Attachment 1-3

Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)

Evaluation of Dermal Contact and Inhalation Exposure Pathways for the Purpose of Setting Eco-SSLs

OSWER Directive 92857-55

November 2003

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EVALUATING THE DERMAL CONTACT AND INHALATION EXPOSURE PATHWAYS FOR THE PURPOSE OF SETTING ECO-SSLs

1.0 POTENTIAL EXPOSURE PATHWAYS

Pursuant to USEPA guidance, a complete exposure pathway consists of the following four elements: 1) sources and release mechanisms, 2) retention and transport media, 3) exposure points, and 4) exposure routes (USEPA, 1989). If any of these elements are missing, the pathway is considered to be incomplete. Exposure pathways can be characterized as incomplete, complete, or potentially complete. The risks from some complete or potentially complete pathways may be considered insignificant due to 1) low levels of contaminants, 2) low exposure frequency, or 3) because they are insignificant as compared to other “risk-driving” pathways. According to USEPA guidance (1997), complete or potentially complete exposure pathways should be evaluated quantitatively. However, pathways considered less significant may not warrant further quantitative evaluation for an ERA. Complete, but insignificant exposure pathways should be qualitatively evaluated and identified as a source of uncertainty.

The sections below discuss the dermal contact and inhalation exposure routes and present both dose and risk information for the 24 Eco-SSL contaminants. The analyses supports the conclusion that these pathways are generally less significant when compared to the ingestion pathways and do not warrant inclusion in the derivation of the Eco-SSLs. However, the site manager and/or risk assessor should not automatically dismiss these pathways on a site-by-site basis.

1.1 Dermal Contact with Contaminants in Soil

Potential receptors for which Eco-SSLs were derived included plants, soil invertebrates, birds and mammals. Although dermal exposure through direct contact with soil can be considered a complete exposure pathway for birds and mammals, this exposure pathway is usually considered to be incidental due to low frequency and/or duration of exposure and the relative contribution to risk compared to oral exposures. While methods are available to quantitatively assess dermal exposure to humans (USEPA, 1992), the data necessary to estimate dermal exposures for wildlife are generally not available (USEPA, 1993; Sample et al., 1997). Feathers of birds, fur on mammals, and scales on reptiles are believed to reduce dermal exposure by limiting the contact of the skin surface with the contaminated media. Studies assessing the toxicity of dermal exposures for wildlife species are limited. Available studies generally report results for laboratory rodents and are performed by shaving the fur and applying the contaminant directly to the exposed skin. This type of exposure rarely occurs in the environment.

Classes of chemicals known or suspected to be of concern via dermal absorption include volatile organic compounds (VOCs), pesticides, and petroleum compounds. Petroleum compounds are more likely to cause physical disruption and impairment in wildlife (e.g. oiling feathers, disabling flight, or interfering with temperature regulation) rather than chemical effects.

Conditions under which dermal pathways may need to be considered on a site-specific basis include:

- Species with little or no fur or feathers
- Species that spend a lot of time exposed to soil (i.e., in burrows)
- Where the contaminants of concern may be significantly more toxic via the dermal pathway compared to the oral pathway.
- Where dermal exposures may be substantially higher compared to oral exposures (i.e., pesticides applied directly to trees or soil surfaces).

Metals

Even though information is limited on the rate and extent of dermal absorption of metals in soil across the skin, most scientists consider that this pathway to be minor in comparison to exposures resulting from direct soil ingestion. This view is based on the following concepts: 1) most metals tend to bind to soils thus reducing the likelihood they would dissociate from the soil and cross the skin; and, 2) ionic species, such as metals, have a relatively low tendency to cross the skin, even when contact does occur. Based on these considerations, along with a lack of data to allow reliable estimation of dermal uptake of metals from soil, USEPA Region VIII generally recommends that dermal exposure to metals in soils not be evaluated quantitatively (USEPA, 1995).

VOCs

Since VOCs rapidly volatilize from surface soil, dermal contact by terrestrial wildlife to these contaminants in surface soils is expected to be minimal. However, this exposure pathway could be important for burrowing animals and may need further consideration on a site-specific basis if burrowing receptors and substantial VOC are identified.

Pesticides

There is some evidence to suggest that organophosphate (OP) pesticides are more toxic by dermal uptake compared to oral exposure. Driver et al. (1990) studied the uptake of agricultural chemicals to avian wildlife and found that routes of uptake in order of contribution to toxicological response were: dermal > preening >= oral > inhalation. They concluded that "thin avian skin may be even more conductive to OP uptake compared to mammalian skin" and "the principal barrier layer (*stratum corneum*) of the skin is greatly reduced in birds".

Henderson et al. (1993) evaluated oral and dermal exposures for the domestic pigeon (*Columba livia*) by applying treatments to the feet. The order of oral toxicity was the same as that for dermal toxicity: parathion > diazinon > methidathion. The data from this study suggests that dermally-applied pesticides were stored in the body, gradually appearing in the blood stream. Abou-Donia and Graham (1978) observed a similar toxic response to leptophos in hens dosed by long term application of the pesticide onto the comb compared to oral administration.

Each of these studies reports toxicity via dermal exposure to OP pesticides resulting from either direct application of the pesticide to the skin or spray application onto branches (perches). For avian wildlife, exposure to contaminants in soils is not expected to occur in a similar manner. There could however be site-specific conditions that result in dermal exposures to pesticides and these may need to be considered in a site-specific ERA.

1.2 Inhalation

Inhalation exposure pathways related to soil contamination generally consist of :

- Inhalation of volatile organic chemicals (VOCs) in ambient air (volatilization from soil)
- Inhalation of soil dust particles.

VOCs

VOCs are defined by USEPA (1998) as chemicals with Henry's Law constants greater than 10^{-5} atm-m^3/mol and molecular weights less than 200 grams/mol. Cal/EPA (1994) guidance defines a VOC as a chemical with a Henry's Law constant greater than 10^{-5} atm-m^3/mol and a vapor pressure greater than 10^{-3} mm Hg. VOCs are expected to disperse very rapidly in air following volatilization from soil or groundwater. This dispersion, caused by wind and advection, is likely to result in very low exposure point concentrations of VOCs in ambient air. Additionally, because VOCs have log Kow values less than 3.5, they are unlikely to be taken up and bioaccumulated in plant and animal tissues at significant levels (USEPA and USACE, 1998).

Additionally, most VOCs are generally not highly toxic to wildlife species. For humans, VOCs are mostly a concern because of their carcinogenic effects and the non-cancer effects of these chemicals seldom drive human health risk results. For derivation of wildlife Eco-SSLs, carcinogenic endpoints were not considered in the derivation of toxicity reference values (TRVs) (Appendix 4-3).

Since VOCs rapidly volatilize from surface soil, inhalation of VOCs from surface soil by wildlife species should be insignificant. However, this pathway may be significant for burrowing species and may need to be evaluated further based on site-specific conditions.

Metals and SVOCs

Metals and semi-volatile organic compounds (SVOCs) can sorb to dust particles and potentially be inhaled by ecological receptors. The fraction of dust that cannot be inhaled is considered non-respirable. Non-respirable dust can potentially be ingested and is, in fact, accounted for in published incidental soil ingestion values for wildlife species (USEPA, 1993). The fraction of dust that is respirable differs from species to species and little data exist to determine exact respirable fractions for individual ecological receptors. When the dust inhalation exposure pathway is evaluated for human receptors, it generally makes up a relatively insignificant fraction of the total multi-pathway risk (less than 5 percent, based on best professional judgement and the results presented by Carlsen, 1996).

Conditions under which inhalation pathways may need to be considered include:

- Sites where significant levels of VOCs are detected in soil gas within soil depths where wildlife species of concern may burrow.
- Sites with extensive VOC contamination in soils and/or groundwater.
- Sites with special-status species that occupy burrows and where any one of the above conditions is found.
- Where the contaminants of concern being evaluated are more toxic by the inhalation pathway compared to the oral pathway.

2.0 EXAMPLE DOSE ESTIMATES

To further demonstrate the relative contribution of the dermal and inhalation pathways to overall risk estimates compared to oral, the following analyses was completed. The following tables present examples of doses, toxicity and risk estimated for the oral, dermal, and inhalation pathways for different classes of chemicals at the same exposure concentration.

Exposure (Dose)

Very conservative assumptions and models were used in the dose estimation. The exposure and modeling assumptions, as well as a discussion of the conservatism of these values, are presented in an attachment and are summarized in Table 1.

The meadow vole was selected for this example because: (1) exposure assumptions are readily available (USEPA, 1993); (2) the small body weight of the meadow vole tends to maximize dose; and. (3) the meadow vole is an herbivore (simple diet). The use of a simplified diet decreased the number of dietary exposure pathways and allows for a more conservative evaluation of percent contribution of the dermal and inhalation pathways. The ingestion of invertebrates generally results in a higher dose compared to plant ingestion, which would decrease the relative contribution of the other pathways.

Table 1. Relative Dose Contributions for Meadow Vole[a]

Chemical	Dose (mg/kg-day) and Percent Contribution			
	Soil Ingestion	Plant Ingestion	Dermal Contact	Inhalation
Lead	0.78 38%	1.3 63%	4.1E-04 0.02%	7.9E-08 <0.001%
Fluoranthene	0.78 37%	1.3 63%	5.3E-03 0.2%	7.9E-08 <0.001%
DDT	0.78 79%	0.21 21%	1.2E-03 0.1%	7.9E-08 <0.001%

[a] Based on soil concentrations of 100 mg/kg and using standard exposure assumptions from USEPA, 1993, 1996, 1998. See attachment.

As shown in Table 1, the oral pathways (i.e., soil and biota ingestion) are the primary contributors to exposure (dose). For species ingesting invertebrates the primary exposure would be attributed to the invertebrate ingestion and the percent contribution of the dermal and inhalation pathways to the total dose would be even lower. Regardless, the contribution to the total dose associated with the dermal exposure pathway is 0.5% or less. The inhalation pathway contribution is very low at less than 0.01% for particulates and less than 1% for volatiles.

Absorption Factors

A comparison of dermal absorption factors against oral absorption factors indicates that 70% of the Eco-SSL COCs have a dermal absorption factor ranging from 1 to 33% of the oral absorption factor. Of the 21 COCs for which both dermal and oral absorption factors are available, 80% have a dermal absorption factor ranging from 1 to 33% of the oral absorption factor (see Table 2). Based on these findings, it can be assumed that, in general, the absorbed dermal dose is much lower than the absorbed oral dose for most COCs and the dermal exposure pathway is much less significant compared to the oral exposure pathway.

Toxicity

Comparison of the oral toxicity values (slope factor and reference dose) with respective dermal and inhalation toxicity values for each of the 24 Eco-SSL contaminants reveals little difference between the two values. If there is a difference, it is due to the conversion of oral toxicity values to dermal values using the oral absorption fraction (RAGS, Appendix A).

$$\text{Dermal RfD} = \text{Oral RfD} \times \text{Oral Absorption Factor}$$
$$\text{Dermal SF} = \text{Oral SF} / \text{Oral Absorption Factor}$$

This may result in a slightly greater dermal toxicity than oral toxicity since most oral absorption fractions are less than 100%.

A similar comparison of oral versus inhalation toxicity values reveals that for many of the Eco-SSL contaminants, the inhalation toxicity may be greater than the oral toxicity. These contaminants include hexavalent chromium, aluminum, barium, beryllium, cadmium, and manganese.

Risk Comparison

Table 3 presents a summary of oral, dermal and inhalation risk values from exposure to 1 ppm in soil for each of the 24 Eco-SSL contaminants (where toxicity information is available). In addition, ratios of risk values for dermal:oral and inhalation:oral are presented for each contaminant and summarized for all the contaminants. In general, the dermal risks ranged from less than 1% to 11% of the oral risks, and averaged 2.5% of oral risks. The inhalation risks ranged from 0.0001% to 0.1022% of the oral risks, and averaged 0.0172% of oral risks. These comparisons clearly indicate that dermal and inhalation risks from soil are much less significant than risks from ingesting soil for the Eco-SSL COCs.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The Eco-SSL Task Group characterizing exposure pathways for terrestrial wildlife decided not to include the dermal or inhalation pathways in the Eco-SSL wildlife exposure model based on best professional judgement. The discussion presented here provides a conceptual basis for this decision. It is anticipated that the contribution of the dermal and inhalation pathways will be negligible for most sites. However, a site-specific evaluation of the complete and potentially complete exposure pathways for terrestrial wildlife should be completed for each site. If this evaluation concludes that receptors may be more highly exposed to contaminants through the dermal and/or inhalation pathways because of site-specific conditions, then these pathways would need to be evaluated in the baseline risk assessment or a screening analyses separate from the use of Eco-SSLs.

Table 2
Summary of Eco-SSL Contaminant Relative Toxicity Values

Chemical	Oral RfD mg/kg-d		Oral Absrptn Fraction %	Source	Dermal Absrptn Fraction %	Source	Dermal [1] RfD mg/kg-d		Inhalation RfD mg/kg-d		RfD Comparison Oral/Dermal --	RfD Comparison Oral/Inh --	Dermal Abs/ Oral Abs %	Abs < 1?
Dieldrin	5.00E-05	IRIS	100.0%	cons assm	10.0%	EPA, 1995	5.00E-05	IRIS	--	--	1	--	10%	YES
Total PCBs	--	--	96.0%	ATSDR (McLachlan 1993)	6.0%	EPA, 1995	--	--	--	--	--	--	6%	YES
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	3.00E-03	IRIS	100.0%	cons assm	100.0%	cons assm	3.00E-03	IRIS	--	--	1	--	100%	NO
Trinitrotoluene (TNT)	5.00E-04	IRIS	94.0%	ATSDR (Army 1981d)	100.0%	cons assm	4.70E-04	IRIS	--	--	1.1	--	106%	NO
DDT & metabolites	5.00E-04	IRIS	70.0%	ATSDR (70-90 %, Keller & Yearny 1980)	10.0%	EPA, 1995	3.50E-04	IRIS	--	--	1.4	--	14%	YES
Pentachlorophenol (PCP)	3.00E-02	IRIS	90.0%	ATSDR (Braun et al, 1979)	24.4%	EPA, 1995	2.70E-02	IRIS	--	--	1.1	--	27%	YES
Polycyclic Aromatic Hydrocarbons (PAHs)	--	--	40.0%	ATSDR (Foth et al 1988a for BAP)	10.0%	EPA, 1995	--	--	--	--	--	--	25%	YES
Aluminum	1.00E+00	NCEA	27.0%	ATSDR (Gupta et al 1986)	1.0%	EPA, 1995	2.70E-01	NCEA	1.00E-03	NCEA	4	1000	4%	YES
Antimony	4.00E-04	IRIS	100.0%	cons assm	1.0%	EPA, 1995	4.00E-04	IRIS	--	--	1.0	--	1%	YES
Arsenic	3.00E-04	IRIS	95.0%	ATSDR (Bettley & O'Shea 1975)	3.2%	EPA, 1995	2.85E-04	IRIS	--	--	1.1	--	3%	YES
Barium	7.00E-02	IRIS	5.0%	ATSDR (ICRP 1973)	1.0%	EPA, 1995	3.50E-03	IRIS	1.40E-04	H-Alt	20	500	20%	YES
Beryllium	2.00E-03	IRIS	1.0%	ATSDR (Morgareidge et al, 1975)	1.0%	EPA, 1995	2.00E-05	IRIS	5.70E-06	IRIS	100	351	100%	NO
Cadmium-water	5.00E-04	IRIS	4.6%	ATSDR (McLellan et al 1978)	1.0%	EPA, 1995	2.30E-05	IRIS	5.70E-05	NCEA	22	8.8	22%	YES
Cadmium-food	1.00E-03	IRIS	25.0%	ATSDR (Rahola et al 1973)	1.0%	EPA, 1995	2.50E-04	IRIS	5.70E-05	NCEA	4	18	4%	YES
Chromium III	1.50E+00	IRIS	0.5%	ATSDR (0.5 - 2%, Anderson 1986)	1.0%	EPA, 1995	7.50E-03	IRIS	--	--	200	--	200%	NO
Chromium VI	3.00E-03	IRIS	0.5%	ATSDR (0.5 - 2%, Anderson 1986)	1.0%	EPA, 1995	1.50E-05	IRIS	3.00E-05	IRIS	200	100	200%	NO
Cobalt	6.00E-02	NCEA	18.0%	ATSDR 18-97%(Sorbie et al 1971; Valberg et al 1969)	1.0%	EPA, 1995	1.08E-02	NCEA	--	--	6	--	6%	YES
Copper	4.00E-02	H	60.0%	ATSDR (Weber et al, 1969; Strickland et al 1972)	1.0%	EPA, 1995	2.40E-02	H	--	--	1.7	--	2%	YES
Iron	3.00E-01	NCEA	100.0%	cons assm	1.0%	EPA, 1995	3.00E-01	NCEA	--	--	1.0	--	1%	YES
Lead	--	--	50.0%	ATSDR (Chamberlain et al,1978)	1.0%	EPA, 1995	--	--	--	--	--	--	2%	YES
Manganese-Nonfood	2.00E-02	IRIS	3.0%	ATSDR 3-5%(Davidsson et al 1988; 1989; Mena et al 1969)	1.0%	EPA, 1995	6.00E-04	IRIS	1.43E-05	IRIS	33	1399	33%	YES
Nickel	2.00E-02	IRIS	1.0%	ATSDR 1-10%(Ambrose et al 1976; Ho & Furst 1973; Tedeschi & Sunderman 1957)	1.0%	EPA, 1995	2.00E-04	IRIS	--	--	100	--	100%	NO
Selenium	5.00E-03	IRIS	90.0%	ATSDR 90-95% (Griffiths et al 1976; Thomson 1974; Thomson & Steward 1974; Thomson et al 1978)	1.0%	EPA, 1995	4.50E-03	IRIS	--	--	1.1	--	1%	YES
Silver	5.00E-03	IRIS	21.0%	ATSDR (East et al, 1980; MacIntyre et al 1978)	1.0%	EPA, 1995	1.05E-03	IRIS	--	--	5	--	5%	YES
Vanadium	7.00E-03	H	1.0%	ATSDR (Roshchin et al 1980)	1.0%	EPA, 1995	7.00E-05	H	--	--	100	--	100%	NO
Zinc	3.00E-01	IRIS	20.0%	ATSDR 20-30%	1.0%	EPA, 1995	6.00E-02	IRIS	--	--	5	--	5%	YES
													# YES	20
													Total	27
													% where derm abs factor less than oral abs factor	74.07%

Notes:

[1] Dermal toxicity values are adjusted from oral toxicity values based on oral absorption fractions and the following equations (RAGS, Appendix A: Dermal RfD = Oral RfD x Oral Absorption Efficiency; Dermal SF = Oral FS /Oral Absorption Efficiency

cons ass = Conservative assumption

Table 3
Summary of Risks and Risk Comparisons

Chemical	Soil Conc (mg/kg)	BW (kg)	Soil Ingest rate (kg/day)	**Intake$_{soil\ ing}$ (mg/kg-day)**	Skin Surface Area (cm2/day)	Soil-skin Adher factor (kg/cm2)	Dermal Abs Factor (unitless)	**Intake$_{soil\ derm}$ (mg/kg-day)**	PEF (kg/m3)	Inhal rate (m3/day)	**Intake$_{soil\ part\ inh}$ (mg/kg-day)**	RfD Oral mg/kg-d	RfD Dermal mg/kg-d	RfD Inhal mg/kg-d	**Noncancer Risk Oral**	**Noncancer Risk Dermal**	**Noncancer Risk Inhal**	**Risk Ratio Dermal:Oral**	**Risk Ratio Inhal:Oral**
Dieldrin	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.1	**4.08E-05**	7.58E-10	3.90E-02	**7.92E-10**	5.00E-05	5.00E-05	--	**1.52E+02**	**8.15E-01**	**--**	0.5371%	--
Total PCBs	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.06	**2.45E-05**	7.58E-10	3.90E-02	**7.92E-10**	--	--	--	**--**	**--**	**--**	--	--
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	1	**4.08E-04**	7.58E-10	3.90E-02	**7.92E-10**	3.00E-03	3.00E-03	--	**2.53E+00**	**1.36E-01**	**--**	5.3710%	--
Trinitrotoluene (TNT)	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	1	**4.08E-04**	7.58E-10	3.90E-02	**7.92E-10**	5.00E-04	4.70E-04	--	**1.52E+01**	**8.67E-01**	**--**	5.7139%	--
DDT & metabolites	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.1	**4.08E-05**	7.58E-10	3.90E-02	**7.92E-10**	5.00E-04	3.50E-04	--	**1.52E+01**	**1.16E-01**	**--**	0.7673%	--
Pentachlorophenol (PCP)	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.244	**9.94E-05**	7.58E-10	3.90E-02	**7.92E-10**	3.00E-02	2.70E-02	--	**2.53E-01**	**3.68E-03**	**--**	1.4561%	--
Polycyclic Aromatic Hydrocarbons (PAHs)	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.1	**4.08E-05**	7.58E-10	3.90E-02	**7.92E-10**	--	--	--	**--**	**--**	**--**	--	--
Aluminum	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	1.00E+00	2.70E-01	1.00E-03	**7.59E-03**	**1.51E-05**	**7.92E-07**	0.1989%	0.0104%
Antimony	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	4.00E-04	4.00E-04	--	**1.90E+01**	**1.02E-02**	**--**	0.0537%	--
Arsenic	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.032	**1.30E-05**	7.58E-10	3.90E-02	**7.92E-10**	3.00E-04	2.85E-04	--	**2.53E+01**	**4.58E-02**	**--**	0.1809%	--
Barium	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	7.00E-02	3.50E-03	1.40E-04	**1.08E-01**	**1.16E-03**	**5.66E-06**	1.0742%	0.0052%
Beryllium	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	2.00E-03	2.00E-05	5.70E-06	**3.79E+00**	**2.04E-01**	**1.39E-04**	5.3710%	0.0037%
Cadmium-water	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	5.00E-04	2.30E-05	5.70E-05	**1.52E+01**	**1.77E-01**	**1.39E-05**	1.1676%	0.0001%
Cadmium-food	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	1.00E-03	2.50E-04	5.70E-05	**7.59E+00**	**1.63E-02**	**1.39E-05**	0.2148%	0.0002%
Chromium III	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	1.50E+00	7.50E-03	--	**5.06E-03**	**5.43E-04**	**--**	10.7420%	--
Chromium VI	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	3.00E-03	1.50E-05	3.00E-05	**2.53E+00**	**2.72E-01**	**2.64E-05**	10.7420%	0.0010%
Cobalt	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	6.00E-02	1.08E-02	--	**1.26E-01**	**3.77E-04**	**--**	0.2984%	--
Copper	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	4.00E-02	2.40E-02	--	**1.90E-01**	**1.70E-04**	**--**	0.0895%	--
Iron	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	3.00E-01	3.00E-01	--	**2.53E-02**	**1.36E-05**	**--**	0.0537%	--
Lead	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	--	--	--	**--**	**--**	**--**	--	--
Manganese-Nonfood	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	2.00E-02	6.00E-04	1.43E-05	**3.79E-01**	**6.79E-03**	**5.54E-05**	1.7903%	0.0146%
Nickel	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	2.00E-02	2.00E-04	--	**3.79E-01**	**2.04E-02**	**--**	5.3710%	--
Selenium	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	5.00E-03	4.50E-03	--	**1.52E+00**	**9.06E-04**	**--**	0.0597%	--
Silver	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	5.00E-03	1.05E-03	--	**1.52E+00**	**3.88E-03**	**--**	0.2558%	--
Vanadium	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	7.00E-03	7.00E-05	--	**1.08E+00**	**5.82E-02**	**--**	5.3710%	--
Zinc	1	0.0373	0.000283	**7.59E-03**	15.2	1.00E-06	0.01	**4.08E-06**	7.58E-10	3.90E-02	**7.92E-10**	3.00E-01	6.00E-02	--	**2.53E-02**	**6.79E-05**	**--**	0.2686%	--
																	Max ratio	**10.7420%**	**0.1022%**
																	Min ratio	**0.0537%**	**0.0001%**
																	Mean ratio	**2.4558%**	**0.0172%**

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ATTACHMENT

ASSUMPTIONS USED IN THE DOSE CALCULATIONS

The following presents the equations and assumptions used to estimate doses for the meadow vole.

Table A1. Chemical Dose via Soil Ingestion

A. Intake Equation:

$$\text{Dose}_{\text{soil}}\ (\text{mg/kg-day}) = \frac{\text{Cs x IRs}}{\text{BW}}$$

B. Variables and Assumptions:

Variable	*Value*	*Units*	*Description*	*Source*
Cs	100	milligrams per kilogram	Chemical concentration in soil	Assumption
IRs	0.000283	Kilograms per day	Soil ingestion rate	2.4 percent of food ingestion (USEPA, 1993); total soil ingestion, includes incidental ingestion during grooming, etc.
BW	0.0373	kilograms	Body weight	Average of males and females, year-round (USEPA, 1993)

Table A2. Chemical Dose via Plant Ingestion

A. Intake Equation:

$$\text{Dose}_{plant}\ (\text{mg/kg-day}) = \frac{Cp \times IRp}{BW}$$

B. Variables and Assumptions:

Variable	*Value*	*Units*	*Description*	*Source*
Cp	Cs x PUF [a]	milligrams per kilogram	Chemical concentration in plant tissue	Chemical-specific [a]
IRp	0.0118	kilograms/day	Plant ingestion rate	Median of range of values (USEPA, 1993)
BW	0.0373	kilograms	Body weight	Average of males and females, year-round (USEPA, 1993)

[a] Plant uptake factors (PUFs): lead, 0.0412; fluoranthene, 0.0425; and DDT, 0.0065. From Baes et al., 1984 for inorganics and Travis and Arms, 1988 for organics. Models incorporate site-specific factors such as percent moisture in the food items and the percentage of reproductive and vegetative portions ingested. Values above are taken from previously conducted agency-approved ERAs for the meadow vole.

Table A3. Chemical Dose via Dermal Contact

A. Intake Equation:

$$Dose_{dermal}\ (mg/kg\text{-}day) = \frac{Cs \times SA \times AF \times ABS}{BW}$$

B. Variables and Assumptions:

Variable	*Value*	*Units*	*Description*	*Source*
Cs	100	milligrams per kilogram	Chemical concentration in soil	Assumption
SA	15.2	square centimeters per day	Surface area	10 percent of total surface area (USEPA, 1993); V. Hayssen *pers. comm.* (March, 1993)
AF	0.000001	kilograms per square centimeter	Soil-to-skin adherence factor	Upper end of range of values for naked human skin (USEPA, 1992)
ABS	lead, 0.01; fluoranthene, 0.13; DDT, 0.03	unitless	Absorption fraction of chemical from soil	USEPA, 1998
BW	0.0373	kilograms	Body weight	Average of males and females, year-round (USEPA, 1993)

Table A4. Chemical Dose via Inhalation

A. Intake Equation:

$$Dose_{inhal}\ (mg/kg\text{-}day) = \frac{Ca \times IRa}{BW}$$

B. Variables and Assumptions:

Variable	*Value*	*Units*	*Description*	*Source*
Ca	Chemical-specific	milligrams per cubic meter	Chemical concentration in air	Cs x PEF (non-volatiles) Cs / VF (volatiles) (see below)
IRa	0.039	Cubic meters per day	Inhalation rate	by allometric equation; USEPA, 1993
BW	0.0373	kilograms	Body weight	Average of males and females, year-round (USEPA, 1993)

The following modeling and chemical-specific factors were used:

> Calculation of Ca for non-VOCs – Cs x (7.6 x 10^{-10} kg/m^3). Particulate emission factor (PEF) from USEPA, 1996.
>
> Calculation of Ca for VOCs – Cs divided by VF, where VF (Volatilization factor) for 1,1,1-TCA (only chemical meeting definition of a VOC) is 15,000 m^3/kg. From USEPA, 1998 (consistent with emission and dispersion models presented in USEPA's Soil Screening Guidance [USEPA, 1996]; default site factors and chemical-specific factors used in the derivation, as specified by USEPA, 1998). The VF value is highly conservative for use with ecological receptors because the equation assumes no dispersion. This is a highly unlikely scenario for ecological receptors because they are unlikely to spend 24 hours/day in a burrow or other enclosed air space.

Dose Estimation

The attached table (Table 5) presents the dose estimation using the equations and assumptions presented above.

Uncertainties

The assumptions presented above were developed to be conservative in nature. Conservative assumptions include the following:

- The AF (soil-to-skin adherence factor) is based on 1992 USEPA guidance which has since been updated and recommends lower AFs. This guidance is still in *Interim Draft* form and not yet accepted in all states and regions. Also, the AFs presented are for naked human skin. These values are likely overly conservative for adult/juvenile wildlife species, which have fur and feathers that would tend to prevent dermal contact of soil directly with underlying skin. These values may be applicable for evaluating exposures to hairless young. (Note that ingestion of soil by preening of feathers and grooming of fur is included in the soil ingestion rate.)

- The air models used in the above evaluation are those developed by USEPA for evaluating human health exposures. These values may be overly conservative for many wildlife species. Additionally, the use of site-specific soil parameters and other site-specific factors tend to results in lower air concentrations (i.e., the models use the most conservative assumptions). However, the models may underestimate exposures for species that spend a lot of time in underground burrows in areas of VOC contamination (Carlsen, 1996). Exposure time considerations and more site-specific modeling assumptions may be needed to evaluate some wildlife receptors.

- To be conservative and provide a generic evaluation, no area use factors or other weighting factors were used.

Table A5. Dose Estimation for the Meadow Vole

Chemical	Soil Concentration (mg/kg)	Air Concentration (mg/m^3)[a]	Plant Uptake Factor (unitless)	Dermal Absorption Factor (unitless)	Meadow Intakes (mg/kg bw-day)[d]			
					Soil Ingestion	Plant Ingestion	Dermal Contact	Inhalation
Inorganics								
Lead	100	7.6.E-08	0.041	0.010	7.6E-01	1.3E+00	4.1E-04	7.9E-08
Semivolatile Organics								
Fluoranthene	100	7.6.E-08	0.043	0.13	7.6E-01	1.3E+00	5.3E-03	7.9E-08
4,4'-DDT	100	7.6.E-08	0.007	0.03	7.6E-01	2.1E-01	1.2E-03	7.9E-08
Volatile Organics								
1,1,1-TCA	100	6.7.E-03	NA	0.10	7.6E-01	NA	4.1E-03	7.0E-03

mg/kg	Milligrams per kilogram.
mg/m^3	Milligrams per cubic meter.
mg/kg bw-day	Milligrams per kilogram body weight - day.
NA	Not applicable.

[a] Based on soil concentration / PEF for non-volatiles and soil concentration / VF for volatiles.
[b] Seet text for intake equations, input parameters, and assumptions.