Soil Lead Abatement and Children's Blood Lead Levels in an Urban Setting

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ABSTRACT

Objectives. The effect of abating soil lead was assessed among Baltimore children. The hypothesis was that a reduction of 1000 parts per million would reduce children's blood lead levels by 0.14 to 0.29 μmol/L (3–6 μg/dL).

Methods. In 2 neighborhoods (study and control), 187 children completed the protocol. In the study area, contaminated soil was replaced with clean soil.

Results. Soil lead abatement in this study did not lower children's blood lead.

Conclusions. Although it did not show an effect in this study, soil lead abatement may be useful in certain areas. (*Am J Public Health.* 1998;88: 1837–1839)

In 1987, the US Environmental Protection Agency (EPA) selected Baltimore, along with Boston and Cincinnati, for 1 of 3 soil lead studies with standardized protocols and an EPA oversight expert panel.

In Baltimore, the hypothesis was that a clinically important reduction in children's blood lead (0.14–0.29 μmol/L) would result from reducing soil lead by 1000 parts per million (ppm) or more.

Methods

Subjects and Materials

A prospective longitudinal study design was used to investigate the effect of soil abatement on children's blood lead. Noncontiguous Baltimore neighborhoods were selected based on (1) sufficient children to test the hypothesis (birth rate and census data), (2) areas of exposed soil around homes, (3) pre-1950 urban housing away from major industries or highways, (4) comparable demographics (census data), and (5) moderate risk for lead exposure (census tracts in which more than 4 children had hospitalizations for lead poisoning in the 4 previous years were excluded to avoid unrelated lead reduction interventions).

Randomization was used to assign neighborhoods to study and control conditions. Soil abatement, if found effective, was to be conducted later in the control area. Subjects were enrolled if they (1) had written informed parental consent, (2) were 6 months to 6 years of age, and (3) had been living in the same house (in the selected neighborhoods) for at least 3 months and the family was not planning to move.

Initially, 408 children in 263 houses were enrolled, with equal representation from each area. Owners of properties where study subjects lived were approached for permission to do soil abatement and exterior paint stabilization. One hundred eighty-seven children (representing 111 properties) completed the study (Table 1). Demographic and environmental data for completers and dropouts were similar.

The Maryland Department of Health and Mental Hygiene Laboratories Administration conducted all laboratory analyses. External quality control by the Centers for Disease Control and Prevention revealed no statistically significant time trends and good laboratory quality control.

Properties and children were characterized by means of environmental, biological, and questionnaire data before and after soil abatement. Protocol details have been published elsewhere.[1] Within a week after the intervention, interior dust and soil were sampled again.

One consideration for the study design was the need to notify Baltimore City of all housing violations, including lead-based paint. Exterior paint was to be stabilized, but no interior abatement was planned. Interior paint was therefore tested only at the end of the study. Families were informed of the possibility of lead in their interior paint and about managing lead hazards. Children's whole venous blood lead concentrations were measured by graphite furnace atomic absorption spectroscopy[2] on 6 different occasions (Table 1). Delayed landlord consent postponed the environmental intervention, so 2 additional preabatement rounds were added to the baseline, along with 3 postintervention rounds of biological measurements. At each round, a questionnaire assessed factors such as behavior, household adult occupations, and demographic and nutritional data that might influence lead uptake. Postabatement measurements of blood lead were taken after 3 months to allow reequilibration.

As a means of preventing soil recontamination, exterior paint was stabilized in both the study and control areas before soil

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abatement. In summer and fall 1990, loose paint was wet scraped and then cleaned up with a high-efficiency particulate air vacuum. Surfaces were primed and painted twice with latex paint. Strict containment was practiced during the procedure to avoid contamination and protect occupants and workers. Families were off-site during stabilization.

Soil was abated when even one surface soil lead sample exceeded 500 ppm. At 90% of the properties, all soil was abated. In 10%, either the entire front or back yard was abated. Further details have been published elsewhere.[1,3] Soil abatement (the intervention) consisted of removing the top 6 in [15 cm] of soil, replacing it with "lead-free" soil (less than 50 ppm), and then sodding or seeding, all within 1 week of exterior paint stabilization. Two years later, sampling was repeated at 50 abated and 44 unabated properties via the original protocols and diagrams.

Statistical Analysis

The purpose of the statistical models was to investigate the hypothesis that soil abatement is efficacious in decreasing the blood lead concentrations of urban children. Blood lead concentration was designated as the response variable in the regression models. Since the distribution of blood lead concentrations was skewed, a natural log transformation was applied to blood lead data. The resulting distribution of blood lead was normal.

Longitudinal models allowed for inferences based on the data from the entire study. The main obstacle in combining data from different rounds of sampling was that repeated blood lead measurements on an individual child or on multiple children living in the same household were likely to be positively correlated. The presence of such correlations violates the assumption of independent responses necessary for ordinary least squares regression. Longitudinal techniques for regression models with dependent responses allow data from each round of sampling to be combined. Methods developed by Zeger and Liang[4,5] were applied, via SAS PROC MIXED (SAS Institute Inc, Cary, NC), to the combined data set. An autoregressive correlation structure was used to model the dependency among each child's blood lead levels. A random effect was used to model correlations between children within the same household.

Results

Before intervention, the 2 communities were comparable in terms of demographic and other characteristics. Contrary to expectations, only 110 of 204 properties (54%) had any preabatement soil samples above 1000 ppm. For each property, the measure of soil lead contamination used was the trimean (the point halfway between the median and mean of the quartiles) of the samples from that property. The trimean is a robust measure of location.[6] Prior to the intervention, the average trimean soil lead level was 501.3 ppm (SE = 312.1) in the control area; in the treatment area, the level was 503.6 ppm (SE = 268.2). Abatement initially reduced the average trimean level to 33.6 ppm (SE = 34.9) in the treament area. A 2-sample t test indicated no significant difference in the average trimean level of soil lead between treatment and control groups at baseline ($t = 0.049$). The t statistic comparing trimeans of abated properties before and after intervention was 13.15, a statistically significant difference.

One year postabatement, blood lead levels in both groups fell below baseline, but there was no significant effect of soil abatement on children's blood lead. Differences between the treatment and control groups were not significant in any of the cross-sectional models or longitudinal models (Tables 1 and 2). Two years postabatement, soil sampling showed significant lead reaccumulation.

Discussion

The Baltimore Lead in Soil Project results provide evidence that soil abatement of individual residential properties has no impact on the blood lead level of children at the soil lead levels encountered. The EPA uptake biokinetic model predicted that the decrease in blood lead related to lowering soil lead by 1000 ppm would be 0.14 to 0.29 µmol/L (3–6 µg/dL).[7] With an average trimean soil lead decrease of 550 ppm, we hypothesized that children's blood lead levels would decrease by 0.04 to 0.14 µmol/L (1–3 µg/dL).

TABLE 1—Number of Children and Estimates of the Distribution of Children's Blood Lead Concentrations (µg/dL) at Each Round of Biological Sampling

			All Subjects Sampled During the Study		Subjects Who Completed the Last 3 Rounds of Sampling	
Round of Sampling	Dates of Sampling	Study Group	No. of Subjects (Properties)	Blood Lead Concentration Geometric Mean (95% CI)	No. of Subjects (Properties)	Blood Lead Concentration Geometric Mean (95% CI)
1	8/22/88–12/2/88	Treatment	212 (143)	11.0 (4.7, 23.0)	79 (54)	12.1 (5.5, 22.0)
		Control	196 (120)	10.9 (4.1, 29.1)	74 (47)	10.9 (4.1, 23.5)
2	2/2/89–8/15/89	Treatment	173 (113)	10.2 (4.7, 23.6)	80 (54)	10.6 (5.2, 23.5)
		Control	149 (93)	10.4 (4.9, 24.2)	74 (47)	9.9 (4.6, 21.9)
3	1/22/90–8/13/90	Treatment	154 (92)	9.7 (4.5, 22.8)	98 (61)	9.6 (4.4, 22.1)
		Control	116 (70)	9.2 (4.3, 22.0)	82 (51)	9.1 (4.3, 22.5)
4[a]	1/3/91–3/26/91	Treatment	112 (66)	8.6 (3.9, 21.1)	99 (60)	8.5 (3.9, 21.1)
		Control	88 (51)	7.8 (3.6, 23.1)	83 (50)	7.7 (3.6, 23.1)
5[a]	5/22/91–7/19/91	Treatment	107 (62)	9.6 (4.5, 23.8)	99 (60)	9.4 (4.5, 23.3)
		Control	89 (51)	8.1 (3.6, 22.0)	83 (50)	8.1 (3.6, 22.0)
6[a]	8/19/91–9/30/91	Treatment	104 (61)	9.7 (4.2, 19.7)	99 (59)	9.7 (4.2, 19.8)
		Control	83 (50)	8.4 (3.5, 21.2)	83 (50)	8.4 (3.5, 21.2)

Note. Two subsets of study data were used. The first subset represented all children sampled throughout the study (513 children living in 299 properties), and the second subset represented children who completed the study protocol and were present for the last 3 rounds of sampling (182 children living in 121 properties). Confidence intervals (CIs) were constructed via the observed 5th and 95th percentiles of the empirical distribution of children's blood lead concentrations for each study group during each round of sampling.
[a]Intervention.

TABLE 2—Parameter Estimates for the Effects of Study Group on Blood Lead Both Preintervention and Postintervention, as Estimated With Covariate Adjusted and Unadjusted Longitudinal Models

Parameter and Contrast of Interest	Total Effect (Unadjusted for Covariates) Estimate (SE)	Covariate Adjusted Effect Estimate (SE)
Treatment group: preintervention	2.38 (0.050)	2.47 (0.113)
Control group: preintervention	2.25 (0.055)	2.38 (0.122)
Treatment group: postintervention	2.24 (0.050)	2.44 (0.120)
Control group: postintervention	2.08 (0.055)	2.30 (0.129)
Contrast 1: treatment group (preintervention – postintervention)	0.135 (0.027)	0.030 (0.034)
Contrast 2: control group (preintervention – postintervention)	0.173 (0.029)	0.075 (0.036)
Contrast 3: treatment (preintervention – postintervention) – control (preintervention – postintervention)	–0.038 (0.040)	–0.045 (0.037)

Note. Estimates are based on a longitudinal model applied to a sample of 182 children living in 121 houses who completed the study protocol and were present for the last 3 rounds of sampling. The covariate adjusted model accounted for the effects of time, seasonality, socioeconomic status, age, and mouthing behavior. Contrasts 1 and 2 represent the reduction in the natural log transformed from preintervention to postintervention for the treatment and control groups, respectively. Contrast 3 represents the difference between contrasts 1 and 2 (the difference in [preintervention – postintervention] reductions attributable to the soil abatement procedure in the treatment group).

Why, then, was this hypothesis not substantiated? First, soil lead concentrations were lower than anticipated (mean of trimean = 564 ppm). A 1983 study[8] of lead in Baltimore garden soil found levels around 10 000 ppm. In this study, 98% of the soil samples had lead trimeans of 1500 ppm or lower. Published data from the Boston study, where baseline soil lead was about 2000 ppm, revealed that lowering the median soil lead level by 1790 ppm was associated with a decrease in blood lead levels of only 0.04 to 0.08 μmol/L (0.8–1.6 μg/dL). The authors concluded that soil lead abatement was unlikely to be a useful intervention in most US urban areas.[9] A more recent report suggests average blood lead reductions of 2.5 μg/dL in selected subsamples.[10]

The present study was conducted in neighborhoods where paints constitute the primary lead source. The study addressed whether an intervention interrupting a single pathway (i.e., soil) for transport of lead to children would be effective alone. Other pathways, such as indoor dust, are important as well. It was recognized that loose exterior paint would recontaminate soil; thus, such situations were stabilized. Interior paint and furnishings were not mitigated. Among toddlers who are indoors most of their time, household dust is considered the final common pathway for paint or soil lead to blood.[11] In addition, abatement was not conducted on adjacent properties as originally intended. Furthermore, the reduction in soil lead was not sustained. Reaccumulation occurred, suggesting that soil abatement on isolated properties may waste resources.

The Society for Environmental Geochemistry and Health has recognized that many factors may affect the bioavailabiity of lead in soil. In preparing guidelines on the subject, the society realized that no single soil lead–blood lead ratio is applicable in all situations.[12] It thus recommended that soil lead issues be evaluated on a site-specific basis.

In urban areas such as Baltimore, abatement of soil at moderate lead levels in individual noncontiguous properties appears inefficacious. Soil abatement is clearly less important than addressing the problem of lead-based paint in this setting. However, as the Boston study showed, soil abatement may be useful where soil lead levels are higher.[9] □

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