COMPARISON OF UPDATED LEADSPREAD TO INTEGRATED UPTAKE, EXPOSURE, AND BIOKINETIC MODEL (IEUBK) FOR PREDICTING BLOOD LEAD IN CHILDREN

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ABSTRACT

California Department of Toxic Substances Control has revised LeadSpread, its spreadsheet model for predicting distributions of blood lead in adults and children. Here we compare revised LeadSpread (BloodPb7.xls) to USEPA's IEUBK model (ver. Lead99d). Structurally, the two models are very different. IEUBK is a multi-compartment, time-dependent model, while LeadSpread 7 uses empirical relationships under steady-state assumptions. IEUBK allows a user-specified maternal blood lead concentration, indoor/outdoor ratios for dust, activity, and air, and optional inputs for additional sources of lead, such as paint. LeadSpread does not offer these features, but it has a plant uptake pathway. IEUBK estimates blood lead for children up to 7 years old, while LeadSpread 7 provides estimates for 1-2 year old children, with or without pica, and for adults. Operationally, IEUBK is a compiled model run in DOS, while LeadSpread 7 is a spreadsheet model run in Microsoft Excel®. Slope factors describing change in blood lead per unit of lead content in food, drinking water, or environmental media are explicit in LeadSpread 7, and they can be derived from IEUBK by running the model iteratively. For change in blood lead vs. lead in air, LeadSpread 7 has a discernible slope, while IEUBK does not. For drinking water and food, IEUBK shows faster rises in blood lead per unit concentration of lead than does LeadSpread 7. For ingestion of soil, IEUBK includes a saturable and a non-saturable process. Because the saturable process is sub-linear, we describe two slope factors for IEUBK, one for 0-700 and one for 0-7,000 mg lead/kg soil. The one slope factor in LeadSpread 7 for soil ingestion vs. change in blood lead is about equal to the larger of the two for IEUBK. We compared outputs of the two models for children 1-2 years old. Using recommended defaults, 20 mg lead/kg of soil, and 15 µg/L lead/L in drinking water, IEUBK predicted a geometric mean blood lead of 1.9 µg/dL with a 99th percentile of 5.6 µg/dL, while LeadSpread 7 predicted 1.7 and 5.2 µg/dL. A large data base (NHANES III) reports a geometric mean blood lead of 2.6 µg/dL for children 1-2 years of age in the Western United States, while the mean value is 2.0 µg/dL for the subset of children living in post-1973 housing. The latter value is comparable to both models.

INTRODUCTION

Carlisle and Wade (1992) compared the then-current versions of DTSC's Lead Risk Assessment Spreadsheet Model (LeadSpread) with the U.S. EPA's Integrated Exposure, Uptake and Biokinetic model (IEUBK). Both models have been revised since that publication; hence, a new comparison was undertaken. The models were compared in terms of structure, operational features, types of inputs and outputs, and the incremental change in predicted blood lead concentration corresponding to a unit increase in lead concentration in air, soil, food, and water.

Structurally, the two models are very different. IEUBK is a multi-compartment, pharmacokinetic model, based on lead metabolism studies in infant and juvenile baboons. Gastrointestinal absorption is modeled as the sum of a saturable active mechanism and a linear passive mechanism, thus giving a sublinear response slope. LeadSpread 7 (see Poster #341) is based on empirical relationships in humans and assumes steady-state conditions. All uptake pathways are linear with dose. The available inputs and outputs are compared in Table 1:

TABLE 1

COMPARISON OF IEUBK WITH LEADSPREAD 7

PARAMETER	IEUBK	LeadSpread 7
Structure:		
Soil ingestion	Varies by year	Pica is separate
Gastrointestinal absorption	Nearly linear at low levels of lead in soil; Sublinear at higher levels.	Linear
Dermal uptake	Not available	Yes
Outputs by age	Child any age from 0 to 7 yr	Child age 1-2 yr or adult
Defaults	Mid-1980's	Late 1990's
Software	DOS	Windows/Excel
Input:		
Lead in soil	User specified (Default = 200 mg/kg)	User specified (Default = 20 mg/kg)
Lead in drinking water	User specified (Default = 4 µg/L)	User specified (Default = 15 µg/L)
Lead in air	User specified (Default = 0.28 µg/m^3) Can also specify a ratio of indoor to outdoor	User-specified (Default = 0.10 µg/m^3) Ambient plus site emissions
Lead in dust	Optional multiple source analysis	Equal to soil lead
Maternal blood lead	User specified (Default = 2.5 µg/dL)	Not included
Lead in home-grown produce	User-specified	Calculated from lead in soil
Other sources of lead	Optional (lead paint)	Not available
Bioavailability	Optionally user specified	User specified (Default = 0.44)
Output:		
Compartments reported	Several	Blood only
Blood lead distribution	Geometric mean, then read percentiles of distribution from graph	Calculates 50th, 90th, 95th, 98th and 99th percentiles
Remedial goals for soil	Not available	Calculates soil lead associated with blood lead of 10 µg/dL at 95th & 99th percentiles

RESULTS

Figures 1 through 5 show comparisons of predictions of mean blood lead for the 1-2 year old child. IEUBK was used with two sets of inputs: (1) with its own recommended defaults, and (2) with the defaults recommended by DTSC. LeadSpread 7 used recommended DTSC defaults. When the inputs were the same or nearly so, the two models produce roughly similar results. Table 2 shows a comparison of NHANES III, LeadSpread, and IEUBK.

FIGURE 1 - Low Levels of Lead in Soil: LeadSpread 7 predicts linear increases in blood lead with increasing levels of lead in soil. IEUBK produces sublinear curves. This occurs because IEUBK has both saturable and non-saturable components for absorption of lead from the gastrointestinal tract.

FIGURE 1
CHANGES IN MEAN BLOOD LEAD WITH CHANGES IN SOIL LEAD AT LOW SOIL LEAD CONCENTRATIONS

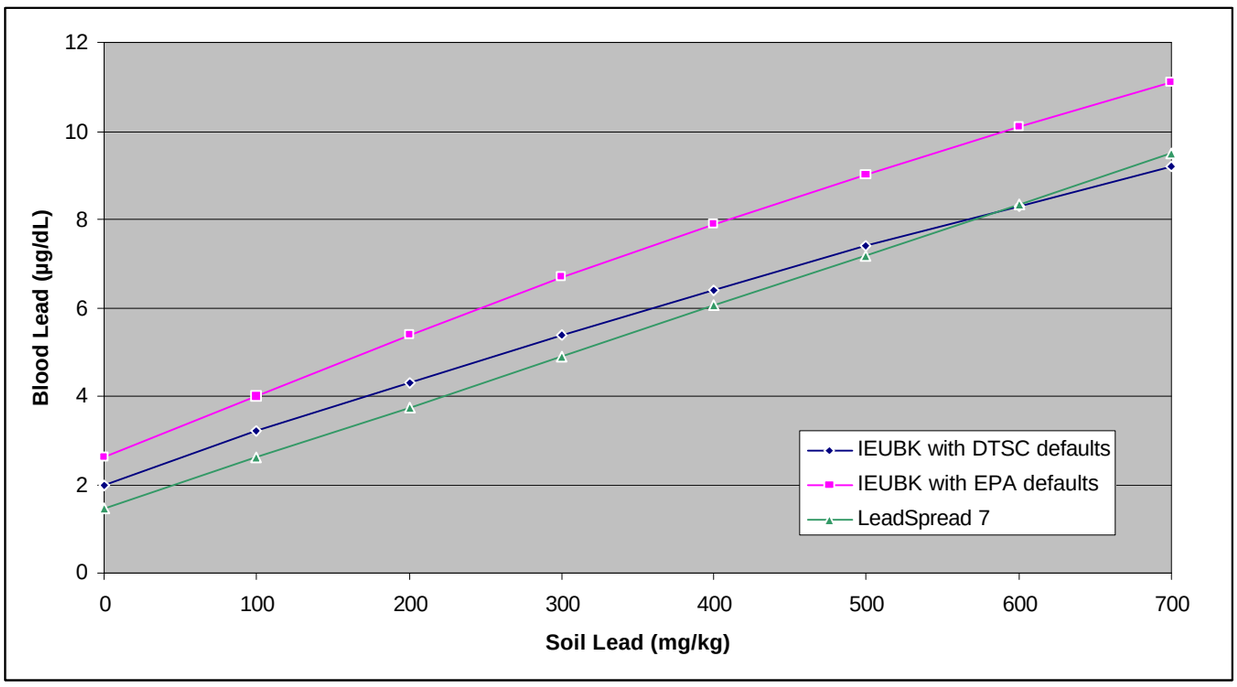

FIGURE 2 - High Levels of Lead in Soil: The sublinear effect of the saturable component of absorption in the IEUBK model is dramatically apparent at higher concentrations of lead in soil.

FIGURE 2
CHANGES IN MEAN BLOOD LEAD WITH CHANGES IN SOIL LEAD AT HIGH SOIL LEAD CONCENTRATIONS

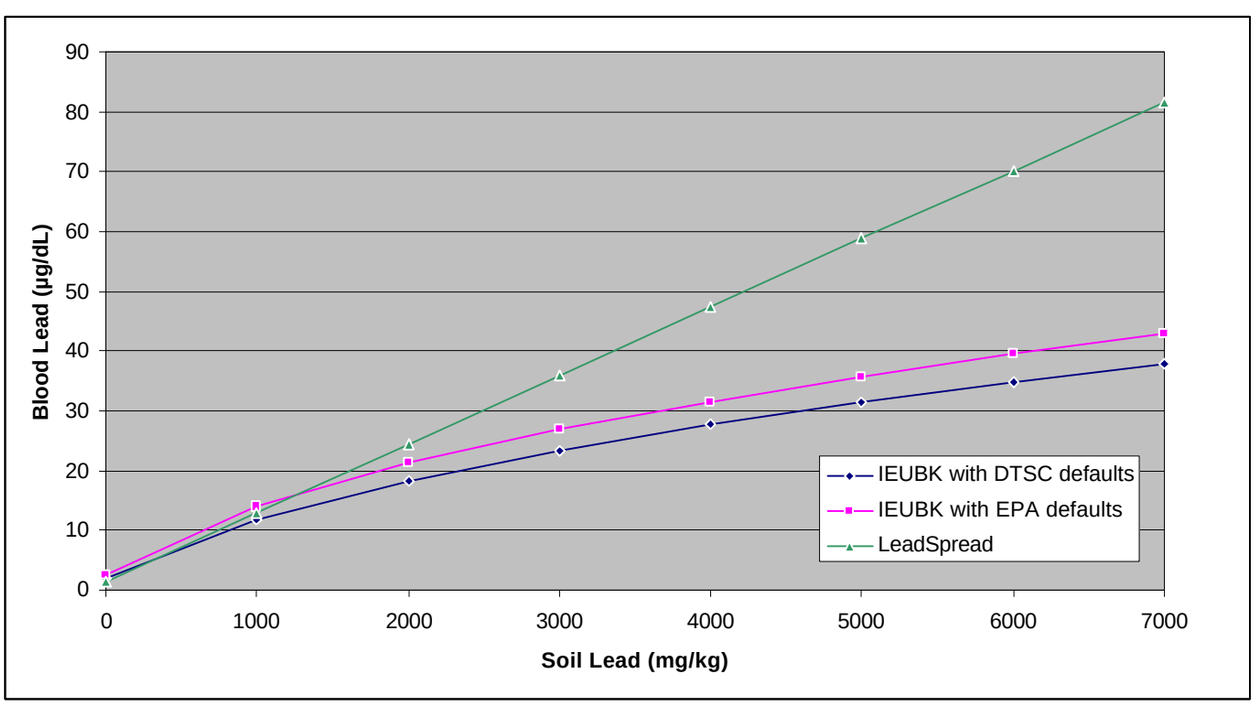

FIGURE 3 - Lead in Drinking Water: IEUBK and LeadSpread 7 have linear responses to changes in concentrations of lead in drinking water. Slopes are similar, indicating similar predicted uptake of lead. IEUBK predicts higher blood lead with USEPA defaults, because the default values are higher for lead in soil, ingestion of soil, and lead in food.

FIGURE 3
CHANGES IN MEAN BLOOD LEAD WITH CHANGES IN CONCENTRATION OF LEAD IN DRINKING WATER

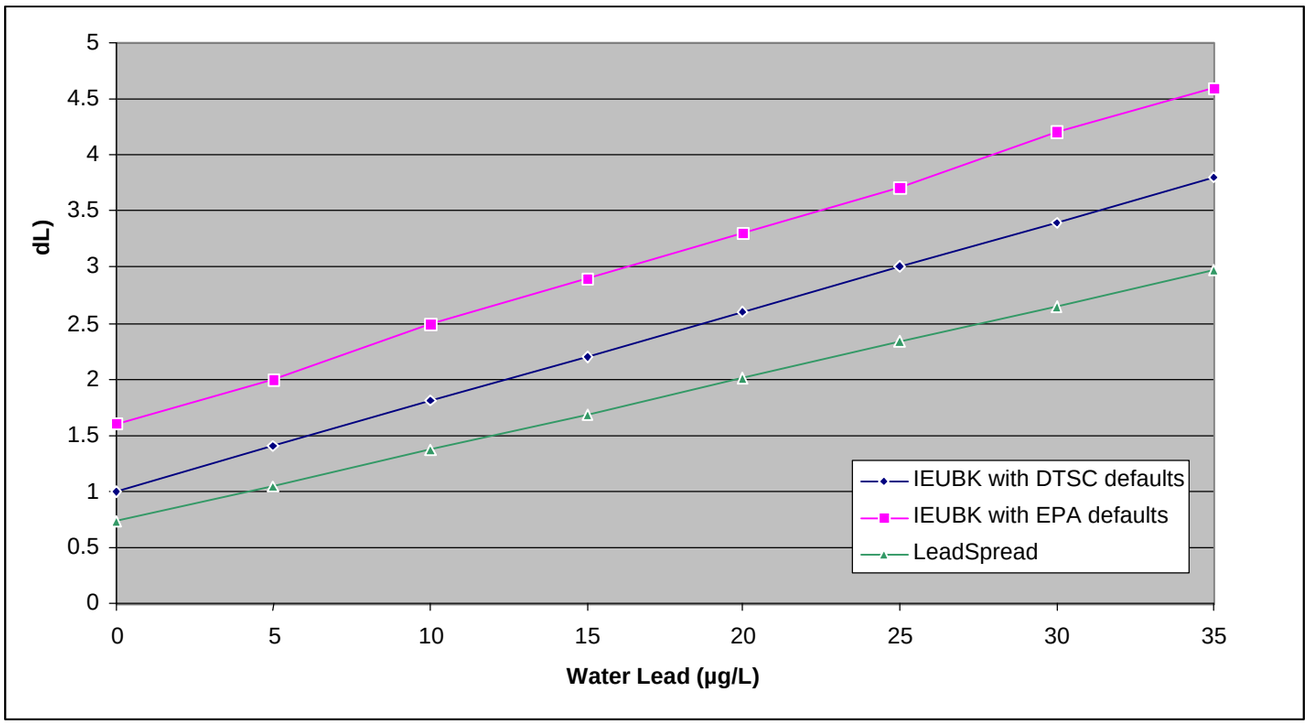

FIGURE 4 - Lead in Food: IEUBK predicts faster increases for blood lead with increasing concentrations of lead in food, principally due to a higher factor for uptake of lead from water. When DTSC defaults are used in IEUBK, the slopes are similar.

FIGURE 4
CHANGES IN MEAN BLOOD LEAD WITH CHANGES IN CONCENTRATION OF LEAD IN FOOD

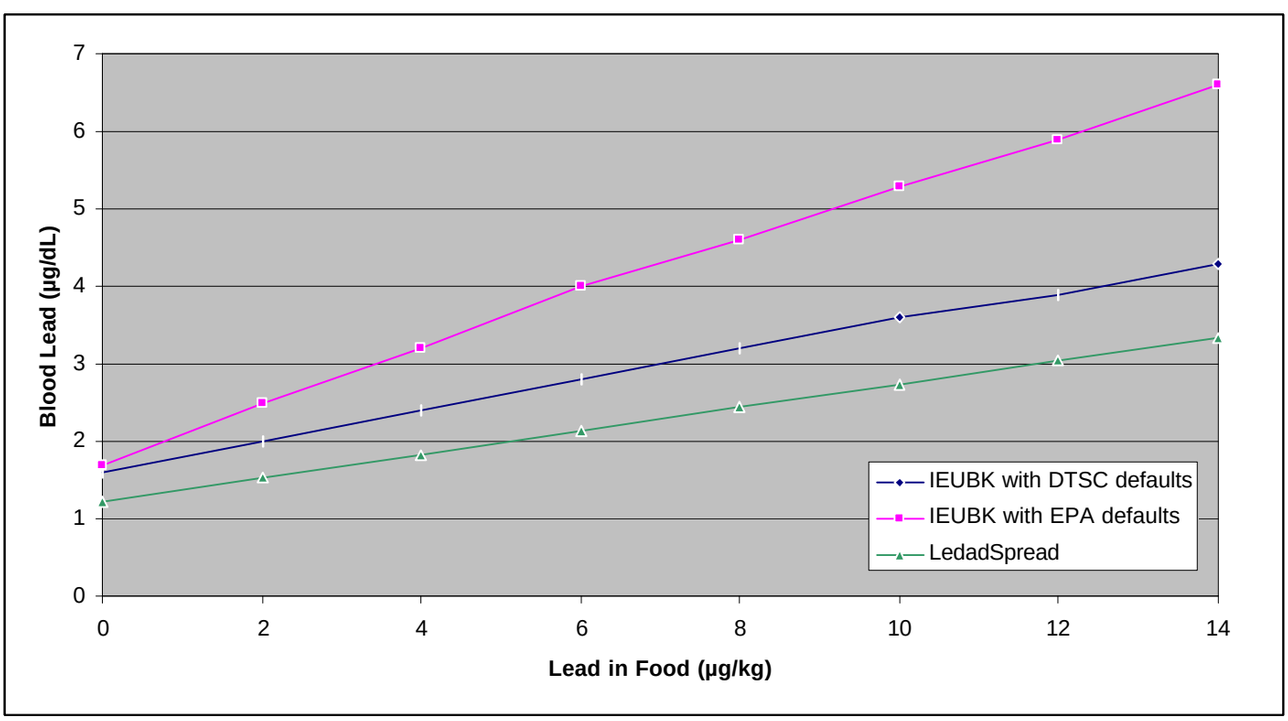

FIGURE 5 – Lead in Air: IEUBK has no discernible response to changes of the concentration of lead in air, while LeadSpread 7 demonstrates a shallow slope. Of the four principal sources of exposure (air, water, food, and soil), airborne lead makes the smallest contribution, using default inputs.

FIGURE 5
CHANGES IN MEAN BLOOD LEAD WITH CHANGES IN LEAD IN AIR

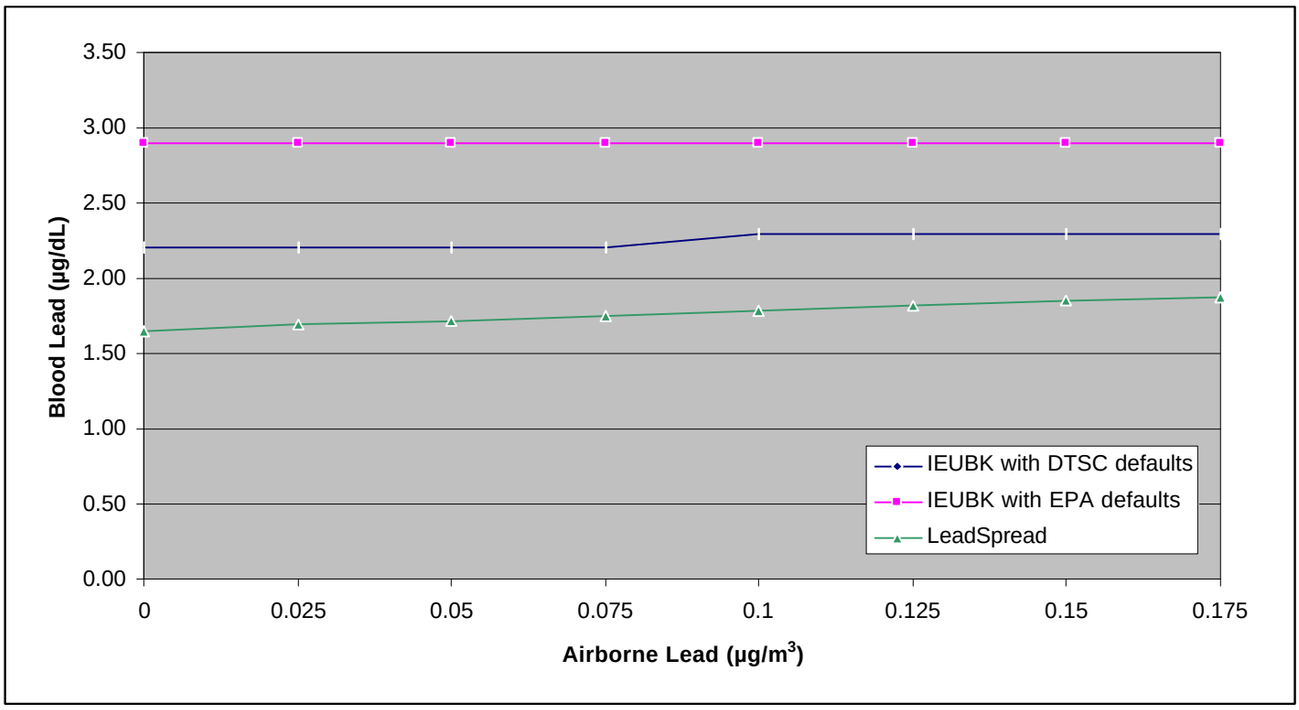

TABLE 2

COMPARISON OF LEADSPREAD AND IEUBK TO NHANES III, USING RECOMMENDED DEFAULTS WITH 20 MG LEAD/KG FOR SOIL AND 15 µG LEAD/L FOR WATER

	Mean (µg/dL)	99th Percentile
NHANES III		
Children 1-2 Years Old in Western U.S.	2.6	--
Children 1-2 Years Old in Western U.S. Living in post-1973 Housing	1.9	--
LeadSpread, 1-2 Year Old Child	1.7	5.2
IEUBK, 1-2 Year Old Child	1.9	5.6

CONCLUSIONS

1. IEUBK describes the pharmacokinetics of the absorption and distribution of lead in greater detail than LeadSpread 7. However, LeadSpread 7 is easier to use.

2. At high concentrations of lead in soil, the two models diverge significantly, because IEUBK has a saturable component for uptake of lead, while LeadSpread 7 does not.

3. LeadSpread 7 predicts generally lower blood lead than IEUBK for the 1-2 year old child, because it incorporates defaults reflecting decreases in ambient levels of lead in food, water, and air. Differences between predictions from the two models become much smaller when the recommended defaults for LeadSpread are used in IEUBK.

4. Predictions from both LeadSpread and IEUBK are in agreement with NHANES III, when data are limited to children living in post-1973 housing.

REFERENCES

CARLISLE, J. C., AND WADE, M. J. (1992), “Predicting Blood Lead Concentrations From Environmental Concentrations”, Regulatory Toxicology and Pharmacology, 16:280-289.

USEPA (1994), “Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children”, Office of Solid Waste and Emergency Response, EPA/540/R-93/081, NTIS Publication No. PB93-968510, February, 1994.