

**Addendum
to
Final Study Area Screening
Evaluation Report
for
CED Drum Storage Area**

**Risk Screening Level Evaluation -
Commercial Scenario**

**Naval Construction Battalion Center
Davisville, Rhode Island**



**Northern Division
Naval Facilities Engineering Command
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**ADDENDUM
TO
FINAL STUDY AREA SCREENING
EVALUATION REPORT
FOR
CED DRUM STORAGE AREA
RISK SCREENING LEVEL EVALUATION -
COMMERCIAL SCENARIO**

**NAVAL CONSTRUCTION BATTALION CENTER
DAVISVILLE, RHODE ISLAND**

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1.0 INTRODUCTION

This document is an Addendum to the Final Study Area Screening Evaluation (SASE) Report for the Construction Engineering Department (CED) Drum Storage Area at NCBC - Davisville, dated September 1994. The Addendum presents a Risk Screening Evaluation of the CED Drum Storage Area for the planned commercial reuse of the site. Site risks identified in the residential scenario risk screening evaluation are further evaluated in this document.

This document provides a screening level evaluation for soils at the CED Drum Storage Area to assess potential impacts on human receptors. The screening levels are benchmark concentrations which can be used to identify specific chemicals or pathways of concern which may or may not warrant further investigation. The discussion is based on qualitative comparison of detected concentrations to calculated screening levels.

The screening levels are calculated in accordance with available agency-wide and regional-specific risk assessment guidance documents including the following:

- Soil Screening Guidance (USEPA, December 1994).
- Risk Assessment Guidance for Superfund, Volume I, Parts A and B (December 1989 and December 1991).
- Risk Assessment Guidance for Superfund, Volume I, Supplemental Guidance (March 25, 1991).
- Risk Update Number 2 (USEPA Region I, August 1994).

Additional reference materials are used on an as-needed basis and are identified throughout the text.

Screening levels are calculated for soil only, as potential exposure routes for other site media are incomplete. Groundwater at the site is not currently used, and the State classification for this medium at the site ("GB") identifies water quality to be impacted by contamination of an unspecified nature. There are no permanent surface water features at the site and sediments were only able to be collected in catch basins at the site; therefore, human exposure to this medium is considered incomplete.

The soil screening levels are calculated to be consistent with current and potential future land use and consider relevant soil exposure routes. Current use of the facility and planned future zoning of the site as industrial identify industrial/commercial land use exposures to be appropriate for developing the soil screening levels. For conservatism, USEPA Region I high-end exposure inputs for noncontact occupational exposures are used in the screening level calculations.

This report is structured to provide an orderly and detailed presentation of the Technical Approach and Methodology (Section 2.0) used in the calculation of the soil screening levels and risk evaluations for the soil (Section 3.0), groundwater (Section 4.0), and air (Section 5.0) exposure pathways. Section 6.0 presents a summary of the risk evaluation process.

2.0 TECHNICAL APPROACH AND METHODOLOGY

This section of the risk evaluation identifies the approach and methods used in the screening process. Subsections provide a discussion of the current and proposed site usage, the conceptual site model upon which the evaluation is based, and details regarding the development and calculation of the soil screening levels.

2.1 SITE CONDITIONS AND CONCEPTUAL SITE MODEL

The CED Drum Storage Area reportedly operated as a drum storage yard for a period of approximately six years. Storage of drums ceased in 1974. Drums containing waste petroleum products and solvents were stored in an open, grassy yard. No secondary containment structures were in place. The area is currently undeveloped. The nearest identified well is hydraulically upgradient at the site and located approximately 2,000 feet to the northwest of the site.

At the present time, the CED Drum Storage Area is inactive and NCBC-Davisville is in the process of closure. At the completion of closure of NCBC-Davisville, the facility is intended to be used by private interests and local and state agencies as a commercial/industrial complex. Most of the current facilities will be retained and the proposed zoning for the site is industrial land use. Provisions which restrict the site land use to industrial zoning in perpetuity are currently being developed by regional planners in North Kingstown, where the site is located.

Site groundwater has been assigned a "GB" classification, which identifies it as a groundwater source of marginal quality and limited potential for development as a source of drinking water. For "GB" classified groundwaters, the State of Rhode Island water quality standards do not apply, unless there exists a present or future need to upgrade classification to "GA" (General Laws, Rhode Island, 46-13.1-4). Anticipated future land use of the site for commercial/industrial use precludes use of the groundwater as a domestic water source. The nearest identified well to the site is located approximately 2,000 feet to the northeast of the site and is identified as being hydraulically upgradient.

Based on anticipated land use, a conceptual site model can be developed. The single, relevant exposure scenario is industrial/commercial land use. The groundwater at the site is currently used for potable purposes and is not expected to be developed for such purposes. No seasonal or permanent surface water bodies exist in the immediate vicinity of the site. Consequently, soil is the only medium of concern

at the site. Associated direct contact exposure routes include ingestion and inhalation of fugitive dusts and volatiles emitted from the soil.

The lack of permanent surface water features at the site reduces the potential significance of any impact to ecological receptors that the site may have. The area in the general vicinity of the site is characteristically flat and is well vegetated, with grasses covering the entire site except the paved areas. These surface characteristics at the site result in low migration potential (i.e., erosion) for surface materials and any chemicals which may be associated. However, sediments were collected in a drainage ditch at the site and are used to characterize potential impacts to downstream receptors.

2.2 SOIL SCREENING LEVEL DEVELOPMENT

Soil screening levels are calculated for protection of human health. Human health protection is ensured for each of the evaluated exposure pathways by selecting the minimum noncarcinogenic or carcinogenic screening concentration which is calculated for detected chemicals. Sample calculations and screening level spreadsheet calculations are presented in the Appendix to this addendum.

For noncarcinogenic health effects, a target hazard quotient of one (1.0) is used to assess potential for occurrence of adverse health effects. A limitation in this approach is that potential cumulative impacts of multiple chemicals with the identical toxic endpoints are not accounted for. To compensate for this limitation, potentially cumulative contributions of individual chemicals to a hypothetical, single target organ are evaluated. Discussion of this procedure is provided in the following subsection.

For carcinogens, a target incremental cancer risk of 10^{-6} is used as the benchmark. The basis for this risk level is the lower end of the 10^{-6} to 10^{-4} "acceptable" risk range presented in the National Contingency Plan (NCP). The 10^{-6} cancer risk level is identified as the point of departure and is considered by the USEPA to be conservative and appropriate for use in a developing screening level concentrations for individual carcinogens. The cumulative effect of carcinogens typically encountered at Superfund sites at the individual 10^{-6} risk level is not likely to exceed the 10^{-4} upper risk range goal commonly used by the USEPA in CERCLA activities.

The procedure for developing industrial soil screening levels is identical to that for developing residential screening levels, however, industrial land use exposure input parameters are used, consistent with the conceptual site model. Discussion of development of screening levels is presented on a pathway-specific basis.

2.2.1 Soil Ingestion Pathway

As discussed in the USEPA reference document "Soil Screening Guidance" (USEPA, December 1994), generic screening levels are used for this exposure pathway because full-scale site-specific methods are too complex and generally impractical for use in a screening level evaluation. The generic method has been conservatively weighted using high-end exposure parameters, as available, so as to not underestimate potential toxic chemical effects.

The soil ingestion pathway screening concentration for noncarcinogens is calculated using the following equation:

$$SL = \frac{THQ \times BW \times AT \times 365 \text{ days/yr}}{\frac{1}{RfD_o} \times 10^{-6} \text{ mg/Kg} \times EF \times ED \times IR}$$

Where:	SL	= Soil screening level (mg/Kg)
	THQ	= Target hazard quotient (unitless)
	BW	= Receptor body weight (Kg)
	AT	= Averaging time (yr)
	RfD _o	= Oral reference dose (mg/Kg-day)
	EF	= Exposure frequency (days/yr)
	ED	= Exposure duration (yr)
	IR	= Ingestion rate (mg/day)
	365, 10 ⁻⁶	= Conversion factors

Similarly, the soil ingestion pathway screening concentration for carcinogens is calculated using the following equation:

$$SL = \frac{TR \times BW \times AT \times 365 \text{ days/yr}}{CSF_o \times 10^{-6} \text{ mg/Kg} \times EF \times ED \times IR}$$

Where:	SL	= Soil screening level (mg/Kg)
	TR	= Target hazard quotient (unitless)
	BW	= Receptor body weight (Kg)
	AT	= Averaging time (yr)

CSF _o	=	Oral reference dose (mg/Kg-day)
EF	=	Exposure frequency (days/yr)
ED	=	Exposure duration (yr)
IR	=	Ingestion rate (mg/day)
365, 10 ⁻⁶	=	Conversion factors

A summary of the input parameters used in the calculation of soil pathway screening levels is included in Table 2-1.

2.2.2 Inhalation Pathway

Calculation of soil screening levels for the inhalation exposure pathway involve a somewhat more complex approach when compared to the generic development of soil ingestion pathway screening levels. Site- and chemical-specific data are used to estimate particulate and volatile emission rates from site soils.

Chemical specific volatilization factors (VFs) consider soil moisture, bulk density, organic carbon content, and particle density, and chemical-specific transport properties to estimate volatilization potential. Based on the observed maximum concentrations detected at the site, saturated conditions do not exist in the soil for any of the detected chemicals. Calculation of the volatilization factor is a two-step process: 1) calculate the α (alpha) term, and then 2) calculate the volatilization factor as follows:

1) the α term

$$\alpha = \frac{D_{ei} \times \theta_a}{\theta_a + \frac{\beta (1 - \theta_a)}{K_{as}}} , D_{ei} = D_i \left(\frac{\theta_a^{3.33}}{\theta_t^2} \right) , K_{as} = \frac{H \times 41}{K_{oc} \times f_{oc}}$$

Where:	D _i	=	Chemical diffusivity in air (cm ² /sec)
	θ_a	=	Air-filled porosity (fraction)
	θ_t	=	Total porosity (fraction)
	β	=	Soil dry bulk density (gm/cm ³)
	H	=	Chemical Henry's Law constant (atm-m ³ /mol)
	K _{oc}	=	Chemical organic carbon partition coefficient (L/Kg)
	f _{oc}	=	Soil fraction organic carbon
	41	=	Conversion factor

2) the volatilization factor (VF)

$$VF = \left(\frac{Q}{C} \right) \times \frac{(3.14 \times \alpha \times T)^{0.5}}{(2 \times D_{ei} \times \theta_a \times K_{as})} \times \left(\frac{10^{-4} m^2}{cm^2} \right)$$

Where:

Q/C	=	Inverse of the mean concentration at the center of a 30-acre square source (g/m ² -sec per Kg/m ³)
α	=	Alpha term
T	=	Exposure duration (seconds)
3.14	=	Pi (constant)
2	=	Constant
10 ⁻⁴	=	Conversion factor

The site-specific particulate emission factor (PEF) provides an estimate of the mass of fugitive dusts generated at a site per unit volume air in the breathing zone. The PEF primarily considers meteorologic conditions (mean windspeed, etc.) and soil particle size distribution to determine atmospheric erosion potential. Empirical relationships developed by Cowherd, et al. (1985) are used to define some of the variables in the PEF estimation equation. This calculation is as follows:

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

Where:

Q/C	=	Inverse of the mean concentration at the center of a 30-acre square source (g/m ² -sec per Kg/m ³)
3600, 0.036	=	Conversion factors
V	=	Fraction vegetative cover
U_m	=	Mean annual windspeed (m/sec)
U_t	=	Threshold erosional windspeed measured at a height of 7 m (m/sec)
F(x)	=	Function presented in Cowherd (1985)
x	=	Function dependent on U_m and U_t and presented in Cowherd (1985)

After calculation of the VF and PEF, screening levels can be determined. The inhalation pathway screening concentration for noncarcinogens and carcinogens are calculated using the following equations:

$$SL = \frac{THQ \times AT \times 365 \text{ days/yr}}{\frac{1}{RfC} \times EF \times ED \times \left[\frac{1}{VF} + \frac{1}{PEF} \right]}$$

Where:

SL	=	Soil screening level (mg/Kg)
THQ	=	Target hazard quotient (unitless)
AT	=	Averaging time (yr)
RfC	=	Inhalation reference concentration (mg/m ³)

EF = Exposure frequency (days/yr)
 ED = Exposure duration (yr)
 VF = Volatilization factor (m³/Kg)
 PEF = Particulate emission factor (m³/Kg)
 365, 1000 = Conversion factors

and,

$$SL = \frac{TR \times AT \times 365 \text{ days/yr}}{URF \times 1000 \text{ } \mu\text{g/mg} \times EF \times ED \times \left[\frac{1}{VF} + \frac{1}{PEF} \right]}$$

Where: SL = Soil screening level (mg/Kg)
 TR = Target risk (unitless)
 AT = Averaging time (yr)
 URF = Inhalation unit risk factor ($\mu\text{g}/\text{m}^3$)⁻¹
 EF = Exposure frequency (days/yr)
 ED = Exposure duration (yr)
 VF = Volatilization factor (m³/Kg)
 PEF = Particulate emission factor (m³/Kg)
 365, 1000 = Conversion factors

A summary of the input parameters used in the calculation of soil pathway screening levels is included in Table 2-1.

2.3 SCREENING LEVEL RISK EVALUATION

As identified in the preceding Section 2.2, the screening levels are calculated for individual chemicals which provide specific risks under specific exposure scenarios. The risk evaluation for site-specific data is performed using a two-tier approach.

Primary consideration of maximum detected concentrations of chemicals as they compare to the screening levels provides a means of identifying any one chemical which may pose immediate and significant risks. This direct comparison is an initial screening.

A secondary evaluation is also performed to quantify risks associated with multiple chemical exposure and the contributions that several chemicals may have on a common toxic endpoint. Both noncancer (systemic) and cancerous effects are considered.

TABLE 2-1
SUMMARY OF SCREENING LEVEL CALCULATION INPUTS
INDUSTRIAL LAND USE RECEPTOR
CED DRUM STORAGE AREA, NCBC DAVISVILLE, RHODE ISLAND

Parameter	Value	Rationale/Source
Receptor Exposure Inputs - Ingestion/Inhalation Pathways		
Target hazard quotient (THQ)	1.0	USEPA, December 1994
Target cancer risk (TR)	10^{-6}	USEPA, December 1994
Body weight (BW)	70 Kg	USEPA, March 25, 1991
Averaging time (AT)	ED - noncarcinogens 70 yrs - carcinogens	USEPA, December 1989
Exposure frequency (EF)	150 days/yr	USEPA Region I high end occupational exposure, August 1994
Exposure duration (ED)	25 yrs	USEPA, March 25, 1991
Ingestion rate (IR)	100 mg/day	USEPA Region I high end occupational exposure, August 1994
Site-specific Soil/Meteorologic Data		
Soil air-filled porosity (θ_a)	0.284	Calculated value
Soil total porosity (θ_t)	0.434	Calculated value
Soil dry bulk density (β)	1.50 gm/cm ³	Estimated value
Fraction organic carbon in soil (f_{oc})	0.006 (i.e., 0.6%)	Average from analytical data
Soil moisture content	9.5%	Average from analytical data
Fraction vegetative cover (V)	0.50 (i.e., 50%)	Conservative estimate
Mean annual windspeed (U_m)	5 m/sec	Estimate based on NE United States coastal city meteorological data
Threshold frictional windspeed measured at a height of 7 m (U_t)	6.44 m/sec	Calculated from Cowherd (1985), based on 0.25 mm mode particle size
Particulate emission factor (PEF)	1.39×10^7 m ³ /Kg	Calculated from Cowherd (1985)
Inverse of the mean concentration at the center of a 30-acre square source (Q/C)	35.1 gm/m ² -sec per m ³ /Kg (for VF) 46.84 gm/m ² -sec per m ³ /Kg (for PEF)	USEPA, December 1994

Noncarcinogenic screening levels are based on an established hazard quotient of one (1.0), which corresponds to a concentration at which adverse systemic effects are possible. Two or more chemicals, which may not individually effect a target organ, can result in additive adverse effects. To compensate for this limitation, noncancer risk fractions (equal to the ratio of the maximum reported concentration to the noncarcinogenic screening level) are calculated for chemicals with maximum concentrations which are comparable to the screening level (greater than 1 percent). The cumulative effects are determined by summing individual risk scores and comparing the result to a value of unity. If the total score is greater than one, adverse effects are possible, and evaluation of chemical-specific target organs is warranted. If the total score is less than one, occurrence of adverse systemic effects is not likely, and the noncancer evaluation is complete.

A similar approach is used for evaluating carcinogens. Cumulative effects are determined by adding risk scores, but the screening level is based on an incremental cancer risk of 10^{-9} . The total cancer risk score is roughly equivalent to cancer incidence per one million receptors, or can be alternately used as an incremental cancer risk (number $\times 10^{-9}$). The risk estimate is overly conservative, as not all carcinogens affect the same target organ. The use of maximum concentrations and high end exposure scenario inputs in the risk assessment calculation result in a "worst-case" exposure.

3.0 SOIL EXPOSURE PATHWAY RISK EVALUATION

The soil exposure risk evaluation is based on direct contact exposure (ingestion) to chemicals detected in surface and subsurface soil at the CED Drum Storage Area. The screening is based on comparison of the calculated screening concentrations for detected chemicals to the respective maximum detected chemical concentrations in soil. For chemical concentrations which approach or exceed screening concentrations, a detailed evaluation is made to assess potential for additive chemical toxic effects.

Maximum detected surface and subsurface soil concentrations and respective soil screening concentrations are presented in Table 3-1 and Table 3-2, respectively. Analytical results are presented in Appendix A.

As shown in Table 3-1, only the maximum concentration for arsenic exceeds the soil screening concentration for the ingestion exposure route. All other maximum chemical concentrations are less than respective screening concentrations. The arsenic screening concentration is exceeded at sampling location SS5 (maximum at 4.4 mg/Kg) and at sampling locations SS1A, SS4A, and SS7A, all of which were collected in the second round of surface soil sampling. No site-specific background data (for the CED Drum Storage Area) are available for the soils. However, the maximum detection reported for arsenic is less than the respective maximum base-wide background concentration (8.1 mg/Kg) and the average background concentration which is reported for soils in the Eastern United States (4.8 mg/Kg, from Shacklette, et al., 1984). Risks associated with the exceedences are not distinguishable from those which are background-related.

The cumulative risk associated with carcinogenic effects is approximately 3.9×10^{-6} . Although this value exceeds the lower risk range bound of 10^{-6} , it is well below the upper risk range value of 10^{-4} . Noteworthy individual contributions to this risk level are provided by arsenic (the only individual chemical which exceeds the 10^{-6} level, providing a 41% contribution to the total risk), beryllium (19%), PAH compounds (together accounting for about 33% of the total risk), and PCBs (5%). Considered collectively, PAHs contribute a cancer risk greater than 10^{-6} (i.e., 1.3×10^{-6}), but each individual compound risk is below 10^{-6} .

To account for possible additive effects of exposure to multiple chemicals with the same toxic endpoint, a further evaluation is performed. The ratio of the maximum concentration to the respective noncancer or carcinogenic screening concentration (presented as the "risk fraction" in Table 3-1) is calculated for each chemical which has a maximum concentration which is a potentially significant (>0.01 fraction)

TABLE 3-1
SOIL EXPOSURE PATHWAY RISK EVALUATION
DETECTED SURFACE SOIL CHEMICALS
CED DRUM STORAGE AREA, NCBC DAVISVILLE, RHODE ISLAND

Detected Chemical	Maximum Detected Concentration	Soil Ingestion Exposure SSL	Maximum Detected Concentration > SSL?	Location(s) Where Maximum Exceeds SSL	Risk Fraction		
					NC	Carc	
Organic Compounds (µg/Kg)							
Methylene chloride (c)	46 J	640,000	No	None	-	-	
Chloroform (c)	2 J	Pure compound ^{II}	No	None	-	-	
Tetrachloroethene (c)	2 J	92,000	No	None	-	-	
Naphthalene (n)	230 J	68,000,000	No	None	-	-	
2-Methylnaphthalene (n)	120 J	68,000,000	No	None	-	-	
Acenaphthene (n)	57 J	100,000,000	No	None	-	-	
Dibenzofuran (n)	58 J	6,800,000	No	None	-	-	
Fluorene (n)	63 J	68,000,000	No	None	-	-	
Phenanthrene (-)	310 J	NA	NE	NE	NE	NE	
Carbazole (c)	37 J	240,000	No	None	-	-	
Anthracene (n)	140 J	510,000,000	No	None	-	-	
Fluoranthene (n)	950 J	68,000,000	No	None	-	-	
Pyrene (n)	950	510,000,000	No	None	-	-	
Benzo(a)anthracene (c)	870	6,500	No	None	-	0.13	
Chrysene (c)	960	650,000	No	None	-	-	
bis(2-Ethylhexyl)phthalate (c)	300 J	340,000	No	None	-	-	
di-n-Octyl phthalate (n)	82	34,000,000	No	None	-	-	
Benzo(b)fluoranthene (c)	700	6,500	No	None	-	0.11	
Benzo(k)fluoranthene (c)	610	65,000	No	None	-	0.01	
Benzo(a)pyrene (c)	530	650	No	None	-	0.82	
Indeno(1,2,3-cd)pyrene (c)	320 J	6,500	No	None	-	0.05	
Dibenz(a,h)anthracene (c)	120 J	650	No	None	-	0.18	
Benzo(g,h,i)perylene (-)	300 J	NA	NE	NE	NE	NE	
n-Nitrosodiphenylamine (c)	130 J	970,000	No	None	-	-	
di-n-Butyl phthalate (n)	19 J	170,000,000	No	None	-	-	
Aldrin (c)	2.4 J	280	No	None	-	-	
Heptachlor epoxide (c)	2.9 J	520	No	None	-	-	
Dieldrin (c)	10 J	300	No	None	-	0.03	
Endrin (n)	6.8 J	510,000	No	None	-	-	
4,4'-DDE (c)	5.3 J	14,000	No	None	-	-	
4,4'-DDT (c)	30 J	14,000	No	None	-	-	
Endosulfan II (n)	7.4 J	10,000,000	No	None	-	-	
4,4'-DDD (c)	9 J	20,000	No	None	-	-	
Endosulfan sulfate (n)	22 J	10,000,000	No	None	0.02	-	
Endrin aldehyde (n)	22 J	510,000	No	None	-	-	
Chlordane (alpha- and gamma-isomers combined) (c)	24 J	3,700	No	None	-	0.01	

**TABLE 3-1
SOIL EXPOSURE PATHWAY RISK EVALUATION
DETECTED SURFACE SOIL CHEMICALS
CED DRUM STORAGE AREA, NCBC DAVISVILLE, RHODE ISLAND
PAGE 2 OF 2**

Detected Chemical	Maximum Detected Concentration	Soil Ingestion Exposure SSL	Maximum Detected Concentration > SSL?	Location(s) Where Maximum Exceeds SSL	Risk Fraction	
					NC	Carc
Aroclor-1260 (c)	130 J	620	No	None	-	0.21
Inorganic Analytes (mg/Kg)						
Aluminum (n)	9,310	Pure analyte ¹⁾	No	None	-	-
Arsenic (c)	4.4	2.7	Yes	SS5, SS1A, SS4A, SS7A	-	1.6
Barium (n)	106 J	120,000	No	None	-	-
Beryllium (c)	0.83 J	1.1	No	None	-	0.75
Cadmium (n)	0.89	850	No	None	-	-
Calcium (-)	1,480	NA	NE	NE	NE	NE
Chromium (Cr ⁺³) (n)	28.8 J	Pure analyte ¹⁾	No	None	-	-
Chromium (Cr ⁺⁶) (c)	28.8 J	8,500	No	None	-	-
Cobalt (n)	7.5	102,000	No	None	-	-
Copper (n)	111 J	63,200	No	None	-	-
Iron (-)	16,200	NA	NE	NE	NE	NE
Lead (-)	205	150 - 500 ²⁾	No	None	-	-
Magnesium (-)	2,580 J	NA	NE	NE	NE	NE
Manganese (n)	222 J	8,520	No	None	0.03	-
Mercury (n)	4.8	511	No	None	0.01	-
Nickel (n)	13.4	34,100	No	None	-	-
Potassium (-)	1,160 J	NA	NE	NE	NE	NE
Selenium (n)	0.44	8,520	No	None	-	-
Sodium (-)	383 J	NA	NE	NE	NE	NE
Vanadium (n)	18.6 J	11,900	No	None	-	-
Zinc (n)	146 J	511,000	No	None	-	-
Cumulative risk fraction (based on HQ=1.0 and ICR=10 ⁻⁶)					0.06	3.9

(n) - Screening level based on occurrence of noncancer health effects (HQ = 1.0).

(c) - Screening level based on incremental cancer risk of 10⁻⁶.

(-) - Screening level not calculated, toxicity data not available.

1 - Pure product indicates oral exposure to pure chemical under prescribed exposure scenario would not result in adverse health effects (i.e., risks above benchmark levels).

2 - Rhode Island lead-safe range for residential soil exposure. Upper bound used for comparison of analytical data.

J Estimated positive result.

NA Toxicity data not available.

NE Not evaluated.

**TABLE 3-2
SOIL EXPOSURE PATHWAY RISK EVALUATION
DETECTED SUBSURFACE SOIL CHEMICALS
CED DRUM STORAGE AREA, NCBC DAVISVILLE, RHODE ISLAND**

Detected Chemical	Maximum Detected Concentration	Soil Ingestion Exposure SSL	Maximum Detected Concentration > SSL?	Location(s) Where Maximum Exceeds SSL	Risk Fraction	
					NC	Carc
Organic Compounds (µg/Kg)						
Methylene chloride (c)	59	640,000	No	None	-	-
bis(2-Ethylhexyl)phthalate (c)	100 J	340,000	No	None	-	-
di-n-Octyl phthalate (n)	34	34,000,000	No	None	-	-
4,4'-DDT (c)	84 J	14,000	No	None	-	-
4,4'-DDD (c)	56 J	20,000	No	None	-	-
Endosulfan sulfate (n)	13 J	10,000,000	No	None	-	-
Endrin aldehyde (n)	12 J	510,000	No	None	-	-
Inorganic Analytes (mg/Kg)						
Aluminum (n)	14,300	Pure analyte ¹⁾	No	None	-	-
Arsenic (c)	4.1	2.7	Yes	B2-S2, B4-S2, B6-S1, B10A-S2	-	1.5
Barium (n)	49.8 J	120,000	No	None	-	-
Beryllium (c)	0.91 J	1.1	No	None	-	0.83
Calcium (-)	1,230	NA	NE	NE	NE	NE
Chromium (Cr ³⁺) (n)	18.0 J	Pure analyte ¹⁾	No	None	-	-
Chromium (Cr ⁶⁺) (c)	19.0 J	8,500	No	None	-	-
Cobalt (n)	18.1 J	102,000	No	None	-	-
Copper (n)	43.9 J	63,200	No	None	-	-
Iron (-)	31,600	NA	NE	NE	NE	NE
Lead (-)	16.1	150 - 500 ²⁾	No	None	-	-
Magnesium (-)	5,000	NA	NE	NE	NE	NE
Manganese (n)	535	8,520	No	None	-	-
Nickel (n)	24.9	34,100	No	None	-	-
Potassium (-)	2,440 J	NA	NE	NE	NE	NE
Sodium (-)	139	NA	NE	NE	NE	NE
Thallium (n)	0.17 J	119	No	None	-	-
Vanadium (n)	21.0	11,900	No	None	-	-
Zinc (n)	71.3	511,000	No	None	-	-
Cumulative risk fraction (based on HQ-1.0 and ICR-10 ⁶)					NE	2.3

(n) - Screening level based on occurrence of noncancer health effects (HQ-1.0).

(c) - Screening level based on incremental cancer risk of 10⁻⁶.

(-) - Screening level not calculated, toxicity data not available.

1 - Pure product indicates oral exposure to pure chemical under prescribed exposure scenario would not result in adverse health effects (i.e., risks above benchmark levels).

2 - Rhode Island lead-safe range for residential soil exposure. Upper bound used for comparison of analytical data.

J Estimated positive result.

NA Toxicity data not available.

NE Not evaluated.

contributor to overall risk. The cumulative hazard index for significant contributors to noncancer risk is 0.06 for surface soil ingestion. This value is less than one, indicating the effects of multiple chemicals acting on the same toxic endpoint are not significant or likely to result in the occurrence of adverse systemic health effects.

Although proposed land use restricts residential development, industrial zoning for the site does not prohibit excavation of subsurface soils during construction. To evaluate risks to human health associated with subsurface soil exposure, a second evaluation is performed. Table 3-2 provides a risk evaluation summary for subsurface soil chemicals and considers only chemicals with maximum reported concentrations which are greater than respective maximum surface soil concentrations. This approach is not deficient in evaluating the subsurface soils, as maximum detected concentrations of all organic compounds detected in soils are noted at surface locations, and all of the maximum concentrations of other inorganic analytes is considered in the surface soil evaluation.

As summarized in Table 3-2, the maximum, and several other concentrations of arsenic detected in subsurface soils, are noted to be greater than respective risk-based screening levels for soil. The maximum (4.1 mg/Kg) corresponds to an incremental cancer risk of 1.5×10^{-6} . The screening concentration is also exceeded at sampling locations B4-S2, B6-S1, and B10A-S2. As with surface soil arsenic concentrations, the detected subsurface soil arsenic concentrations are less than respective maximum base-wide and Eastern U.S. arsenic concentrations. Risks associated with arsenic cannot be distinguished from background risk levels.

Noncancer health hazards are not expected because all of the reported maximum concentrations are insignificant when compared to respective noncancer risk soil screening concentrations. For carcinogens, only the maximum arsenic and beryllium concentrations are greater than one percent of the respective screening concentrations. The additive incremental cancer risk for these two chemicals is 2.3×10^{-6} . This risk level is marginally greater than the lower bound risk range goal of 10^{-6} to 10^{-4} . Arsenic accounts for almost two-thirds of this risk. The beryllium risk is less than 10^{-6} , and is not anticipated to provide additive effects, because the tumor sites for arsenic (skin) and beryllium (bone) are different. As previously noted, the concentrations of these chemicals are not significantly different than background levels.

4.0 GROUNDWATER PATHWAY RISK EVALUATION

The groundwater pathway risk evaluation provides a qualitative and semi-quantitative evaluation of current and potential future risks to human health and the environment based on available analytical results for groundwater. The qualitative assessment consists of a comparison of maximum reported chemical concentrations to background concentrations and regulatory standards which have been developed for protection of human health. The quantitative portion of the evaluation is performed to identify concentrations which exceed respective regulatory standards. The groundwater samples collected from monitoring wells at the CED Drum Storage Area were analyzed for TCL organic compounds and TAL metals. Analytical results are presented in Appendix A.

At the present time, the CED Drum Storage Area is abandoned and the rest of the Davisville facility is in the process of closure. Although residential land and groundwater use provides the basis for the qualitative risk evaluation for groundwater, development of the site and groundwater in this manner is unlikely based on the following considerations:

- NCBC Davisville was formerly used in an industrial/commercial capacity and the existing facilities are designed and equipped for further use as such;
- Planned future zoning of the facility and the site as industrial prohibits development of the property as residential (Phone conversation with Susan Licardi, North Kingstown Planning Department, February 2, 1995);
- Groundwater at the site is identified as having a "GB" classification, indicating the groundwater source may not be suitable for public or private drinking water without treatment as a result of known or presumed degradation; and
- Proximity of the site to saline and brackish surface water bodies and hydrogeologic characteristics of the aquifer indicate development of the site groundwater for domestic use could result in salt water intrusion.

At the completion of closure of NCBC Davisville, the facility is intended to be used by private interests as a commercial/industrial complex. Most of the current facilities will be retained and the proposed zoning for the site is industrial land use. Provisions which restrict the site land use to industrial zoning in

perpetuity are currently being developed by regional planners in North Kingstown, where the site is located.

As previously noted, site groundwater has been assigned a "GB" classification, which identifies it as a groundwater source of marginal quality and limited potential for development as a source of drinking water. For "GB" classified groundwaters, the State of Rhode Island water quality standards do not apply, unless there exists a present or future need to upgrade classification to "GA" (General Laws, Rhode Island, 46-13.1-4). Anticipated future land use of the site for commercial/industrial use precludes use of the groundwater as a domestic water source.

The groundwater at the site is currently not used for potable purposes, and as such, is not subject to the provisions of the Safe Drinking Water Act (SDWA). However, lacking appropriate and relevant regulatory requirements for this medium, the SDWA Maximum Contaminant Levels (MCLs) for chemicals detected in groundwater are used for comparison. Table 4-1 presents a comparison of maximum detected groundwater chemical concentrations to upgradient monitoring well sample results and SDWA MCLs.

Even in the unlikely event that the site is developed as residential, use of the site groundwater for domestic purposes would not be likely. Installation of a production well at the CED Drum Storage Area would result in drawdown to the local aquifer, which would be necessarily replaced by groundwater from the surrounding area. The aquifer materials (silty and gravelly sands) are highly transmissive. Saline or brackish surface water environments (Narragansett Bay, Allen Harbor, and numerous tidal marshes and flats) are located within 1,000 feet of the site and salt water intrusion to a production well at the site is likely.

Although all maximum concentrations of detected organic compounds in groundwater are noted to be greater than concentrations detected in the upgradient well (2-MW-1), these concentrations do not exceed the MCLs. Trichloroethene is detected at a maximum concentration equal to the MCL. Similarly, all maximum concentrations of detected inorganics except cobalt are greater than respective upgradient concentrations. Iron, lead, and manganese have maximum concentrations which are greater than their SDWA benchmark concentrations. For iron and manganese, the exceeded standards are secondary MCLs, which are based on aesthetic considerations. The lead standard is an "action level" which is used as a trigger for implementing treatment of water supply and distribution systems when greater than 5% of water samples collected from "at home taps" exceed this standard.

Groundwater samples collected at the CED Drum Storage Area were collected using hand bailers, which can provide highly turbid unfiltered metals samples. As bailers are dropped in the well for purging and sample collection, agitation, groundwater flow, and drawdown disturbs the natural formation material allowing finer materials (suspended solids) to pass through the sand pack. Suspended solids in the samples can contribute considerable amounts of inorganic material to an otherwise "clean" groundwater sample. Analyses of both total (unfiltered) and dissolved (filtered) lead in groundwater samples collected from monitoring wells MW-5 and MW-6 provide an example of this effect. Total lead results range from 35.9 $\mu\text{g/L}$ to 59.4 $\mu\text{g/L}$ and compare to dissolved results for the same samples which range from 2.0 $\mu\text{g/L}$ to 2.9 $\mu\text{g/L}$.

Suspended solids in groundwater samples can significantly impact reported concentrations of inorganics in the same samples, as demonstrated in the duplicate sample results for MW-6. Variation in individual sample results for total lead in these samples, directly attributable to differences in the amount of suspended material, is noted in the unfiltered samples (35.9 $\mu\text{g/L}$ versus 59.4 $\mu\text{g/L}$). Significantly lower dissolved lead in the filtered sample from the same well (2.0 $\mu\text{g/L}$) identifies suspended solids in the groundwater to be a source of significant detections of lead in the groundwater.

TABLE 4-1
GROUNDWATER EXPOSURE PATHWAY RISK EVALUATION
GROUNDWATER CHEMICALS - CED DRUM STORAGE AREA (µg/L)
NCBC DAVISVILLE, RHODE ISLAND

Detected Chemical	Frequency of Detection	Maximum Detected Concentration	Upgradient (2-MW-1) Concentration	SDWA MCL	Maximum Concentration > MCL?
Trichloroethene	2/5	5	1	5	No
Tetrachloroethene	2/5	3	ND	5	No
Heptachlor	1/5	0.084	ND	0.4	No
Aluminum	5/5	19,400	9,170	NA	NE
Arsenic	5/5	12.1	8.2	50	No
Barium	5/5	192	ND	2,000	No
Beryllium	5/5	2.8	2.1	4	No
Calcium	5/5	18,900	8,440	NA	NE
Cobalt	5/5	80.7	193	NA	NE
Iron	5/5	97,300	29,700	300 ⁽²⁾	Yes
Lead	5/5	85.9 (2.9) ⁽¹⁾	44.7	15 ⁽³⁾	Yes
Magnesium	5/5	6,150	4,280	NA	NE
Manganese	5/5	5,660	4,560	50 ⁽²⁾	Yes
Nickel	5/5	44.9	40.0	100	No
Potassium	5/5	5,340	2,440	NA	NE
Sodium	5/5	23,700	6,720	NA	NE
Vanadium	5/5	26.4	17.6	NA	NE
Zinc	5/5	79.8	64.7	5,000	No

- 1 - Maximum filtered lead result presented in parenthesis for comparison. Based on the two available sample results, dissolved lead concentrations are approximately 5% of reported total lead results.
- 2 - Secondary MCL
- 3 - Action level
- ND - Analyte not detected in upgradient (background) well sample.
- NA - Not available
- NE - Not evaluated

The groundwater samples collected at the CED Drum Storage Area are believed to provide inorganics data which are representative of naturally-occurring concentrations. Comparison of maximum detected concentrations to upgradient concentrations collected at a single location reveal no significant difference between site-related and background levels. The differences between sample results, which can be as much as three times higher in site groundwater samples, can be attributed to different amounts of suspended material in the individual groundwater samples.

The strict application of the SDWA action level to groundwater at the CED Drum Storage Area is not appropriate. The relevancy of aesthetic standards (secondary MCLs) for iron and manganese is also questionable. Iron and manganese are necessary human nutrients.

In conclusion, maximum detected concentrations of groundwater chemicals at the CED Drum Storage Area are noted to exceed SDWA benchmark levels for iron, lead, and manganese. However, strict application of MCLs and action levels are not appropriate for this groundwater because; 1) the groundwater is not currently a source of potable water, 2) the groundwater has a class "GB" designation which necessitates treatment prior to use as a source of drinking water, 3) the current and future land use is commercial/industrial and there are no plans for developing the groundwater resource as a water supply, and 4) proximate saline environments which surround the site would likely impact the aquifer if it were developed as a water supply. Therefore, current and proposed future groundwater exposure pathway is incomplete and irrelevant.

5.0 AIR PATHWAY RISK EVALUATION

The potential risks posed by chemicals detected in surface soil to receptors via the air pathway are evaluated using the inhalational exposure screening concentrations. Development of inhalation exposure screening levels is described in Section 2.2. Analytical results are presented in Appendix A. Tables 5-1 and 5-2 summarize maximum detected chemical concentrations in surface and subsurface soil, respectively, and associated air pathway screening values. Although presented in the tables, the air pathway screening value for hexavalent chromium is not used in the risk characterization, because this particular form of chromium is not believed to be present at the site. This conclusion is based on known site operations and the nature of the materials which are known to have been stored there.

As identified in Table 5-1, none of the maximum concentrations of chemicals detected in surface soils at the CED Drum Storage Area are greater than respective air pathway soil screening concentrations. Consequently, these chemicals can be viewed as being no significant threat to human health under an industrial land use scenario. In addition, the potential for exposure to multiple chemicals to affect individual receptors is insignificant, as evidenced by the cumulative hazard index of 0.58 and cancer risk of 0.31×10^{-6} (i.e., 3.1×10^{-7}). Both of these risk estimates are less than appropriate lower end USEPA risk goals.

Evaluation of subsurface soils which may be exposed to the surface during construction activities is provided in Table 5-2. As with the surface soils, all maximum concentrations of detected chemicals in subsurface soils are less than respective noncancer or carcinogenic screening levels for the air pathway. To account for possible cumulative effects, risk fractions are calculated for individual chemicals and cumulative risk fractions for the industrial land use scenario. The total hazard quotient (0.59) and cancer risk (2.1×10^{-7}) are well below the lower risk range goals.

**TABLE 5-1
AIR PATHWAY RISK EVALUATION
DETECTED SURFACE SOIL CHEMICALS
CED DRUM STORAGE AREA, NCBC DAVISVILLE, RHODE ISLAND**

Detected Chemical	Maximum Detected Concentration	Soil Inhalation Exposure SSL	Maximum Detected Concentration > SSL?	Location(s) Where Maximum Exceeds SSL	Risk Fraction		
					NC	Carc	
Organic Compounds (µg/Kg)							
Methylene chloride	(c) 46 J	13,000	No	None	-	-	
Chloroform	(c) 2 J	600	No	None	-	-	
Tetrachloroethene	(c) 2 J	33,000	No	None	-	-	
Naphthalene	(-) 230 J	NA	NE	NE	NE	NE	
2-Methylnaphthalene	(-) 120 J	NA	NE	NE	NE	NE	
Acenaphthene	(-) 57 J	NA	NE	NE	NE	NE	
Dibenzofuran	(-) 58 J	NA	NE	NE	NE	NE	
Fluorene	(-) 63 J	NA	NE	NE	NE	NE	
Phenanthrene	(-) 310 J	NA	NE	NE	NE	NE	
Carbazole	(-) 37 J	NA	NE	NE	NE	NE	
Anthracene	(-) 140 J	NA	NE	NE	NE	NE	
Fluoranthene	(-) 950 J	NA	NE	NE	NE	NE	
Pyrene	(-) 950	NA	NE	NE	NE	NE	
Benzo(a)anthracene	(c) 870	230,000	No	None	-	-	
Chrysene	(c) 960	23,000,000	No	None	-	-	
bis(2-Ethylhexyl)phthalate	(-) 300 J	NA	NE	NE	NE	NE	
di-n-Octyl phthalate	(-) 82	NA	NE	NE	NE	NE	
Benzo(b)fluoranthene	(c) 700	140,000	No	None	-	-	
Benzo(k)fluoranthene	(c) 610	890,000	No	None	-	-	
Benzo(a)pyrene	(c) 530	46,000	No	None	-	-	
Indeno(1,2,3-cd)pyrene	(c) 320 J	480,000	No	None	-	-	
Dibenz(a,h)anthracene	(c) 120 J	50,000	No	None	-	-	
Benzo(g,h,i)perylene	(-) 300 J	NA	NE	NE	NE	NE	
n-Nitrosodiphenylamine	(-) 130 J	NA	NE	NE	NE	NE	
di-n-Butyl phthalate	(-) 18 J	NA	NE	NE	NE	NE	
Aldrin	(c) 2.4 J	2,200	No	None	-	-	
Heptachlor epoxide	(c) 2.9 J	45	No	None	-	-	
Dieldrin	(c) 10 J	16,000	No	None	-	0.08	
Endrin	(-) 8.8 J	NA	NE	NE	NE	NE	
4,4'-DDE	(-) 5.3 J	NA	NE	NE	NE	NE	
4,4'-DDT	(c) 30 J	440,000	No	None	-	-	
Endosulfan II	(-) 7.4 J	NA	NE	NE	NE	NE	

**TABLE 5-1
AIR PATHWAY RISK EVALUATION
DETECTED SURFACE SOIL CHEMICALS
CED DRUM STORAGE AREA, NCBC DAVISVILLE, RHODE ISLAND
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Detected Chemical	Maximum Detected Concentration	Soil Inhalation Exposure SSL	Maximum Detected Concentration > SSL?	Location(s) Where Maximum Exceeds SSL	Risk Fraction	
					NC	Carc
4,4'-DDD (-)	9 J	NA	NE	NE	NE	NE
Endosulfan sulfate (-)	22 J	NA	NE	NE	NE	NE
Endrin aldehyde (-)	22 J	NA	NE	NE	NE	NE
Chlordane (alpha- and gamma-isomers combined) (c)	24 J	15,000	No	None	-	-
Aroclor-1260 (-)	130 J	NA	NE	NE	NE	NE
Inorganic Analytes (mg/Kg)						
Aluminum (-)	9,310	NA	NE	NE	NE	NE
Arsenic (c)	4.4	22.0	No	None	-	0.20
Barium (n)	108 J	17,000	No	None	0.01	-
Beryllium (c)	0.83 J	39.6	No	None	-	0.02
Cadmium (n)	0.89	52.8	No	None	0.02	-
Calcium (-)	1,480	NA	NE	NE	NE	NE
Chromium (Cr ⁺³) (n)	28.8 J	67.8	No	None	0.42	-
Chromium (Cr ⁺⁶) (c)	28.8 J	7.9	NE	NE	NE	NE
Cobalt (-)	7.5	NA	NE	NE	NE	NE
Copper (-)	111 J	NA	NE	NE	NE	NE
Iron (-)	18,200	NA	NE	NE	NE	NE
Lead (-)	205	NA	NE	NE	NE	NE
Magnesium (-)	2,580 J	NA	NE	NE	NE	NE
Manganese (n)	222 J	1,700	No	None	0.13	-
Mercury (n)	4.8	10,200	No	None	-	-
Nickel (c)	13.4	398	No	None	-	0.03
Potassium (-)	1,160 J	NA	NE	NE	NE	NE
Selenium (-)	0.44	NA	NE	NE	NE	NE
Sodium (-)	383 J	NA	NE	NE	NE	NE
Vanadium (-)	18.6 J	NA	NE	NE	NE	NE
Zinc (-)	148 J	NA	NE	NE	NE	NE
Cumulative risk fraction (based on HQ=1.0 and ICR=10 ⁻⁶)					0.58	0.31

- (n) - Screening level based on occurrence of noncancer health effects (HQ = 1.0).
- (c) - Screening level based on incremental cancer risk of 10⁻⁶.
- (-) - Screening level not calculated, toxicity data not available.
- 1 - Pure product indicates inhalational exposure to pure chemical under prescribed exposure scenario would not result in adverse health effects (i.e., risks above benchmark levels).
- J - Estimated positive result.
- NA - Toxicity data not available.
- NE - Not evaluated.

**TABLE 5-2
AIR PATHWAY RISK EVALUATION
DETECTED SUBSURFACE SOIL CHEMICALS
CED DRUM STORAGE AREA, NCBC DAVISVILLE, RHODE ISLAND**

Detected Chemical	Maximum Detected Concentration	Soil Inhalation Exposure SSL	Maximum Detected Concentration > SSL?	Location(s) Where Maximum Exceeds SSL	Risk Fraction		
					NC	Carc	
Organic Compounds (µg/Kg)							
Methylene chloride (c)	59	13,000	No	None	-	-	
bis(2-Ethylhexyl)phthalate (-)	100 J	NA	NE	NE	NE	NE	
di-n-Octyl phthalate (-)	34	NA	NE	NE	NE	NE	
4,4'-DDT (c)	84 J	440,000	No	None	-	-	
4,4'-DDD (-)	56 J	NA	NE	NE	NE	NE	
Endosulfan sulfate (-)	13 J	NA	NE	NE	NE	NE	
Endrin aldehyde (-)	12 J	NA	NE	NE	NE	NE	
Inorganic Analytes (mg/Kg)							
Aluminum (-)	14,300	NA	NE	NE	NE	NE	
Arsenic (c)	4.1	22.0	No	None	-	0.19	
Barium (n)	49.8 J	17,000	No	None	-	-	
Beryllium (c)	0.91 J	39.6	No	None	-	0.02	
Calcium (-)	1,230	NA	NE	NE	NE	NE	
Chromium (Cr ³⁺) (n)	19.0 J	67.8	No	None	0.28	-	
Chromium (Cr ⁶⁺) (c)	19.0 J	7.9	NE	NE	NE	NE	
Cobalt (-)	19.1 J	NA	NE	NE	NE	NE	
Copper (-)	43.9 J	NA	NE	NE	NE	NE	
Iron (-)	31,600	NA	NE	NE	NE	NE	
Lead (-)	16.1	NA	NE	NE	NE	NE	
Magnesium (-)	5,000	NA	NE	NE	NE	NE	
Manganese (n)	535	1,700	No	None	0.31	-	
Nickel (c)	24.9	NA	NE	NE	NE	NE	
Potassium (-)	2,440 J	NA	NE	NE	NE	NE	
Sodium (-)	139	NA	NE	NE	NE	NE	
Thallium (-)	0.17 J	NA	NE	NE	NE	NE	
Vanadium (-)	21.0	NA	NE	NE	NE	NE	
Zinc (-)	71.3	NA	NE	NE	NE	NE	
Cumulative risk fraction (based on HQ = 1.0 and ICR = 10 ⁻⁶)					0.59	0.21	

- (n) - Screening level based on occurrence of noncancer health effects (HQ = 1.0).
- (c) - Screening level based on incremental cancer risk of 10⁻⁶.
- (-) - Screening level not calculated, toxicity data not available.
- 1 - Pure product indicates inhalational exposure to pure chemical under prescribed exposure scenario would not result in adverse health effects (i.e., risks above benchmark levels).
- J - Estimated positive result.
- NA - Toxicity data not available.
- NE - Not evaluated.

6.0 CONCLUSIONS

This section summarizes the qualitative risk evaluations performed for receptors exposed to soil via the identified soil exposure pathways. The conclusions presented are based on planned future land use and the conceptual site model discussed in Section 2.0. Under the evaluated exposure scenario, adults are exposed in an occupational setting under USEPA Region I high end industrial land use exposure inputs. Consideration of all relevant current and future exposure pathways which are consistent with the conceptual site model has been made.

All soil screening levels have been calculated based on the minimum soil concentration which results in a Hazard Index of one or an Incremental Cancer Risk of 10^{-6} . These benchmarks are commonly used by the USEPA to identify potentially unacceptable risks for CERCLA regulated hazardous waste site. The screening levels which have been calculated are considered to be protective of human health. Evaluation is performed by comparing maximum detected chemical concentrations to respective screening values.

6.1 SOIL EXPOSURE PATHWAY

Based on direct comparison of reported maximum concentrations of detected chemicals in surface soil, adult receptors exposed to surface and subsurface soil via ingestion will incur risks above the USEPA benchmark levels for arsenic only. However, based on a comparison of the reported maximum arsenic concentrations in the surface and subsurface soil (4.4 mg/Kg) to background, these risks are not greater than those associated with exposure to maximum background arsenic concentrations in the soils at the facility (8.1 mg/Kg) and to average arsenic concentrations in the soils in the Eastern United States (4.8 mg/Kg). Although the risk associated with exposure to arsenic is within the 10^{-6} to 10^{-4} cancer risk range goal commonly used by the USEPA in CERCLA related activities, this calculated risk cannot be identified as being significantly different from background risks for this chemical in the Eastern United States.

To account for possible cumulative effects which may be associated with exposure to multiple chemicals with a common toxic endpoint, further evaluation of the soil data was performed. Risk fractions were calculated for individual chemicals and added together for each soil data set to provide an estimate of the total Hazard Index and Incremental Cancer Risk for the relevant exposure pathway. Only chemicals which might potentially pose a threat to human health, as indicated by maximum concentrations which are greater than 1% of the screening level, are considered.

For both surface and subsurface soil, the cumulative hazard indices were less than unity, indicating adverse systemic health effects attributable to multiple chemical effects on common toxic endpoints is not likely. Cumulative cancer risk in surface soil (3.9×10^{-6}) and subsurface soil (2.3×10^{-6}) marginally exceed the lower end of the USEPA cancer risk range goal of 10^{-6} and is well below the 10^{-4} upper risk range goal. As previously identified, the only individual chemical which exceeded the 10^{-6} level is arsenic, a chemical which is not to be detected within background concentration ranges in both surface and subsurface soil.

6.2 GROUNDWATER EXPOSURE PATHWAY

As identified in Section 4.0, the groundwater at the CED Drum Storage Area is identified as having a "GB" classification, which limits its potential use as a domestic water supply. Additionally, proposed zoning for the site (industrial) precludes development of the site as residential. Consequently, domestic groundwater use at the site is not considered to be a relevant exposure pathway.

Maximum reported analytical results for groundwater sampled at the site indicate exceedences of the Safe Drinking Water Act standards for iron, lead, and manganese. Results of analysis of both filtered and unfiltered groundwater samples for lead indicate a significant disparity between total (unfiltered) and dissolved (filtered) groundwater results. Because of the sampling method used (hand bailing) and high turbidity (from suspended material) associated with the unfiltered samples from the use of this sampling technique, the total metals results used in the groundwater evaluation are believed to provide an erroneous evaluation of groundwater quality with respect to the iron, lead, and manganese. Concentrations which would be observed in clarified groundwater (suitable for consumption) are expected to be significantly lower than those reported in this screening evaluation.

Since development of this groundwater for public and residential use is not anticipated (proposed restrictions for land use as industrial) the applicability of the SDWA is not considered appropriate. Therefore, no risks can be associated with this exposure pathway and medium at the CED Drum Storage Area.

6.3 AIR EXPOSURE PATHWAY

Based on direct comparison of reported maximum concentrations of surface and subsurface soil chemicals to air pathway screening concentrations, no risks which exceed USEPA benchmarks are identified for

chemicals detected at the CED Drum Storage Area. In addition, all associated cumulative risks for principle risk contributors in the surface and subsurface soil are less than the lower USEPA risk benchmark values (i.e., 10^{-6} cancer risk and hazard index of 1.0).

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APPENDIX A

RISK EVALUATION SUPPORT DOCUMENTATION

- **Sample Calculations**
- **Spreadsheet Printouts**
- **Guidance Documentation (USEPA, December 1994)**
- **Background Soil Data (Shacklette, et al.)**

CLIENT CTO 127 - CED DRUM		JOB NUMBER 8659	
SUBJECT SOIL SCREENING LEVELS			
BASED ON USEPA, DECEMBER 1994		DRAWING NUMBER	
BY TJS	CHECKED BY KMB 02/10/95	APPROVED BY	DATE 02/07/95

PURPOSE: CALCULATE SOIL SCREENING CONCENTRATIONS FOR DETECTED CHEMICALS WHICH ARE PROTECTIVE OF HUMAN HEALTH AND THE ENVIRONMENT. EVALUATION OF DIRECT INGESTION AND INHALATION OF FUGITIVE DUST AND VOLATILES FROM SOIL ARE CONSIDERED FOR HUMAN HEALTH. TARGET CANCER RISKS (10^{-6}) AND HAZARD QUOTIENTS (1.0) ARE SPECIFIED FOR EACH DETECTED CHEMICAL.

PROTECTION OF GROUNDWATER IS BASED ON EQUILIBRIUM PARTITIONING WITH A POINT OF COMPLIANCE IDENTIFIED AT THE DOWNGRAIDENT EDGE OF THE SOURCE AREA.

RELEVANT EQUATIONS:

- INGESTION OF SOIL

- NONCARCINOGENS

$$SL = \frac{THQ \cdot BW \cdot AT \cdot 365 \text{ day/yr}}{\left(\frac{1}{RFD}\right) \cdot 10^{-6} \frac{\text{kg}}{\text{mg}} \cdot EF \cdot ED \cdot IR}$$

- CARCINOGENS

$$SL = \frac{TR \cdot BW \cdot AT \cdot 365 \text{ day/yr}}{CSF \cdot 10^{-6} \frac{\text{kg}}{\text{mg}} \cdot EF \cdot ED \cdot IR}$$

CLIENT	@TO 127 - CED Drum	JOB NUMBER	8659
SUBJECT	SOIL SCREENING LEVELS		
BASED ON	USEPA, DEC 1994	DRAWING NUMBER	
BY	TJS	CHECKED BY	KAB 02/10/95
		APPROVED BY	
		DATE	02/07/95

WHERE:

- THQ = TARGET HAZARD QUOTIENT (1.0)
- TR = TARGET CANCER RISK (10^{-6})
- SL = SOIL SCREENING LEVEL (mg/kg)
- BW = RECEPTOR BODY WEIGHT (kg)
- AT = AVERAGING TIME (YR) = ED (NONCARCINOGENS)
= 70 YR (CARCINOGENS)
- RFD_o = ORAL Reference Dose ($\text{mg}/\text{kg day}$)
- CSF_o = ORAL CANCER SLOPE FACTOR ($\text{mg}/\text{kg day}$)⁻¹
- EF = EXPOSURE FREQUENCY (day/YR)
- ED = EXPOSURE DURATION (YR)
- IR = INGESTION Rate (mg/day)
- 365^d/YR, $10^{-6} \text{ kg}/\text{mg}$ = CONVERSION FACTORS

• INHALATION OF DUST/VOLATILES FROM SOIL

- NONCARCINOGENS

$$SL = \frac{THQ \cdot AT \cdot 365 \text{ day/YR}}{EF \cdot ED \cdot \left[\left(\frac{1}{RFC} \right) \left(\frac{1}{VF} + \frac{1}{PEF} \right) \right]}$$

- CARCINOGENS

$$SL = \frac{TR \cdot AT \cdot 365 \text{ day/YR}}{URF \cdot 1000 \text{ } \mu\text{g}/\text{mg} \cdot EF \cdot ED \cdot \left[\frac{1}{VF} + \frac{1}{PEF} \right]}$$

WHERE:

- RFC = REFERENCE CONCENTRATION (mg/m^3)
- URF = UNIT RISK FACTOR (m^3/mg)⁻¹
- 1000 $\mu\text{g}/\text{mg}$ = UNIT CONVERSION FACTOR
- and.....

CLIENT PTO 127 - CED DRUM		JOB NUMBER 8659	
SUBJECT SOIL SCREENING LEVELS			
BASED ON USEPA, DEC 1994		DRAWING NUMBER	
BY THS	CHECKED BY KMS	APPROVED BY	DATE 02/07/95

VF = VOLATILIZATION FACTOR (m^3/kg)
 PEF = PARTICULATE EMISSION FACTOR (m^3/kg)

- VF and PEF are calculated as follows:

$$① \quad VF = \left(\frac{Q}{C}\right) \left[\frac{(3.14 \cdot \alpha \cdot T)^{0.5}}{2 \cdot De_i \cdot \theta_a \cdot K_{aw}} \right] \left(10^{-4} \frac{m^2}{cm^2}\right)$$

and

$$\alpha = \frac{De_i \cdot \theta_a}{\theta_a + \frac{\rho_s(1-\theta_a)}{K_{aw}}}$$

$$② \quad PEF = \frac{3600 \text{ s/hr}}{0.036 \times (1-V) \times \left(\frac{u_m}{u_t}\right)^3 \times F(x)} \left(\frac{Q}{C}\right)$$

WHERE: $\frac{Q}{C}$ = INVERSE OF MEAN CONCENTRATION AT CENTER OF A SQUARE 30 ACRE SOURCE ($g/m^2 \cdot s$ PER kg/m^3)

T = EXPOSURE DURATION (SEC)

De_i = EFFECTIVE CHEMICAL DIFFUSIVITY ($\frac{cm^2}{s}$) = $D_i \frac{\theta_a^{3.33}}{\theta_t^2}$

θ_a = AIR FILLED POROSITY (FRACTION) = $\theta_t - \frac{M\beta}{\rho_w}$

θ_t = TOTAL POROSITY (FRACTION) = $1 - \frac{\beta}{\rho_s}$

D_i = CHEMICAL DIFFUSIVITY IN AIR (cm^2/sec)

M = SOIL MOISTURE CONTENT (FRACTION)

β = SOIL DRY BULK DENSITY (g^m/cm^3)

ρ_w = DENSITY OF WATER (g^m/cm^3)

ρ_s = SOIL PARTICLE DENSITY (g^m/cm^3)

K_{aw} = SOIL-TO-AIR PARTITIONING COEFFICIENT ($\frac{g^m \text{ soil}}{cm^3 \text{ air}}$) = $\frac{H \cdot 4.1}{K_d}$

H = HENRY'S LAW CONSTANT ($\frac{atm \cdot m^3}{mole}$)

K_d = SOIL-WATER PARTITIONING COEFFICIENT (l/kg) = $K_{oc} \cdot f_{oc}$

f_{oc} = FRACTION ORGANIC CARBON (FRACTION)

CLIENT QTO 127 - CED DRUM		JOB NUMBER 8659	
SUBJECT SOIL SCREENING LEVELS			
BASED ON USEPA, DEC 1994		DRAWING NUMBER	
BY JHS	CHECKED BY JNS 02/10/95	APPROVED BY	DATE 02/07/95

(CONTINUED) K_{oc} = ORGANIC CARBON PARTITIONING COEFFICIENT (l/kg)
 $3600^3/hr$, 41 = UNITS CONVERSION FACTOR
 γ = FRACTION OF VEGETATIVE COVER
 U_m = Mean annual windspeed (m/sec)
 U_t = Threshold erosional windspeed measured at 7M HEIGHT (m/sec)
 $F(x)$ = FUNCTION PROVIDED IN COWHELD (1985).
 $X = 0.885 \left(\frac{U_t}{U_m} \right)$

° PROTECTION OF GROUNDWATER

$$SL = C_w \left[K_d + \frac{\theta_w + \theta_a H'}{\beta} \right] \times DAF$$

WHERE: C_w = GROUNDWATER ATTAINMENT STANDARD (mg/L)
 (IN ORDER OF PREFERENCE ① NON ZERO MCLG, ② MCL, ③ RISK-BASED CONCENTRATION)

$$\theta_w = \text{WATER-FILLED POROSITY (FRACTION)} = \theta_t - \theta_a$$

$$H' = H \times 41 \text{ (UNITLESS)}$$

$$DAF = \text{DILUTION-ATTENUATION FACTOR (DEFAULT = 10)}$$

CLIENT CTO 127 - CED DRUM		JOB NUMBER 8659	
SUBJECT SOIL SCREENING LEVELS			
BASED ON USEPA, DEC 1994		DRAWING NUMBER	
BY JHS	CHECKED BY JMB 12/10/95	APPROVED BY	DATE 02/07/95

ASSUMPTIONS:

① INDUSTRIAL LAND USE WITH ONLY ADULT RECEPTORS EXPOSED UNDER HIGH-END NONCONTACT CONDITIONS

IR = 100 mg/day	USEPA REGION I HIGH END EXPOSURE
EF = 150 d/YR	" " " " "
ED = 25 YR	USEPA, MARCH 25, 1991
BW = 70 kg	" " " "

EXPOSURE TO METHYLENE CHLORIDE CONSIDERED, THE FOLLOWING TOXICITY/TRANSPORT DATA ARE AVAILABLE:

$RFD_0 = 6 \times 10^{-2} \text{ mg/kg-day}$
 $CSF_0 = 7.5 \times 10^{-3} \text{ kg-day/mg}$
 $RFC = 3.0 \times 10^0 \text{ mg/m}^3$
 $URF = 4.69 \times 10^{-7} (\text{mg/m}^3)^{-1}$
 $D_i = 1.05 \times 10^{-1} \text{ cm}^2/\text{sec}$
 $H = 2.03 \times 10^{-3} \text{ atm}\cdot\text{m}^3/\text{mol}$
 $K_{oc} = 8.8 \times 10^0 \text{ l/kg}$

② Site-specific data are available to facilitate transport modeling:

$V = 0.50$ (conservative estimate)
 $M = 0.10$ (from analytical results)
 $\beta = 1.5 \text{ g/m}^3$ (estimate of silty sand)
 $\rho_s = 2.65 \text{ g/cm}^3$ (estimate)
 $f_{oc} = 0.006$ (conservative estimate)
 $u_m = 5.0 \text{ m/sec}$ (estimate based on location, proximity to other sites)
 mode of aggregate size = 0.25 mm (estimate from analytical data)
 Roughness height = 0.6 cm (estimate for grassy/paved field)

CLIENT OTO 127 - CED DRUM	JOB NUMBER 8659
SUBJECT SOIL SCREENING (LEVELS)	
BASED ON USEPA, DEC 1994	DRAWING NUMBER
BY JHS	CHECKED BY KMS 02/10/95
APPROVED BY	DATE 02/07/95

SAMPLE CALCULATION:

• INGESTION OF SOIL

- NONCARCINOGENS

$$SL = \frac{(1.0)(70 \text{ kg})(25 \text{ yr})(365 \text{ day/yr})}{\left(\frac{1}{6 \times 10^{-2} \text{ mg/kg day}}\right) \left(10^{-6} \frac{\text{kg}}{\text{mg}}\right) \left(150 \frac{\text{day}}{\text{yr}}\right) (25 \text{ yr}) (100 \frac{\text{mg}}{\text{day}})} = 1.02 \times 10^5 \frac{\text{mg}}{\text{kg}}$$

- CARCINOGENS

$$SL = \frac{(10^{-6})(70 \text{ kg})(70 \text{ yr})(365 \text{ days/yr})}{(7.5 \times 10^{-3} \frac{\text{kg day}}{\text{mg}}) (10^{-6} \frac{\text{kg}}{\text{mg}}) (150 \frac{\text{day}}{\text{yr}}) (25 \text{ yr}) (100 \text{ mg/day})} = 6.36 \times 10^2 \frac{\text{mg}}{\text{kg}}$$

MINIMUM VALUE IS ACCEPTED AS INGESTION SCREENING LEVEL - 636 mg/kg

• INHALATION OF DUST / VOLATILES FROM SOIL

- CALCULATE PRELIMINARY VALUES

$$\theta_t = 1 - \frac{1.59 \text{ mg/cm}^3}{2.659 \text{ mg/cm}^3} = 0.434$$

$$\theta_a = 0.434 - \frac{(1.59 \text{ mg/cm}^3)(0.10)}{1.9 \text{ mg/cm}^3} = 0.284$$

$$\theta_w = 0.434 - 0.284 = 0.150$$

$$Dei = \left(1.05 \times 10^{-1} \frac{\text{cm}^2}{\text{sec}}\right) \frac{(0.284)^{3.33}}{(0.434)^2}$$

$$Dei = 8.43 \times 10^{-3} \frac{\text{cm}^2}{\text{sec}}$$

CLIENT CTO 127 - CED DRUM		JOB NUMBER 8659	
SUBJECT SOIL SCREENING LEVELS			
BASED ON USEPA, DEC 1994		DRAWING NUMBER	
BY JHS	CHECKED BY AMS 02/10/95	APPROVED BY	DATE 02/07/95

$$K_{as} = \frac{(2.03 \times 10^{-3} \text{ atm} \cdot \text{m}^3 / \text{mol}) (41)}{(8.8 \times 10^4 \text{ kJ}) (0.006)} = 1.58 \frac{\text{gm soil}}{\text{cm}^3 \text{ air}}$$

$$\alpha = \frac{(8.43 \times 10^{-3} \text{ cm}^2 / \text{sec}) (0.284)}{0.284 + \frac{(2.659 \text{ gm/cm}^3) (1 - 0.284)}{1.58 \frac{\text{gm soil}}{\text{cm}^3 \text{ air}}}} = 1.61 \times 10^{-3} \text{ cm}^2 / \text{sec}$$

USING DEFAULT VALUES FOR $\frac{Q}{C}$ FOR WORST CASE CITIES (i.e. -

Los Angeles for Volatiles ($\frac{Q}{C} = 35.1$) and MINNEAPOLIS FOR DUST ($\frac{Q}{C} = 46.84$)

THE FOLLOWING CALCULATIONS CAN BE MADE.

$$VF = \left(\frac{35.1}{\frac{\text{g} \cdot \text{m}^3}{\text{m}^2 \cdot \text{s} \cdot \text{kg}}} \right) \left[\frac{[(3.14)(1.61 \times 10^{-3} \text{ cm}^2 / \text{sec})(25 \text{ yr} = 365 \text{ d} \cdot 24 \text{ hr} \cdot 3600 \text{ s/hr})]^{0.5}}{(2)(8.43 \times 10^{-3} \text{ cm}^2 / \text{sec})(0.284)(1.58 \frac{\text{gm soil}}{\text{cm}^3 \text{ air}})} \right] (10^{-4} \frac{\text{m}^2}{\text{cm}^2})$$

$$VF(\text{MeCl}_2) = 9.26 \times 10^2 \frac{\text{m}^3}{\text{kg}}$$

and

$$PEF = \left(\frac{46.84}{\frac{\text{g} \cdot \text{m}^3}{\text{m}^2 \cdot \text{s} \cdot \text{kg}}} \right) \left[\frac{3600 \text{ s/hr}}{(0.036)(1 - 0.50) \left(\frac{5.0 \text{ m/s}}{6.44 \text{ m/s}} \right)^3 (1.44)} \right]$$

$$PEF = 1.39 \times 10^7 \frac{\text{m}^3}{\text{kg}}$$

CLIENT (TO 127 - CED DRUM)		JOB NUMBER 8659	
SUBJECT SOIL SCREENING LEVELS			
BASED ON USEPA, Dec 1994		DRAWING NUMBER	
BY JHS	CHECKED BY KMS 02/10/95	APPROVED BY	DATE 02/07/95

③ NONCARCINOGENS

$$SL = \frac{(1.0)(25 \text{ yr})(365 \text{ day/yr})}{(150 \text{ d/yr})(25 \text{ yr}) \left[\left(\frac{1}{3.0 \times 10^6 \frac{\text{mg}}{\text{m}^3}} \right) \left(\frac{1}{9.26 \times 10^{-2} \frac{\text{m}^3}{\text{kg}}} + \frac{1}{1.39 \times 10^7 \frac{\text{m}^3}{\text{kg}}} \right) \right]}$$

$$SL_{nc} = 6.76 \times 10^3 \text{ mg/kg}$$

④ CARCINOGENS

$$SL = \frac{(10^6)(70 \text{ yr})(365 \text{ day/yr})}{(4.69 \times 10^{-7} \frac{\text{m}^3}{\text{mg}})(1000 \frac{\text{kg}}{\text{mg}})(150 \frac{\text{day}}{\text{yr}})(25 \text{ yr}) \left[\frac{1}{9.26 \times 10^{-2} \frac{\text{m}^3}{\text{kg}}} + \frac{1}{1.39 \times 10^7 \frac{\text{m}^3}{\text{kg}}} \right]}$$

$$SL_c = 1.35 \times 10^1 \text{ mg/kg}$$

MINIMUM VALUE IS ACCEPTED AS INHALATION SCREENING LEVEL -

13.5 mg/kg

CLIENT CTO 127 - CED DRUM		JOB NUMBER 8659	
SUBJECT SOIL SCREENING LEVELS			
BASED ON USEPA Dec 1994		DRAWING NUMBER	
BY ZHS	CHECKED BY MS 02/10/95	APPROVED BY	DATE 02/07/95

• PROTECTION of GROUNDWATER

FOR METHYLENE CHLORIDE, AN MCL OF 0.005 mg/L IS NOTED.

$$SL = (0.005 \text{ mg/L}) \left[(8.8 \times 10^{-4} \text{ kg}) (0.006) + \frac{(0.150) + (0.384) (2.03 \times 10^{-3} \frac{\text{atm} \cdot \text{m}^3}{\text{mol}}) (41)}{1.5 \frac{\text{g}}{\text{cm}^3} \text{ kg/L}} \right] (10)$$

$$SL = 8.4 \times 10^{-3} \text{ mg/kg}$$

GROUNDWATER PROTECTION GOAL OF 8.4 mg/kg IS ACCEPTED.

CLIENT CTO 127 - CED DRUM		JOB NUMBER 8659	
SUBJECT SOIL SCREENING LEVELS			
BASED ON USEPA DECEMBER 1994		DRAWING NUMBER	
BY ZAS	CHECKED BY KMS 02/10/95	APPROVED BY	DATE 02/07/95

REFERENCES

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OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE.

INTEGRATED RISK INFORMATION SYSTEM (IRIS). ON-LINE. Jan. 1995

COWHERD C., G. MULESCI, et al. 1985 "RAPID ASSESSMENT OF
EXPOSURE TO PARTICULATE EMISSIONS FROM SURFACE CONTAMINATION.
EPA/600/8-85/002. OFFICE OF HEALTH AND ENVIRONMENTAL ASSESSMENT,
WASHINGTON DC.

SCREENING CRITERIA VALUES SPREADSHEET

SOIL SCREENING LEVELS (USEPA, December 1994, EPA/540/R-94/101)

This spreadsheet calculates soil screening levels for protection of human health and the environment.

Health based screening levels for soil are based on carcinogenic and noncarcinogenic effects (incurred at USEPA risk levels of $1e-6$ cancer and 1.0 hazard index benchmarks). Relevant exposure routes include direct ingestion of soil and inhalation of volatiles and fugitive dusts from soils. Environmental protection (for groundwater) screening levels consider chemical mobility and health and regulatory standards. Site specific data are used as available.

To use spreadsheet: 1) Input desired receptor and site information in shaded cells, 2) Identify potential chemicals of concern and transport data in appropriate cells, 3) Print spreadsheet using "ALT-P" macro.

Land Use: Industrial

	Adult	Child	
Receptor Exposure Data: Ing Rate (IR)	100	NA	(mg/day)
Exp Freq (EF)	150	NA	(days/yr)
Exp Dur (ED)	25	NA	(yr)
Body Wt (BW)	70	NA	(Kg)
Avg Time (AT)	9125	0	(days - noncarcinogens)
	25550	25550	(days - carcinogens)
Age-adjusted Ing Rate (F)		35.71	(mg-yr/Kg-day)

Site-specific Soil Information:	Vegetative cover:	0.50	(fraction)
	Soil bulk density (dry)	1.50	(gm/cm ³)
	Soil moisture content	0.100	(fraction)
	Soil particle density	2.65	(gm/cm ³)
	Soil organic carbon	0.006	(fraction)
Calculated Soil Data:	Soil porosity	0.434	(fraction)
	Air-filled porosity	0.284	(fraction)
	Water filled porosity	0.150	(fraction)
Site-specific Meteorological Data:	Mean annual windspeed	5.0	(m/sec)
	Mode of aggregate size	0.25	(mm)
	Roughness height	0.60	(cm)
Calculated Meteorological Data:	Threshold friction velocity	36.47	(cm/sec)
	Threshold speed (@7m)	6.44	(m/sec)
	x, variable for F(x)	1.14	
	F(x)	1.44	
	Particulate emission factor	1.39E+07	(m ³ /Kg)

SCREENING CRITERIA VALUES SPREADSHEET

Analyte/Compound	RfDo (mg/kg/day)	RfDi (mg/kg/day)	Sfo (kd-day/mg)	Sfi (kd-day/mg)	Koc (L/kg)	Henry's Const. (atm-m ³ /mol)	Vi (cm ³ /mol)	MW (g/mol)	Di (cm ² /sec)	Dei (cm ² /sec)	Kas (g/cm ³)	Alpha (cm ² /sec)	VF (m ³ /kg)
2-Methylnaphthalene	4.00E-02				9.40E+02	4.60E-04		142.2	5.90E-02	4.73E-03	3.34E-03	2.37E-06	2.99E+04
4,4'-DDD			2.40E-01		7.70E+05	2.20E-08		320	5.00E-02	4.01E-03	1.95E-10	1.17E-13	1.34E+08
4,4'-DDE			3.40E-01		4.40E+06	6.80E-05		318	5.00E-02	4.01E-03	1.06E-07	6.34E-11	5.78E+06
4,4'-DDT	5.00E-04		3.40E-01	3.40E-01	3.90E+06	1.58E-05		354.5	5.00E-02	4.01E-03	2.77E-08	1.66E-11	1.13E+07
Acenaphthene	6.00E-02				4.60E+03	9.10E-05		154.2	5.00E-02	4.01E-03	1.35E-04	8.12E-08	1.62E+05
Aldrin	3.00E-05		1.70E+01	1.70E+01	9.60E+04	1.60E-05		365	5.00E-02	4.01E-03	1.14E-06	6.84E-10	1.76E+06
Aluminum	1.00E+00							2.70E+01	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Anthracene	3.00E-01				1.40E+04	8.60E-05		178.2	5.00E-02	4.01E-03	4.20E-05	2.52E-08	2.90E+05
Aroclor			7.70E+00		5.30E+05	2.60E-03	2.65E+02	328.4	4.97E-02	3.99E-03	3.35E-05	2.00E-08	3.25E+05
Arsenic	3.00E-04		1.75E+00	1.51E+01				74.92	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Barium	7.00E-02	1.43E-04						137.34	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Benzo(a)anthracene			7.30E-01	6.10E-01	2.00E+05	1.00E-06		228.28	5.00E-02	4.01E-03	3.42E-08	2.05E-11	1.02E+07
Benzo(a)pyrene			7.30E+00	6.10E+00	5.50E+06	4.90E-07		252	5.00E-02	4.01E-03	6.09E-10	3.66E-13	7.61E+07
Benzo(b)fluoranthene			7.30E-01	6.10E-01	5.50E+05	1.22E-05		252.3	5.00E-02	4.01E-03	1.52E-07	9.10E-11	4.82E+06
Benzo(g,h,i)perylene					1.60E+06	1.44E-07		276	5.00E-02	4.01E-03	6.15E-10	3.69E-13	7.57E+07
Benzo(k)fluoranthene			7.30E-02	6.10E-02	5.50E+05	3.87E-05		252.3	5.00E-02	4.01E-03	4.81E-07	2.89E-10	2.71E+06
Beryllium	5.00E-03		4.30E+00	8.40E+00				9.01	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Bis(2-ethylhexyl)phthalate	2.00E-02		1.40E-02		2.00E+09	3.00E-07	4.93E+02	390.62	3.66E-02	2.94E-03	1.03E-12	4.50E-16	2.17E+09
Cadmium	5.00E-04			6.30E+00				112.4	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Carbazole			2.00E-02		1.00E+05	1.00E+06			5.00E-02	4.01E-03	6.83E+04	4.01E-03	7.10E-02
Chlordane	6.00E-05		1.30E+00	1.29E+00	1.40E+05	9.40E-05		409.8	5.00E-02	4.01E-03	4.59E-06	2.76E-09	8.77E+05
Chloroform	1.00E-02		6.10E-03	8.05E-02	4.40E+01	2.88E-03	7.70E+01	119.38	9.13E-02	7.32E-03	4.47E-01	4.59E-04	2.01E+03
Chromium (III)	1.00E+00	5.71E-07						52	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Chromium (VI)	5.00E-03			4.20E+01				52	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Chrysene			7.30E-03	6.10E-03	2.00E+05	1.05E-06		228.3	5.00E-02	4.01E-03	3.59E-08	2.15E-11	9.91E+06
Cobalt	6.00E-02							58.93	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Copper	3.71E-02							63.54	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Cyanide	2.00E-02								0.00E+00	0.00E+00	ERR	ERR	0.00E+00
Dibenzo(a,h)anthracene			7.30E+00	6.10E+00	3.30E+06	7.30E-08		278.4	5.00E-02	4.01E-03	1.51E-10	9.08E-14	1.53E+08
Dibenzofuran	4.00E-03				8.13E+03	1.00E-06			5.00E-02	4.01E-03	8.41E-07	5.05E-10	2.05E+06
Dieldrin	5.00E-05		1.60E+01	1.60E+01	1.70E+03	4.57E-10		381	5.00E-02	4.01E-03	1.84E-09	1.10E-12	4.38E+07
Di-n-butylphthalate	1.00E-01				1.70E+05	2.80E-07	3.09E+02	278.3	4.66E-02	3.74E-03	1.13E-08	6.29E-12	1.83E+07
Di-n-octylphthalate	2.00E-02				3.60E+09	1.70E-05		391	5.00E-02	4.01E-03	3.23E-11	1.94E-14	3.31E+08
Endosulfan	6.00E-03				9.60E-03	1.91E-05		406.9	5.00E-02	4.01E-03	1.36E+01	2.69E-03	2.92E+02
Endrin	3.00E-04				1.70E+03	4.00E-07		381	5.00E-02	4.01E-03	1.61E-06	9.65E-10	1.48E+06
Fluoranthene	4.00E-02				3.80E+04	6.50E-06		202.3	5.00E-02	4.01E-03	1.17E-06	7.02E-10	1.74E+06
Fluorene	4.00E-02				7.30E+03	6.40E-05		116.2	5.00E-02	4.01E-03	5.99E-05	3.60E-08	2.43E+05
Heptachlor epoxide	1.30E-05		9.10E+00	9.10E+00	2.20E+02	3.90E-04		389.2	5.00E-02	4.01E-03	1.21E-02	7.26E-06	1.70E+04
Indeno(1,2,3-cd)pyrene			7.30E-01	6.10E-01	1.60E+06	6.95E-08		276.3	5.00E-02	4.01E-03	2.97E-10	1.78E-13	1.09E+08
Lead								207.19	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Manganese	5.00E-03	1.43E-05						54.94	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Mercury	3.00E-04	8.57E-05						200.59	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Methylene chloride	6.00E-02	8.57E-01	7.50E-03	1.64E-03	8.80E+00	2.03E-03	5.95E+01	84.94	1.05E-01	8.43E-03	1.58E+00	1.61E-03	9.28E+02
Naphthalene	4.00E-02				9.40E+02	4.60E-04	1.40E+02	128.2	7.04E-02	5.65E-03	3.34E-03	2.83E-06	2.74E+04
Nickel	2.00E-02			8.40E-01				58.71	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
N-nitrosodiphenylamine			4.90E-03		6.48E+02	6.60E-04		198.2	5.00E-02	4.01E-03	6.96E-03	4.17E-06	2.25E+04
Phenanthrene					1.78E+04	3.93E-05		178E+02	5.00E-02	4.01E-03	1.51E-05	9.06E-09	4.83E+05
Pyrene	3.00E-02				3.80E+04	5.10E-06		202.3	5.00E-02	4.01E-03	9.17E-07	5.51E-10	1.96E+06
Selenium	5.00E-03							78.96	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Tetrachloroethene	1.00E-02		5.20E-02	2.03E-03	3.64E+02	1.53E-02	1.11E+02	165.83	7.62E-02	6.12E-03	2.87E-01	2.52E-04	2.78E+03
Thallium	7.00E-05							204.37	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Vanadium	7.00E-03							50.94	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00
Zinc	3.00E-01							65.37	0.00E+00	0.00E+00	0.00E+00	ERR	0.00E+00

SCREENING CRITERIA VALUES SPREADSHEET

Analyte/Compound	URF (ug/m3)-1	RIC (mg/m3)	Kd (l/kg)	Air Inh. SSLc (mg/kg)	Air Inh. SSLc (mg/kg)	Air Inh. SSLmin (mg/kg)	Soil Exp. Ing. SSLc (mg/kg)	Soil Exp. Ing. SSLc (mg/kg)	Soil Exp. Ing. SSLmin (mg/kg)	Groundwater MCLG/MCL/Cw (mg/l)
2-Methylnaphthalene	NA	NA	5.64E+00	NA	NA	NA	68133.333	NA	68133.333	6.8133
4,4'-DDD	NA	NA	4.62E+03	NA	NA	NA	NA	19.872	19.872	0.0020
4,4'-DDE	NA	NA	2.64E+04	NA	NA	NA	NA	14.027	14.027	0.0014
4,4'-DDT	9.71E-05	NA	2.34E+04	4.37E+02	NA	437.425	851.667	14.027	14.027	0.0014
Acenaphthene	NA	NA	2.76E+01	NA	NA	NA	102200.000	NA	102200.000	10.2200
Aldrin	4.86E-03	NA	5.76E+02	2.19E+00	NA	2.192	51.100	0.281	0.281	0.0000
Aluminum	NA	NA	1.50E+03	NA	NA	NA	*****	NA	1703333.333	0.0500
Anthracene	NA	NA	8.40E+01	NA	NA	NA	511000.000	NA	511000.000	51.1000
Aroclor	NA	NA	3.18E+03	NA	NA	NA	NA	0.619	0.619	0.0005
Arsenic	4.31E-03	NA	3.32E+00	2.20E+01	NA	22.013	511.000	2.725	2.725	0.0500
Barium	NA	5.01E-04	2.71E+01	NA	1.70E+04	16975.879	119233.333	NA	119233.333	2.0000
Benzo(a)anthracene	1.74E-04	NA	1.20E+03	2.30E+02	NA	229.728	NA	6.533	6.533	0.0001
Benzo(a)pyrene	1.74E-03	NA	3.30E+04	4.61E+01	NA	46.056	NA	0.653	0.653	0.0002
Benzo(b)fluoranthene	1.74E-04	NA	3.30E+03	1.40E+02	NA	140.089	NA	6.533	6.533	0.0002
Benzo(g,h,i)perylene	NA	NA	9.60E+03	NA	NA	NA	NA	NA	NA	need data
Benzo(k)fluoranthene	1.74E-05	NA	3.30E+03	8.86E+02	NA	886.497	NA	65.333	65.333	0.0002
Beryllium	2.40E-03	NA	5.00E+02	3.96E+01	NA	39.571	8516.667	1.109	1.109	0.0040
Bis(2-ethylhexyl)phthalate	NA	NA	1.20E+07	NA	NA	NA	34066.667	340.667	340.667	0.0341
Cadmium	1.80E-03	NA	6.69E+00	5.28E+01	NA	52.761	851.667	NA	851.667	0.0050
Carbazole	NA	NA	6.00E+02	NA	NA	NA	NA	238.467	238.467	0.0238
Chlordane	3.69E-04	NA	8.40E+02	1.52E+01	NA	15.248	102.200	3.669	3.669	0.0020
Chloroform	2.30E-05	NA	2.64E-01	5.96E-01	NA	0.596	17033.333	781.858	781.858	0.0800
Chromium (III)	NA	2.00E-06	2.21E+03	NA	6.78E+01	67.785	*****	NA	1703333.333	0.1000
Chromium (VI)	1.20E-02	NA	3.66E+01	7.91E+00	NA	7.914	8516.667	NA	8516.667	0.1000
Chrysene	1.74E-06	NA	1.20E+03	2.26E+04	NA	22649.312	NA	653.333	653.333	0.0002
Cobalt	NA	NA	5.46E+01	NA	NA	NA	102200.000	NA	102200.000	10.2200
Copper	NA	NA	2.22E+01	NA	NA	NA	63193.667	NA	63193.667	1.3000
Cyanide	NA	NA	need data	NA	NA	NA	34066.667	NA	34066.667	0.2000
Dibenzo(a,h)anthracene	1.74E-03	NA	1.98E+04	4.99E+01	NA	49.934	NA	0.653	0.653	0.0003
Dibenzofuran	NA	NA	4.88E+01	NA	NA	NA	6813.333	NA	6813.333	0.6813
Dieldrin	4.57E-03	NA	1.02E+01	1.58E+01	NA	15.761	85.167	0.298	0.298	0.0000
Di-n-butylphthalate	NA	NA	1.02E+03	NA	NA	NA	170333.333	NA	170333.333	17.0333
Di-n-octylphthalate	NA	NA	2.16E+07	NA	NA	NA	34066.667	NA	34066.667	3.4067
Endosulfan	NA	NA	5.76E-05	NA	NA	NA	10220.000	NA	10220.000	1.0220
Endrin	NA	NA	1.02E+01	NA	NA	NA	511.000	NA	511.000	0.0020
Fluoranthene	NA	NA	2.28E+02	NA	NA	NA	68133.333	NA	68133.333	6.8133
Fluorene	NA	NA	4.38E+01	NA	NA	NA	68133.333	NA	68133.333	6.8133
Heptachlor epoxide	2.60E-03	NA	1.32E+00	4.46E-02	NA	0.045	22.143	0.524	0.524	0.0002
Indeno(1,2,3-cd)pyrene	1.74E-04	NA	9.60E+03	4.83E+02	NA	483.128	NA	6.533	6.533	0.0004
Lead	NA	NA	9.95E+01	NA	NA	NA	NA	NA	NA	0.0150
Manganese	NA	5.01E-05	1.48E+02	NA	1.70E+03	1697.588	8516.667	NA	8516.667	0.0500
Mercury	NA	3.00E-04	1.00E+01	NA	1.02E+04	10173.656	511.000	NA	511.000	0.0020
Methylene chloride	4.69E-07	3.00E+00	5.28E-02	1.35E+01	6.77E+03	13.493	102200.000	635.911	635.911	0.0050
Naphthalene	NA	NA	5.64E+00	NA	NA	NA	68133.333	NA	68133.333	6.8133
Nickel	2.40E-04	NA	4.00E+02	3.96E+02	NA	395.708	34066.667	NA	34066.667	0.1000
N-nitrosodiphenylamine	NA	NA	3.89E+00	NA	NA	NA	NA	973.333	973.333	0.0973
Phenanthrene	NA	NA	1.07E+02	NA	NA	NA	NA	NA	NA	need data
Pyrene	NA	NA	2.28E+02	NA	NA	NA	51100.000	NA	51100.000	5.1100
Selenium	NA	NA	2.72E+00	NA	NA	NA	8516.667	NA	8516.667	0.0500
Tetrachloroethene-	5.80E-07	NA	2.18E+00	3.26E+01	NA	32.642	17033.333	91.718	91.718	0.0050
Thallium	NA	NA	1.50E+02	NA	NA	NA	119.233	NA	119.233	0.0005
Vanadium	NA	NA	2.00E+02	NA	NA	NA	11923.333	NA	11923.333	1.1923
Zinc	NA	NA	2.00E+02	NA	NA	NA	511000.000	NA	511000.000	5.0000

SCREENING CRITERIA VALUES SPREADSHEET

Analyte/Compound	Groundwater SSL (mg/Kg) DAF = 1.0	Groundwater SSL (mg/Kg) DAF = 10
2-Methylnaphthalene	39.133	391.3286
4,4'-DDD	9.181	91.8117
4,4'-DDE	37.033	370.3261
4,4'-DDT	32.824	328.2438
Acenaphthene	283.101	2831.0122
Aldrin	0.016	0.1616
Aluminum	75.005	750.0500
Anthracene	4297.544	42975.4411
Aroclor	1.590	15.9006
Arsenic	0.171	1.7100
Barium	54.400	544.0000
Benzo(a)anthracene	0.120	1.2001
Benzo(a)pyrene	6.600	66.0002
Benzo(b)fluoranthene	0.660	6.6002
Benzo(g,h,i)perylene	0.000	0.0000
Benzo(k)fluoranthene	0.660	6.6002
Beryllium	2.000	20.0040
Bis(2-ethylhexyl)phthalate	408800.003	4088000.0341
Cadmium	0.034	0.3395
Carbazole	185103.438	1851034.3827
Chlordane	1.680	16.8020
Chloroform	0.031	0.3091
Chromium (III)	221.010	2210.1000
Chromium (VI)	3.670	36.7000
Chrysene	0.240	2.4002
Cobalt	559.034	5590.3400
Copper	28.990	289.9000
Cyanide	0.020	0.2000
Dibenzo(a,h)anthracene	5.940	59.4003
Dibenzofuran	33.304	333.0358
Dieldrin	0.000	0.0031
Di-n-butylphthalate	17375.703	173757.0337
Di-n-octylphthalate	73584000.341	735840003.4112
Endosulfan	0.102	1.0241
Endrin	0.021	0.2060
Fluoranthene	1554.122	15541.2168
Fluorene	299.109	2991.0872
Heptachlor epoxide	0.000	0.0028
Indeno(1,2,3-cd)pyrene	3.840	38.4004
Lead	1.494	14.9400
Manganese	7.405	74.0500
Mercury	0.020	0.2020
Methylene chloride	0.001	0.0084
Naphthalene	39.133	391.3286
Nickel	40.010	400.1000
N-nitrosodiphenylamine	0.389	3.8866
Phenanthrene	0.000	0.0000
Pyrene	1165.591	11655.9120
Selenium	0.141	1.4100
Tetrachloroethene	0.012	0.1201
Thallium	0.075	0.7505
Vanadium	238.586	2385.8590
Zinc	1000.500	10005.0000

United States
Environmental Protection
Agency

Office of
Solid Waste and
Emergency Response

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Soil Screening Guidance

Office of Emergency and Remedial Response
Hazardous Site Control Division

Quick Reference Fact Sheet

NOTICE: This document is draft for review only and should not be used until the guidance is finalized following public comment and peer review.

BACKGROUND

On June 19, 1991, the U.S. Environmental Protection Agency's (EPA's) Administrator charged the Office of Solid Waste and Emergency Response (OSWER) with conducting a 30-day study to outline options for accelerating the rate of cleanups at National Priorities List (NPL) sites. One of the specific proposals of the study was for OSWER to "examine the means to develop standards or guidelines for contaminated soils."

On June 23, 1993, EPA announced the development of "Soil Trigger Levels" as one of the Administrative Improvements to the Superfund program. On September 30, 1993, a draft fact sheet was released that presented generic Soil Screening Levels (SSLs) for 30 chemicals. The fact sheet presented standardized equations to model exposures to soil contaminants via ingestion, inhalation, and migration to ground water. The fact sheet provided generic defaults for each parameter in the equations and a sampling methodology to measure soil contaminant levels. The SSL initiative underwent widespread review both within and outside the Agency. Suggestions were made on how to improve the methodology and increase the usefulness of screening levels by finding simple ways to modify them using site-specific data.

Based on that review, EPA modified the SSLs into a Soil Screening framework that emphasizes the application of standardized equations for the site-specific evaluation of soil contaminants. This framework provides an overall approach for developing SSLs for specific contaminants and exposure pathways at a site under a residential land use scenario. Areas with soil contaminant concentrations below SSLs generally would not warrant further study or action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The Soil Screening framework's point of departure is a simple methodology for calculating site-specific SSLs using easily obtained site data with standardized equations. An option for conducting a more detailed site-specific analysis is also included in the framework. In addition, default parameters are

used in the standardized equations to produce a table of generic Soil Screening Levels for 107 chemicals that update those presented in the September 30, 1993, draft SSL fact sheet. These generic SSLs are included in the framework as a default option for use when site-specific values are not available.

PURPOSE OF SOIL SCREENING FRAMEWORK

The Soil Screening framework represents the first of several tools EPA plans to develop to standardize the evaluation and cleanup of contaminated soils. SSLs streamline the remedial investigation/feasibility study (RI/FS) process by accelerating and increasing consistency in decisions concerning soil contamination. As a future companion to the Soil Screening framework, EPA also intends to develop a methodology to identify levels of contamination that clearly warrant a response action or, possibly, concentrations for which treatment would be required. The screening levels at the low end and the higher concentration values that warrant response can be used to identify the bounds of a risk management continuum (Figure 1). Generally, within this continuum lies a range of possible cleanup levels that will continue to be determined on a site-specific basis.

EPA anticipates the use of the Soil Screening framework as a tool to facilitate prompt identification of the contaminants and exposure areas of concern during both remedial actions and some removal actions under CERCLA. SSLs do not trigger

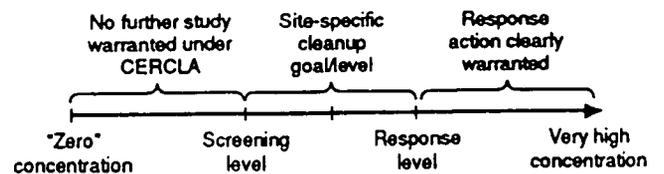


Figure 1. Risk management spectrum for contaminated soil.

the need for response actions or define "unacceptable" levels of contaminants in soil. SSLs may serve as Preliminary Remediation Goals (PRGs) under certain conditions (see section on Use of SSLs as Preliminary Remediation Goals/Cleanup Levels). In the future, EPA will consider expanding the guidance to address the Resource Conservation and Recovery Act (RCRA) Corrective Action program.

The SSLs are, as noted above, intended for use as a tool; their use is not mandatory at sites being addressed under CERCLA. The framework leaves a broad range of discretion to the site manager, both on whether the SSL approach is appropriate for a site and, if it is used, on the appropriate method. This guidance anticipates three optional approaches—simple site-specific, detailed site-specific, and generic. In the first two, some or all default values would be replaced as appropriate with site-specific data. Furthermore, the models themselves are not codified as rules and can be modified if appropriate, although some explanation should be provided if such modification is made.

SOIL SCREENING FRAMEWORK

A Soil Screening Level is a chemical concentration in soil that represents a level of contamination below which there is no concern under CERCLA, provided conditions associated with the SSLs are met. Generally, if contaminant concentrations in soil fall below the SSL, and there are no significant ecological receptors of concern, then no further study or action is warranted for residential use of that area. (Some States have developed screening numbers that are more stringent than the generic SSLs presented in this fact sheet; therefore further study may be warranted under State programs.) Concentrations in soil above either the generic or site-specific screening level would not automatically designate a site as "dirty" or trigger a response action. However, exceeding a screening level suggests that a further evaluation of the potential risks that may be posed by site contaminants is appropriate to determine the need for a response action.

The Soil Screening framework presents three approaches for establishing screening levels. The option emphasized in this Fact Sheet is a simple method that incorporates readily obtainable, site-specific data into standardized equations to derive site-specific screening levels for selected contaminants. When questions still exist at a site regarding whether or not contaminant levels are of concern, as a second approach, more tailored screening levels can be derived for most contaminants by incorporating additional site data into more complex fate and transport models. The third approach is to apply the generic SSLs presented in Appendix A. Although the default parameters used to derive the generic SSLs are not necessarily "worst case," they are conservative.

The progression from generic to simple site-specific and detailed (full-scale) site-specific SSLs usually will involve an increase in investigation costs and a decrease in conservatism (Figure 2). Generally, the decision of which method to use

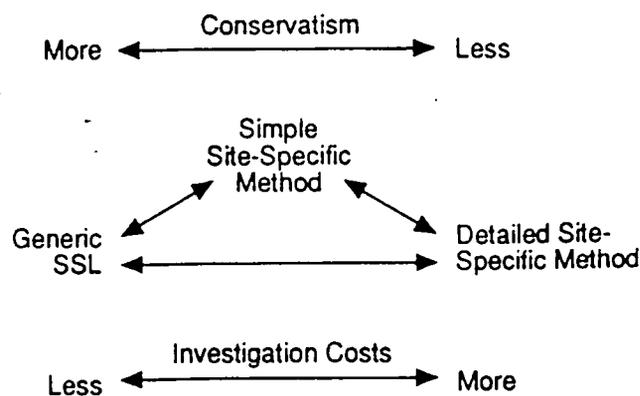


Figure 2. Components of the Soil Screening framework.

involves balancing the increased investigation costs with the potential savings associated with higher (but protective) SSLs. Therefore, the framework promotes the option of using site-specific data to derive screening levels. More guidance regarding which option to use is presented later in this fact sheet.

Site-Specific SSLs: Simple Method

The simple method for developing site-specific SSLs requires the collection of a small number of easily obtained site parameters (e.g., fraction organic carbon, percent soil moisture, and dry bulk density) for use in the standardized equations so that the calculated screening levels can be appropriately conservative for the site but not as conservative as the generic values. Once derived, the user then compares measured site or area contaminant concentrations to the site-specific screening levels. If concentrations do not exceed the SSLs for each pathway of concern, it would generally be appropriate to exclude the area from further investigation. If the levels are exceeded, the site manager may decide that a more comprehensive evaluation is needed to determine the risk posed via a particular exposure pathway (see Technical Background section).

Site-Specific SSLs: Detailed Approach

A more detailed method for developing site-specific SSLs is a full-scale model evaluation requiring the collection of additional site data. Full-scale modeling allows the application of complex transport and fate models and allows for consideration of a finite contaminant source. Applying these models will further define the risk associated with exposure via the inhalation or migration to ground water pathway. The model application may show that there is no concern over exposure from the pathway, thereby eliminating it from further concern. This potential outcome provides the incentive for incurring the cost and time to conduct a comprehensive site evaluation.

Generic SSLs

Generic SSLs can be used in place of site-specific screening levels. The decision to use generic SSLs will likely be driven by time and cost. The site manager must weigh the cost of conducting a more site-specific investigation with the potential for deriving a higher SSL that provides for an appropriate level of protection. The Technical Background section of this guidance presents a more detailed discussion of the level of effort required to conduct further study of site conditions and risks. Appendix A provides generic SSLs for 107 chemicals.

SCOPE OF SOIL SCREENING FRAMEWORK

The Soil Screening framework has been developed for 107 chemicals using assumptions for residential land use activities for three pathways of exposure (see Figure 3):

- Ingestion of soil
- Inhalation of volatiles and fugitive dusts
- Ingestion of contaminated ground water caused by migration of chemicals through soil to an underlying potable aquifer.

Reviews of risk assessments at hazardous waste sites indicate that these pathways are the most common routes of human exposure to contaminants in the residential setting. These are also the pathways for which generally accepted methods, models, and assumptions have been developed that lend themselves to a standardized approach. Data on dermal exposures have also been considered, and the generic SSL for

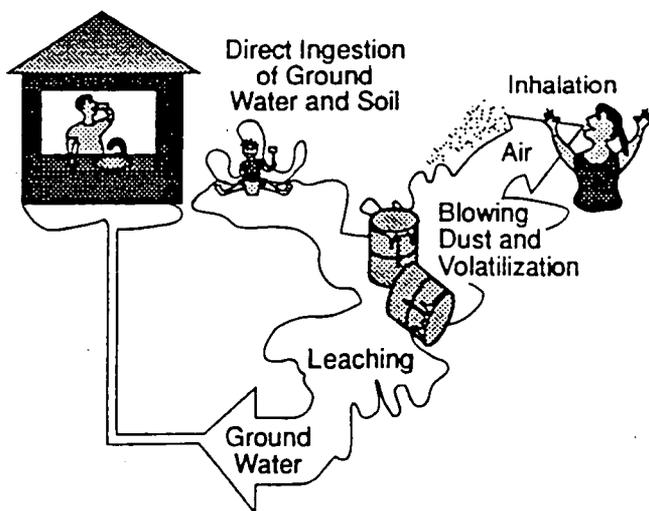


Figure 3. Exposure pathways addressed by the Soil Screening framework.

Highlight 1: Key Attributes of the SSL Framework

- Standardized equations are presented to address three individual human exposure pathways.
- Parameters are identified for which site-specific information is needed to develop site-specific SSLs.
- Default values are provided and used to calculate generic SSLs that are consistent with Superfund's concept of "Reasonable Maximum Exposure" (RME).
- SSLs are generally based on a 10^{-6} risk for carcinogens, or a hazard quotient of 1 for noncarcinogens. SSLs for migration to ground water are based on nonzero maximum contaminant level goals (MCLGs), or, when not available, maximum contaminant levels (MCLs). Where neither of these are available, the aforementioned risk-based targets are used.

pentachlorophenol has been modified accordingly. The scope of the SSL framework is limited to human exposure via the pathways listed above; therefore, sites with other significant exposure pathways, nonresidential land uses, possible ecological concerns, or unusual site conditions should consider their associated risks on a site-specific basis apart from the SSL framework. Key attributes of the Soil Screening framework are given in Highlight 1.

Soil Ingestion Pathway

For the direct soil ingestion pathway, only generic SSLs were developed. Simple and full-scale site-specific methods were not developed because cost and complexity make developing site-specific data for this pathway, such as soil ingestion rates or chemical-specific bioavailability, generally impracticable. However, EPA is evaluating the data available to support adjustment of the exposure frequency term based on regional climatic conditions.

Inhalation Pathway

For inhalation of volatiles and fugitive dust, both generic values and a method for incorporating site-specific data into the standardized equations have been developed. To estimate the site-specific potential for volatilization of contaminants, soil conditions such as fraction organic carbon, soil moisture content, and dry bulk density must be evaluated. To estimate the site-specific potential for generation of fugitive dusts, other parameters must be evaluated, such as mean annual windspeed, threshold friction velocity, and the mode soil aggregate size to further tailor the SSLs to the site. For both the inhalation of volatiles and fugitive dust pathways, a site-specific determination of the area of contamination and meteorologic inputs can be incorporated into dispersion calculations.

Migration to Ground Water

The simple site-specific method for addressing potential contaminant migration to ground water uses the same soil parameters required to address volatilization, along with easily obtainable hydrogeologic parameters. The simple site-specific method for this exposure pathway also requires a determination of the area of contamination.

Other Pathways

Additional exposure pathways to contaminants in soil—dermal absorption, plant uptake, and migration of volatiles into basements—may contribute significantly to the risk to human health in a residential setting. The Superfund program has evaluated the data and methods available to address these potential exposures and has incorporated as much information as possible into the SSL framework.

Based on limited empirical data, the ingestion SSL for pentachlorophenol has been adjusted to account for potential dermal exposure. Additionally, empirical data indicate that plant uptake may be important for some chemicals (i.e., As, Cd, Hg, Ni, Se, Zn). The fact that these chemicals' potential for plant uptake and dermal absorption has been noted in Appendix A should not be misinterpreted to mean that other chemicals are not of potential concern for dermal exposure or plant uptake. As additional information becomes available, other chemicals may be addressed as well.

At this time, Superfund does not believe that the potential for migration of contaminants into basements can be reasonably incorporated into the SSL framework. The parameters required for the models (e.g., the number and size of cracks in basement walls) do not lend themselves to standardization or to evaluation of potential future exposure, and the models have not been adequately validated. The Technical Background Document (U.S. EPA, 1994e) provides a detailed analysis of available modeling of this pathway.

Other Land Uses

Longer-term efforts will be required to develop standardized tools to address exposures relevant to other land uses such as industrial land use. The results of these efforts may be included in future revisions of this guidance.

Ecological Receptors

As part of the baseline risk assessment, an ecological assessment should be conducted at every Superfund site. The SSL framework does not attempt to define significant ecological receptors or quantify ecological risks. However, a comparable list of screening level benchmarks, called Ecotox Thresholds, is being developed by Office of Emergency and Remedial Response (OERR) for application during the ecological risk assessment addressed in OSWER Directive No. 9285.7-17 (U.S. EPA, 1994d). These values are defined as media-

specific chemical concentrations above which there is sufficient concern regarding adverse effects to ecological receptors to warrant further site investigation. OERR is developing guidance on designing and conducting ecological risk assessments that will describe the use of such screening values in the Superfund Remedial Investigation process.

HOW TO USE THE SOIL SCREENING FRAMEWORK

The decision to use the Soil Screening framework at a site will be driven by the potential benefits of eliminating areas, exposure pathways, or contaminants from further investigation. By identifying areas where concentrations of contaminated soil are below levels of concern under CERCLA, the framework provides a means to focus resources on exposure areas, contaminants, and exposure pathways of concern.

Highlight 2 outlines the process of applying the Soil Screening framework at a site. To enable early comparison with site background concentrations and to provide information necessary for determining an adequate sample size, site-specific SSLs should be developed as early in the process as possible. They can be adjusted during the process to accommodate additional site information and the resulting changes to the conceptual site model.

Developing a Conceptual Site Model

The primary condition for use of SSLs is that exposure pathways of concern and conditions at the site match those taken into account by the Soil Screening framework. Thus, at all sites it will be necessary to develop a conceptual site model to identify likely contaminant source areas, exposure pathways, and potential receptors. This information can be used to

Highlight 2: Using the Soil Screening Framework

- Develop site conceptual model and compare with SSL conceptual model to determine applicability of framework.
- Determine if background contaminant concentrations are above generic SSLs.
- Select approach (simple or detailed site-specific, generic) and develop SSLs.
- Measure average soil contaminant concentrations in exposure areas (EAs) of concern.
- Compare average soil concentrations with SSLs and eliminate site or area of site where EA mean concentration is less than SSL.
- Consider further study or use of SSLs as PRGs for sites or site areas with contaminant concentrations greater than SSLs.

determine the applicability of the framework at the site and the need for additional information.

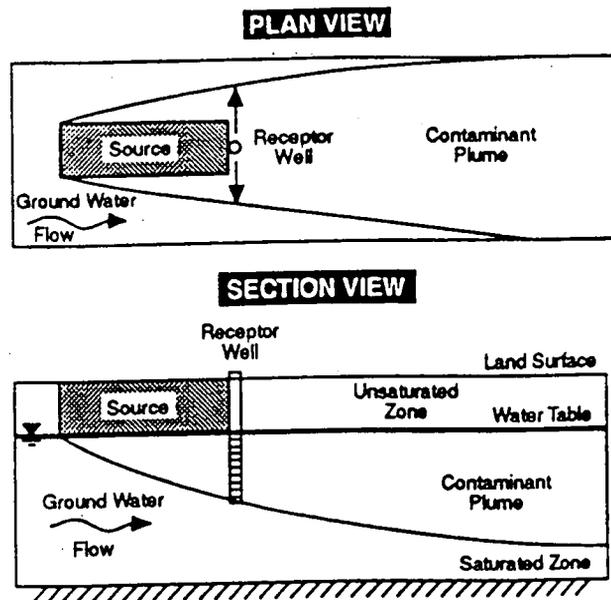
A conceptual site model is developed from available site sampling data, historical records, aerial photographs, and hydrogeologic information. The model establishes a hypothesis about possible contaminant sources, contaminant fate and transport, exposure pathways, and potential receptors. The DQO Guidance for Superfund (U.S. EPA, 1993a) provides an excellent discussion on the development of a conceptual site model. The rationale for including the contaminant migration to ground water exposure pathway should be consistent with EPA ground water policy (U.S. EPA, 1988, 1990b, 1992a, 1992b, 1993b).

The conceptual model upon which the generic SSLs are based is a 30-acre property that has been divided up for residential use. Thus, the generic SSLs have been developed to be protective for source areas up to 30 acres. The contamination is assumed to be evenly distributed across the area of concern and extends from the ground surface to the top of the aquifer. The soil type is assumed to be loam that has 50 percent vegetative cover. Loam is soil with approximately equal proportions of sand and silt. Exposure to contaminants can occur via ingestion of soils, inhalation of volatiles and fugitive dusts, or migration to ground water.

For the migration to ground water pathway, the point of compliance is assumed to be at the edge of the site, which is assumed to be homogeneously contaminated. No attenuation is considered in the unsaturated zone; however, dilution is assumed within the aquifer to the point of compliance. For the generic conceptual site model, the source is assumed to extend across the entire site. See Figures 3 and 4 for a graphic representation of aspects of the conceptual model applicable to the Soil Screening framework.

Partitioning of contaminant mass between media is not addressed in the SSL framework because the fate and transport models used to derive the generic SSLs are based on the assumption of an infinite source. Although the assumption is highly conservative, a finite source model cannot be applied unless there are accurate data regarding source size and volume. Obviously, in the case of the generic SSLs, such data are not available. It is also unlikely that such data will be available from the limited subsurface sampling that is done to apply the simple site-specific method. Thus, it is most likely that a finite source model would be applied as part of a detailed site-specific investigation. EPA will continue to seek consensus on the appropriate methods to incorporate contaminant partitioning and a finite source into the simple site-specific method. The results of these efforts may be included in future updates to this guidance.

The Technical Background Document (U.S. EPA, 1994e) presents information on equations and models that can accommodate finite sources and predict the subsequent impact on either ambient air or ground water. However, when using



Default assumptions:

- Infinite source
- Source extends to water table
- Well at downgradient edge of source
- 30-acre source size

Figure 4. Migration to ground water pathway—SSL conceptual model.

a finite source model, the site manager should recognize the uncertainties inherent in site-specific estimates of subsurface contaminant distributions and use conservative estimates of source size and concentrations to allow for such uncertainties.

The following questions should always be considered in the development of the conceptual site model before applying the Soil Screening framework:

- Is the site adjacent to surface waterbodies where the potential for contamination of surface water by overland flow or release of contaminated ground water should be considered?
- Are there potential terrestrial or aquatic ecological concerns?
- Is there potential for land use other than residential?
- Are there other likely human exposure pathways that were not considered in development of the SSLs (e.g., local fish consumption; raising of beef, dairy, or other livestock)?
- Are there unusual site conditions (e.g., area of contamination greater than 30 acres, unusually high fugitive dust levels due to soil being tilled for agricultural use, or heavy traffic on unpaved roads)?

If the conceptual site model indicates that residential assumptions are appropriate for your site and no pathways of concern other than those covered by the Soil Screening framework are present, then the framework may be applied directly to the site. If the conceptual site model indicates that the site is more complex than the scenario outlined in this guidance, the framework above will not be sufficient. Additional pathways, receptors, or chemicals must be evaluated on a site-specific basis.

Considering Background Contamination

A necessary step in determining the usefulness of the SSL framework is the consideration of background contaminant concentrations, since the framework will have little utility where background concentrations exceed the SSLs.

EPA may be concerned with two types of background at sites: naturally occurring and anthropogenic. Natural background is usually limited to metals whereas anthropogenic (i.e., human-made) background includes both organic and inorganic contaminants.

Generally, EPA does not clean up below natural background; however, where anthropogenic background levels exceed SSLs and EPA has determined that a response action is necessary and feasible, EPA's goal will be to develop a comprehensive response to the widespread contamination. This will often require coordination with different authorities that have jurisdiction over other sources of contamination in the area (such as a regional air board or RCRA program). This will help avoid response actions that create "clean islands" amid widespread contamination. The background information and understanding of the site developed as part of the conceptual model can help determine background concentration.

When considering background, one should also consider the bioavailability and mobility of compounds. Some compounds may form complexes that are immobile and unlikely to cause significant risk. This situation is more likely to occur with naturally occurring compounds. Therefore, background concentrations of compounds exceeding the SSLs do not necessarily pose a threat. Alternately, activities at a site can adversely affect the natural soil geochemistry, resulting in the mobilization of compounds. Consequently, background contamination should be considered carefully. Regardless, where background concentrations are higher than the SSLs, the SSLs generally will not be the best tool for site decisionmaking.

Sampling Exposure Area

After the conceptual site model has been developed, and the applicability of the Soil Screening framework is determined, the next step is to collect a representative sample set for each exposure area. An exposure area is defined as that geographic area in which an individual may be exposed to contamination over time. Because SSLs are developed for a residential scenario, EPA assumes the exposure area is a 0.5-acre residential lot.

In those situations where little or no sampling has been done, it will be beneficial to collect the site data required for the simple site-specific methodology in tandem with the collection of samples to identify contaminant concentrations. The site manager should work to limit the total number of trips to the site by maximizing the usefulness of the samples collected. (See section on Measuring Contaminant Concentrations in Soil for additional guidance.)

Comparing Exposure Area Concentration to SSLs

The fourth step is to compare onsite soil contaminant concentrations with site-specific SSLs or the generic SSLs listed in Appendix A. At this point, it is reasonable to review the conceptual site model with the actual site data in hand to reconfirm the accuracy of the conceptual site model and the applicability of the Soil Screening framework. Once this is confirmed, site contaminant levels may be compared with the SSLs.

In Appendix A, the first column to the right of the chemical name presents levels based on direct ingestion of soil. The second column presents the levels based on inhalation of volatiles or soil particulates. The third column presents SSL values for the migration to ground water pathway multiplied by a dilution and attenuation factor (DAF) of 10 to account for natural processes that reduce contaminant concentrations in the subsurface. The fourth column contains the SSL multiplied by a DAF of 1, which may be appropriate to use in instances where there are high water tables, karst topography, fractured bedrock, or source size greater than 30 acres. The lowest SSL of the three pathways (ingestion, inhalation, and ground water with DAF of 10) is highlighted in bold for each contaminant.

Generally, the comparison of SSLs to site contaminant levels will result in one of three outcomes:

1. Site-measured values indicate that an area falls below all of the SSLs. Soils from these areas of the site generally can be eliminated from further evaluation under CERCLA.
2. Site-measured data indicate that one or more SSLs have clearly been exceeded. In this case, the SSLs have helped to identify site areas, contaminants, and exposure pathways of potential concern on which to focus further analysis or data-gathering efforts.
3. A site-measured value exceeds one pathway-specific value but not others. In this case, it is reasonable to focus additional site-specific data collection efforts only on data that will help determine whether there is truly a risk posed via that pathway or by a limited set of chemicals at the site. When an exceedance is marginally significant, a closer look at site-specific conditions and exposures may result in the area being eliminated from further study.

Use of SSLs as Preliminary Remediation Goals/Cleanup Levels

SSLs are not nationwide cleanup levels or standards. Where the basis for response action exists and all exposure pathways of concern are addressed by the SSLs, the SSLs may serve as PRGs as defined in HHEM, Part B (U.S. EPA, 1991d). A PRG is a strictly risk-based value that serves as the point of departure for the establishment of site-specific cleanup levels. PRGs are modified to become final cleanup levels based on a consideration of the nine-criteria analysis described in the National Contingency Plan (NCP, Section 300.430 (3)(2) (i)(A)), including cost, long-term effectiveness, and implementability. See *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (U.S. EPA, 1991e) for guidance on how to modify PRGs to generate cleanup levels.

The SSLs should only be used as site-specific cleanup levels when a nine-criteria evaluation using the SSLs as PRGs for soils indicates that a selected remedy achieving the SSLs is protective, ARAR-compliant, and appropriately balances the other criteria, including cost. An example is a small site or exposure area where the cost of additional study would exceed the cost of remediating to the generic SSLs.

Addressing Exposure to Multiple Chemicals

The SSLs generally correspond to a 10^{-6} risk level for carcinogens and a hazard quotient (HQ) of 1 for noncarcinogens. This "target" hazard quotient is used to calculate a soil concentration below which it is unlikely for even sensitive populations to experience adverse health effects. The potential for additive effects has not been "built in" to the SSLs through apportionment. For carcinogens, EPA believes that setting a 10^{-6} risk level for individual chemicals and pathways generally will lead to cumulative risks within the 10^{-4} to 10^{-6} risk range for the combinations of chemicals typically found at Superfund sites.

For noncarcinogens, there is no widely accepted risk range. Thus, for developing national screening levels, options are either (1) to set the risk level for individual contaminants at the RfD or RfC (i.e., a hazard quotient of 1), or (2) to set chemical-specific concentrations by apportioning risk based on some arbitrarily chosen fraction of the acceptable risk level (e.g., one-fifth or one-tenth the RfD or RfC). The Agency believes, and EPA's Science Advisory Board agrees (U.S. EPA, 1993d), that noncancer risks should be added only for those chemicals with the same toxic endpoint or mechanism of action.

Highlight 3 lists the chemicals from Appendix A that have SSLs based on noncarcinogenic toxicity and affect the same target organ. If more than one chemical detected at a site affects the same target organ (i.e., has the same critical effect as defined by the RfD methodology), site-specific SSLs for each chemical in the group should be divided by the number of chemicals present. The concentration of contaminants at the

Highlight 3: SSL Chemicals with Noncarcinogenic Toxic Effects on Specific Target Organs

Kidney	Circulatory System
Acetone	Antimony
1,1-Dichloroethane	Barium
Dimethyl phthalate	p-Chloroaniline
2,6-Dinitrotoluene	cis-1,2-Dichloroethylene
Di-n-octyl phthalate	Nitrobenzene
Nitrobenzene	Zinc
2,4,5-Trichlorophenol	Reproductive System
Vinyl acetate	Carbon disulfide
Liver	2-Chlorophenol
Acetone	1,2,4-Trichlorobenzene
Chlorobenzene	Gross Pathology
Di-n-octyl phthalate	Diethyl phthalate
Nitrobenzene	2-Methylphenol
2,4,5-Trichlorophenol	Naphthalene
Central Nervous System	Nickel
Butanol	Vinyl acetate
2,4-Dichlorophenol	
2,4-Dinitrotoluene	
2,6-Dinitrotoluene	
2-Methylphenol	

site should then be compared to the SSLs that have been modified to account for this potential additivity.

Because the combination of contaminants will vary from site to site, apportioning risk to account for potential additive effects could not be considered in the development of generic SSLs. Furthermore, for certain noncarcinogenic organics (e.g., ethylbenzene, toluene), the generic SSLs are not based on toxicity but are determined instead by a "ceiling limit" concentration (C_{sat}) at which these chemicals may occur as nonaqueous phase liquids (NAPLs) in soil (see Technical Background section). For these reasons, the potential for additive effects and the need to apportion risk must be a site-specific determination.

TECHNICAL BACKGROUND

The models and assumptions supporting the Soil Screening framework were developed to be consistent with Superfund's concept of "reasonable maximum exposure" (RME) in the residential setting. The *Risk Assessment Guidance for Superfund, Volume 1* (U.S. EPA, 1989b) and the *Standard Default Exposure Factors* guidance (U.S. EPA, 1991b) outlined the Superfund program's approach to calculating an RME. Since that time, the Agency (U.S. EPA, 1991a) has coined a new term that the Superfund program believes corresponds to the definition of RME: "high-end individual exposure."

The Superfund program's method to estimate the RME for chronic exposures on a site-specific basis is to combine an average exposure point concentration with reasonably

conservative values for intake and duration in the exposure calculations. The default intake and duration assumptions are presented in the *Standard Default Exposure Factors* guidance (U.S. EPA, 1991b). The duration assumptions were chosen to represent individuals living in a small town or other nontransient community. (Exposure to members of a more transient community is assumed to be shorter and thus associated with lower risk.) Exposure point concentrations are either measured at the site (e.g., ground water concentrations at a receptor well) or estimated using exposure models with site-specific model inputs. An average concentration term is used in most assessments where the focus is on estimating long-term, chronic exposures. Where the potential for acute toxicity is of concern, exposure estimates based on maximum concentrations may be more appropriate.

The resulting site-specific estimate of RME is then compared with chemical-specific toxicity criteria such as RfDs or RfCs. EPA recommends using criteria from the Integrated Risk Information System (IRIS) (U.S. EPA, 1994c) and Health Effects Assessment Summary Tables (HEAST) (U.S. EPA, 1993c), although values from other sources may be used in appropriate cases.

The Soil Screening framework differs from a site-specific estimate of risk in that the exposure equations and models are run in reverse to backcalculate to an "acceptable level" of contaminant in soil. Toxicity criteria are used to define the acceptable level: a level corresponding to a 10^{-6} risk for carcinogens and a hazard quotient of 1 for noncarcinogens. The concept of backcalculating to an acceptable level in soil was presented in RAGS Part B (U.S. EPA, 1991d), and the Soil Screening framework serves to update Part B for addressing residential soils. Site-specific SSLs are consistent with the Superfund approach to estimating RME on a site-specific basis. Standard default factors are used for the intake and duration assumptions, site-specific inputs are used in the exposure models, and chemical-specific concentrations averaged over the exposure area are used for comparison to the SSLs.

Consistent with the site-specific SSLs, the generic SSLs use the same intake and duration assumptions and are compared to area average concentrations. However, the generic SSLs are based on a hypothetical site model. In developing the parameters for the hypothetical site, the Superfund program considered the conservatism inherent in the exposure models (e.g., assumption of an infinite source) and then combined high-end and central tendency parameters for size, location, and soil characteristics. The resulting generic SSLs should be protective for most site conditions across the Nation.

OERR performed a sensitivity analysis to determine which parameters most influenced the output of the volatilization and fugitive dust models used to calculate SSLs for the inhalation pathway. For fugitive dusts, the particulate emission factor (PEF) was most sensitive to threshold friction velocity, which was set at a "high-end" value. For calculation of the

volatilization factor (VF), soil moisture content was set at a conservative value because it drives the air-filled soil porosity that in turn provides the pathway for chemicals to volatilize from soils. Climatic conditions have a significant impact on dispersion of both volatile and particulate emissions and were set at high-end values to be protective for conditions at most sites. Different high-end meteorological data sets were selected to calculate 90th percentile dispersion coefficients for the VF and for the PEF.

For the migration of contaminants from soils to ground water, only average soil conditions are used to calculate generic SSLs because of the conservatism inherent in the partition equation. The generic DAF for this pathway was developed using a weight of evidence approach to be protective under most hydrogeologic conditions across the country as described in the following section on the migration to ground water.

Characteristics of the generic, hypothetical site used to develop generic SSLs were described previously in the section discussing the conceptual site model. The Technical Background Document (U.S. EPA, 1994e) accompanying this guidance describes the pathway-specific equations, assumptions, and methodology that form the basis for both the simple site-specific approach and the generic SSLs. The Technical Background Document also describes development of the specific default input values used to calculate generic SSLs for the inhalation and migration to ground water pathways.

The generic SSLs are based on default assumptions. EPA recognizes that site-specific conditions may differ significantly from these default assumptions. The Soil Screening framework emphasizes the substitution of some of the generic fate and transport assumptions with site-specific data to derive site-specific SSLs. However, one purpose of the SSLs is to define a level in soil below which no further study or action would be required. Therefore, alternative levels that are set using site-specific data should generally be calculated assuming the RME/"high-end" individual exposure.

The following sections present the standardized equations and default assumptions that form the basis for the simple site-specific methodology and the generic SSLs. The soil ingestion discussion is limited to default assumptions because only generic SSLs have been developed for this pathway.

Direct Ingestion

Agency toxicity criteria for noncarcinogens establish a level of daily exposure that is not expected to cause deleterious effects over a lifetime (i.e., 70 years). Depending on the contaminant, however, exceeding the RfD (i.e., the "acceptable" daily level) for a short period of time may be cause for concern. For example, if there is reason to believe that exposure to soil may be higher at a particular stage of an individual's lifetime, one would need to protect for that shorter period of high exposure. Because a number of studies have shown that inadvertent

ingestion of soil is common among children age 6 and younger (Calabrese et al., 1989; Davis et al., 1990; Van Wijnen et al., 1990), the SSLs in the default option are set at concentrations that are protective of this increased exposure during childhood by ensuring that the chronic reference dose (or RfD) is not exceeded during this shorter (6-year) time period (Equation 1). If there is reason to believe that exposures at a site may be significant over a short period of time (e.g., extensive soil excavation work in a dry region), depending on the contaminant, the site manager should consider the potential for acute health effects as well.

Equation 1: Screening Level Equation for Ingestion of Noncarcinogenic Contaminants in Residential Soil	
$\text{Screening Level (mg/kg)} = \frac{\text{THQ} \times \text{BW} \times \text{AT} \times 365 \text{ d/yr}}{1/\text{RfD}_o \times 10^{-6} \text{ kg/mg} \times \text{EF} \times \text{ED} \times \text{IR}}$	
Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
BW/body weight (kg)	15
AT/averaging time (yr)	6 ^a
RfD _o /oral reference dose (mg/kg-d)	chemical-specific
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	6
IR/soil ingestion rate (mg/d)	200
^a For noncarcinogens, averaging time is equal to exposure duration.	

In some cases, children may ingest large amounts of soil (i.e., 3 to 5 grams) in a single event. This behavior, known as pica, may result in relatively high short-term exposures to contaminants in soils. Such exposures may be of concern for contaminants that primarily exhibit acute health effects. Review of clinical reports on contaminants addressed in this guidance suggests that acute effects of cyanide and phenol may be of concern in children exhibiting pica behavior. If soils containing cyanide and phenol are of concern and pica behavior is expected at a site, the protectiveness of the ingestion SSLs for these chemicals should be reconsidered.

For carcinogens, both the magnitude and duration of exposure are important. Duration is critical because the toxicity criteria are based on "lifetime average daily dose." Therefore, the total dose received, whether it be over 5 years or 50 years, is averaged over a lifetime of 70 years. To be protective of exposures to carcinogens in the residential setting, OERR focuses on exposures to individuals who may live in the same residence for a "high-end" period of time (i.e., 30 years). As mentioned previously, exposure to soil is higher during childhood and decreases with age. Thus, Equation 2 uses a time-weighted average soil ingestion rate for children and adults. The derivation of this time-weighted average is presented in U.S. EPA (1991d).

Equation 2: Screening Level Equation for Ingestion of Carcinogenic Contaminants in Residential Soil	
$\text{Screening Level (mg/kg)} = \frac{\text{TR} \times \text{AT} \times 365 \text{ d/yr}}{\text{SF}_o \times 10^{-6} \text{ kg/mg} \times \text{EF} \times \text{IF}_{\text{soil/adj}}}$	
Parameter/Definition (units)	Default
TR/target cancer risk (unitless)	10 ⁻⁶
AT/averaging time (yr)	70
SF _o /oral slope factor (mg/kg-d) ⁻¹	chemical-specific
EF/exposure frequency (d/yr)	350
IF _{soil/adj} /age-adjusted soil ingestion factor (mg-yr/kg-d)	114

Inhalation of Volatiles and Fugitive Dusts

Agency toxicity data indicate that risks from exposure to some chemicals via inhalation far outweigh the risks via ingestion. The models and assumptions used to calculate SSLs for inhalation of volatiles and fugitive dusts are updates of the equations presented in U.S. EPA's HHEM Part B guidance (U.S. EPA, 1991d). The volatilization factor (VF), soil saturation limit (C_{sat}), particulate emission factor (PEF), and dispersion model have all been revised.

Another change from the Part B methodology is the separation of the ingestion and inhalation pathways. Toxicity criteria for oral exposures are presented as administered doses in units of milligrams per kilograms per day (mg/kg-d); whereas, the inhalation criteria are presented as concentrations in air (µg/m³ or mg/m³) that require conversion to an estimate of internal dose to be comparable to the oral route. EPA's Office of Research and Development (ORD) now believes that the conversion from concentration in air to internal dose is not always appropriate and suggests evaluating these exposure routes separately.

As explained in HHEM Part B, the basic principle of the volatilization model is applicable only if the soil concentration is at or below soil saturation (C_{sat}). Above this level the model cannot predict an accurate VF. C_{sat} is the concentration at which soil air, pore water, and sorption sites are saturated and above which free-phase contaminants may be present. For compounds that are liquid at ambient soil temperatures, C_{sat} indicates a concentration above which NAPLs may be suspected in site soils and further investigation may be necessary. Thus, for liquid compounds for which the SSL exceeds C_{sat}, the SSL is set at C_{sat}. For compounds that are solid at soil temperatures for which the SSL exceeds C_{sat}, volatile emissions can be assumed to be of no concern and the SSL is calculated considering particulate emissions only (i.e., the 1/VF term in Equation 3 or 4 is set to zero).

Equation 3: Screening Level Equation for Inhalation of Carcinogenic Contaminants in Residential Soil	
$\text{Screening Level (mg/kg)} = \frac{\text{TR} \times \text{AT} \times 365 \text{ d/yr}}{\text{URF} \times 1000 \mu\text{g/mg} \times \text{EF} \times \text{ED} \times \left[\frac{1}{\text{VF}} + \frac{1}{\text{PEF}} \right]}$	
Parameter/Definition (units)	Default
TR/target cancer risk (unitless)	10 ⁻⁶
AT/averaging time (yr)	70
URF/inhalation unit risk factor (μg/m ³) ⁻¹	chemical-specific
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
VF/soil-to-air volatilization factor (m ³ /kg)	chemical-specific
PEF/particulate emission factor (m ³ /kg)	6.79 x 10 ⁸

Equation 4: Screening Level Equation for Inhalation of Noncarcinogenic Contaminants in Residential Soil	
$\text{Screening Level (mg/kg)} = \frac{\text{THQ} \times \text{AT} \times 365 \text{ d/yr}}{\text{EF} \times \text{ED} \times \left[\frac{1}{\text{RfC}} \times \left(\frac{1}{\text{VF}} + \frac{1}{\text{PEF}} \right) \right]}$	
Parameter/Definition (units)	Default
THQ/target hazard quotient (unitless)	1
AT/averaging time (yr)	30
EF/exposure frequency (d/yr)	350
ED/exposure duration (yr)	30
RfC/inhalation reference concentration (mg/m ³)	chemical-specific
VF/soil-to-air volatilization factor (m ³ /kg)	chemical-specific
PEF/particulate emission factor (m ³ /kg)	6.79 x 10 ⁸

Equations 3 through 7 form the basis for deriving both simple site-specific and generic SSLs for the inhalation pathway. The following parameters in the standardized equations can be replaced with specific site data to develop a more site-specific SSL:

- VF and C_{sat}
 - Average soil moisture content
 - Average fraction organic carbon content
 - Dry soil bulk density

Equation 5: Derivation of the Volatilization Factor	
$\text{VF (m}^3/\text{kg)} = \text{Q/C} \times \frac{(3.14 \times \alpha \times T)^{1/2}}{(2 \times D_{ei} \times \theta_a \times K_{sa})} \times 10^{-4} \text{ m}^2/\text{cm}^2$ <p>where</p> $\alpha = \frac{D_{ei} \times \theta_a}{\theta_a + (\rho_s)(1 - \theta_a)/K_{sa}}$	
Parameter/Definition (units)	Default
VF/volatilization factor (m ³ /kg)	—
Q/C/inverse of the mean conc. at the center of a 30-acre-square source (g/m ² -s per kg/m ³)	35.10
T/exposure interval (s)	9.5 x 10 ⁸ s
D _{ei} /effective diffusivity (cm ² /s)	D _i (θ _a ^{3.33} /m ²)
θ _a /air-filled soil porosity (L _{air} /L _{soil})	0.28 or n-wp _b
D _i /diffusivity in air (cm ² /s)	chemical-specific
n/total soil porosity (L _{poro} /L _{soil})	0.43 (loam)
w/average soil moisture content (g _{water} /g _{soil} or cm ³ _{water} /g _{soil})	0.1 (10%)
ρ _b /dry soil bulk density (g/cm ³)	1.5 or (1 - n) ρ _s
ρ _s /soil particle density (g/cm ³)	2.65
K _{sa} /soil-air partition coefficient (g-soil/cm ³ -air)	(H/K _d) x 41 (41 is a conversion factor)
H/Henry's law constant (atm-m ³ /mol)	chemical-specific
K _d /soil-water partition coefficient (cm ³ /g)	K _{oc} x f _{oc}
K _{oc} /organic carbon partition coefficient (cm ³ /g)	chemical-specific
f _{oc} /organic carbon content of soil (g/g)	0.006 (0.6%)

Equation 6: Derivation of the Soil Saturation Limit	
$C_{sat} = \frac{S}{\rho_b} (K_d \rho_b + \theta_w + H' \theta_a)$	
Parameter/Definition (units)	Default
C _{sat} /soil saturation concentration (mg/kg)	—
S/solubility in water (mg/L-water)	chemical-specific
ρ _b /dry soil bulk density (kg/L)	1.5 or (1 - n) ρ _s
n/total soil porosity (L _{poro} /L _{soil})	0.43 (loam)
ρ _s /soil particle density (kg/L)	2.65
K _d /soil-water partition coefficient (L/kg)	K _{oc} x f _{oc} (organics)
K _{oc} /soil organic carbon/water partition coefficient (L/kg)	chemical-specific
f _{oc} /fraction organic carbon of soil (g/g)	0.006 (0.6%)
θ _w /water-filled soil porosity (L _{water} /L _{soil})	wp _b or 0.15
θ _a /air-filled soil porosity (L _{air} /L _{soil})	n - wp _b or 0.28
w/average soil moisture content (kg _{water} /kg _{soil} or L _{water} /kg _{soil})	0.1 (10%)
H'/Henry's law constant (unitless)	H x 41, where 41 is a conversion factor
H/Henry's law constant (atm-m ³ /mol)	chemical-specific

Equation 7: Derivation of the Particulate Emission Factor	
$\text{PEF}(\text{m}^3/\text{kg}) = \text{Q/C} \times \frac{3600 \text{ s/h}}{0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x)}$	
Parameter/Definition (units)	Default
PEF/particulate emission factor (m^3/kg)	6.79×10^8
Q/C/inverse of the mean conc. at the center of a 30-acre-square source ($\text{g}/\text{m}^2\text{-s}$ per kg/m^3)	46.84
V/fraction of vegetative cover (unitless)	0.5 (50%)
U_m /mean annual windspeed (m/s)	4.69
U_t /equivalent threshold value of windspeed at 7 m (m/s)	11.32
F(x)/function dependent on U_m/U_t derived using Cowherd (1985) (unitless)	0.194

- PEF
 - Mean annual windspeed
 - Threshold friction velocity (as determined by):
 - mode of the surface soil aggregate size
 - roughness height
 - correction for nonerodible particles
 - f(x)
 - Equivalent threshold windspeed at a 7-m anemometer height.

Site location (to some extent) and site size (i.e., "area of contamination") can be factored into the simple site-specific methodology for the inhalation pathways. The dispersion factor (Q/C) for both volatiles and fugitive dusts was calculated using a 90th percentile meteorological data set selected from 29 data sets across the United States (see Technical Background Document [U.S. EPA, 1994e]). Los Angeles was selected as the 90th percentile data set for volatiles and Minneapolis was selected as the 90th percentile data set for fugitive dusts. Replacing the default city and site size of 30 acres will affect the Q/C values in both the VF and PEF equations (Equations 5 and 7). The Technical Background Document supporting this guidance (U.S. EPA, 1994e) provides a table of Q/C values for 29 cities across the country over a range of contaminant source areas for use in the simple site-specific method.

The particulate emission factor derived by using the default values in Equation 7 results in an ambient air concentration of approximately $1.5 \mu\text{g}/\text{m}^3$. This represents an annual average emission rate that is based on wind erosion and is not appropriate for evaluating the potential for more acute exposures.

Migration to Ground Water

The methodology for addressing migration of contaminants from soil to ground water reflects the complex nature of contaminant fate and transport in the subsurface. In this methodology, a concentration in soil is backcalculated from an acceptable ground water concentration. The generic SSLs presented in Appendix A for this pathway represent a conservative estimation of the concentration of a contaminant in soil that would not result in exceedances of the acceptable concentration of a contaminant in ground water. Flexibility to consider site-specific conditions is addressed in the simple and detailed site-specific methodologies.

The first step in applying the SSL framework is a comparison of the SSL conceptual model presented earlier in this document with the conceptual model developed for the site. This forms the basis for determining the appropriateness of conducting a more detailed investigation and the applicability of the SSL guidance for the migration to ground water pathway. Some of the assumptions used to develop the SSL conceptual model have implications for the ground water pathway. Highlight 4 lists assumptions implicit in the conceptual model that should be understood before applying the SSL ground water framework.

Both the simple site-specific and generic methods are based on the commonly used equilibrium soil/water partition equation (Equation 8) that describes the ability of contaminants to sorb

Equation 8: 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 \times 10 DAF
K_d /soil-water partition coefficient (L/kg)	chemical-specific, $K_{oc} \times f_{oc}$ (organics)
K_{oc} /soil organic carbon/water partition coefficient (L/kg)	chemical-specific
f_{oc} /fraction organic carbon in soil (g/g)	0.002 (0.2%)
θ_w /water-filled soil porosity ($L_{\text{water}}/L_{\text{soil}}$)	0.3 or w_p
w/average soil moisture content ($\text{kg}_{\text{water}}/\text{kg}_{\text{soil}}$ or $L_{\text{water}}/\text{kg}_{\text{soil}}$)	0.2 (20%)
ρ_b /dry soil bulk density (kg/L)	1.5 or $(1 - n) \rho_s$
n/soil porosity ($L_{\text{pore}}/L_{\text{soil}}$)	0.43 (loam)
ρ_s /soil particle density (kg/L)	2.65
θ_a /air-filled soil porosity ($L_{\text{air}}/L_{\text{soil}}$)	0.13 or $(n - \theta_w)$
H' /Henry's law constant (unitless)	$H \times 41$
H/Henry's law constant ($\text{atm}\cdot\text{m}^3/\text{mol}$)	chemical-specific (assume to be zero for inorganic contaminants except mercury)

Highlight 4: Simplifying Assumptions of the Default Conceptual Model for Ground Water

1. The source of contamination is defined as an evenly contaminated 30-acre site. Source size has significant implications for the development of the dilution/attenuation factor. Large sources generally tend to result in low DAFs, while smaller sources generally justify higher DAFs. Where actual source size differs significantly from the default 30-acre assumption, the user should consider a site-specific evaluation to develop a more site-specific DAF.
2. The soil contamination extends from the surface to the top of the aquifer. This is a reasonable assumption for sites where the water table is fairly shallow (e.g., 5 to 10 feet below surface). However, in areas where the water table is very deep, this assumption may not be valid and should be considered in the decision to apply a detailed site-specific evaluation.
3. No attenuation is considered in the unsaturated zone. This assumption also has implications for the DAF. As discussed above, a detailed site-specific evaluation should be considered at sites that have a very thick uncontaminated unsaturated zone because a higher DAF may be justified.
4. The point of compliance is at the edge of the site, which is assumed to be uniformly contaminated. This conservative assumption also has implications for the calculation of the DAF. The user should consider whether this assumption is valid for the site in question and whether further evaluation would be appropriate.
5. The simple site-specific or generic DAF assumes that an unconfined, unconsolidated aquifer with homogeneous and isotropic hydrologic properties underlies the site. A DAF greater than 1 may not be appropriate for soils underlain by karst or fractured rock aquifers.
6. NAPLs are not present. If NAPLs are present in soils, the SSLs do not apply (i.e., further investigation is necessary).

to organic carbon in soil (Dragun, 1988). An adjustment to relate sorbed concentration in soil to the analytically measured total soil concentration has been added to the equation.

The partition equation contains parameters for chemical-specific (Henry's law constant; K_d or K_{oc}) and subsurface characteristic variables (dry bulk density, porosity, air-filled and water-filled pore space). In the default method, national default values for the parameters in the partition equation were used to calculate the generic SSLs in Appendix A. Nonzero ground water maximum contaminant level goals (MCLGs) were used as the acceptable ground water limits for each contaminant in the partitioning equation. If nonzero MCLGs were not available, maximum contaminant levels (MCLs) were

used. If MCLs were not available, concentrations associated with a target cancer risk of 10^{-6} and/or a noncancer HQ of 1 were derived using Agency toxicity criteria. The acceptable ground water limit is multiplied by the DAF of 10 to obtain a target soil leachate concentration for calculating generic SSLs.

In the simple site-specific method, site-measured data would replace the default values for the subsurface characteristic and soil variables (i.e., fraction organic carbon, dry bulk density, average soil moisture content). These variables would then be used to calculate a more site-specific screening value. Even this screening number is fairly conservative because of the underlying assumptions regarding the absence of attenuation and placement of the well adjacent to the source.

As described above, the C_{max} ceiling limit defines (for organic chemicals that are liquid at soil temperatures) a concentration above which chemicals may occur as NAPLs in soil. For liquid chemicals present at concentrations greater than C_{max} , NAPL presence may be suspected and the Soil Screening framework would not be applicable (i.e., further investigation is necessary). See U.S. EPA (1992b) for guidance on determining the likelihood of NAPL occurrence in the subsurface and on conducting the additional investigations necessary if NAPL occurrence is suspected at a site.

Partitioning of inorganic constituents in the subsurface is more complex than for organics. A variety of soil conditions affect the derivation of the partitioning coefficient for inorganics, while organic carbon is the parameter that most affects organic partitioning. For this reason, the EPA MINTEQ2 equilibrium geochemical speciation model was used to calculate K_d values for the metals, which were then used in Equation 8. K_d values for metals are most significantly affected by pH; therefore, metal K_d values were calculated over a range of subsurface pH conditions (4.9 to 8.0). K_d values corresponding to this pH range are presented in the revised Technical Background Document (U.S. EPA, 1994e) for use in the simple site-specific method. Based on the pH at the site, the appropriate K_d should be selected and used in the calculation. Also note that all metals except mercury are essentially nonvolatile and their Henry's law constant (H') in Equation 8 should be set at zero.

Generic SSLs for inorganics corresponding to a pH of 6.8 are presented in Appendix A for the default method. Table 1 lists inorganic SSLs corresponding to pH values of 4.9 and 8.0 and a DAF of 10. If pH conditions at a site are not known, the generic SSL corresponding to a pH of 6.8 should be used in the default method. Table 1 also includes SSLs for ionizing organics, whose partitioning behavior is also pH dependent. Readers are referred to the Technical Background Document (U.S. EPA, 1994e) for a more detailed discussion of the derivation of K_d values for inorganics and K_{oc} values for ionizing and nonionizing organics.

The framework also includes the option of using a leach test instead of the partitioning equation. In some instances a leach

Table 1. pH-Specific SSLs for Metals and Ionizing Organics (mg/kg) (DAF = 10)

Chemical	pH 4.9	pH 8
Arsenic	13	16
Barium	16	340
Beryllium	0.1	19,000
Cadmium	0.06	230
Chromium (+6)	31	14
Mercury	0.006	4
Nickel	1	140
Selenium	9	1
Thallium	0.2	0.5
Zinc	180	1.6E+6
Benzoic acid	300	280
2,4-Dichlorophenol	0.5	0.3
Pentachlorophenol	0.2	0.01
2,4,5-Trichlorophenol	200	26
2,4,6-Trichlorophenol	0.07	0.01

test may be more useful than the partitioning method, depending on the constituents of concern and the possible presence of RCRA wastes. This guidance suggests using the EPA Synthetic Precipitation Leaching Procedure (SPLP, EPA SW-846 Method 1312, see the Technical Background Document [U.S. EPA, 1994e]). The SPLP was developed to model an acid rain leaching environment and is generally appropriate for a contaminated soil scenario. Like most leach tests, the SPLP may not be appropriate for all situations (e.g., soils contaminated with oily constituents may not yield suitable results). Therefore, discretion is advised when applying the SPLP.

The Agency is aware that there are many leach tests available for application at hazardous waste sites, some of which may be appropriate in specific situations (e.g., the Toxicity Characteristic Leaching Procedure, known as the TCLP, models leaching in a municipal landfill environment). It is beyond the scope of this document to discuss in detail other leaching procedures and the appropriateness of their use. *Stabilization/Solidification of CERCLA and RCRA Wastes* (U.S. EPA, 1989c) and the SAB's review of leaching tests (U.S. EPA, 1991c) contain information on the application of various leach tests to various waste disposal scenarios. The user is encouraged to consult these documents for further information.

DETERMINING THE DILUTION/ATTENUATION FACTOR

As contaminants move through soil and ground water, they are subjected to a number of physical, chemical, and biological processes that generally reduce the eventual contaminant concentration level at receptor points. The reduction in

concentration can be expressed succinctly by the DAF, defined as the ratio of the soil leachate concentration to the receptor point concentration. The lowest possible value of DAF is 1, corresponding to the situation where there is no dilution or attenuation of a contaminant; i.e., the concentration at the receptor point is the same as that in the soil leachate. High DAF values, on the other hand, correspond to a high degree of dilution and attenuation of the contaminant from the leachate to the receptor point.

The soil/water partition equation relates concentrations of contaminants adsorbed to soil organic carbon to soil leachate concentrations in the unsaturated zone. Contaminant migration through the unsaturated zone to the water table generally reduces the soil leachate concentration by attenuation processes such as adsorption and degradation. Ground water transport in the saturated zone further reduces concentrations through adsorption, degradation, and dilution. Generally, to account for this reduction in concentration, acceptable ground water limits are multiplied by a DAF to obtain a target soil leachate concentration for the partition equation.

A default DAF of 10 is applied to calculate the generic SSLs. A weight of evidence method was used to determine this default DAF. In the weight-of-evidence approach, OERR evaluated a number of methods for calculating DAFs. Included in this approach was an evaluation of DAFs calculated by the EPACMTP model, using a range of assumptions including those associated with the conceptual site model for the generic SSLs. The comparison also included DAFs calculated from a more simplified mixing-zone equation, as well as acceptable DAFs used in existing State programs. The comparison indicated that, for the default scenario, a DAF of 10 is conservatively protective of the majority of site conditions, including the site scenario developed for the generic SSLs. The Technical Background Document (U.S. EPA, 1994e) supporting this guidance contains additional detail on the development of the generic DAF.

The simple site-specific method relies on a fairly simple mixing zone equation (Equation 9) to calculate a site-specific dilution factor to be used instead of the default DAF. In this method, site-measured values for hydraulic gradient, hydraulic

Equation 9: Derivation of Dilution Factor	
$\text{dilution factor} = 1 + \frac{Kd}{iL}$	
Parameter/Definition (units)	10 ⁻³ days (100 ft / 30 ft)
dilution factor (unitless)	
K/aquifer hydraulic conductivity (m/yr)	
i/hydraulic gradient (m/m)	
d/mixing zone depth (m)	
i/infiltration rate (m/yr)	
L/source length parallel to ground water flow (m)	

0.004
3.75
0.6
30

$$DF = 1 + \frac{(315)(0.004)(6)}{(0.6)(30)}$$

conductivity, and estimates of infiltration, contaminant source length, and mixing-zone depth are used to calculate the dilution factor. The mixing-zone depth is estimated from an equation relating it to aquifer thickness, infiltration rate, ground water velocity, and source length parallel to flow (Equation 10).

Equation 10: Estimation of Mixing Zone Depth	
$d = (0.0112 L^2)^{0.5} + d_a \{1 - \exp[(-L)/(Kd_a)]\}$	
Parameter/Definition (units)	
d/mixing zone depth (m)	
L/source length parallel to ground water flow (m)	
I/infiltration rate (m/yr)	
K/aquifer hydraulic conductivity (m/yr)	
d _a /aquifer thickness (m)	

60
15
5

Detailed Site-Specific Method

In this investigation, site-specific data are collected and used in a fate and transport model to determine whether a threat to ground water exists and, if so, to further determine site-specific cleanup goals as would typically be done for the remedial investigation/feasibility study (RI/FS). Consequently it represents the highest level of site-specificity in evaluating the migration to ground water pathway. A DAF is not used in this method because the model would account for fate and transport mechanisms in the subsurface. The advantage of this approach is that it accounts for site hydrogeologic, climatologic, and contaminant source characteristics and may result in fully protective but less stringent remediation goals. However, the additional cost of collecting the data required to apply the model should be factored into the decision to conduct a detailed site-specific investigation.

Choosing a model for site-specific application is integral to an accurate evaluation of potential concern. However, the data used in the application and interpretation of the results are equally important. In an effort to provide useful information for a model application, EPA's ORD Laboratories in Ada, Oklahoma, and Athens, Georgia, conducted an evaluation of nine unsaturated zone fate and transport models. The information in this report is summarized in the Technical Background Document (U.S. EPA, 1994e) supporting this guidance. These nine models are only a subset of the potentially appropriate models available to the public and are not meant to be construed as having received EPA approval. EPA also has developed guidance for the selection and application of ground water transport and fate models and for interpretation of model applications. The user is referred to *Ground Water Modeling Compendium* (U.S. EPA, 1994b) and *Framework for Assessing Ground Water Model Applications* (U.S. EPA, 1994a) for further information.

MEASURING CONTAMINANT CONCENTRATIONS IN SOIL

In order to compare site soil concentrations with the SSLs, it is important to develop a sampling strategy that will result in an accurate representation of site contamination. This Soil Screening Guidance recommends that site managers use the Data Quality Objectives (DQO) process (Figure 5) to develop a sampling strategy that will satisfy Superfund program objectives. The site manager can use the DQO process to conveniently organize and document many site-specific features and assumptions underlying the sampling plan. In the last step of the DQO process, "Optimize the Design for Obtaining Data," the site manager can choose between two alternative approaches to measuring surface soil contaminant concentrations. The first is a site-specific strategy that uses site-specific estimates of contaminant variability to determine how many samples are needed to support the screening decision. The second is a fairly prescriptive approach that can be used in lieu of the site-specific strategy. Recommendations for subsurface sampling that can be modified to accommodate site-specific conditions are also included in the guidance.

Exposure to site contaminants over a long (chronic) period of time is best represented by an arithmetic average concentration for an exposure area (U.S. EPA, 1992d). Therefore, measurement of site concentrations for comparison to the SSLs should

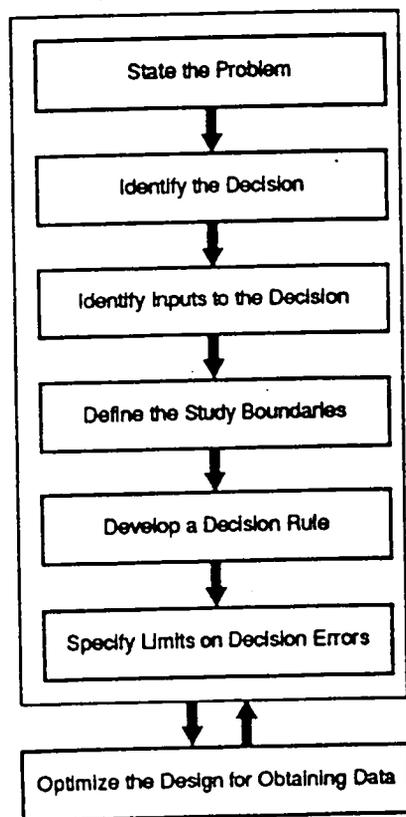


Figure 5. The Data Quality Objectives process.

be based on the arithmetic mean concentration as well. For the purposes of this guidance, the Agency has assumed that the size of a typical residential lot (0.5 acre) is an appropriate averaging area for residential land use. For large sites that could be divided into multiple residential lots, the site should be sectioned into appropriate 0.5-acre parcels.

For measurement of surface soil samples for the inhalation and ingestion pathways, samples should be collected over a depth of 6 inches because it is the top 6 inches of soil that is most likely to be ingested or inhaled as fugitive dusts. Additional sampling beyond 6 inches may be appropriate, depending on the contaminant's mobility. If soils at the site are of concern for the migration to ground water pathway as well as the ingestion and/or inhalation pathways, then surface soils should be sampled first since the results of the composite samples may indicate source areas to target for subsurface sampling.

As discussed previously, the initial steps for implementing the Soil Screening framework are to (1) develop the conceptual site model and determine the applicability of the framework; (2) determine if background concentrations exceed the (generic) SSLs; and (3) select the method (simple site-specific, detailed site-specific, or generic) to determine the SSLs. Once these steps have been completed, it will then be necessary to choose either a site-specific or a generic, prescriptive sampling strategy for surface soils.

Surface Soils—Site-Specific Strategy

The site-specific sampling strategy utilizes a sampling design approach that allows statistically valid conclusions to be drawn about contaminant concentrations at a site based on relatively limited sampling. EPA recommends that site managers use this strategy to determine the number of samples needed to compare average contaminant concentrations within each exposure area against the SSLs. The site-specific strategy provides procedures for ensuring that screening decisions can be made with acceptable levels of confidence despite variability in soil contaminant concentrations that can sometimes mask true conditions at the site. This approach provides flexibility to incorporate site-specific information about likely contamination patterns so that sampling can be concentrated in areas where uncertainty about the risk posed by soil contaminants is greatest.

The sampling design developed for the site should be based on the conceptual site model and should reflect conditions at the site. It is flexible in that the information used to develop the conceptual site model (historical records, aerial photographs, existing sampling data, etc.) can also be used to develop an appropriate sampling strategy. Such a strategy may include stratification of the site, if appropriate, into areas where soil contaminant concentrations are expected to clearly exceed the SSLs, areas where soil contaminant concentrations are expected to fall well below the SSLs, and areas of the site where there is greater uncertainty as to whether soil contaminant concentrations exceed the SSLs.

This classification of areas of the site can help in designing an efficient sampling plan, since the number of samples required to support good decision making depends on the contaminant variability likely to be encountered and how greatly contaminant concentrations differ from the SSLs. By grouping similar areas together, each area can be sampled in accordance with the level of uncertainty or variability associated with that area. For example, EPA expects that a relatively small number of samples will be needed to make the screening decision where average contaminant concentrations clearly exceed or are well below the SSLs. More intensive sampling is expected for those areas where relatively high contaminant variability or concentrations close to the SSLs make it more difficult to determine with confidence whether the average contaminant concentration exceeds the screening level.

Inherent in the statistically based site-specific sampling strategy is the specification of limits on decision errors, which is performed in the sixth step of the DQO process. Limits on decision errors are quantitative performance requirements for the quality and quantity of data that will support the screening decision. These performance requirements are specified in terms of the probability of making a decision error, which can occur in two ways:

- Type I: The data mislead the site manager into deciding that the exposure area concentration is below the SSLs when the true average contaminant concentration exceeds the screening level; or
- Type II: The data mislead the site manager into deciding that the exposure area concentration is above the SSL and further investigation is required when in fact the true average contaminant concentration is less than the SSL.

To ensure consistency in applying the framework, EPA has specified tolerable limits on decision errors at the program level. The Technical Background Document (U.S. EPA, 1994e) provides a full discussion of the Soil Screening framework's limits on decision errors and of the site-specific strategy in general. EPA encourages the project manager to seek the assistance of a statistician or the Regional quality assurance staff for the development of the sampling strategy. For more detailed guidance on the DQO process the user should refer to the Technical Background Document and *Data Quality Objectives for Superfund (Interim Final)* (U.S. EPA, 1993a).

Surface Soils—Prescriptive Approach

The guidance provides a second sampling methodology—a "prescriptive approach"—that can be used as an alternative to the site-specific approach. A sampling design effort is required for the site-specific strategy, whereas the prescriptive approach provides a simple, standard sampling approach that will be most useful for small sites that do not warrant an extensive design effort. It emphasizes composite sampling for

nonvolatile contaminants and specifies the number of samples to be collected for analysis of volatile contaminants. It differs from the site-specific approach in that the same sampling strategy must be applied to each 0.5-acre exposure area. Although it does not explicitly control decision errors, preliminary simulations suggest that it does not underestimate mean concentrations for commonly occurring patterns of soil contamination. Additional simulations comparing the performance of the prescriptive approach to the site-specific strategy will be a subject of peer review.

Studies by ORD indicate that at least 20 samples per exposure area are needed to closely estimate the true mean. To balance the need for statistical confidence in determining a meaningful arithmetic mean contaminant concentration with the costs of analyzing multiple samples for each exposure area, EPA recognizes the benefits of composite samples and advocates compositing, where appropriate. Compositing may mask contaminant levels that are slightly higher than the SSL, but areas of high contamination will still be detected. Compositing is a reasonable approach and an efficient use of resources since the Superfund program is interested in the average exposure over time. (See the Technical Background Document [U.S. EPA, 1994e] for a more detailed discussion of compositing and its limitations.)

Using the prescriptive approach, 20 discrete samples can be reduced to four composite samples. (The exposure area can be divided into quadrants and five random samples can be collected and composited within each quadrant.) The contaminant concentrations from the four composite samples should be compared directly with their respective SSLs. If any one of the composites equals or exceeds the SSL, then that portion of the exposure area should be studied further.

Compositing is not appropriate for volatile organic compounds (VOCs) since much of the contaminant will be lost during homogenization of the soil (U.S. EPA, 1989a, 1992c). For VOCs, 10 discrete samples can be taken per exposure area and any sample above the SSL would trigger the need for additional study in that exposure area. Additionally, it is not appropriate to average the contaminant levels in each exposure area and evaluate the mean concentration against the SSLs because 10 discrete samples may underestimate the true mean.

Subsurface Sampling

For the migration to ground water pathway, subsurface soils that have constituents that might contribute to ground water contamination are of primary concern. Therefore, it is the source areas that are of interest and not necessarily a 0.5-acre exposure area as specified for the ingestion and inhalation pathways. To determine whether contaminants in the subsurface soils (defined as below 6 inches for the purposes of implementing SSLs) potentially pose a risk to ground water, the guidance suggests sampling at least two boreholes using split spoon or Shelby tube samples in each source area. Samples should begin at 6 inches below ground surface and

continue at 2-foot intervals until no contamination is encountered. If the average concentration in any borehole exceeds the SSL, then further site-specific study is warranted.

Subsurface sampling depths and intervals can be adjusted at a site to accommodate site-specific information on subsurface contaminant distributions and geological conditions. In addition, soil investigation for the migration to ground water pathway should not be conducted independent of ground water investigation. Ground water should be sampled to determine whether there is concern for existing ground water contamination, and the results should be considered in the holistic application of the Soil Screening framework.

Geostatistics

If the SSLs are to be compared with the data resulting from the initial sample collection efforts of the remedial investigation, the site manager may want to consider using geostatistics to estimate contaminant concentrations across the site. Geostatistics is probably most appropriate to use in the detailed site-specific approach. Geostatistics is a field of study in which statistical analyses of geologic or environmental data are conducted. It differs from single-sample classical statistics in that it assumes that variability and independence between samples is not random, but that there is some spatial continuity between samples. Geostatistics can be used to estimate contaminant concentrations at unsampled points and estimate average contaminant concentrations across the site.

Software packages have been developed to facilitate geostatistical analyses. One package is GEO-EAS, developed by EPA's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada. Assistance and consultation with skilled geostatisticians is recommended prior to initiating any sampling plan to ensure that the sampling strategy will capture the critical data necessary for the geostatistical analyses.

WHERE TO GO FOR FURTHER INFORMATION

More detailed discussions of the technical background and assumptions supporting the development of the Soil Screening framework are presented in the *Technical Background Document for Soil Screening Guidance* (U.S. EPA, 1994e). For additional copies of this Fact Sheet and/or the Technical Background Document, call the National Technical Information Service (NTIS) at (703) 487-4650.

NOTICE: This guidance is based on policies in the Final Rule of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), which was published on March 8, 1990 (55 *Federal Register* 8666). The NCP should be considered the authoritative source.

The policies set out in this document are intended solely as guidance to the U.S. Environmental Protection Agency (EPA) personnel; they are not final EPA actions and do not constitute rulemaking. These policies are not intended, nor can they be relied upon, to create any rights enforceable by any party in litigation with the United States. EPA officials may decide to follow the guidance provided in this document, or to act at variance with the guidance, based on an analysis of specific site circumstances. EPA also reserves the right to change the guidance at any time without public notice.

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Appendix A. Generic Soil Screening Levels for Superfund^a

NOTICE: These values were developed for use in application of the Soil Screening Guidance only. They were developed for specific exposure pathways constituting a residential scenario and should only be used in that context.

CAS No.	Chemical	Pathway-specific values for surface soils (mg/kg)		Migration to ground water pathway levels (mg/kg)	
		Ingestion	Inhalation	With 10 DAF	With 1 DAF
83-32-9	Acenaphthene	4,700 ^b	— ^c	200 ^b	20 ^b
67-64-1	Acetone	7,800 ^b	62,000 ^d	8 ^b	0.8 ^b
309-00-2	Aldrin	0.04 ^e	0.5 ^e	0.005 ^e	5E-4 ^{e,f}
120-12-7	Anthracene	23,000 ^b	— ^c	4,300 ^b	430 ^b
71-43-2	Benzene	22 ^e	0.5 ^e	0.02	0.002 ^f
56-55-3	Benzo(a)anthracene	0.9 ^e	— ^c	0.7	0.07 ^f
205-99-2	Benzo(b)fluoranthene	0.9 ^e	— ^c	4	0.4
207-08-9	Benzo(k)fluoranthene	9 ^e	— ^c	4	0.4
50-32-8	Benzo(a)pyrene	0.09 ^{e,f}	— ^c	4	0.4
111-44-4	Bis(2-chlorethyl)ether	0.6 ^e	0.3 ^{e,f}	3E-4 ^{e,f}	3E-5 ^{e,f}
117-81-7	Bis(2-ethylhexyl)phthalate	46 ^e	210 ^d	11	1
75-27-4	Bromodichloromethane	5 ^e	1,800 ^d	0.3	0.03
75-25-2	Bromoform	81 ^e	46 ^e	0.5	0.05
71-36-3	Butanol	7,800 ^b	9,700 ^d	8 ^b	0.8 ^b
85-68-7	Butyl benzyl phthalate	16,000 ^b	530 ^d	68	7
86-74-8	Carbazole	32 ^e	— ^c	0.2 ^{e,f}	0.02 ^{e,f}
75-15-0	Carbon disulfide	7,800 ^b	11 ^b	14 ^b	1 ^b
56-23-5	Carbon tetrachloride	5 ^e	0.2 ^e	0.03	0.003 ^f
57-74-9	Chlordane	0.5 ^e	10 ^e	2	0.2
108-90-7	Chlorobenzene	1,600 ^b	94 ^b	0.6	0.06
124-48-1	Chlorodibromomethane	8 ^e	1,900 ^d	0.2	0.02
67-66-3	Chloroform	110 ^e	0.2 ^e	0.3	0.03
218-01-9	Chrysene	88 ^e	— ^c	1	0.1 ^f
72-54-8	DDD	3 ^e	— ^c	0.7 ^e	0.07 ^e
72-55-9	DDE	2 ^e	— ^c	0.5 ^e	0.05 ^e
50-29-3	DDT	2 ^e	80 ^e	1 ^e	0.1 ^e
53-70-3	Dibenzo(a,h)anthracene	0.09 ^{e,f}	— ^c	11	1
84-74-2	Di-n-butyl phthalate	7,800 ^b	100 ^d	120 ^b	12 ^b
95-50-1	1,2-Dichlorobenzene (o)	7,000 ^b	300 ^d	6	0.6
106-46-7	1,4-Dichlorobenzene (p)	27 ^e	7,700 ^b	1	0.1 ^f
91-94-1	3,3-Dichlorobenzidine	1 ^e	— ^c	0.01 ^{e,f}	0.001 ^{e,f}
75-34-3	1,1-Dichloroethane	7,800 ^b	980 ^b	11 ^b	1 ^b
107-06-2	1,2-Dichloroethane	7 ^e	0.3 ^e	0.01 ^f	0.001 ^f
75-35-4	1,1-Dichloroethylene	1 ^e	0.04 ^e	0.03	0.003 ^f
156-59-2	cis-1,2-Dichloroethylene	780 ^b	1,500 ^d	0.2	0.02
156-60-5	trans-1,2-Dichloroethylene	1,600 ^b	3,600 ^d	0.3	0.03
78-87-5	1,2-Dichloropropane	9 ^e	11 ^b	0.02	0.002 ^f
542-75-6	1,3-Dichloropropene	4 ^e	0.1 ^e	0.001 ^{e,f}	1E-4 ^{e,f}
60-57-1	Dieldrin	0.04 ^e	2 ^e	0.001 ^{e,f}	1E-4 ^{e,f}
84-66-2	Diethyl phthalate	63,000 ^b	520 ^d	110 ^b	11 ^b
131-11-3	Dimethyl phthalate	7.8E+5 ^b	1,600 ^d	1,200 ^b	120 ^b
121-14-2	2,4-Dinitrotoluene	160 ^b	— ^c	0.2 ^{b,f}	0.02 ^{b,f}
606-20-2	2,6-Dinitrotoluene	78 ^b	— ^c	0.1 ^{b,f}	0.01 ^{b,f}

Appendix A (continued)

CAS No.	Chemical	Pathway-specific values for surface soils (mg/kg)		Migration to ground water pathway levels (mg/kg)	
		Ingestion	Inhalation	With 10 DAF	With 1 DAF
117-84-0	Di- <i>n</i> -octyl phthalate	1,600 ^b	— ^c	— ^g	— ^g
115-29-7	Endosulfan	470 ^b	— ^c	4 ^b	0.4 ^b
72-20-8	Endrin	23 ^b	— ^c	0.4	0.04
100-41-4	Ethylbenzene	7,800 ^b	260 ^d	5	0.5
206-44-0	Fluoranthene	3,100 ^b	— ^c	980 ^b	98 ^b
86-73-7	Fluorene	3,100 ^b	— ^c	160 ^b	16 ^b
76-44-8	Heptachlor	0.1 ^e	0.3 ^e	0.06	0.006
1024-57-3	Heptachlor epoxide	0.07 ^e	1 ^e	0.03	0.003
118-74-1	Hexachlorobenzene	0.4 ^e	1 ^e	0.8	0.08 ^f
87-68-3	Hexachloro-1,3-butadiene	8 ^e	1 ^e	0.1 ^f	0.01 ^f
319-84-6	α-HCH (α-BHC)	0.1 ^e	0.9 ^e	4E-4 ^{e,f}	4E-5 ^{e,f}
319-85-7	β-HCH (β-BHC)	0.4 ^e	16 ^e	0.002 ^e	2E-4 ^{e,f}
58-89-9	γ-HCH (Lindane)	0.5 ^e	— ^c	0.006	6E-4 ^f
77-47-4	Hexachlorocyclopentadiene	550 ^b	2 ^b	10	1
67-72-1	Hexachloroethane	46 ^e	49 ^e	0.2 ^{e,f}	0.02 ^{e,f}
193-39-5	Indeno(1,2,3- <i>c,d</i>)pyrene	0.9 ^e	— ^c	35	3
78-59-1	Isophorone	670 ^e	3,400 ^d	0.2 ^{e,f}	0.02 ^{e,f}
72-43-5	Methoxychlor	390 ^b	— ^c	62	6
74-83-9	Methyl bromide	110 ^b	2 ^b	0.1 ^b	0.01 ^{b,f}
75-09-2	Methylene chloride	85 ^e	7 ^e	0.01 ^f	0.001 ^f
91-20-3	Naphthalene	3,100 ^b	— ^c	30 ^b	3 ^b
98-95-3	Nitrobenzene	39 ^b	110 ^b	0.09 ^{b,f}	0.009 ^{b,f}
1336-36-3	Polychlorinated biphenyls (PCBs)	1 ^h	— ^{c,h}	— ^h	— ^h
129-00-0	Pyrene	2,300 ^b	— ^c	1,400 ^b	140 ^b
100-42-5	Stryene	16,000 ^b	1,400 ^d	2	0.2
79-34-5	1,1,2,2-Tetrachloroethane	3 ^e	0.4 ^e	0.001 ^{e,f}	1E-4 ^{e,f}
127-18-4	Tetrachloroethylene	12 ^e	11 ^e	0.04	0.004 ^f
108-88-3	Toluene	16,000 ^b	520 ^d	5	0.5
8001-35-2	Toxaphene	0.6 ^e	5 ^d	0.04 ^f	0.004 ^f
120-82-1	1,2,4-Trichlorobenzene	780 ^b	240 ^b	2	0.2 ^f
71-55-6	1,1,1-Trichloroethane	— ^c	980 ^d	0.9	0.09
79-00-5	1,1,2-Trichloroethane	11 ^e	0.8 ^e	0.01 ^f	0.001 ^f
79-01-6	Trichloroethylene	58 ^e	3 ^e	0.02	0.002 ^f
108-05-4	Vinyl acetate	78,000 ^b	370 ^b	84 ^b	8 ^b
75-01-4	Vinyl chloride	0.3 ^e	0.002 ^{e,f}	0.01 ^f	0.001 ^f
1330-20-7	Xylenes (total)	1.6E+5 ^b	320 ^d	74	7
	Ionizable Organics				
65-85-0	Benzoic acid	3.1E+5 ^b	— ^c	280 ^{b,i}	28 ^{b,i}
106-47-8	<i>p</i> -Chloroaniline	310 ^b	— ^c	0.3 ^{b,i}	0.03 ^{b,i}
95-57-8	2-Chlorophenol	390 ^b	53,000 ^d	2 ^{b,i}	0.2 ^{b,i}
120-83-2	2,4-Dichlorophenol	240 ^b	— ^c	0.5 ^{b,i}	0.05 ^{b,i}
105-67-9	2,4-Dimethylphenol	1,600 ^b	— ^c	3 ^{b,i}	0.3 ^{b,i}
51-28-5	2,4-Dinitrophenol	160 ^b	— ^c	0.1 ^{b,i}	0.01 ^{b,i}
95-48-7	2-Methylphenol	3,900 ^b	— ^c	6 ^{b,i}	0.6 ^{b,i}

Appendix A (continued)

CAS No.	Chemical	Pathway-specific values for surface soils (mg/kg)		Migration to ground water pathway levels (mg/kg)	
		Ingestion	Inhalation	With 10 DAF	With 1 DAF
86-30-6	N-Nitrosodiphenylamine	130 ^e	— ^c	0.2 ^{e,f,i}	0.02 ^{e,f,i}
621-64-7	N-Nitrosodi-n-propylamine	0.09 ^{e,f}	— ^c	2E-5 ^{e,f,i}	2E-6 ^{e,f,i}
87-86-5	Pentachlorophenol	3 ^{e,j}	— ^c	0.01 ^{f,i}	0.001 ^{f,i}
108-95-2	Phenol	47,000 ^b	— ^c	49 ^{b,i}	5 ^{b,i}
95-95-4	2,4,5-Trichlorophenol	7,800 ^b	— ^c	120 ^{b,i}	12 ^{b,i}
88-06-2	2,4,6-Trichlorophenol	58 ^e	210 ^e	0.06 ^{e,f,i}	0.006 ^{e,f,i}
Inorganics					
7440-36-0	Antimony	31 ^b	— ^c	— ^k	— ^k
7440-38-2	Arsenic \oplus	0.4 ^e	380 ^e	15 ⁱ	1 ⁱ
7440-39-3	Barium	5,500 ^b	3.5E+5 ^b	32 ⁱ	3 ⁱ
7440-41-7	Beryllium	0.1 ^e	690 ^e	180 ⁱ	18 ⁱ
7440-43-9	Cadmium \oplus	39 ^b	920 ^e	6 ⁱ	0.6 ⁱ
7440-47-3	Chromium (6+)	390 ^b	140 ^e	19 ⁱ	2 ⁱ
7439-92-1	Lead	400 ⁱ	—	—	—
7439-97-6	Mercury \oplus	23 ^b	7 ^{b,i}	3 ⁱ	0.3 ⁱ
7440-02-0	Nickel \oplus	1,600 ^b	6,900 ^e	21 ⁱ	2 ⁱ
7782-49-2	Selenium \oplus	390 ^b	— ^c	3 ⁱ	0.3 ⁱ
7440-22-4	Silver	390 ^b	— ^c	— ^k	— ^k
7440-28-0	Thallium	— ^c	— ^c	0.4 ⁱ	0.04 ⁱ
7440-62-2	Vanadium	550 ^b	— ^c	— ^k	— ^k
7440-66-6	Zinc \oplus	23,000 ^b	— ^c	42,000 ^{b,i}	4,200 ^{b,i}
57-12-5	Cyanide	1,600 ^b	— ^c	— ^k	— ^k

DAF = Dilution and attenuation factor.

^a Screening levels based on human health criteria only.

^b Calculated values correspond to a noncancer hazard quotient of 1.

^c No toxicity criteria available for that route of exposure.

^d Soil saturation concentration (C_{sat}).

^e Calculated values correspond to a cancer risk level of 1 in 1,000,000.

^f Level is at or below Contract Laboratory Program required quantitation limit for Regular Analytical Services (RAS).

^g Chemical-specific properties are such that this pathway is not of concern at any soil contaminant concentration.

^h A preliminary remediation goal of 1 ppm has been set for PCBs based on *Guidance on Remedial Actions for Superfund Sites with PCB Contamination*, EPA/540G-90/007, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC, 1990, and on Agency-wide efforts to manage PCB contamination.

ⁱ SSL for pH of 6.8.

^j Ingestion SSL adjusted by a factor of 0.5 to account for dermal exposure.

^k Soil/water partition coefficients not available at this time.

^l A preliminary remediation goal of 400 mg/kg has been set for lead based on *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities*, OSWER Directive #9355.4-12, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, DC, July 14, 1994.

\oplus Indicates potential for soil-plant-human exposure.

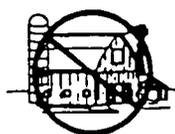
Levels developed for residential use only:



Residential



Industrial



Agricultural

ELEMENT CONCENTRATIONS IN SOILS, CONTERMINOUS UNITED STATES

1, unlike the geometric means shown in table 2, are estimates of geochemical abundance (Miesch, 1967). Arithmetic means are always larger than corresponding geometric means (Miesch, 1967, p. B1) and are estimates of the fractional part of a single specimen that consists of the element of concern rather than of the typical concentration of the element in a suite of samples.

Concentrations of 46 elements in samples of this study are presented in table 2, which gives the determination ratios, geometric-mean concentrations and deviations, and observed ranges in concentrations. The analytical data for most elements as received from the laboratories were transformed into logarithms because of the tendency for elements in natural materials, particularly the trace elements, to have positively skewed

TABLE 2.—Mean concentrations, deviations, and ranges of elements in samples of soils and other surficial materials in the conterminous United States

[Means and ranges are reported in parts per million ($\mu\text{g/g}$), and means and deviations are geometric except as indicated. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. <, less than; >, greater than]

Element	Conterminous United States				Western United States (west of 96th meridian)				Eastern United States (east of 96th meridian)				
	Mean	Deviation	Estimated arithmetic mean	Ratio	Mean	Deviation	Observed range	Estimated arithmetic mean	Ratio	Mean	Deviation	Observed range	Estimated arithmetic mean
Al, percent	4.7	2.48	7.2	661:770	5.8	2.00	0.5 - >10	7.4	450:477	3.3	2.87	0.7 - >10	5.7
As	5.2	2.23	7.2	728:730	5.5	1.98	<0.10 - 97	7.0	521:527	4.8	2.56	<0.1 - 73	7.4
B	26	1.97	33	506:778	23	1.99	<20 - 300	29	425:541	31	1.88	<20 - 150	38
Ba	440	2.14	580	778:778	580	1.72	70 - 5,000	670	541:541	290	2.35	10 - 1,500	420
Be	.63	2.38	.92	310:778	.68	2.30	<1 - 15	.97	169:525	.55	2.53	<1 - 7	.85
Br	.56	2.50	.85	113:220	.52	2.74	<0.5 - 11	.86	78:128	.62	2.18	<0.5 - 5.3	.85
C, percent	1.6	2.57	2.5	250:250	1.7	2.37	0.16 - 10	2.5	162:162	1.5	2.88	0.06 - 37	2.6
Ca, percent	.92	4.00	2.4	777:777	1.8	3.05	0.06 - 32	3.3	514:514	.34	3.08	0.01 - 28	.63
Ce	63	1.78	75	81:683	65	1.71	<150 - 300	75	70:489	63	1.85	<150 - 300	76
Co	6.7	2.19	9.1	698:778	7.1	1.97	<3 - 50	9.0	403:533	5.9	2.57	<0.3 - 70	9.2
Cr	37	2.37	54	778:778	41	2.19	3 - 2,000	56	541:541	33	2.60	1 - 1,000	52
Cu	17	2.44	25	778:778	21	2.07	2 - 300	27	523:533	13	2.80	<1 - 700	22
F	210	3.34	430	598:610	280	2.52	<10 - 1,900	440	390:435	130	4.19	<10 - 3,700	360
Fe, percent	1.8	2.38	2.6	776:777	2.1	1.95	0.1 - >10	2.6	539:540	1.4	2.87	0.01 - >10	2.5
Ga	13	2.03	17	767:776	16	1.68	<5 - 70	19	431:540	9.3	2.38	<5 - 70	14
Ge	1.2	1.37	1.2	224:224	1.2	1.32	0.58 - 2.5	1.2	130:131	1.1	1.45	<0.1 - 2.0	1.2
Hg	.058	2.52	.089	729:733	.046	2.33	<0.01 - 4.6	.065	534:534	.081	2.52	0.01 - 3.4	.12
I	.75	2.63	1.2	169:246	.79	2.55	<0.5 - 9.6	1.2	90:153	.68	2.81	<0.5 - 7.0	1.2
K, percent ¹	1.5	.79	None	777:777	1.8	.71	0.19 - 6.3	None	537:537	1.2	.75	0.005 - 3.7	--
La	30	1.92	37	462:777	30	1.89	<30 - 200	37	294:516	29	1.98	<30 - 200	37
Li	20	1.85	24	731:731	22	1.58	5 - 130	25	479:527	17	2.16	<5 - 140	22
Mg, percent	.44	3.28	.90	777:778	.74	2.21	0.03 - >10	1.0	528:528	.21	3.55	0.005 - 5	.46
Mn	330	2.77	550	777:777	380	1.98	30 - 5,000	480	537:540	260	3.82	<2 - 7,000	640
Mo	.59	2.72	.97	57:774	.85	2.17	<3 - 7	1.1	32:524	.32	3.93	<3 - 15	.79
Na, percent	.59	3.27	1.2	744:744	.97	1.95	0.05 - 10	1.2	363:449	.25	4.55	<0.05 - 5	.78
Nb	9.3	1.75	11	418:771	8.7	1.82	<10 - 100	10	322:498	10	1.65	<10 - 50	12
Nd	40	1.68	46	120:538	36	1.76	<70 - 300	43	109:332	46	1.58	<70 - 300	51
Ni	13	2.31	19	747:778	15	2.10	<5 - 700	19	443:540	11	2.64	<5 - 700	18
P	260	2.67	430	524:524	320	2.33	40 - 4,500	460	380:382	200	2.95	<20 - 6,800	360
Pb	16	1.86	19	712:778	17	1.80	<10 - 700	20	422:541	14	1.95	<10 - 300	17
Rb	58	1.72	67	221:224	69	1.50	<20 - 210	74	107:131	43	1.94	<20 - 160	53
S, percent	.12	2.04	.16	34:224	.13	2.37	<0.08 - 4.8	.19	20:131	.10	1.34	<0.08 - 0.31	.11
Sb	.48	2.27	.67	35:223	.47	2.15	<1 - 2.6	.62	31:131	.52	2.38	<1 - 8.8	.76
Sc	7.5	1.82	8.9	685:778	8.2	1.74	<5 - 50	9.6	389:526	6.5	1.90	<5 - 30	8.0
Se	.26	2.46	.39	590:733	.23	2.43	<0.1 - 4.3	.34	449:534	.30	2.44	<0.1 - 3.9	.45
Si, percent ¹	31	6.48	None	250:250	30	5.70	15 - 44	None	156:156	34	6.64	1.7 - 45	--
Sn	.89	2.36	1.3	218:224	.90	2.11	<0.1 - 7.4	1.2	123:131	.86	2.81	<0.1 - 10	1.5
Sr	120	3.30	240	778:778	200	2.16	10 - 3,000	270	501:540	53	3.61	<5 - 700	120
Ti, percent	.24	1.89	.29	777:777	.22	1.78	0.05 - 2.0	.26	540:540	.28	2.00	0.007 - 1.5	.35
Th	8.6	1.53	9.4	195:195	9.1	1.49	2.4 - 31	9.8	102:102	7.7	1.58	2.2 - 23	8.6
U	2.3	1.73	2.7	224:224	2.5	1.45	0.68 - 7.9	2.7	130:130	2.1	2.12	0.29 - 11	2.7
V	58	2.25	80	778:778	70	1.95	7 - 500	88	516:541	43	2.51	<7 - 300	66
Y	21	1.78	25	759:778	22	1.66	<10 - 150	25	477:541	20	1.97	<10 - 200	25
Yb	2.6	1.79	3.1	754:764	2.6	1.63	<1 - 20	3.0	452:486	2.6	2.06	<1 - 50	3.3
Zn	48	1.95	60	766:766	55	1.79	10 - 2,100	65	473:482	40	2.11	<5 - 2,900	52
Zr	180	1.91	230	777:778	160	1.77	<20 - 1,500	190	539:541	220	2.01	<20 - 2,000	290

¹Means are arithmetic, deviations are standard.

TELEPHONE CONVERSATION REPORTING FORM

ISSUE DATE	02/10/95
FILE NUMBER	
TELEPHONE NUMBER	(412) 921-8921
TELEPHONE NUMBER	(401) 294-3331
DATE OF CALL	02/02/95
TIME	4:10 <input type="checkbox"/> A.M. <input checked="" type="checkbox"/> P.M.
JOB NUMBER	8659

RECORDED BY: **NORMAN STRAUB**

CALL TO FROM NAME: **SUSAN LICARDI**

COMPANY: **NORTH KINGSTOWN PLANNING DEPT**

ADDRESS: **NORTH KINGSTOWN CITY HALL, N. KINGSTOWN**

CONFERENCE CALL NO YES (If YES, list conferees, conferees company, etc. in notes.)

CLIENT/PROJECT: **US NAVY - CTD127 - CED DRUM STORAGE AREA**

SUBJECT: **ZONING @ CED DRUM STORAGE AREA**

CONVERSATION NOTES:

SL INFORMED ME THAT IT WAS NOT WITHIN THE PLANNING DEPT'S JURISDICTION TO ZONE LAND CURRENTLY OPERATED OR ADMINISTERED BY THE FEDERAL GOV'T. HOWEVER, SINCE DAVISVILLE IS SATED FOR CLOSURE, THEY HAVE STARTED TO IDENTIFY LAND USES AT THE FACILITY. CURRENTLY, THE AREAS IMMEDIATELY ADJACENT TO AND INCLUDING THE SITE ARE PLANNED TO BE USED FOR INDUSTRIAL OR OPEN SPACE ZONINGS. THESE TWO ARE THE ONLY TWO ZONINGS CURRENTLY IDENTIFIED FOR THE FACILITY. UNDER NO CONDITIONS ARE ANY OF THE SITE LOCATIONS TO BE CONSIDERED FOR RESIDENTIAL LAND USE.

ACTION/RESPONSE		
RESPONSIBLE PERSON	ACTION NEEDED	DUE DATE

COPIES TO:

RECORDER'S SIGNATURE
