Appendix C

Preliminary Remediation Goals for Lead in Soil at the Omaha Lead Site

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MEMORANDUM

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1.0 INTRODUCTION

This memorandum presents preliminary remediation goals (PRGs) for protection of residents from lead in surface soil at the Omaha Lead Site (OLS).

The PRG for lead in soil is the average concentration of lead in a residential yard that is associated with no more than a 5% chance that a child (age 0-84 months of age) living at the property will have a blood lead level that exceeds 10 μg/dL (USEPA 1998).

2.0 METHOD FOR CALCULATING THE PRG FOR LEAD

Mathematical Model

The standard model developed by the USEPA to assess the risks of lead exposure in residential children is referred to as the Integrated Exposure Uptake Biokinetic (IEUBK) model (USEPA 1994). This model requires input data on the levels of lead in various environmental media at a specific location, and on the amount of these media contacted by a child living at that location. All of these inputs to the IEUBK model are central tendency point estimates (i.e., arithmetic means or medians). These point estimates are used to calculate an estimate of the central tendency (the geometric mean, GM) of the distribution of blood lead values that might occur in a population of children exposed to lead under the specified conditions. Assuming the distribution is lognormal, and given (as input) an estimate of the variability between different children (this is specified by the geometric standard deviation or GSD), the model calculates the expected distribution of blood lead values, and estimates the probability that any random child might have a blood lead value over 10 μg/dL. For convenience, the probability of having a blood lead level above 10 μg/dL is referred to as P10.

The PRG is computed by finding the concentration of lead in soil that yields a P10 value equal to EPA's health-based goal (P10 ≤ 5%). This may be done in a number of different ways. For this site, the soil PRG was calculated by running a batch file that calculated the value of P10 for a range of different soil levels, and finding the soil level that yielded a P10 value of 5%.

Input Parameters

The IEUBK model input parameters used in the PRG model runs are the same values used in the baseline human health risk assessment (USEPA 2008a). These values are presented in Table 1. Most of the values are the national defaults recommended for use by USEPA (USEPA 1994). Some of the values (i.e., the relative bioavailability of lead, the relationship between lead in dust and soil, and the concentration of lead in air and water) are based on site-specific data, as described in the risk assessment (USEPA 2008a).

3.0 RESULTS

Based on the approaches and inputs specified above, the resulting PRG for protection of current and future residential children at the OLS from lead in soil is 298 mg/kg.

This PRG corresponds to the acceptable concentration of lead in the "fine" particle fraction (< 250 µm) of soil. This is because it is believed that the fine fraction of soil is most likely to adhere to the hands of children. This PRG is appropriate for comparison to lead measured in fine-grained soil (< 250 µm) using an accurate analytical method such as Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES).

However, most data on the concentration of lead in residential yards at the OLS are based on measurements of the bulk soil fraction (< 2 mm) using X-ray fluorescence (XRF). This complicates the use of the PRG of 298 mg/kg in two ways:

- First, as is often observed at mining, milling and smelting sites, the concentration of lead in soil at this site is slightly higher (about 4%) in the fine-grained soil fraction than in the bulk fraction (USEPA 2008a). This is because metal-rich particles derived from mining, milling and smelting operations tend to be smaller than most soil particles. Because children are assumed to ingest mainly particles from the fine fraction, application of the PRG to the bulk fraction could be under-protective.
- Second, measurements of lead in soil using XRF are sometimes not the same as measurements by ICP. This is because XRF measurements are subject to a wide variety of interferences (e.g., water content, particle size, presence of other metals, etc.). Thus, to the extent that XRF yields a biased estimate of the true concentration, use of XRF data for comparison to the PRG might cause an error in either direction. At this site, XRF tends to underestimate the concentration of lead in soil by an average of about 16%.

Because of the observable differences in lead concentrations associated with the soil particle size and the potential for differences between the XRF and ICP analytical techniques utilized at this site, and because the PRG will usually be applied to measurements of bulk soil analyzed using XRF, the risk-based PRG of 298 mg/kg was converted to a Bulk-XRF equivalent concentration using the linear relationships derived in the risk assessment (USEPA 2008a):

$$Bulk(XRF) = \frac{Fine(ICP)}{1.16 \cdot 1.04}$$

Based on this equation, the risk-based PRG for lead in the fine fraction of soil using ICP-AES of 298 mg/kg corresponds to a PRG of 247 mg/kg in the bulk soil fraction analyzed using XRF.

4.0 UNCERTAINTY ANALYSIS

The PRG values derived above for lead are somewhat uncertain, due to uncertainty in the true values of the input parameters used in the IEUBK model calculations. This uncertainty includes all of the inputs listed in Table 1. Of these parameters, the uncertainty in the soil and dust ingestion rates and in the true geometric standard deviation (GSD) are usually the most important. In addition to these user-adjustable parameters, there are also a large number of other pharmacokinetic variables that are used in the model but are not subject to revision by the model user.

For the purposes of this evaluation, a series of alternative PRG calculations were performed to evaluate the uncertainty in the PRG that arises from two of the site-specific model inputs used at this site: 1) relative bioavailability (RBA), and 2) the relationship between lead in indoor dust to that in residential yard soil. All other input values (e.g., concentration of lead in the diet, GSD, etc.) were maintained at the values shown in Table 1.

Alternate Relative Bioavailability Estimates

For RBA, four alternative values were evaluated. These values included the IEUBK model default RBA for lead (0.6), as well as a low estimate (0.7), best estimate (0.8) and high estimate (0.9) based on site-specific data. These alternative RBA values and their bases are presented in Table 2 (Panel A, upper section).

Alternate Estimates of the Relationship Between Lead in Soil and Indoor Dust

The concentration of lead in indoor dust input parameter (Cdust) is estimated from the concentration of lead in outdoor soil (Csoil) using an equation that is derived from site-specific data. The general equation is as follows:

$$Cdust = D0 + M_{sd} \cdot Csoil$$

where:

D0 = Concentration of lead in dust (mg/kg) that is not attributable to outdoor soil
Cdust = concentration of lead in indoor dust (mg/kg)
Csoil = outdoor soil lead concentration (mg/kg)
M_{sd} = mass fraction of soil in dust (mg Pb/kg in dust per mg Pb/kg in soil)

Appendix F of the risk assessment (USEPA 2008a) describes a number of different statistical methods that were evaluated for quantifying this relationship from site-specific data. In order to provide a range of possible alternative estimates of the relationship, the results of three alternative statistical methods were used. These methods included the approach that is considered to be "best" for estimating the model parameters (D0 and M_{sd}), one method that is judged to have a tendency to overestimate the value of M_{sd}, and another method that is thought to likely underestimate the value of M_{sd}. The resulting equations are shown in Table 2 (Panel A, lower section). In addition, the equation recommended as the default by USEPA (1994) was also used. In this approach, the value of D0 is determined by the contribution of air to dust (Cdust = 100 mg/kg in dust per $\mu g/m^3$ in air · 0.036 $\mu g/m^3$ = 3.6 mg/kg).

Results

Using the alternate values/approaches for deriving estimates of RBA and the concentration of lead in indoor dust, a total of 16 alternative PRG estimates were calculated. The results are shown in Table 2 (Panel B) and summary statistics of the PRG estimates are shown in Table 2 (Panel C). Best estimates are indicated by grey shading.

The results in Panel B clearly show that relative bioavailability has a significant impact on the PRG values, while the 3 methods for estimating indoor dust lead concentrations have a relatively minor impact on the PRG estimates. As seen in Panel C, the PRG for lead in the fine fraction of soil measured using ICP-AES ranges from 251 to 442 mg/kg. If lead is measured in bulk soil using XRF, the PRGs range from 208 to 366 mg/kg.

Note that all of the PRG values calculated above are conditional on the assumed human exposure parameters and the toxicokinetic assumptions in the IEUBK model. If any of the assumptions for these exposure parameters, or changes to the IEUBK model occur in the future, then the PRG calculations may need to be revisited.

5.0 REFERENCES

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Table 1. IEUBK Model Inputs

A. Age-Independent Model Inputs:

PARAMETER	VALUE	BASIS
Soil concentration (mg/kg)	Property-specific	Yard-wide average concentration[1] (excluding drip zone samples)
Indoor dust concentration (mg/kg)	Property-specific	Calculated using site-specific M_{sd} equation: $C_{dust} = 42 + 0.74 \bullet C_{soil}$
Air concentration (µg/m^3)	0.036	Average concentration in air at the Site (2000 – 2002) (USEPA 2008b)
Indoor air concentration (ug/m^3)	30% of outdoors	USEPA (1994a) default
Drinking water concentration (µg/L)	1.36	Average concentration in tap water at the Site. Assumes water consumed is 50% first draw and 50% post flush
Absorption Fractions: Air Diet Water Soil Dust	 32% 50% 50% 40% 40%	 USEPA (1994a) default USEPA (1994a) default USEPA (1994a) default Site-specific value Site-specific value
Fraction soil	45%	USEPA (1994a) default
GSD	1.6	USEPA (1994a) default

[1] Fine fraction, ICP-equivalent concentration of lead in soil: Fine(ICP) = Coarse(XRF) · 1.16 · 1.04

B. Age-Dependent Model Inputs:

	AIR		DIET	WATER	SOIL
Age (years)	**Time Outdoors (hrs)**	**Ventilation Rate (m^3/day)**	**Dietary Intake [2] (µg/day)**	**Intake (L/day)**	**Intake (mg/day)**
0-1	1.0	2.0	2.26	0.20	85
1-2	2.0	3.0	1.96	0.50	135
2-3	3.0	5.0	2.13	0.52	135
3-4	4.0	5.0	2.04	0.53	135
4-5	4.0	5.0	1.95	0.55	100
5-6	4.0	7.0	2.05	0.58	90
6-7	4.0	7.0	2.22	0.59	85

2] Revised USEPA (2008a) recommended dietary intake parameters, based on updated dietary lead estimates from the Food and Drug Administration's Total Diet Study (FDA 2006) and food consumption data from NHANES III (CDC 1997) .

Table 2. Uncertainty Analysis of PRG Estimate

A. VARIABLE INPUT VALUES

Parameter	Method	Value	Notes
Relative Bioavailability (RBA)	Default	0.6	USEPA recommended default value.
	Lower Bound	0.7	Mean RBA estimated from in vitro bioavailability (IVBA) data
	Best Estimate	0.8	RBA value used in the risk assessment, derived based on a weight-of-evidence evaluation of the *in vivo* and in vitro RBA estimates.
	Upper Bound	0.9	Average of *in vivo* RBA point estimates
Equation for Estimating the Concentration of Lead in Dust (Cdust)	Default	Cdust = 0.7*Csoil + 3.6	USEPA recommended default value for Msd (0.7). Site-specific intercept value, calculated by: intercept = Cair * USEPA default conversion factor for the concentration of lead in indoor dust from outdoor air.
	Lower Bound	Cdust = 0.36*Csoil + 154	Cdust equation based on the 3-Group Approach (Method 5 in Appendix F), a method for estimating Cdust that is biased low.
	Best Estimate	Cdust = 0.74*Csoil + 42	Cdust equation used in the risk assessment, based on the 95th UCL of the mean OLS slope (Method 2 in Appendix F). Method appears to be unbiased (centered around 1).
	Upper Bound	Cdust = 0.85*Csoil + 0	Cdust equation based on the One-Group (Zero Intercept) Approach (Method 6 in Appendix F). This method for estimating Cdust is biased high.

B. PRG RESULTS (concentration of lead in the fine fraction, analyzed by ICP)

		Equation for Estimating Cdust			
		Default	Lower Bound	Best Estimate	Upper Bound
RBA	Default	442	442	406	404
	Lower Bound	378	360	344	346
	Best Estimate	331	299	298	304
	Upper Bound	294	251	262	270

C. SUMMARY STATISTICS OF PRG ESTIMATES

		PRG (mg/kg)			
		Average	Minimum	Maximum	Best Estimate
ICP	Fine	**339**	**251**	**442**	**298**
	Bulk	326	241	425	287
XRF	Fine	293	216	381	257
	Bulk	281	208	366	247