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FINAL REPORT

SOURCES OF LEAD IN SOIL: A LITERATURE REVIEW
VOLUME II: STUDY ABSTRACTS

Prepared By

Battelle Memorial Institute

Technical Programs Branch
Chemical Management Division
Office of Pollution Prevention and Toxics
Office of Prevention, Pesticides, and Toxic Substances
U.S. Environmental Protection Agency
Washington, DC 20460

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AUTHORS AND CONTRIBUTORS

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Battelle Memorial Institute (Battelle)

Battelle was responsible for conducting the literature search, obtaining and reviewing the identified articles and reports, developing the conclusions and recommendations derived from the review, and preparing this report.

U.S. Environmental Protection Agency (EPA)

The Environmental Protection Agency was responsible for managing the review, providing guidance on the objectives for the review and report, contributing to the development of conclusions and recommendations, and coordinating the EPA and peer reviews of the draft report. In addition, EPA provided access to study results not yet available in the general literature. The EPA Work Assignment Managers were Samuel Brown and John Schwemberger; the EPA Project Officers were Jill Hacker and Sineta Wooten; the EPA Section Chief was Phil Robinson; and the EPA Branch Chiefs were Cindy Stroup and Brion Cook.

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EXECUTIVE SUMMARY

Title X of the Housing and Community Development Act, known as the Residential Lead-Based Paint Hazard Reduction Act of 1992, contains legislation designed to evaluate and reduce exposures to lead in paint, dust, and soil in the nation's housing. As amended in Title X, §403 of Title IV of the Toxic Substances Control Act (TSCA), EPA is required to "promulgate regulations which shall identify, for the purposes of this title and the Residential Lead-Based Paint Hazards Reduction Act of 1992, lead-based paint hazards, lead-contaminated dust, and lead-contaminated soil."

Integral to the development of the §403 mandated standards (especially for soil) is information on the sources, extent, and geographic breadth of elevated lead contamination of soil ("elevated" because lead is naturally present in soil in many geographic regions). Such information provides perspective when considering what level of lead in soil will be defined as hazardous, and is suggestive of the potential efficacy of some interventions prompted by promulgation of the standards.

The purpose of the study summarized in this report was to search and review the scientific literature on the sources of elevated soil-lead concentrations. More importantly, the basis upon which elevated soil-lead levels were attributed to a particular source was also identified. Literature searches were conducted to identify relevant articles and were supplemented by studies previously uncovered by the authors of this report. In all, 36 relevant studies were identified, forming the basis for this report.

The results of the literature search indicate that studies assessing soil-lead concentrations and sources have been conducted in a wide variety of communities across the United States. The scientific literature, however, contains a preponderance of urban and smelter community studies. Rural studies were relatively rare, their soil-lead levels usually used only as a measure of background lead when examining results from urban environments.

Consistent with what might be expected, three sources of elevated soil-lead levels were identified in the literature: (1) lead-based paint; (2) point source emitters; and (3) leaded gasoline emissions. Eight types of supporting evidence, commonly reported in the literature as justification for asserting that a particular source contributes to elevated soil-lead levels, were identified: (1) residential area pattern; (2) paint-lead loading on exterior walls of residence; (3) age of residence; (4) type and condition of housing; (5) distance from a hypothesized source of elevated soil-lead levels; (6) ambient air-lead levels; (7) traffic volume on roadways in the vicinity of areas being examined; and (8) community area pattern.

The implications of the reviewed information concerning questions of source apportionment were investigated. No definitive evidence was found within the literature, however, suggesting a particular source can be regularly identified as responsible for elevated soil-lead concentrations at a residence. In fact, many studies cite more than one source as commonly responsible for elevated soil-lead levels. Moreover, labor- and cost-intensive techniques for carefully apportioning the sources of lead exposure to soil suggest varying relative contributions from candidate sources. It may be possible on a case-by-case basis to apportion the responsible sources, but no generalizations are possible based on readily obtained categorical factors (e.g., urban verus rural, northeast versus southwest). It is worth noting that within the literature lead-based paint is often cited as the source responsible for higher concentrations of lead in the surrounding soil; homes with extreme lead levels in their soil were often found to be coated with lead-based paint.

Although the results of this study suggest that a single source cannot be universally associated with elevated soil-lead levels, the results do confirm the suspected pairwise associations between elevated soil-lead levels and lead-based paint, leaded gasoline emissions, or point source emissions. As such, interventions targeting these sources should prove at least partially beneficial in reducing lead contamination of soil. In particular, lead-based paint interventions, such as those prompted by the promulgation of the §403 standards, should have an additional benefit of removing a source of lead in soil above and beyond any benefit seen in reduced indirect exposure to elevated dust-lead levels and direct exposure to paint chips.

ARTICLE ABSTRACTS

Abstract of Soil - Lead Studies
Abstract A-1

Study Name: Urban Soil Lead Abatement Demonstration Project
(Three-City Soil Lead Abatement Demonstration Project)

Study Dates: 1988-1992

Study Locations: Boston, Massachusetts; Baltimore, Maryland; Cincinnati, Ohio

References:

Elias, R., Marcus, A., and Grant, L. (1996) "Urban Soil Lead Abatement Demonstration Project, Volume 1: EPA Integrated Report," U.S. Environmental Protection Agency, Report No. EPA/600/P-93/001AF.

Farrell, K., Chisolm, J., Rohde, C., Lim, B., Brophy, M., Strauss, W. (1992) "Baltimore Soil Lead Abatement Demonstration Project," U.S. Environmental Protection Agency Draft Report.

United States Environmental Protection Agency. (1991) "Three City Urban Soil-Lead Demonstration Project: Midterm Project Update," Final Report.

Weitzman, M., Aschengrau, A., Bellinger, D., Jones, R., Hamlin, J. S., and Beiser, A. (1993) "Lead-Contaminated Soil Abatement and Urban Children's Blood Lead Levels," *Journal of the American Medical Association*. 269(13):1647-1654.

Aschengrau, A., Beiser, A., Belinger, D., Copenhafer, D., and Weitzman, M. (1994) "The Impact of Soil Lead Abatement on Urban Children's Blood Lead Levels: Phase II Results from the Boston Lead-In-Soil Demonstration Project," *Environmental Research.* 67:125-148.

Van Leeuwen, P., Bornschein, R., and Clark, S. (1992) "Cincinnati Lead Soil Demonstration Project," Presented at the Hazardous Materials Control/Superfund 92: 13th Annual Conference and Exhibition, p 280-284.

McIntyre, D. and Fletcher, B. (1992) "Boston Lead-In-Soil Demonstration Project," Presented at the Hazardous Materials Control/Superfund 92: 13th Annual Conference and Exhibition, p 274-277.

Objectives:

<u>Primary Objective:</u> examine whether a reduction of environmental lead levels in dust and soil will result in decreased blood-lead levels in children

Secondary Objectives:

Boston: conduct the experiment so as to more clearly separate the beneficial results of abating lead in soil and in dust

Baltimore: examine if a reduction in residential soil lead will result in a corresponding reduction in the amount of lead in interior household dust

Cincinnati: test whether interim interior dust abatement, in conjunction with exterior dust and soil abatement, will result in a greater reduction in blood lead than either abatement method alone

Sampling Frame:

Boston: Children aged 6 to 48 months old, with blood-lead levels between 7 and 24 µg/dL, residing in one of the study areas where there is a history of high incidence of lead poisoning. Each child enrolled was randomly assigned to one of three experimental groups: Study (52 children, 34 properties), Control A (51 children, 36 properties), or Control B (47 children, 30 properties). The Study group received interior paint stabilization, interior dust abatement, and soil abatement in the first year of the study and no further treatment. Control Group A received interior paint stabilization and interior dust abatement in the first year. Only interior paint stabilization was performed for Control Group B in the first year of the study. At the beginning of the second year of the study, soil abatement treatments were done for both control groups. Preliminary soil samples were collected to determine eligibility. Detailed soil sampling was conducted before, immediately following, and nine months following the soil intervention.

Baltimore: Study areas were chosen for comparable demographic, soil-lead, and housing characteristics. The 63 Study Group properties received soil abatement and exterior paint stabilization, and 51 Control Group properties received exterior paint stabilization (this includes six properties in the study area that did not receive soil abatement). Soil-lead concentrations were sampled before and immediately following (for the study group) the intervention.

Cincinnati: Three study areas (A, B, and C) were chosen based upon a set of eight criteria designed to ensure comparable demographic and housing characteristics. The chosen areas contained housing that had previously undergone extensive rehabilitation to remove or encapsulate most of the lead-based paint. A total of 215 land parcels were sampled (Area A: 55 land parcels; Area B:74 parcels; Area C: 86 parcels). There were nine phases of environmental and biological monitoring, which took place before and after each abatement cycle. Phase 00 included the project design and initial measurements. Area A received soil lead, exterior and interior dust abatement treatments between Phases 01 and 02. Area B received interior dust abatement between phases 01 and 02 and exterior dust and soil abatement between Phases 05 and 06. Area C served as a control group during the study, receiving all abatement treatments after Phase 09 was completed. Soil samples were collected at seven points throughout the study.

Sampling Method:

Boston: Soil samples were taken throughout the property using line source, targeted, or small area patterns. Both top and bottom of each 15 cm deep core sample were taken for analysis. The most commonly used line source soil sampling method consisted of parallel lines 0.5 m from the foundation and boundary areas. More lines were added for larger properties. Each line was split into 7 meter segments, and a 2 foot by 2 foot composite soil sample was taken from a random point in each segment. An average of eight top and bottom samples were taken from each household.

Baltimore: The soil area was measured to determine the sampling scheme (different schemes were used for small, large, and very large areas). The entire soil region surrounding the residence was sampled. The area was partitioned into front, back, etc. For each core sample, the top 2" and bottom 2" were retained. For small areas, less than two meters in either direction, a single core sample was taken; areas less than 10 feet wide had a core sample at the house foundation and one at the boundary; for larger regions 16-20 feet long, the region was divided in half and core samples were taken at the foundation, boundary, and mid-yard lines.

Cincinnati: Soil samples were taken throughout a property using line source, targeted, or small area patterns. Both surface scrapings and core samples were collected for analysis. Line source sampling consisted of taking samples from lines that were 0.5 meters, 10 feet, and 15-20 feet away from a boundary, such as a building or sidewalk, depending on the size of the yard. Areas too small for a line pattern were randomly sampled, and areas such as play equipment were targeted.

Analysis Method: X-Ray Fluorescence

Results for Soil:

Soil-Lead Concentrations (μg/g) for each Study Group by City and Round

City	Study Group	Statistic	Round[2] 1	2	3	4	5	6	7
Boston	Study Group	N[3]	35	26	35	21			
		25th %tile	1678	98	70	100			
		Median[4]	2413	125	113	174			
		75th %tile	3367	160	192	284			
		A. Mean[4]	2625	139	234	206			
	Control A	N	36		35	22			
		25th %tile	1813		1480	161			
		Median	2477		2148	278			
		75th %tile	3300		3286	505			
		A. Mean	2831		2502	429			
	Control B	N	30		30	17			
		25th %tile	1611		1572	110			
		Median	2268		2155	204			
		75th %tile	3890		3880	240			
		A. Mean	2728		2679	307			
Cincinnati	Area A	N	112	104	104	100	100	101	103
		25th %tile	79	0	18	24	25	24	25
		Median	273	0	28	41	38	42	37
		75th %tile	1190	88	64	78	112	122	117
		A. Mean	991	166	132	140	163	198	167
	Area B-B[4]	N	26	26	26	26	26	26	26
		25th %tile	42	50	58	62	49	41	37
		Median	89	87	93	99	64	52	55
		75th %tile	107	115	131	126	93	79	77
		A. Mean	122	117	153	277	67	59	68
	Area B-D	N		92	88	86	84	82	88
		25th %tile		219	228	307	17	22	24
		Median		758	667	768	29	41	68
		75th %tile		1561	1400	1424	155	156	465
		A. Mean		1141	966	1084	351	334	508
	Area B-F	N	46	48	49	48	48	48	47
		25th %tile	104	125	108	93	21	19	32
		Median	608	760	294	379	37	70	50
		75th %tile	1421	1740	1159	1109	605	1406	713
		A. Mean	1045	1256	817	814	511	929	835
	Area C-G	N	118	120	120	119	120	119	121
		25th %tile	8	17	46	41	43	45	38
		Median	69	114	124	97	99	109	111
		75th %tile	221	268	308	180	216	202	197
		A. Mean	176	202	573	187	192	179	169
	Area C-M	N	44	55	49	49	48	47	48
		25th %tile	100	139	109	109	110	102	132
		Median	349	637	338	277	349	363	416
		75th %tile	1179	1376	795	509	673	848	860
		A. Mean	809	1013	654	525	613	501	530

Soil-Lead Concentrations (µg/g) for each Study Group by City and Round (continued)

City	Study Group	Statistic	Round[2] 1	2	3	4	5	6	7
Baltimore	Study Group	N	56			56			
		25th %tile	374			12			
		Median	511			29			
		75th %tile	674			73			
		A. Mean	532			69			
	Control Group	N	45						
		25th %tile	372						
		Median	515						
		75th %tile	650						
		A. Mean	568						
	Control Group in Study Area	N	6						
		25th %tile	167						
		Median	182						
		75th %tile	214						
		A. Mean	189						

1. This table was abstracted from Table A-1 of the Integrated Report. Dashed lines indicate when the soil intervention was performed.
2. Round is defined in the Integrated Report to be "a distinct period of time when one or more measurement were made...There is no consistent pattern for when abatement occurred for the different individual cities." [Integrated Report p. 2-10]
3. N equals the number of properties or land parcels.
4. This is the median or mean of the average soil-lead levels for each property/parcel.
5. In the Integrated Report, Areas B and C were split into neighborhoods and analyzed separately.

Comments:

There have been numerous publications on the Urban Soil Lead Abatement Demonstration Project . In particular, review draft reports detailing the results for each city have been made available to the public. However, these reports have not been formally released by EPA. Therefore, only results published in the Integrated Report were included.

Complex statistical methods such as cross-sectional structural equations models, repeated measures analysis of variance, and longitudinal structural equations models were used to model changes in blood-lead concentrations that occur in response to changes in environmental lead.

Conclusions:

"Soil abatement reduced soil-concentrations in all three studies, and there was no evidence of soil recontamination in either Boston or Cincinnati. There were no follow-up measures of soil in Baltimore that would detect recontamination." In Boston, the reductions of lead in the soil persisted throughout the two year follow-up period. [Integrated Report p.1-18, 1-19]

“There was some evidence for exterior dust recontamination in Cincinnati. The Cincinnati group suggests that this might be caused by chipping and peeling lead-based paint from the exterior surfaces of nearby buildings not included in the project.” [Integrated Report p. 1-18]

Abstract of Soil-Lead Studies
Abstract A-2

Study Name: Helena Valley Lead Study

Study Dates: 1983 **Study Location:** East Helena, Montana

References:

Lewis and Clark County Health Department, Montana Department of Health and Environmental Sciences, Centers for Disease Control, U.S. Department of Health and Human Services, and U.S. EPA. (1986) "East Helena, Montana: Child Lead Study, Summer 1983," Final Report.

Centers for Disease Control. (1983) "East Helena, Montana Child Lead Study," Report by the CDC, Public Health Services, U.S.Department of Public Health and Human Services, Atlanta, GA.

Objectives:

Evaluate residential exposures to smelter-associated lead and other heavy metals in neighborhoods near an operating lead smelter in East Helena, Montana.

Sampling Frame:

Three study areas were identified as follows: Area 1: within 1 mile of the smelter; Area 2: 1-2.25 miles from the smelter, Area 3: more than 5 miles from the smelter. All households with children aged 1 to 5 years and having resided in the area at least 3 months were sought for the study. In all, 396 children aged 1 to 5 years were sampled.

Sampling Method:

Composite core samples one to three inches in depth were taken. The first sample was a composite of 8 subsamples, four from the front of the house and 4 from the rear. Subsamples from the front of the were collected at least .5 meters from the curb and no more than 2.5 away from the curb. Subsamples from the rear were collected at least 6 meters from painted surfaces. The second sample was a composite of 4 subsamples taken from the side of the house within 1 meter of the foundation. The third sample was a composite from the child's play area and the fourth sample was a composite from the garden if such was present.

Analysis Method: Atomic Absorption Spectrometry

Results for Soil:

Soil Levels	Geometric Means			Ranges		
	Area 1	**Area 2**	**Area 3**	**Area 1**	**Area 2**	**Area 3**
Comp	720	217	86	81 - 3414	58 - 1252	54 - 237
Side	796	169	92	41 - 7964	3 - 883	47 - 500
Play	365	121	73	3 - 5770	3 - 6030	28 - 373
Garden	539	179	95	70 - 2038	50 - 599	58 - 162

Correlation Between Soil Lead:

	Side	Play	Garden	Dust
Comp	.78	.50	.76	.70

Eq#	**Indep. Var.**	**Coefficient**	**Dependent Variable:**
1)	Ln(soil)	0	Ln(PbB)

Eq#	**Type**	**Add. Indep. Variables:**
1)	Log-Linear Multiple Regression	Air, Dust, Home Location Mouthing Variables

Comments:

All statistical analysis was done on log-transformed variables.

The multiple (backwards stepwise) log-linear regression was performed to estimate the independent contribution to blood lead from lead in soil or in dust, or in soil and dust together.

Principal component analysis was done to reduce the dimensionality of the mouthing behavior related variables.

Paired t-tests comparisons were made between the 1 inch and the 3 inch core samples. (18 pairs)

Conclusions:

"when the variables designating home location are added to the model, soil lead is no longer a statistically significant contributor to the variance in children's blood lead levels" [Reference p. 31]

Soil lead contamination is associated with children's blood lead levels as evidenced by highly significant differences among the three study areas in the lead levels of all four types of soil tested and these differences are mirrored by highly significant area differences in children's blood levels. In addition, due to strong similarities in the age of the children, the positive association between blood and soil lead levels is not likely to be due to a confounding effect of age or age-related behavioral characteristics.

"Children living closer to the smelter had higher blood lead levels than children living farther away." [Reference p. 33]

"Distribution of soils with high lead levels is not uniform throughout the valley." [Reference p. 21]

"No statistically significant difference was found between the lead levels in 1 and 3 inch soils cores collected in front and side yards." [Reference p. 21]

Significant correlations exist between environmental lead levels.

No trends of association between erythrocyte protoporphyrin level and soil lead level are apparent.

Abstract of Soil - Lead Studies
Abstract A-3

Study Name: Baltimore, Maryland Urban Garden Soil Study

Study Dates: 1982 **Study Location:** Baltimore, Maryland

References:

Mielke, H. W., Anderson, J. C., Berry, K. J., Mielke, P. W., Chaney, R. L, and Leech, M. (1983) “Lead Concentrations in Inner-City Soils as a Factor in the Child Lead Problem,” *American Journal of Public Health*. 73(12):1366-1369.

Objectives:

Measure and survey the distribution of soil lead within metropolitan Baltimore via measuring and surveying vegetable garden soils.

Sampling Frame: All urban residences in Baltimore.

Sampling Method:

Soil samples were randomly collected from 422 vegetable gardens within an area defined by a 30 mile radius from a designated center point in downtown Baltimore.

Analysis Method: Varian atomic absorption spectrophotometer with deuterium background correction.

Results for Soil:

Lead (N= 422, p-value < $^{*}10^{-23}$)

Percentiles (ppm)										
Max 10900	90 777.5	80 421	70 258.5	60 167	50 100	40 55.5	30 35	20 24.5	10 14.5	Min 1

Comments:

* proportionate measure of having more extreme result (i.e. more extreme clustering of the high group) by chance alone.

Statistical analysis was completed using an approach termed Multi-Response Permutation Procedures or MRPP. The 422 soil samples were partitioned at the median value into high-low groups of 211 each. The test statistic is based on the average distance between all pairs of sites within the high group.

Conclusions:

"Although some literature proposes that house paint is the major source of lead contamination, the urban patterns of soil lead in Baltimore suggests that the inner-city lead contamination is due to another source." [p. 1367] These sources include activities such as emissions from industries and incinerators, paints, solders, insecticides, rubbish and emissions from vehicular traffic.

High levels of traffic are the reason for elevated lead levels of garden soils near unpainted brick structures in the inner city of Baltimore.

Residences with elevated garden soil lead levels (those above the median) were more tightly clustered toward the center of Baltimore as to be explained by chance error in 1 to the trillion raised to the second power. (i.e. p-value $< 10^{-23}$)

Abstract of Soil - Lead Studies
Abstract A-4

Study Name: Brigham and Women's Hospital Longitudinal Lead Study

Study Dates: 1979-1983 **Study Location:** Boston, Massachusetts

References:

Rabinowitz, M. B. and Bellinger, D. C. (1988) "Soil Lead - Blood Lead Relationship among Boston Children," *Bulletin of Environmental Contamination and Toxicology*. 41:791-797.

Rabinowitz, M., Leviton, A., Needleman, H., Bellinger, D., and Waternaux, C. (1985) "Environmental Correlates of Infant Blood Lead Levels in Boston," *Environmental Research*. 38:96-107.

Objectives:

Identify sources and magnitude of lead exposure in early childhood (pregnancy through two years).

Examine the association between soil lead and blood lead levels.

Sampling Frame:

Births at Brigham and Women's Hospital between April 1979 and April 1981 were categorized into the highest, lowest or middle deciles of umbilical cord blood lead. Families resided within a 12-mile radius of the hospital, spoke English as their primary language, and the infants had no serious illness. 589 infants were eligible, 249 enrolled and 202 children completed the 2 year follow-up. Soil lead values were taken at the homes of 195 infants.

Sampling Method:

Soil samples were taken from the top centimeter of soil from each of 3 points that were one meter apart and at least 3 meters from any road or structure. Soil samples were collected at the 18 and 24 month visits and preference was given to any obvious play area.

Analysis Method: Flame atomic absorption

Results for Soil:

	N	Mean (μg/g)	Median (μg/g)	Range
PbS	195	702	365	7 - 13240

Correlation Between Soil Lead with Blood and Environmental Lead:

	PbA	Road Score	Pb Paint	PbB	PbD
PbS	.18	.01	-.07	.30	.40

Eq #	Indep. Var.	Coefficient	Dependent Variable:
1)	Ln(PbS)	8.9 μg/L/ μg/kg	Ln(PbB)
2)	Ln(PbS)	.8 ln μg/g/ μg/kg	Ln(PbB)

Eq #	Type	Add. Indep. Variables:
1)	Simple Log linear reg.	None
2)	Stepwise Log linear reg.	Ln(PbD), season, refinish

Comments:

The stepwise regression used both forward and backward elimination. Results shown are for 18 month olds (N = 212). For all other age groups (6, 12, 24) PbS had a coefficient of 0.

The simple log-linear regression uses all of the data, not just the data up to 18 months.

Correlations were done using Spearman's nonparametric rank correlation procedure.

Conclusions:

There is a connection between PbS and PbB.

Lead levels in soil and dust rose across the levels of blood lead.

Lead levels in soil, air and dust were strongly correlated.

Abstract of Soil - Lead Studies
Abstract A-5

Study Name: The Butte-Silver Bow Environmental Health Lead Study

Study Dates: 1990 **Study Location:** Butte, Montana

References:

Butte-Silver Bow Department of Health and Department of Environmental Health, University of Cincinnati. (1991) "The Butte-Silver Bow Environmental Health Lead Study," Draft Final Report.

Objectives:

"ascertain whether or not the children of Butte...are currently exhibiting elevated blood lead concentrations"

"identify and quantify accessible lead...in the environment"

"establish the extent of association between sources of environmental lead and blood lead and to estimate the relative contribution of these sources of lead to the children's blood lead"

"provide residence-specific data to guide future remediation efforts"

[Quotes from reference p. 6]

Sampling Frame:

"Butte historically has been an important mining, milling and smelting district." [Reference p. 3] Children less than 72 months of age residing for at least 3 months prior to survey, in one of seven study neighborhoods (A-F) in the environs of Butte. The seven neighborhoods vary in their proximity to known mining wastes and age of neighborhood. Areas A and G are close to old mine sites while Areas C and D are near a copper mill and tailings. Areas E and F are homes built after WWI not near any mine or tailings. Finally, Area B was mostly mobile homes close to mine tailings. Blood samples were taken from 430 individuals with 294 less than 72 months of age. There were 650 composite soil samples collected.

Sampling Method:

Soil core samples were taken at 2 cm depth and exterior surface dust samples were collected. A composite sample of soil cores from perimeter (three feet from building wall) of the residence was collected. Each composite consisted of 8 to 12 soil core samples. Composite cores were also taken from garden, bare yard area, and play areas/sand box if such were present. A composite exterior surface dust sample was collected by vacuum over paved areas and other hard surfaces near the residence's entrance.

Analysis Method: Atomic Absorption Spectrometry

Results for Soil:

	N	Geometric Mean (ppm)	Geometric Std. Dev. (ppm)	Range 5% - 95%
House Perimeter	215	515.51	2.89	71.7 - 2356
Garden	82	317.64	3.11	49.9 - 1399
Play Area	169	254.63	3.80	19.5 - 1639
Bare Area	184	430.67	3.09	62.3 - 2460
Area A	145	750.24	2.45	
Area B	10	249.75	1.70	
Area C	7	139.45	2.70	
Area D	9	230.31	2.33	
Area E	21	151.02	2.14	
Area F	12	178.17	1.89	
Area G	11	1030.56	1.46	

Correlation Between Soil Lead with Blood and Environmental Lead:

	PbS_{gard}	PbS_{bare}	PbS_{play}	Ext. Pt	Int. Pt	Rd. Dst
PbS_{perm}	.83	.86	.62	.59	.50	.64
Int. Dust	.53	.60	.51	.54	.43	.51
Blood Lead	.10	.26	.24	.19	.19	.19

Corr (PbS_{perm}, Blood Lead) = .24

Eq #	Indep. Var.	Coefficient	Dependent Variable:
1)	$Ln(PbS_{perm})$	0	$Ln(PbB)$
2)	$Ln(PbS_{perm})$	22.485	$Ln(PbD_{interior})$

Eq#	Type	Add. Indep. Variables:
1)	Log-linear Least Squares Backwards Elimination	$Ln(PbD_{int})$, Work, Child's age, Mouth, House age Socio-economic Status
2)	Structural Equations Analysis Log-Linear Equation	$Ln(PbD_{int})$, $Ln(PbP_{ext})$, Child's age, Mouth, Work

Comments:

Field duplicates were collected at 10% of the sampling sites.

Regression analysis was based on only 192 families. One child was randomly selected per family. Regression was performed to examine those factors most related to blood lead levels.

The Structural Equations Analysis had four dependence relations and was performed to investigate the pathways of lead contamination of children's blood.

Conclusions:

"Lead based house paint contributes to lead contaminated soil which in turn contributes to lead contaminated house dust. Only lead in house dust was directly related to blood lead."

"40% of the variability in soil lead is attributable to lead based paint. The remaining 60% is due to the heterogenous distribution of lead in soil, and lead from other sources."

"Locations of residence and age of housing were found to be strong predictors of soil lead and dust lead concentrations. Environmental lead concentrations were found to be the highest in older neighborhoods."

[Quotes from reference pp. 125-126]

Abstract of Soil - Lead Studies
Abstract A-6

Study Name: Charleston Lead Study

Study Dates: 1973 **Study Location:** Charleston, South Carolina

References:

Galke, W. A., Hammer, D. I., Keil, J. E., and Lawrence, S. W. (1975) "Environmental Determinants of Lead Burdens in Children," In: *International Conference on Heavy Metals in the Environment: Symposium Proceedings*, T. C. Hutchinson, S. Epstein, A. I. Page, J. VanLoon and T. Davey (eds.), Institute for Environmental Studies, Toronto, ON, Canada, 3:53-74.

See Also: US Environmental Protection Agency Report No. EPA-600/J-78-022. Washington, D.C.: Available from: NTIS, PB-283567. Springfield, VA.

Objectives:

Examine two hypothesis:

(1) Blood lead levels are positively related to soil lead levels.

(2) Blood lead levels are positively related to automobile traffic, independent of soil lead exposure.

Sampling Frame:

Four recruitment areas: high traffic/high soil lead; high traffic/low soil lead; low traffic/high soil lead; and low traffic/low soil lead, were established based on prior knowledge of population characteristics. African American pre-school aged children were sampled from each of these areas.

In all, 194 children from 170 families were sampled, but because of incomplete data, only 187 children from 164 families were used in subsequent analysis.

Sampling Method:

A soil sample was taken from child's chief play area. The exact methodology is not available in reference.

Analysis Method: Atomic absorption spectrophotometry

Results for Soil:

	Median (ppm)	75th %tile	Range
PbS	585	1400	9 - 7890

		Median Traffic Volume (cars/day)	Range
Facing Street	PbS<585 ppm	100	100 - 12275
	PbS≥585 ppm	100	100 - 15575
All Streets Within 76 Meters	PbS<585 ppm	1100	100 - 35300
	PbS≥585 ppm	3200	100 - 35400

Comments:

Several regressions were performed, regressing soil lead levels against each paint lead variable and traffic volume. Analytical results were not available in the reference. A separate analysis was completed for each traffic volume representation. Additional regressions were performed regressing PbB on soil, traffic, and paint lead levels.

Additional descriptive statistics were presented for various soil, traffic, age, and blood levels.

Conclusions:

Soil lead exposure was the best index to environmental lead in this study.

"Regressing soil lead levels against each paint lead variable and traffic volume variable independently found significant relations between soil lead and exterior siding paint, window sill paint, and traffic (as a dichotomous variable). Still, none of these relationships explained much of the soil lead variability." [Reference p. 61]

Children's blood lead level was positively related to soil, traffic, and paint (determined using multiple regression analysis [i.e. a positive coefficient])

Blood lead levels were related to exposure to traffic, independent of soil exposure (determined using multiple regression analysis).

Abstract of Soil-Lead Studies
Abstract A-7

Study Name: The Cincinnati Longitudinal Lead Study

Study Dates: 1980-1987 **Study Location:** Cincinnati, Ohio

References:

Bornschein, R. L., Hammond, P. B., Dietrich, K. N., Succop, P., Krafft, K., Clark, S., Berger, O., Pearson, D., and Que Hee, S. (1985) "The Cincinnati Prospective Study of Low-Level Lead Exposure and Its Effects on Child Development: Protocol and Status Report," *Environmental Research.* 38:4-18.

Que Hee, S .S., Peace, B., Clark, S., Boyle, J. R., Bornschein, R. L., and Hammond, P. B. (1985) "Evolution of Efficient Methods to Sample Lead Sources, Such as House Dust and Hand Dust, in the Homes of Children," *Environmental Research.* 38:77-95.

Bornschein, R. L., Succop, P. A., Krafft, K. M., Clark, C. S., Peace, B., and Hammond, P. B. (1986) "Exterior Surface Dust Lead, Interior House Dust Lead and Childhood Lead Exposure in an Urban Environment," Conference in Trace Metals in Environmental Health, Columbia, MO.

Bornschein, R. L., Succop, P., Dietrich, K. N., Clark, S., Que Hee, S., and Hammond, P. B. (1985) "The Influence of Social and Environmental Factors on Dust Lead, Hand Lead, and Blood Lead Levels in Young Children," *Environmental Research*. 38:108-118.

Objectives:

Integrate information on exposure history (from birth to 5 years), cognitive and behavioral development, and health and social functioning in order to delineate the association between chronic, low level lead exposure and behavioral development.

Sampling Frame:

Enrolled expectant mothers residing in one of a group of census tracts identified as having a long history of producing children with elevated blood lead levels. The mothers were patients at one of three prenatal clinics in the area intending to deliver at Cincinnati General Hospital.

Sampling Method:

Surface scrapings were collected from play areas and/or from immediately outside dwelling unit entry. Samples were taken from 80 houses.

Analysis Method: Atomic Absorption Spectroscopy

Results for Soil:

	N	Geometric Mean (ppm)	Geometric Std. Dev. (ppm)	Range
PbS	80	1360.32	4.67	76-54519

Age/Type-condition of Home	N	Geometric Mean (ppm)
20th Century/Public	14	572
19th Century/Rehabilitated	18	804
19th Century/Satisfactory	7	2540
19th Century/Deteriorated	13	2670

Correlation Between Soil Lead with Blood and Environmental Lead:

	Ln(XRF/Hazard)	Ln(PbD)	Ln(PbB)
Ln(PbS)	**.41**	**.57**	**.30**

Eq #	Independent Variable	Coefficient	Dependent Variable:
1)	Ln(PbS)	.268	Ln(PbD)

Eq #	Type	Additional Independent Variables:
1)	Structural Equations	Ln(XRFHAZ), Ln(PbH),Ln(PbD)

Comments:

There were three equations in the structural analysis. The results presented are reduced structural model for children 18 months old.

Conclusions:

"There is evidence to support the hypothesis that exterior environmental lead can result in blood lead elevations through the path PbS—>PbD—>PbH—>PbB. An increase in PbS from 0 to 1000 ppm results in an indirectly mediated increase in PbB of 6.2 µg/dl." [Reference 3 p. 331]

"PbS is low outside public housing units, while being considerably higher and more variable outside other home types." [Reference 3 p. 324]

Abstract of Soil - Lead Studies
Abstract A-8

Study Name: The Omaha Lead Study

Study Dates: 1971-1977 **Study Location:** Omaha, Nebraska

References:

Angle, C. R. and McIntire, M. S. (1979) "Environmental Lead and Children: The Omaha Study," *Journal of Toxicological and Environmental Health*. 5:855-870.

Angle, C. R., McIntire M. S., and Colucci, A. V. (1974) "Lead in Air, Dustfall, Soil, House Dust, Milk and Water: Correlation with Blood of Urban and Suburban School Children," *Trace Substances in Environmental Health - VIII*, Ed. D. D. Hemphill, pp 23-29.

Angle, C. R., Marcus, A. H., Cheng, E. H., and McIntire, M. S. (1984) "Omaha Childhood Blood Lead and Environmental Lead: A Linear Total Exposure Model," *Environmental Research.* 35:160-170.

Objectives:

Obtain data to predict and understand the relationship between air lead levels, dustfall rates and the resulting soil accumulation as it pertains to the blood lead concentrations of children.

Sampling Frame:

Children were recruited from three areas of interest: urban commercial (C), urban mixed (M) which is a residential area contiguous with downtown, and a suburban (S) area. No attempt was made to randomize (all subjects were volunteers) nor obtain equal distribution among the three areas. In total, 1074 children were sampled. Of those sampled, 242 were 1-5 years old and 832 6-18 years old.

Sampling Method:

Two inch core samples were taken halfway between the building and lot line. Samples were collected on all four sides of the building. The values reported were the arithmetic means for each site. Soil samples were collected from 37 individual houses and 148 samples were also taken at each child's school. A total of 20 sites were sampled 1 to 5 times.

Analysis Method: Not available in reference

Results for Soil:

	N	Geometric Mean (μg/g)	Range 5%-95%
Site C	69	262	53-1615
Site M	56	339	20-4792
Site S	51	81	16-341

Correlation Between Soil Lead with Blood and Environmental Lead:

	Ln(PbA)	Ln(PbDF)	Ln(PbHD)	Ln(PbB)	Ln(PbB) 1-5 yr, 6-18 yr
Ln(PbS)	.37	.35	.27	.29	.29

Eq #	Independent Variable	Coefficient	Dependent Variable
1)	Ln(PbS)	.1253	Ln(PbB)
2)	Ln(PbS)	.0046	Ln(PbB)

Eq #	Type	Additional Independent Variables
1)	Multiple log-linear regression	House dust, air
2)	Non-linear regression	House dust, air

Conclusions:

The re-analysis of the data concluded that the regression model is better than the power model in explaining the relationship between environmental lead and blood levels.

Continued control of PbA will likely result in the existing Pb in the environment, such as soil lead, becoming a more significant contributor of Pb to blood than PbA.

Community-wide changes in PbB are multifactorial. Air, soil, water, housing, and socioeconomic shifts all have an additive or possibly even synergistic effect on blood lead.

Abstract of Soil-Lead Studies
Abstract A-9

Study Name: Leadville Metals Exposure Study

Study Dates: 1987 - 1988 **Study Location:** Leadville, Colorado

References:

Colorado Department of Health, University of Colorado at Denver, and U.S. Department of Health and Human Services. (1990) "Leadville Metals Exposure Study," Final Report.

Cook, M., Chappell, W., Hoffman, R., and Mangione, E. (1993) "Assessment of Blood Lead Levels in Children Living in a Historic Mining and Smelting Community," *American Journal of Epidemiology*. 137(4):447-455.

Objectives:

"Characterize the levels of heavy metals in the residential environment and the relationships of human exposure to environmental concentrations."

"Determine the extent to which environmental, behavioral and socio-economic factors are predictive of heavy metal exposure."

"Determine the levels of heavy metals and other indicators of metal toxicity in the blood and urine of individuals, principally young children, residing in Leadville."

[Quotes from first reference p. 1]

Compare the results to national averages and the results from similar mining, milling, and smelting communities.

Sampling Frame:

All households with children aged 6 to 71 months residing in Leadville census tract for at least three months preceding the study; an additional sample consisted of households with children aged 6 years and older. A total of 2631 eligible individuals were identified with 239 children between 6 and 71 months of age.

The initial sample size was 300 individuals of which 150 were children 6 to 71 months old. Twenty-five children from each sex were randomly selected in each of three age groups: 6-14, 15-44, 45-65 years.

The final sample size was 233 individuals of which 150 were children 6 to 71 months of age; 29, 6 - 14 years old; 28, 15 - 44 years old; 26, 45 - 65 years old.

Soil and dust samples were collected from 105 households.

Sampling Method:

A composite sample of four 1 inch core samples (taken along roof edge drip lines) were taken at the front, rear and in reported play areas. In addition, surface scrape samples were collected at the entry-way and in reported play areas.

Analysis Method:

Described in "EPA User's Guide to the Contract Laboratory Program" December, 1986 and "Contract Laboratory Statement of Work" July, 1985.

Results for Soil:

	N	Geometric Mean (ppm)	Geometric Std. Dev. (ppm)	Range 5% - 95%
Core Front	168	1108.3	2.8	49 - 15100
Core Rear	166	914.7	3.1	10 - 27800
Scrape Play	111	868.1	3.7	2.7 - 8620

Correlation Between Soil Lead:

	D. Flr	D. Sill	C. Frnt	C. Ply	S. Ply	S. Entry
C. Rear	.24	.26	.52	.64	.37	.35

Eq #	Independent Variable	Coefficient	Dependent Variable
1)	Ln(C. Rear)	.13	Ln(PbB)

Eq #	Type	Additional Independent Variables
1)	Linear Regression, Stepwise Forward Elimination	C. Frnt, C. Ply, Scrapes, Behavior variables

Sample Type Children <6 years	Contaminant Level (ppm)	Blood Lead Level <10 (μg/dl)	Blood Lead Level >10 (μg/dl)	X^2	Odds Ratio
Core Rear	<500	33	4	18.1	8.40
	>500	56	57	(<.001)	(2.8-25.26)*

Comments:

* 95 % confidence interval.

All statistical analyses were performed with log-transformed blood lead values.

Values below the detection limit were replaced with ½ of the detection limit for statistical analysis.

All children were used in the analysis including siblings.

Stepwise (forward elimination) regression was used to develop models explaining the variation in blood lead levels.

Odds ratios were calculated for behavioral characteristics and blood lead levels. Significant associations were tested using a Chi-Square test.

Conclusions:

"Core samples collected at the rear of the house were significantly correlated with all other dust and soil samples collected." [Reference p. 32]

"Significant associations exist between blood lead levels greater than or equal to 10 μg/dl and soil lead levels greater than 500 ppm for core samples collected taken at the rear of the house...and scrape samples collected in the play area." [Reference p. 33]

"Soils in Leadville were found to have much higher levels of lead than soils in other parts of the United States." [Reference p. 51]

Abstract of Soil - Lead Studies
Abstract A-10

Study Name: The HUD Abatement Demonstration Study

Study Dates: 1989 - 1990

Study Location: Baltimore, MD; Washington, D.C.; Seattle, WA; Tacoma, WA; Indianapolis, IN; Denver, CO; Birmingham, AL

References:

U.S. Department of Housing and Urban Development. (1991) "The HUD Lead-Based Paint Abatement Demonstration (FHA)," Office of Policy Development and Research, Washington, D.C.

Objectives:

Develop reliable estimates of the cost of lead-based paint abatement.

Examine the extent of exposure to hazards experienced by workers during abatement.

Examine the extent of post-abatement hazards presented to new residents.

Sampling Frame:

HUD-owned, FHA foreclosed, single family homes in target cities.

There were 455 paired (pre- and post-abatement) soil samples taken corresponding to 130 dwelling units.

Sampling Method:

A series of samples was collected approximately one to three feet from the base of each exterior wall. Each series consisted of 5 samples, which were collected at evenly spaced intervals and then combined to make a composite which was then analyzed for lead content.

Analysis Method: Flame atomic absorption

Results for Soil:

	N	Arithmetic Mean (ppm)
Pre-Abatement	455	755.0
Post-Abatement	455	867.5

Comments:

A paired t-test was used to determine significance between before and after abatement means.

Additional tests were also completed. The methodology of these tests is unavailable in the reference. These additional tests examined the relationship between abatement strategy and increases in soil lead greater than 250 ppm.

Conclusions:

Post-abatement soil lead levels were significantly higher, at the .01 level, than pre-abatement levels.

There was some evidence of a statistical relationship between abatement strategy and increases in soil lead greater than 250 ppm. Units abated under the Hand-Scraping and Chemical Strategies were most likely to experience soil lead increases of over 250 ppm.

Abstract of Soil-Lead Studies
Abstract A-11

Study Name: The National Lead Survey

Study Dates: 1989-1990

Study Location: Various urban areas throughout the US; 30 counties in the 48 contiguous states

References:

Weitz, S., Clickner, R. P., Blackburn, A., Buches, D., et al. (1990) "Comprehensive and Workable Plan for the Abatement of Lead-Based Paint in Privately Owned Housing: Report to Congress," U.S. Department of Housing and Urban Development, Washington, D.C.

Rogers, J., Clickner, R., Vendetti, M., and Rinehart, R. (1993) "Data Analysis of Lead in Soil," U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Report Number EPA 747-R-93-011.

Objectives:

Estimate the number of dwelling units in the U.S. with interior and exterior lead based paint, by year built, type of housing, threshold level of lead concentration, and census region.

Estimate the number of multifamily residences with lead-based paint in common areas, by the year built, threshold level of lead concentration, and census region.

Estimate the costs of abating lead-based paint in public and privately owned housing.

Investigate the associations among soil, dust, and paint measurements.

Identify the variables that predict soil and dust lead levels.

Sampling Frame:

Multi-stage stratified sampling design by dwelling unit age and type, of housing in the U.S. built before 1980.

284 privately owned dwelling units and 97 public housing units were sampled.

Sampling Method:

Data were collected from three soil sample sites: along the drip line of the XRF wall (less than 1 foot from the foundation); at a remote location (½ the distance from the property line and the foundation, between 5-30 feet from the foundation); at the most-used entryway. Three soil samples were also taken from playgrounds. Three subsamples were collected at each site and composited into a single sample. The top 2-3 cm were sampled using a corer.

Analysis Method: Inductively coupled plasma-atomic emission spectrometry.

Results for Soil:

	N	Geometric Mean (ppm)	Geometric Std. Dev. (ppm)	95% CI
Soil Entry	260	83	4.35	70 - 100
Soil Remote	253	47	4.14	40 - 56
Soil Drip	249	72	5.37	58 - 89

Correlation With Soil Lead:

	Soil Entry	Soil Drip	Soil Remote
Soil Entry (ppm)	--	.715	.609
Soil Drip (ppm)	.715	--	.678
Soil Remote (ppm)	.609	.678	--
Exterior Paint Lead (mg/sq cm)	.277	.274	.274
Exterior Painted Area (sq ft)	.134	.156	.151
Dwelling Unit Age	.584	.590	.534
Traffic Vehicles (miles/day)	.202	.238	.281

Multiple Log Regression Results:

Independent Variable	Parameter Estimates for Dependent Variable Model		
	Drip Line	Entry	Remote
Paint Lead			
Dry Rooms	.02	.07	-.03
Wet Rooms	.08	.07	.09*
Exterior	.07*	.05	.05
Proportion Damaged Paint			
Dry Rooms	-4.1*	-8.5	-4.6
Wet Rooms	-1.7	1.1	-1.6
Exterior	-0.3	0.1	0.4
Painted Surface Area			
Dry Rooms	-.16	-.09	-.21*
Wet Rooms	-.06	-.07	.02
Exterior	.03	.09	.02
Number of Wet Rooms	-.57*	-.54*	-.35
Number of Dry Rooms	0.00	-.13	.18
Local Traffic	.08	-.10	.26*
Unit Age	1.55*	1.20*	.95*

Comments:

* Significant at the 5 percent level.

Correlations were calculated on log-transformed data.

Other regressions were also done with principal components and using linear combinations representing differences in dust concentrations between wet and dry rooms.

Conclusions:

"...the probability of excessive soil lead somewhere on the property...is four to five times larger when exterior lead-based paint is present than when it is not." [First Reference p. 3-17]

“There is also strong statistical evidence that exterior lead-based paint, especially defective paint, is an important source of lead in soil; and lead in the soil, as well as interior lead-based paint, is a source of interior dust lead on the floors.” [First Reference p. 3-32]

The entryway and drip line soil concentrations were not significantly different. However, the remote soil concentrations was, on the average, significantly lower than either the drip line or entryway soil concentrations.

“The strongest predictors of soil-lead are dwelling unit age and county of residence, for all three sample locations.” [Second Reference p.89]

“The parameter estimates suggest that paint lead from dwelling surfaces contribute more to the entrance and drip line soil lead samples than to the remote sample.” [Second Reference p.89]

Local traffic volumes were only significant for the remote soil samples. However, “...significant positive estimates for the square of the traffic volume for the drip line and entrance samples suggests that a contribution of lead from traffic may be significant at higher traffic volumes.” [Second Reference p.89]

“...a combination of increased exterior paint damage in conjunction with higher exterior lead loadings is associated with increased drip line soil lead concentrations...” [Second Reference p.93]

Soil lead concentrations generally decreased with increasing age of the the dwelling.

Abstract of Soil - Lead Studies
Abstract A-12

Study Name: Silver Valley - Revisited Lead Study

Study Dates: 1983 **Study Location:** Kellogg, Idaho

References:

Panhandle District Health Department, Idaho Department of Health and Welfare, Centers for Disease Control, and U.S. Environmental Protection Agency. (1986) “Kellogg Revisited**S**1983: Childhood Blood Lead and Environmental Status Report,” Final Report of the U.S. Public Health Service.

Yankel, A. J., von Lindern, I. H., and Walter, S. D. (1977) “The Silver Valley Lead Study: The Relationship Between Childhood Blood Lead Levels and Environmental Exposure,” *Journal of the Air Pollution Control Association*. 27(8):763-767.

Objectives:

“To determine the current blood levels of children aged 1-9 in the Silver Valley area.”

“To compare the blood levels of that population to national norms.”

“To study the relationship between children's blood levels and the environmental exposures under current conditions.”

“Identify sources, transport mechanisms, and factors important to lead absorption under current conditions.”

[Quotes from reference p. 2]

Document the health and environmental improvements since the initial Silver Valley Lead study in 1974 and the closure of the smelter in 1981.

Sampling Frame:

Three study areas were identified; Area 1: all residences within 1 mile of the smelter; Area 2: all residences 1-2.25 miles from the smelter, Area 3: all residences 2.5 - 6 miles from the smelter. All households in Area 1 were sampled while every other residence was sampled in Areas 2 and 3. A total of 364 children were tested.

Sampling Method:

Composite core samples were taken from the top one inch of soil. The first sample was a composite of 8 subsamples, 4 from the front of the house and 4 from the rear. These subsamples were collected at least 1.5 meters from the curb, street, sidewalk or the house. The second sample was a composite of 4 subsamples taken from the side of the house within 1 meter of the foundation. The third and fourth samples were composites from the child's play area and the garden if such was present. In addition, at every 7th residence in the survey, duplicate soil core samples and special soil samples were collected via a 5-inch hand trowel.

Analysis Method: Atomic Absorption Spectrometry

Results for Soil:

Soil Levels	Geometric Means			Ranges		
	Area 1	**Area 2**	**Area 3**	**Area 1**	**Area 2**	**Area 3**
Comp*	3474	2632	481	322 - 18400	53 - 20700	151 - 2915
Side	5163	2512	541	83-17550	108-41200	97-7375
Play	3616	996	431	258-15585	80-34475	37-6370v
Garden	507	978	318	95-2705	141-5160	118-1102

Correlation Between Soil Lead:

	Side	Play	Garden	Dust
Comp	.75	.22	.59	.57

Eq#	**Indep. Var.**	**Coefficient**	**Dependent Variable:**
1)	Ln(comp)	.0616	Ln(PbB)

Eq#	**Type**	**Add. Indep. Variables:**
1)	Log-Linear Least Squares	House dust, child's age behavioral variables

Comments:

The blood and environmental measurements were log transformed for statistical analysis.

Multiple log-linear regression models were used to determine which variables were significantly related to blood lead.

Stepwise regression models (backwards, MAXR) were also constructed to assess the independent significance of soil lead and dust lead in predicting blood lead levels.

Conclusions:

"Soil lead contamination was associated strongly with children"s PbB levels in Shoshone County." [Reference p. 34]

"The results of this study support the conclusion that, in absence of significant air lead contamination, children who are exposed to heavily leaded soils may develop lead toxicity." [Reference p. 38]

"Very little lead was found in other environmental media, indicating that the positive association between house dust lead contamination and children"s PbB levels was likely to have occurred as a result of the soil lead contamination." [Reference p. 38]

"Children who played on non-grassy surfaces in the most heavily contaminated areas...had statistically significantly higher mean PbB levels than children who played on grassy areas." [Reference p. 36]

Abstract of Soil - Lead Studies
Abstract A-13

Study Name: Midvale Community Lead Study Final Report

Study Dates: 1989 **Study Location:** Midvale, Utah

References:

Bornschein, R. L., Clark, S., Pan, W., and Succop, P. (1990) "Midvale Community Lead Study," Final Report, University of Cincinnati.

Objectives:

1. "ascertain whether or not the children of Midvale... are currently exhibiting elevated blood lead concentrations"

2. "identify and quantify accessible lead and arsenic... in the environment e.g. lead in soil, dust, paint and water or arsenic in soil and dust"

3. "establish the extent of association between certain sources of environmental lead and blood lead"

[Quotes from reference p. 6]

Sampling Frame:

Children aged 6 to 72 months living in a neighborhood of residential and commercial buildings parallel to the Sharon Steel Mill tailings and former smelter site. Blood lead samples were obtained for 291 individuals, 181 from children less than 6 years of age. Complete blood lead, interview, exterior and interior environmental data were collected from a random sample of 112 of the 249 eligible children in the area.

Sampling Method:

Soil cores at 2 cm depth, and exterior surface dust samples were collected. A composite sample of soil cores from the perimeter of the residence was collected. The perimeter was defined to be three feet from building wall. A maximum of 12 soil core samples could be taken per composite. Composite cores were also taken from garden, bare yard area, and play areas/sand box if such were present. A composite exterior surface dust sample was collected by vacuum over paved areas and other hard surfaces near the residence's entrance.

Analysis Method: Atomic Absorption Spectrometry

Results for Soil:

	N	Geometric Mean (ppm)	Geometric Std. Dev. (ppm)	Range Min - Max
Building Perimeter	112	341.81	2.54	58 - 6665
Garden	46	294.59	2.65	57 - 2746
Play Area	42	77.95	5.52	1 - 6665
Bare Area	88	313.20	2.60	24 - 2920

Correlation Between Soil Lead with Blood and Environmental Lead:

	PbS_p	PbS_g	PbS_{ply}	PbS_b	PbD_{ext}	PbD_{int}	XRF_{ext}	XRF_{int}
PbS_{max}	.96	.05	.16	.39	.77	.74	.43	.36
	N-S	E-W	DM	DS	DMPl	DMSPL		
PbS_{max}	.68	-.74	-.68	-.60	-.07	-.45		

N-S, E-W = North-South, East-West grid coordinates resp.
DM = Distance to mill building; DS = Distance to smelter stack
DMPL = Distance to mill property line; DMSPL = Min {DM, DS}

Eq#	Indep. Var.	Coefficient	Dependent Variable:
1	$Ln(XRF_E)$	.179	Ln (Pbs_{perm})
	E-W	-.0009	
	N-S	.0001	
	Housing Age		
	19th C	.040	
	Post WWII	-.567	
2	Soilfill (Y)	-.552	$Ln(PbD_{ext})$
	$Ln(PbS_p)$	.748	
3	$Ln(PbS_{max})$	.144	Ln(PbB)
4	$Ln(XRF_E)$	.3010	$Ln(PbS_{max})$
	E-W	-.0009	
	N-S	.0001	

Eq #	Type	Add. Indep. Variables:
1,2)	Log-Linear Reg. Backward Elimination	XRF_{int}, DS, DM, Age
2,3)	Structural Equations Analysis	House Age,SES,Age

(two dependence relations) Mouthing Behaviors

Comments:

Field duplicates were collected at 10% of the sample sites.

In the correlations all lead variables were log transformed.

Conclusions:

"Lead based house paint and lead contaminated soil were identified as the principal contributors to blood lead."

"Location of residence was found to be a strong predictor of soil lead concentrations."

"The effect of soil lead on blood lead is both small and weak. Blood lead was found to increase 1.25 µg/dl/1000 ppm increase in lead in soil. About 3.0% - 12% of the variance in blood lead is attributable to lead in soil."

[Quotes from reference pp. 127-128]

"Environmental soil and dust lead concentrations were generally moderately correlated...correlations between environmental lead and blood lead concentrations were considerably weaker."

[Quote from reference p. 32]

Abstract of Soil - Lead Studies
Abstract A-14

Study Name: Minnesota Soil Lead Study

Study Dates: 1986-1987

Study Location: 27 counties in Minnesota, concentrating in Duluth, St. Cloud, Minneapolis, St. Paul, and Rochester

References:

Schmitt, M. D. C., Trippler, D. J., Wachtler, J. N., and Lund, G. V. (1988) "Soil Lead Concentrations in Residential Minnesota as Measured by ICP-AES," *Water, Air, and Soil Pollution*. 39:157-168.

Trippler, D. J., Schmitt, M. D. C., and Lund, G. V. (1989) "Soil Lead in Minnesota," In: *Lead in Soil: Issues and Guidelines, Supplement to Volume 9 of Environmental Geochemistry and Health*. Edited by Davis, B.E. and Wixson, B.G., pp 273-280.

Mielke, H. W., Adams, J. L., Reagan, P. L., and Mielke, P. W., Jr. (1989) "Soil-Dust Lead and Childhood Lead Exposure as a Function of City Size and Community Traffic Flow: The Case for Lead Abatement in Minnesota," In: *Lead in Soil: Issues and Guidelines, Supplement to Volume 9 of Environmental Geochemistry and Health*. Edited by Davis, B. E. and Wixson, B. G., pp 253-271.

Objectives:

Describe "...the extent of lead contamination in the soil, the lead concentrations in the blood of populations at contaminated sites, the size of the population at risk from exposure to lead in the soil...." [Reference p. 254]

Evaluate the quantitative relationship between soil lead and childhood blood lead as observed among cities in the study.

Sampling Frame:

Cross-section (27) of all counties in Minnesota, based on socio-economic data from 1980 census.

Reports of >1000 mg Pb/kg in the soil resulted in MDH protocol blood testing on a sample of children within 5 blocks.

Two separate soil datasets were collected corresponding to paired (187) and unpaired (1266) blood samples. In all, 2454 soil samples were taken.

Sampling Method:

Foundation samples were collected within 1.5 meters of the building. Yard samples (front, back, and side) were taken at the midpoint of the yard and at least 1.5 m from a foundation. Street samples were collected within 1.5 m of the curb. In addition samples were collected in the following sites: garden, downspout, industrial, open, play area, and side yard. Soils were sampled from the top 2 cm.

Analysis Method: Inductively coupled plasma-atomic emission spectroscopy.

Results for Soil:

	N	Geometric Mean (ppm)	Geometric Std. Dev. (ppm)
Minneapolis			
Foundation	199	665	3.5
Backyard	119	186	2.6
St. Paul			
Foundation	127	472	4.5
Backyard	114	119	3.8
Duluth			
Foundation	32	455	5.2
Backyard	32	106	4.1
Rochester			
Foundation	19	65	8.4
Backyard	15	23	4.1
St. Cloud			
Foundation	13	85	7.5
Backyard	18	25	4.9
Outstate			
Foundation	67	105	9.2
Backyard	34	18	2.7

Frequency table of yard soil lead data:

Soil Lead (mg/kg)	Percent of samples: Minneapolis	St. Paul	Duluth	St. Cloud	Rochester
< = 50	6.4	20.5	13.5	76.2	68.2
51 - 150	26.0	28.5	40.4	19.0	27.3
151 - 300	36.2	30.0	19.2	4.8	0.0
301 - 600	21.9	13.5	21.2	0.0	0.0
601 - 1200	8.7	5.0	3.8	0.0	4.5
> = 1201	0.8	2.5	1.9	0.0	0.0

Comments:

Comparisons made between yard, street-side, foundation, blood and other related tests were completed using Fisher's exact test (usually comparing frequencies for <=150 mg/kg and >=151 mg/kg)

Conclusions:

"...soil lead concentrations in cities and the blood lead concentrations of the childhood population generally vary in a lock-step manner with each other." [Reference p. 257]

"The state soil data support earlier findings that environments of the three largest cities of Minnesota are burdened with the highest concentrations of soil lead." [reference p. 260] In fact, there is a consistent trend of soil or dust lead and blood lead that corresponds with city size: that is, the largest cities have the highest lead concentration and the smallest cities have the lowest.

There is a strong association between blood lead and soil lead.

"There is no discernible general pattern between the age of the dwellings within a community and the lead concentrations of either the soil or the blood of the childhood population." [Reference p. 264]

Generally, the highest contaminated soil levels are found in inner cities with the most severely contaminated soils being located near the foundations of private residences. In addition, the soil levels tended to decrease with increasing distance from the city center.

Abstract of Soil-Lead Studies
Abstract A-15

Study Name: New Haven, Connecticut Lead Study

Study Dates: 1974-1977 **Study Location:** New Haven, Connecticut

References:

Stark, A. D., Quah R. F., Meigs, J. W., and DeLouise, E. R. (1982) "The Relationship of Environmental Lead to Blood-Lead Levels in Children," *Environmental Research*. 27:372-383.

Stark, A. D., Meigs, J. W., Fitch, R. A., and Delousie, E. R. (1987) "Family Operational Cofactors in the Epidemiology of Childhood Lead Poisoning," *Archives of Environmental Health.* 33:222-226.

Objectives:

1) Determine the important environmental sources of lead in New Haven.

2) Determine how these sources are distributed throughout the city.

3) Examine the relationship between these sources and observed blood lead levels of children in New Haven.

Sampling Frame:

A screening of 80%, 8289 individuals, of the population of 1 to 6 year old children residing in New Haven. From this screening a subset was sampled. A child was included in the subset if the child had lived at the same address for at least one year and if the child had at least two blood tests during that time both of which were <=29 µg% or 30-39 µg% or >=40 µg%. The final sample consisted of 377 children. Each of the 377 children had environmental measures taken.

Sampling Method:

Surface scrape samples were taken close to the house and close to the street. A sample of 5-10 g of soil was taken from the top ½ inch of soil.

Analysis Method: Delves Cup Atomic Absorption Spectrophotometry

Results for Soil:

	Level of Socioeconomic Status				
	1	2	3	4	5
Near Soil Level	*233.3 **(398.1)	756.5 (125.9)	1327.3 (251.2)	830.5 (316.2)	703.5 (199.5)
Far Soil Level	209.5 (79.4)	700.1 (39.8)	660.1 (63.1)	665.2 (63.1)	599 (199.5)

Construction Year

	1910-1919	**1920-1929**	**1930-1939**	**1940-1949**	**1950-1959**	**1960-1969**	**1970-1977**
NEAR	1200.1 *	1273.3	1299	444	929.6	309.7	131.3
Soil	63.1 **	79.4	251.2	1258.9	398.1	501.2	50.1
(ppm)	41 ***	42	29	86	29	29	3
FAR	798.2	770.1	917.6	507.4	479.3	390.2	310.9
Soil	39.8	39.8	39.8	316.2	100	50.1	63.1
(ppm)	41	42	42	86	29	30	3

* Geometric Means
** Geometric Standard Deviations
*** Sample Size

Correlation Between Soil Lead with Blood and Environmental Lead:

	Near Soil	Air	Dust	Kitchen Paint	Age of Building	Exterior Paint
Far Soil	.3044	-.15	.154	.192	-.2632	.2806
Near Soil	------	-.068	.188	.202	-.2333	.4332

Eq #	Independent Variable	Coefficient	Dependent Variable
1)	Ln(near soil)	.14247	Ln(PbB)
2)	Ln(far soil)	.14324	Ln(PbB)
3)	Ln(near soil), Ln(far soil)	0.0 0.0	Ln(PbB)

Eq #	Type	Additional Independent Variables
1)	Simple log-linear regression	None
2)	Simple log-linear regression	Porch and kitchen paint levels
3)	Multiple log regression model: best N variable model)	Exterior Paint Levels, socioeconomic variables

Comments:

The simple linear regression was performed to determine the proportion of variation in children's blood lead levels associated with each of the environmental variables.

Multiple regression was performed in an attempt to further explain the above variation as a function of environmental, personal, and economic variables.

Conclusions:

“Substantial amounts of lead were present in the soil, paint, and house dust throughout New Haven.” [Reference p. 382]

Based on regression results, the most important variables on blood lead levels were soil lead near home and street and exterior paint. (Log of near home soil lead, r=.22; log of near street lead, r=.197; log of exterior house paint lead, r=.143).

Elevated levels of lead in the proximate environment do not explain most of the variation in blood lead across the population (11.7% via multiple regression).

Abstract of Soil-Lead Studies
Abstract A-16

Study Name: New Orleans Lead Study

Study Dates: 1983 **Study Location:** New Orleans, Louisiana

References:

Mielke, H. W. (1991) "Lead in Residential Soils: Background and Preliminary Results of New Orleans," *Water, Air, and Soil Pollution*. 57-58:111-119.

Mielke, H. (1995) "Lead in New Orleans Soils: New Images of an Urban Environment," *Environmental Geochemistry and Health*. 16(3-4):123-128.

Objectives:

Map community patterns of lead in New Orleans.

Sampling Frame:

Residential neighborhoods within 283 census tracts in the New Orleans metropolitan area.

Sampling Method:

Ten to fifteen samples were collected from the top 2.5 cm of the soil using a stainless steel garden trowel. In each census tract, ten streetside samples (within 1 m of the street), 2 houseside (within 1 m of the house) and 2 samples were collected from open areas such as vacant lots or parks. A total of 3,704 soil samples were collected.

Analysis Method: Flame atomic absorption spectrometers and deuterium background correction

Results for Soil:

Location	N	Median (µg/g)	Min (µg/g)	Max (µg/g)
Inner-city				
Foundation	201	840	8	69000
Streetside	723	342	4	9450

Location	N	Median (μg/g)	Min (μg/g)	Max (μg/g)
Open Area	74	212	10	10600
Mid-City				
Foundation	220	110	1	24400
Streetside	765	110	1	6340
Open Area	80	40	2	3960
Suburban				
Foundation	332	50	2	5650
Streetside	1195	86	2	2150
Open Area	114	28	4	540

Lead (N= 60, p-value < $^{*}10^{-6}$)

Comments:

* proportionate measure of having more extreme result (i.e. more extreme clustering of the high group) by chance alone.

Statistical analysis was completed using an approach termed Multi-Response Permutation Procedures or MRPP. The 114 census tracts were sorted according to their median. The top, middle, and bottom 20 tracts were used in the analysis. Additional analysis was performed by visually inspecting a topographical map of soil-lead levels.

Conclusions:

There were extreme differences between inner-city and non inner-city census tracts as evidenced by the small p-value of the above test.

“The most extreme lead levels are found next to foundations of homes located in the inner-city.” [Second reference p.124]

“Lead in soil of vacant lots and open spaces away from streets and households in the inner-city is still higher that any lead levels in mid-city and suburban locations.” [Second reference p.124]

An exponential decrease in soil-lead levels was observed with increasing distance from the center of the city. The authors suggest that this may be due to an increased presence of lead-based paint in the inner-city and a history of higher traffic congestion.

Abstract of Soil - Lead Studies
Abstract A-17

Study Name: Honolulu Park Soil Lead and Mercury Study

Study Dates: 1972, 1987 **Study Location:** Honolulu, Hawaii

References:

Fu, S., Hashimoto, H., Siegel, B. Z., and Siegel, S. M. (1989) "Variations in Plant and Soil Lead and Mercury Content in a Major Honolulu Park, 1972 to 1987, a Period of Significant Source Reduction," *Water, Air, and Soil Pollution*. 43:109-118.

Objectives:

To compare lead and mercury levels from 1972 to 1987 to determine if significant reductions in soil lead and soil mercury levels exist. Additionally, to examine the effect of traffic volume on lead and mercury soil levels.

Sampling Frame:

A 150 meter transect extending N to S for 150 meters from a grassy median along Ala Moana Boulevard.

Sampling Method:

Soil samples were taken from a strip one meter in width running the length of the transect. Loose debris was removed and surface soil scrapings, 5 to 6 cm, were taken. Each soil sample had a net weight of over 50 grams.

Analysis Method: Flame Atomic Absorption Spectrophotometry

Results for Soil:

	N	Arithmetic Mean (µg/g)	Arithmetic Std. Dev. (µg/g)
1972 Survey	14	467	93
1987 Survey	18	367	37

Conclusions:

The relationship between soil-lead levels and distance from automotive sources such as a roadway was reaffirmed as soil levels fell as the distance from the roadway increased only to increase as the beach road was reached.

Abstract of Soil - Lead Studies
Abstract A-18

Study Name: Telluride Lead Study

Study Dates: 1986 **Study Location:** Telluride, Colorado

References:

Bornschein, R. L., Clark, S., Grote, J., Peace, B., Roda, S., and Succop, P. (1988) "Soil Lead-Blood Lead Relationship in a Former Lead Mining Town," In: *Lead in Soil: Issues and Guidelines, Supplement to Volume 9 of Environmental Geochemistry and Health*. Edited by Davis, B.E. and Wixson, B.G., pp 149-160.

Objectives:

To further examine and investigate the association between lead in soil and blood lead levels.

Investigate the threat of lead poisoning due to residual lead.

Sampling Frame:

Residents of a town containing former lead mining and milling operations. Ninety-four young children (<= 72 months) were sampled. In addition, older children and young adults, pregnant women and occupationally exposed adults were also sampled. Total sample size: 258 individuals and 45 residences, 5 daycare centers or schools and numerous parks.

Sampling Method:

Composite core (2.5 cm deep) samples were taken from grassy areas around the perimeter of the residence and along the street or sidewalk.

Soil surface scrapings were taken from exposed soil in play areas, paths through the yard or playground, and from paved areas outside entryway.

Analysis Method: Not available in Reference

Results for Soil:

	N	Geometric Mean (ppm)	Geometric Std. Dev. (ppm)	Range 5% - 95%
PbS_{core}	45	145	3.2	17 - 804
PbS_{scrape}	45	178	2.5	16 - 1895

Correlation Between Soil Lead with Blood and Environmental Lead:

	PbB	PbD	XRF_{ext}	PbS_{scrape}	PbS_{core}
PbD	-.30	---			
XRF_{ext}	NS	NS	---		
PbS_{scrape}	NS	.51	.40	---	
PbS_{core}	NS	.46	.49	.67	---
Dist 1	NS	NS	NS	NS	.43
Dist 2	NS	-.38	NS	-.35	NS

PbS_{scrape} = median surface scraping in µg/g
PbS_{core} = median 1 inch soil core in µg/g
XRF_{ext} = maximum exterior XRF
Dist 1 = distance of house from tailing pond in feet
Dist 2 = distance of house from railway and creek in feet

Eq#	Indep. Var.	Coefficient	Dependent Variable
1)	$\text{Ln}(PbS_{scrape})$	.40	Ln(PbD)
2)	$\text{Ln}(XRF_{ext})$ Dist 2	.288 .001	$\text{Ln}(PbS_{scrape})$

Eq#	Type	Add. Indep. Variables:
1,2)	Structural Equation analysis	Age, PbH_{hands}

Comments:

Environmental lead measures were log transformed.

Only 45 children had complete environmental, social and blood lead data available.

Structural Equations Analysis was used to investigate the lead-blood pathways and the associated correlations. Equations for blood, hand dust and soil lead were developed. The resulting equations from a system of log-linear equations.

Conclusions:

Accessibility of the soil, particle size, chemical speciation and bioavailability of lead affect the risk of soil to blood lead.

"Soil lead and PbS_{scrape} immediately around the residence...were low and comparable to that seen in lead abated housing in inner-city Cincinnati." [Reference p. 152]

"No simple, direct association was found to be significant between PbS_{scrape} or PbS_{core} and PbH_{hand} or PbB." [Reference p. 154] However, the exposure model of an indirect pathway from soil lead to blood lead was confirmed.

PbS_{scrape} --> PbD --> PbH_{hand} --> PbB

"PbS_{core} was not associated with PbD after adjusting for the influence of PbS_{scrape}. This again suggests that although PbS_{core} is a reservoir of lead with potential for future child exposure, it is the available surface lead (PbS_{scrape}) which is most associated with other current Pb levels." [Reference p. 155].

Abstract of Soil-Lead Studies
Abstract A-19

Study Name: Mt. Pleasant Soil Lead Study

Study Dates: 1990 **Study Location:** Mt. Pleasant, Michigan

References:

Francek, M. A. (1992) “Soil Lead Levels in a Small Town Environment: A Case Study from Mt. Pleasant, Michigan,” *Environmental Pollution*. 76:251-257.

Francek, M. A., Makimaa, B., Pan, V., and Hanko, J. H. (1994) “Small Town Lead Levels: A Case Study from the Homes of Pre-schoolers in Mt. Pleasant, Michigan,” *Environmental Pollution*. 84(2):159-166.

Objectives:

Examine the relationship between traffic variables, wind direction, home age, home condition, wall orientation and soil-lead levels. In addition, evaluate soil-lead levels for schools, an abandoned dump, and a salvage yard.

In particular, the relationship between household lead levels and home age, distance to road, traffic volume adjacent to the home, and the amount of exposed soil was investigated.

Sampling Frame:

Roadsides, schools, and homes in Mt. Pleasant, Michigan.

Sampling Method:

Soil samples were collected from 42 homes at 189 locations 0-5 cm in depth, using a stainless steel trowel. Roadside samples (n=83) were collected from three traffic volume categories: low (Average Daily Traffic or ADT < 8000), moderate (8000<ADT<20000), and heavy (ADT >20000). Home samples were collected from within one meter of the wall avoiding sites with flaking paint (n=55). School samples were collected at entrances, playgrounds, and adjacent parking lots (n=27). In addition, three samples were taken at the city dump and three at a salvage yard. Eighteen background samples were also collected along a 500 m^2 grid in and around city limits.

Analysis Method: Flame Atomic Absorption Spectrophotometry

Results for Soil:

	N	Arithmetic Mean (ppm)	Arithmetic Std. Dev. (ppm)	Median (ppm)	Range
Roadside Soils	83	320	125	280	100-840
Homes	55	1176	2419	460	100-16839
School	27	191	48	200	100-260
City Dump	3	167	44	200	100-200
Salvage Yard	3	893	195	940	600-1140
Play Area Soil	42	53	205	7	0-594
Background	18	172	42	200	100-220

Roadside soils by Traffic Volumes:

	N	Arithmetic Mean (ppm)	Arithmetic Std. Dev. (ppm)	Median (ppm)	Range
Heavy	33	343	106	320	180-540
Moderate	14	345	170	320	200-840
Low	26	286	126	250	100-620

Soil-Lead Levels by Condition of Home:

Condition of Home	N	Arithmetic Mean (ppm)	Arithmetic Std. Dev. (ppm)
Excellent	6	203	60
Good	18	347	446
Fair	13	2537	4631
Poor	18	1346	858

Play Area Soil Soil-Lead Levels by Age of Home:

Age of Home	N	Arithmetic Mean (ppm)	Arithmetic Std. Dev. (ppm)	Range (ppm)
<30 years old	16	3	3	1-9
30-60 years	12	28	54	0-187
>60 years	14	132	149	0-594

Correlation Between Soil Lead and Related Variables:

	Soil Lead
Traffic Volume	.27 (p=.019)
Home age	.59 (p<.001)

Comments:

One-way analysis of variance, correlation and t-tests were used to examine the data. Various groups such as high, moderate and low traffic volume, were compared using the F-test associated with the analysis of variance. Variables were log transformed for all analysis.

Conclusions:

There exists a positive relationship, though weak, between roadside soil-lead levels and increasing traffic.

Strong changes in soil-lead levels are not due to prevailing wind patterns nor automobile idling behavior.

There was no significant difference in the soil-lead levels found near houses in good or excellent condition from those found near homes in fair or poor condition.

There is a positive relationship between home age and soil-lead levels. In addition, "former use of lead based paints on older homes elevated soil-lead levels." [First Reference p.225]

In general soil levels were inversely related to distance from the roadway.

Abstract of Soil - Lead Studies
Abstract A-20

Study Name: Illinois Soil-Lead Study

Study Dates: 1985

Study Location: City of Chicago; six suburban counties surrounding Chicago; rest of Illinois ("downstate").

References:

LaBelle, S. J., Lindahl, P. C., Hinchman, R. R., Ruskamp, J., and McHugh, K. (1987) "Pilot Study of the Relationship of Regional Road Traffic to Surface-Soil Lead Levels in Illinois," Published Report of the Argonne National Laboratory, ANL/ES-154.

Objectives:

This study was conducted to evaluate soil-lead levels as a function of proximity to roadways and overall traffic density. In addition, questions concerning lead levels in relationship to traffic volume were also of concern.

Sampling Frame:

Playgrounds, parks, schools, and day care centers in the city of Chicago and its suburbs. Similar areas throughout the rest of Illinois.

Sampling Method:

Four to eight soil samples were taken at 158 locations. Each location was on the property of a park, playground, school, or day care and was near a "well traveled" road. In addition, most soil samples were collected from bare play areas used by children under 7 years of age. All but one of the soil samples taken at each location were from the top 5 cm of soil. One sub-surface, 25-30 cm, soil sample was taken at each location. Surface samples were taken 10 and 100 feet from the roadway edge and near play equipment. In addition field replicates were collected at five locations.

Analysis Method: Atomic Absorption Spectrophotometry

Results for Soil:

Region	N	Surface Arithmetic Mean (ppm)	N	Subsurface Arithmetic Mean (ppm)
City of Chicago	256	157	50	118
Suburbs	244	83	61	49
Downstate	167	44	48	27

Samples other than those near play equipment

Total Traffic Volume	N	Arithmetic Mean (ppm)	Arithmetic Std. Dev. (ppm)
<5000	96	90	13
5000 - 9999	30	141	33
10000 - 19999	77	187	23
2000 - 49999	87	265	26
>50000	63	236	41

Eq#	Indep. Var.	Coefficient	Dependent Variable:
1)	Ln(PbS)	-0.141	Distance from nearest Road
		-0.629	*Traffic Vol. Busiest Road
		.756	*Ttl. Traffic Vol all roads
		.377	Depth conc. soil lead
		.114	Annual local traffic density
2)	PbS	.055	*Traffic Vol. Busiest Rd.
		2.910	Annual Local traffic density

* Only for roads within .25 miles of the sampling.

Eq#	Type	Add. Indep. Variables:
1)	Log-Log	None
2)	* Physical Model (exponential)	None

Comments:

Individual regression analysis was also completed without including depth concentration of lead in soil as an independent variable.

Additional regression analyses were completed for each region separately. Also examined via regression was a subset of the data including only surface soil samples where the surface soil-lead levels were greater than the subsurface-lead level.

Conclusions:

While elevated soil-lead levels were found, they were generally less, 25-300 ppm, than soil-lead levels found near industrial sources or leaded paint.

There is a relationship between the surface soil-lead concentration near road and the traffic on and distance from the road.

The physical model was not as powerful as the log-log regression model in explaining the patterns of surface soil-lead levels.

The lead levels in Chicago suburbs were similar to the levels found in Chicago itself. In addition, both of these levels were higher than those found in downstate Illinois.

The patterns of soil-lead concentrations support the hypothesis that leaded-gasoline emissions are a source of lead in the soil.

Abstract of Soil-Lead Studies
Abstract A-21

Study Name: Dallas Soil Lead Contamination Study

Study Dates: 1982 **Study Location:** Dallas, Texas

References:

Brown, K. W., Mullins, J. W., Richitt, E. P., Jr., Flatman, G. T., Black, S. C., and Simon, S. J. (1985) "Assessing Soil Lead Contamination in Dallas, Texas," *Environmental Monitoring and Assessment*. 5:137-154.

Objectives:

"To determine and identify distribution patterns of soil lead concentrations within three designated study areas." [Reference p.139]

Sampling Frame:

A one mile radius from each of two smelters owned by RSR Corporation (RSR) and Dixie Metal Company (DMC) and operated inside city limits. A reference area (REF) inside city limits was also sampled.

Sampling Method:

A total of 177 sampling locations within a one mile radius of a smelter were marked for sampling. In addition, 80 locations were identified for sampling in a half-mile reference area. A total of 2795 soil core samples were collected. Soil core samples were taken at a depth of 7.5 cm and were two cm in diameter. Four samples were taken at each location and composited into a single sample. If possible, soil samples were collected greater than 20 feet from painted buildings and as far as possible from any vehicle activity.

Analysis Method: Atomic Absorption Spectroscopy

Results for Soil:

	Maximum Inside Isopleth (ppm)	68% CI (ppm)	Maximum Outside Isopleth (ppm)

DMC Smelter	3000	1666 - 5400	300
RSR Smelter	2500	1389 - 5000	300
Reference	500		200

Comments:

Statistical analysis was performed using the geostatistical methodology of kriging. This permitted evaluation of both spatial variability but also a means to identify the estimated variance for each point within the sampling area.

Conclusions:

"Among a few patterns of high values both DMC and RSR have a single dominant pattern that includes the smelter.... The closure of the pattern implies the source is inside and there is a steep gradient demarking the polluted area therefore indicating that the smelters are probably the source of lead." [Reference p. 153]

The soil-lead values between the two smelters were similar and both differed from the levels identified in the reference area.

Abstract of Soil-Lead Studies
Abstract A-22

Study Name: Aspen Garden Soil Lead Study

Study Dates: 1983 **Study Location:** Aspen, Colorado

References:

Boon, D. Y. and Soltanpour, P. N. (1992) "Lead, Cadmium, and Zinc Contamination of Aspen Garden Soils and Vegetation," *Journal of Environmental Quality*. 21:82-86.

Objectives:

"The objective of this study, conducted in 1983, was to determine the source and extent of Pb, Cd, and Zn contamination of Aspen garden soils and metal concentrations in vegetables grown in contaminated gardens." [Reference p.82]

Sampling Frame:

Household gardens in Aspen. In addition, areas that were visible mine dumps or areas suspected of being mine dumps.

Sampling Method:

Surface soil samples, 0-15 cm depth, were collected from 65 gardens. Of the gardens sampled, 50 were located directly on top of mine dump materials. Additionally, between 5 and 10 samples were taken from each of 18 different dump locations. These samples were then combined into a single composite sample for each location.

Analysis Method: ICP Emission Spectrometry

Results for Soil:

	N	Arithmetic Mean (mg/kg)	Arithmetic Std. Dev. (mg/kg)	Range
Mine Dump	65	6375	5973	135 - 21700
Garden Soil	65	172	155	9.2 - 808
Background		10		

Comments:

Results were also presented in the article for other heavy metals and for vegetation lead uptake.

Regression analysis was performed to relate soil-lead levels and vegetation uptake.

Conclusions:

Garden soils situated on mine dump materials in Aspen are contaminated with lead.

Abstract of Soil-Lead Studies
Abstract A-23

Study Name: El Paso, Texas Lead Study

Study Dates: 1971 - 1973 **Study Location:** El Paso, Texas

References:

Landrigan, P., Gehlbach, S., Rosenblum, B., Shoults, J., Candelaria, R., Barthel, W., Liddle, J., Smrek, A., Staehling, N., and Sanders, J. (1975) "Epidemic Lead Absorption Near an Ore Smelter: The Role of Particulate Lead," *New England Journal of Medicine*. 292(3):123-129.

Rosenblum, B. F., Shoults, J. M., and Candelaria, R. (1976) "Lead Health Hazards from Smelter Emissions," *Texas Medicine*. 72(1):44-56.

Objectives:

To ascertain "the prevalence and severity of lead absorption in this locale, and to evaluate the role here of particulate lead in lead uptake." [Reference p. 123]

Sampling Frame:

The survey area was divided along 1970 U.S. census tract boundaries into three roughly concentric sections 1.6 to 2.6 km in diameter with the smelter at the center.

All families in Area I were selected and a random sample of households was sampled in Areas II and III. In all, 670 households participated and netted 758 individuals (1 to 19 years old) as part of the random sample survey.

Additional monitoring of environmental variables occurred before and after the above survey (monitoring of El Paso was the original project).

The review that follows concentrates on the random sample survey.

Sampling Method:

Soil samples were collected at 99 sites in El Paso and at three remote sites at depths of 2.5, 5.0 and 7.5 cm. These sites were distinct from the homes sampled in the random sample survey).

Surface soil scrapings were taken. (466 samples)

Analysis Method: Atomic Absorption Spectrophotometry

Results for Soil:

	N	Geometric Mean (ppm)	Geometric Std. Dev. (ppm)	Range
Area I	82	1791	Not Avail.	Not Avail.
Area II	184	684	Not Avail.	Not Avail.
Area III	200	370	Not Avail.	Not Avail.
Within 200m of Smelter	54	3457	Not Avail.	560 - 11450

Comments:

Comparisons done in this study were completed using ANOVA and F-tests.

Only trace amounts of lead (< 50 ppm) were found at the remote sites. High levels were found within 200 meters of the smelter, and lead content was consistently highest at the surface. (From soil monitoring March 1972 - June 1973)

Conclusions:

Soil lead levels in Areas II and III were not significantly different, but both were significantly lower than the soil lead level in Area I.

"In Area I, a significant relation ($p <.05$) was found between soil lead content and blood lead levels in subjects one to 19 years old." [Reference p. 127] This relation was not found in Areas II or III.

Particulate lead from soil contributed relatively less to lead uptake than did dust.

"Soil lead, although valuable as an index of environmental contamination, appears to be relatively immobile and thus less accessible for absorption." [Reference p. 128]

Abstract of Soil - Lead Studies
Abstract A-24

Study Name: Corpus Christi Soil-Lead Study

Study Dates: 1984 **Study Location:** Corpus Christi, Texas

References:

Harrison, G. (1987) "A Survey of the Lead Distribution in the Soil of Corpus Christi, Texas," *Texas Journal of Science*. 39(1):15-22.

Objectives:

"To present a detailed overview of lead distribution in a major city based on numerous closely-spaced sampling sites, and to look for anomalies or trends, or lack of." [Reference p. 16]

Sampling Frame:

Parks, schools, and roadside embankments within the city limits of Corpus Christi. There were 485 locations sampled, 94 in parks, 12 at schools, and the remainder in various locations. The only limitation on sampling was that only vegetated non sandy soil was sampled.

Sampling Method:

Soil samples were taken from the top two centimeters with a Teflon knife.

Analysis Method: Flameless Atomic Absorption Spectrophotometry

Results for Soil:

	N	Arithmetic Mean (ppm)	Arithmetic Std. Dev.(ppm)	Range (ppm)
All Samples	485	208	236	8 - 2969
Parks	94	55	66	8 - 318
Schools	57	57	77	11 - 258
All others	379	250	250	8 - 2969

Conclusions:

The hypothesis that leaded gasoline emissions is concentrated around roadways and is directly proportional to traffic volume/flow was reaffirmed.

Abstract of Soil-Lead Studies
Abstract A-25

Study Name: Maine Urban Soil Study

Study Dates: 1988 **Study Location:** Portland, Maine

References:

Krueger, J. A. and Duguay, K. M. (1989) "Comparative Analysis of Lead in Maine Urban Soils," *Bulletin of Environmental Contamination and Toxicology*. 42:574-581.

Objectives: To survey and document soil-lead levels in Portland, Maine.

Sampling Frame:

Homes at least 30 years old, parks, and playgrounds in Portland, Maine. Homes were considered to be high risk locations while parks and playground were thought to be low risk locations. There were 100 samples taken; 75 from high risk areas, 25 from parks or playgrounds.

Sampling Method:

Samples were collected randomly from the top .5 cm of soil in parks and playgrounds. Four samples were collected at random along a line approximately two feet from the foundation.

Analysis Method: X-Ray Fluorescence, Atomic Absorption Analysis

Results for Soil:

	N	**Geometric Mean (ppm)**	**Range (ppm)**
High Site Risk	75	1275	50 - 10900
Low Site Risk	25	205	50 - 700

Lead Level Ranges

	% Low 0 - 499 (ppm)	**% Moderate 500 - 999 (ppm)**	**% High >1000 (ppm)**
High Risk	50	13	37
Low Risk	92	8	0

Conclusions:

Soil located adjacent to the foundation of homes older than 30 years are significantly contaminated with lead.

"The lead in paint chips remains relatively intact, close to the original location with little leaching." [Reference p. 581]

Abstract of Soil - Lead Studies
Abstract A-26

Study Name: Beltsville Roadway Study

Study Dates: 1971 - 1977 **Study Location:** Beltsville, MD

References:

Milberg, R. P., Lagerwerff, J. V., Brower, D. L., and Biersdorf, G. T. (1980) "Soil Lead Accumulation Alongside a Newly Constructed Roadway," *Journal of Environmental Quality*. 9:6-8.

Objectives:

Determine yearly rates of roadside soil-lead accumulation. In addition, predict soil-lead accumulation based on traffic volume.

Sampling Frame:

Sides of Interstate I-95 near Beltsville, Maryland. "The highway runs in a north-south direction and consists of six lanes divided by a 30-m-wide grass median strip." [Reference p.6]

Sampling Method:

A single soil sample was collected yearly on both sides of the roadway at distances of 8, 25, and 50 meters from the edge of the roadway. Samples were collected from the sides of a pit, 30cm X 60cm, at depths of 0-5,5-10,and 10-15 cm. Additionally, a series of four samples was collected in 1977 from pits dug at 5 meter increments. These additional pits ran parallel to the highway approximately 25 meters from the edge of the road.

Analysis Method: Atomic Absorption Spectrophotometry

Results (ppm) for Soil, 0-5 cm depth, West of I-95:

Distance (meters)	Year						
	1971	1972	1973	1974	1975	1976	1977
8	16.8	19.4	49.4	100	120	176	130
25	18.4	20.0	21.2	35.6	19.2	22.8	40.8
50	16.8	12.8	21.2	23.6	19.6	20.0	22.8

Results (ppm) for Soil, 5-10 cm depth, West of I-95:

Distance (meters)	Year						
	1971	1972	1973	1974	1975	1976	1977
8	11.2	8.4	21.4	22.0	16.7	36.7	28.0
25	18.4	10.4	14.4	8.0	10.8	10.8	21.6
50	16.4	18.0	15.0	15.6	5.2	9.6	20.0

Correlation Between Soil Lead Accumulation Rates with Distance from West edge of Roadway:

Distance (Meters)	Correlation Coefficient, r
8	.92
25	.53
50	.19

Comments:

Correlations analysis was performed via simple linear regression.

Similar results were presented for the area East of I-95.

Conclusions:

"In general, after 1971, soil-lead levels decreased with distance from the roadway and with depth in the soil profile." [Reference p.7.]

The accumulation rate fell rapidly as the distance from the roadway increased.

Accumulation rate was correlated with traffic volume.

Abstract of Soil - Lead Studies
Abstract A-27

Study Name: Heavy Metal Exposure Smelter Study

Study Dates: 1978-1979

Study Location: Bartlesville, Oklahoma; Palmerton, Pennsylvania; Ajo, Arizona; Anaconda, Montana

References:

Hartwell, T. D., Handy, R. W., Harris, B. S., Williams, S. R., and Gehlbach, S. H. (1983) "Heavy Metal Exposure in Populations Living Around Zinc and Copper Smelters," *Archives of Environmental Health*. 38(5):284-295.

Handy, R. W., Hariss, B. S. H., Hartwell, T. D., and Williams, S. R. (1986) "Epidemiologic Study Conducted in Populations Living Around Non-Ferrous Smelters, Vol. I," U.S. Environmental Protection Agency Report Number EPA/600/1-81/070A.

Objectives:

Estimate the levels of arsenic, cadmium, lead, zinc, copper, and magnesium in biologic and environmental media in the various smelter communities. Also, examine the levels of these chemicals as a function of distance from a smelter.

Sampling Frame:

Each of the four communities were stratified into seven or eight exposure regions. Within each of these regions, five sampling segments (e.g. city blocks) were selected at random. Finally, households within the sampling segment were selected at random and screened for eligible participants (individuals who had no occupational exposure and had lived in the study area for the preceding 12 months).

Sampling Method: Soil samples were collected from random areas in the yard.

Analysis Method: Flame atomic absorption spectrophotometry

Results for Soil:

Median Soil-Lead Levels by Distance from the Smelter

Bartlesville (n=38)		Palmerton (n=42)		Ajo (n=53)		Anaconda (n=49)	
Distance from Smelter (km)	Median (µg/g)	Distance from Smelter (km)	Median (µg/g)	Distance from Smelter (km)	Median (µg/g)	Distance from Smelter (km)	Median (µg/g)
3.5-24.0	34.8	11.0-26.0	532	3.4-68.0	57.8	10.0-26.0	75
1.3-3.7	243	5.4-14.5	117	1.0-6.4	64.5	3.5-21.0	115
0.8-4.3	829	3.3-9.9	326	0.5-2.3	76.5	2.0-11.0	294
0.8-1.5	821	0.3-2.8	331	0.5-1.3	94.8	2.0-3.5	424

Correlation Between Distance from the Smelter and Soil-Lead Levels

	Correlation*	Sample Size
Bartlesville	-0.40	165
Palmerton	0.13	65
Ajo	-0.13	90
Anaconda	-0.19	74

Comments:

* A negative correlation indicates that metal levels decrease as distance from the smelter increases. The tests for significance were calculated using Spearman's correlation coefficient.

Tests of significance between the four sampling strata at each site were conducted using the Kruskal-Wallis test statistic.

Conclusions:

There was a "...general trend toward increasing levels of environmental metal burdens with proximity to the smelter." [First reference p. 287]

Abstract of Soil-Lead Studies
Abstract A-28

Study Name: Survey of Lead Levels Along Interstate 880

Study Dates: 1993

Study Location: Alameda County, California

References:

Teichman, J., Coltrin, D., Prouty, K., and Bir, W. A. (1993) "A Survey of Lead Contamination in Soil Along Interstate 880, Alameda County, California," *Journal of the American Industrial Hygiene Association*. 54(9):557-559.

Objectives:

"Determine the levels of lead in soils taken from yards in close proximity to a major freeway." [reference p. 557]

Sampling Frame:

Private homes, parks and playgrounds (21 samples), and public housing developments in Alameda County along Interstate 880 or within a 1-mile radius. There were 138 samples collected from residences (116 east of the interstate, 22 west).

Sampling Method:

Both surface (top 0.5 to 0.75 inches) and subsurface samples were collected. The subsurface samples were collected from 3 to 8 inches in depth. In all, approximately 200 samples were collected.

Analysis Method: Flame atomic absorption spectroscopy

Results for Soil:

Comparison of Subsurface and Surface Soil-Lead Levels (n=19)

Surface (ppm)			Subsurface (ppm)		
Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
567.7	195.3	2026.6	618.3	369.8	1405.7

Comparison of Downwind (East) and Upwind (West) Surface Soil-Lead Levels

East (ppm) n=116			West (ppm) n=22		
Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
594.3	22.3	3187.4	263.3	89.7	862.0

Conclusions:

The subsurface soil-lead levels are higher than the surface lead levels.

The soil-lead levels downwind of the interstate were higher than those found on the upwind side of the interstate.

Abstract of Soil - Lead Studies
Abstract A-29

Study Name: Albuquerque Street Dirt Lead Study

Study Dates: 1981

Study Location: Albuquerque, New Mexico

References:

Franz, D. A. and Hadley, W. M. (1981) “Lead in Albuquerque Street Dirt and the Effect of Curb Paint,” *Bulletin of Environmental Contamination and Toxicology*. 27(3):353-358.

Objectives:

The purpose of this study is to investigate the source of lead in street-side soil samples. In particular, to determine the possible contribution of curb paint.

Sampling Frame:

The Albuquerque urban area. Samples were collected from residential and school yards (16) and in three areas adjacent to city streets: residence side of walk (7), curbs and gutters (13), and central medians (7). Additional samples were collected from the medians of three city streets to examine the effects of curb paint particles.

Sampling Method:

All samples were collected using a plastic scoop and brush. For the median, samples were taken in close proximity to a painted curb and at least 30 meters from any painted surface. Residential and school yard samples were collected at least 30 meters from the street.

Analysis Method: Flame atomic absorption spectrophotometry

Results for Soil:

Description	Lead Levels (µg/g)	Sample Size
Residential and school Yards	3-110	16
City Streets, residence side of walks*	270-1640	7
City Streets, curbs and gutters*	950-3540	13
City Streets, central medians*	980-5280	7

Relationship Between Mean Soil-Lead Levels and Proximity to Painted Curb

Site**	Close (<2 meters from Painted curb)		Distant (> 30 meters from painted curb)	
	Mean (ppm)	**SD**	**Mean (ppm)**	**SD**
A	1770	240	1120	190
B	3720	820	2600	180
C	4860	430	3660	220

Comments:

* Average traffic volume > 14,000 vehicles/day

** Average traffic volume 23,200 - 30,000 vehicles/day, sample sizes unavailable in reference.

Significance tests (95% confidence) were made using the Student's t-test.

Conclusions:

In all three of the median sites, the mean lead levels for the close samples were significantly higher than those of the distant samples collected from the same median.

"The erosion of leaded roadway paint constitutes a hitherto unrecognized contribution to high lead levels in urban street dirt in Albuquerque, and possibly in other cities." [reference p.357] However, the authors conclude that "automotive emissions constitute the most significant source of lead." [reference p.357]

“The highest lead concentrations were found in dirt on and adjacent to busy streets, while near-background levels were found in soils from residential streets and schoolyards.” [reference p.354]

“At any given street collection site, lead levels were lowest in the soil on the residence side of the sidewalk, higher in the dirt from curb and gutter, and highest in the soil from a median strip.” [reference p.354]

Abstract of Soil - Lead Studies
Abstract A-30

Study Name: Identification of Lead Sources through Stable Isotope Ratio Techniques: Case Studies

Study Dates: 1978-1979

Study Location: Oakland, California

References:

Yaffe, Y., Flessel, C. P., Wesolowski, J. J., del Rosario, A., Guiruis, G., Matias, V., Gramlich, J. W., Kelly, W. R., DeGarmo, T. E., and Coleman, G. C. (1983) "Identification of Lead Sources in California Children Using the Stable Isotope Ratio Technique," *Archives of Environmental Health*. 38(4):237-245.

Objectives:

The objective of this study was to examine the feasibility of using the isotopic ratio method to identify sources of lead in children.

Sampling Frame:

Two different case control studies were conducted. In both cases, the children resided in Alameda county. For the first case, the sources of lead for 8 children from an extended family living in the same house were investigated. For the second case study, sources of lead for twins of a previously lead-burdened mother were examined.

Sampling Method:

In the first case study, four surface soil samples (<1 inch in depth) were collected around the home (2 backyard and curbside, 2 alongside house) and near the street curb.

For the second case study, eight surface soil samples were collected from the front (4), side (1) and backyard (2). One sample was collected from the backyard of a neighboring yard where the twins frequently played.

Analysis Method: Flame Atomic Absorption Spectrophotometry

Results for Soil:

Description	No. of Samples	Average Pb Ratio	Median Pb Conc.(ppm)	Range (ppm)
Case I:				
Backyard and Curbside	2	2.084	1160	1050-1260
Alongside house	2	2.068	1300	1220-1370
Case II:				
Front Yard	4	2.126	2430	480-7130
Sideyard	1	2.085	1420	*
Backyard	2	2.080	1100	940-1300
Neighbor's Backyard	1	2.102	990	*

Comments:

As only a very limited number of samples were collected the results of this study should be interpreted with caution.

Conclusions:

The authors concluded that in both cases, the results of the isotopic ratio analysis suggests that the lead in the backyard soil samples derived primarily from the weathering of nearby exterior paint.

Abstract of Soil - Lead Studies
Abstract A-31

Study Name: California Lead Study: Three High-Risk Communities

Study Dates: 1987-1991

Study Location: Alameda, Sacramento, Los Angeles Counties

References:

Sutton, P., Athanasoulis, M., Flessel, P., Guirguis, G., Haan, M., Schlag, R., and Goldman, L. (1995) “Lead Levels in the Household Environment of Children in Three High-Risk Communities in California,” *Environmental Research*. 68:45-57.

Objectives:

Examine the levels of lead in these three high-risk communities. In addition, determine how well environmental lead levels are predicted by age of housing.

Sampling Frame:

Within Alameda, Sacramento, and Los Angeles counties, communities with a high risk for childhood lead poisoning were selected for sampling based upon: the number of children between 1 and 6 years, older housing, and populations having cultural and/or ethnic risk factors. Census blocks were used to determine the number of children between 1-6 years living in a particular community. Any households in the selected census tracts with a child between 1-6 years were eligible for the study. In Los Angeles county, a random sample of blocks within two census tracts were selected and households with a child between 1 and 6 years were eligible. In all, 933 households (358 in Oakland, 343 in Los Angeles, 232 in Sacramento) were surveyed.

Sampling Method:

Surface soil samples (<1 inch in depth) were collected using a trowel. Visible paint chips were removed from the sample prior to analysis of lead content. Samples were collected from the front, side, and rear yards. In addition, soil samples were collected near secondary structures and rain drains in Los Angles and Oakland. Each soil sample was a composite of four sub-samples.

Analysis Method: Flame Atomic Absorption Spectrophotometry

Results for Soil:

	No. Houses Sampled	Geometric Mean (ppm)	+- 1 Std. Deviation	Range (ppm)
Oakland:				
Front-yard	231	716	313-1639	56-5827
Rear-yard	141	889	377-2096	78-7175
Side-yard	147	942	339-2221	57-6985
Los Angeles:				
Front-yard	290	181	88-372	17-1481
Rear-yard	236	215	102-454	31-8269
Side-yard	245	203	88-467	28-4554
Sacramento:				
Front-yard	221	225	90-563	17-3795
Rear-yard	197	217	92-513	32-7770
Side-yard	198	290	99-846	11-12094

Logistic Regression Results*

Independent Variable	Adjusted Odds Ratio	95% Confidence Interval
Reported exterior paint change in last year	1.77	0.73-4.28
Exterior paint >= 5000 ppm	2.11	1.03-4.33
Home built before 1920 compared to post 1950	10.43	3.11-35.03
Home built 1920-1950 compared to post 1950	2.07	0.64-6.65
Home located in Oakland compared to Los Angeles	46.39	15.90-135.33
Home located in Sacramento compared to Los Angeles	3.90	1.42-10.66

* Dependant variable was soil concentration categorized into above or below 500 ppm

Comments:

All analysis was completed using log-transformed values for the environmental samples.

Multiple logistic regression analysis was used to examine the relationship between soil lead concentration and related variables. T-tests, chi-square analysis, correlations, and analysis of variance were also used to analyze soil and the other environmental samples.

Conclusions:

"Age of housing is highly predictive of the presence of environmental lead-levels and paint deterioration. In this survey age of housing was the best measured predictor of lead in soil and dust" [reference p.56] However, the authors also state that "for soil lead levels, construction year is probably a measure of historical paint lead levels, the deterioration of paint, and the deposition of atmospheric lead in soil over time." [reference p.55]

"Soil lead levels measured next to homes (i.e., in the side yards) in Oakland and Sacramento were significantly higher that the front and rear yards, presumably due to lead paint and rain run-off." [reference p.55]

Abstract of Soil - Lead Studies
Abstract A-32

Study Name: Champaign-Urbana Lead Study

Study Dates: 1976

Study Location: Champaign-Urbana, Illinois

References:

Solomon, R. L. and Hartford, J. W. (1976) “Lead and Cadmium in Dusts and Soils in a Small Urban Community,” *Enviromental Science and Technology*. 10(8):773-777.

Objectives:

Survey the lead levels on settled dusts and soils in a small urban community. In addition, it was desired to examine the lead levels in areas where the homes were in good condition, painted with non-lead or low-lead paints, and in low traffic areas.

Sampling Frame:

Residential and nonresidential homes in the Champaign-Urbana community. In all, 288 soil samples were collected in residential homes that were in good condition, painted with non-lead or low-lead paints, and in low traffic areas. Additionally, soil samples were collected from 7 homes coated with leaded paint, and located in high traffic areas. Finally, 183 soil samples were collected from 20 brick or stone buildings designated as nonresidential.

Sampling Method:

The soil samples were collected using a standard soil boring tool. The top 2.5 cm were extracted from the 15-cm core and analyzed for lead.

Exterior dust samples were collected with a specially modified vacuum using a 0.5 x 0.5 meter template.

Analysis Method: Atomic absorption spectrometry

Results for Soil:

Description*	Median (ppm)	Range
Side Lawn Near (<1 meter) House	50	30-990
Rear Lawn Near (<1 meter) House	100	20-1060
Far Front Lawn	70	20-110
Far Lawn	40	20-110

Comments:

* Results for 10 homes in good condition, painted with non-lead or low-lead paints, and in low traffic areas. A total of 288 samples were collected, however the exact number of samples at each location is unavailable in the reference.

Conclusions:

Lead-based paint alone is not an adequate indicator of the presence of high soil lead concentration.

"Soil lead is high near the road and falls off but then increases to the highest level adjacent to the stone buildings. The latter increase is possibly due to leaching of window trim paint, but more likely is due to wash-off of non-paint source settled lead from roofs or ledges." [reference p.776]

The soil lead levels in the brick and stone non-residential buildings were "...higher than that found adjacent to the frame houses painted with high lead paint. This strongly suggests that a wash-off of settled lead of airborne origin occurs." [reference p.776]. In particular the soil-lead levels are "...several times higher that normal residential values due to higher vehicular traffic in the area." [reference p.776]

Abstract of Soil - Lead Studies
Abstract A-33

Study Name: Cincinnati Roadside Soil Study

Study Dates: 1990

Study Location: Cincinnati, Ohio

References:

Tong, S. T. (1990) "Roadside Dusts and Soils Contamination in Cincinnati, Ohio," *Environmental Management*. 14(1):107-114.

Objectives:

Examine the current levels of lead in roadside soil. In addition, to investigate the relationship between lead-levels in the roadside soil, housing age, and traffic volume.

Sampling Frame:

The sampling in this study was performed in selected areas of The Greater Cincinnati Metropolitan District. Sampling areas were identified by road system (defined by average daily traffic volume, ADT) and neighborhood (defined by age of housing). In all, samples were collected from three road systems: highways (ADT >20,000), boulevards (8000<ADT<20000), and one-way streets or cul-de-sacs (<8000 ADT), within two neighborhoods: pre-1950 housing and post-1960 housing. A total of 60 sites (10 in each road system by neighborhood combination) were sampled. The road systems were defined by average daily traffic volume (ADT). An effort was made to exclude industrial areas or poor neighborhoods with deteriorated housing.

Sampling Method:

At each sampling site, surface soil samples were collected at the edge of the pavement. The samples were collected at depths of 0-5 cm and 15-20 cm.

Analysis Method: Leeman Plasma Spectrophotometer with background correction

Results for Soil:

	0-5 cm Soil Sample (n=60)		15-20 cm Soil Sample (n=60)	
	Mean (ppm)	SD	Mean (ppm)	SD
Average Daily Traffic Volume				
>20,000	1125.7	1282.8	1318.0	1311.9
8,000 - 20,000	999.7	1043.5	1045.2	957.1
<8,000	886.9	623.5	1540.0	1423.8
Housing Age				
Pre-1950	1256.2	1254.3	1602.4	1563.8
Post-1960	752.0	557.4	999.7	744.7

Comments:

Streetside dust was also collected using a brush and dustpan. Dust samples were also collected 30 meters from the roadway.

One-way analysis of variance was used to investigate relationships between soil-lead levels and traffic flow, housing age, rainfall levels, and other factors.

Conclusions:

"The amount of lead in the surficial soil was lower than the underlying horizons." [reference p.109]

"The mean values of lead in the topsoil, wet and dry dust samples at the curb, and dry dust samples 30 meters from the curb, were higher in places with higher vehicular traffic." [reference p.109] However, a statistical difference was not observed.

Older neighborhoods had higher levels of lead.

Abstract of Soil-Lead Studies
Abstract A-34

Study Name: Granite City Lead Exposure Study

Study Dates: August-September 1991

Study Location: Granite City, Illinois

References:

Kimbrough, R., Levois, M., and Webb, D. (1995) "Survey of Lead Exposure Around a Closed Lead Smelter," *Pediatrics*. 95(4):550-554.

Kimbrough, R. D., LeVois, M., and Webb, D. R. (1994) "Management of Children with Slightly Elevated Blood Levels," *Pediatrics.* 93(2):188-191.

Objectives:

Test the hypothesis that elevated soil-lead is related to blood-lead levels in children living in the vicinity of a closed smelter.

Sampling Frame:

A population census was conducted in an area extending 4 km from the smelter to identify households with children under 6 years of age. All households with children under 6 were asked to participate in the study. Environmental samples were collected from four concentric circular regions centered by the smelter. Each region was approximately 1 km wide.

Sampling Method:

Two soil (core, 1 inch in depth) samples were collected from 10 play area locations and composited into a single sample for each location. Unless the play area was near the building, an effort was made to avoid sampling from the building dripline.

Analysis Method: EPA Method 6010 Using Inductively Coupled Argon Plasma Emission Spectroscopy

Results:

	N	A. Mean	Min	Max	S.D
Soil (ppm)	338	449	37	3010	420

Variables Positively Correlated With Soil Lead (P-value <.01):

Dust lead loading
Indoor lead paint
Age of home
Poor rating of the "Condition of the house"

Comments:

Data analysis was performed through two-tailed t-tests and chi-square analyses for categorical variables.

Older homes were generally closer to the smelter than newer homes which could be a confounding factor in the relationship between distance from the smelter and soil lead levels.

Conclusions:

"Condition of the house, lead in paint, lead in dust, lead in soil, smoking of the parents, proximity to the closed smelter, education and income of the parents, and behavioral factors for the children predicted PbB in young children." [reference p553.]

Many of the environmental factors were related to each other. In particular, soil lead levels were related to age and condition of the home.

Abstract of Soil - Lead Studies
Abstract A-35

Study Name: Rochester Side-by-Side Dust Collection Study

Study Dates: March 1991 - September 1992

Study Location: Rochester, New York

References:

Lanphear, B. P., Emond, M., Jacobs, D. E., Weitzman, M., Tanner, M., Winter, N. L., Yakir, B., and Eberly, S. (1994) "A Side-By-Side Comparison of Dust Collection Methods for Sampling Lead-Contaminated House Dust," *Environmental Research.* 68(2):114-123.

Department of Pediatrics, Biostatistics, and Environmental Medicine, The University of Rochester School of Medicine, New York, and The National Center for Lead-Safe Housing, Columbia, Maryland. (1995) "The Relation of Lead-Contaminated House Dust and Blood Lead Levels among Urban Children," Final Report, Volume II, #MLDP T0001-93.

Objectives:

There were three objectives of this study: 1) to determine if dust-lead loading were a better predictor of blood-lead than dust lead-concentrations; 2) to compare dust sampling techniques for efficiency and performance; 3) to identify interior surfaces for routine sampling.

Sampling Frame:

Children aged 12 to 30 months who had resided in the same residence since 6 months of age. In addition, the children had to live in the city of Rochester and spend only a limited time away from their house. Children were identified for the study from randomized hospital records.

Sampling Method:

A composite soil sample (of three samples) was collected from core (top ½ inch) samples taken on each side of the child's house. These samples were collected from bare soil areas around the perimeter of the foundation. In addition, composite soil samples were collected from bare soil play areas.

Analysis Method: Flame atomic absorption spectroscopy

Results for Soil:

Type of Sample	n	Geometric Mean (µg/g)	± 2 Standard Deviations
Foundation Coarse Soil	182	981	52-18565
Foundation Fine Soil	182	732	54-9994
Play Area Coarse Soil	82	299	30-2961
Play Area Fine Soil	82	271	35-2104

Correlation Between Soil and Paint Samples

Sample Type	Correlation with Foundation Coarse Soil
Foundation Fine Soil	.84
Exterior Paint	.37

Comments:

Fine and coarse soil samples were created in the laboratory by sieving the soil samples through a 2 mm mesh sieve followed by a 250 µm mesh sieve.

Conclusions:

"...foundation soil lead appeared to be higher than play area soil lead and the coarse-sieved foundation soil fraction appeared to have a higher lead concentration than the fine-sieved soil fraction." [reference p.118]

Abstract of Soil - Lead Studies
Abstract A-36

Study Name: Washington, D.C. Soil Lead Study

Study Dates: Unavailable in Reference

Study Location: Washington, D.C.

References:

Elhelu, M. A., Caldwell, D., and Hirpassa, W. (1995) "Lead in Inner-City Soil and Its Possible Contribution to Children's Blood Lead," *Archives of Environmental Health*. 50(2):165-169.

Objectives:

The objective of this study was to assess the source of lead in inner-city soils in Washington, D.C.

Sampling Frame:

Soil samples were randomly collected from 239 homes throughout the eight wards of Washington, D.C.

Sampling Method:

Soil samples were collected from unpaved front yards approximately 1 meter from the dwelling. Each soil sample was collected at a depth of 15 cm. On average, the dwellings were 4.5 m from the road.

Analysis Method: Perkin Elmer 2100 Atomic Absorption Spectrophotometer

Results for Soil:

	Ward							
%-tile	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Max	4905	4520	815	4575	5056	1720	3740	6015
75	1145	975	105.7	294.9	380.4	427.9	274.9	307.9
Median	444.2	471.4	53.7	198.9	221.9	260.4	144.4	129.7
25	228.	344.8	25.1	95.5	101.3	125	70.3	68.45
Min	36.4	48.3	10.2	32.7	12	13.8	36.2	22.2
n (# of Sites)	30	30	30	30	30	30	30	30

* Extracted from Table 1. Reference p.167

Comments:

Only 24% of the houses in Ward 3 had a painted exterior. Approximately 74% of the houses in the other seven wards had painted exteriors.

Conclusions:

The authors conclude that paint, rather than vehicular emission, was the main source of lead in Washington, D.C. soils.

"Concentrations of lead in soil may be high near a road, but may be highest in areas adjacent to buildings." [reference 166]