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SHORT SHEET:
Estimating the Soil Lead Concentration Term for the Integrated Exposure Uptake Biokinetic (IEUBK) Model

Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Washington, DC 20460

NOTICE

This document provides technical and policy guidance to the U.S. Environmental Protection Agency (EPA) staff on making risk management decisions for contaminated sites. It also provides information to the public and to the regulated community on how EPA intends to exercise its discretion in implementing its regulations at contaminated sites. It is important to understand, however, that this document does not substitute for statutes that EPA administers or their implementing regulations, nor is it a regulation itself. Thus, this document does not impose legally-binding requirements on EPA, states, or the regulated community, and may not apply to a particular situation based upon the specific circumstances. Rather, the document suggests approaches that may be used at particular sites, as appropriate, given site-specific circumstances.

U.S. ENVIRONMENTAL PROTECTION AGENCY

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NCEA/Research Triangle Park
Andrew Rooney

OSRTI
Aaron Yeow
Larry Zaragoza

Associate
Scott Everett
Department of Environmental Quality
Salt Lake City, UT

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Background

The soil lead concentration term (PbS) is the only input parameter of the Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children for which a site-specific value is always required (although a site-specific value for soil *and* dust are preferred [EPA, 1994]). As stated in the Guidance Manual for the IEUBK Model (EPA, 1994), the average, or arithmetic mean of soil lead concentration from a representative area in the yard should be used for the PbS. The PbS may reflect the current exposure scenario (*i.e.*, to predict current risk) or future exposure scenarios (EPA, 1994).

This short sheet describes how to estimate the PbS for the residential exposure scenario and recommends the use of the arithmetic mean or average concentration for the PbS. Specifically, this document provides recommendations for under what circumstances the data should be weighted when estimating the PbS, and how the data should be weighted for a residential yard, which includes common play areas located within apartment complexes. The soil concentrations obtained by these averaging procedures give appropriate central estimates for use in estimating blood lead levels for residential children. However, these central estimates are subject to uncertainty, and if a risk assessor seeks to provide a conservative estimate of the average concentration of lead present in yard soil, an upper bound estimate on the mean may be appropriate for that purpose.

Children may also be exposed to lead at locations outside of the residence (*e.g.*, daycare center, park). Exposure to such secondary sources of lead may be evaluated using the approach recommended by EPA (2003b). Other EPA documents related to estimating the PbS address the soil particle size fraction that should be analyzed (EPA, 2000), and the number, location and type of samples that should be collected (EPA, 2003a).

The Superfund Lead-Contaminated Residential Sites Handbook (EPA, 2003a) recommends dividing the residential property into two to four quadrants, depending upon the size of the residential property, and collecting a five-point composite from each quadrant (see Figures 4-1a, 4-1b, and 4-2 of the Handbook). This does not preclude the use of individual samples to estimate the PbS when this approach is preferred over composite sampling. The Handbook also recommends sampling drip zones, gardens, play areas, driveways and crawl spaces separately; i.e., these samples are not to be included as part of the 5-point composites from each quadrant of the residential property.

The TRW recommends that the soil lead exposure point concentration should be based on the appropriate sample depth for the exposure scenario being assessed. In general, exposure to surface soil should be assessed through measurements of lead concentration determined from soil samples that are collected from within the 0–1" depth interval (EPA, 1996, 2003a). However, in future use scenarios for sites that anticipate excavation (e.g., basements), children might be exposed to soil contamination below the 0–1" depth interval, and the appropriate sampling depth, therefore, might be deeper than the 0–1" interval (EPA, 1989, 2003a). In all cases, measurements of lead in the <250 μm soil fraction should be used to estimate the exposure point concentration (EPA, 2000).

Recommendations

In general, the method that is used to estimate the PbS will depend upon the information that is available for the site. This includes information on the geography of the site (*e.g.*, size of play area), and the behavior patterns of the child (*i.e.*, the time spent by the child in various areas of the property). The *unweighted average* (*i.e.*, Case 1) is appropriate for predicting risks for current exposure scenarios and for future use scenarios. The *area-weighted average* and *time-weighted average* may not be appropriate for future use scenarios where assumptions regarding site layout (*e.g.*, location and size of play area) and behavior patterns may be unknown or uncertain. Example calculations for these three approaches are provided in Table 1.

Case 1: Information on geography of the site and behavior patterns is not available - *unweighted average*. This is the simplest approach to estimating the EPC. This approach is consistent with the random exposure assumption that is often made in Superfund risk assessment. Each composite sample is given equal weight in the estimation of the EPC. An implicit assumption of this approach is that all

areas of the yard (*i.e.*, each quadrant, play area, etc.) contribute equally to exposure regardless of their size. In this situation, the PbS should be estimated by a simple unweighted average of the 5-point composites and the composites from other areas where the child may be exposed to lead in soil (*e.g.*, play area, drip zone, driveway, etc.) (Equation 1). However, before including these other areas of the yard in estimating the EPC, one should carefully consider whether children may be directly exposed to surface soil in these areas (see EPA, 2003a for further detail).

Equation 1 - Case 1: unweighted average

$$PbS = \frac{\sum_{i=1}^{n} y_i + p + other}{n + 2}$$

where,

y_i = lead concentration measured in composite from yard quadrant *i*
n = number of quadrants (depends on size of property; see Section 4.2.2 of EPA, 2003a)
p = lead concentration measured in play area composite
other = unweighted average lead concentration measured in all other areas

Case 2: Information on geography of the site is available but the behavior patterns are unknown - *area-weighted average.* An area-weighted estimate of the PbS is also consistent with the random exposure assumption that is often made in Superfund risk assessment (EPA, 1989, 1992). This approach represents an improvement over Case 1 where it is assumed all areas of the yard contribute equally to exposure regardless of their size. The area-weighted approach assumes that exposure is proportional to the size of the yard area (i.e., quadrant, play area, etc.) sampled. For example, given the sampling scenario shown in Figure 1, an unbiased estimate of the PbS (assuming random exposure) is provided by Equation 2. If the site map(s), with sampling areas shown, are available in a geographic information system (GIS), the area of each quadrant and play area (if present) can be readily obtained, and the sample weights shown in Equation 2 are easily calculated (see Equation 2).

Equation 2 - Case 2: spatially-weighted average

$$PbS = \left(\sum_{i=1}^{n} w_i \cdot y_i \right) + \left(\sum_{j=1}^{m} w_j \cdot other_j \right)$$

where,

w_i = spatial weight for lead concentration measured in composite from yard quadrant i = (area of quadrant i) / (total area of property)

w_j = spatial weight for lead concentration measured in composite from *other area j* = (area of *other area j*) / (total area of property)

$Other_p$ = lead concentration measured in *other area j* composite

Case 3: Information on behavior patterns is available - *time-weighted average.* When information on the time spent by the child in various areas of the residential property is available, the PbS should be estimated by a time-weighted average of the 5-point composites, and the composites from the play and other relevant areas (Equation 3). Note that this approach may not be applicable to some future use scenarios.

Equation 3 - Case 3: time-weighted average

$$PbS = \left(\sum_{i=1}^{n} t_i \cdot y_i \right) + \left(\sum_{j=1}^{m} t_j \cdot other_j \right)$$

where,
t_i = proportion of time child spends in yard quadrant i = (time child spends in yard quadrant i per day) / (total time child spends in yard per day)

t_j = proportion of time child spends in *other area j* = (time child spends in *other area* per day) / (total time child spends in yard per day)

Notes:
1) The spatial weights ($w_{1, 2,....n}$, $w_{1, 2,....m}$,) should sum to 1; similarly, the time weights ($t_{1, 2,....n}$, $t_{1, 2,....m}$,) should sum to 1.

2) The *other* term drops out of Equation 3 if the child is not exposed to lead in other areas (e.g., garden, play areas) (*i.e.*, when $t_{1,2,...m} = 0$).

3) Equations 2 and 3 will produce the same estimate for PbS if the time spent within each area of the yard is proportional to the size of the area (*i.e.*, if one assumes random exposure).

References

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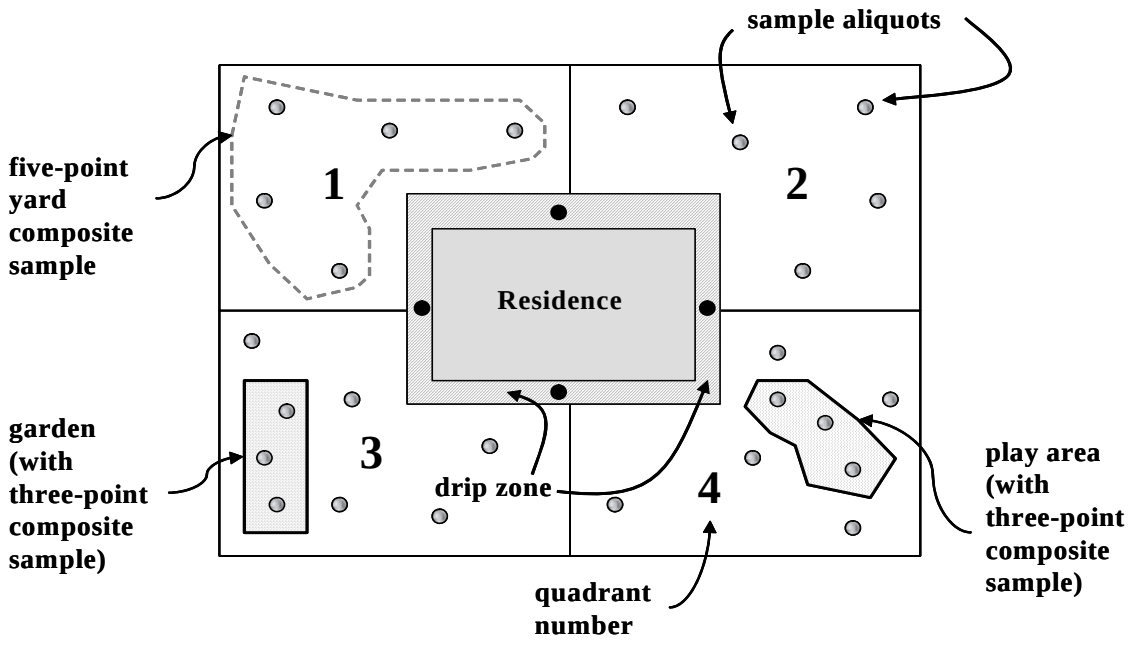

Figure 1. Example residential property site plan. The figure shows a typical residential property that has been divided into four quadrants, with garden and play areas present. Five-point composites (*i.e.*, composites made up of five aliquots) are shown for each quadrant, and three-point composites are shown for the garden and play areas. The number of aliquots for the garden and play area depend upon the size of these areas; a minimum of three is recommended. Note that the composite samples for each quadrant do not include aliquots from the garden or play area; the latter two are sampled separately. Estimation of the soil concentration term (PbS) is illustrated in Table 1.

Figure adapted from Figure 4-2 of the Superfund Lead-Contaminated Residential Sites Handbook (EPA, 2003a).

Table 1. Estimation of the soil concentration term (PbS) for the IEUBK model.

unweighted estimate (Equation 1)		**spatially-weighted estimate (Equation 2)**			**time-weighted estimate (Equation 3)**		
yard area	concentration measured in composite (y_i)	yard area	concentration measured in composite (y_i)	spatial weights	yard area	concentration measured in composite (y_i)	time weights
quadrant 1	100	quadrant 1	100	0.20	quadrant 1	100	0.10
quadrant 2	50	quadrant 2	50	0.20	quadrant 2	50	0.10
quadrant 3	75	quadrant 3	75	0.20	quadrant 3	75	0.15
quadrant 4	150	quadrant 4	150	0.20	quadrant 4	150	0.20
garden	600	garden	600	0.10	garden	600	0.05
play area	500	play area	500	0.10	play area	500	0.40
PbS:	**246**	**PbS:**	**185**		**PbS:**	**286**	
			sum of weights:	1		sum of weights:	1