Variability in Soil Lead Concentrations in Washington State

Summary of Previous Materials Relevant to This Issue: The materials for the March 18th meeting included: (1) a summary of available information on arsenic and lead soil contamination prepared by Landau Associates: (2) maps displaying the range of arsenic and lead soil concentrations in the Tacoma Smelter Plume; and (3) a summary of data collected in soil surveys in Washington State. This information was designed to illustrate that lead concentrations in soils are highly variable and was intended to provide context for the Board's review of Ecology's working definition for lead-contaminated soils.

SAB Questions and Requests for Additional Evaluation: At the March 18th meeting, the Board reviewed the tables summarizing the range of lead concentrations in various Washington studies. The Board expressed concerns about whether available data was robust enough to detect elevated levels at particular properties given the large variations in soil concentrations. The Department agreed to provide additional information on the variations in soil lead concentrations.

Ecology's Review and Responses: Ecology and local health departments conduct two types of soil sampling studies. First, the agencies conduct studies that are designed to identify broad areas of concern. The information from these types of studies is used to prepare maps such as the maps showing lead and arsenic concentrations in areas around the former Asarco smelter. These studies are not designed to provide enough information to make property-specific decisions. Second, Ecology and local agencies conduct studies that are designed to evaluate soil concentrations at individual properties within these broader areas of concern. Most of the discussion at the March 18th meeting appeared to center around the second category of soil sampling. The following paragraphs provide two examples that illustrate (1) the variability in soil concentrations found at individual properties and (2) the sampling strategies being used to evaluate individual properties.

- Sampling Results for Child Play Areas in Western Washington: In late 1999, staff from Public Health - Seattle King County and the Department of Ecology collected soil samples from 48 child play areas at schools, child care facilities, parks and camps on Vashon and Maury Islands. Six to eight soil cores were collected from most play areas and soil from 5 depth intervals were analyzed for arsenic and lead. Lead concentrations ranged from non-detectable to 900 mg/kg with the highest concentrations reported in the two upper depth intervals (0-2" and 2-6"). MTCAStat was used to calculate the mean and upper 95th upper confidence limit on the mean (UCL95) for the upper two depth intervals at each of the 48 child play areas. Mean lead concentrations ranged from 8 to 176 mg/kg. UCL95 values ranged from 20 to 1641 mg/kg. The distribution of sample results, mean soil concentrations and UCL95 values for the 48 child play areas are shown in Table 1. Table 2 provides a comparison of the arithmetic means, the standard deviations, UCL95 and maximum values for the 10 play areas with the highest mean lead concentrations. In all cases, the average concentrations were below the MTCA Method A soil cleanup level (250 mg/kg). However, standard deviations for the 10 areas ranged from 39 to 185 and the UCL95s for eight of the 10 play areas exceeded 250 mg/kg.

Table 3 illustrates the variations in soil concentrations measured in samples collected at three different child play areas (e.g. playground, ballfield, open space) located at the same school property. Ecology uses the UCL95 as part of a three-part test to evaluate compliance with the MTCA cleanup standards. Seven of the 10 child play areas included in Table 2 had UCL95 values that exceeded 250 mg/kg. Ecology has also developed criteria for deciding whether some type of interim action is needed to more quickly reduce exposure to contaminated soils. For schools, interim actions would be pursued when the average concentrations in a play area exceed 700 mg/kg (or any single sample exceeds 1400 mg/kg). Additional testing is performed at child play areas where the UCL95 exceeds 700 mg/kg.

Table 1: Distributions of Average and Individual Lead Concentrations Found in Surface Soils at Child Use Areas on Vashon and Maury Islands (mg/kg)

Area	Depth	N	Lead Concentrations (mg/kg) - Percentiles						% > MTCA
			10%	25%	50%	75%	90%	MAX	
Maury/Vashon Island Child Use Areas									
Soil Samples	0-2”	322	5	10	19	35	69	900	2% (6)
Child Use Area Averages	0-6”	48	13	16	24	52	80	176	0
UCL on CUA Averages	0-6”	48	25	30	53	282	843	1641	27% (13)

Table 2: Summary Statistics for Child Play Areas on Vashon and Maury Islands with Highest Average Lead Concentrations

Decision Unit	MEAN	DIST	SD	UCL95	Max
Site 3-30-1	176.0	Neither	--	900	900
Site 1-28-2	134.4	Z-statistic	185.2	242	580
Site 2-21-1	107.3	Lognormal	95.6	582	440
Site 1-27-1	99.8	Lognormal	99.6	1641	300
Site 2-22-1	83.2	Lognormal	78	222	240
Site 1-39-1	78.1	Lognormal	98.3	457	360
Site 1-27-3	73.9	Lognormal	105.7	1278	300
Site 1-45-1	73.0	Lognormal	66.3	325	200
Site 2-35-2	70.2	Lognormal	80	507	230
Site 1-28-1	68.6	Normal	38.8	95	130

Table 3: Lead Concentrations from Three Child Play Areas Located on The Same Property

Sample Location	Decision Unit 1	Decision Unit 2	Decision Unit 3
1	300	380	170
2	150	21	300
3	68	6.9	26
4	110	19	33
5	140	19	17
6	14	5.4U	5.2
7	8	20	28
8	8.6	16	12

- Sampling Results for Play Areas at Schools in Eastern Washington: In Spring 2001, Ecology staff collected soil samples from child play areas (e.g. playground, ball field, other open areas) at several schools in the Wenatchee area. Ecology collected 5-10 surface soil samples from each child play area and analyzed the samples for arsenic and lead. Lead concentrations ranged from non-detectable to 1650 mg/kg. MTCAStat was used to calculate the arithmetic mean and upper 95th upper confidence limit on the mean (UCL95) for each school property. Mean lead concentrations for individual child play areas ranged from 10 to 718 mg/kg. UCL95 values ranged from 20 to 6746 mg/kg. Table 4 provides a comparison of the arithmetic mean, the standard deviations, UCL95 and maximum values for the 10 play areas with the highest lead concentrations. For five child play areas, the average concentrations exceeded 250 mg/kg. Standard deviations for the 10 child play areas ranged from 10 to 555 and the UCL95s for seven of the ten play areas exceeded 250 mg/kg. Table 5 provides the individual sample results for three of the ten child play areas with the highest average concentrations.

Table 4: Summary Statistics for a Subset of Wenatchee Area Schools

Decision Unit	N	MEAN	DIST	SD	UCL95	Max
#A	7	718	Normal	555	1126	1650
#B	6	606	Lognormal	543	6746	1500
#C	7	597	Lognormal	124	717	750
#D	7	554	Lognormal	396	2755	1050
#E	10	361	Lognormal	158	540	600
#F	5	222	Lognormal	236	1896	631
#G	7	190	Normal	99	263	280
#H	9	145	Lognormal	65	218	289
#I	6	25	Lognormal	19	122	51
#J	7	23	Lognormal	10	38	36

Table 5: Lead Concentrations from Three Child Play Areas

Sample Location	Play Area A	Play Area B	Play Area C
1	742	87.7	550
2	971	1500	750
3	75.6	373	530
4	807	135	400
5	14.4	567	560
6	767	971	660
7	1650		730

Variability in Child Blood Lead Concentrations in Washington State

Summary of Previous Materials Relevant to This Issue: The materials for March 18th meeting included (1) the most recent summary of the blood testing results prepared by the Department of Health (March 2003); (2) a summary of 2002 testing results (by county) with information on the percentage of children with blood concentrations greater than 10 ug/dL and between 5 and 9 ug/dL; and (3) a copy of the document "Washington State Childhood Blood Lead Screening Recommendations" which provides the rationale and recommendations for current child blood lead testing programs in Washington.

SAB Questions and Requests for Additional Evaluation: Dr. Faustman stated that it is difficult to interpret the available data because blood lead testing performed in Washington is non-random (children are tested only if parent requests testing or the physician recommends testing). The Board recommended that Ecology examine the NHANES III data for Washington State (which included a random sampling design) separately from the blood lead testing results that are collected from clinics where children are tested only upon request.

Ecology's Review and Responses: Ecology contacted the Department of Health Childhood Lead Poisoning Prevention Program to discuss the possibility of examining the NHANES III data for Washington State. Ecology was informed that the NHANES III data for Washington children is included in the overall lead testing information compiled by DOH. However, the DOH manager responsible for that program (Eric Ossiander) expressed reservations about using that information to gain a better understanding of blood lead concentrations in Washington children since the Washington data is part of a national survey and the sampling weights used in the study are based on national and regional population statistics. Consequently, we have not pursued this issue further. However, I am attempting to obtain the summary statistics from the NHANES III study broken down by ethnic group for the West Region.

Lead Exposure from Dermal Contact with Lead-Contaminated Soils

Summary of Previous Materials Relevant to This Issue: The evaluations included in the January 2004 discussion materials are based on the assumption that dermal contact with lead-contaminated soils is unlikely to be a significant exposure pathway relative to ingestion of soil/dust, food and drinking water because (1) lead tends to bind tightly to soil particles which reduces the likelihood that it will disassociate from the soil that adheres to the skin surface and (2) lead has a relatively low ability to cross the skin even when is does disassociate from soil particles. At the January 12th SAB meeting, Ecology identified two questions relevant to this issue: (1) Is the conclusion "dermal contact with lead-contaminated soils does not represent a significant contributor to overall lead exposure" consistent with current scientific information? and (2) If not, what approach should Ecology use to evaluate potential lead exposure resulting from dermal contact with lead-contaminated soils?

SAB Questions and Requests for Additional Evaluation: The Board was not comfortable with the general assumption on dermal contact given that (1) there is a large amount of uncertainty regarding the dermal absorption factor, (2) the range of dermal-to-ingestion ratios (< 1% to 15%) do not take into account higher potential dermal exposures that might occur when children play in mud or moist soils, and (3) the information materials provided by Ecology indicate that dermal exposure could be as high as 10-15% of estimated exposures resulting from incidental ingestion of soil and dust. The Board recommended that Ecology:

- Contact Dr. John Kissel (University of Washington) in order to obtain (1) information on dermal absorption of lead and (2) his opinion on the significance of the dermal contact pathway relative to overall exposure to lead-contaminated soils.
- Run the IEUBK model with dermal exposure included as alternate exposure source if the available information indicated it was plausible that dermal contact might contribute more than 1-2% of the overall exposure to lead-contaminated soils.
- Consider the uncertainty and variability in the parameters used to characterize dermal contact exposures when evaluating the overall uncertainty and variability in exposure estimates. At a minimum, the Board recommended that Ecology provide a qualitative discussion of this pathway when discussing uncertainty and variability in exposure estimates.

Ecology's Review and Responses: Ecology contacted Dr. Kissel to discuss several issues relevant to lead- and arsenic-contaminated soils. Dr. Kissel has extensive experience in this area. He was a member of the EPA Science Advisory Panel charged with reviewing EPA's evaluation of exposure and health risks associated with the use of CCA-treated wood. He is presently a member of the National Research Council committee charged with reviewing EPA's response to lead-contaminated soil problems in the Couer de Alene Basin. The results of that conversation and additional Ecology evaluations are organized around the following four questions:

- What is an appropriate dermal absorption factor to use when evaluating the potential lead exposure via dermal contact: Dr. Kissel noted there is considerable variability and uncertainty (including uncertainty on the amount of variability) associated with estimating the amount of soil-bound lead absorbed through the skin. He stated that it is standard practice to use a dermal permeability coefficient (K_p) value of 10^{-3} when evaluating the potential for dermal absorption of metals resulting from bathing and swimming. Although he was not aware of specific information for lead-contaminated soils, he recommended that Ecology contact the California Department of Toxics Substances Control (DTSC). The DTSC (2004)[1] has developed a lead risk assessment spreadsheet (California LeadSpread Model) that California agencies use to estimate blood lead concentrations that might result from exposure to lead via dietary intake, soil and dust ingestion, inhalation and dermal contact. DSTC selected a default dermal absorption value (0.0006 (0.06%)) that is based on a study by Moore et al. (1980)[2]. The DSTC default value is also consistent with information on (1) dermal absorption fraction for cadmium in soil (0.001 (0.1%)) and (2) the K_p values for lead (10^{-4}) and cadmium (10^{-3}) that is included in EPA guidance materials[3]. Specifically, a dermal absorption fraction for lead 0.001 (0.1%) can be extrapolated from the cadmium values by assuming that relative absorption rates for the two substances in water are also applicable (on a relative basis) to contaminated soils.

- What is the relative contribution of exposure resulting from dermal contact with lead-contaminated soils to other lead exposure pathways?: Dr. Kissel expressed the opinion that the amount of exposure from dermal contact with lead-contaminated soils was probably less than the standard error associated with estimated exposure resulting from incidental ingestion if traditional approaches and assumptions are being used to characterize the soil ingestion pathway (e.g. soil ingestion rate = 100-200 mg/day). To explore this issue further, Ecology used the dermal exposure assessment methods and parameters specified in the MTCA Cleanup Regulation to estimate potential lead uptake (ug/day) resulting from contact with soils containing 500 mg/kg. Figure 1 summarizes the exposure model and input parameters used to prepare those estimates. The estimated lead uptake resulting from dermal contact was then compared with lead uptake estimates for the pathways included in the IEUBK model. The evaluation results are summarized in Table 6 and compared with pathway contributions predicted

---

[1] Department of Toxic Substances Control. 2004. LeadSpread. Materials downloaded from DTSC website in April 2004 (http://www.dtsc.ca.gov.ScienceTechnology/ledspred.html). It is not clear from the website materials when the model was last updated.

[2] ATSDR (1999) includes a summary of the results from Moore et al. (1990). ATSDR (1999) states "...[f]ollowing skin application of ^{203}Pb-labeled lead acetate in cosmetic preparations (0.1 mL of a lotion containing 6 mmol lead acetate/L or 0.1 g of a cream containing 9 mmol lead/acetate/kg) to 8 male volunteers for 12 hours, absorption was < 0.03%, but expected to be 0.06% during normal use of such preparations (Moore et al. 1990). Most of the absorption took place by 12 hours of exposure."

[3] EPA distributed draft dermal assessment guidance for public review in September 2001. The EPA document identifies default dermal permeability coefficients (K_p values) for use in evaluating dermal exposure due to water contact. The document lists K_p values for lead (10^{-4}) and cadmium (10^{-3}). The EPA document does not include a dermal absorption rate for evaluating dermal contact with lead-contaminated soils. However, EPA does identify a dermal absorption factor for cadmium (0.1%). (EPA. 2001. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E Supplemental Guidance for Dermal Risk Assessment) Interim. Review Draft – for Public Comment. September 2001).

by the California Leadspread Model. Both models predict that lead uptake resulting from dermal contact with lead-contaminated soils will be small (@ 1% of exposure from all pathways) relative to lead uptake from soil/dust ingestion, drinking water and diet.[4] [NOTE: The California Leadspread Model identifies consumption of homegrown vegetables (grown in lead-contaminated soils) as an important source of lead exposure. This issue is discussed in a later section.]

Figure 1: Dermal Exposure Equation

$$Pb\ Uptake_D = PbS*SA*AF*ABS_D*EF_D*UCF$$

Where:

$PbUptake_D$	=	Dermal Uptake (ug/day)
PbS	=	Soil lead concentration (500 ug/g)
SA	=	Surface area (2200 cm^2)
AF	=	Soil adherence factor (0.2 mg/cm^2-event)
EvF	=	Event frequency (1 event/day)
ABS_D	=	Dermal absorption fraction (0.001)
EF_D	=	Exposure frequency (1)
UCF	=	Unit conversion factor (10^{-3} g/mg)

Table 6: Relative Pathway Contributions at Soil Lead Concentration of 500 mg/kg Predicted for Child Exposure Using the California Leadspread Model (DSTC, 2004)

Pathway	Relative Contribution based on California LeadSpread Model	Relative Contributions based on IEUBK Model	
		ug/day	%
Soil Contact	<1%	0.2	1 %
Soil Ingestion	45%	15.0	86 %
Inhalation (bkgrd + soil related)	<1%	0.06	<1 %
Water Ingestion	12%	0.9	6 %
Food (bkgd)	6%	1.3	6 %
Food (soil related)	35%	--	--

- <u>Does consideration of the dermal contact pathway make a large difference in blood lead concentrations predicted by the IEUBK model?</u>: Ecology ran the IEUBK model with estimated lead intake from dermal contact included as an alternate exposure source. The model was run using a range of dermal absorption fractions

[4] The conclusions regarding relative pathway contributions and the dependence on assumptions for dermal absorption are consistent with the conclusions and results of the human health screening analysis for the Spokane River child use areas prepared by the Environmental Protection Agency.

(0.1, 0.5 and 1%). Table 7 summarizes the results of the screening analysis. The results indicate that consideration of dermal contact does not make a large difference in predicted blood lead concentrations and P_{10} values when a dermal absorption fraction of 0.001 (0.1%) is used to evaluate exposure.

Table 7: Comparison of Predicted Blood Lead Concentrations Associated With Soil Concentrations of 500 mg/kg Using Different Dermal Contact Assumptions (12-36 month and 0-84 month age intervals)

	Dermal/Total Pb Uptake	12-36 months		0-84 months	
		CTE	P_{10}	CTE PbB	P_{10}
Default (No Dermal Absorption)	--	6.6	19.2	5.4	9.6
Dermal Contact (0.1% AB_D)	0.01	6.7	19.8	5.5	10.1
Dermal Contact (0.5% AB_D)	0.05	7.0	22.3	5.7	12.0
Dermal Contact (1.0% AB_D)	0.1	7.3	25.5	6.1	14.5

- Is the variability (uncertainty) in the dermal absorption factor a major contributor in the overall variability in dermal exposure estimates? A screening level assessment was conducted in order to gain a sense of the variability surrounding the exposure estimates produced using standard risk assessment methods and how variability in individual input parameters contributes to the overall variability in exposure estimates. For purposes of this evaluation, dermal absorption was considered to be a variable parameter (as opposed to an uncertain one). The relative contribution of each parameter was assessed by performing a Monte Carlo Analysis with Crystal Ball 2000® software. This analysis involved using computer simulation[5] to combine probability distributions for several parameters in the exposure equation with point estimates for the remaining parameters. The dermal exposure model was used to estimate lead uptake (expressed as ug/day) resulting from dermal contact with lead contaminated soils is shown in Figure 1. The distributions and point estimates used in the analysis are listed in Table 8.

Table 8: Point Estimates and Distributions Used to Evaluate Variability in Dermal Lead Uptake Estimates

Parameter	Distribution
Soil Lead Concentration (ug/g)	Lognormal (AM = 500, SD = 400)
Surface Area (cm^2)	Point estimate = 2200
Adherence Factor (mg/cm^2 - event)	Lognormal (GM = 0.11; GSD = 2.0)
Event Frequency (event/day)	Point estimate = 1
Absorption Fraction (unitless)	Uniform (0.001 to 0.01)
Exposure Frequency (unitless)	Triangular (0.1, 0.4, 1.0)

[5] The results are based on 10,000 Monte Carlo runs. This was found to be a sufficient number of runs to provide a stable output. The evaluation was performed based on the assumption there are not significant correlations among the parameters characterized by probability distributions.

The results of this analysis (Table 9) indicate that the variability in the dermal uptake estimates is influence by four factors. The assumed variability in dermal absorption fraction contributes approximately 25% to the overall variability in dermal uptake estimates.

Table 9: Contribution to Variance in Average Daily Lead Intake for Dermal Exposure		
	#1[6]	#2
Soil Adherence Factor	37 %	33 %
Soil Concentration	35 %	31 %
Dermal Absorption Factor	26 %	24 %
Exposure Frequency	--	12 %
Surface Area/Body Weight	2 %	--

The IEUBK model was run using dermal lead uptake values ranging from 0.22 to 2.2 ug/day. Table 10 indicates that the point estimate (0.22 ug/day based on use of a dermal absorption fraction = 0.001 (0.1%)) falls near the 50th percentile value of the simulated distribution. The IEUBK model is designed to predict mean blood lead concentration based on estimates of mean lead uptake. Consequently, the point estimate value (0.2 ug/day) is approximately half of the mean value which would provide an estimate that is more comparable to other pathways.

Table 10: Estimated Lead Uptake for Dermal Contact at Soil Concentration of 500 ppm (mg/kg/day)	
	Estimated Lead Uptake
Point Estimate	0.2 ug/day
Mean of Probabilistic Distribution	0.4 ug/day
50th	0.2 ug/day
75th	0.46 ug/day
90th	0.95 ug/day
95th	1.41 ug/day
Maximum of Probabilistic Distribution	10.4 ug/day
Standard Deviation	0.59
Ratio of 90th Percentile/10th Percentile	23.8
Percentile Value for Point Estimate Value	@ 50th

[6] The initial modeling runs were based on calculating lead exposure in units of ug/kg/day. With that model, the "surface area" term was replaced by surface area/body weight ratios and the analyses were run using a lognormal distribution for surface area/body weight ratio (Lognormal (AM = 0.0641; SD = 0.0114; range (0.0421 – 0.1142).). This distribution was obtained from the EPA Child-Specific Exposure Factors Handbook. The initial analyses indicate that the variability in this term was a relatively minor contributor to the overall variation in exposure estimates (< 2%). Consequently, this term was replaced by a point estimate for surface area (MTCA value = 2200 cm^2) so that exposure estimates are expressed in terms of ug/day which are directly comparable to uptake values estimated for other pathways using the IEUBK model.

Summary and Conclusions: Ecology continues to believe that exposure from dermal contact with lead contaminated soils is a small contributor to overall lead exposure. However, Ecology agrees that a more explicit discussion of this pathway should be included in future discussions of uncertainty and variability.

> Certain organo-lead compounds (e.g. lead acetate) are able to penetrate the skin and enter the blood stream. In contrast, the predominant forms of inorganic lead in the environment are believed to be poorly absorbed as a result of dermal contact with lead-contaminated soils (ATSDR, 1999; EPA, 1986; White, 1998; DTSC, 2004). Consequently, the IEUBK model does not address exposure/uptake via the dermal route of exposure. Other lead exposure models provide specific methods for evaluating this pathway (e.g. the California LeadSpread Model developed by the California Department of Toxic Substances Control). Evaluations performed with the DTSC model produce results that are consistent with the assumptions underlying the IEUBK model (e.g. exposure via dermal contact is predicted to be small relative to lead exposure from other pathways). However, there is considerable uncertainty and variability associated with estimating the amount of lead exposure via this pathway. Exposure estimates are sensitive to assumptions on the extent of dermal absorption, amount of soil adhering to the skin and frequency of contact. Dermal absorption factors ranging from 0.1 to 1.0 percent have been used by different agencies when evaluating exposures associated with dermal contact with lead-contaminated soils. This analysis was performed using dermal absorption factors at the low end of this range. Consequently, the conclusions regarding the significance of this pathway should be reviewed if future studies support the use of higher values.

Lead Exposure from Inhalation of Re-Suspended Soil and Dust

Summary of Previous Materials Relevant to This Issue: The evaluations included in the January 2004 discussion materials are based on three key assumptions: (1) children may be exposed to lead-contaminated soils as a result of re-suspension of contaminated soils due to wind erosion or human activities and the subsequent inhalation of re-suspended particulates; (2) inhalation exposure is a minor contributor to overall lead exposure; and (3) the default exposure assumptions built into the IEUBK model provide a conservative (health protective) approach for addressing this pathway[7]. The latter two assumptions are based on an evaluation of potential exposure resulting from re-suspended soil and dusts prepared by Landau Associates (Landau, 2003). The Board has been asked whether they agree with Ecology's decision to use the default exposure parameters (particularly the default airborne lead concentration) to estimate lead uptake arising from the inhalation of re-suspended soils and dust.

SAB Questions and Requests for Additional Evaluation: The Board reviewed the technical memorandum prepared by Landau Associates. The discussion focused on the three assumptions underlying the January 2004 discussion materials. On the first assumption, the Board concluded that Ecology should consider this pathway when estimating overall lead exposure. However, the Board did not reach a conclusion on the second and third assumptions due to questions surrounding the level of conservatism built into the fugitive dust models. The Board noted that, while the IEUBK default assumption appears to provide an upper-bound estimate, there are still questions related to the methods and assumptions used to predict the levels of airborne lead that might be present as a result of windblown dust/re-suspended soils and dust. The Board recommended that Ecology:

- Contact Dr. Timothy Larson (University of Washington) to obtain information on the use of EPA models and the extent to which they overestimate or underestimate ambient air concentrations.
- Work with Landau Associates, the EPA Air Program or the Ecology Air Quality Program to expand this evaluation to address the Board's concerns.

Ecology's Review and Responses: Ecology contacted Dr. Timothy Larson and members of the Ecology Air Quality Program to discuss this issue. The results of those conversations and additional Ecology evaluations are organized around following four questions.

- Does the approach for evaluating wind-blown dust included in the EPA Soil Screening Guidance provide a conservative method for characterizing potential exposure?: One estimate of airborne lead was derived using an EPA screening

[7] The Environmental Protection Agency has used this approach to evaluate health risks at Federal Superfund sites. For example, this approach (i.e. assuming airborne lead concentration of 0.1 ug/m3) was used when evaluating health risks in the Couer de Alene. The baseline risk assessment for that site states that the use of this assumption is consistent with air quality measurements in the Basin.

model that is commonly used to estimate the transfer of contaminated soil into the ambient air as a result of windblown soil re-suspension of surface soils. With this model, airborne dust levels are estimated using the reciprocal value of the particulate emission factor (PEF). Since the March meeting, I have reviewed additional information which indicates this model is commonly used by Superfund programs during screening level analyses and forms the basis for the default values in California's LeadSpread Model. I also contacted Dr. Larson (University of Washington) to discuss this model. He was not familiar with this particular model and suggested that Ecology contact Dr. Candis Claiborn at Washington State University who he thought was more familiar with this type of model. I will attempt to contact Dr. Clairborn prior to the May 28th meeting. I also spoke with the Ecology Air Quality Program staff working on Washington's policy for addressing situations where air quality standards are exceeded due to natural events (e.g. windblown dust). They reviewed the model and underlying assumptions and concluded that the model should produce a conservative estimate of windblown dust. However, they also noted the model is relatively old and the program currently uses models that enable use of more realistic assumptions.

- <u>Does the use of national default parameters provide conservative estimates of airborne lead concentrations associated with windblown dust in Washington?</u>: Based on the assumption that the model truly does provide a conservative approach, Ecology conducted additional screening analyses in order to consider potential regional differences in model outputs. A key factor in the EPA screening equation is the particulate emission factor (PEF) which represents an estimate of the amount of dust that may be suspended from the soil surface due to wind erosion. The concentration of respirable particulate matter (expressed as PM_{10}) is calculated as the reciprocal of the PEF value. The earlier analysis was based on a PEF value of 4.63 x 10^9 m^3/kg which produces estimated PM_{10} and airborne lead concentrations of 0.2 ug/m^3 and 4 x 10^{-5} ug/m^3, respectively. However, PEF values vary depending on several factors (e.g. soil moisture, soil type, parcel size etc) and the EPA guidance materials contain information for taking some of those factors into account by varying the Q/C[8] value according to region and parcel size. Table 11 provides a comparison of predicted airborne lead concentrations using EPA default regional values applicable to Eastern and Western Washington. The comparison indicates that the use of PEF values based on regional default parameters that more closely reflect conditions in Washington results in estimates of PM_{10} and airborne lead concentrations that are 5 to 10 times higher than the estimates based on the national default value. The higher estimates are similar to the default values used by the State of California when evaluating exposure to lead-contaminated soils. Consequently, it appears that some of the assumptions inherent in the use of national default values would under-predict PM_{10} levels for some Washington exposure scenarios. However, all of the estimated values are lower than the IEUBK concentration term (1.0 E-01 ug/m^3).

[8] The calculated PEF values are sensitive to the assumptions made regarding the Q/C factor which varies with geographic area and property size.

Table 11: Range of Predicted PM10 Concentrations Predicted Using Fugitive Dust Screening Model in EPA (1996)

	Q/C[9]	PEF	PM_{10}	Airborne Lead[10]
	(g/m^2-s per kg/m^3	m^3/kg	ug/m^3	ug/m3
EPA Default (EPA, 1996)	90.8	1.3E+09	7.6E-01	2E-04
Landau Associates (2003)	---	4.6E+09	2.2E-01	4E-05
California Screening Value[11]	38.5	5.6E+08	1.8E+00	4E-04
Eastern WA (Using EPA values for Boise ID)				
0.5 acre	69.1	1.0E+09	1.0E+00	2E-04
1 acre	60.88	8.8E+08	1.1E+00	2E-04
2 acre	53.94	7.8E+08	1.3E+00	3E-04
5 acre	46.57	6.8E+08	1.5E+00	3E-04
10 acre	41.87	6.1E+08	1.6E+00	3E-04
30 acre	35.75	5.2E+08	1.9E+00	4E-04
Western WA (Using EPA values for Seattle WA)				
0.5 acre	82.72	1.2E+09	8.3E-01	2E-04
1 acre	72.62	1.1E+09	9.5E-01	2E-04
2 acre	64.38	9.3E+08	1.1E+00	2E-04
5 acre	55.66	8.1E+08	1.2E+00	3E-04
10 acre	50.09	7.3E+08	1.4E+00	3E-04
30 acre	42.86	6.2E+08	1.6E+00	3E-04

- Why are the airborne lead concentrations predicted using actual PM_{10} data higher than the airborne lead concentrations predicted using the EPA Screening Model?: Landau Associate included estimates of airborne lead concentrations that were based on PM_{10} concentrations measured at ambient monitoring stations in Spokane and Washington. Specifically, the maximum reported PM_{10} concentration from Spokane and Yakima Counties (100 ug/m^3) was used to estimate $PM_{2.5}$ and airborne lead concentrations of 60 ug/m^3 and 1 x 10^{-2} ug/m^3, respectively. At the March 18th SAB meeting, Dr. Landau noted the results of the initial analysis raised questions on the level of conservatism because the predicted concentrations using the EPA screening model were much lower than estimated levels based on observed particulate matter (PM_{10}) data (Dr. Landau noted these results were the opposite of what one would expect when using a screening model). Obviously, there are many possible explanations. As discussed above, the use of the EPA Screening Model with the

---

[9] Q/C values obtained from Exhibit 11 of Soil Screening Guidance: User's Guide published by EPA's Office of Solid Waste and Emergency Response in July 1996 (Publication 93355.4-23)

[10] All calculated values rounded to one significant figure.

[11] The California Office of Environmental Health Hazard Assessment (OEHHA) recently published the document entitled "Guidance for School Risk Assessment Pursuant to Health and Safety Code Section 901(f): Guidance California LeadSpread Model includes default dust concentration in outdoor air (1.5 ug/m3) based on EPA Soil Screening Guidance (EPA, 1996)

national default values results in estimates that are 5-10 times lower than estimates based on region-specific default values. In addition, the direct comparison of the two estimates is somewhat misleading because of differences in the underlying data and assumptions. In particular, the maximum PM_{10} measurements are based on concentrations measured during a 24 hour period. Consequently, such measurements provide a conservative estimate of average ambient dust concentrations. However, the PEF represents an annual average emission rate based on wind erosion. Consequently, it is reasonable to anticipate that estimates based on maximum values would be greater than estimates based on annual averages. A recent report published by the Ecology Air Quality Program summarizes the annual mean $PM_{2.5}$ concentrations for Spokane and Yakima for the years 1999 through 2001. In both areas, annual mean $PM_{2.5}$ concentrations were 8-10 ug/m3. This range is 6-7 times lower than the estimated $PM_{2.5}$ value used in the earlier analysis.

- How do the revised estimates of airborne lead concentrations compare with the IEUBK default value? Ecology used the information summarized above to prepare additional estimates of airborne lead concentrations. The results of those analyses are summarized in Table 12. The underlying assumptions used to prepare each estimate are summarized in the accompanying footnotes. In general, the revised estimates are higher than the earlier estimates prepared using the EPA Screening Method. However, all of the estimated values are below the default value in the IEUBK model. I have also included information from a large study where researchers from Washington State University and the University of Washington have studied the potential relationships between particulate toxic metals and hospital visits for asthma. As part of that effort, the study team analyzed particulate matter samples collected from January 1995 to March 1999 for a wide range of metals (including the lead). Information on the metal concentrations measured in the coarse fraction is summarized in Clairborn et. al. (2002). As shown in Table 12, the average lead concentration in the coarse fraction is similar to estimates based on measure PM_{10} and an assumed soil lead concentration of 200 mg/kg. The study team is currently finishing a final project report that will include information on metal concentrations in the finer particulate fractions.

Table 12: Comparison of Approaches for Estimating Airborne Pb Concentrations for Use in IEUBK Model					
Estimate	Soil Pb Concentration (mg/kg)	Measured or Estimated PM_{10} (ug/m^3)	Measured or Estimated $PM_{2.5}$ (ug/m^3)	Pb Enrichment (soil-to-finer particles)	Measured or Predicted Airborne Pb Concentration (ug/m3)
IEUBK (Model Default)[12]	--	--	--		1 E-01
Measured PM_{10} (Maximum PM10 measurements + 200 mg/kg soil concentration + Pb enrichment in finer soil fraction)[13]	200	100	60	3	4 E-02
PEF Screen (Eastern Washington PEF values + 200 mg/kg soil concentration + Pb enrichment in finer soil fraction)[14]	200	2.0	--	3	1 E-03
Spokane Metals Study[15] (Coarse Fraction Concentration + adjustment for Pb enrichment in finer soil fraction)	--	--	--	3	5 E-03
Spokane Pb (Average annual $PM_{2.5}$ Measurements + 200 mg/kg soil lead concentration + Pb enrichment in finer soil fraction)[16]	200	--	10	3	6 E-03

---

[12] The IEUBK default is based on the lower end of the range (0.1 – 0.3 ug/m^3) of outdoor air lead concentrations reported in U.S. cities without major point sources of lead in 1988.

[13] Landau Associates used information on the maximum PM10 dust concentrations from Spokane and Yakima County to calculate an estimated airborne lead concentration of $1x10^{-2}$ ug/m^3. Key assumptions include: (1) lead concentrations in airborne dust are the same as those in soils; (2) estimated maximum $PM_{2.5}$ concentrations are 60% of maximum PM_{10} concentrations. An additional multiplier (3) was included to account for potential enrichment in windblown dust relative to parent soils. This a high-end estimate used by Stern (1994) to estimate lead concentration in household dust derived from outdoor soils.

[14] Landau Associates used the EPA Screening Model to produce an estimate of airborne lead concentrations. This estimate was prepared using that model and the following data and assumptions: (1) a PEF based on region default values was used to estimate PM10 concentrations; (2) PM10 concentrations were assumed to be a surrogate for PM2.5 levels; (3) average soil lead concentrations are 200 mg/kg; and (4) the Pb concentrations in the smaller airborne particulates are enriched (by a factor of 3) relative to soil concentrations in the parent soil.

[15] Claiborn, C.S., Larson, T. and L. Sheppard. 2002. Testing the Metals Hypothesis in Spokane, Washington. Environ. Health Perspect. 110(suppl 4): 547-552. Table 3 summarizes Pb concentrations in the coarse particulate samples collected in Spokane from January 1995 to March 1999. The results summarized in Table 3 are mean lead concentration (1.6 ng/m3), standard deviation (1.1), number of samples with detected Pb concentrations (565) and percentage of samples with detectable levels of Pb (35.3%).

[16] The Ecology Air Quality Program published the “1999-2002 Air Quality Data Summary” in January 2004. The data summaries for Spokane and Yakima Counties indicate that annual PM2.5 concentrations ranged from 8-10 ug/m3 during the period from 1999 to 2001 (the data for 2002 were identified as not fully validated). This information was used to produce an estimate of airborne lead concentrations using the following assumptions: (1) all of the PM2.5 is derived from soil; (2) average soil lead concentrations are

- <u>How sensitive are the results of the IEUBK model to changes in the airborne lead concentrations?</u> Ecology ran the IEUBK model using three values for airborne lead concentrations that varied by an order of magnitude (EPA default value (0.1 ug/m^3), 10X the EPA default (1.0 ug/m^3) and 0.1X the EPA default (0.01 ug/m^3)). As discussed above, the lower end of this concentration range is similar to the range of airborne lead concentrations predicted using measured PM_{10} concentrations. The results of the screening analysis indicate that order-of-magnitude changes in the airborne lead concentration parameter have a small impact on the predicted blood lead concentrations and P_{10} values.

Table 13: Comparison of Predicted Blood Lead Concentrations

	Lead Concentrations		Air Uptake as % if Total Daily Uptake	CTE PbB	P_{10}
	Soil (mg/kg)	Air (ug/m3)		(ug/dL)	(%)
IEUBK Default	200	0.1	0.5%	3.5	1.2
Higher Air Lead Levels	200	1.0	5%	3.6	1.5
Lower Air Lead Levels	200	0.01	0.05%	3.5	1.2

<u>Summary and Conclusions</u>: Ecology continues to believe that evaluations performed using airborne lead concentration included in the IEUBK parameters is a reasonable approach for estimating lead intakes that might result from inhalation of wind-blown dust. Specifically, the range of airborne lead concentration estimates developed using several different approaches fall 1-2 orders of magnitude below the IEUBK default value. Ecology recognizes there a great deal of uncertainty associated with estimating ambient dust concentrations resulting from the re-suspended soils and dust. However, the results of the IEUBK model appear relatively insensitive to changes in airborne lead concentrations. For example, the IEUBK model was run using an ambient air lead concentration of 1 ug/m^3. This is 10 times the default value and 100 - 1000 times the airborne lead concentrations predicted using fugitive dust models and Washington ambient air data. This high-end estimates produces a relatively small increase in the CTE PbB and P_{10} values predicted by the IEUBK model.

200 mg/kg; and (3) the Pb concentrations in the smaller airborne particulates are enriched (by a factor of 3) relative to soil concentrations in the parent soil.

Estimating Lead Concentrations in Soil-Derived Indoor Dust

Summary of Previous Materials Relevant to This Issue: Children may be exposed to lead-contaminated soils that are mixed with other sources of indoor dust. In most cases, information on lead concentrations in indoor dust is not available and the IEUBK model includes several options for estimating lead concentrations in indoor dust based the lead concentrations measured in outdoor soils. The January 2004 discussion paper was prepared using the approach currently recommended by the EPA Technical Review Work Group for Lead[17]. Under this approach, soil-derived indoor dust concentrations are estimated by multiplying soil levels by 70% and adding 10 mg/kg to account for contributions from air deposition. This approach differs from the approach used to establish soil cleanup levels for other hazardous substances under the Model Toxics Control Act. The methods in the MTCA Cleanup Regulation reflect an underlying assumption that soil and dust concentrations are equal.

SAB Questions and Requests for Additional Evaluation: At the March 18th meeting, the Board was informed that insulation materials used in many homes in Washington contain rock wool made from Asarco slag. The Board recommended that Ecology consider this and other information to determine whether the default relationships between lead concentrations in soil and household dust are appropriate for Washington. It was noted that Metro had funded several dust studies by John Roberts that might be a source of Washington-specific information.

Ecology's Review and Responses: Ecology reviewed this issue and the following response is organized around a series of four questions:

- What is the basis for the EPA default value?: The M_{SD} is a conversion factor used to estimate lead concentrations in indoor dust that are derived from outdoor soil. EPA states that the M_{SD} may be used to approximate lead concentrations in indoor dust when: (1) soil is the major source of indoor dust lead; (2) the soil data are representative of that portion of the soil fraction and matrix which contributes to indoor dust (i.e. no enrichment or reduction in the soil fraction that is transported indoors); and (3) the areas where soil samples are collected coincide with the major source areas for soil derived indoor dust. Although, the EPA guidance materials[18] do not contain specific references for the default value, the document includes the following information: "...[t]he selection of a default value for the soil-to-dust coefficient was based on empirical data. In sites where soil-to-dust coefficients have been measured and where paint does not contribute greatly to dust, the range was 0.09 to 0.85. Among the sites where soil-to-dust coefficients have been measured are the following: East Helena, 0.85 (0.81 and 0.89); Midvale, 0.70 (0.68, 0.72); Butte, 0.26;

[17] Environmental Protection Agency. 2003. IEUBK Model Mass Fraction of Soil in Indoor Dust (M_{SD}) Variable. Produced by the Technical Review Workgroup for Lead.
[18] Environmental Protection Agency. 1994b. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children.

and Kellogg, 0.09. Recent data suggest that the coefficient decreases over time at some sites where major sources of soil lead deposition are no longer active...”

- Is the EPA default value based on data collected in exposure situations similar to exposure situations in Washington State?: Ecology has previously considered this issue when developing cleanup requirements for the Dupont Works site. At that site, Ecology agreed that it was appropriate to use a value (45%) that is lower than the EPA value because (1) new homes at the site will not contain lead-based paint, (2) leaded gasoline will not be used in motor vehicles in the future and (3) future roads in the area will not have been impacted by past use of leaded gasoline[19]. However, the rationale used to justify a lower value for this site may not be applicable to areas of the state which include older homes that contain lead-based paint and existing roads that have been impacted by past use of leaded gasoline. As part of this effort, Glass[20] (1997) analyzed information on arsenic concentrations in soils and dust obtained several previous studies (1) the University of Washington Exposure Pathways Study in the Ruston/North Tacoma/Vashon Island area, (2) Puget Sound Air Pollution Control study of 11 homes in the Ruston/North Tacoma/Vashon Island area, (3) the Department of Health study of 10 homes in the Everett Smelter Site. The Exposure Pathway Study results provided the most extensive set (109 concentration pairs + 10 concentration pairs from Bellingham) and includes information that was collected after the smelter was closed (the smelter was closed midway through the study). Glass calculated dust/soil concentration ratios that ranged from 0.08 to 8.05 (excluding 4 outliers with ratios greater than 10) and performed a series of regression analyses. The results for all areas are summarized in Table 14. Glass concluded that “...[t]he overall linear regression coefficient for the Ruston/North Tacoma Exposure Pathways Study soil-to-dust analysis supports the default factor of 70 as applicable to sites where air concentrations reflect a substantial ongoing source...”

Table 14: Summary of Regression Analyses Performed by Glass (1997) for Arsenic Concentrations in Soil and Dust Samples from the Exposure Pathways Study ($R^2 > 0.5$)

Analysis	Regression Equation	Dust/Soil (soil concentration of 100 mg/kg As)
Linear Model – All Areas	DUST = 51.7 + 0.732 SOIL (R^2 = 59.8%)	0.732
Log-Log Model - All Areas	DUST = 4.08 * SOIL$^{(0.702)}$ (R^2 = 51.8%)	0.726
Linear - Ruston	DUST = 142 + 0.679 SOIL (R^2 = 53.9%)	0.679
Linear – Census Tract 604	DUST = 6.7 + 0.880 SOIL (R^2 = 61.3%)	0.88
Linear – Vashon (exclude 1 outlier)	DUST = 11.9 + 0.722 SOIL (R^2 = 61.4)	0.722

[19] The Dupont Works site is not expected to have significant non-soil sources (e.g. no lead paint or air sources), so transfer coefficient value of 70% is too high for this site.” (p. 2). Gradient Corp. 1997. Estimating the Soil-to-Dust Transfer Coefficient. Prepared for Washington Department of Ecology. February 12, 1997.

[20] Glass, G. 1997. Review of Soil-to-Dust Submittals (Letter of July 11, 1997 Mike Blum to Greg Glass. Memorandum from Greg Glass to Mike Blum (August 12, 1997).

As noted above, EPA states that the M_{SD} may be used to approximate the concentration of Pb in indoor dust when: (1) soil is the major source indoor dust lead; (2) the soil data are representative of that portion of the soil fraction and matrix which contributes to indoor dust (i.e. no enrichment or reduction in the soil fraction that is transported indoors); and (3) the areas where soil samples are collected coincide with the major source areas for soil derived indoor dust.

- What information is available on the variability in the relationship between lead concentrations in outdoor soils and soil derived indoor dust?: Several approaches have been used to characterize the relationship between lead concentrations in soils and indoor dust.
  - Stern (1994)[21] estimated indoor dust concentrations as a product of (1) the concentration of lead in the soil, (2) the fraction of indoor dust that is soil derived (F) and the (3) ratio (S) of concentrations of lead in soil-derived indoor dust to the concentration of lead in soil. Stern (1994) used a triangular distribution (0.2, 0.3, 0.5) to characterize the fraction of soil that is soil derived and a triangular distribution (1.0, 1.2, 3.0) to characterize the enrichment of lead in indoor dust (relative to outdoor soil). The range of values reflected in these distributions were selected based on information from several studies and reflect an underlying assumptions that (1) lead concentrations in soil and dust increase as the size of soil and dust particles decrease and that (2) indoor dust is enriched in smaller size particles relative to outdoor soil.
  - Trowbridge and Burmaster[22] (1997) compiled information on 12 rare earth elements from studies concentration data was available for both soil and dust. The available information produced 26 estimates of a dust-to-soil ratio that ranged from 0.2 to 0.92. The authors concluded that a lognormal distribution fit the data very well ($r^2 = 0.9729$) with an arithmetic mean and arithmetic standard deviation of 0.445 and 0.1687, respectively.
  - Glass (1997) and Gradient (1997) reviewed available information on soil-to-dust transfer ratios. Gradient recommended using a soil-to-dust transfer coefficient of 15 to 45%. Glass recommended a range of 15-50% "with relatively high confidence" or 20-45% with somewhat lesser but still appreciable confidence. In discussing the range of values, Glass provided an excellent discussion of the factors that might influence soil-to-dust transfer. His calculations demonstrate there is considerable variability in the ratios calculated using the data from Exposure Pathways Study depending on (1) choice of dataset (whole area vs subareas); (2) choice of regression method (linear vs log-log model) and (3) handling of outliers. For example, the dust-to-soil ratios calculated using a linear regression model range from -0.046 (Census tract 604 for soils less than 100 ppm) to 1.687 (based on results from the Bellingham control area). However, there were also wide variations in the R^2 values associated with the different analyses.

---

[21] Stern, A.H. 1994. Derivation of a Target Level of Lead in Soil at Residential Sites Corresponding to a De Minimus Contribution to Blood Lead Concentration. Risk Analysis 14 (6): 1049- 1056.
[22] Trowbridge, P.R. and D.E. Burmaster. 1997. A Parametric Distribution for the Fraction of Outdoor Soil in Indoor Dust. Journal of Soil Contamination 6: 161-168.

The dust-to-soil ratios from the five analyses that resulted in R^2 values greater than 0.5 were consistent with the EPA default value (See Table 13).

- What information should be considered when designing a site-specific or Washington-specific soil-to-dust transfer factor?: There are many non-soil sources of lead that might contribute to lead concentrations in indoor dust (e.g. lead-based paint). The possibility that Asarco slag was used in home insulation materials in Washington was discussed at the March 18th meeting. I have discussed this with several Ecology site managers who confirmed that site-specific evaluations had found evidence that Asarco slag has been used in home insulation materials in Washington homes. However, I could not find any information on the extent to which this material was used in home insulation or the possible impact on indoor dust concentrations. If studies were performed in Washington to develop a soil-to-dust transfer factor, this is the type of information that would need to be considered during study design and interpretation of results. Similarly, the household dust surveys conducted by Roberts et al. provide information on the range of lead concentrations in Washington homes. However, the results from those investigations do not provide sufficient information on soil concentrations to allow a calculation of a soil-to-dust transfer coefficient.

Variability in Soil Ingestion Rates

Summary of Previous Materials Relevant to This Issue: The default values in the IEUBK model (85 – 135 mg/day) represent central tendency estimates (CTE) for children (ages 0-84 months) and are based on studies conducted in Massachusetts, Montana and Washington. At the January 12th meeting, Ecology requested that the Board address two questions relevant to this issue: (1) Are the exposure parameters and assumptions used in the evaluation consistent with current scientific information? and (2) Are there particular population groups where the exposure parameters and assumptions used in this evaluation do not provide an appropriate characterization of potential exposure?

SAB Questions and Requests for Additional Evaluation: The Board reviewed and discussed the exposure parameters and assumptions summarized on page 21 of the January discussion materials. Dr. Norman noted that the parameters could be divided into two groups (1) parameters that are not expected to vary between areas (e.g. parameters used to estimate the amount of lead absorbed from the gastrointestinal tract) and (2) exposure factors where Washington-specific values might be different than the national default values. The Board appeared to agree that the national default values were consistent with current scientific information. However, the Board recommended that Ecology give further consideration to the applicability of certain parameters to Washington State. With respect to soil ingestion rates, the Board suggested that Ecology evaluate the default soil ingestion rate in light of more recent re-analyses of soil ingestion data and the characteristics of Washington exposure scenarios (e.g. amount of bare vs grass-covered soils).

Ecology's Review and Responses: : Ecology reviewed this issue and the following response is organized around a series of four questions:

- <u>What information is available on the variability in soil/dust ingestion rates?:</u> Soil/dust ingestion rates likely vary by age, activity pattern, accessible dust and soil and other factors. The IEUBK model includes default assumptions for the amount of soil and dust ingested by young children. In contrast to the MTCA Cleanup Regulation and EPA Superfund guidance which specifies a single value (200 mg/day) for young children (0-6 years of age), EPA selected a series of age-specific default values that range from 85 to 135 mg/day. The IEUBK guidance materials do not provide a clear description of how the individual age-group values were selected. However, EPA based its' selection on the results of four studies that applied a trace element approach to quantify ingestion rates. Table 15 presents the summary statistics for the four studies (Davis, et al. 1991; Calabrese et al. 1989; Binder et al. 1986; Clausing et al. 1987). When view together, the results of the various studies indicate that soil/dust ingestion rates vary by study area, age and the tracer element used to prepare the estimate.

Table 15: Summary of Daily Intake of Soil and Dust Estimated From Elemental Abundances (Information from Table 2-6 in EPA (1994) and Individual Studies)

		Soil/Dust Intake (mg/day)			
	Element	Median	Mean	Std Dev	Range
Davis et al. 1991	Al	25	39	14.4 (SE)	-279 to 903
Ages 2 – 7 years	Si	59	82	12.2 (SE)	-404 to 535
	Ti	81	246	119.7	- 5820 to 6182
Calabrese et al. 1989	Al	30	154	852	6837 (max)
Ages 1-4 years	Ti	30	170	218	6707 (max)
	Y	11	65	85	6736 (max)
	Zr	11	23	21	1391 (max)
Binder et al. 1986	Al	121	181	203	25 to 1324
Ages 1-3 years	Si	136	184	175	31 to 799
	Ti	618	1834	3091	4 – 17,076
Clausing et al. 1987	Al	92	232	--	979 (max)
Ages 2 – 4 years	Ti	269	1431	--	11,620
	AIR	106	124	--	302

- What approaches have been used to characterize the variability in soil/dust ingestion rates? Several individuals and organizations have developed distributions to characterize the variability in soil/dust ingestion rates. This has been done for the general population and I am not aware of efforts to examine particular groups of children (other exposures related to pica behavior and tribal consumption patterns). Most of the approaches start with the selection of a lognormal distribution and then use different datasets to select distribution parameters. Most recently, EPA[23] used a lognormal distribution (arithmetic mean of 60.6, standard deviation of 80.5, a lower bound of 0 and an upper bound of 500) which is based on a reanalysis of the data from the Calabrese et al. study. Table 16 summarizes several of the approaches used by state and federal agencies.

[23] Environmental Protection Agency. 2003. *A Probabilistic Exposure Assessment for Children Who Contact CCA-Treated Playsets and Decks: Using the Stochastic Human Exposure and Dose Simulation Model for the Wood Preservative Scenario (SHEDS-Wood).*

Table 16: Examples of Distributions Developed to Characterize Variability in Child Soil/Dust Ingestion Rates	
Source	Distribution
EPA Region VIII[24]	Lognormal (AM = 100; SD = 53)
EPA Office of Pesticide Programs	Lognormal (M = 60, SD = 80, UB = 500)
Oregon Department of Environmental Quality[25]	Lognormal (mean of natural logarithms = 4; standard deviation of natural logs = 0.3, LB = 0 and UB = 480)
Stern (New Jersey Department of Environmental Protection)[26]	Triangular (50, 100, 200)

- Is the variability (uncertainty) in the soil ingestion rate a major contributor in the overall variability in soil/dust exposure estimates? A screening level assessment was conducted in order to gain a sense of (1) the variability in lead uptake associated with incidental soil and dust ingestion predicted by the exposure and uptake components of the IEUBK model and (2) how the variability in individual input parameters contributes to the overall variability in exposure estimates. With this approach, probability distribution functions (PDFs) are used in place of the point estimate values as inputs for a number of exposure parameters. Computer simulation techniques (Monte Carlo Analysis) were used to combine probability distribution functions and point estimates. The evaluation was performed using the Crystal Ball 2000® software. Figure 2 describes the exposure equation used to estimate lead uptake resulting from incidental ingestion of soil and dust. Table 17 summarizes the distributions and point estimates used in this analysis.

---

[24] EPA Region VIII used several approaches to characterizing the soil/dust ingestion rates as part of the risk assessment for the Vasquez Boulevard/I-70 site outside Denver CO. One approach involved fitting a lognormal distribution selected to match EPA guidance values of 100 mg/day and 200 mg/day for CTE and RME exposures.

[25] The Oregon Department of Environmental Quality (DEQ) guidance document on probabilistic risk assessment includes a probability density function based on data from Calabrese et al. (1989) and Davis et al. (1990).

[26] Stern (1994) also based the selection of a triangular distribution (and the distribution parameters) on information in Calabrese et al. (1989) and Davis et al. (1990).

Figure 2: Soil/Dust Ingestion Equation

$$Pb\ Uptake = (PbS*SIR*F_s*AbS*EF_{sd}) + (PbS*M_{SD}*DEF*SIR*(1-F_s)*AbS*EF_{sd})$$

Where:

PbUptake = Lead uptake (ug/day)
PbS = Soil lead concentration (ug/g)
SIR = Soil/dust ingestion rate (g/day)
F_s = Fraction ingested as soil (unitless)
M_{SD} = Mass fraction of outdoor soil to indoor dust (unitless)
AbS = Absorption fraction (unitless)
EF_s = Exposure frequency (unitless)
DEF = Soil/dust enrichment factor (unitless)

Table 17: Point Estimates and Distributions Used to Evaluate Variability in Soil/Dust Ingestion Exposure Estimates

Parameter	IEUBK Parameter	Distribution
Soil Lead Concentration (PbS)	500	Lognormal (M = 500, SD = 400 UB = 2000)
Soil/dust ingestion rate (SIR)	135	Lognormal (M = 60, SD = 80, UB = 500)
Fraction Ingested as Soil (F_s)	0.45	Triangular (0.1, 0.45, 0.8)
Mass Fraction of outdoor to indoor soil ($_{MSD}$)	0.70	Lognormal (M = 0.445; SD = 0.1687; Range = 0.2 – 0.92)
Absorption Fraction (AbS)	0.30	Lognormal (M = 0.27; SD = 0.12; Range (0.1 to 0.8)
Exposure Frequency (EF_s)	1	Triangular (0.1, 0.4, 1.0)
Soil/dust Enrichment Factor	1	Triangular (1.0, 1.2, 3.0)

The Monte Carlo analysis was performed using was performed using 1000, 5000 and 10,000 simulations. The results based on 5000 and 10,000 simulations were very similar. The results of the probabilistic exposure assessment (based on 10,000 simulations) are summarized in Tables 18 and 19. Table 18 indicates that the variation in exposure estimates for this pathway is primarily due to variability in the soil ingestion rates and soil concentrations.

Table 18: Contribution to Variance in Soil Lead Uptake Estimates from Incidental Soil/Dust Ingestion	
Parameter	Contribution
Soil Ingestion Rate	55 %
Soil Concentration	24 %
GI Absorption Factor	8 %
Exposure Frequency	8 %
Soil/dust enrichment factor	4 %
Fraction Ingested as Soil	0.8 %
Soil/Dust Conversion Factor	0.6 %

The IEUBK model predicts that a 12-36 month old child will have a daily lead uptake of 15.4 ug/day due to incidental soil/dust ingestion of soils (at soil concentration of 500 mg/kg). Table 19 indicates that the point estimate falls between the 90th and 95th (@ 93rd) percentile values of a simulated lead distribution of lead uptake associated with the incidental ingestion of soil and dust. The IEUBK model is designed to predict mean blood lead concentrations based on estimates of mean lead uptake. Consequently, the point estimate value (15.4 ug/day) appears to represent a higher percentile value than the estimates for lead uptake via other pathways. However, these higher end estimates may also compensate for (1) lead uptake from other pathways that are not explicitly considered in the IEUBK model (i.e. dermal contact) or (2) lead uptake from pathways that are not fully characterized (i.e. consumption of homegrown vegetables). In this case, the lead uptake estimates from all pathways may be a reasonable central tendency estimate.

Table 19: Estimated Lead Uptake for Soil/Dust Ingestion Pathway at Soil Concentration of 500 ppm (mg/kg/day)	
	Estimated Lead Uptake
Point Estimate	15.3 ug/day
Mean of Probabilistic Distribution	4.4 ug/day
50th	1.8 ug/day
75th	4.6 ug/day
90th	10.2 ug/day
95th	17.2 ug/day
Maximum of Probabilistic Distribution	163.9 ug/day
Standard Deviation	8.3
Ratio of 90th Percentile/10th Percentile	33.9
Percentile Value for Point Estimate Value	@ 93rd

- **Relationship Between Soil Ingestion Rates and Grass Cover:** The relationship between soil ingestion rates and grass cover was an issue considered by Ecology during the Department's review of Asarco's proposal to consider new scientific information the company believed was relevant to the Everett Smelter site cleanup. This issue was considered in the context of Asarco's argument that grass is an effective cover that will minimize contact with contaminated soils and exposure to community residents. No new scientific information was presented in support of this position other than the common sense argument that grass cover should reduce potential contact relative to bare soils. In reviewing this issue, Ecology stated:

  > Scientific studies using a chemical tracer methodology have provided most of the information for development of an RME (typical resident) soil contact assumption. Information in those studies provides a technical basis for evaluation of the effectiveness of grass cover. In a study by van Wijnen et al. (1990), soil contact rates were estimated using tracer methodology for children in cities, at campgrounds, and in hospitals (i.e. with only indoor exposures). The campground settings are in part described as having "fields that were mostly covered with grass". The children at campgrounds showed substantially increased soil contact rates in comparison to the other two groups. A study of 64 children in Amherst, Massachusetts (See Calabrese et al. 1989; the same data set has been re-evaluated several times by the authors) occurred in a setting in which almost all of the children's yards had a well-established and well maintained grass cover (confirmed in discussions with the lead author). This is one of the most detailed and extensive studies of soil contact rates in children. The most recent evaluations of the Amherst data show variable levels of soil contact across individuals, with the upper end of the range of estimated soil contact rates being consistent with the RME assumption in MTCA. Thus, the studies of soil contact rates in children do not support the claim that grass cover minimizes soil contact. (Ecology[27], 1999, pp. 56-57).

---

[27] Ecology. 1999. Review of Asarco's "New Science" Submittals Regarding Arsenic and Lead. January 1999.

Lead Exposure from Consumption of Homegrown Vegetables

Summary of Previous Materials Relevant to This Issue: The evaluations included in the January 2004 discussion materials are based on two key assumptions: (1) children may be exposed to lead as a result of lead uptake into fruits and vegetables grown in lead-contaminated soils; and (2) lead concentrations in fruits and vegetables grown in lead-contaminated soils are similar to lead concentrations in the national food supply; and (3) the default exposure assumptions built into the IEUBK model address this pathway. At the January 12th meeting, the Board was asked whether these assumptions were consistent with current scientific information.

SAB Questions and Requests for Additional Evaluation: Drs. Faustman and Dr. Landau stated that they believe this pathway could be significant and that an assumption that exposures are equivalent to lead exposure via the national food supply may underestimate exposure. Dr. Faustman observed that studies have shown that lead is transferred from soil to plants. The Board recommended that Ecology evaluate this pathway further and suggested that Dr. John Kissel may have information on (1) plant uptake of lead and (2) information on the consumption of homegrown fruits and vegetables in Washington.

Ecology's Review and Responses: Ecology has compiled and evaluated additional information on this issue. The results of those evaluations are organized around following five questions:

- <u>What information is available on lead concentrations in the national food supply and food items grown in lead-contaminated soils</u>? The distribution of lead among different fruits and vegetable is highly variable. Seeds and fruits typically have lower lead concentrations than leaves, stems or roots. Roots and tubers usually have the highest lead concentrations with the skin having higher lead concentrations than the inner flesh. Leafy vegetables have also been found to concentrate various metals. The Food and Drug Administration estimates that background lead concentrations in foods in the United States average 3.07 ug/kg (0.003 ug/g). This value is based on data from the FDA Total Diet Study (FDA, 1999) and is the value used in the California LeadSpread Model to characterize background dietary exposure. At the March 18th meeting, the Board discussed the recent incident in Washington where elevated levels of lead were found in carrots as part of the routine monitoring required by the U.S. Department of Agriculture. The carrots were grown in fields near Quincy Washington and harvested in the fall of 1997. The lead concentrations in the nine batches of carrots tested for lead ranged from non-detectable (<125 ug/kg) to 1660 ug/kg[28]. Subsequent investigations revealed that the field was located on a former

[28] The 9 batches of carrots had the following lead concentrations: ND (< 125 ug/kg), ND, ND, ND, 127, 203, 280, 1540 and 1660 ug/kg. Two batches of mixed vegetables were also tested with reported levels of ND and 290 ug/kg. It is not clear whether these are dry weight or wet weight concentrations. The range of tissue concentrations falls at the low end of the range of lead concentrations in a small sample (24 samples) of garden vegetables grown in the Couer de Alene Basin (0.48 – 48.6 ug/g with a mean of 7.8 ug/g and a standard deviation of 10.7).

orchard. Ten[29] composite soil samples were collected and analyzed for lead and arsenic. Lead concentrations in the 10 composite samples ranged from 18 to 490 mg/kg with higher concentrations being found in the western portions of the field. The company stated that the field was harvested in an east to west pattern with lead concentrations in carrots declining as the harvest progressed. The company concluded that trend in carrot concentration was consistent with geographic distribution of soil lead concentrations (high soil concentrations in western portions of the field that declined to low (18 to 95 mg/kg) in the eastern portions of the field.

- <u>What information is available on the relationships between lead in plants and soil that could be used to predict plant uptake factors?</u> There is limited information available on the levels of lead in plants grown in lead-contaminated soils. Consequently, risk assessors must use models to predict plant concentrations. Two approaches are commonly used: (1) plant uptake factors which assume a constant relationship between soil and plant concentrations at increasing concentrations); and (2) regression models which are used to estimate plant uptake factors that vary with soil concentration. Both approaches are complicated by the fact that uptake of lead into plants is highly variable and varies with (1) soil concentration levels, (2) plant types and cultivars and (3) soil characteristics (e.g soil type, pH, moisture, etc.). The following approaches have been used to estimate lead concentrations in plants:

  - The California Department of Toxics Substances (DSTC, 2002) has included methods for evaluating lead exposure resulting from consumption of garden fruits and vegetables grown in lead contaminated soils. The methods use a plant uptake factor of 0.045. The references embedded in the spreadsheet model state that this value is based on plant uptake studies by Chaney et al. 1982).

  - Baes et al. (1984)[30] developed plant uptake factors that are commonly used for human health and ecological risk assessments. These include plant uptake factors for root crops (0.006) and above-ground vegetables (0.045). However, results from subsequent field studies indicate that the use of the Baes et al. factors tend to under-predict the uptake of lead at soil concentrations near background levels and over-predict plant concentrations at higher soil concentrations.

  - The Bechtel Jacobs Company (1998)[31] developed plant uptake factors and regression models for estimating the uptake of inorganic elements by above-ground plant tissues. The uptake factors and models for lead were developed using published data from 21 studies that included a range of plant types, soil lead concentrations and soil types. BJC calculated a plant uptake factor for lead (mean = 0.245, standard deviation = 0.916; median = 0.0389; 90th percentile 0.468; lognormal distribution was the closest fit). BJC also used the available

---

[29] Composite soil samples were collected from 10 grids (each about 7 acres in size). Each Composites included 10 subcomposites from 12 inch depth. Lead concentrations were highest in the western sample grids.
[30] Baes, C.F., Sharp, R.D., Sjoreen, A.L. and R.W. Shor. 1984. A review and analysis of parameters for assessing transport of environmentally released radionuclides through agriculture. ORNL – 5786. U.S. Dept. of Energy, Oak Ridge National Laboratory.
[31] Bechtel Jacobs Company. 1998. Empirical Models for the Uptake of Inorganic Chemicals from Soil to Plants. Prepared for U.S. Department of Energy. Office of Environmental Management.

data to develop a regression model (ln (concentration in above ground plant) = B_o + B_1(ln [concentration in soil] where concentrations are expressed in mg/kg DW) with B_o equal to -1.088 +/- 0.334 and B_1 equal to 0.666 +/- 0.071. BJC evaluated the reliability of the estimation methods and found that use of the uptake factor and regression model over-predicted plant concentrations 100 % and 95% of the time, respectively. BJC cautioned that the models developed in the study should not be used to estimate lead concentrations in fruits, seeds and roots.

- Glass and SAIC[32] (1992) prepared a baseline risk assessment for the Ruston/North Tacoma Superfund site. The study did not evaluate ingestion of garden vegetables as a potential residential exposure pathway for lead-contaminated soils (this pathway was considered for arsenic-contaminated soils). Appendix E of the document includes an evaluation of plant uptake factors. Although the evaluation focused on arsenic, the appendix includes information that can be used to calculate plant uptake factors for lead using the same procedures as those used for arsenic[33].

Table 20: Comparison of Plant Uptake Factors Used to Predict Plant Lead Concentrations at Soil Lead Concentration of 200 and 500 mg/kg

Approach	Method	Plant Uptake Factor		Predicted Lead Concentration (ug/g wet wt)	
		200	500	200	500
Above Ground Vegetables					
Baes et al. (1984)	Uptake Factor	0.045	0.045	1.3	3.4
DSTC (2002)	Uptake Factor	0.045	0.045	1.3	3.4
BJC (1998) (above ground)	Uptake Factor	0.039	0.039	1.2	2.9
BJC (1998) (above ground)	Regression	0.025	0.016	0.7	1.2
Based on Glass & SAIC (1992)	Regression	0.06	0.02	1.8	1.5
Root Vegetables					
Baes et al. (1984)	Uptake Factor	0.006	0.006	0.1	0.3
DSTC (2002)	Uptake Factor	0.045	0.045	0.8	1.9
Based on Glass & SAIC (1992)	Regression	0.02	0.01	0.3	0.4

- <u>Is it reasonable to assume that lead concentrations in vegetables grown in lead-contaminated soils are similar to lead concentrations in the national food supply</u>? Available information indicates that lead concentrations in garden vegetables grown

[32] Glass, G. and Science Applications International Corporation (SAIC). 1992. Baseline Risk Assessment: Ruston/North Tacoma Subunit, Tacoma Smelter Operable Unit, Commencement Bay Superfund Site, Tacoma Washington.

[33] Tissue concentrations for 228 garden vegetable samples were compared to average soil concentrations. The data were grouped into six food categories (i.e. lettuce, beets, beet greens, cabbage, chard and carrots) and used to estimate plant uptake ratios for arsenic using a log-log regression equation. This analysis produced regression values (slope and intercept) that were used to estimate plant uptake factors at different soil arsenic concentrations.

in lead-contaminated soils might be significantly higher than average concentrations measured in the national food supply.

- What is the potential contribution of exposure resulting from consumption of garden vegetables grown in lead-contaminated soils relative to other lead exposure pathways?: Ecology used the alternate diet source module in the IEUBK model to evaluate the potential contribution of this pathway to overall lead exposure. The module allows users to enter values for lead concentrations in food and percent of diet from the alternate source. Ecology ran the model using (1) a vegetable concentration of 1 ug/g (wet wt), (2) a diet fraction of 20%. Garden soil concentrations were assumed to be equal to yard soil concentrations. The evaluation results are summarized in Table 21 and compared with pathway contributions predicted by the California Leadspread Model. Both models predict that lead uptake resulting from consumption of garden vegetables grown in lead-contaminated soils could be an important contributor to overall lead exposure.

Table 21: Relative Pathway Contributions at Soil Lead Concentration of 500 mg/kg Predicted for Child Exposure Using the California Leadspread Model (DSTC, 2004)

Pathway	California LeadSpread Model	IEUBK Model	
		ug/day	%
Soil Contact	<1%	--	--
Soil Ingestion	45%	13.6	50 %
Inhalation (Bkgrd + soil related)	<1%	0.05	< 1 %
Water Ingestion	12%	0.8	3 %
Food (bkgd)	6%	1.3	5 %
Food (soil related)	35%	11.6	42 %

- How does consideration of lead exposure associated with consumption of homegrown garden vegetables influence the blood lead concentrations and P_{10} values predicted by the IEUBK model? Ecology used the IEUBK model to predict blood lead concentrations and P_{10} values for an exposure scenario that included potential lead exposures resulting from ingestion of garden vegetables grown in lead-contaminated soils. The evaluation results were compared with the predicted blood lead concentrations and P_{10} values included in the January 2004 discussion materials. As expected, consideration of potential lead exposure resulting from consumption of homegrown vegetables results in (1) higher predicted blood lead concentrations (relative to the January 2004 evaluations that did not consider this pathway) and (2) higher predicted P_{10} values.

Table 22: Comparison of Predicted Blood Lead Concentrations Using Different Assumptions on Consumption of Homegrown Vegetables (12-36 month age interval)						
	IEUBK (w/o HGV)		IEUBK (with HGV)		Differences	
Soil Concentration	CTE	P_{10}	CTE	P_{10}	CTE	P_{10}
200	2.8	0.4	7.3	24.9	4.5	24.5
500	5.4	9.6	9.4	44.6	4.0	35.0

Summary and Conclusions: Available information indicates it is not reasonable to automatically assume lead concentrations in home grown vegetables are similar to lead concentrations in the national food supply. However, there are several sources uncertainty and variability that complicate efforts to estimate plant uptake, consumption of homegrown vegetables, etc. Ecology would welcome the Board's recommendations on ways to approach this issue.