned hazardous waste sites.
- Provided for liability of persons responsible for releases of hazardous waste at these sites.
- Established a trust fund to provide for cleanup when no responsible party could be identified.

CERCLA (cont'd)

- The law authorizes two kinds of response actions:
  - Short-term removals, where actions may be taken to address releases or threatened releases requiring prompt response.
  - Long-term remedial response actions, that permanently and significantly reduce the dangers associated with releases or threats of releases of hazardous substances that are serious, but not immediately life threatening.

SDWA

- Passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply.
- Amended in 1986 and 1996
- Requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and ground water wells.

SDWA (cont'd)

Authorizes EPA to set national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants that may be found in drinking water.

- Maximum Contaminant Level Goal (MCLG)
- Maximum Contaminant Level (MCL)

Soil Screening Levels (SSLs)

- SSLs are not national cleanup standards
- Level of contamination in soil above which there is concern enough to warrant site-specific study of risks.
- Levels above this would not automatically trigger remedial action, nor designate a site as "dirty.“
- Generally, where soil concentrations fall below this level, no further action or study would be required.

Soil Screening Level Guidance

- http://epa.gov/superfund/resources/soil/
- Soil Screening Guidance – June 1996
  - Fact Sheet
  - User's Guide
  - Technical Background Document
- Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites – December 2002

Role of SSLs

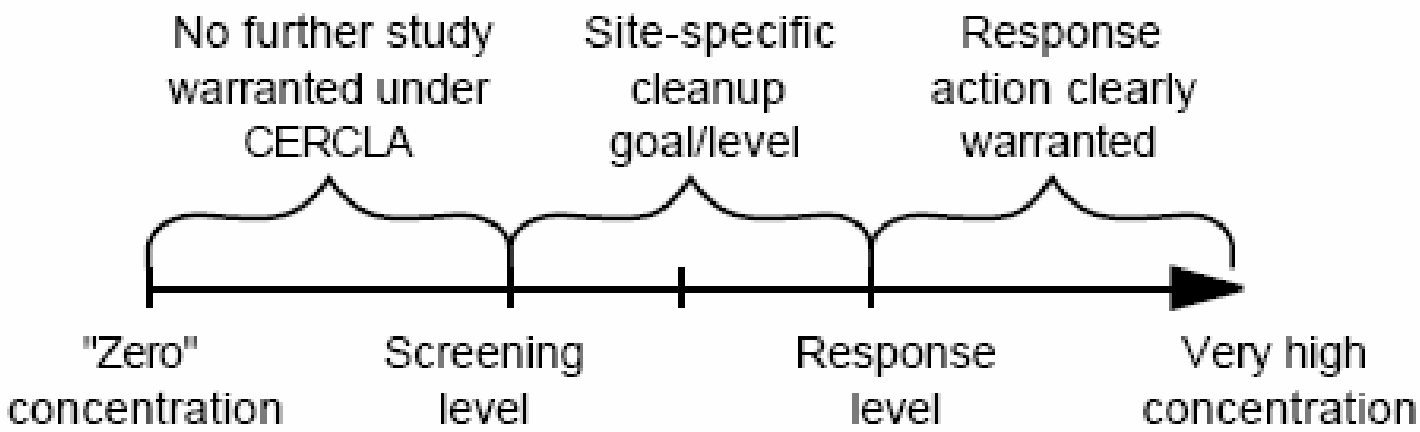

Exhibit 1. Conceptual Risk Management Spectrum for Contaminated Soil

Development of SSLs

- Risk-based concentrations derived from standardized equations combining exposure information assumptions with EPA toxicity data.
  - Generic SSLs
  - Simple site-specific SSLs
  - Site-specific SSLs based on more detailed modeling

Generic SSLs

- Generic SSLs for the most common contaminants found at National Priority List (NPL) sites have been developed.

- Based on a number of default assumptions chosen to be protective of human health for most site conditions.

General SSL Equation

$$\text{SSL (mg/kg)} = \frac{\text{Target Risk x Exposure}}{\text{Toxicity}}$$

Target Risk/Hazard Index

- Cancer
  - Target Risk = 10^{-6}
- Non-cancer
  - Hazard Index = 1

Exposure Scenarios

- Residential
  - On-site Resident
- Non-residential (Industrial/Commercial)
  - Outdoor Worker
  - Indoor Worker
- Construction
  - Construction Worker
  - Off-site Resident

Exposure Pathways

- Ingestion (surface and shallow subsurface soil)
- Dermal absorption (surface and shallow subsurface soil)
- Inhalation (fugitive dust, outdoor vapors)
- Inhalation (indoor vapors)
- Migration to ground water

Exhibit 1-2
SUMMARY OF DEFAULT EXPOSURE FACTORS FOR SIMPLE SITE-SPECIFIC SOIL SCREENING EVALUATIONS

Scenario[1]	Residential	Non-Residential (Commercial/Industrial)		Construction	
Receptor	**On-site Resident[2]**	**Outdoor Worker**	**Indoor Worker**	**Construction Worker**	**Off-site Resident**
Exposure Frequency (d/yr)	350	225	250	site-specific	site-specific
Exposure Duration (yr)	30 [6 (child)[4] for non-cancer effects]	25	25	site-specific	site-specific
Event Frequency (events/d)	**1**	1	NA	1	NA
Soil Ingestion Rate (mg/d)	200 (child) 100 (adult)	100	50	330	NA
Ground Water Ingestion Rate[3] (L/d)	2	2	2	NA	NA
Inhalation Rate (m^3/d)	20[5]	20	20	20	20
Surface Area Exposed (cm^2)	**2,800 (child) 5,700 (adult)**	3,300	NA	3,300	NA
Adherence Factor (mg/cm^2)	**0.2 (child) 0.07 (adult)**	0.2	NA	0.3	NA
Body Weight (kg)	15 (child) 70 (adult)	70	70	70	70
Lifetime (yr)	70	70	70	70	70

1 This exhibit presents information on simple site-specific soil screening evaluations for three exposure scenarios -- residential, commercial/industrial, and construction. Additional exposure scenarios (e.g., agricultural and recreational) may be appropriate for certain sites. Given the lack of generic information available for these scenarios, site managers will typically need to use detailed site-specific modeling to develop SSLs for them.

2 Items in bold represent changes to the residential soil screening exposure scenario presented in the 1996 *SSG*.

3 SSLs for the migration to ground water pathway are based on acceptable ground water concentrations, which are, in order of preference: a non-zero Maximum Contaminant Level Goal (MCLG), a Maximum Contaminant Level (MCL), or a health-based level (HBL) based on a 1×10^{-6} incremental lifetime cancer risk or a hazard quotient of one due to ingestion of contaminated ground water. When an HBL is used, it is based on these ground water ingestion rate values.

4 A child is defined as an individual between one and six years of age.

5 We evaluate residential inhalation exposure to children and adults using the RfC toxicity criterion, which is based on an inhalation rate of 20 m^3/day. No comparable toxicity criterion specific to childhood exposures is currently available. EPA has convened a workgroup to identify suitable default values for modeling childhood inhalation exposures, as well as possible approaches for adjusting toxicity values for application to such exposures.

Toxicity

- EPA Integrated Risk Information System (IRIS) http://www.epa.gov/iris
- EPA Provisional Peer Reviewed Toxicity Values (PPRTVs)
- Other peer-reviewed sources such as:
  - California Environmental Protection Agency (Cal EPA) toxicity values http://www.oehha.ca.gov/risk/chemicalDB/index.asp
  - The Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs) http://www.atsdr.cdc.gov/mrls.html

Equation B-1
Screening Level Equation for Combined Ingestion and Dermal Absorption Exposure to Carcinogenic Contaminants in Soil - Residential Scenario

$$\text{Screening Level (mg/kg)} = \frac{TR \times AT \times 365\,d/yr}{(EF \times 10^{-6}\,kg/mg)[(SF_o \times IF_{soil/adj}) + (SF_{ABS} \times SFS \times ABS_d \times EV)]}$$

Parameter/Definition (units)	Default
TR/target cancer risk (unitless)	10^{-6}
AT/averaging time (years)	70
EF/exposure frequency (days/year)	350
SF_{ABS}/dermally adjusted cancer slope factor $(mg/kg\text{-}d)^{-1}$	chemical-specific (Equation B-3)
SFS/age-adjusted dermal factor (mg-yr/kg-event)	**360 (Equation B-5)**
ABS_d/dermal absorption fraction (unitless)	chemical-specific (Appendix C)
EV/event frequency (events/day)	1
SF_o/oral cancer slope factor $(mg/kg\text{-}d)^{-1}$	chemical-specific (Appendix C)
$IF_{soil/adj}$/age-adjusted soil ingestion factor (mg-yr/kg-d)	114[a]

[a] Calculated per *RAGS, Part B,* Equation 3.

Equation B-2
Screening Level Equation for Combined Ingestion and Dermal Absorption Exposure to Non-Carcinogenic Contaminants in Soil - Residential Scenario

$$\text{Screening Level (mg/kg)} = \frac{THQ \times BW \times AT \times 365\,d/yr}{(EF \times ED \times 10^{-6}\,kg/mg)\left[\left(\frac{1}{RfD_o} \times IR\right) + \left(\frac{1}{RfD_{ABS}} \times AF \times ABS_d \times EV \times SA\right)\right]}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
BW/body weight (kg)	15
AT/averaging time (years)	6[a]
EF/exposure frequency (days/year)	350
ED/exposure duration (years)	6
RfD_o/oral reference dose (mg/kg-d)	chemical-specific (Appendix C)
IR/soil ingestion rate (mg/d)	200
RfD_{ABS}/dermally-adjusted reference dose (mg/kg-d)	chemical-specific (Equation B-4)
AF/skin-soil adherence factor (mg/cm²-event)	**0.2**
ABS_d/dermal absorption factor (unitless)	chemical-specific (Appendix C)
EV/event frequency (events/day)	1
SA/skin surface area exposed-child (cm²)	**2,800**

[a] For non-carcinogens, averaging time equals to exposure duration.

Equation B-6
Screening Level Equation for Inhalation of Carcinogenic Fugitive Dusts - Residential Scenario

$$\text{Screening Level (mg/kg)} = \frac{TR \times AT \times 365\,d/yr}{URF \times 1{,}000\,\mu g/mg \times EF \times ED \times \frac{1}{PEF}}$$

Parameter/Definition (units)	Default
TR/target cancer risk (unitless)	10^{-6}
AT/averaging time (yr)	70
URF/inhalation unit risk factor $(\mu g/m^3)^{-1}$	chemical-specific (Appendix C)
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
PEF/particulate emission factor (m^3/kg)	**1.36×10^9 (Equation B-8)**

Equation B-7
Screening Level Equation for Inhalation of Non-carcinogenic Fugitive Dusts - Residential Scenario

$$\text{Screening Level (mg/kg)} = \frac{THQ \times AT \times 365 d/yr}{EF \times ED \times \left[\frac{1}{RfC} \times \frac{1}{PEF}\right]}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
AT/averaging time (yr)	30[a]
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
RfC/inhalation reference concentration (mg/m^3)	chemical-specific (Appendix C)
PEF/particulate emission factor (m^3/kg)	**1.36×10^9 (Equation B-8)**

[a] For non-carcinogens, averaging time equals exposure duration.

Equation B-9
Screening Level Equation for Inhalation of Carcinogenic Volatile Contaminants in Soil - Residential Scenario

$$\text{Screening Level (mg/kg)} = \frac{TR \times AT \times 365 d/yr}{URF \times 1{,}000 \mu g/mg \times EF \times ED \times \frac{1}{VF}}$$

Parameter/Definition (units)	Default
TR/target cancer risk (unitless)	10^{-6}
AT/averaging time (yr)	70
URF/inhalation unit risk factor $(\mu g/m^3)^{-1}$	chemical-specific (Appendix C)
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
VF/soil-to-air volatilization factor (m^3/kg)	**chemical-specific (Equation B-11)**

Equation B-10
Screening Level Equation for Inhalation of Non-carcinogenic Volatile Contaminants in Soil - Residential Scenario

$$\text{Screening Level (mg/kg)} = \frac{THQ \times AT \times 365 d/yr}{EF \times ED \times \left[\frac{1}{RfC} \times \frac{1}{VF}\right]}$$

Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
AT/averaging time (yr) Outdoor Worker	30[a]
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
RfC/inhalation reference concentration (mg/m^3)	chemical-specific (Appendix C)
VF/soil-to-air volatilization factor (m^3/kg)	chemical-specific (Equation B-11)

[a] For non-carcinogens, averaging time equals exposure duration.

Inhalation of Indoor Vapors

OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance) – November 2002

http://www.epa.gov/correctiveaction/eis/vapor.htm

Migration to Ground Water

- SSLs for the migration to ground water pathway are based on acceptable ground water concentrations, which are, in order of preference:
  - non-zero MCLG
  - MCL
  - Health-based level (HBL) based on a $1x10^{-6}$ incremental lifetime cancer risk or a hazard quotient of one due to ingestion of contaminated ground water.

Maximum Contaminant Level Goal (MCLG)

- The level of a contaminant in drinking water below which there is no known or expected health risk.
- These goals are not enforceable levels because they do not take available technology into consideration, and therefore are sometimes set at levels which public water systems cannot meet.

Maximum Contaminant Level (MCL)

- The maximum amount of a contaminant allowed in water delivered to a user of any public water system.
- MCLs are set as close to MCLGs as feasible, considering available technology and cost.
- Enforceable standard

Migration to Ground Water (cont'd)

- Four-Tiered approach
  - Tier 1: based on partitioning model incorporating national default parameters which can be modified by a dilution – attenuation factor (DAF).
  - Tier 2: substitutes site-specific values of organic carbon, soil porosity, fraction water content, and soil bulk density.

Migration to Ground Water (cont'd)

- Four-Tiered approach (cont'd)
  - Tier 3: site-specific application of a leach test (SPLP) with a DAF
  - Tier 4: uses an appropriate fate and transport model for the site. In this case, the site-specific groundwater modeling eliminates the need for DAFs.

Equation B-13
Soil Screening Level Partitioning Equation for Migration to Ground Water

$$\text{Screening Level in Soil (mg/kg)} = C_w \left[K_D + \frac{(\theta_w + \theta_a H')}{\rho_b} \right]$$

Parameter/Definition (units)	Default
C_w/target soil leachate concentration (mg/L)	(nonzero MCLG, MCL, or HBL)[a] × dilution factor
K_d/soil-water partition coefficient (L/kg)	organics = $K_{oc} \times f_{oc}$ inorganics = see Appendix C[b]
K_{oc}/soil organic carbon/water partition coefficient (L/kg)	chemical-specific[c]
f_{oc}/fraction organic carbon in soil (g/g)	**0.002 (0.2%)**
θ_w/water-filled soil porosity (L_{water}/L_{soil})	**0.3**
θ_a/air-filled soil porosity (L_{air}/L_{soil})	$n - \theta_w$
ρ_b/dry soil bulk density (kg/L)	**1.5**
n/soil porosity (L_{pore}/L_{soil})	$1 - (\rho_b/\rho_s)$
ρ_s/soil particle density (kg/L)	2.65
H′/dimensionless Henry's law constant	chemical-specific[c] (assume to be zero for inorganic contaminants except mercury)

[a] Chemical-specific (see Appendix C).
[b] Assume a pH of 6.8 when selecting default K_d values for metals.
[c] See Appendix C.

SSL Resources

- Appendices in Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites

- SSL Calculator:

  http://rais.ornl.gov/calc_start.shtml

Preliminary Remediation Goals (PRGs)

- SSLs can be used as PRGs (“draft” cleanup levels) provided appropriate conditions are met (i.e., conditions found at a specific site are similar to conditions assumed in developing the SSLs).
- PRGs may then be used as the basis for developing final cleanup levels based on the nine-criteria analysis described in the NCP.

Role of the Baseline Risk Assessment in Superfund

- http://www.epa.gov/oswer/riskassessment/baseline.htm
- Discusses modification of PRGs to generate cleanup levels.
- Remphasizes $1x10^{-6}$ to $1x10^{-4}$ as the target risk range for risk management decisions.

EPA CERCLA Background Policy

- http://www.epa.gov/oswer/riskassessment/pdf/role.pdf
- Generally, under CERCLA, cleanup levels are not set at concentrations below natural background or below anthropogenic background concentrations.
- The reasons for this approach include:
  - cost-effectiveness
  - technical practicability
  - potential for recontamination

Case Study - Arsenic

Generic SSL for Arsenic in a residential scenario:

- Ingestion-Dermal : 0.4 mg/kg
- Inhalation of Fugitive Particulates : 770 mg/kg
- Migration to Ground Water
  - DAF = 20 : 6 mg/kg
  - DAF = 1 : 0.3 mg/kg

Case Study - Arsenic

- Target risk 10^{-6} = 0.4 kg/mg
- Target risk 10^{-5} = 4 kg/mg
- Target risk 10^{-4} = 40 kg/mg

- Relative bioavailability = 50%

- Site background 20 mg/kg arsenic

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