CHAPTER 8
Residential Lead Risk Assessments

8.1 Introduction to Residential Lead Risk Assessments

The OLEM risk assessment process includes analytical data collection and evaluation of lead concentrations in all affected media, exposure assessment, toxicity assessment, and risk characterization, which includes the uncertainties, quantification, and qualification associated with the potential current and future risks to human health.

> Verify that you are using the most recent version of EPA's residential lead modeling software as well as the latest guidance and training, available on the TRW Lead Committee's website at http://www.epa.gov/superfund/lead-superfund-sites.

This chapter describes how to conduct risk assessments for residential land use scenarios where lead is a contaminant of concern. The IEUBK model for lead in children[100] is the risk assessment tool that predicts blood lead concentrations (and associated probability of exceeding a target BLL) in areas where there is a current or potential future exposure scenario (U.S. EPA 1998, 1994a). The results of the IEUBK model with site-specific information support removal and remedial response actions at contaminated residential sites to ensure that the most sensitive population (children <7 years of age) will be protected[101] (Breen 2024, U.S. EPA 2020e, 2020f, 1998, 1994a).

Users of this Handbook, including RPMs and OSCs, are encouraged to work with the regional risk assessors early in the site characterization process to ensure adequate data collection that supports an assessment to ensure removal or remedial decisions are defensible. For more information on EPA risk assessments, visit EPA's Waste and Cleanup Risk Assessment webpage.[102]

8.2 Data Evaluation

It is important to understand the available data for the site in terms of the CSM, DQOs, and QAPP for sampling and analysis (these are described in Chapter 6). This will allow the site team to identify and understand the data gaps, assumptions, uncertainties, and limitations

[100] The IEUBK model can be found at: https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals.
[101] In a residential setting, evaluation of the child is protective of an adult exposure scenario.
[102] https://www.epa.gov/risk/superfund-risk-assessment.

associated with the risk assessment to reach a well-informed risk management decision. Data evaluation and data gap analysis may result in a recommendation to conduct additional data collection that could further inform the risk management decision. This is especially true for model parameters that are particularly influential in the IEUBK model (*e.g.*, soil lead concentration and bioavailability). When conducting a risk assessment, it is important to identify the key site-related variables and assumptions that contribute most to uncertainty. Data uncertainty should be assessed for each data set.

8.3 Exposure Assessment

Exposure is contact between a person and a chemical in one or more media (*e.g.*, soil, groundwater, air, etc.). Exposure assessment measures (or estimates) the magnitude, frequency, duration, and route of exposure. Children can be exposed to lead by multiple exposure pathways (ingestion, inhalation, dermal) from lead-contaminated media (*e.g.*, dust, soil, water, air, food, etc.) (U.S. EPA 2024, ATSDR 2007, U.S. EPA 2000c) and are generally considered the most sensitive receptor for residential land use areas. Refer to the TRW Lead Committee website[103] for additional information.

Exposure assessments should consider both current and potential future land use scenarios. EPA currently uses the IEUBK model for residential scenarios (the receptor is young children <7 years of age, which is the most sensitive population).[104] For more information, see: https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals.[105]

The IEUBK model accounts for intake and uptake components of lead exposure and allows the user to input site-specific exposure information (*e.g.*, concentration of lead in environmental media and media intakes) to predict blood lead concentrations. Predicted blood lead concentrations provide one indication of the associated lead risk for both current and potential future land use assumptions. The predictive accuracy of the IEUBK model output is dependent

[103] http://www.epa.gov/superfund/lead-superfund-sites.

[104] For non-residential exposures where young children are not frequent receptors, the ALM is used to estimate maternal and fetal BLLs.

[105] EPA is currently developing the All Ages Lead Model (AALM) to improve predictive accuracy for lead dosimetry following a wide range of exposure conditions and populations. It is anticipated that the AALM will predict blood and tissue lead concentrations resulting from exposures to lead in air, drinking water, surface dust, food, or other exposure pathways, allowing users to simulate multi-pathway exposures that are constant or that vary in time increments as small as 1 day, and that occur at any age from birth to 90 years. As of the release of this Handbook, the AALM is for use as a research tool only and has not been approved for Superfund site risk assessment. **The IEUBK is the only model approved for Superfund HHRAs for young children.**

on the representativeness of the input data (Brown et al. 2023, U.S. EPA 2021b,d, 2003b, 1994a).

8.4 Exposure Point Soil Lead Concentration

The average, or arithmetic mean, of soil lead concentration from an EU (e.g., the yard) is the EPC and is recommended as the soil lead concentration data entry for the IEUBK model.

The soil and dust lead concentrations are important input values for the IEUBK model. A site-specific arithmetic mean soil lead concentration is recommended. Indoor dust lead concentration may be derived from indoor dust sampling or from outdoor soil data using multiple source analysis in the IEUBK model (White et al. 1998). Please refer to EPA's IEUBK guidance manual and user's guide for additional information on the multiple source analysis (U.S. EPA 2021b, 1994b). The soil lead concentration parameter is the only input parameter of the IEUBK model for which a site-specific value is required (although soil lead bioavailability is highly recommended) to generate a meaningful site-specific risk estimate (the default values may be used for all other inputs assuming they represent site conditions). Alternatively, the *Find Soil Pb Concentration* function of the IEUBK model can be used to calculate a site-specific soil PRG, but soil and dust lead bioavailability are highly influential, and that information should be included in the PRG calculation on a site-specific basis.

An EPC is the contaminant concentration within an EU to which receptors are exposed (see Sections 6.5 and Appendix A). Estimates of the EPC represent the concentration term used in an exposure assessment. For additional information, refer to OSWER 9200.1-78 (U.S. EPA 2007a), *Short Sheet: Estimating the Soil Lead Concentration Term for the Integrated Exposure Uptake Biokinetic (IEUBK) Model*.[106]

The EPC used in the IEUBK model should be the average, or arithmetic mean, of soil lead concentration from a representative exposure area in the yard (generally, this is ¼ to 1 acre area around the residence). This approach is generally recommended; however, it may not be appropriate for some sites. Without detailed exposure information, the average concentration is usually the most appropriate for predicting current and future exposure risks.

For example, spatially weighted averages may be used when the location (*i.e.,* coordinates) of each sample is available and the relative size of the areas is known and small (<0.5 acre). The spatially weighted average assumes that exposure is proportional to the size of the various

[106] https://www.epa.gov/superfund/lead-superfund-sites-guidance#estim.

areas of the yard being sampled (*e.g.,* garden, play areas). This assumes that contact with soil in all areas of the EU is equally likely (U.S. EPA 1989b).

Alternatively, time-weighted averages can be used when both geographical information and behavior patterns are known. In this case, consideration is given to how much time a child spends in various areas of the yard, and the most-frequented areas are weighted more heavily.

The appropriate method for estimating the EPC depends on the DQOs and sampling plan designed to support the baseline risk assessment (see U.S. EPA 2007a). It is recommended that the risk assessor (and perhaps a statistician) be involved in the SAP and QAPP as early as possible. This can prevent unexpected errors and low-confidence data results for the inputs to the IEUBK.

The soil lead concentration is generally used to predict current risk. The soil concentrations obtained by the previously described averaging are central tendency estimates for use in estimating blood lead concentrations for young children (<7 years of age). However, these central tendency estimates are subject to uncertainty, and if a risk assessor seeks to provide a protectively high estimate of the average concentration of lead present in yard soil, then an upper confidence limit (UCL) of the mean may be appropriate. The issue is whether there is confidence in the arithmetic mean value as the most representative EPC for lead risk calculations. The geometric standard deviation (GSD) in the IEUBK model is intended to address variability in blood lead concentrations in a population of similarly exposed individuals, not in the EPC. If the EPC varies substantially within an EU, then the population may not be "similarly exposed." The IEUBK model can use a UCL as a soil lead EPC; however, results may be biased high if the sampling plan is inadequate. Alternatively, the site team may also consider dividing the EU into smaller EUs. A well-designed sampling plan, including ICS, would be expected to provide narrower confidence limits around the mean.

Additional information, equations, and examples on calculating soil lead EPCs for use in the IEUBK model can be found in EPA's guidance documents (U.S. EPA 2020f, 1994b) and OSWER 9200.1-78 *Short Sheet: Estimating the Soil Lead Concentration Term for the Integrated Exposure Uptake Biokinetic (IEUBK) Model* (U.S. EPA 2007a).

8.5 Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children

The IEUBK model was developed to evaluate exposure, estimate risk, and determine remedial or removal PRGs or cleanup goals. Lead is assessed differently from other contaminants in risk assessments because there is no reference dose (RfD) or slope factor available to estimate the

probability of adverse health effects. Since 1994, OLEM has used the IEUBK model as the risk assessment tool to support environmental cleanup decisions at residential sites for children <7 years of age (U.S. EPA 1994a, 1994b).

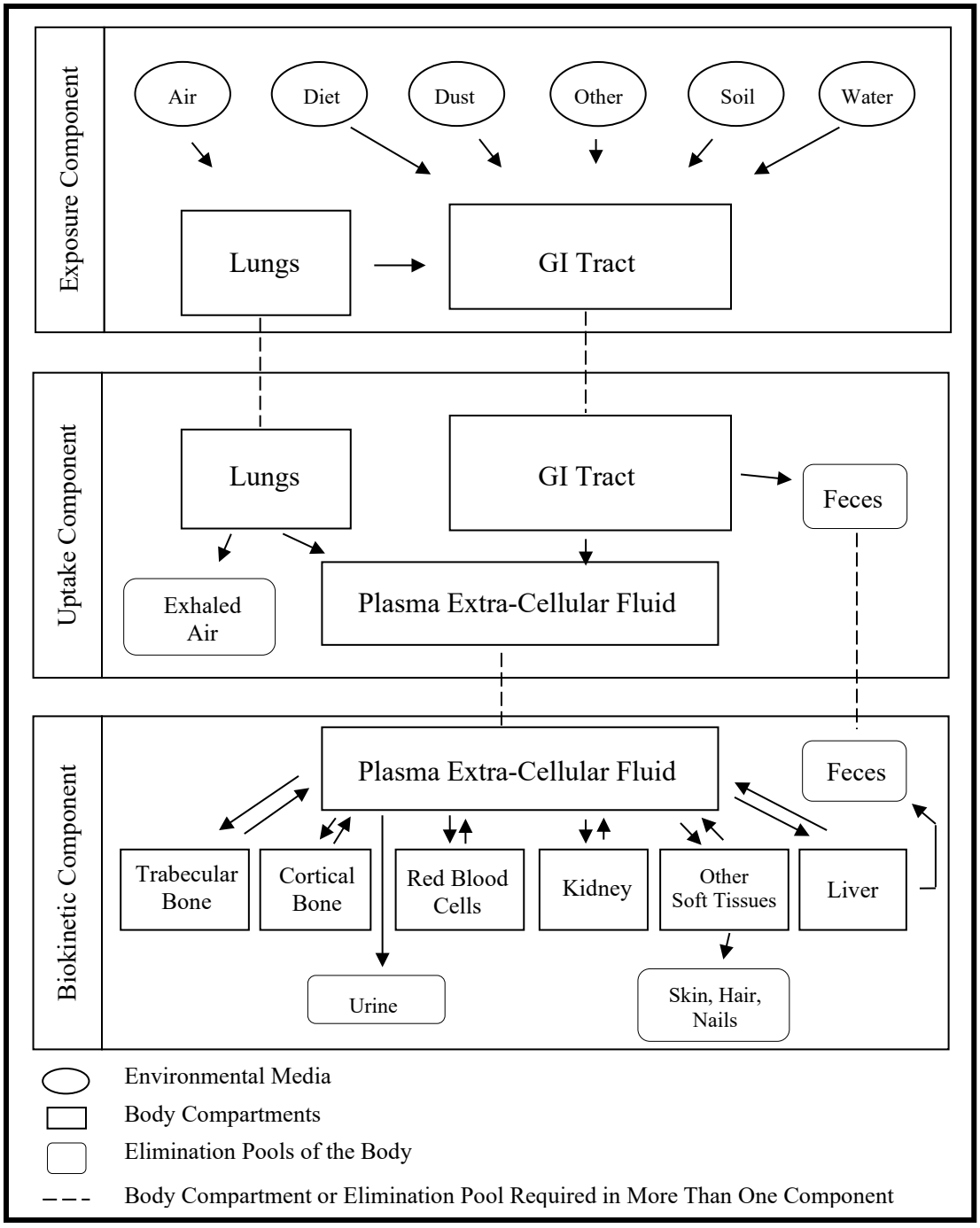
The IEUBK model uses more than 100 input parameters that are initially set to default values (U.S. EPA 2021b, 2021c).[107] Default values represent national averages or other central tendency values derived from: (a) empirical data in the open literature that included lead concentrations in exposure media (*e.g.,* diets representative of national food sources); (b) intake rates based on ambient air, water, food, and soil/dust; and (c) exposure durations (White et al. 1998). As previously stated, while site-specific environmental data improve the reliability of the IEUBK model for risk assessment, the concentration of lead in soil at the site is the only required site-specific input parameter for a lead risk assessment. More information on the IEUBK model and training can be found online at http://www.epa.gov/superfund/lead-superfund-sites.

The IEUBK model is a tool for making rapid calculations of a complex set of equations, which include many exposure, uptake, and biokinetic parameters, as shown in Figure 8-1 (U.S. EPA 2021b). The representativeness of the model output is dependent upon the representativeness of the input data, which are often assessed in terms of completeness, comparability, reproducibility, and accuracy (U.S. EPA 2021b, 1994b, 1994c).

The IEUBK model should be used to support environmental cleanup decisions for residential scenarios at CERCLA and RCRA Corrective Action sites (Breen 2024, U.S. EPA 2020f, 1994a, 1994c).

[107] The Technical Support Document for the IEUBK model provides a detailed explanation of the equations, parameter values, and the sources of data considered for the IEUBK model.

Figure 8-1. Structure of the IEUBK Model



8.6 Limitations of the IEUBK Model

The IEUBK model cannot be used to assess short-term, infrequent, or acute exposures, or the deliberate ingestion of soil when the ingestion rate is excessive (soil pica). Infrequent and non-continuous exposures (*i.e.*, <1 day/week over a minimum duration of 90 days) produce oscillations in blood lead concentrations associated with the absorption and subsequent clearance of lead from the blood between each exposure event that cannot be simulated using the IEUBK model (Lorenzana et al. 2005). The IEUBK model can only provide an approximation

of quasi-steady-state blood lead concentrations during non-continuous exposure scenarios of at least 1 day per week lasting for at least 90 consecutive days. That is, the model predicts a geometric mean blood lead concentration (this is also the median concentration) associated with continuous exposures of sufficient duration to reach equilibrium (U.S. EPA 2003c).[108] The reliability of the IEUBK model predictions for exposures of <3 months has not been assessed, and the IEUBK model generally should not be used to evaluate exposure scenarios shorter than 90 consecutive days. In such cases where infrequent and non-continuous exposures occur, options should be discussed with the regional risk assessor (consultation with the TRW Lead Committee is also available for EPA site teams).

The IEUBK model does not aim to reproduce the observed blood lead concentration (PbB) for any specific child or community since there can be diverse lead exposures to varied environmental lead concentrations within the community, because of the practical limitations of default exposure characterizations, uncertainty in site-specific exposure, housekeeping differences, variability in behavior, and variability in uptake and biokinetics (White et al. 1998). In the simplest scenario, the model uses environmental lead concentrations and bioavailability at a residence to predict the plausible distribution of PbBs of children who might reside at the residence either currently or in the future. Most importantly, the IEUBK model is not a substitute for medical evaluation of an individual child when a known or suspected lead exposure is identified.

The initial placeholder soil lead concentration in the IEUBK model of 200 ppm is a reasonable and representative initial value for the IEUBK model for soil lead concentration for the conterminous United States (White et al. 1998, U.S. EPA 1994b). Neither this initial value nor the values identified by the USGS in their nationwide background study represent soil lead concentrations at a specific lead-contaminated site and may not be relevant for characterizing soil lead concentrations for Superfund sites. A site-specific soil lead EPC is required, and soil lead bioavailability information is highly recommended, to use the IEUBK model to assess risk to young children.

Because the IEUBK model assesses risk from exposure to multiple media, the *Find Soil Pb Concentration* function of the IEUBK model (whereby the model identifies a soil lead concentration that meets criteria specified by the user) may not find a solution when the

[108] Based on estimates of the first-order elimination half-time for lead in blood—approximately 30 days for adults (Chamberlain et al. 1978, Rabinowitz et al. 1976) — a constant lead intake rate of at least 1 day per week over a duration of 90 days would be expected to achieve a blood lead concentration that is sufficiently close to the quasi-steady state (Lorenzana et al. 2005, U.S. EPA 2003c).

exposures from non-soil sources exceed the risk benchmark specified by the user. This situation indicates that there is no level of soil lead that will achieve the target BLL, and background concentrations may be used to define the cleanup level.

8.7 Toxicity Assessment

Young children are adversely impacted by lead exposure and lead has a range of adverse health effects (*e.g.*, neurological, developmental, etc.). Epidemiological studies have evaluated the health effects of lead in all organ systems. For the most studied endpoints (neurological, hematological, immunological, reproductive, and developmental), effects occur at the lowest lead blood levels studied (see Table 8-1). A threshold for adverse health effects for lead has not been established (ATSDR 2020, U.S. EPA 2024, CDC 2012). Depending on the chemical and physical characteristics of lead, however, <100% of lead entering the body is readily absorbed into systemic circulation (U.S. EPA 2024). The relative amount of lead absorbed is referred to as bioavailability, a characteristic critical to understanding how the body absorbs and reacts to lead exposure, as well as determining the risk of detrimental health effects associated with lead exposure (U.S. EPA 2007c).[109] See Section 6.13 for more information on soil lead bioavailability.

In recognition of there being no known threshold for adverse health effects of lead exposure in children, the CDC adopted the ACCLPP (2007) recommendations to eliminate the term "level of concern" and instead use a blood lead "reference value" for recommending public health actions based on elevated PbB. The CDC has recommended using the 97.5th percentile of blood lead distribution in children from 1 to 5 years of age, as determined by NHANES (CDC 2012). The age range of the IEUBK was changed to match CDC's age range. The reference value is not a health-based value; it is a statistic representing the upper tail (*i.e.*, 2.5%) of the U.S. population. The CDC blood lead reference value is used to identify children with PbB that are higher than most (97.5%) children in the United States; in other words, a high estimate of background PbBs. A lower CDC blood lead reference value means that more children will be identified as having excessive lead exposure prompting parents, doctors, public health officials, and communities to more aggressively prevent lead exposure. Using the 2007-2010 NHANES data, the BLL reference value associated with the 97.5th percentile is 5 µg/dL (CDC 2012). In May 2021, CDC used NHANES data from 2015-2016 and 2017-2018 data collection cycles to update the BLL reference value to 3.5 µg/dL and it has been steadily decreasing for decades (Egan et al. 2021).

[109] See https://www.epa.gov/superfund/soil-bioavailability-superfund-sites.

Table 8-1. Summary of Health Effects of Lead Exposure, Evidence from the 2024 Integrated Science Assessment for Lead (U.S. EPA 2024)

Health Outcome Group	Lifestage	Causality Determination[1]	Health Outcome	Blood Pb Evidence[2]	Bone/Tooth Pb Evidence
Nervous System Effects	Children	Causal	Cognitive effects: IQ decrements; impaired memory, learning, and executive function; academic achievement	Prenatal, early childhood, and adolescence: <5 µg/dL	No data
		Causal	Externalizing behaviors: attention, impulsivity, and hyperactivity; ADHD-related behaviors and Clinically Diagnosed ADHD	Prenatal and early childhood: <5 µg/dL	Tooth Pb levels associated with attention, impulsivity, and hyperactivity; ADHD-related behaviors
		Likely to be Causal	Externalizing behaviors: conduct disorders, aggression, and criminal behavior	Prenatal, early childhood, adolescence, and young adulthood[3]: <10 µg/dL	Limited evidence demonstrating an association between tibia Pb levels and aggression scores
		Likely to be Causal	Internalizing behaviors: anxiety and depression	Prenatal and early childhood: <7 µg/dL	Limited evidence demonstrating an association between tooth Pb levels and anxiety and depression
		Likely to be Causal	Motor function	Prenatal and early childhood (infancy through 3 years) : <15 µg/dL	No data
		Suggestive	Sensory Function	Early childhood through adolescence: <5 µg/dL	No data
		Suggestive	Social cognition and behavior: increased autism risk and autistic behavior; reduced social cognition	Prenatal, early childhood, and early adolescence: <5 µg/dL	Limited evidence demonstrating an association between tooth Pb levels and ASD
	Adults	Causal	Cognitive effects: decrements in IQ and global cognitive function	Childhood: ≤10 µg/dL Adulthood: <5 µg/dL	Tibia and patella Pb levels associated with cognitive function decrements
		Likely to be Causal	Psychopathological effects: anxiety and depression	Childhood: ≤20 µg/dL	Tibia Pb levels associated with depressive symptoms
		Suggestive	Sensory function: auditory effects	Adulthood: <5 µg/dL	Limited evidence demonstrating an association between tibia Pb levels and hearing threshold
		Suggestive	Neurodegenerative disease: ALS and Parkinson's Disease	Adulthood: <5 µg/dL	Limited evidence demonstrating an association between tibia Pb levels and Parkinson's Disease

Health Outcome Group	Lifestage	Causality Determination[1]	Health Outcome	Blood Pb Evidence[2]	Bone/Tooth Pb Evidence
Cardiovascular Effects	Adults	Causal	CV effects and CV-related mortality: increased blood pressure, hypertension, and CVD mortality	<5 µg/dL	Tibia and patella Pb levels consistently associated with hypertension and CVD mortality
Renal Effects	Adults	Causal	Renal effects: Decreased kidney function (kidney disease and decreased eGFR)	<5 µg/dL	Limited evidence demonstrating tibia and patella Pb level associations with reduced kidney function
Immune System Effects	Children	Likely to be causal	Immunosuppression: higher susceptibility to viral and bacterial infection, reduced antibiotic resistance, and reduced vaccine antibodies	<5 µg/dL	No data
	Children	Suggestive	Sensitization and allergic responses: Asthma incidence	≥5 µg/dL	No data
Hematological Effects	Children and Adults	Causal	Altered heme synthesis and decreased RBC survival and function	<10 µg/dL	No data
Reproductive and Developmental Effects	Children	Causal	Development: Delayed pubertal onset	<5 µg/dL	No data
		Likely to be Causal	Pregnancy and birth outcomes: preterm birth, low birthweight	<5 µg/dL	No Data
	Adults	Causal	Male reproductive function: effects on sperm/semen production, quality, and function	<5 µg/dL	No data
		Likely to be Causal	Female reproductive function: effects on hormone levels and menstrual/estrous cyclicity	<5 µg/dL	Limited evidence demonstrating tibia and patella Pb levels associations with early menopause
Hepatic Effects	Adults	Suggestive	Higher serum biomarkers of liver function (e.g., AST, ALT, and ALP)	<5 µg/dL	No data
Musculoskeletal Effects	Children	Likely to be Causal	Higher prevalence of dental caries and tooth loss	<5 µg/dL	No data
	Adults	Likely to be Causal	Higher prevalence of osteoporosis, dental caries, and tooth loss	<5 µg/dL	No data
Mortality	Adults	Causal	Total (nonaccidental) mortality	<5 µg/dL	Patella Pb levels associated with total mortality
Cancer	Adults	Likely to be Causal	Evidence of tumor development in animal studies; human evidence inconsistent	Human evidence inconsistent	No data

Abbreviations: ADHD, Attention-Deficit/Hyperactivity Disorder; ALP, Alkaline Phosphatase; ALT, Alanine Transaminase; ASD, Autism Spectrum Disorder; AST, Aspartate Aminotransferase; ALS, Amyotrophic Lateral Sclerosis; CV, Cardiovascular; CVD, Cardiovascular Disease IQ, Intelligence Quotient; Pb, Lead

[1]The 2024 Pb ISA evaluates the weight of the available evidence to reach causality determinations on the health effects of Pb. Conclusions on the overall strength of evidence are described using a five-level hierarchy that classifies the weight of evidence for causation. These causality determinations are made for broad health and welfare effect categories and are informed by evaluating evidence across scientific disciplines for consistency, coherence, and biological plausibility, as well as for uncertainties. This table summarizes health outcomes for which the evidence indicates a causal relationship ("causal") or likely to be causal relationship ("likely to be causal"), or is suggestive of, but not sufficient to infer a causal relationship ("suggestive"). The ISA's approach to evaluating the weight of evidence and reaching causality determinations is described in more detail in the Preamble to the Integrated Science Assessments (U.S. EPA 2015a).

[2]The blood Pb levels reported in this table represent the lowest group or population mean blood Pb levels associated with the specified health outcome(s). Blood Pb may reflect both recent as well as past exposures because Pb is both taken up by and released from the bone. The relative proportion of BLLs resulting from recent versus past exposure is uncertain in the absence of specific information about the pattern of exposure contributing to observed BLLs, which is generally not ascertainable in epidemiologic studies. This uncertainty is greater in adults who have lengthy exposure histories and were likely exposed to high levels of Pb prior to the phaseout of leaded gasoline. Thus, the extent to which adult BLLs reported in this table reflect potentially higher exposure histories is undiscernible, as is the extent to which these past Pb exposures (magnitude, duration, frequency) may or may not elicit effects.

[3]Includes overlap with adult populations (7 to 33 years old)

8.8 Uncertainty

The uncertainty section of a lead risk assessment should discuss and, where possible, estimate the direction and magnitude of uncertainty associated with influential parameters used to estimate risk. Areas of uncertainty that may make an appreciable difference in the risk assessment results or conclusions are appropriate topics for an uncertainty discussion (U.S. EPA 2014b). The primary sources of uncertainty relative to assumptions, results, and conclusions are:

- Uncertainty in site characterization and data quality;
- Uncertainty in the representation of the EPCs;
- Uncertainty in the exposure assessment; and
- Uncertainty in the IEUBK estimation of the risk.

Influential parameters that contribute to exposure estimates that exceed risk benchmarks are a particularly important focus for uncertainty discussion because consideration of uncertainty in these parameters can inform risk management decisions. Influential parameters are also those that have the largest effect on the risk estimate when varied across a plausible range, as determined by site-specific information that informs that range of possible values.

The IEUBK model has been evaluated at a target PbB level of 5 µg/dL and shown to accurately predict the geometric mean PbB level, the probability of the PbB levels exceeding 5 µg/dL, and the distribution of observed individual PbB levels for children living at the Bunker Hill Superfund Site (Brown et al. 2022). Application of the IEUBK at lower soil lead levels has not been evaluated and may create additional uncertainty in the estimate of risk. The increased relative influence of other sources of lead on predicted PbB levels, most notably exposure through diet, is a key uncertainty in the model's estimate of risk at a target PbB level below 5 µg/dL. At a target PbB level of 5 µg/dL and above, more than half of the predicted PbB comes from soil and dust lead levels. Below a target PbB level of 5 µg/dL, diet becomes a major contributer to the predicted PbB levels. The effect of variability in dietary exposure on the model predictions is

unknown, but likely to be large where diet is a major contributor to the predicted PbB levels. Another key uncertainty is that the relationship between PbB levels and soil lead levels at low PbB levels (*e.g.*, <200 mg/kg) is not well characterized and may not be linear as it is where there are higher soil lead levels and PbB levels (Mielke et al. 2019, Zahran et al. 2011). If this relationship is non-linear at levels below the target PbB level of 5 µg/dL, the IEUBK may tend to predict lower PbB levels than what may be observed in a population. Where the IEUBK model is used with a target PbB level <5 µg/dL, the uncertainty section of the risk assessment should discuss these additional uncertainties in the model predictions.

8.9 Risk Characterization

Risk characterization is the bridge between risk assessment and risk management. Risk characterization integrates and summarizes information gathered during the three phases of risk assessment (data collection and evaluation, exposure assessment, and toxicity assessment) relating toxicity and exposure assessments. This may include the development of PRGs.

It is important to identify and understand the assumptions, uncertainties, and limitations associated with the risk assessment to reach a fully informed risk management decision. Moreover, uncertainty analysis may identify areas at a site where additional data collection could aid in the selection of a cleanup response. This is especially true for model parameters that require site-specific input (*i.e.*, soil lead EPC and bioavailability). When conducting a risk assessment, it is more important to identify and prioritize the key site-related variables and assumptions that contribute most to uncertainty than it is to precisely quantify the degree of uncertainty in the entire risk assessment. Data uncertainty needs to be assessed for each data set.