Refining Risk Assessment, Relative Bioavailability of Lead in Soil and Dust Evidence from Blood Lead at Bunker Hill

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Abstract

Environmental issue being addressed - More than a century of mining and smelting at Bunker Hill contaminated soil and interior dust with lead and other metals. Following closure of the smelter in 1981, lead in soil and dust were identified as primary exposure pathways for children living on the Bunker Hill Site in the Silver Valley, Idaho.

Scientific approach to resolving the issue - Soil and dust have been sampled annually as contaminated soil was replaced with clean soil at schools, parks, businesses, and approximately 2,200 residences. Annual voluntary blood lead screening has recruited over 50% of exposed children every year from 1988 through 2002. Blood lead levels have decreased as soil and dust lead levels have declined as the soil cleanup progressed. Bioavailability was estimated by comparing lead uptake from over 5,000 blood lead measurements paired with estimates of lead intake from thousands of soil and dust measurements. Lead intakes were estimated using a range of assumptions of the relative importance of lead levels in 1) house dust, 2) residential soil from a child's own yard, 3) soil from neighboring yards, and 4) the mean concentration from all yards in a town. The impact of various exposure assumptions on the estimated intake was minimal because of correlations among these measures of exposure.

Partnerships - Region 10 EPA partnered with the Panhandle Health District, the Idaho Department of Environmental Quality, the EPA Office of Research and Development, and the Idaho Department of Health and Welfare.

Impact - Since 1989, when the residential soil cleanup began, children's blood lead levels at Bunker Hill, Idaho have decreased significantly. Blood lead concentrations are now comparable to the U.S. national average - but annual variations have been observed. This work suggests that an important source of variation may be an increased uptake of lead from house dust relative to soil. From 1988 to 2002, the estimated aggregate bioavailability of soil and dust averaged 18% over a range of 12-23%. Higher aggregate bioavailability coincided with increased intakes of dust relative to soil, suggesting that lead in dust is more bioavailable than soil. Attempts to separate soil and dust bioavailability are sensitive to soil and dust ingestion rate assumptions. However, assuming 10% soil and 25% dust bioavailability explains the annual variation in aggregate soil/dust bioavailability observed from 1988 to 2002. Greater bioavailability of dust may be caused by smaller particles in dust relative to soil which may account for an increase in bioavailability (due to greater surface area) and ingestion rate (smaller particles are more likely to cling to hands and fingers). This work provides support for health benefits of soil remediation and the importance of lead in house dust to young children. Risk managers and public health workers can better prioritize actions to protect children from dangerous levels of lead exposure.

Background

In risk assessment, bioavailability refers to the fraction of an external dose that enters systemic circulation (National Academy of Sciences, 2003). If the concentration of lead in environmental media available for exposure is included in the external dose, then bioavailability can include ingestion rates as well as the uptake fraction. Lead exposure from soil or dust is modeled as the product of concentration (μg/g), ingestion rate (g/day), and the unitless fraction available for uptake (i.e., bioavailability). See Figure 1 for predicted and observed blood lead levels using an aggregate soil/dust bioavailability of 18%.

Methods

Aggregate bioavailability of lead in soil and dust has been estimated annually by comparing blood lead levels in resident children (internal dose) to lead concentrations in soil and dust (external dose) using age-specific default soil/dust ingestion rates of the EPA IEUBK Lead Model (U.S. Environmental Protection Agency, 2001).

Blood lead levels were converted to lead uptake using age-specific biokinetic slope factors which are the basis of the IEUBK Lead Model (Harley & Kneip, 1985; U.S. Environmental Protection Agency, 2001).

Definitions

Bioavailability (unitless)	= Internal dose (μg/day) per external dose (μg/day)
Internal dose (day/dL)	= Blood lead level (μg/dL) per biokinetic slope factor
Biokinetic slope factor	= Blood lead level (μg/dL) per lead uptake (μg/day)
External dose (μg/day)	= Sum of (soil+dust+ air+water+diet) intakes

Results

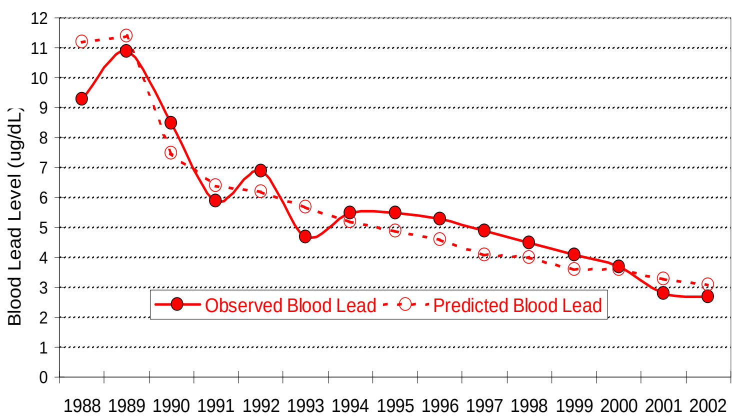

Figure 1 Observed and Predicted Blood Lead Using 18% Aggregate Bioavailability for Soil and Dust

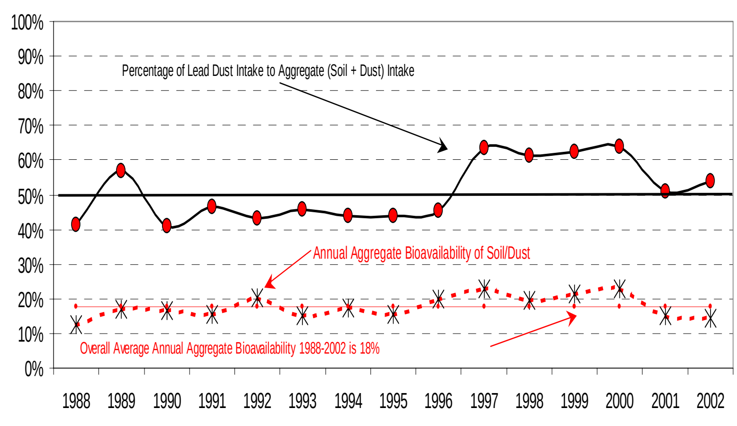

Figure 2 Aggregate Soil and Dust Bioavailability and Percentage of Lead Intake from Dust

Methods Continued

Lead biokinetic slope factors at an uptake of 20 μg day (Harley & Kneip, 1985)

Age (months)	Biokinetic Slope Factor (day/dL)
0-12	0.297
13-24	0.404
25-36	0.366
37-48	0.350
49-60	0.363
61-72	0.345
72-84	0.325
85-96	0.248
97-108	0.232

Separating soil and dust bioavailability

Annual aggregate soil and dust bioavailability and the percent of lead intake from soil versus dust were tabulated from 1988 through 2002 (see Figure 2). Discrete bioavailability for soil and dust were calculated using the Solver function in Microsoft Excel 2000®.

Discussion

Although measurements of lead bioavailability in soil media are available, similar measurements for lead in dust are lacking (National Academy of Sciences, 2003). Relative bioavailability of lead in soil and dust can be inferred from slope factors which relate concentrations in environmental media to blood lead concentrations in children, but this necessarily combines absorption with ingestion and other measures of exposure. Although soil and dust slope factors are highly variable, values soil slope factors are generally less than dust slope factors (Succop et al., 1998). Direct comparison between soil and dust bioavailability are impeded by differences in units. Soil lead is reported as a mass based concentration while dust lead is often reported as a mass per area basis (i.e., loading) which is a better predictor of blood lead levels than a mass based concentration (Lanphear et al., 1995; Lanphear et al., 1998; Succop et al., 1998)

Conclusion

Analysis of estimated annual aggregate bioavailability and the relative soil and dust intakes suggest geometric mean bioavailability of 10% and 25%, respectively (average values are 36% and 11%). These results are consistent with observed increases in aggregate bioavailability during years when dust lead intakes were greater than soil lead intakes and predicted blood lead levels were below observed levels. Greater effective bioavailability of dust relative to soil could be caused in part by enhanced dermal adherence, ingestion, and absorption due to smaller particle size (Kissel et al., 1996; Steele et al., 1990; U.S. EPA Technical Review Workgroup for Lead, 1999). Differential assumptions of soil and dust bioavailability could be used to refine risk assessments and predictive blood lead modeling.

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