Lead Soil Screening Levels and Cleanup at California Hazardous Waste Sites

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ABSTRACT

In 2007, CalEPA developed a new toxicity evaluation of lead replacing the 10 µg/dL threshold blood lead concentration (PbB) with a source-specific "benchmark change" of 1 µg/dL (the estimated incremental increase in children's PbB reducing IQ by 1 point). Here we show the resulting derivation of the revised California Human Health Screening Levels (CHHSLs) using the new PbB criterion and newer blood lead population data. The updated CHHSLs of 80 and 320 mg/kg lead in soil for residential and industrial/commercial land use scenarios, respectively, are lower than previous Cal-modified USEPA Region 9 Preliminary Remediation Goals (PRGs) of 150 and 800 mg/kg. To evaluate lead risk and cleanup options, DTSC recommends calculating the 95 percent upper confidence limit on the arithmetic mean (95%UCL) lead concentration. If individual samples exceed the CHHSL, the exposure area itself would not exceed the CHHSL as long as the 95%UCL is below the CHHSL (assuming no hot spots). If data are insufficient to calculate a 95%UCL, comparison of the maximum detected concentration to the CHHSL is appropriate. In such cases, additional sampling or cleanup may be warranted. In our experience, the upper lead concentration associated with a 95%UCL of 80 mg/kg is about 150 mg/kg unless there are hot spots. At sites A and B (with maximum lead concentrations of 2078 and 4100 mg/kg) removing samples with lead above 144 and 180 mg/kg lead, respectively, results in predicted 95%UCLs of ~80 mg/kg. The actual maximum threshold for lead to achieve a specific 95%UCL for a given site depends on many factors such as contaminant distribution and confirmation sampling results. Depending on site-specific conditions, cleanup goals consistent with a 95%UCL equal to the revised residential CHHSL can be approached by excavating contaminated soils with lead concentrations above approximately twice the revised CHHSL. A 95%UCL should be calculated using remaining soil and confirmation sampling data following remediation.

INTRODUCTION

- REVISED CHHSLs: 80 mg/kg lead in soil for residential land use and 320 mg/kg lead in soil for industrial land use.
- Lead is a common contaminant at hazardous waste sites.
- CURRENT USES OF LEAD: batteries, ammunition, paint, glass and ceramic products, casting metals, wheel balancers, fishing weights, stabilizer in PVC, sheet lead and nuclear radiation shielding.
- FORMER USES OF LEAD: gasoline additive, household paint, pesticides.
- HEALTH EFECTS OF LEAD (ATSDR, 2007)
  - Children considered most sensitive population
  - Effects on almost all organs and systems
  - Primary targets - nervous system, kidney, hematological and cardiovascular systems
  - Can cause tumors in laboratory animals
- HISTORICAL SITE SCREENING
  - 10 µg/dL blood lead level (PbB) level of concern, based on Centers for Disease Control
  - Previous 2004 Cal-modified and USEPA Region 9 Preliminary Remediation Goals (based on 10 µg/dL PbB) of 150 and 800 mg/kg lead in soil for residential and industrial/commercial land uses, respectively
- EMERGING USE OF LOWER CRITERIA BASED ON NEWER LEAD TOXICITY EVALUATIONS; EXAMPLES INCLUDE:
  - 2009 CalEPA OEHHA California Human Health Screening Levels (CHHSLs) for soil (discussed herein)
  - 2008 USEPA National Ambient Air Quality Standard (NAAQS)

2009 CalEPA OEHHA LEAD SOIL SCREENING LEVELS

The recent adoption of a 1 µg/dL benchmark for source-specific incremental change in blood lead necessitated updates of the CalEPA OEHHA Soil Screening Levels for lead (CHHSLs). The previous CHHSLs for lead, 150 and 3500 mg/kg for residential and commercial/industrial scenarios, respectively, were calculated as the maximum soil concentration which, combined with an assumed background blood lead level or a background exposure from food, and air, and water, would result in a total blood lead level not exceeding 10 µg/dL. The current CHHSLs are calculated as the level in soil that could result in less than or equal to a 1 µg/dL increase in blood lead, irrespective of background exposures. To develop the residential CHHSL for lead we queried the Department of Toxic Substances Control's Leadspread model (DTSC, 2007) for the soil lead concentrations that would yield a 1 µg/dL increase in blood lead in a 90th percentile child. For the commercial/industrial CHHSL we queried the U.S. EPA's Adult Lead Model (ALM) (U.S. EPA, 2005) for the soil lead concentration that would yield a 1 µg/dL increase in blood lead in a 90th percentile pregnant adult worker. Model inputs and outputs were as follows:

EXPOSURE FACTORS FOR RESIDENTIAL AND COMMERCIAL/INDUSTRIAL SCENARIOS

FACTOR	UNITS	RESIDENTIAL	COMMERCIAL/INDUSTRIAL
Lead in Soil/Dust	µg/g	77	320
Soil ingestion	mg/day	100	50
Ingestion constant	(µg/dL)/(µg/day)	0.16	0.4
Oral Absorption fraction	unitless	0.44	0.12
Skin area	cm^2	2900	NA
Soil adherence	$µg/cm^2$	200	NA
Dermal uptake constant	(µg/dL)/(µg/day)	0.0001	NA
Respirable dust	ug/m^3	1.5	NA
Breathing rate	m^3/day	6.8	NA
Inhalation constant	(µg/dL)/(µg/day)	0.192	NA
Exposure days per year	days/yr	365	250
Background lead in air, water, food, blood*	$µg/m^3$	0	0
Geometric Standard Deviation (GSD)**	µg/dL	1.6	1.8
Fetal/maternal PbB ratio	unitless	NA	0.9
Increase in blood lead (90th %ile child or fetus)	µg/dL	1	1

* Neither background exposures nor the food pathway were included in calculating the CHHSLs. Because the home grown produce pathway was not considered, the CHHSLs may not be appropriate for sites where gardening or farming may occur.

** For the residential scenario, a GSD based on blood lead levels in geographically limited populations of children was used (U.S. EPA, 2007). For the commercial/industrial scenario, the default GSD in ALM (2.1) was changed to 1.8. U.S. EPA (2001) recommended a value of 1.8 for relatively homogeneous populations.

PRACTICAL APPLICATION – REMEDIATION OF LEAD CONTAMINATION

Source: http://www.fotonomy.com

Lead-based paint peeling from a home.

Source: http://beepsandchirps.com

COMPARISON OF TWO APPLICATIONS OF CRITERIA

	NOT TO EXCEED	95% UCL of MEAN
	Each sample must be less than the criterion.	The upper bound estimate of the mean must be less than the criterion.
ADVANTAGES	Easier to determine when to stop removal in the field.	Less stringent Less Cost May be technically easier
DISADVANTAGES	Cost May cause excessive removal	Must also address hot spots

Excavation of contaminated soil.

Source: http://myconstructionphotos.smugmy.com

CASE STUDIES

SITES A, B, AND C

SITE HISTORY

- SITE A - Former Southern California Residential Site
- SITE B - Northern California School Site with Industrial Contamination
- SITE C - Former Southern California Burn Dump Site

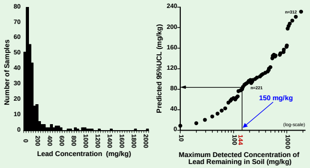
LEAD CONTAMINATION

- Plots A below illustrate the data distribution at each of the Sites
- Detections up to 2078, 4100, and 1320 mg/kg lead at Sites A, B, and C, respectively
- Large number of relatively low concentrations of lead, with high outliers at each Site

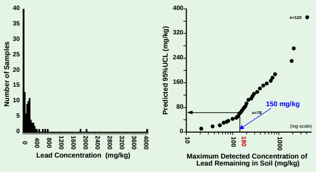
APPLICATION OF 95%UCL OF MEAN APPROACH

- ProUCL 4.00.05 (U.S. EPA, 2010) was used to calculate *predicted* lead 95%UCLs at each site assuming excavation of soil with lead above various concentrations in each data set. Plots B below illustrate the results on a semi-log scale. "N" represents the number of samples used to calculate the *predicted* 95%UCLs at various assumed maximum detected concentrations of lead remaining in soil.
- Assuming removal of soil with lead above the 2004 Cal-modified residential soil PRG of 150 mg/kg, the predicted 95%UCLs at each site approach 80 mg/kg (the revised CHHSL). The predicted 95%UCL for Site A is 84 mg/kg, Site B - 63 mg/kg, and Site C - 56 mg/kg. This is depicted by the line and arrow on each plot.
- Removing samples with lead above 144, 180, and 245 mg/kg, respectively at Sites A, B, and C, results in predicted 95%UCLs of ~80 mg/kg. These concentrations are shown in red on each plot.
- Plots B illustrate *predicted* 95%UCLs after removing lead above 150 mg/kg. To confirm the acceptability of a remediation, a 95%UCL needs to be calculated using remaining soil and confirmation sampling data following remediation. Hot spots, if present, also need to be addressed.

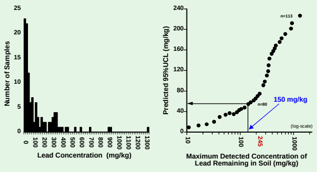
SITE A – Residential



SITE B – Industrial

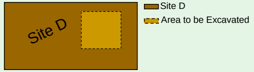


SITE C – Burn Dump



SITE D

- SITE D – Former Northern California Industrial Incinerator Site
- Simulation of future confirmation samples prior to a remedial excavation of lead in soil
- Three scenarios describe hypothetical range of confirmation data (CD) relative to original data set
  - Scenario 1 – CD is "clean"
  - Scenario 2 – CD is "half as contaminated as the area to be excavated"
  - Scenario 3 – CD is "clean & contaminated"



SUMMARY OF SIMULATED 95%UCL RESULTS FOR A LEAD REMOVAL EVALUATION WITH AN INDUSTRIAL SCENARIO (MG/KG)

	Original Site Data Without Simulated Data	Distribution	Summary Statistics of *Raw Data*				Calculated 95% UCLs	
			Mean	Std Dev	Min	Max		
	All Site Data (n=123)	Non-parametric	312	1210	4	10000	996	
	All Site Data Except Data in Area to be Excavated (n=86)	Non-parametric	33.3	97.7	4	730	79.5	
	All Site Data Except Data in Area to be Excavated + Simulated Confirmation Data (n=50)	Simulation Distribution	Summary Statistics of *Simulated 95% UCLs*				Probability of UCL Exceeding: 800 mg/kg	320 mg/kg
			Mean UCL	Std Dev UCL	Min UCL	Max UCL	Industrial PRG	Industrial CHHSL
Scenario	Assuming the confirmation sample population has:							
1	The same mean and standard deviation of all site data except data in area to be excavated	Lognormal	64.4	5.0	56.0	83.1	0%	0%
		Non-parametric	67.1	14.3	37.0	98.2	0%	0%
2	A mean and standard deviation equal to one-half the mean and standard deviation of only site data in area to be excavated	Lognormal	447	123	179	857	1%	84%
		Non-parametric	560	144	158	951	3%	94%
3	The same mean and standard deviation of all site data	Lognormal	322	136	108	800	0%	43%
		Non-parametric	450	267	64.7	1279	12%	63%

Notes: The 50 hypothetical confirmation samples were simulated 200x for each Scenario. Simulations performed with Oracle Crystal Ball 7.0 software utilizing a Monte Carlo stochastic method.
Source: Model for Site D courtesy of URS Group, San Francisco, CA 94111

FACTORS AFFECTING THE 95% UCL ESTIMATION

Several factors affect the upper bound estimation of remaining contamination and thus the acceptability of the remediation.

- HOT SPOTS. A cleanup that achieves a target 95% UCL concentration is not acceptable if hot spots remain that can result in significant exposure. Example: play area in a residential yard.
- DISTRIBUTION CLASSIFICATION. The best fit distribution(s) for a sample population strongly affects the estimated 95% UCL concentration.
- SAMPLE SIZE. Larger sample sizes are more likely to achieve the target 95% UCL concentration.
- MEAN AND VARIANCE. Populations with lower means and variances are more likely to achieve the target 95% UCL concentration.

DISCUSSION

- New 2009 CalEPA CHHSLs for lead incorporate OEHHA's updated toxicity evaluation of lead replacing the 10 µg/dL threshold blood lead concentration with a source-specific "benchmark change" criterion based on IQ effects. This paper evaluates the practical implementation of these new screening levels in risk assessment and site cleanup in California.
- This paper proposes comparison of a 95% UCL based on remaining soil and confirmation sample data following remediation to the revised CHHSL. This would replace the traditional use of the CHHSL or other cleanup goal as a "not-to-exceed" level.
- Two important caveats are: 1) Hot spots must be addressed separately; 2) The CHHSLs for lead only consider soil and only a subset of possible exposure pathways. For some sites this is incomplete and the use of CHHSLs is inappropriate.
- In our experience, cleanup goals consistent with a 95%UCL equal to the revised residential CHHSL can generally be approached by excavating contaminated soils with lead concentrations above approximately 150 mg/kg, as supported by the case studies presented here. However, a 95%UCL should be calculated using remaining soil and confirmation sampling data following remediation to ensure the cleanup is protective of human health and the environment.
- The upper bound estimate of remaining contamination and thus the acceptability of the remediation depends on many factors, such as sample size, inclusion of confirmation soil data, the mean, and heterogeneity.

FUTURE DIRECTIONS

REVISION OF DTSC'S LEADSPREAD MODEL

- Replace the 10 µg/dL blood lead concentration with a 1 µg/dL increase.
- Include other environmental media such as water and air, and incorporate exposure pathways not considered in the CHHSL.

EVALUATION OF LEAD IN SOIL BY OTHER AGENCIES SUCH AS U.S. EPA

- U.S. EPA's Ambient Air Quality Criteria Document for Lead (AQCD, U.S. EPA 2006) presents evidence of adverse health effects at blood lead concentrations below 10 µg/dL.
- U.S. EPA's Integrated Exposure Update Biokinetic Model for Lead in Children (IEUBK) and Adult Lead Model (ALM) are currently based on 10 µg/dL blood lead concentration. However, U.S. EPA's websites indicate the soil lead policy may be updated.

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DISCLAIMER

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