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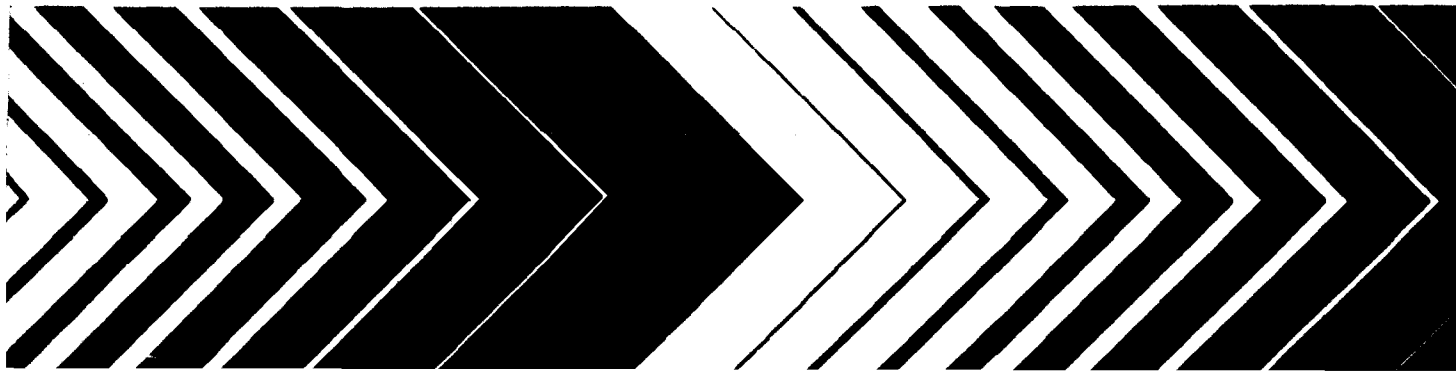
Urban Soil Lead Abatement Demonstration Project

Review Draft (Do Not Cite or Quote)

Volume II: Part 1
Boston Report

Notice

This document is a preliminary draft. It has not been formally released by EPA and should not at this stage be construed to represent Agency policy. It is being circulated for comment on its technical accuracy and policy implications.



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Environmental Criteria and Assessment Office
Office of Health and Environmental Assessment
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Research Triangle Park, NC 27711

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ACKNOWLEDGMENTS

This project was successfully accomplished only through the hard work and dedication of many people working together towards a common goal—to take an important step in reducing the insidious impact of lead contamination on children. The project could not have been completed without their focused drive. Listed below are the people from Region I, external to the Lead Free Kids staff, who had major roles in bringing this about. Thanks to them and to the many others, including the many unnamed contributors in Region I, and those from EPA Headquarters, Research Triangle Park, EMSL, and CDC, who contributed to this difficult endeavor.

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1. EXECUTIVE SUMMARY

Perceptions of the child lead poisoning problem have steadily changed as evidence has accumulated demonstrating subtle but serious consequences of lead exposure levels previously believed to be innocuous. Whereas concern 25 years ago was directed at symptomatic children with blood lead levels of 60 μg/dL and above, the Centers for Disease Control recently redefined lead poisoning as a blood lead level greater than 10 μg/dL. It is estimated that in 1984 17% of all children in the United States aged six months to five years had blood lead levels of 15 μg/dL or greater and that in many cities as many as 35-50% have blood lead levels in excess of 10 μg/dL. There is currently no lead level believed to be safe for children.

Children have multiple potential sources of lead exposure. The most important recognized sources include lead contaminated paint, dust, and water. Paint used on both interior and exterior surfaces of houses through the 1950's and continuing, to some extent through much of the 1970's, often contained high concentrations of lead. Dust is now recognized as a major vector by which children are exposed to lead via normal hand-to-mouth activities. Lead in house dust derives, in part, from deteriorating lead based paint within the house, and in part from lead contaminated soil and dust from areas outside the home. Children may also ingest lead from pottery, canned foods, and numerous other sources, although these are generally viewed as minor sources of exposure for most children.

Concern has been raised recently that lead contaminated soil in older urban areas is another important vector for children's exposure to lead. The sources of soil contamination include deteriorated exterior paint, past deposition of airborne lead from gasoline, and point sources such as smelters, incinerators, and other industrial activities. At present lead contaminated soil is neither regularly removed as part of a comprehensive strategy to prevent childhood lead poisoning, nor removed as part of environmental interventions on behalf of children who have already suffered excessive exposure. In part, this is due to the lack of data demonstrating the effectiveness of lead contaminated soil abatement.

There is general agreement that children's exposure to lead should be reduced as much as possible and that there is an urgent need to develop practical means for the prevention and

treatment of low level lead exposure. In 1986 the reauthorization of the Superfund toxic waste cleanup program (SARA) included a provision providing funds for projects to evaluate the impact of residential lead contaminated soil abatement on children's blood lead levels. Boston was chosen to implement one of these projects; Baltimore and Cincinnati are the sites of the other two projects.

This report describes the randomized environmental intervention study conducted in Boston to determine the effect of removing lead contaminated soil on children's blood lead levels. The study was designed to test the following hypothesis:

> A reduction of 1,000 PPM or more of lead in soil accessible to children will result in a mean decrease of at least 3 μg/dL in the blood lead levels of urban preschool children living in areas with high soil lead levels, multiple potential sources of lead exposure, and a high incidence of lead poisoning.

The report also describes the range of costs associated with lead contaminated soil, dust, and paint abatement and practical issues that arose during these abatement activities.

The study was conducted by investigators from the Boston University Schools of Medicine and Public Health, the Harvard School of Medicine, and the Boston Department of Health and Hospitals with full approval of the Human Studies Committee of the Trustees of Health and Hospitals of the City of Boston and in conjunction with the United States EPA (Region I, and Research Triangle Park which is coordinating the Three-City Study).

1.1 LEAD POISONING AND LEAD CONTAMINATED SOIL IN BOSTON

As in many cities in the United States, childhood lead poisoning is a common problem in Boston. It has been estimated that approximately 24% of Boston children 6 months to 5 years of age have blood lead levels greater than 15 μg/dL and 69% have blood lead levels greater than 10 μg/dL. While occurring throughout most of the City, most of the lead poisoning cases are concentrated within very limited geographic areas. Thirty percent of all cases in the City between October 1979 and February 1985 occurred among the 4% of preschool children who resided in 28 areas encompassing two-three city blocks. In these areas more than one of every four children was poisoned during this period. Whereas the

average surface soil lead concentration in Boston is approximately 600 PPM, the surface soil lead level in these areas averaged more than 3,000 PPM in tests done before the start of our study.

1.2 IDENTIFICATION AND ENROLLMENT OF STUDY POPULATION

The study population was drawn from children living in and around the areas described above who were under four years of age on August 1, 1989 and had finger stick blood lead levels of 10-20 μg/dL determined as part of the screening efforts of the Boston Childhood Lead Poisoning Prevention Program between January and June 1989. Additional children up to four years of age who lived on the same premises as these children were also identified for enrollment. Homes of potential participants were visited by study staff to determine if they met the following additional eligibility criteria: the cumulative amount of chipping or peeling paint did not exceed 30% of the total surface area on the exterior walls of the child's home or exceed 40% on the walls of abutting premises (these percentages were determined by visual inspection); premises had a yard of at least ten square feet composed of dirt and/or grass that was accessible to the child; the mean or median surface soil lead level was 1,500 PPM or greater; the child resided in a dwelling with eight or fewer residential units, was mobile, and had never been lead poisoned; and the family resided on premises for at least three months and had no plans to move within the three months of enrollment.

All children meeting these criteria had venous blood lead determinations beginning in August, 1989 and those with lead levels between 7 and 24 μg/dL were enrolled. The baseline venous lead levels were obtained prior to any environmental abatement activities. Children with blood lead levels above 24 μg/dL were excluded because they met the former definition of lead poisoning and were likely to undergo medical and environmental interventions that could obscure any changes associated with the study interventions. All these children were referred to the Boston Childhood Lead Poisoning Prevention Program and followed according to Massachusetts state law and lead program case management protocols.

Informed consent for participation was obtained both from the parents and landlord. One hundred and fifty two children were enrolled in the study. Participants were randomly assigned to one of three groups: 54 in the Study Group, 51 in Control Group A, and 47 in Control Group B. The Study Group received loose interior paint removal, interior dust abatement, and soil abatement. Control Group A received loose interior paint removal and interior dust abatement. Control Group B received only loose interior paint removal. Several study groups were employed to enable separation of the effects of soil and interior dust abatement. Children who moved during the study were traced and whenever possible, interviews and blood, handwipe, and environmental samples were obtained at both the new and original residence according to the study schedule.

1.3 ENVIRONMENTAL MEASUREMENTS

1.3.1 Soil

Soil sampling was conducted to determine eligibility of properties, characterize the potential exposure of participants to lead from the soil, document lead levels after abatement and monitor the rate of recontamination after abatement. A detailed protocol for soil sampling and analysis was developed in conjunction with the EPA. After enrollment, approximately eight composite surface and eight core samples at a depth of 15 cm were taken at each property. Post abatement and recontamination assessment samples were taken at every other previously sampled location. Soil samples were analyzed by x-ray fluorescence by the EPA Region I Laboratory.

1.3.2 Dust

Household dust sampling was conducted to characterize the potential exposure of children to lead from dust, to document the reduction in dust lead levels following abatement, and to monitor rates of recontamination after abatement. Dust on upfacing surfaces believed most accessible to the child was sampled. Six-seven samples in each household were obtained from the following locations: entry floor, and the window wells and floors from the kitchen, living room, and child's bedroom. Both the lead concentration in the dust and the amount of dust per unit area (loading) were determined. A detailed

protocol for dust sampling and quality assurance plan for the sampling and analysis of soil and dust was developed by Region I of the EPA.

1.3.3 Water

Two water samples were taken during the course of the study. Each was a first flush sample taken by the parent from the cold water faucet in the kitchen. Water samples were analyzed by a private laboratory. Water lead sampling and analysis was conducted according to the standard EPA protocol.

1.3.4 Paint

In the second year of the study (1990) portable x-ray fluorescence analyzers (PGT XK-3) were used to identify lead in paint. Measurements were taken in the child's bedroom, kitchen, and living room. One measurement was taken on the lower part of the wall and one was taken on the window sill in each room according to a detailed protocol for lead paint inspection.

1.4 CHILD AND FAMILY MEASURES

1.4.1 Social and Behavioral Questionnaire

Questionnaires were administered to parents to ascertain family demographic characteristics and possible sources of lead exposure, to obtain information about renovations, and to characterize children's exposure to lead in soil. Follow-up interviews were conducted toward the end of the study to assess changes in child behavior, house cleaning and new renovations.

1.5 OUTCOME MEASURES

1.5.1 Blood Samples

Venous samples were obtained to determine blood lead levels on three occasions: the first was taken prior to any abatement activities, the second an average of six months after

abatement activities, and the third an average of 11 months post-abatement. Serum ferritin levels were obtained at baseline. Blood lead levels were determined using graphite furnace atomic absorption and FEP levels were determined using a zinc protoporphyrin hematofluorometer. The detection limit was 1 μg/dL for blood lead, and a total method coefficient of variation was 13.8% at the 10 μg/dL blood lead level. The laboratory maintained a strict internal quality control system for the blood lead analyses. In addition, the laboratory participated in the external quality control system developed and overseen by the Centers for Disease Control.

1.5.2 Hand Lead Determinations

Handwipe samples were obtained each time blood samples were drawn. Parents were asked not to wash the child's hands for the two hours immediately preceding sampling. Wearing disposable gloves, a study staff member wiped all surfaces of each hand, front and back up to the wrist, with three commercial wetwipes. To assess the extent of any contamination during sampling, field blanks consisting of six additional wipes were handled so as to simulate wiping the child's hands, and set aside to determine the background wetwipe lead levels. Field blanks were taken for every tenth child. Each set of six wetwipes was composited for chemical analysis and extraction of the lead utilized 1N hot HNO_3. The total quantity of lead was reported in μg per pair of hands.

1.5.3 Environmental Interventions

The purpose of the soil abatement was to remove lead contaminated soil accessible to the children living on the premises. A six inch layer of topsoil was removed and replaced with 8 inches of clean topsoil. A water permeable geotextile fabric barrier was laid directly on top of the exposed subsurface immediately following removal of topsoil and prior to placement of clean topsoil, so as to protect against recontamination by the subsurface soil. The lead content of the surface soil was tested and then covered with sod, grass seed, bark, or mulch. The abated lots ranged from 12 to 702 square meters, and 3-182 cubic yards of soil were removed per lot. Soil disposal was accomplished in accordance with guidelines developed in conjunction with the Massachusetts Department of Environmental Protection.

Lead contaminated soil was removed to a location with limited access - a quarry abutting a cemetery in Boston.

The purpose of loose paint abatement was to minimize lead based paint as a potential source of children's exposure during the study period by removing loose chipping paint from the inside of the home. Loose paint abatement consisted of vacuuming the loose paint areas with HEPA (High Efficiency Particulate Aerosol Filter) vacuums, washing loose paint areas with a trisodium phosphate and water solution, and painting the window wells with primer.

The purpose of the interior dust abatement was to significantly reduce the amount of lead bearing dust in the treated homes. It consisted of HEPA vacuuming and wiping surfaces with a wet cloth, or for furniture, with an oil treated rag. Floors, including carpeted areas, woodwork, walls, and furniture surfaces were cleaned.

1.6 ANALYSIS

First, crude analyses were conducted of the change from baseline blood lead levels to the first and second post-abatement blood lead levels. Analysis of variance was used to compare mean blood lead changes among the intervention groups and paired t-tests were used to determine whether the mean changes in blood lead levels within an intervention group were significantly different from zero.

Analysis of covariance was used to compare the intervention groups with respect to post-abatement blood lead levels adjusted for pre-abatement levels. The post-abatement blood lead levels were reasonably normally distributed and did not require any transformations. The base model that was used to obtain estimates of adjusted post-abatement blood lead means in the intervention groups was:

$$Y_i = b_0 + b_1 Z_{1i} + b_2 Z_{2i} + b_3 X_i + e_i$$

where for the ith child,

Y_i = post-abatement blood lead level

Z_{1i} = 1 if in Control Group A, otherwise 0

Z_{2i} = 1 if in Control Group B, otherwise 0

X_i = pre-abatement blood lead

e_i = error term

The coefficients, b_0, b_1, b_2, and b_3 were estimated using least squares methods, and t-tests were used to test the null hypothesis that b_1 and b_2 were equal to zero.

Potential confounders of the relationship between group assignment and post-abatement blood lead were added to the base model one at a time to obtain adjusted estimates of the group effect adjusted for baseline blood lead level and the potential confounder. More complex models that controlled for several variables simultaneously were also developed. Potential confounders included age, sex, race, socioeconomic status as measured by the Hollingshead Index, mouthing behaviors, and environmental sources of lead (e.g., paint and water). In most instances, the variables were categorized; cutoffs were based on the frequency distribution of the particular variable or on external considerations.

1.7 RESULTS

Only three of the 152 (2%) children enrolled dropped out before completion of the study. Another 22 (14.5%) moved from their original premises but were followed. Baseline characteristics of children in the three groups were similar in most respects. The average age of children was similar across groups, as was the proportion of subjects in the lowest socioeconomic level according to the Hollingshead Index (Classes 4-5). However, the mean pre-abatement blood lead level was higher among children assigned to the Study Group. The proportion of Hispanics was higher in the Study Group than the Control Groups and the proportion of Blacks was lower. There was also a larger proportion of males in the Study Group. Median surface soil lead levels were, on average, about 800 PPM higher than those taken at a depth of 15 centimeters.

Median interior floor dust lead levels were similar to the median surface soil levels and median window well dust lead levels were five to seven times higher. The soil and floor dust lead levels were similar across the intervention groups. Window well dust lead levels were more variable across the groups but the differences were not statistically stable. Median first flush tap water lead levels were all above 14 μg/dL and were similar across groups. Lead-based paint was detected in almost all participants' homes and XRF readings on the walls and woodwork were similar among the groups.

1.7.1 Blood Lead Levels

1.7.1.1 Crude Analyses

Mean blood lead levels in all the three groups declined at the first post-abatement sampling round (POST1) and rose at the second post-abatement sampling round (POST2) although for no group did the mean return to the baseline. At POST1 the average blood lead decline was 2.87 μg/dL in the Study Group, 3.52 μg/dL in Control Group A, and 2.04 μg/dL in Control Group B. All declines were significantly different from zero. Between POST1 and POST2 the average blood lead level increased 1.39 μg/dL in the Study Group, 2.69 μg/dL in Control Group A and 1.52 μg/dL in Control Group B. The increases in the two Control Groups were significantly different from zero but the increase in the Study Group was not ($p=.08$).

Two siblings in the Study Group became lead poisoned sometime between the POST1 and POST2 sampling rounds. Their blood lead levels were 19 μg/dL and 12 μg/dL at baseline (PRE) (September 1989), 10 μg/dL and 17 μg/dL, respectively, at POST1 (March 1990) and 35 μg/dL and 43 μg/dL, respectively, at POST2 (July 1990). No other children experienced a blood lead rise of this magnitude during the study. In fact, these two children's POST2 blood lead levels were more than three standard deviations higher than the overall mean POST2 level. The increases were believed to be unrelated to the study interventions since the elevated levels were detected many months after the abatement activities and the siblings were exposed to leaded paint at another site that was being renovated. Therefore, these two children were excluded from subsequent analyses. Without these children, the mean blood lead level in the Study Group increased by only 0.46 μg/dL between POST1 and POST2.

Because the PRE and POST2 sampling rounds are most closely matched on season, subsequent analyses focused on this comparison. The mean decline in blood lead was 2.44 μg/dL in the Study Group ($p=0.001$), 0.91 μg/dL in Control Group A ($p=0.04$) and 0.52 μg/dL in Control Group B ($p=0.31$). The mean blood lead level of the Study Group declined 1.53 μg/dL more than that of Control Group A (95% Confidence Interval: - 2.87, - 0.19) and 1.92 μg/dL more than that of Control Group B (95% Confidence Interval: - 3.28, - 0.56). The magnitude of the decline in blood lead associated with soil abatement was independent of a child's baseline blood lead level.

1.7.2 Adjusted Analyses

Potential confounding variables were added to the base model one at a time to obtain adjusted estimates of the group effect. The POST2 blood lead levels adjusted for baseline level were generally similar to crude levels. The adjusted mean difference between the Study and Control Groups were slightly diminished but remained statistically significant. The differences between the Study Group and Control Groups A and B were - 1.28 (p=.02) and - 1.49 (p=.01), respectively. Group assignment was a significant predictor of POST2 blood lead levels (p=0.02).

The results were also similar when the analysis included only children who lived on the study premises for at least 300 days after the pre-abatement blood lead test thereby eliminating children who moved during the follow-up period. Here, the differences between the Study Group and Control Groups A and B were - 1.42 (p=.02) and - 1.49 (p=.02), respectively.

The results were also quite similar when age, sex, socioeconomic status, ferritin levels, mouthing and handwashing behaviors, spending time away from home, spending time outside the study area, playing in the yard, eating food outdoors, sitting on the floor inside the home, eating canned foods including those imported from foreign countries, lead related jobs and hobbies and cigarette smoking among household residents, living in owner occupied premises, the presence of chipping paint, the presence of pets that go outdoors, and tap water lead levels were added to the base model one at a time. When the paint lead variables were added, differences between the Study and Control Groups were somewhat diminished (-1.19 and - 1.34 μg/dL for Control Groups A and B, respectively) and the group effect was borderline significant (p=0.06). When race was added to the base model, differences were also diminished (- 0.92 and - 1.26 μg/dL) and the group effect was not statistically significant (p=0.09). However, no statistically significant differences in crude or adjusted POST2 blood lead levels were seen among Study Group children of different races.

No "dose-response" relationship was observed between the mean change in blood lead level and the starting soil lead level or the size of the excavated area. POST2 abatement blood lead levels were quite similar for children in the lowest and highest pre-abatement soil lead categories and the smallest and largest excavated yard areas. The lack of a trend should be evaluated in light of the study eligibility criteria that restricted the soil and blood lead

ranges. Only six children in the Study Group had median pre-abatement soil lead levels that were less than 1,000 PPM, and pre-abatement blood lead levels were restricted to 7 through 24 μg/dL.

Exploratory multivariate analyses were also conducted to control simultaneously for several potential confounding variables. Two variable selection methods were used. First, a backward elimination procedure identified variables that were statistically significant predictors of POST2 blood lead levels. When Pre-Pb, age, race, and lead jobs were controlled simultaneously the adjusted POST2 blood lead levels were 10.36, 11.26, and 11.66 μg/dL for Groups S, A, and B, respectively, and the adjusted differences between the Study Group and Control Groups A and B were 0.90 and 1.31 μg/dL, respectively. The overall group effect was not statistically significant (p=.08).

Second, a potential confounding variable was selected for the multivariate model if its inclusion in the base model altered the magnitude of difference between the Study Group and either Control Group by more than 10%. The variables identified by this criterion were race, socioeconomic status, and playing or sitting on the floor. In a model controlling these variables and Pre-Pb, the adjusted differences between the Study Group and Control Groups A and B were 0.80 and 1.21 μg/dL, respectively. The overall group effect was not statistically significant (p=.16).

1.7.3 Handwipe Lead Levels

Because the handwipe field blank lead levels varied considerably and were not individually matched to the participants, background levels were taken into account by subtracting the maximum or median field blank level for each sampling round. When the maximum level was subtracted, the mean hand lead level in all groups declined from the pre-abatement to the first post-abatement sampling round. The mean hand lead level in the Study Group changed little at the second post-abatement sampling round while it increased in the Control Groups. When the median level was subtracted, the mean hand lead level in the Study Group declined at the first and second post-abatement sampling rounds. The mean hand lead levels in the two Control Groups first declined and then rose to a level higher than baseline.

Because the PRE and POST2 sampling rounds are most closely matched on season, we focused subsequent analyses on this comparison. When the maximum blank level was subtracted, the mean hand lead level decreased by 3.61 μg in the Study Group (p=.02), 0.99 μg in Control Group A (p=.69), and 0.36 μg in Control Group B (p=.85). When the median blank lead level was subtracted the mean hand lead levels declined by 2.75 μg in the Study Group (p=.08), and 0.68 in Control Group A (p=.79) and increased by 0.76 in Control Group B (p=.72).

When the POST2 hand lead levels were adjusted for baseline level the mean differences between the Study Group and the two Control Groups were diminished; the magnitude of the reduction was greater for the Control Group A comparison. Group assignment was not, however, a significant predictor of POST2 hand lead levels (p values were .48 and .43, respectively).

1.8 CONCLUSION

One of the most difficult aspects of the childhood lead problem is identifying the sources of lead and determining their relative contribution to children's lead burden. Lead based paint and household dust have received most of the attention to date. Far less attention has been paid to urban outdoor sources of lead, especially soil, except in cases of stationary sources such as smelters. Our findings suggest that lead contaminated soil does contribute to the blood lead levels of urban children.

Numerous previous studies have shown that soil and dust lead levels are correlated with children's blood lead levels. These studies have relied largely on cross-sectional data, often from communities with point sources of lead such as smelters, where soil lead concentrations are far greater than those typically found in urban settings. The current study found that soil abatement alone (Study vs. Control Group A) was associated with a 0.8 to 1.4 μg/dL decline in blood lead levels and that soil and interior dust abatement combined (Study Group vs. Control Group B) was associated with a 1.2 to 1.6 μg/dL decline. These blood lead changes were observed approximately one year following soil abatement in which surface soil lead levels were dropped an average of 1,856 PPM.

Although designed and conducted to produce rigorous results, the study has several limitations. Participants were chosen to be representative of the population of urban preschool children who are at risk of lead exposure by using the Boston Childhood Lead Poisoning Prevention Program to identify potential participants from neighborhoods with the highest rates of lead poisoning and by using as wide a range of blood lead levels as was practical. Since no study subjects had blood lead levels below 7 μg/dL or in excess of 24 μg/dL at baseline, the study provides no information about the effect of lead contaminated soil abatement for children with these lead levels. Similarly, a different effect might have been found for children who had a greater blood lead contribution from soil, such as in communities with smelters or other stationary sources where soil lead levels are substantially higher than those seen in this study, or where differences in particle size result in differences in bioavailability.

There are little data available about rates of change in children's blood lead levels following a change in exposure to a potential source of lead. It is possible that the intervention would have been associated with a greater reduction in children's blood lead levels had they been followed for a longer period of time. In addition, all children in the study were exposed to lead contaminated soil prior to enrollment and so we are unable to investigate whether exposure to lead contaminated soil in the first year of life is associated with higher blood lead levels. Lastly, the unit of abatement was the single premises rather than clusters of premises. It is possible that the effect of lead contaminated soil abatement on children's blood lead levels would have been greater had we also removed lead contaminated soil from properties that surrounded Study Group children's premises.

In conclusion, this intervention study suggests that an average 1,856 PPM reduction in soil lead levels results in a 0.8-1.6 μg/dL reduction in the blood lead levels of urban children with multiple potential sources of exposure to lead.

This study provides information about soil abatement as a secondary prevention strategy, that is the benefit to children already exposed to lead derived, in part, from contaminated soil. It can not be used to estimate the primary prevention effect of soil abatement. Since children's post-abatement blood lead levels reflect both recent exposure and body burdens from past exposure, the benefit observed is probably less than the primary

prevention benefit, that is the benefit of abating lead contaminated soil before children are exposed to it so as to prevent increases in blood levels and body stores.

Soil lead tends to be concentrated at the surface and it is not rapidly removed by natural processes. Once soil is contaminated with lead, it is likely to remain contaminated indefinitely. In the future, soil is likely to become one of children's most intense sources of lead as the current housing stock, 52% of which is estimated to have dangerous concentrations of lead paint, ages and is replaced. Lead contaminated soil abatement may well result in long-term reductions in environmental lead so that multiple future generations of children benefit as they move onto abated properties. This thesis is currently untested, however, and must be validated by monitoring abated properties for rates of reaccumulation of lead.

1.9 IMPLICATIONS

Soil abatement in this study was associated with an approximately 0.8-1.6 μg/dL reduction in children's blood lead levels, slightly less than what was originally hypothesized. The clinical and public health implications of a reduction of this magnitude are not readily apparent. The magnitude of reduction in blood lead observed suggests that lead contaminated soil abatement may not be a particularly useful clinical intervention for children with low level lead exposure. It might be extremely useful, however, in specific situations, such as if soil lead were extremely high or the particular child had pica for soil. It is also a relatively inexpensive and low technology intervention. Although there are no data regarding the relative safety of soil and lead based paint abatement, it seems unlikely that soil abatement is as dangerous to children, families, and workers as lead based paint abatement can be.

Although the average benefit associated with abatement of lead-contaminated soil is modest in this study, the societal impact may be substantial. Consider, for example, the impact on the blood lead distribution of an average decline of 1 or 2 μg/dL in the mean blood lead level of a population of children assuming a starting mean blood lead level of 12 μg/dL, a standard deviation of 4, and a normal distribution. We also assume that the amount of change (as opposed to the percentage of change) is constant for all starting values, as we observed in our own sample in which the distribution of starting values was truncated.

Specifically, this assumption may not apply to children with starting blood lead values greater than 25 μg/dL. A decline of 2 μg/dL in the mean blood lead level results in 72% as many children with levels exceeding 10 μg/dL, 47% as many children with levels exceeding 15 μg/dL, and 26% as many children with levels exceeding 20 μg/dL (values of 10, 15, and 20 μg/dL were chosen because they correspond to the new CDC definition of lead poisoning and the new action levels for environmental and medical intervention, respectively). Even a 1 μg/dL decline in mean blood lead level results in 87%, 70%, and 52% as many children with levels of 10, 15, and 20 μg/dL, respectively. The percentage shifts may differ somewhat in a more representative sample in which the distribution of starting values is likely to be log normal.

Policy decisions regarding urban lead contaminated soil abatement as a lead control strategy will require numerous considerations. For example, are other types of remediation (e.g. planting grass cover and shrubs) equally effective but less expensive and intrusive? How does the cost effectiveness of soil abatement compare to other lead exposure reduction activities, such as paint abatement? Will it be practical to perform large scale abatements without encountering problems regarding the disposal of lead contaminated soil? Will future research help specify whether changes in children's blood lead levels of the magnitude seen in this study are clinically relevant or prudent from a public health or societal perspective? And will we develop and sustain the resolve and commit the resources needed to prevent what remains the most important environmental health problem of children in the United States?

2. BACKGROUND

Perceptions of the child lead poisoning problem have steadily changed as evidence has accrued demonstrating subtle but serious metabolic and developmental consequences of lead exposure levels previously believed to be innocuous.[1,2] Childhood lead poisoning was initially perceived as a disease (often presenting as encephalopathy and sometimes resulting in seizures, coma, or death) associated with the ingestion of peeling lead paint. Over the past two decades, as scientific evidence has consistently revealed deleterious effects at lower and lower lead levels, regulatory agencies have reduced the acknowledged level of children's lead burden requiring environmental and medical intervention and clinical guidelines have been revised accordingly. Whereas concern was initially directed at symptomatic children with blood lead levels of 60 μg/dL and above, lead poisoning is currently defined by the Centers for Disease Control (CDC) as a blood lead level of 10 μg/dL or greater.[3] The Agency for Toxic Substances and Disease Registry estimates that approximately 17% of all children in the United States aged six months to five years have blood lead levels of 15 μg/dL or greater.[4] There is currently no lead level believed to be safe for children.

Children are exposed to lead from multiple sources.[4-10] The most important sources include lead contaminated paint, dust, soil, and water. Paint used on both the interior and exterior of houses through the 1950's and continuing, to some extent through the 1970's, often contained high concentrations of lead.[11] It is estimated that 42 million homes in the United States, or approximately 52% of all housing units, contain paint with more than 0.7 mg/cm sq. of lead.[4] This enormous reservoir of lead, estimated to represent more than three million tons, is easily accessible to young children.

More recently, concern has been raised that lead contaminated soil in older urban areas is another important vector for children's exposure to lead.[4,12,13] The sources of soil contamination include lead paint chips from deteriorated exterior paint, past deposition of airborne lead from gasoline, and point sources such as smelters and other industrial activities.

House dust is, in part, composed of soil[10,14] and can therefore be contaminated by exterior lead sources. Other sources of house dust lead may be deteriorating lead based paint

from furnishings or interior walls.[6,8,15] Drinking water may contain high concentrations of lead from old pipes or leaded solder. Children may also ingest lead from pottery and canned foods although this is generally viewed as a minor contributor to exposure for most children.[4]

There is a general consensus that children's exposure to lead should be reduced as much as possible.[4,16] With clear and growing evidence of long-term adverse cognitive and behavioral deficits associated with levels of lead as low as 10 μg/dL,[1,4] increasing numbers of authorities have argued that there is an urgent need to develop practical and cost effective approaches for the prevention and treatment of low level lead exposure.[4,11,17] It was in response to this mandate that the Boston Lead-In-Soil/Lead Free Kids Demonstration Project was conducted. The study was designed to provide scientifically rigorous data about the effectiveness of lead contaminated soil abatement in lowering children's blood lead levels, the cost of removing lead contaminated soil, and a number of related questions relevant to policymakers, public health officials, child advocates, and clinicians.

2.1 LEAD POISONING IN BOSTON

As in many U.S. cities, childhood lead poisoning is a widespread problem in Boston. Children between the ages of nine months to six years are at greatest risk because they have a high degree of hand-to-mouth activity, they absorb ingested lead more efficiently, and because of the heightened vulnerability of their developing nervous systems to lead toxicity. In recent years in Boston, the rate of identified lead poisoned children in this age group ranged from 1.5% and 2.0%, on the basis of pre-1991 CDC guidelines (i.e., blood lead level greater than 25 μg/dL).

In order to identify the areas in Boston with the highest rates of childhood lead poisoning, the Boston Department of Health and Hospitals' Office of Environmental Affairs mapped all children in Boston identified as lead poisoned between October 1979 and February 1985. These efforts demonstrated that lead poisoning in Boston, while occurring throughout most of the City, was, to a surprising degree, concentrated within very limited geographic areas.[18] It showed that four high prevalence neighborhoods accounted for 87% of the city's lead poisoned children but only 56% of the at-risk (nine months to six year old)

population. It also showed that children living in 28 2-3 city block areas produced nearly 30% of Boston's child lead poisoning cases despite accounting for only 4% of the child population aged nine months to six years. In each of these small areas, designated Emergency Lead Poisoning Areas (ELPAs), an average of more than 30 children were lead poisoned. This represents more than one of every four children.

2.2 CONTAMINATED SOIL IN BOSTON

The soil in Boston is contaminated by lead-based paint which has weathered or been scraped off the exterior of buildings and by the deposition of lead in gasoline exhaust.

Scientific studies that correlate increases in blood lead levels with exposure levels have not shown a significant contribution by exposure to soil with less than 500 parts per million (PPM) lead. These studies have suggested that soil lead levels of 500-1,000 PPM can significantly contribute to children's lead burdens, although other factors such as particle size, distribution and lead species are important.[4,10,13,19-21] At present, however, lead contaminated soil is regularly not removed either as part of a comprehensive strategy to prevent childhood lead poisoning, or an environmental intervention on behalf of children who already have suffered excessive exposure. In part, this may be due to the lack of data demonstrating the effectiveness of lead contaminated soil abatement. In the ELPA's described above the surface soil lead level averaged more than 3,000 PPM, or 3-6 times the "acceptable level" established by the CDC.[3,18] Testing at numerous sites throughout Boston has revealed much lower average lead levels of 600-700 PPM.

In October, 1986 the reauthorization of the Superfund toxic waste cleanup program (SARA) was signed into law. Included in the bill was a provision, Section 111 (a) (6), providing funds for "a pilot program for removal, decontamination, or other action with respect to lead-contaminated soil in one to three different metropolitan areas." Boston was chosen to implement the first of the projects.

The EPA convened two workshops of lead experts to provide consultation on the design of the study. The first workshop was held in April, 1987 in Raleigh, North Carolina. It brought together individuals with expertise in the health effects of lead exposure, epidemiology of lead toxicity, the biogeochemistry of lead, and the abatement of

environmental sources of lead. A general design and evaluation for the study was drafted at this workshop. A second workshop was held in Lexington, Massachusetts in June, 1987. It was devoted to a continuing exploration of (1) possible study designs that could provide scientifically rigorous data on the relationship between preschool children's exposure to lead contaminated soil and blood lead levels, and the effectiveness of the removal of lead contaminated soil in reducing low level lead exposure; (2) the ethical, legal, and logistical constraints on the design of any such study conducted in Boston, Massachusetts; and (3) the process by which broad-based scientific, pediatric, and public health acceptance of a scientifically sound and implementable design could be achieved.

2.3 IMPLEMENTATION

The first phase of the study ran for ten months from May 28, 1987 to March 31, 1988. It involved: (1) location and establishment of study facilities; (2) procurement of equipment and supplies; (3) recruitment of some staff; (4) examination of scientific, legal and ethical problems and issues; and (5) efforts directed at developing a study design in conjunction with EPA staff. During this phase the significant implications of the Massachusetts Lead Poisoning Prevention Law for the design and conduct of the study were explored.

In response to these issues, and in an effort to resolve related scientific and ethical issues, a small group of medical, scientific, and public health experts assumed responsibility for designing and implementing a lead contaminated soil abatement study in Boston, Massachusetts early in 1988. They were: Michael Weitzman, M.D. (Principal Investigator), Ann Aschengrau, Sc.D. (Coinvestigator), David Bellinger, Ph.D. (Coinvestigator) and Mr. Ronald Jones, B.A. (Coinvestigator).

An initial draft of a proposed study design was submitted to the Environmental Protection Agency on January 22, 1988. In May of 1988 the investigators hosted a meeting attended by Evan Charney, M.D., representatives of the Massachusetts Department of Public Health, the Conservation Law Foundation, the Centers for Disease Control, and the Environmental Protection Agency. At this meeting the investigators presented their proposed study design and two alternative designs, one by Dr. Renate Kimbrough of the Environmental Protection Agency and another by Dr. Michael Rabinowitz, then of Harvard

Medical School. The attendees unanimously endorsed and suggested ways to strengthen the study design proposed by the investigators from the Boston Lead-In-Soil Demonstration Project.

In August of 1988 a revised study design that incorporated suggestions from the May, 1988 meeting was submitted to the Environmental Protection Agency along with letters of support from participants in the May meeting. The study was given the Environmental Protection Agency's full support, contingent on the approval of the Human Studies Committee of the Trustees of Health and Hospitals of the City of Boston. In the fall of 1988 the proposal was submitted to the Human Studies Committee of the Trustees of Health and Hospitals of the City of Boston, and recruitment of staff began. In December of 1988 the full approval of the Human Studies Committee was obtained. Enrollment of study participants began in January 1989.

This document represents the final report to the Environmental Protection Agency, and as such describes in detail the study's design, implementation, problems encountered, data collection and analysis, and findings.

3. STUDY ADMINISTRATION

The study was managed by a team consisting of a Principal Investigator (Michael Weitzman, M.D.) and three Coinvestigators (Ann Aschengrau, Sc.D., David Bellinger, Ph.D., and Ronald Jones, B.A.). The day-to-day management was the responsibility of a full time study Administrator (Natalie Zaremba) and Assistant Epidemiologist (Julie Shea, MPH). An organizational chart can be found on page 23.

The study was designed to evaluate the impact of a large scale environmental intervention on the blood lead levels of a specific target population. It required a concerted effort by the U.S. Environmental Protection Agency, the Trustees of Health and Hospitals of the City of Boston, Inc., the City of Boston, and the study's investigators and staff. Responsibilities for the various aspects of the study are listed below.

THE U.S. ENVIRONMENTAL PROTECTION AGENCY:

1. Provided funding to conduct the study.
2. Designated a Project Manager from EPA Region I.
3. Assisted in the development of Protocols.
4. Provided analyses of soil and dust environmental samples.
5. Provided representatives for community meetings and other activities conducted as part of the Community Relations Plan.
6. Provided for or assisted with training and guidance in the collection of soil and dust samples.
7. Assisted the study staff in the calibration of equipment.

THE TRUSTEES OF HEALTH AND HOSPITALS:

1. Provided bookkeeping, accounting, and other fiscal services.
2. Provided personnel management services for the study.
3. Provided internal fiscal audits for the study.
4. Provided for the long-term maintenance and storage of client records and data.

THE CITY OF BOSTON:

1. Provided assurance of appropriate removal and disposal of lead contaminated soil.
2. Ensured access through rights-of-way and easement necessary to the study.
3. Provided logistical support during the soil removal phase of the study.
4. Assisted in the resolution of the soil disposal controversy.

THE STUDY'S INVESTIGATORS AND STAFF:

1. Developed study Protocols and provided for their review.
2. Developed a Community Relations Plan and provided for its implementation.
3. Provided a Management Staff to supervise all study activities except those specifically provided by the Trustees, EPA, or the City. Project Management Staff coordinated all phases of field work.
4. Acquired and maintained suitable space for an operations center and for training of study staff.
5. Acquired and maintained computerized data systems suitable for recording, storing, and analyzing data generated in the course of the study.
6. Provided for recruitment of households in areas selected for the study.
7. Prepared and printed instructions, maps, questionnaires, consent forms, and other materials to be used in the study.
8. Collected environmental samples for quality control purposes.
9. Furnished equipment and containers for soil and dust environmental samples and provided appropriate sample preparation.
10. Contracted for the laboratory analysis of blood samples and provided appropriate sample preparation.
11. Contracted for the laboratory analysis of water samples.
12. Provided personnel to conduct interviews, draw blood, collect handwipes and environmental samples, and use the XRF machine for paint lead analysis.
13. Validated all environmental data and maintained the following:
    a. Area maps used in the study;
    b. Questionnaires;
    c. Tabulation of blood lead and free erythrocyte protoporphyrin results by name, age, and address; and
    d. Forms recording lead readings by the XRF device.
14. Implemented quality assurance measures throughout the study, except for laboratory work performed by the EPA.
15. Followed standard chain-of-custody measures for all samples.
16. Provided follow-up for all study children found to be lead poisoned according to CDC guidelines.
17. Notified all parents of the results of blood and environmental tests and provided an interpretation of the results.
18. Developed and implemented a data analysis plan in conjunction with EPA and other appropriate organizations.

19. Developed and implemented a plan to secure the cooperation of community residents and property owners who were directly affected by the study but were not the parents of children participating in the study.
20. Advertised for, negotiated, and managed contracts for interior dust and loose paint abatements, soil abatement, moving, storage, and deleading.
21. Prepared draft and final study reports in conjunction with the EPA.
22. Provided necessary, authorized equipment.
23. Provided lead poisoning education, supportive services or referrals to parents of children in the study.

4. HUMAN STUDIES REVIEW

During the fall of 1988 the Boston Department of Health and Hospitals Human Studies Review Committee reviewed the proposal submitted to Region I of the Environmental Protection Agency in August, 1988 as well as all study protocols. The complex ethical, legal, and scientific concerns raised about the study in 1987 and early 1988 by the Massachusetts Department of Public Health, the legal counsels of the City of Boston and Region I of the Environmental Protection Agency were also submitted to the Human Studies Review Committee for the Committee's review. Full approval of the Human Studies Review Committee was granted in December, 1988 and Annual Reports were submitted to the Committee in December 1989 and 1990.

5. STUDY DESIGN

5.1 PURPOSE

The purpose of the Boston Lead-In-Soil Demonstration Project was to determine the effect of removing lead contaminated soil on children's blood lead levels. The hypothesis tested was:

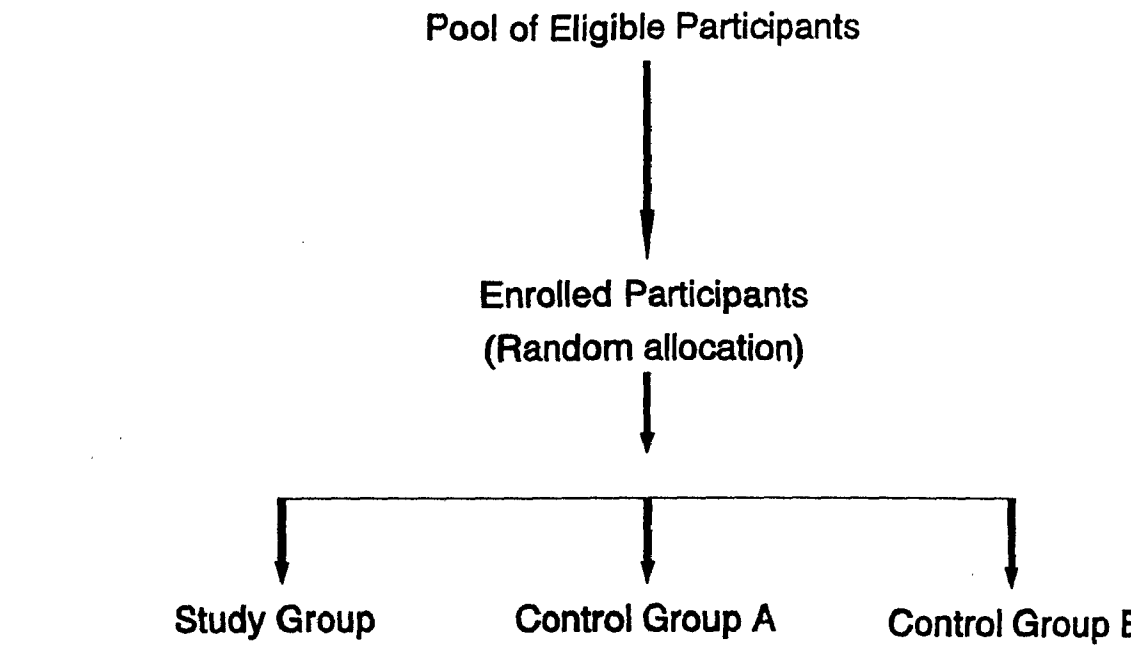
> A significant reduction (equal to or greater than 1,000 PPM) of lead in soil accessible to children will result in a mean decrease of at least 3 μg/dL in the blood lead levels of children living in areas with multiple possible sources of lead exposure and a high incidence of lead poisoning.

We were also interested in a series of related questions relevant to explicating whether lead contaminated soil is an important vector for lead exposure for children living in highly lead contaminated environments and whether soil abatement is a feasible intervention: Is the soil abatement more or less effective for certain subsets of children? Is interior dust abatement effective in reducing children's blood lead levels and how quickly and to what extent do soil and house dust become recontaminated after abatement? What is the cost of soil and dust abatement? What problems can be anticipated if lead contaminated soil abatement were widely adopted as a strategy for the primary and secondary prevention of childhood lead poisoning?

The final study design, described in detail in the following sections, is illustrated on the next page in Figure 5-1.

5.2 IDENTIFICATION OF STUDY POPULATION

The study used the ongoing city-wide screening efforts of the Boston Childhood Lead Poisoning Prevention Program (BCLPPP) to identify potential participants. The BCLPPP receives the results of capillary blood screening tests (blood lead levels and free erythrocyte protoporphyrin levels) for many of the preschool children living in Boston. The source



Year 1	Loose Paint, Dust, and Soil Abatement	Loose Paint and Dust Abatement	Loose Paint Abatement
Year 2	*	Soil Abatement, *	Soil Abatement, *

* Interior and Exterior Paint Abatement if Indicated and Desired

Figure 5-1. Study Designs.

neighborhoods of Boston who were under four years of age on August 1, 1989 who had finger stick blood lead screening tests done as part of their routine health care between January and June 1989 and whose screening levels were between 10 and 20 μg/dL. Additional children under four years of age who lived on the same premises as the BCLPPP participant during the recruitment period were also identified for possible enrollment. The map (Figure 5-2) on the following page shows the area of Boston involved in the Study.

5.3 ELIGIBILITY CRITERIA

Homes of potential study participants were visited by trained study field staff, and families and landlords were contacted to determine if potential participants met the following additional eligibility criteria:

1. The participant's parent(s) or caretaker(s) and, if applicable, landlord agreed to participate;

2. Exterior walls of premises had little or no chipping paint. On a drive-by inspection, study staff judged by visual inspection that (1) the cumulative amount of chipping paint on the exterior walls (excluding trim, but including porches) did not exceed 30% of the total surface area; and (b) the cumulative amount of exterior chipping paint on the adjacent wall of an abutting premises (including trim) did not exceed 40%.

3. Premises had a yard of at least ten square feet composed of dirt, grass or a combination thereof and was accessible to the child.

4. The child resided in a dwelling with eight or fewer residential units.

5. Average or median surface soil lead level was 1,500 PPM or greater.

6. Child was mobile

7. Child had never been lead poisoned.

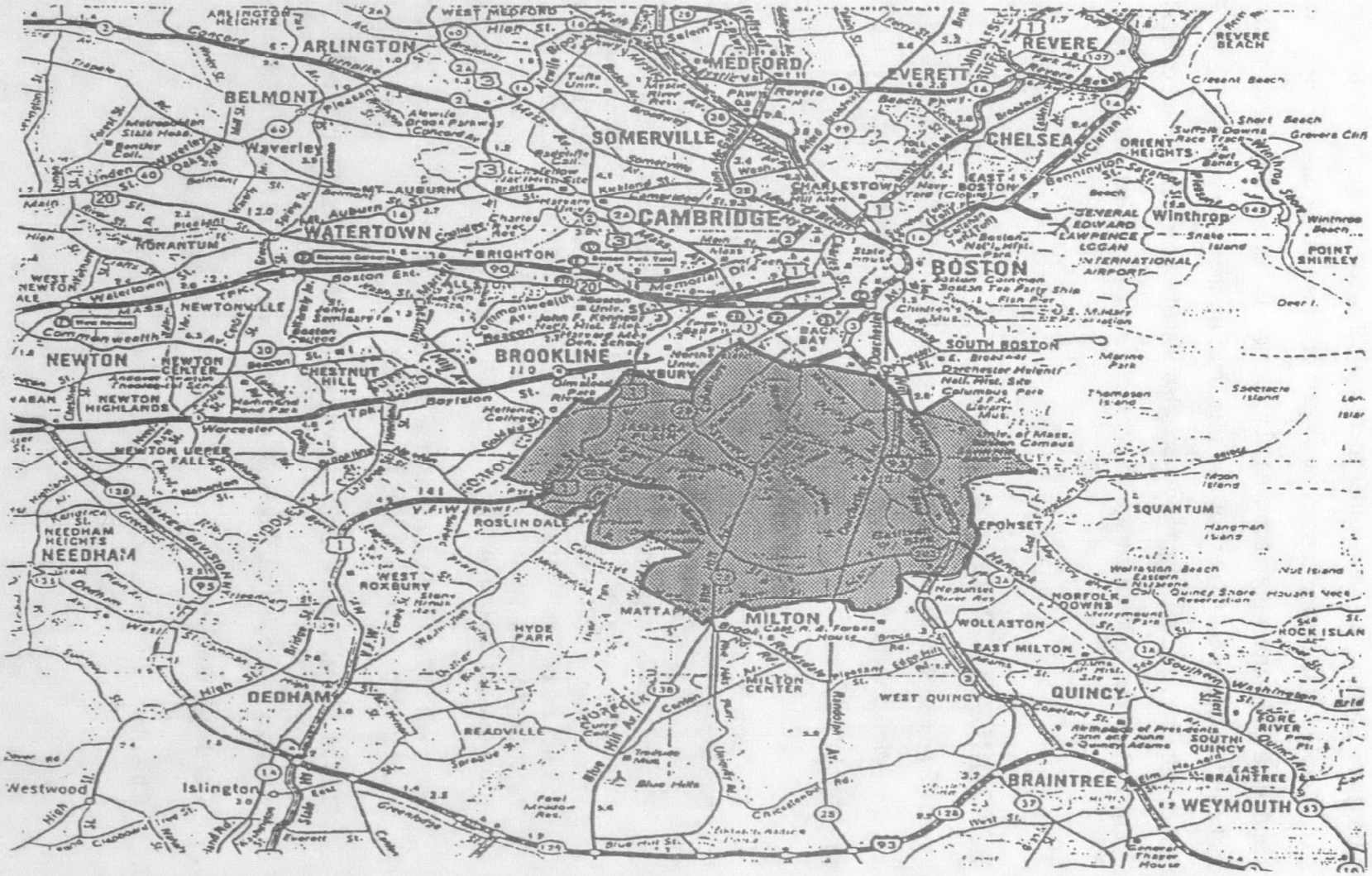


Figure 5-2. Map of study area.

8. Family resided on premises for at least three months (as of the baseline venous blood lead test).

9. Family had no definite plans to move within the next three months after enrollment.

5.4 RATIONALE FOR ELIGIBILITY CRITERIA

The choice of eligibility criteria was motivated by both scientific and practical considerations. The paramount concern from a scientific standpoint was to maximize the ability of the study to detect a decrease in blood and hand lead levels following soil abatement.

Children residing in Dorchester, Roxbury, Mattapan, and Jamaica Plain were targeted because these areas were known to have a high incidence of childhood lead poisoning as well as elevated soil lead levels. Only children up to four years of age at baseline were included because these children still have a high degree of hand-to-mouth activity.

Participant children were required to be mobile, live in small to medium sized residences, have accessible yards composed, at least in part, of contaminated soil because these children would have the opportunity to come into both direct and indirect contact with contaminated soil. The exact yard and premises size requirements were arbitrarily chosen. The minimum soil contamination level was set at 1,500 PPM in order to make possible the 1,000 PPM decline in soil lead specified in the study hypothesis.

Based on the precision of the analytic method used to determine blood lead level, the hypothesized drop in blood lead levels following abatement, and the sample size requirements, we established 7 μg/dL as the minimum baseline blood lead level required for eligibility. Children whose baseline blood lead levels were above 24 μg/dL were excluded. They met the current definition of lead poisoning and so were likely to undergo medical and environmental interventions during the follow-up period (i.e. chelation and paint deleading) that could overwhelm the changes expected from the study interventions. Previously lead poisoned children were excluded because of the possibility that their response to the study interventions might differ from that of non-poisoned children due to their elevated body lead burden.

Homes and abutting properties were required to have little or no exterior chipping paint in order to minimize the likelihood that any impact of the abatement would be attenuated by the rapid recontamination of study premises' soil (please see Eligibility Protocol for a description of how the extent of chipping was ascertained).

Three months residency at the current premises was required to ensure that a child's baseline blood and hand lead levels reflect the lead levels in various environmental media around the premises. Lastly, families were included only if they had no definite plans to move within the three months following enrollment to minimize attrition during the course of the study.

These eligibility criteria were applied both to children identified through the BCLPPP and other children living on the premises. Children were not excluded if they attended a day care center or day camp in the summer.

Eligibility criteria were generally evaluated in the following sequence: routine blood screening, drive-by assessment to determine exterior condition of the home, sample soil, interview family, search for other children residing on the premises, recruit landlord. All children meeting the criteria received a venous blood lead determination beginning in August, 1989. If the blood lead level was between 7 and 24 μg/dL and the child's parents and the landlord of the premises agreed to participate, the child was enrolled in the study. This was considered the child's baseline blood lead level for the purposes of this study. All baseline venous blood lead levels were obtained prior to any environmental abatement activities.

At enrollment, informed consent for the subsequent environmental sampling, interview, blood tests, hand lead determinations, etc. was obtained from the parent or caretaker. Consent for the soil abatement was also obtained from the landlord.

The families of children with lead levels outside the eligible range were informed of the results and of the reasons for excluding their children from the study. All children with blood lead levels above 24 μg/dL were referred to the Boston Childhood Lead Poisoning Prevention Program and followed according to Massachusetts state law and lead program case management protocols.

Figure 5-3 Eligibility Assessment and Recruitment Flow Sheet depicts the eligibility assessment and recruitment sequence, the numbers of children assessed and eligible at each step of the process, and the final number of children enrolled. The numbers and percentage

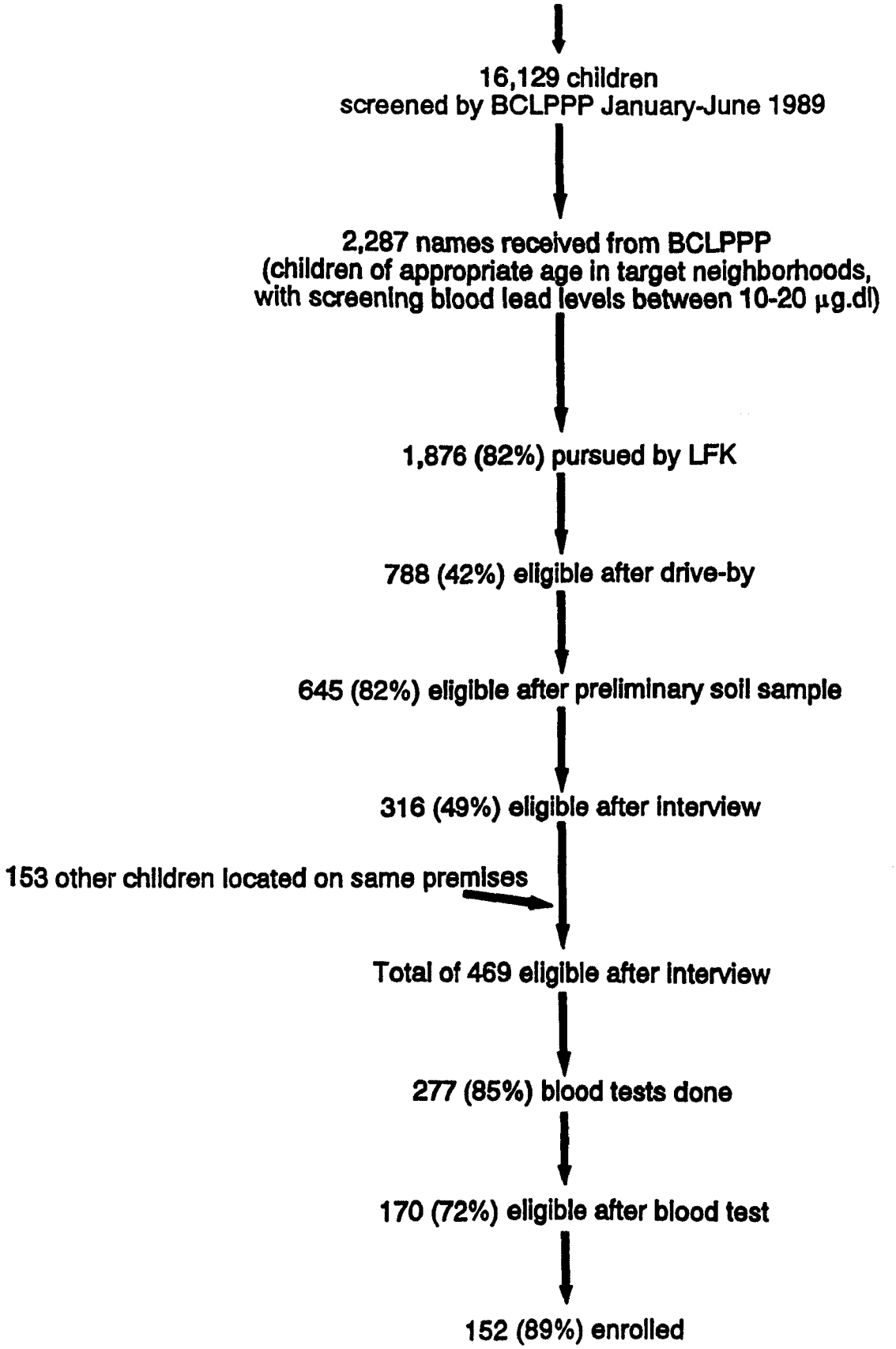


Figure 5-3. Eligibility Assessment And Recruitment Flow Chart.

of children judged ineligible by reason ineligible are given in Table 5-1. One hundred and fifty two children were ultimately enrolled in the study.

5.5 INTERVENTION

As eligible participants were enrolled, they were randomly assigned to one of three groups using a computer generated random number table: the Study Group, Control Group A, or Control Group B (the randomization unit was the child's premises). Randomization was used to enhance the probability that the three groups would be comparable with respect to measured and unmeasured characteristics.

The study design is illustrated in Figure 5-1. The Study Group received loose interior paint removal, interior dust abatement, and soil abatement in the first year. The unit of abatement activity was the single premises on which the subject(s) lived. Control Group A received loose paint removal and interior dust abatement in the first year of the study and soil abatement in the second year. Control Group B received only loose interior paint removal in the first year and soil abatement in the second year. The unit of abatement activity for Control Groups A and B was also single premises.

The purpose of including several intervention groups was to enable separation of the effects of soil and interior dust abatement. Removal of lead paint hazards was not included as a study intervention but was suggested and facilitated, when indicated, after the second follow-up study blood lead level was determined.

5.6 STUDY SIZE

We enrolled 152 children in the study: 54 children in the Study Group, 51 in Control Group A, and 47 in Control Group B. Using data from other studies conducted with comparable populations, we estimated that there would be, at most, a 15-20% attrition rate during the course of the study and based our original statistical power calculations on a final study size of 122 children. (See section on attrition and follow-up.) The statistical power of the study to detect a 3 μg/dL difference in blood lead levels between the Study Group and

TABLE 5-1. PERCENT OF CHILDREN JUDGED INELIGIBLE ACCORDING TO REASON FOR INELIGIBILITY

Reason Ineligible*	Percent
More than eight residential units on premises	19.3
Yard less than ten square feet	1.6
Yard inaccessible to child	0.4
Cumulative exterior chipping paint on premises (excluding trim, including porches and walls) exceeded 30% of total surface area	5.2
Cumulative exterior chipping paint on adjacent side of an abutting premises (including trim) exceeded 40%	2.3
At least 50% of the preliminary soil samples were not in excess of 1,500 PPM lead, or the average of the soil sample results did not exceed 1,500 PPM lead	6.2
Case manager unable to contact parent/guardian after five attempts	0.6
Paint deleading scheduled to be performed	0.9
Family intended to move in next three months	2.3
Parent/guardian was not interested in participating	4.1
Child's sibling had been lead poisoned while living at this residence and an environmental intervention was to be performed	0.0***
Case manager unable to contact landlord after five attempts	0.8
Landlord not interested in participating	6.8
Data error unable to be resolved from screening form*	0.1
Child did not have a permanent address	0.7
Case manager determined that landlord was not interested in participating prior to landlord recruitment attempt	4.3
Child moved during eligibility phase	9.5
Child lived in public housing	2.5
Duplicate name/listing (e.g. child was screened twice during eligibility phase)*	0.6
Premises located in unsafe area	0.7
Foster child	0.3
Child did not reside in Mattapan, Dorchester, Jamaica Plain, or Roxbury*	0.0***
Landlord and/or parent claimed that premises were scheduled to be deleaded	0.5
Residents claimed no children live on premises	0.3
Family was not located at the address. (This code was used when a case manager was not sure if the family had moved, but could not find the family at the premises)	1.0

TABLE 5-1 (cont'd). PERCENT OF CHILDREN JUDGED INELIGIBLE ACCORDING TO REASON FOR INELIGIBILITY

Reason Ineligible*	Percent
Language barrier	0.5
Case manager unable to contact a resident on the premises (e.g., landlord) for permission to sample soil	0.7
Child's venous baseline blood level was below 7μg/dL*	2.2
Child's venous baseline blood level was 25μg/dL or greater*	0.5
Child was not in the eligible age range	0.0***
Phlebotomist unable to draw blood for baseline sample	0.0***
Disposition of premises unable to be determined before enrollment deadline (12/8/89)	2.7
Subject moved after receiving baseline blood draw but before abatement was done	0.1
Parent claimed that child had been lead poisoned	0.2
Soil results not reported from EPA	0.1
Subject not interested in participating after baseline blood draw but before abatement was done	0.1
Child lived in a dwelling in which there were insufficient number of other children less than four years old**	0.1
Interior chipping paint exceeded 16 square feet**	0.2
No Date of Birth in BCLPPP+ data	3.6
No Pb Level in BCLPPP data	9.4
Pb in error in BCLPPP data	3.3
No address in BCLPPP data	1.6
Total	100.0

*Ineligibility codes issued in-house by the Assistant Epidemiologist.
**Code became inapplicable during the course of the study.
***Only one child in each of these categories.
+BCLPPP = Boston Childhood Lead Poisoning Prevention Program.

Note that ineligibility codes were issued for all children whose names were received from BCLPPP as well as for "other" children who were recruited on the premises by case managers.

each Control Group was excellent (.89-.91). The assumptions underlying these power calculations were:

1. Mean blood lead level of 12.6.

2. Standard deviation of the blood lead level of 4.1.

3. Alpha level of 0.05 (two-tailed).

The estimates of mean and standard deviation were derived from the baseline study data.

5.7 CHANGES IN STUDY DESIGN AND SAMPLE SIZE

Two major changes in the proposed study design were made after the study design was submitted to the EPA in August 1988: elimination of one arm of the soil abatement group and a reduction in sample size from 330 to 152. Both changes were made with the approval of the Centers for Disease Control and the Environmental Protection Agency.

We originally intended to divide the Study Group into two subgroups. For one subgroup, the unit of abatement activity would be the study subject's premises, and, for the other, the unit would be an approximate six to seven house cluster of homes including and adjacent to the study subject's home. The goal was to determine whether one abatement strategy produced a greater decline in children's blood lead levels than the other. Difficulties in recruiting landlords and budgetary constraints required us to abandon the cluster subgroup and limit the Study Group to single residence abatement units. This reduction limited somewhat the scope of the inferences that could be drawn about the impact of soil abatement but in no way compromised the scientific integrity of the study.

In addition, we originally planned to include 330 children in the study: 130 in the Study Group (65 each in the cluster and single premises subgroups) and 100 in each Control Group. The power of this sample size to detect both 3 and 2 μg/dL drops in blood lead levels was excellent. Several reductions in the sample size were made during the course of participant recruitment and 152 children were ultimately enrolled (approximately 50 in each group). The final sample size met the minimum required by the Centers for Disease Control

(i.e., 150 participants) and still had excellent power (.89 to .91) to detect a 3 μg/dL decrease in blood lead levels (even with 20% attrition).

The sample size was reduced because of difficulties recruiting landlords, budgetary constraints, elimination of the cluster concept, and a larger than expected percentage of baseline blood lead levels below the eligibility criteria of 7 μg/dL. The initial screening blood lead determinations were based on finger stick samples, while the confirmatory baseline levels were based on venous samples. We anticipated that almost all of the baseline lead levels would fall within the eligible range (7 to 24 μg/dL) but only about 70% did. We suspect that the initial finger stick samples were prone to contamination during sampling.

5.8 ATTRITION AND FOLLOW-UP OF STUDY POPULATION

This study utilized randomization to achieve comparable Study and Control Groups. Attrition because of population mobility and loss of interest can threaten comparability of groups, terminate the assigned intervention, and/or result in a sample size so small as to increase the likelihood of finding no effect when one does in fact exist. We recognized that not all attrition could be avoided during the approximately 18 months that participant families were involved in the study, and we anticipated 15-20% attrition. Table 5-2 lists by Study Group the number of children initially enrolled, the number who moved during the study but were followed so that blood and environmental samples could be obtained, the number dropped from the study, and the number who remained at their original premises.

TABLE 5-2. FOLLOW-UP STATISTICS BY PARTICIPANT GROUP

	Starting Population of Children	Moved But Were Followed	Dropped Out Before 2nd Follow-Up Blood Test	Still at Original Premises at 2nd Follow-Up Blood Test
Study Group	54	11 (20.4%)	0 (0.0%)	43 (79.6%)
Control Group A	51	8 (15.7%)	2 (3.9%)	41 (80.4%)
Control Group B	47	3 (6.4%)	1 (2.1%)	43 (91.5%)
Total	152	22 (14.5%)	3 (2.0%)	127 (83.6%)

Valuable information on the effects of the intervention was gathered even from children who moved during the course of the study. In effect these children received a partial intervention. To obtain the necessary information on these children, the study staff made a concerted effort to trace these families and obtain blood, handwipe, and environmental samples according to the study schedule. Tracing methods included contacting friends, neighbors, relatives, and landlords as well as the U.S. postal service. Information that would facilitate tracing was collected at enrollment.

All families successfully traced were interviewed to obtain information on the date and reason for moving. An attempt was made to obtain all environmental exposure data at both the new and original residence as well as to obtain blood and handwipe samples. The amount of time that a child resided at an abated residence was taken into account in certain analyses.

In order to minimize the number of participants who dropped out due to lack of sustained interest or commitment, parents and property owners were offered carefully considered incentives to remain in the study until its completion. Incentives were also available to families who moved away from their original address but remained involved in the study. The incentives for participating families included a $25 per month gift certificate at a local supermarket or general purpose store and at the end of the study a $150 gift certificate at one of a variety of stores.

Property owners' cooperation also was vital to the study. In addition to having lead contaminated soil removed, property improvement assistance in the form of assistance in deleading proved to be a very effective incentive. The study offered to pay (1) the full cost of interior and exterior paint deleading of owner-occupied homes; and (2) up to $2,000 towards the cost of interior and exterior paint deleading for non-owner occupied premises. Table 5-3 lists the numbers of owner and non-owner occupied premises in the study, households offered assistance with deleading, and the numbers agreeing to and receiving assistance with interior lead paint abatement.

The money spent for participant incentives was a relatively inexpensive way to promote good will and encourage continued participation in the study. Study participants performed an invaluable service to children in these communities and ultimately throughout the United States. Even though every effort was made to minimize the disruption to families,

TABLE 5-3. INTERIOR AND EXTERIOR PAINT DELEADING ACTIVITIES *

	Units in Owner-Occupied Premises	Units in Non-Owner Occupied Premises	Total
Total	90	33	123
Offered Deleading Assistance	90	33	123**
Agreed to and Received Both Interior and Exterior Deleading Assistance	41***	5	46****
Received Only Exterior Deleading	7	2	9

*Deleading activities occurred from August to February, 1991 after all study samples were collected.
**Six units already had deleading certificates (4 nonowner-occupied, 2 owner-occupied).
***One owner did not receive a compliance letter.
****Several units were in the same premises.

Note that a single family home was counted as one unit; all single family homes were owner-occupied.

the study design required repeated visits to the homes of study participants for environmental and biologic samplings and environmental interventions. These activities were intrusive and, for many families, the purpose unclear. Thus, it was anticipated that some participants might tire of the inconveniences related to the study and drop out. If this had happened in sufficient numbers, the success of the study would have been seriously jeopardized and the investments of time and money wasted. Participant incentives were critical in mitigating these problems. Similarly, the study would not have been conducted without landlord participation, necessitating our offer of assistance with lead paint abatement.

6. PARENT EDUCATION AND COMMUNITY RELATIONS STRATEGIES

Educational materials were developed and provided to all participating parents and the public. They included information on the sources of lead in the environment, known effects of lead on a child's well-being, and methods for reducing children's lead exposure (such as wet mopping, washing hands). In addition, all parents were told the soil lead levels on their premises and their children's blood lead levels.

The success of this study was dependent upon participant and community support and cooperation. As a result, efforts to inform, educate, and involve potential participants and community leaders were integral to conducting the study. The receptivity of parents and property owners to enrolling and remaining in the study was related to a variety of factors. For example, the degree to which participants and landlords perceived that participation was in their best interest was a vital aspect of whether the individuals approached were willing to enroll and remain involved despite substantial inconvenience. It was also reasoned that whether participation resulted in positive recognition and improved standing in the community or was a source of stigmatization would also impact upon enrollment and retention. Thus, in addition to one-to-one educational activities and incentives for participating families and landlords, a detailed community relations program was developed. Community relations activities were designed to enhance the likelihood of positive responses to the above mentioned concerns through activities that increased community acceptance of the study.

An underlying objective of the community relations strategy was to ensure that the study resulted in the least possible amount of intrusion for the community, and that, to the extent possible, participants were recognized for their contribution to the success of the study. A major priority was to ensure that communication with the community, especially potential participants, was timely, forthright, and well presented. Thus, materials were translated into the appropriate languages and study staff remained in close contact with participating families and landlords and helped them plan and prepare for each of the study's activities.

It was also extremely important that respected and trusted members of the community be apprised of the study's objectives, methods, progress, and difficulties. Thus, a Community Advisory Committee was convened and met with the study's investigators during the course of the study, both to keep them informed and to obtain their input into various aspects of the study.

The effectiveness of the incentives employed and the community relations activities are evidenced by the fact that the requisite number of families were enrolled and that only 3 of the 152 (2%) children enrolled dropped out before completion of the study, despite numerous intrusive and disruptive study related activities.

7. ENVIRONMENTAL MEASUREMENTS AND ANALYSIS

7.1 SOIL

Soil sampling was conducted to determine eligibility of properties, characterize the potential exposure of participant children to lead from the soil, document the reduction in soil lead levels, and monitor the rate of recontamination after abatement. Preliminary soil sampling to determine eligibility was conducted from approximately April to November, 1989. The start date was chosen to allow for melting of snow and frost prior to sampling. After eligible properties were identified and preabatement blood samples taken from the children, detailed soil sampling of the properties was undertaken. Playgrounds frequented by the children were also sampled. Follow-up sampling was conducted right after the soil abatement to document the drop in soil lead levels and at approximately nine months after abatement to assess the rate of recontamination. A detailed protocol for soil sampling and analysis was developed in conjunction with the EPA and the other Lead-In-Soil Demonstration Project teams from Baltimore and Cincinnati. Boston also participated in an exercise to evaluate the merits of the wet digest method versus XRF and based on this, a decision was reached to use XRF for soil analysis. The soil sampling process is summarized below.

7.2 PRELIMINARY SOIL SAMPLING TO DETERMINE ELIGIBILITY

Following the drive-by survey of exterior paint conditions, a potential study participant was approached by a study staff member who described the study and asked for permission to sample the soil. If the potential participant was not available, other occupants of the property were briefly told about the study and asked for permission to sample the soil. In some cases preliminary soil sampling occurred before speaking with any residents, in which case flyers about the study were left for all residents. In most cases, four composited surface samples were taken within two meters of the house, one from each side of the house where soil was present. Samples were analyzed by X-Ray Fluorescence (XRF) at the EPA

Region I Laboratory. The property was eligible if the median or the mean soil lead level was equal to or greater than 1,500 PPM.

7.3 DETAILED SOIL SAMPLING

After a child was enrolled, composited soil samples were taken throughout the property both at the surface and at a depth of 15cm using one of three pattern sampling methods described in the Appendix: line source, targeted, or small area patterns. The line source soil sampling pattern used for most of the premises involved drawing lines parallel to the premises about 0.5 meters away from the foundation and about 0.5 meters from the property boundary. Depending on the size of the property, more parallel lines were added in between the foundation and property boundary lines. Each parallel line was then divided into segments seven meters in length. Composite soil samples were taken from a 2 by 2 foot square at a random point along each line segment. The composite sample consisted of five samples taken from the center and each corner of the square. The number of composited surface and core samples taken varied according to the size of the yard. On average eight of each were taken. Pattern selection was made according to the layout of the property. Samplers made sketches showing property and sample locations. All soil samples were transported to the EPA Region I laboratory and analyzed by XRF. Soil abatement was documented immediately after landscaping by taking composite surface soil samples at every other previously sampled location marked in copies of property sketches. On average, four composite surface samples were taken at this stage.

7.4 RECONTAMINATION ASSESSMENT SOIL SAMPLING

Approximately nine months after the initial soil abatement was conducted, composite surface soil samples were taken to determine the extent of soil recontamination. These samples were taken at every other previously sampled location marked on the property sketches. On average about five composited samples were taken from each premises.

The schedule for soil sampling was as follows:

	Study Group	Control Group A	Control Group B
Summer-Fall 1989	Test Abate* Test**	Test	Test
Summer-Fall 1990	Test	Test Abate* Test**	Test Abate* Test**

* This refers only to soil abatement.

** These tests were conducted to document reductions in soil lead levels immediately following the soil abatement.

7.5 DUST

Household dust sampling was conducted to characterize the potential exposure of children to lead from dust, to document the reduction in dust lead levels following abatement, and to monitor rates of recontamination after abatement. Our intent was to sample dust on upfacing surfaces most accessible to the child (i.e., bare floors, window sills, and wells). The Sirchee-Spittler modified dust buster was used to obtain the samples. This instrument is a hand-held dust vacuum unit whose sampling head was modified to catch the dust sample in a fine mesh (325) stainless steel screen. This modification enabled better sample recovery than would be possible with the woven fiber cloth that is usually supplied with commercially available dust busters. We generally took six samples in each household from the following locations: the participant child's bedroom window well and floor, the kitchen window well and floor, and the living room window well and floor. The three floor dust samples were later composited into a single sample because the individual samples were often lighter (less than 10 μg) than considered optimal for accurate XRF analysis. We determined the lead concentration in the dust (PPM), the amount of dust per unit area (mg/m^2), and the lead loading (mg/m^2).

A detailed protocol for the dust sampling was developed by Dr. Thomas Spittler of Region I of the Environmental Protection Agency and is included in the Appendix.

The schedule for dust sampling was as follows:

	Study Group	Control Group A	Control Group B
Summer-Fall 1989	Test Abate* Test**	Test Abate* Test**	Test
Winter 1990	Test	Test	Test
Summer-Fall 1990	Test	Test	Test

* This refers only to interior dust abatement.
** These tests were conducted to document reductions in dust lead levels immediately after the dust abatement with HEPA vacuuming.

7.6 WATER

Two water samples were taken during the course of the study. Each was a first flush sample taken by the parent from the cold water faucet in the kitchen. Water samples were analyzed by the Hall-Kimbrell Laboratory in Lawrence, Kansas. The water lead sampling and analysis protocol can be found in the Appendix. Elevated water lead levels (i.e., above 50 μg/L) were reported to the participants. These participants were also informed of ways to reduce the lead content of their drinking water.

The schedule for water sampling was as follows:

	Study Group	Control Group A	Control Group B
Winter-Spring 1990	Test	Test	Test
Summer-Fall 1990	Test	Test	Test

7.7 PAINT

In the last year of the study portable x-ray fluorescence analyzers (PGT XK-3) were used to identify lead in paint. Measurements were taken in the child's bedroom, kitchen, and living room. One measurement was taken on the lower part of the wall and one was taken

on the window sill in each room. A detailed protocol for lead paint inspection is included in the Appendix.

The schedule for interior paint sampling was as follows:

	Study Group	Control Group A	Control Group
Summer-Fall 1990	Test	Test	Test

7.8 QUALITY ASSURANCE FOR SOIL AND DUST SAMPLING AND ANALYSIS

A quality assurance plan for the sampling and analysis of soil and dust was developed by the EPA Region I and is included in the Appendix. It includes a description of the proper procedures for soil sampling, sample custody, equipment calibration and analysis, internal quality control checks and corrective actions.

8. SOCIAL AND BEHAVIORAL QUESTIONNAIRE

After the baseline soil sampling, the case managers administered two questionnaires to the child's parent or caretaker. The goals were to (1) gather information necessary to characterize the study population and (2) assess factors that bear on a child's contact with various sources of lead. Dr. Edmund Maes of the Centers for Disease Control initiated the development of the questionnaire which was modified by Dr. Ann Aschengrau and consultants from the Center for Survey Research at the University of Massachusetts, Boston. Copies of the questionnaires are included in the Appendix.

One questionnaire, designated the "family questionnaire", was concerned with family demographics (e.g., family size, parent's occupation and education, house cleaning), possible sources of lead exposure (e.g., hobbies), and data on recent renovations and deleading activities.

Another questionnaire, designated the "child questionnaire", collected information intended to characterize each child's exposure to lead in soil. The respondent was asked to identify the child's outside play areas (both in the immediate area of the dwelling and in the neighborhood), to estimate the amount of time the child usually spends in each location, the amount of time spent away from home (e.g., day care), handwashing, hand-to-mouth activities, vitamin use, and nutritional data.

Because (1) the lead content of different foods may vary and (2) diet and nutritional status may affect lead kinetics, specifically absorption, we also administered a food frequency questionnaire.

After the interview, a study staff member measured the height and weight of the child and obtained systolic and diastolic blood pressure readings. Parents' height and weight were also obtained by interview.

Follow-up "family" and "child" interviews were done toward the end of the study to assess changes in child behavior, house cleaning, new renovations, and increases in lead related knowledge.

The study staff were trained in proper interviewing techniques by a staff member of the Center for Survey Research of the University of Massachusetts. Each interviewer was

required to tape her first few interviews and feedback was given. Interviews were translated into Spanish, Portuguese, Creole, and Haitian Creole, and administered, as needed, in these languages. These foreign languages were used in a total of 17.6% of the interviews.

9. BIOLOGICAL SAMPLING AND MEASURES

9.1 BLOOD SAMPLING

On three occasions during the study, blood samples of 2-3 ml each were drawn from the antecubital vein for determination of blood lead, FEP (free erythrocyte protoporphyrin) levels, and ferritin levels. The first sample was taken beginning in September 1989 prior to any abatement activities, the second taken an average of six months (beginning in March 1990) after initial abatement activities, and the third taken an average of 11 months after initial abatement activities (beginning July, 1990). Serum ferritin levels were obtained only at baseline.

All laboratory analysis results were reviewed within one day of receipt from the contract laboratory and health care providers were notified of the results. Any children with blood lead levels of 25 μg/dL or above were referred to the Boston Childhood Lead Poisoning Prevention Program and followed according to Massachusetts state law and accepted pediatric health practices.

An optional fourth blood sample was proposed in the original study design to be obtained during 1991 if sufficient funds were available and if the effect of the soil abatement was unclear.

The schedule for blood sampling was follows:

	Study Group	Control Group A	Control Group B
Fall 1989	Test	Test	Test
Winter 1990	Test	Test	Test
Fall 1990	Test	Test	Test
1991 Optional *	Test	Test	Test

* For children still residing on the original enrollment premises.

9.2 BLOOD SAMPLE ANALYTIC PROCEDURES

We selected Environmental Sciences Associates (ESA) Laboratories in Bedford, Massachusetts to perform the blood lead and free erythrocyte protoporphyrin (FEP) analyses since they met all of our stringent performance criteria including experience in performing biologic analyses for health studies, participation in proficiency testing programs, continuous OSHA certification and a detection limit of 1 μg/dL for blood lead. In quality assurance testing administered by the CDC, ESA's coefficients of variation were 20.9, 13.8, and 7.1 % at the 4, 10 and 46 μg/dL blood lead levels. Bioran Laboratories in Cambridge, Massachusetts performed ferritin analyses.

ESA Laboratories determined blood lead levels using graphite furnace atomic absorption and EP levels using an ESA model zinc protoporphyrin hematofluorometer. Protocols describing both methods are included in the Appendix.

9.3 HAND LEAD DETERMINATIONS

Handwipe samples were obtained each time blood samples were drawn. Parents were asked not to wash the child's hands for the two hours immediately preceding sampling. Wearing disposable gloves, a study staff member wiped all surfaces of each hand, front and back up to the wrist, with three commercial wetwipes (Walgreen's Wetwipes). Sampling took place inside the child's home. To assess the extent of any contamination during sampling, field blanks consisting of six additional wipes were handled so as to simulate wiping the child's hands, and set aside to determine the background wetwipe lead levels. Field blanks were taken for every tenth child. Each set of six wetwipes was placed in a sealed container, labelled and transported to Dennison Laboratories, Woburn, Massachusetts where they were composited for chemical analysis. Extraction of the lead utilized 1N hot HNO_3. The total quantity of lead was reported in μg per pair of hands. Sampling and Analysis protocols are in the Appendix.

The schedule for hand lead determinations was as follows:

	Study Group	Control Group A	Control Group B
Fall 1989	Test	Test	Test
Winter 1990	Test	Test	Test
Fall 1990	Test	Test	Test
1991 Optional *	Test	Test	Test

* For children still residing on the original enrollment premises.

9.4 QUALITY ASSURANCE AND CONTROL FOR BLOOD LEAD MEASUREMENTS

ESA Laboratories maintained strict internal quality control systems for their blood lead analyses including composition of calibration curves with at least one reagent blank and three standards, running standards both at the beginning and end of large runs, running known control and QC material with every set of standards and every ten samples, and running duplicates and spiked samples every ten samples.

In addition, ESA participated in the external quality control system developed and overseen by Dr. Daniel Paschal of the Centers for Disease Control. CDC developed quality assurance standards for specimen collection, preservation and shipping, analytic method performance, bench and blind quality control materials, accuracy and blanks, and data integrity that are described in detail in a protocol in the Appendix.

The protocol also includes the results of four whole bovine blood pool analyses comparing ESA to the CDC, Cincinnati and Baltimore Lead-In-Soil Demonstration Project laboratories. The conclusions drawn from these analyses were that: (1) ESA and the other laboratory blood lead results were comparable; (2) each laboratory's blood lead data were produced from analytical systems in statistical control (as defined by Shewhart); and (3) no statistically significant time trends were observed.

9.5 REPORTING AND EVALUATION OF CLINICAL DATA

The results of a child's blood lead, FEP, and ferritin analyses were provided to the family and, with the family's permission, to the primary health care provider. Our staff's relationship with primary health care providers, such as neighborhood health centers, was vitally important to the success of the study. Study staff took every opportunity to encourage study participants to maintain ongoing relationships with their primary health care provider.

10. DETAILED DESCRIPTION OF THE INTERVENTIONS

10.1 LOOSE PAINT ABATEMENT

The purpose of loose paint abatement was to remove safely any very loose chipping paint from the inside of the home without generating dust or leaving behind small paint chips. No children were allowed to be on-site during this process. Loose paint abatement consisted of vacuuming the loose paint areas with HEPA (High Efficiency Particulate Aerosol Filter) vacuums, washing loose paint areas with a trisodium phosphate and water solution, and painting the window wells with primer.

Loose paint abatement was conducted to minimize lead based paint as a potential vector for children's exposure during the study period. Loose paint abatement should be distinguished from deleading, which was conducted after the collection of all environmental and child-based samples was completed. Interior and exterior deleading is described in a subsequent section of this report.

10.2 INTERIOR DUST ABATEMENT

The purpose of the interior dust abatement was to significantly reduce the amount of lead bearing dust in the treated homes. It always followed the loose paint abatement.

Dust abatement was accomplished by HEPA vacuuming and wiping surfaces with a wet cloth and furniture with an oil treated rag. Floors, woodwork on walls, window wells, and furniture surfaces were cleaned. Only the living areas were abated. The common entries, stairways, etc. were not cleaned. In the Study Group and Control Group A, interior dust abatement took place at the beginning of the first year. Dust abatement was not done in Control Group B.

Loose paint and dust abatements were performed from October 1989 through January 1990. It became readily apparent that the loose paint and dust abatements were time consuming and logistically complicated to accomplish, largely because of the inconvenience they caused to participating families. Cancellations and postponements by participating

families were frequent. All scheduled work was confirmed twice and attempts were made to have "backups" that could be used to fill openings in schedules made by cancellations.

Families were required to be out of their homes during these abatement activities. Many families considered cancelling just prior to the actual abatements because they had nowhere to go during the several hours it took to perform the abatement. Therefore it was frequently necessary to arrange activities for them during the period in which the loose paint and dust abatements were being conducted. Families were offered lunch at McDonald's Restaurant and free access to the Children's Museum, the New England Aquarium, The Tropical Rain Forest exhibit at the Franklin Park Zoo, or the Museum of Science. Study staff provided transportation to these various sites.

Two case managers from the study staff supervised these abatement activities and used documentation forms to record progress. ACP Cleaning Inc. of Malden, Massachusetts, performed all interior loose paint and dust abatement activities.

10.3 SOIL ABATEMENT

Soil lead was abated on 35 premises in the Study Group during the Fall of 1989. Soil abatement was undertaken on 58 premises in the Control Groups during the Fall of 1990. Eight premises were not abated in the Control Groups. The methods used differed somewhat during the two phases and are described in detail later in this section.

The purpose of the soil abatement was to remove and provide a barrier between lead contaminated soil and the children living on the study premises. The abatement was to be as permanent as feasible given the practical limitations of the study. The strategy for soil abatement involved removing a six inch layer of topsoil and placing a fabric or synthetic barrier topped with 8" of clean topsoil.

The initial plan was to remove 6" of soil, test the soil at the 6" depth, and continue to remove soil until a level was reached where lead was present at less than 500 PPM. This approach called for on-site soil testing, to be carried out with all of the workers and equipment standing by for the results of the analysis. After pilot testing this method during the fall of 1987, it was decided that it was far too time consuming to be practical given the

large number of properties to be abated. A decision was made to remove soil to a set depth of 6" and replace it with 8" of clean topsoil.

In those situations where the driveway consisted of soil and the ground was frozen the area was capped with a minimum 3" layer of asphalt. This approach was employed in four instances. Soil removal was not undertaken in areas where asphalt was used as a barrier.

After excavation to 6" and replacement with 8" of clean topsoil, surface soil or cover was tested to insure that it was not contaminated with lead. Surface soil or cover was retested on average seven months later to ascertain whether it had been recontaminated by subsurface or above surface sources.

Testing and removal protocols emphasized:

- Thorough sampling of the yard.

- Adherence to removal safety procedures for insuring that the removal operation did not spread contamination via dust or mishandled soil to other areas at the study residence or neighboring premises.

- Insuring that replacement soil met requirements for low lead content.

The preparation of a site for soil abatement started well before the actual excavation. The study's abatement coordinator attempted to meet with the property owner. Many yards were found to have abandoned cars, trash, and other debris which had to be removed before abatement. This work was done in large part by ACP Cleaning, Inc., the same contractor who conducted the interior loose paint and dust abatements.

Several different methods were used to verify that the appropriate amount of soil had been removed. One method involved running a string between two reference points on objects such as the edge of a sidewalk or a fencepost. By measuring down from the string to the soil surface before and after excavation a determination could be made as to how much soil was removed. This method proved adequate for level yards, but it was not practical for uneven terrain.

In most cases, permanent features of the property were used as reference points. Before excavation, orange paint was sprayed onto fenceposts, building foundations, and tree trunks at ground level, and notes were made on existing slopes and hills. In most yards this worked well, but it was difficult to accurately measure 6" on very uneven yards. Contractors were urged to err on the side of taking out too much, rather than too little soil.

In situations where soil abatement involved frozen ground it was often impossible to remove less than 12" of soil because the soil was excavated as large, thick, frozen slabs.

10.3.1 Subsurface Fabric/Synthetic Barrier

In most situations, the soil at the 6" level still contained significant amounts of lead. A geotextile fabric barrier made of nonwoven polyethylene and polypropylene material which is water permeable, very durable, and has the appearance of a thick grey felt was laid directly on top of the exposed subsurface immediately following removal of topsoil and prior to placement of clean topsoil. The placement of this barrier served two purposes:

1. It indicated the border between old subsurface and newly applied surface barrier to determine how well the surface barrier would persist over time.

2. It protected against recontamination of the surface soil by the remaining contaminated subsurface soil.

10.3.2 Surface Covers

One of the following surface covers were employed:

- 8" of clean topsoil topped with:

  - sod
  - hardy grass seeding
  - bark or mulch where grass would not grow
  - gravel, crushed stone or crushed bank in driveways and parking areas, walkways, and areas susceptible to erosion

- 3" Asphalt (No soil removal or fabric barrier required).

Selection of surface cover for a particular area was based on:

- Appropriateness for site
- Least cost option that was acceptable to property owner
- Ease of maintenance.

Replacement soil was obtained by the contractor Franklin Environmental Services and was tested by Alpha Analytical Laboratories for lead, 23 other metals, and a number of other contaminants, such as volatile organic components. Laboratory confirmation was given to the study staff indicating that the replacement soil lead level was undetectable.

Where there was sufficient sunlight to support grass, the soil was covered with sod. There were many yards where sod would not grow well. There were also many unpaved driveways and paths where the soil had to be abated, but something other than replacement soil was needed to cover the geotextile fabric. For parts of yards where grass would not grow, bark mulch was used. In these cases 6" of clean soil was put down, followed by 4" of bark mulch. Gravel was used for driveways and heavily travelled walkways. In these cases 2" of clean soil was put down, covered by 6" of gravel.

10.3.3 Soil Abatement Procedures

Lot sizes varied from about 2,000 to 7,500 square feet (including the area occupied by house and sidewalks, etc.). The lots that were abated in 1989 averaged 199 square meters (2,141 sq. ft.) and ranged from 12 square meters to 702 square meters. An average of 41 cubic yards of soil was removed in 1989 (range of 3-168 cubic yards). The lots that were abated in 1990 averaged 178 square meters (1,918 sq. ft.) and ranged from 26 square meters to 656 square meters. An average of 44 cubic yards of soil was removed in 1990 (range of 6-182 cubic yards).

Several different soil abatement methods were used on the 36 Study Group properties abated in 1989. Initially, the soil was loosened with rototillers, then vacuumed into a truck using an industrial vacuum similar to that used to pick up leaves. The second method was to use a Bobcat (brand-name) tractor to dig up large areas and shovels for areas with narrow access. A third method was adopted for digging up properties after the ground had frozen. This called for jackhammers to loosen the soil and backhoes to remove it. Paving parts of the property was another option used after the ground froze.

The first method, using the truck-mounted (Supersucker) vacuum was abandoned relatively quickly for a number of reasons. The soil had to be gathered into piles, then fed into the vacuum. At best, this meant handling each shovelful of soil twice. After heavy rains the soil was wet, requiring extra labor to feed the soil into the vacuum. The machine was so big that it could not move around the property, so all the soil from the backyard had to be taken to the front to be fed into the machine. Rental of the vacuum itself also was extremely expensive. Six properties, including two double sized properties, were abated using this method before it was abandoned.

The majority of properties were abated using the Bobcat tractor combined with hand labor. The Bobcat was able to lift the soil into a dump truck that had a ten cubic yard capacity. In areas of the yard which were done by hand, soil was dug out with shovels, then taken by wheelbarrow to a point where the Bobcat could scoop it up and place it in the truck. This is an especially useful strategy because it can be adapted to almost any property. Eighteen properties, including one double sized property, were excavated using Bobcat and hand-labor. We were forced to abandon this approach when the ground froze in December of 1989.

The last 12 properties in the Study Group were abated during an unusually severe cold spell that began in late November and continued through December of 1989. The ground quickly froze to a depth of over 14", making the use of Bobcats or hand tools impossible. Jackhammer crews and backhoes were added to the work force. The work was very slow, and it became difficult to remove exactly six inches of soil. The backhoe would often remove a slab of frozen soil 12" thick and ten square feet in area. The workday was shortened due to the impact of windchill temperatures of -40 degrees Fahrenheit on workers and equipment.

During this period we offered some property owners the option of having part or all of their property paved with asphalt. One entire property and parts of three others were ultimately paved. Since sod could not be planted during this period, grass seed was spread on the new soil and repeated the following spring.

The general techniques used for soil abatement of properties in Control Groups A and B in 1990 were similar to those used on the properties in the Study Group. The contractor used a Bobcat tractor to excavate large areas. Smaller areas were excavated by hand, and soil was wheelbarrowed to a place where the Bobcat could scoop it up and lift it into a truck. On some occasions a rototiller was used to loosen the soil in preparation for hand digging.

There were, however, two important changes in the soil abatement procedures in 1990. First, in place of gravel for driveways and walks, a material called "crushed bank" was used. This mixture of ground stone (or stone dust) and gravel forms a packed surface which, unlike gravel, is not subject to scattering. It creates an attractive and durable gray gravel-like surface. A layer 8" deep was spread over the geotextile fabric and packed down with a compacting machine. This was used extensively to resurface dirt paths and driveways.

The second important change was that a single contractor did all of the work. During the previous year, two contractors were used. One did the excavation and the other did the landscaping. In the second year, several types of contractors submitted bids, including landscapers, hazardous waste firms, and deleading firms. The contract was awarded to Franklin Environmental Inc., of Wrentham, Massachusetts. This company regularly performs underground storage tank removals, hazardous waste removal and hauling, and asbestos work. Using one contractor made it much easier to coordinate landscaping and excavation activities.

The soil abatement schedule required that every property be prepared well in advance of the commencement of excavation activities. It was clear, from our experience in 1989, that additional staff would be needed to do advance work and to monitor abatement so three "site monitors" were hired in August 1990. They visited properties to be abated and met with landlords to address the following issues in preparation for soil abatement:

Note presence of:

- Debris blocking access to yards
- Locked gates
- 6 foot access for bobcat bulldozer
- Dogs
- Abandoned cars
- Cars blocking access to yard
- Bad traffic or busy intersections
- Narrow streets
- Access to outdoor water spigot

Also:

- Ascertain owner preferences for sod, crushed bank, or bark mulch
- Plan for access to water if not available outside
- Drop off letter explaining process to owner
- Obtain signed cancellation form if owner did not want soil removal

During the fall of 1990 lead contaminated soil was removed from 58 properties on which children in the Control Groups resided. The original schedule called for the soil removal to be done soon after the second follow-up blood sample was obtained and after the exterior deleading was complete in the Control Groups. This required that two properties be

scheduled each week. Abatements did in fact proceed very close to original plans, despite difficulties and unanticipated delays.

Soil removal for Control Groups A and B began in September 1990. Crew size ranged from 6 to 12 people, with an average of 9. Crews typically included a foreman, who coordinated movement of materials and people, a truck driver, a Bobcat operator, and five or six laborers. The contractor worked on as many as four sites at once. Often four sites were excavated in two to three days, and all landscaped simultaneously in the following two days. Most sites were completed in one day. The largest sites took two to three days to complete.

The sites varied in size and difficulty. Some sites had to be abated entirely by hand because there was no access for the Bobcat. This meant using a wheelbarrow to take all of the contaminated soil out and bring all of the clean soil in. Most sites, however, consisted of a combination of areas that could be excavated by Bobcat and smaller areas that had to be excavated by hand.

There were only a few minor delays and the last property was abated on December 11, 1990.

10.3.4 Soil Abatement Safety

A soil abatement health and safety plan was developed to prevent the accidental dispersal of lead-contaminated soil and to protect workers from lead exposure and accidents while work was being done.

The same soil abatement health and safety plan was followed in both the 1989 and 1990 soil abatement phases.

Respirators were used by individuals conducting lead contaminated soil abatements only for the pilot abatements conducted in 1989. During these abatements air monitoring was conducted by Applied Occupational Health Systems (AOHS), an industrial hygiene consultant firm from New Hampshire. Air monitors were put on the perimeter of the site and on the dumpster into which the lead contaminated soil was placed. They were also clipped to the shoulders of some of the workers. These monitors collected data on the amount of lead dust escaping from the work area and the level of lead in air at the site. Area and personal breathing zone air samples were collected by drawing air through 0.8 micron pore size, 37 millimeter diameter mixed cellulose ester filters mounted in closed face cassettes. Air

was drawn through the filters using MSA or Gillian personal air sampling pumps with a flow rate of at least 2.0 liters per minute as established by prior and post calibration using the primary bubble tube method. At the end of the sampling period, the cassettes were capped, sealed, labeled and hand-delivered to the AOHS, American Industrial Hygiene Association (AIHA) accredited laboratory (#342), for analysis utilizing atomic absorption spectroscopy (NIOSH Method 7082).

Monitoring results were compared to the OSHA Permissible Exposure Limits (PEL) and Action Level. The OSHA PEL for lead is 50 mg/m^3. The highest time weighted average exposure found during the pilot abatements was 0.82 mg/m^3. Based on these findings, respiratory precautions were abandoned.

Soil was prevented from becoming airborne by frequent watering using a garden hose during excavation. This worked well as evidenced by air monitoring results during the first abatements in 1989. When the ground was very dry, as it was during the first days of the 1990 abatements, the ground needed to be watered for several hours the day before abatement was scheduled.

Safety measures for preventing soil from being tracked or spilled off site consisted of establishing work areas, and surrounding the areas with plastic dropcloths. Weather permitting, decontamination areas were set up on the plastic, where workers would wash off, then remove their boots and tyvek suits. The decontamination area consisted of wading pools filled with water, scrub-brushes for the boots, and trash bags for the disposal of tyvek suits worn by the workers.

The waste water from the decontamination pools was poured back into the area that was just abated, before the geotextile fabric was in place. Equipment such as shovels, rototillers, and Bobcat bulldozer blades and tires were hosed off in a place where the wash water would drain back into the work area.

The Health and Safety Plan is included in the Appendix.

10.3.5 Soil Disposal

Disposal of the lead contaminated soil in a safe and cost effective manner was critical to the success of the study. This proved to be a difficult task throughout the study.

Soil disposal was accomplished in accordance with guidelines developed in conjunction with the Massachusetts Department of Environmental Protection. Lead contaminated soil was removed to a location to which access was controlled, specifically a granite quarry in the Hyde Park section of Boston (Barry's Quarry) that abuts and will become an extension of an existing cemetery. This site was extremely useful because it was very close to the study properties and was unlikely to result in exposure to the disposed soil.

We began using this site in October 1989. At that time, quarry owners had bulldozers operating every day and arrangements were made to place soil from the study in a designated area of the quarry. Each load of lead contaminated soil from the study was covered with uncontaminated soil from other parts of the quarry to minimize the possibility that children and other individuals would be exposed to the lead in the abated soil. This site also provided minimal risk of contaminating water tables as underground wells are not used and all drinking water in the Boston area comes from a reservoir far west of the City.

On November 3, 1989, during the soil abatement phase of the Study Group, the City Councilor from the Hyde Park section of Boston raised concerns about the safety of disposing of lead contaminated soil in that section of the City. These included questions about whether the lead contaminated soil would harm children or adults in the area, contaminate the community water supply, and reduce property values of homes in this neighborhood. Moreover, the justice and wisdom of taking soil that was believed dangerous to children from one neighborhood and disposing of it in another neighborhood was also questioned. This resulted in the project temporarily suspending use of the quarry in that neighborhood for the disposal of soil.

To stay on schedule, it was crucial that we not halt abatements and so it was essential to use a temporary site for soil storage until the disposal site controversy was resolved. Although soil was not considered hazardous waste by the Environmental Protection Agency or by the Massachusetts Department of Environmental Protection, it was extremely difficult to find an alternate permanent disposal site. Most landfills in the area were closed. The landfills that were open were unwilling to accept lead contaminated soil because the operators of these facilities feared that by accepting the soil they would incur penalties under future regulations. A common concern voiced by the disposal industry is that material legally

accepted today may be declared hazardous in the future and result in additional costs to landfill owners.

We resorted to a temporary storage facility until access to the quarry was restored. The temporary disposal site for soil from 14 properties was a parking lot at the Mattapan Chronic Care Hospital. Permission to use the site was granted by Boston's Commissioner of Health and Hospitals. A trench was cut in the pavement and a silt fence installed to prevent run-off. Plastic drop-cloths were used to cover the soil and prevent dust from being blown off the site. The parking lot was surrounded by woods on two sides and an abandoned building on another. It was well within the grounds of the hospital and close to a rarely used road. The combination of precautions taken to keep the soil in place and the remote location made this a suitable temporary storage site for the lead contaminated soil.

The controversy was eventually resolved in a series of meetings involving city councillors, representatives of the neighborhood in which the quarry is located, the study's principal investigator, the EPA Region I Project Manager, and a representative of the Mayor's Office. Input was also elicited from the Massachusetts Department of Public Health, the Massachusetts Department of Environmental Protection, scientists and others working with the study, and various lead experts not associated with the study. The unanimous consensus of public officials and lead experts was that there was no danger to local residents. The concerns of residents and the City councillor were allayed and permission was granted to resume using the quarry as a disposal site on December 2, 1989. Soil which had been temporarily stored at the Mattapan Hospital site was moved to the quarry on December 7 and 8, 1989. Although successfully resolved, this episode occurred despite substantial efforts at public awareness and community relations that preceded disposal activities and jeopardized the study for a period of time. These issues may have significant implications for future lead contaminated soil abatement and disposal efforts in other communities.

10.3.6 Obstacles to Soil Abatement

Disposal of contaminated soil was clearly the greatest obstacle encountered in the study. It was not, however, the only difficulty confronted. Listed below are some of the other

problems that had to be addressed and that may have implications for future lead contaminated soil abatement efforts:

- Narrow streets that were difficult to negotiate with trucks
- Narrow access for Bobcats (less than six feet wide)
- Bulky trash items in yards
- Non-functioning cars in yards
- Fences that had to be taken down and replaced to gain access to yards
- Availability of tested "clean soil"

11. INTERIOR AND EXTERIOR PAINT DELEADING

Paint deleading was not included as a study intervention but we strongly recommended it to homeowners and landlords after all study interventions, environmental sampling and the second follow-up blood and handwipe sampling were completed. Deleading performed in conjunction with the study met or exceeded minimum requirements of the Massachusetts Lead Law. It included the removal of lead paint from chewable surfaces below five feet and making intact all surfaces above five feet. Specifications written by the study's deleading coordinator required that, whenever possible, dust generating methods be avoided. The preferred deleading methods were off-site treatment of surfaces covered with leaded paint and replacement with new materials. Exterior and common interior areas of multi-unit housing were deleaded, as well as the inside of participant's living units.

All contractors were monitored by the study's inspection staff to ensure that proper safety and health considerations were addressed during the deleading and participant families vacated the premises during deleading. Dust wipe samples were taken upon completion of the deleading to confirm that the premises were safe for families to re-occupy.

11.1 PRE-DELEADING PLANNING

Planning the deleading activities began in January, 1990 when the loose paint and dust abatement interventions were completed. At that time we anticipated deleading as many as 100 units. Because of the logistical complexities that this presented, advice was sought from numerous sources.

All deleading contractors licensed to work in Massachusetts were invited to attend a pre-request for bids "brainstorming" meeting on February 14, 1990. Mark Farfel and Susan Guyeaux who have been involved in research and development of deleading procedures in Baltimore, Maryland also were asked to attend and offer suggestions. The scope of work was described, preliminary specifications explored, and feedback obtained from local contractors. It quickly became apparent that several contractors would be required to perform the work.

The most prominent problem was scheduling defeading around soil abatement activities in Groups A and B so that soil abatement could be completed before the cold weather months when the ground freezes. It was also necessary to delead the exteriors of buildings before soil removal in Groups A and B to prevent recontamination. (Group S received soil abatement the previous year.) These problems led to the decision to develop separate contracts for interior and exterior deleading activities so that these activities could be performed independently, thereby preventing delays that could interfere with soil abatement. It was decided that eight contracts would be needed (four for interior work and four for exterior). This approach allowed for the soil abatement needs to be satisfactorily addressed and allowed medium sized as well as larger deleading companies to bid on the activities.

Requests for bids were put out in three phases due to the time involved in preparing lead paint inspection and bid documents. Each phase ended in competitive negotiations to bring down the initial bids.

Exterior work included the removal of lead contaminated paint from chewable surfaces below five feet on siding, porches, rails, stairs, windows and doorways of common areas as well as the building's exterior surface. Loose paint above five feet was also made intact. If these areas of the home were deteriorated, or if it was too difficult or hazardous to remove the lead paint from a surface, items were removed and replaced with new materials of similar workmanship as other items in the house or neighborhood. Columns with chewable surfaces were covered or scraped to a height of five feet.

Interior deleading consisted of removing lead contaminated paint from chewable surfaces below five feet and making intact all loose paint above five feet on walls within the apartment or housing unit. To minimize deleading hazards, dust generating methods were avoided whenever possible. Replacement and off site dipping were used whenever possible although some use of dry scraping was unavoidable.

The following contractors performed the interior and exterior deleading. All were licensed by the State of Massachusetts to engage in deleading activities:

Action Deleading
Point West Plaza
21 Torrey Street
Brockton, MA 02401

Paint by Numbers
P. O. Box 128
N. Easton, MA 02356

A. Escalada Painting Co.
633 Ferry Street
Marshfiled, MA 02050

Tri-State Restoration
16 Hazel Drive
Hampstead, NH 03841

Contractor hired by the one owner who chose to hire his own contractor:

Tolan and Sons Deleading
44 Coburn Street
Framingham, MA 01701

Subcontractor to Action Deleading:

Webster Environmental
161 Granite Avenue
Dorchester, MA 02124

11.2 DEVELOPMENT OF INSPECTION PROCEDURES

It was originally planned that an inspector from the Office of Environmental Affairs of Boston's Department of Health and Hospitals would perform limited inspections of participants' homes and provide information on the lead paint content in the premises. It was essential for scientific considerations that we have a measure of children's exposure to lead in paint and take this lead source into account when we determined the effectiveness of lead contaminated soil abatement. Because this plan called for inspections to be performed by a "code enforcement inspector," under Massachusetts law it would require that any unit found to have lead paint be deleaded. Such an approach, however, was likely to discourage many families and landlords from participating.

After meetings with representatives of the Massachusetts Department of Public Health, it was decided that the study would hire private inspectors who were not bound by code enforcement inspection requirements. The inspection reports generated by these individuals would be filed with the State's Lead Paint Poisoning Prevention Program, but since the participating children's blood lead levels were below 25 μg/dL, the reports would not be reviewed by state officials and so would not result in mandatory deleading. This allowed the study to obtain the necessary scientific information without putting participating families or owners in legal jeopardy.

In April 1990 private inspectors were hired. Inspection procedures were developed that were consistent with study needs and legal requirements. It was initially expected that these inspectors would only perform a one-time inspection in each unit prior to any deleading activities. It was planned that study case managers would be trained by an industrial hygiene consulting firm to monitor deleading operations. Final deleading compliance letters were to be issued by an inspector from the Office of Environmental Affairs after work was completed. The Massachusetts Department of Labor and Industries, however, refused to grant a waiver of their deleading regulations to allow on-site monitoring by study case managers (even though there is no provision in the regulation for monitoring, i.e. the regulation addresses inspections only). Thus, the only way to provide on-site safety monitoring was to have the private inspectors do both on-site monitoring and inspections. The final compliance letters were issued by the inspector who had performed the initial inspection.

Initial inspections were performed between June and August 1990. Monitoring of deleading activities took place between August and the end of December 1990.

11.3 DELEADING ACTIVITIES

The 152 children participating in the study lived in 123 housing units on 101 premises. Deleading or assistance with deleading was offered to all 123 households. Thirty of these households either moved or refused to have an inspection for lead based paint. Study staff did not pursue deleading in these cases. In all cases, however, irrespective of whether an extensive inspection was performed, at least six measurements of the lead content of interior paint were obtained per unit. Using a PGT (Princeton Gamma Tech) x-ray fluorescence instrument, the inspector obtained measurements of the lead in the paint on the woodwork and on one wall in the kitchen, living room, and child's bedroom. If more than one child lived in the unit, samples were obtained from each child's bedroom. Inspections were refused generally over concern about the legal obligation to delead the unit if an inspection revealed the presence of lead based paint. Study assistance with deleading was first offered at the time families and landlords were recruited to participate in the study. Refusals to have premises inspected or deleaded, however, occurred throughout the study.

Ninety-five units were given full inspections for lead-based paint. Six of these units had previously been deleaded and 32 families refused deleading after the inspection. In an additional seven cases, deleading was refused after the deleading bids went out. Thus, deleading was refused for 39 of the 95 inspected units. Reasons for refusal included unwillingness to prepare for the move and disruptions to lifestyle that the move would entail (e.g., children's transportation to school and adults' transportation to work).

A total of 92 deleading operations were conducted at 46 premises. Each deleading operation refers to either the interior deleading of a unit or the exterior deleading activities associated with that unit. Deleading related work started on August 20, 1990 and all work that could be considered deleading was completed by December 31, 1990. There were tasks that the contractor initially believed to be completed but were found to be incomplete when post-deleading inspections were performed. These and other loose ends brought the completion date for all deleading related activities to February 14, 1991.

Most deleading involved single units within buildings that had two or more living units. Four of the addresses involved deleading two units within the same building and four participating families lived in single family houses. Three non-owner occupied residences participated in study assisted deleading. There were four units on these three properties. The study offered to pay up to $ 2,000 towards deleading units in non-owner occupied households. One owner who had two units at the same address chose to hire his own deleading contractor to perform the work. The study paid $4,000 directly to the contractor and monitored the deleading activities in the same manner as the other households in the study. The remaining two non-owner occupied addresses were deleaded by contractors hired by the study, as was the case for all owner occupied properties.

Forty-five deleading compliance letters were issued at the end of deleading activities. Deleading compliance letters are official documents stating that a property is in compliance with the Massachusetts Lead Law and that previously identified violations have been rectified. One non-owner occupied address was not issued a deleading compliance letter because only the building's exterior was deleaded under the study's guidance. Although the interior of this unit had been previously deleaded, it was done under an older version of the law. The law does not permit issuance of a certificate for exterior deleading alone and does not contain a grandfather clause covering work performed under the old law. In three

additional premises, only exterior deleading was done although we initially had planned to do interior and exterior deleading at these sites. No deleading compliance letters were issued for these premises.

In one dwelling, no compliance certificate was issued although both interior and exterior deleading was completed. On initial inspection of this dwelling access to the basement was prevented by a locked door. During the final inspection after deleading activities were completed, this door was found open and was being used as an entrance to office space created recently by the owners. The inspectors would not issue a compliance letter because this allowed children access to an area that previously had not been inspected. The owners must now have this area inspected and, if necessary, deleaded in order to obtain a certificate of compliance. This is the responsibility of the owners since the study will not be involved in any further inspection or deleading activities.

Weekly progress meetings were held to arrange and monitor deleading activities. Contractors, inspectors, and the study's deleading coordinator attended all meetings and whenever necessary, other members of the study staff attended to discuss issues or problems that required their attention. This forum was used to provide updated information on all changes in field activities, schedules, moving issues, etc., and keep inspectors, contractors, and the project administrator informed of other changes that were required to accomplish tasks in the necessary order.

11.3.1 Exterior Deleading

Exterior deleading work was performed on 46 properties covered under four separate deleading contracts. This work included all common interior areas; other buildings on the properties such as garages; and exterior window sills (except for window sills in participating families' units which were addressed as part of interior deleading). Deleading certificates of compliance were issued for 42 of the 46 exterior deleading operations.

Exterior deleading required from 1 to 41 days per property. A total of 1,156 days were required for the 46 exterior deleading operations. The average duration of exterior deleading was 25 days per site. These figures include all of the work activities, including non-hazardous finish work. All four of the exterior contracts were completed within the scheduled time frame.

Exterior deleading did not require occupants to relocate. All work was performed without disruption to any of the building's occupants except for requiring alternate access during the periods that work was being done on stairways. It was the responsibility of the contractor to check the soil abatement schedule to make sure exterior deleading work did not interrupt the soil work. No exterior deleading took place when properties were undergoing soil removal or landscaping.

Lead painted exterior surfaces were freed of loose or peeling lead paint by chipping and scraping and were then given a primer coat of paint. Application of finish coats of paint were the owner's responsibility.

Common hallways in multi-unit buildings were addressed as part of the exterior deleading contracts. The contractor was responsible for informing other building occupants of the work activities occurring in these areas and to assure that alternate access rules were observed. HEPA vacuum units were installed on the first floor at the entrance to buildings. Containment barriers were set up to make sure that the work area was isolated and that no contamination spread outside of the work area. A warning sign, as required by the Massachusetts Lead Law, was affixed to the outside of the containment area entrance. Work in the common hallways/staircases began on the top floor and proceeded down to the first floor level. Deleading was performed according to the methods developed and explained in the study's specifications and were monitored by the study's inspection team to insure compliance.

11.3.2 Interior Deleading

Interior deleading involved only the inside of the living units of families participating in the study. Exterior window sills of these units were included in the interior deleading contract activities. The unit's occupants and all of their belongings were relocated for the duration of the interior deleading work. A moving contractor was hired by the study to remove the occupant's belongings and furniture prior to the deleading contractor's arrival. All belongings were fumigated to exterminate insects and placed into storage for the duration of the deleading. Damages caused by the movers were addressed prior to the final release of a 15% retainer.

The moving contractor billed additional charges for items that remained in storage for over seven days at a rate of $6.00 per household per day. Additional storage per household ranged from 1 to 43 days and averaged 9.5 days. There were a total of 391 extra storage days, charged at a cost of $2,346. Forty-one households were moved under the moving/storage contract; five households did not require moving assistance.

Case managers and contractors occasionally helped families with last minute packing. In five instances extra charges were incurred when it was necessary to cancel moves since occupants were unprepared. The cost of these cancellations was $1,800. There was only one last minute cancellation that was never rescheduled because the occupants would not or could not pack for moving. In the other four instances of cancellations, moves and deleading were rescheduled. No compensation was made to the deleading contractor in cases where sites were eliminated prior to the scheduled start date. The moving contractor, however, did receive compensation for costs incurred when a move was cancelled or postponed. The total cost of moving and storage (including additional storage costs and cancellation fees) was $33,666.

The duration of interior deleading activities ranged from 3 to 58 days per unit, averaging 15.6 days. A total of 716 days were needed to delead the 46 interior sites. This included only the time during which occupants were required to be out of their homes.

Interior deleading work included 46 households that were addressed under four separate contracts. Most work was started on schedule, but in several instances work was not completed according to schedule. Some of these time overruns were unavoidable. No penalties were assessed against contractors if the explanations for schedule delays were reasonable. There were six cases, however, where these delays were avoidable and penalties in the form of liquidated damages of $1,000 per day were assessed for a total cost of $6,000. All of the penalties were assessed against the same contractor and only after other attempts by study staff to rectify problems were exhausted. These penalties were used as a last resort and only when it was absolutely necessary to maintain the study's best interests. Alterations of time schedules were rarely permitted, and only with approval of the deleading coordinator.

Interior deleading involved the removal of lead paint from chewable surfaces below five feet, and doors and windows and other chewable surfaces within the living unit. This was accomplished by replacement, off-site dipping in paint removing chemical mixtures, and

scraping. Owners had the option to have items that had ornamental detail taken off site to have the lead paint removed by dipping. Loose paint above five feet was made intact. The dipping process did cause some of the older deteriorated materials to separate or dissolve, but this kind of damage was minimal.

Items that had little or no ornamental detail were replaced with #2 pine. When doors were dipped, the door jamb was scraped free of lead paint to a height of five feet on site. In general, this was the only instance where dry scraping was allowed during interior deleading. Dry scraping or the use of chemical solvents was allowed only when there was an architectural or structural reason for not removing the material from the site or when it was required to satisfy the requirements of the Massachusetts Lead Law. When new doors were installed the pre-hung/hollow-core type was used. This eliminated the need for scraping jambs. Since the study investigators and staff believe that dry scraping is an extremely hazardous process, this type of deleading was kept to an absolute minimum.

All items deleaded off site and replaced, and all items that were deleaded on site were given a coat of primer paint by the deleading contractor. This was done to make sure that any fine dust film or residue left on the surface was sealed in. New materials were not painted by the contractor as this was the responsibility of the property owner. Similarly, making the surfaces above five feet intact involved priming only the repaired surfaces. The entire wall surface was left for painting by the owner after deleading was completed.

Prior to removal of the critical barriers, the contractor was required to HEPA vacuum and wet wash all surfaces within the containment area. This cleaning process followed a set sequence beginning with surfaces that were deleaded, then walls and vertical surfaces, then horizontal surfaces, and finally floors. Critical barriers were then removed and the unit HEPA vacuumed again. Wood floors were coated with polyurethane

11.3.3 Temporary Housing

The ability of participants to find short-term housing during interior deleading presented a major obstacle. If the study were to provide temporary housing, these sites would have had to be deleaded or the study would have had to delead them prior to housing families there. Deleaded units were very difficult to locate and unavailable for short-term rental. The study staff investigated the possibility of deleading several units in exchange for

temporary housing. This option was ruled out because of insurance, liability, and other legal reasons. Participants were urged to find their own alternate housing with friends or family. The study paid for lodging only after families had demonstrated a sincere effort and were unable to find temporary housing. Study staff provided participants with a list of hotels/guest houses that would provide lodging. Families made their own lodging arrangements and the study staff set up purchase orders to handle payment.

Seven families were assisted in finding temporary lodging while deleading was being performed. Their stays ranged from 1 to 19 nights, and the average length of temporary lodging paid for by the study was 11 nights. A total of 78 nights of lodging were provided by the study at a total cost of $11,612. An additional 39 families found alternative housing without assistance from the study staff.

11.3.4 Damage Control

Pre-existing damage was recorded prior to the commencement of deleading. The contractor was responsible for giving a written report on the pre-existing damage to the study site monitor before beginning work. Pre-existing damage that was uncovered after the work had started was brought to the attention of the study site monitor and recorded in the monitor's daily log.

Study site monitors were on each site daily when deleading activities were being conducted to assure that deleading activities were done safely with minimum damage. Due to the nature of the work, however, some damage was inevitable. This was understood by participating families and owners beforehand, and it was understood that certain corrections would be the responsibility of the property owner.

In order to avoid damage and excess ripping of wallpaper the contractor was required to cut a seam between door and window casings and wallpapered surfaces before removing doors or windows. There was only one case where wallpaper was torn during the removal of a window casing. There was no conflict since the owner was aware of possible damage.

Owners were requested to remove telephone and electrical cords that came into contact with lead painted surfaces addressed as part of the deleading, before the scheduled start date. If lines were left in place the contractor took appropriate action to work safely around these areas. However, there were several cases where telephone lines left in place were cut or

broken. The contractors were not held responsible for repairs except when there was obvious lack of consideration when they were removed.

Any damage to walls was corrected by the contractor by filling with joint compound and priming. All finish painting was the property owner's responsibility. Any damage that occurred through neglect or carelessness of work crews was corrected by the responsible party. In cases where there was a dispute as to where responsibility lay, the study site monitors and deleading coordinator determined what course of action was appropriate.

All work sites were strictly monitored by on-site study representatives who interrupted or redirected work for reasons of safety or requested corrections according to the specifications.

11.3.5 Clearance Sampling

Massachusetts requires clearance sampling for dust lead levels after interior deleading in situations where dust is visible. The State standard for acceptable dust lead levels after deleading is 200 μg/square foot on the floor, 500 μg/square foot on window sills, and 800 μg/square foot in window wells. When no dust is visible to the inspector, clearance sampling is not required.

The study specifications required that visible dust be removed completely before the work area was considered ready for clearance sampling. Clearance sampling was required for every unit deleaded in conjunction with the study. The study did clearance sampling in two rooms on each floor of each deleaded interior unit and in the common hallway areas. Moreover, the study insisted that all clearance samples meet the lead levels indicated in the Massachusetts Lead Law before the deleading operation was considered complete.

Samples were taken by lead inspectors from the floor, window sill, and window well from each room sampled after contractors informed the inspectors that deleading was complete. Inspectors did not inform contractors where the samples were going to be obtained. The samples were obtained by wiping surfaces with commercially available "Wash and Dries". Inspectors wore disposable gloves, which they changed between samples, and they wiped one square foot on the floor and wiped measured window sills and wells. Blanks were included with each set for quality control purposes. In order to improve the efficiency of sample preparation, study staff added hydrochloric acid to the samples to start

the 15 hour digestion period. Analysis was performed by the Lead Lab at Boston City Hospital using atomic absorption spectrophotometry (spectroscopy). By having the study staff start the digestion process, the turn around time involved in preparation and analysis was reduced by at least one day per unit.

Due to cost constraints, the original plan was to do clearance sampling only after deleading was believed to be completed. However, pre-deleading clearance sampling was performed in the interiors of 17 units to provide data for pre and post-deleading comparisons.

Post-deleading clearance sampling of the 46 household interiors revealed that 32 (70%) of the households had acceptable dust lead levels without additional clean-up. Fourteen (30%) of the households were found to have unacceptable dust lead levels and required a second cleaning and an additional set of samples. Two of these 14 required a third cleaning before acceptable lead levels were obtained.

The failure rate of final wipe samples was very high despite the fact that the sites appeared clean by visual inspection. All deleading contractors working for the study were monitored during deleading activities and wipe samples were not taken unless areas appeared clean of dust and dirt. This, along with limiting dry scraping to areas where it was absolutely necessary, should have provided a work area that was as free of lead contaminated dust as possible. This highlights some of the dangers associated with interior deleading activities and raises questions about the adequacy of visual inspections for dust post interior deleading.

Clearance sampling was performed in conjunction with the final inspection activities that occurred at the completion of interior deleading activities. It took approximately one hour per site to obtain the samples and begin the digestion process.

12. SCHEDULE OF ACTIVITIES

The schedule of activities is shown on Tables 12-1 and 12-2. Table 12-1 gives the timetable of activities by month. The actual dates on which activities began and ended are shown on Table 12-2.

TABLE 12-1. TIMETABLE OF ACTIVITIES

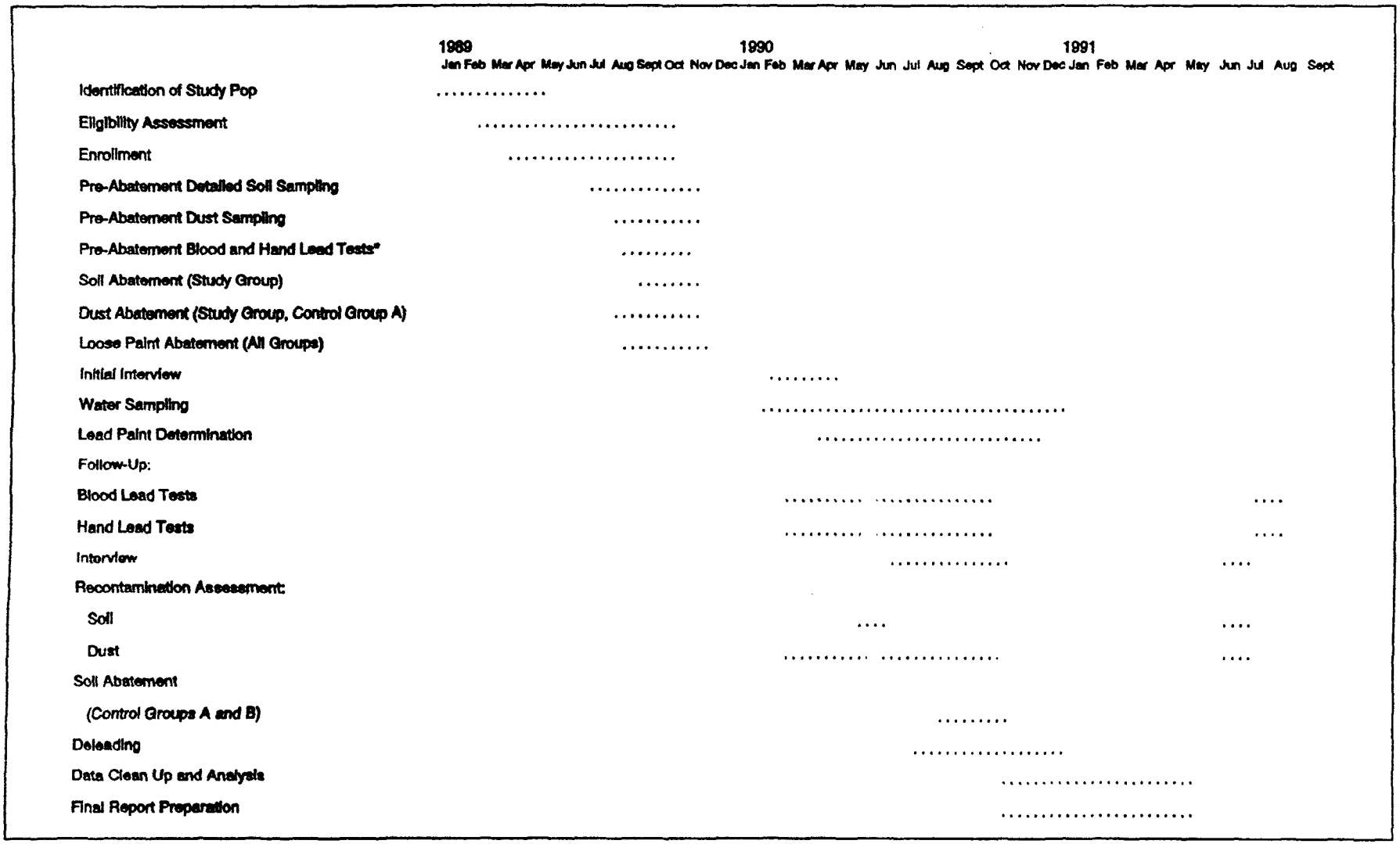


TABLE 12-1. TIMETABLE OF ACTIVITIES

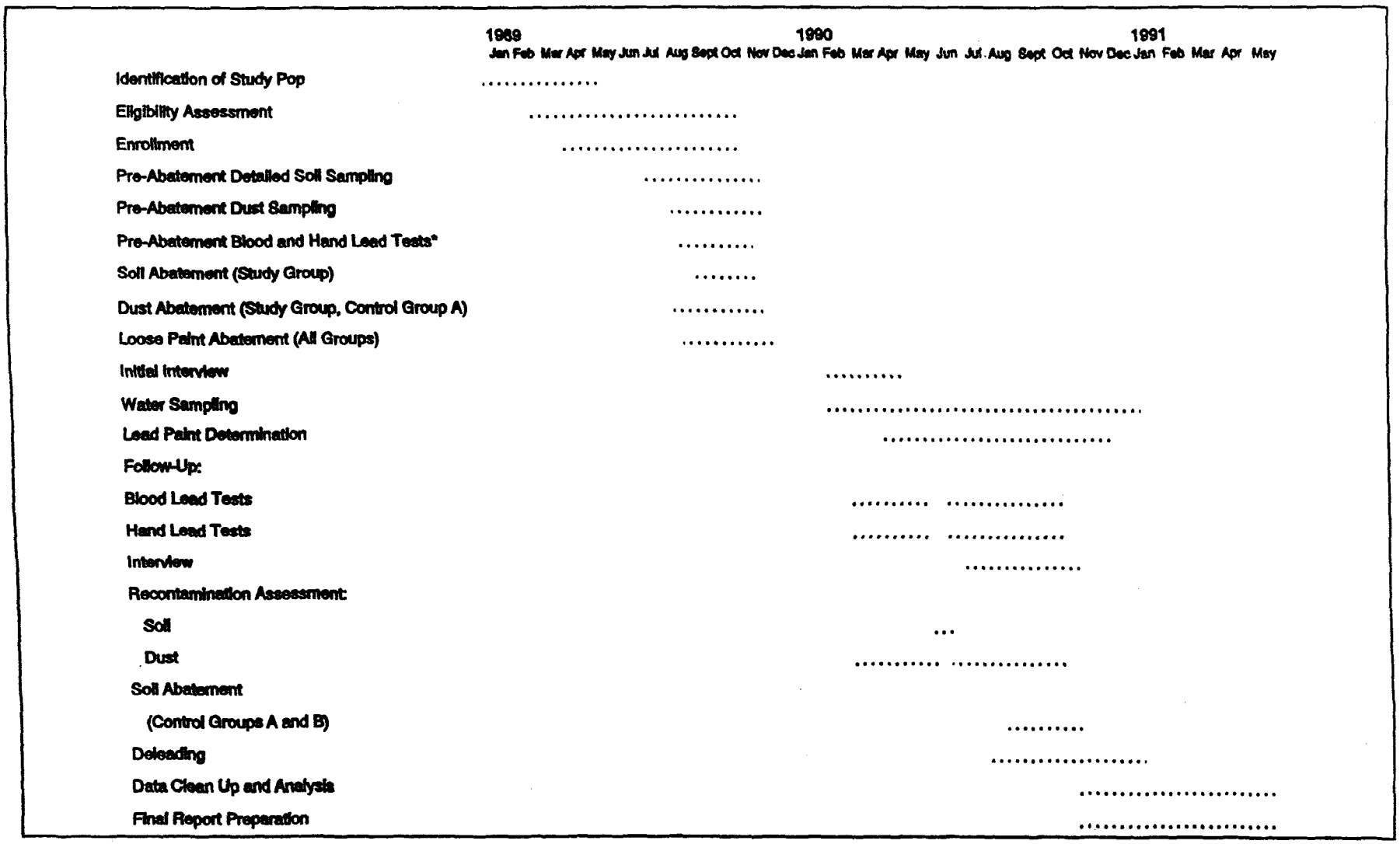


TABLE 12-2. STARING AND ENDING DATES FOR INTERVENTIONS AND SAMPLING

	Started On	Ended On
Baseline Blood Sampling	9/14/89	1/8/90
POST1 Blood Sampling	3/19/90	6/13/90
POST2 Blood Sampling	7/19/90	11/17/90
Baseline Handwipe Sampling	9/13/90	12/20/89
POST1 Handwipe Sampling	3/20/90	7/3/90
POST2 Handwipe Sampling	7/18/90	1/3/91
Preliminary Soil Sampling	4/4/89	11/18/89
Pre-Abatement Detailed Soil Sampling	8/4/89	6/20/90*
Soil Abatement (Study Group)	9/18/89	12/26/89
Soil Abatement (Control Groups A and B)	9/11/90	12/11/90
Soil Recontamination Sampling, Round #1	6/11/90	7/13/90
Pre-Abatement Interior Dust Sampling	8/17/89	1/16/90
Post-Abatement Interior Dust Sampling	10/6/89	3/9/90
Dust Recontamination Sampling, Round #1	3/27/90	6/14/90
Dust Recontamination Sampling, Round #2	7/2/90	12/15/90
Interior Dust Abatement	10/2/89	1/30/90
Interior Loose Paint Abatement	10/2/89	1/30/90
Water Sampling Round #1	2/8/90	7/23/90
Water Sampling Round #2	7/18/90	2/11/91
XRF Lead Paint Determinations	4/10/90	1/7/91
Initial Questionnaire Administration	2/2/90	5/2/90
First Follow-up Questionnaire Administration	7/19/90	3/21/91
Paint Deleading	8/28/90	1/4/91

*Approximately 80% of the detailed soil sampling was completed by 1/24/90. 23 soil samples were taken between 1/24/90 and 6/20/90. Approximately 90% of the detailed soil sampling was completed by 5/25/90. 12 soil samples were taken between 5/25/90 and 6/20/90.

13. DATA COLLECTION AND MANAGEMENT

The study generated and maintained data from the soil, dust, water, paint, blood lead, and hand lead analyses. In addition, information collected from two sets of questionnaires was collected and analyzed. Data collection instruments were developed to gather and code all information.

Quality control and assurance measures were performed at each step of data collection. These included the following measures:

1. All original paper forms were stored by premises identification number or in chronological order in file cabinets enabling easy access and retrieval.

2. Original report sheets from ESA, EPA, Dennison, Bioran, and Hall- Kimbrell laboratories were stored separately.

3. All completed forms and questionnaires were reviewed manually for accuracy and completeness and any questions and problems were resolved in an ongoing manner.

4. The standard data entry validation tools (range checks, picture formats etc.) were used for all data sets created through data entry.

5. The quality of identifiers was assured through table-lookup at data entry. The principal identifiers were validated against a table of valid values and invalid values were rejected. Valid values called up additional identifying information (name, address, etc.) to verify a correct match.

6. Up-to-date source coding listings and coding manuals of all database files structures, programs and documentation was maintained and available for easy access.

7. 100% verification of all data entered by the study's data entry clerk was conducted visually.

8. There were daily and weekly backups of all important files as well as biweekly archiving of all important files in the database format.

9. There was periodic inventory of all collected data.

The study data base consisted of many data files which were either created by data entry using the Paradox database management system, received from the EPA Region I Laboratory as Lotus files, or received from the Boston Childhood Lead Prevention Program (BCLPPP) as Dbase3+ files. All received files were imported into Paradox for data correction. All Paradox files were converted into Statistical Analysis System (SAS) data sets for data management and analysis.

The study had two distinct data collection phases, the "eligibility" phase and the "study" phase, and each phase required its own set of data files. During the eligibility phase, information pertaining to criteria for study enrollment was collected in order to identify subjects who were willing and eligible to participate in the study. Computer files generated during the subject recruitment period were used for study management and for descriptive analyses of the non-participants. When the study phase began, data pertaining to participants were transferred from the eligibility data files to the study files. The eligibility data files were archived.

Data were collected about four separate units of observation: child, family, unit (premises and apartment concatenated) and premises. Some data files contained repeat measures type data, i.e. the same set of data items for the same unit of observation collected at different times. For instance, blood lead test results were collected three times for each child. The goal of the organization of the data base was to make it possible to (1) easily match a child to the data that apply to his premises or apartment, and to (2) easily match information pertaining to a stage of a study (e.g., pre-abatement, post-abatement, etc) across all files with repeated measures data.

The central file was the KID file which provided the means by which data from different files could be combined to form composite case records. The unit of observation for the KID file was a child and each observation contained all the identifiers for that child (child id, family id, premises id, unit id). Any files that did not have identifiers in common were merged through the KID file.

Repeated measure data contained a variable called PHASE that designated the phase of the study in which the test was done. By selecting test results based on values of PHASE, data from different stages of the study can be compared.

A more detailed description of the data management plan including a database configuration and file descriptions was also developed and is included in the Appendix.

14. DATA ANALYSIS

The main purpose of the data analysis was to test the hypothesis that a reduction of at least 1,000 PPM in the concentration of lead in soil with starting concentrations greater than 1,500 PPM results in at least a 3 μg/dL reduction in children's blood lead levels over the following year. First, we conducted crude analyses of the change from baseline blood lead levels (i.e., before any abatement activities) to the first and second post-abatement blood lead levels obtained an average of six and eleven months, respectively, after the abatement activities. We used analysis of variance to compare mean blood lead changes among the intervention groups and paired t-tests to determine whether mean changes in blood lead levels within the intervention groups were significantly different from zero.

Following the crude analyses, we used analysis of covariance to compare the intervention groups with respect to post-abatement blood lead levels adjusted for pre-abatement blood levels. This was necessary because of slight differences in the baseline blood lead levels of children in the three groups. The post-abatement blood lead levels were reasonably normally distributed and did not require any transformations. The base model that we used to obtain estimates of adjusted post-abatement blood lead means in the intervention groups was:

$$Y_i = b_0 + b_1 Z_{1i} + b_2 Z_{2i} + b_3 X_i + e_i$$

where for the ith child,

Y_i = post-abatement blood lead level

Z_{1i} = 1 if in Control Group A, otherwise 0

Z_{2i} = 1 if in Control Group B, otherwise 0

X_i = pre-abatement blood lead

e_i = error term

The coefficients, b_0, b_1, b_2, and b_3 were estimated using least squares methods, and t-tests were used to test the null hypothesis that b_1 and b_{2c} were equal to zero (i.e., Was the mean adjusted post-abatement blood lead level in each Control Group different from that of the Study Group?).

Potential confounders of the relationship between group assignment and post-abatement blood lead were added to the base model one at a time to obtain estimates of the group effect adjusted for baseline blood lead level and the potential confounder. More complex models that controlled for several variables simultaneously were also developed. Potential confounders included age, sex, race, socioeconomic status as measured by the Hollingshead Index, mouthing and handwashing behaviors, and environmental sources of lead (e.g., paint and water). In most instances, the variables were categorized; cutoffs were based on the frequency distribution of the particular variable or on external considerations (e.g., regulatory standards for environmental sources of lead). In some instances, variables were combined before being added to the base model. For example, the following set of variables were developed to describe mouthing behaviors: pacifier use (yes/no), thumb sucking (often/sometimes/rarely/never) and a count of the number of times any other mouthing behaviors were reported at interview (zero/one/two/three-five).

There were several reasons why we decided to use analysis of covariance (ANCOVA) with baseline Pb as a covariate to estimate the differences between groups instead of analysis of variance (ANOVA) with the absolute change in Pb as the dependent variable. Consider the following models:

ANCOVA Model $Y = \alpha, + \beta X + E$

ANOVA Model $W = \gamma, + E$

where Y = post treatment Pb,

X = baseline Pb,

and $W = Y - X$.

The relationship between the ANOVA and ANCOVA models depends on whether you assume a fixed effect model or a mixed model for the ANOVA. The ANCOVA model may be rewritten as a fixed effect ANOVA model if $\beta = 1$.

$$Y = \alpha i + \beta X + E$$

$$Y - X = \alpha i + (\beta - 1) X + E$$

$$W = \alpha i + (\beta - 1) X + E$$

The ANCOVA model does not force the slope of the regression to be equal to one; rather, it allows the slope to be estimated from the data. If the slope is, in fact, equal to one, the two models are equivalent. Samuels[22] shows that the ANOVA mixed model is a special case of the ANCOVA model, with $\beta = \rho$, the correlation between Y and X.

In either case, the ANOVA model provides a less powerful test of treatment differences than does the ANCOVA model. It is recommended only if there is a large imbalance in baseline means, in which case the ANCOVA model may not be valid.[22,23] In our study the mean pre-abatement blood lead level was higher among children assigned to the Study Group; however, this difference was not statistically significant.

An important assumption of the ANCOVA model is that the slopes of the regression lines are equal in the treatment groups. We found this to be the case here, with the interaction term not significantly different from zero ($p > 0.10$).

The data analysis was conducted using SAS statistical software. The statistical methods used (t-test, analysis of variance and analysis of covariance) are described in the SAS manuals and standard statistics text books.

15. RESULTS

15.1 BLOOD LEAD LEVELS

15.1.1 Crude Analysis

Table 15-1 describes the results of crude analyses that examined the change in blood lead levels among all participants following the abatement activities. Mean blood lead levels in all the intervention groups declined at the first post-abatement sampling round (POST1) and rose at the second post-abatement sampling round (POST2) although for no group did the mean return to the baseline. At POST1 the average blood lead decline was 2.87 μg/dL in the Study Group, 3.52 μg/dL in Control Group A, and 2.04 μg/dL in Control Group B. All declines were significantly different from zero. At POST2 the average blood lead level increased 1.39 μg/dL in the Study Group, 2.69 μg/dL in Control Group A and 1.52 μg/dL in Control Group B. The increases in the two Control Groups were significantly different from zero but the increase in the Study Group was not ($p=0.08$).

Two siblings in the Study Group became lead poisoned sometime between the POST1 and POST2 sampling rounds. Their blood lead levels were 19 μg/dL and 12 μg/dL at baseline (September 1989), 10 μg/dL and 17 μg/dL, respectively, at POST1 (March 1990) and 35 μg/dL and 43 μg/dL, respectively, at POST2 (July 1990). No other children in any group experienced a blood lead rise of this magnitude during the course of the study. In fact, these two children's POST2 blood lead levels were more than three standard deviations higher than the overall mean POST2 level. Figure 15-1 depicts the relationship between PRE and POST2 blood lead levels for all children and visually demonstrates that these two children were outliers. Since the elevated levels were detected many months after the abatement activities, we do not believe that the increases were related to the study interventions. We hypothesize that the siblings were exposed to another source of lead, probably leaded paint at another site, and have information from parent reports about their exposure to renovations of an apartment containing lead contaminated paint to support this hypothesis.

Therefore, with the approval of the EPA project officer and a consultant statistician, we excluded these two children from subsequent analyses. Table 15-2 describes the blood lead

TABLE 15-1. CRUDE CHANGES* IN BLOOD LEAD LEVELS AMONG ALL PARTICIPANTS

STUDY PHASE	STUDY GROUP	CONTROL GROUP A	CONTROL GROUP B
Pre-Abatement (Sept. '89-Jan. '90)	13.18 (N=54)	12.37 (N=51)	12.02 (N=47)
	-2.87 p=0.0001	-3.52 p=0.0001	-2.04 P=0.0001
Post-Abatement POST1 (Mar. '90 - June '90)	10.31 (N=54)	8.85 (N=48)	9.83 (n=46)
	+1.39 p=0.08	+2.69 p=0.0001	+1.52 P=0.0001
POST2 (July '90 - Nov. '90)	11.70 (N=54)	11.49 (N=49)	11.35 (n=46)

distributions over time and Table 15-3 describes the average change in blood lead levels with the two lead poisoned siblings excluded. Without these children, the mean blood lead level in the Study Group increased by only 0.46 μg/dL at POST2. This increase was not significantly different from zero (p=0.31). Figures 15-2 and 15-3 depict the blood lead changes graphically.

Because the PRE and POST2 sampling rounds are most closely matched on season, we focused subsequent analyses on this comparison. The mean decline in blood lead was 2.44 μg/dL in the Study Group (p=0.001), 0.91 μg/dL in Control Group A (p=0.04) and 0.52 μg/dL in Control Group B (p=0.31). The mean blood lead level of the Study Group declined 1.53 μg/dL more than that of Control Group A (95% Confidence Interval: -2.87, -0.19) and 1.92 μg/dL more than that of Control Group B (95% Confidence Interval: -3.28, -0.56). Over the course of the study, behavioral changes including more frequent housecleaning and handwashing were similar among the groups and so do not explain these

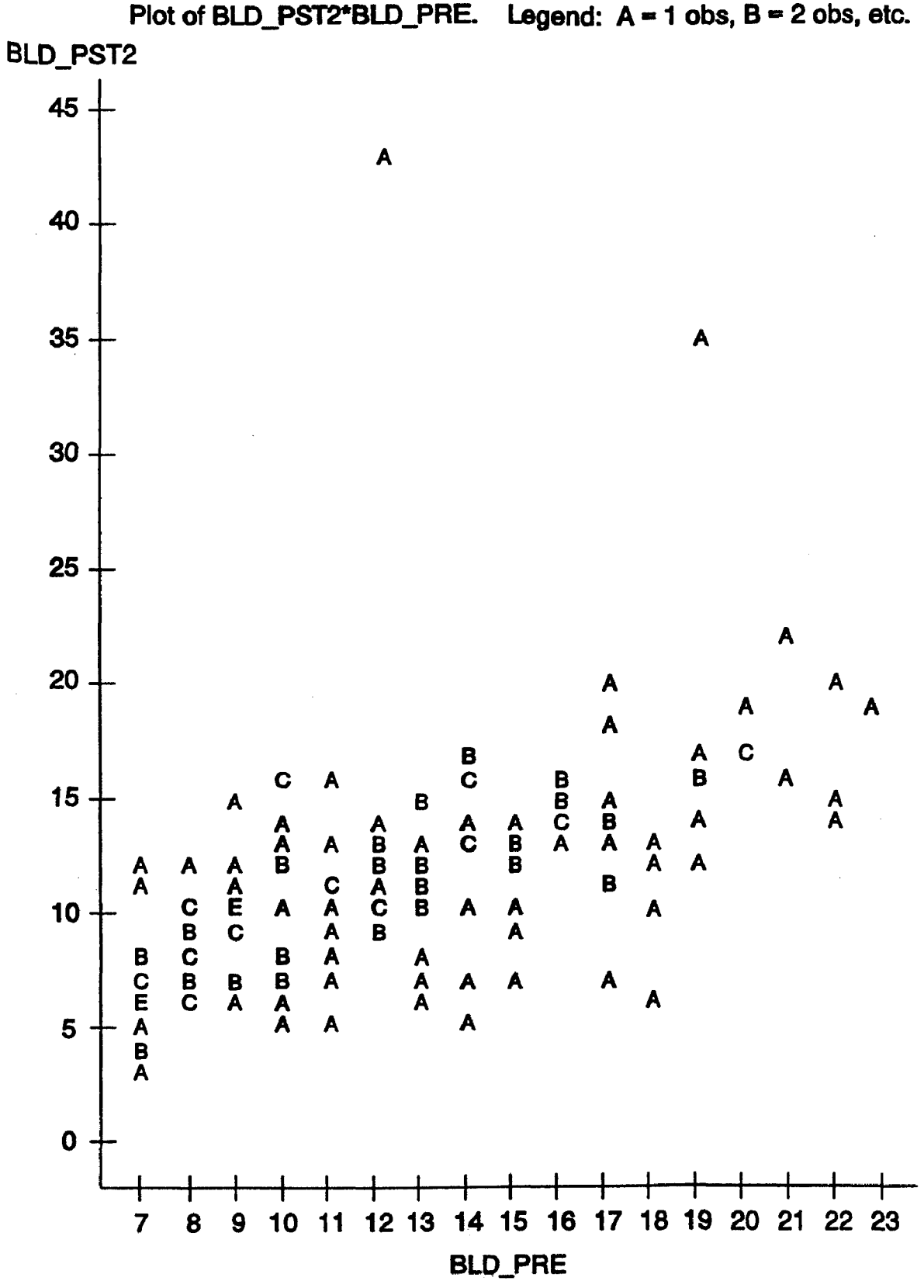


Figure 15-1. Relationship Between Pre And Post2 Blood Lead Levels.

TABLE 15-2. BLOOD LEAD (μg/dL) DISTRIBUTION OVER TIME AND ACCORDING TO GROUP EXCLUDING CHILDREN WHO BECAME LEAD POISONED

	S (N=52)	A (N=51)	B (N-47)	Total (N=150)
PRE				
Minimum	7	7	7	7
25%	9.5	9	9	9
50%	13	12	12	12
75%	16	15	14	15
Maximum	22	23	22	23
Mean	13.10	12.37	12.02	12.51
Standard Deviation	4.36	4.26	3.71	4.13
POST1	(N=52)	(N=48)	(N=46)	(N=146)
Minimum	2	3	4	2
25%	6	6	8	6
50%	10	8	9	9
75%	13	12	12	12
Maximum	22	17	18	22
Mean	10.19	8.85	9.83	9.64
Standard Deviation	4.63	3.79	3.49	4.04
POST2	(N=52)	(N=49)	(N=46)	(N=147)
Minimum	4	3	5	3
25%	7	9	8	8
50%	10	11	11.5	11
75%	14	14	14	14
Maximum	22	20	20	22
Mean	10.65	11.49	11.35	11.15
Standard Deviation	4.04	3.94	3.65	3.88

TABLE 15-3. CRUDE CHANGES* IN BLOOD LEAD LEVELS EXCLUDING CHILDREN** WHO BECAME LEAD POISONED

STUDY PHASE	STUDY GROUP	CONTROL GROUP A	CONTROL GROUP B
Pre-Abatement (Sept. '89-Jan. '90)	13.10 (N=52)	12.37 (N=51)	12.02 (N=47)
	2.90 p=0.001	-3.62 p=0.0001	-2.04 P=0.0001
Post-Abatement POST1 (Mar. '90 - June '90)	10.19 (N=52)	8.85 (N=48)	9.83 (n=46)
	+0.46 p=0.31	+2.69 p=0.0001	+1.52 P=0.0009
POST2 (July '90 - Nov. '90)	10.65 (N=52)	11.49 (N=49)	11.35 (n=46)

*The crude differences in blood lead levels were calculated by taking the average of each child's blood lead change. Only children with blood lead levels for each relevant phase (e.g., PRE and POST1) contributed to the average change for that period and so simply subtracting the average level for one phase from another will sometimes give a slightly different value.

**Two children in the Study Group became poisoned between the POST1 and POST2 sampling rounds.

differences. The impact of soil abatement was independent of the starting blood lead level (Table 15-4).

15.2 CHARACTERISTICS OF FINAL STUDY POPULATION

The final study population excluding the two poisoned siblings consisted of 150 children in 125 families living in 122 units on 100 premises (Table 15-5). The characteristics of the final study population are presented in Table 15-6. The mean pre-abatement blood lead level was higher among children assigned to the Study Group. With two exceptions, the proportions of children in most racial groups were similar among the intervention groups. The proportion of Hispanics was higher in the Study Group than the Control Groups and the proportion of Blacks was lower. There was also a larger proportion of males in the Study

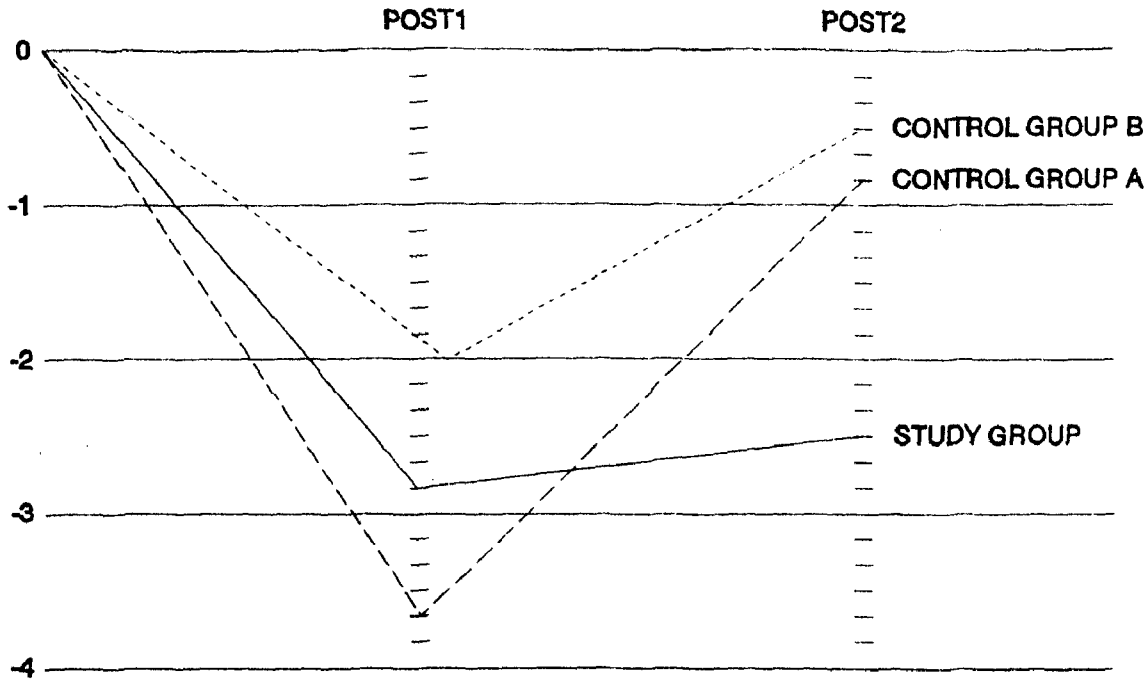
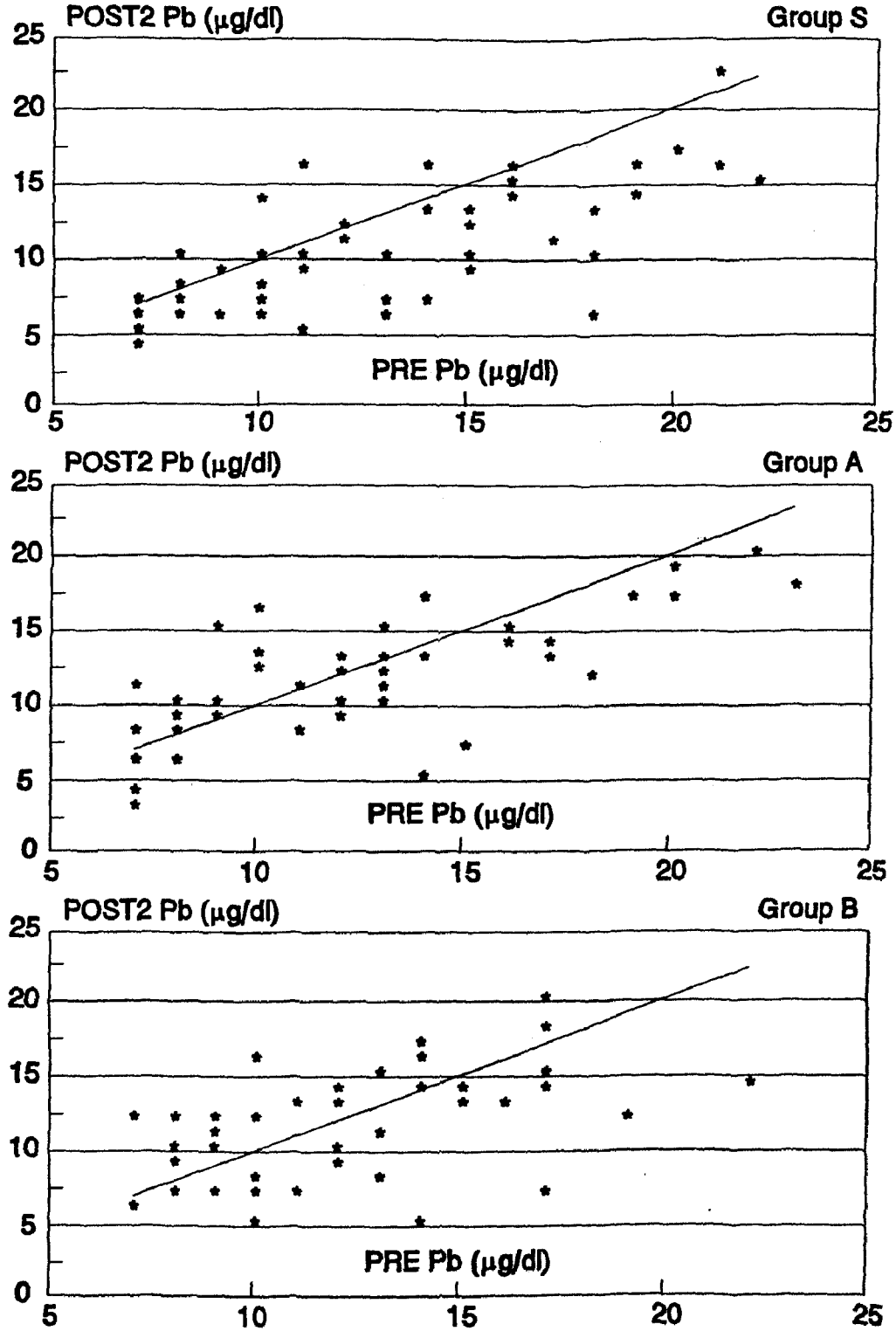


Figure 15-2. Crude Change in Blood Lead Levels Excluding Children Who became Lead Poisoned.

Group. The age distribution varied across groups, however, the average age of the children was quite similar. The proportions of subjects classified in the lowest socioeconomic level according to the Hollingshead Index (Classes 4 and 5) were higher in the Study Group and Control Group B than Control Group A. However, the proportions of owner occupied premises and participant owned units were similar across groups.

Overall, median lead levels in preliminary surface soil samples were approximately 700 PPM higher than median levels in detailed surface samples taken throughout the yard. We believe that this is because the preliminary samples were taken closer to the house. Median surface soil lead levels were also about 800 PPM higher than those taken at a depth of 15 centimeters. Median interior floor dust lead levels were generally similar to the median surface soil levels while median window well dust lead levels were five to seven



Note: Diagonal indicates no change from PRE to POST2

Figure 15-3. Plots of PRE and POST2 Blood Lead Levels According to Group Excluding Children Who Became Lead Poisoned.

TABLE 15-4. ADJUSTED DIFFERENCES IN BLOOD LEAD LEVELS STRATIFIED BY PRE-ABATEMENT BLOOD LEVELS**

Pre-Abatement Blood Lead Levels	S-A	S-B
<15 (N = 105)	-1.35	-1.69
≥ 15 (N = 45)	-0.98	-0.72
<12 (N = 69)	-1.43	-1.47
≥ 12 (N = 81)	-1.17	-1.46
<10 (N = 44)	-0.99	-1.39
≥ 10 (N =106)	-1.35	-1.31
<10 (N = 44)	-1.00	-1.39
10-14 (N = 61)	-1.57	-1.70
≤ 15 (N = 45)	-0.98	-0.72

*Adjusted for pre-abatement blood lead level.
**Excludes two children who became lead poisoned.

TABLE 15-5. DISTRIBUTION OF CHILDREN, FAMILIES, UNITS, AND PREMISES ACCORDING TO GROUP IN THE FINAL STUDY POPULATION

	GROUP			
	S	A	B	TOTAL
NUMBER OF:				
Children	52	51	47	150
Families	43	43	39	125
Units*	42	42	38	122
Premises	34	36	30	100

*Units consists mainly of apartments in multi-unit dwellings.

times higher. Soil and floor dust lead levels were similar across the intervention groups. Window well dust lead levels were more variable across the groups but the differences were not statistically stable.

TABLE 15-6. CHARACTERISTICS OF FINAL STUDY POPULATION

	Study Group Soil, Dust, Loose Paint Abatement (N=52)	Control Group A Dust, Loose Paint Abatement (N=51)	Control Group B Loose Paint Abatement (N=47)	Total (N=150)
Pre-Abatement Blood Lead Level (Mean)	13.1	12.4	12.0	12.5
Pre-Abatement Ferritin Level (Mean)	25.7	24.6	26.6	25.6
Age in Months at Baseline				
% 9-24	34.6	21.6	25.5	27.3
% 25-36	26.9	45.1	29.8	34.0
% 37-51	38.5	33.3	44.7	38.7
Age (Mean)	30.5	31.4	33.1	31.6
% Male	59.6	49.0	51.1	53.3
% Black	42.3	50.0	63.0	51.4
% White	7.7	8.3	4.4	6.9
% Hispanic	26.9	10.4	6.5	15.1
% Cape Verdean	19.2	16.7	15.2	17.1
% Other	3.9	14.6	10.9	9.6
% Class 1-3 SES*	30.0	54.2	26.1	36.8
% Class 4, SES	26.0	14.6	34.8	25.0
% Class 5, SES	44.0	31.3	39.1	38.2
% Owner Occupied Premises**	73.5	86.1	70.0	77.0
% Participant Owned Units***	25.6	29.3	29.0	27.9
Soil Lead Level (Median PPM, Preliminary Sampling)**	2,722	3,163	3,111	2,904
Soil Lead Level (Median PPM, Detailed Sampling)**				
At Surface	2,074	2,230	2,100	2,152
15 cm Depth	1,374	1,244	1,348	1,348
Dust Lead Levels (Median PPM)***				
Floor	2,651	2,513	2,542	2,547
Window Wells	11,815	15,907	13,429	13,832
Water Lead Levels (Median µg/L)***	14.8	14.7	22.0	17.0
Paint Lead Levels (% Undetectable)***				
Wall	30.6	47.4	20.0	33.7
Woodwork	5.1	0.0	11.1	5.2

*According to Hollingshead Index.
**Unit of analysis is the premises.
***Unit of analysis is the housing unit or apartment.

Median first flush tap water lead levels were all above 14 μg/L and were similar across the groups. Lead-based paint was detected in almost all homes and was more likely to be detected on woodwork than walls. XRF readings were similar among the groups.

We also examined the final study population with respect to the calendar months and time interval between children's PRE, POST1 and POST2 blood samples (Table 15-7). The pre-abatement blood sampling round lasted 97 days from September through December 1989. A greater proportion of subjects in Control Group B had their pre-abatement blood drawn towards the end of the round (November and December 1989) than did the Study Group and Control Group A (42.5 vs. 23.1 and 25.5%). The POST1 abatement sampling round lasted 86 days from March through June 1990. A larger proportion of Control Group A was sampled in April compared to the other two groups. The POST2 sampling lasted 121 days and began and ended earlier in the year than the pre-abatement sampling (July through November 1990). However, the mean number of days between PRE and POST1, POST1 and POST2, and PRE and POST2 samples were similar across the groups.

Finally, we examined mean PRE, POST1, and POST2 blood lead levels according to the calendar month of blood sampling (Table 15-8). Mean PRE blood lead levels varied little by month of sampling (12.3 to 12.6 μg/dL). Mean POST1 blood lead levels did vary by sampling month (8.6 to 11.3 μg/dL); the lowest mean level was seen in April (8.6 μg/dL). Mean POST2 blood lead levels increased slightly from August through October (11.0 to 11.9 μg/dL), the months when most of the sampling occurred.

15.2.1 Adjusted Analyses

In the analysis of covariance the intervention groups were compared with respect to post-abatement blood lead levels adjusting for pre-abatement blood levels using a "base model" that included only group variables. Potential confounding variables, described in Table 15-9, were then added to the base model one at a time to obtain adjusted estimates of the group effect.

The POST2 blood lead levels adjusted for baseline level were generally similar to crude levels (Base Model, Table 15-10). The adjusted mean difference between the Study and Control Groups were slightly diminished (columns S-A and S-B) but remained statistically significant. 95% confidence intervals for S-A and S-B were -0.17 to -2.39 and -0.35 to

TABLE 15-7. DISTRIBUTION (%) OF CALENDAR MONTHS AND MEAN INTERVAL BETWEEN BLOOD SAMPLES

	Groups		
	S	A	B
Pre Abatement*			
September 1989	42.6	47.1	36.2
October 1989	30.8	27.5	21.3
November 1989	13.5	5.9	25.5
December 1989	9.6	19.6	17.0
Post-Abatement			
Post 1			
March 1990	42.3	31.3	50.0
April 1990	44.2	56.3	39.1
May 1990	11.5	12.5	4.3
June 1990	1.9	0.0	6.5
Post 2			
July 1990	0.0	2.0	2.2
August 1990	34.6	44.9	39.1
September 1990	36.5	22.4	23.9
October 1990	26.9	26.5	32.6
November 1990	1.9	4.1	2.2
Mean Number (SD**) of Days Between:			
PRE and POST1	175 (30)	177 (38)	167 (33)
POST1 and POST2	158 (24)	151 (33)	158 (29)
PRE and POST2	333 (28)	329 (24)	325 (21)

*All pre-abatement blood samples were taken before soil abatement occurred on the premises.
**SD = Standard Deviation.

TABLE 15-8. MEAN BLOOD LEAD LEVEL ACCORDING TO CALENDAR MONTH OF SAMPLING

	Number in Category	Mean Blood Lead Level (μg/dL)
Pre Abatement*		
September 1989	65	12.6
October 1989	40	12.4
November 1989	22	12.5
December 1989	23	12.3
Post-Abatement		
Post1		
March 1990	60	10.4
April 1990	68	8.6
May 1990	14	10.9
June 1990	4	11.3
Post2		
July 1990	2	10.1
August 1990	58	11.1
September 1990	41	11.0
October 1990	42	11.9
November 1990	4	6.5

-2.62, respectively. Group assignment was a significant predictor of POST2 blood lead levels (p=0.02). In other words, which group a child was in (S, A, or B) was a significant determinant of their POST2 blood lead level. The results were quire similar when the blood lead levels were log transformed.

The results were similar when only one child randomly chosen from each family was included in the analysis (18.4% of families had more than one child). The differences between the Study Group and Control Groups A and B were -1.31 (p=.04) and -1.73 (p=.01), respectively. When the analysis was limited to the first child initially identified on

TABLE 15-9. ADJUSTED ANALYSIS: DESCRIPTION OF VARIABLES ADDED TO THE BASE MODEL

Variable	Categories
Age (In Months at Baseline)	<=30 Months / > 30 Months
Gender	Male/Female
Socioeconomic Status (According to the Hollingshead Index)	Continuous Variable
Race	Black/White/Hispanic/Cape Verdean/Other
Mouthing Behaviors	Yes/No
Pacifier Use	Often/Sometimes/Rarely/Never
Thumb Sucking	Zero/One/Two/Three-Five
Number of All Other Mouthing Behaviors Reported at the First Follow-Up Interview	
Spends Time Away From Home	Yes/No
Spends Time Outside of Study Area	Yes/No
Plays in Home Yard	Yes/No
Eats Food Outdoors	Yes/No
Plays or Sits on Floor Inside Home (# Hours Per Day)	<=One / Two-Four / > Four
Handwashing	
Before Meals and Snacks	Almost Always/Sometimes or Almost Never
After Playing Outdoors	Almost Always/Sometimes or Almost Never
Pets in Household that go Outdoors	Yes/No
Canned Food Intake	
Number of Canned Food Items Eaten in Last Six Months	Zero-Seven
Imported Canned Food Eaten	Yes/No
	<=15 ng/ml / > 15 ng/ml
Ferritin Level	Yes/No
Lead Jobs Among Household Members in Last Year	
Cigarette Smoking Among Household Members	
Lead Hobbies Among Household Members in Last Year	
Paint Lead Variables	
Maximum XRF Reading on Wall	Not Detectable/0.5-9.9/10.0
Maximum XRF Reading on Woodwork	Not Detectable/0.5-9.9/10.0
Number of Places Lead Paint Detected	Zero-Six
Amount of Interior Chipping Paint at Baseline	0-50/51-200/>200 square inches
Water Lead Level (Maximum Lead Ingested from Water, Derived from Water Lead Concentration and Daily Intake)	Not Detectable-6.0/6.1-24.9 />=25.0
Owner Occupied Premises	Yes/No

TABLE 15-10. CRUDE AND ADJUSTED CHANGES IN BLOOD LEAD LEVELS*

	S	A	B			Overall[3] Group Effect
	POST2 Blood Lead Levels			S-A[1]	S-B[2]	
Crude	10.65	11.49	11.35	-1.53	-1.92	
Base Model**	10.26	11.54	11.74	-1.28	-1.49	.02
Base Model Plus Age	10.21	11.57	11.83	1.35 -p=.02	1.61 -p=.01	.01
Base Model Plus Gender	10.21	11.55	11.74	-1.34 p=.02	-1.53 p=.01	.02
Base Model Plus Socioeconomic Status	10.30	11.42	11.80	-1.12 p=.06	-1.50 p=.01	.03
Base Model Plus Race	10.52	11.44	11.78	-0.92	-1.27	.09
Base Model Plus Mouthing Variables	10.80	12.04	12.31	-1.23 p=.04	-1.51 p=.02	.04
Base Model Plus Paint Lead Variables	10.54	11.72	11.88	-1.19	-1.34	.05
Base Model Plus Chipping Paint Variable[4]	10.23	11.55	11.77	-1.31 p=.02	-1.53 p=.01	.02
Base Model Plus Water Lead Level	10.15	11.34	11.59	-1.20 p=.04	-1.44 p=.02	.03
Base Model Plus Time Away From Home	10.23	11.47	11.70	-1.25 p=.03	-1.47 p=.01	.03
Base Model Plus Time Away From Study Area	9.77	10.94	11.25	-1.17 p=.04	-1.48 p=.01	.03
Base Model Plus Yard Play	10.33	11.60	11.85	-1.27 p=.03	-1.51 p=.01	.02
Base Model Plus Outdoor Eating	10.25	11.52	11.79	-1.27 p=.03	-1.54 p=.01	.02
Base Model Plus Play or Sit on Floor Inside	10.45	11.59	11.90	-1.14 p=.06	-1.45 p=.02	.04
Base Model Plus Hand Washing Before Meals	10.15	11.50	11.78	-1.35 p=.02	-1.63 p=.01	.02
After Outdoors	9.96	11.35	11.49	-1.39 p=.02	-1.53 p=.01	.01
Base Model Plus Pets That go Outdoors	10.15	11.45	11.75	-1.30 p=.03	-1.60 p=.01	.02

TABLE 15-10 (cont'd). CRUDE AND ADJUSTED CHANGES IN BLOOD LEAD LEVELS*

	S	A	B			Overall[3] Group Effect
	POST2 Blood Lead Levels			S-A[1]	S-B[2]	
Imported Canned Food	10.21	11.40	11.72	-1.19 p=.04	-1.51 p=.01	.03
Base Model Plus Ferritin Level	10.14	11.42	11.59	-1.28 p=.02	-1.45 p=.01	.02
Base Model Plus Lead Jobs	10.47	11.72	12.01	-1.25 p=.03	-1.54 p=.01	.02
Base Model Plus Lead Hobbies	10.28	11.49	11.85	-1.21 p=.04	-1.57 p=.01	.02
Base Model Plus Smoking	10.26	11.52	11.82	-1.25 p=.03	-1.55 p=.01	.02
Base Model Plus Owner Occupied Premises	10.07	11.24	11.60	-1.17 p=.04	-1.53 p=.01	.02

[1] Crude and adjusted blood lead difference between Group S and A. P values are given if the overall group effect is statistically significant.

[2] Crude and adjusted blood lead difference between Group S and B. P values are given if the overall group effect is statistically significant.

[3] P values associated with group assignment. Describes the statistical stability of the relationship between group assignment and POST2 blood lead levels.

[4] The chipping paint variable included an indicator term for missing.

* Excludes two children who became lead poisoned.

** Base Model: POST2_Pb = Group + Pre_Pb.

a premises (N=85), the differences between the Study Group and Control Groups A and B were -0.92 (p=.17) and -1.46 (p=.04), respectively.

The results were also similar when the analysis included only children who lived on the study premises for at least 300 days after the pre-abatement blood lead test, thereby eliminating children who moved during the follow-up period. Here, the differences between the Study Group and Control Groups A and B were -1.42 (p=.02) and -1.49 (p=.02), respectively.

The results were also similar when we took into account the timing of the blood samples using two different methods. First, we limited the analysis to subjects whose PRE

and POST2 blood samples were most closely matched on calendar time (within sixty days of one year or 305-420 days apart, N=134). Here, we found that the differences between the Study and each Control Group were identical (1.41 μg/dL, p=.02). Second, we included all 150 study subjects and controlled for timing by including indicator terms for calendar month of the PRE blood sample and the number of days between the PRE and POST2 samples. Again, we found similar differences between the Study Group and Control Groups A and B (1.22, p=.03 and 1.30, p=.03, respectively). The latter results were also similar when the model included an interaction term between calendar months and number of days. The interaction was not significant.

The results were also quite similar when age, sex, socioeconomic status, ferritin levels, mouthing and handwashing behaviors, spending time away from home, spending time outside of the study area, playing in the yard, eating food outdoors, sitting on the floor inside the home, eating canned foods including those imported from foreign countries, lead related job and hobbies and cigarette smoking among household residents, living in owner occupied premises, the presence of chipping paint, the presence of pets that go outdoors, and tap water lead levels were added to the base model one at a time (Table 15-10). The results were virtually identical when the continuous variables were treated as such. However, when the paint lead variables were added, differences between the Study and Control Groups were somewhat diminished (-1.19 and -1.34 μg/dL for Control Groups A and B, respectively) and the group effect was borderline significant (p=0.05). When race was added to the base model, differences were also diminished (-0.92 and -1.27 μg/dL) and the group effect was also not statistically significant (p=0.09). However, no statistically significant differences in crude or adjusted POST2 blood lead levels were seen among Study Group children of different races (Table 15-11).

No "dose-response" relationship was observed between the mean change in blood lead level and the starting soil lead level or the size of the excavated yard area (Tables 15-12 and 15-13). POST2 abatement blood lead levels were similar for children with the lowest and highest pre-abatement soil lead levels and the smallest and largest excavated yard areas. The lack of a trend should be evaluated in light of the study eligibility criteria that restricted the soil and blood lead ranges. Only six children in the Study Group had median pre-abatement

TABLE 15-11. CRUDE AND ADJUSTED* POST2 BLOOD LEAD LEVELS AMONG CHILDREN IN THE STUDY GROUP ACCORDING TO RACE

Race	Crude POST2 Blood Lead Level **	Adjusted POST2 Blood Lead Level **
Black (N=22)	11.51	11.27
White (N=4)	11.00	11.54
Hispanic (N=14)	10.05	9.78
Cape Verdean (N=10)	10.76	11.32
Other (N=2)	11.64	11.99

*Adjusted for pre-abatement blood lead level.
**Differences between racial groups were not statistically significant.

TABLE 15-12. CRUDE AND ADJUSTED* POST2 BLOOD LEAD LEVELS AMONG STUDY GROUP PARTICIPANTS ACCORDING TO INITIAL SOIL LEAD LEVEL

Median Pre-Abatement Soil Lead Level (PPM)***	Number In Category	Crude POST2 Blood Lead Level **	Adjusted POST2 Blood Lead Level **
< 1,000	6	9.00	9.17
1,001 - 2,000	18	12.00	11.47
2,001 - 3,000	16	9.81	10.75
> 3,000	12	10.58	10.04

*Adjusted for pre-abatement blood lead level.
**Differences were not statistically significant.
***Adjusted using the weighing factors derived from the intercalibration study.

soil lead levels that were less than 1,000 PPM, and pre-abatement blood lead levels were restricted to 7 through 24 μg/dL.

We also conducted exploratory multivariate analyses to control simultaneously for several potential confounding variables. Two variable selection methods were used. First, a backward elimination procedure identified variables from the list in Table 15-9 that were statistically significant predictors of POST2 blood lead levels. When Pre-Pb, age, race, and

TABLE 15-13. CRUDE AND ADJUSTED* POST2 BLOOD LEAD LEVELS AMONG STUDY GROUP PARTICIPANTS ACCORDING TO THE SIZE OF THE EXCAVATED YARD AREA

Excavated Yard Area (Sq. Feet)	Number In Category	Crude POST2 Blood Lead Level**	Adjusted POST2 Blood Lead Level**
≤ 1,000	11	9.82	10.80
1,001 - 2,000	18	10.67	11.66
> 2,000	23	11.04	10.58

*Adjusted for pre-abatement blood lead level.
**Differences were not statistically significant.

lead jobs were controlled simultaneously the adjusted POST2 blood lead levels were 10.36, 11.26, and 11.66 μg/dL for Groups S, A, and B, respectively, and the adjusted differences between the Study Group and Control Groups A and B were 0.90 (95% CI +0.23 to -2.04) and 1.31 μg/dL (95% CI -0.14 to -2.47), respectively. The overall group effect was not statistically significant (p=.08). These results were quite similar when the blood lead levels were log transformed.

Second, a potential confounding variable was selected for the multivariate model if its inclusion in the base model altered the magnitude of difference between the Study Group and either Control Group by more than 10%. The variables identified by this criterion were race, socioeconomic status, and playing or sitting on the floor. In a model controlling these variables and Pre-Pb, the adjusted POST2 blood lead levels were 10.71, 11.51, and 11.92 μg/dL for Groups S, A, and B, respectively, and the adjusted differences between the Study Group and Control Groups A and B were 0.80 (95% CI +0.45 to -2.05) and 1.21 μg/dL (95% CI +0.06 to -2.48), respectively. The overall group effect was not statistically significant (p=.16). The results were quite similar when the blood lead levels were log transformed.

We also examined the data for the presence of effect modification, that is, differences in soil abatement effectiveness according to the child's characteristics. No statistically significant interactions were seen for age, sex, socioeconomic status, length of residence (since birth or not), residence in an owner occupied home, and behavioral characteristics

such as amount of time spent playing in the yard, eating food outside, handwashing after outside play, thumb sucking, and other mouthing behaviors. However, the data suggested that the effect of the soil abatement was enhanced among children who played in their yards more than 15 hours per week (S-A -2.17 and S-B -3.56) and among children who lived in non-owner occupied housing (S-A -3.08 and S-B -2.44).

15.3 HAND LEAD LEVELS

Tables 15-14 and 15-15 describe the handwipe lead distributions over time and Tables 15-16 and 15-17 describe the results of crude analyses that examined the average change in hand lead levels among the participants following abatement activities. The handwipe field blank lead levels varied considerably within and across phases. The means and standard deviations were 6.0 and 1.9 for PRE, 8.4 and 3.5 for POST1, and 12.3 and 5.4 for POST2. Because the blanks were so variable and were not individually matched to the participants, background levels were taken into account by subtracting the maximum and median field blank level for each sampling round. (Any negative value was treated as zero.) When the maximum level was subtracted, the mean hand lead level in all groups declined from the pre abatement to the first post-abatement sampling round. The mean hand lead level in the Study Group changed little at the second post-abatement sampling round while it increased in the Control Groups (Table 15-16). When the median level was subtracted, the mean hand lead level in the Study Group declined at the first and second post-abatement sampling rounds. The mean hand lead levels in the two Control Groups first declined and then rose to a level higher than baseline (Table 15-17).

Because the PRE and POST2 sampling rounds are most closely matched on season, we focused subsequent analyses on this comparison. When the maximum blank level was subtracted, the mean hand lead level decreased by 3.61 μg in the Study Group ($p=.02$), 0.99 μg in Control Group A ($p=.69$), and 0.36 μg in Control Group B ($p=.85$). When the median blank lead level was subtracted the mean hand lead levels declined by 2.75 μg in the Study Group ($p=.08$), and 0.68 in Control Group A ($p=.79$) and increased by 0.76 in Control Group B ($p=.72$).

TABLE 15-14. HANDWIPE LEAD (μg/pair of hands) DISTRIBUTIONS OVER TIME ADJUSTING FOR MAXIMUM FIELD BLANK LEAD LEVEL* AND EXCLUDING CHILDREN WHO BECAME LEAD POISONED

	S	A	B	Total
Pre	(N=52)	(N=49)	(N=47)	(N=148)
Minimum	0	0	0	0
25%	2.5	2.5	1.5	2.5
50%	4.5	3.5	3.5	4.5
75%	8.0	6.5	8.5	7.5
Maximum	52.5	42.5	35.5	52.5
Mean	6.67	5.67	6.60	6.31
Standard Deviation	8.21	7.08	7.41	7.56
POST1	(N=51)	(N=48)	(N=46)	(N=145)
Minimum	0	0	0	0
25%	0	0	0	0
50%	0	0	0	0
75%	3.0	3.0	4.0	3.0
Maximum	25.0	17.0	59.0	59.0
Mean	2.90	2.10	4.57	3.17
Standard Deviation	5.40	3.42	11.65	7.58
POST2	(N=52)	(N=49)	(N=46)	(N=147)
Minimum	0	0	0	0
25%	0	0	0	0
50%	0	0	0	0
75%	2.5	1.0	7.0	4.0
Maximum	53.0	91.0	58.0	91.0
Mean	3.06	4.14	6.15	4.39
Standard Deviation	8.11	15.85	13.07	12.64

*Negative levels were assigned the value zero.

When the POST2 hand lead levels were adjusted for baseline level the mean differences between the Study Group and the two Control Groups were diminished; the magnitude of the reduction was greater for the Control Group A comparison (Table 15-18). Group assignment was not, however, a significant predictor of POST2 hand lead levels (p values were .48 and 43, respectively).

TABLE 15-15. HANDWIPE LEAD (μg/pair of hands) DISTRIBUTIONS OVER TIME ADJUSTING FOR MEDIAN FIELD BLANK LEAD LEVEL* AND EXCLUDING CHILDREN WHO BECAME LEAD POISONED

	S	A	B	Total
PRE	(N=52)	(N=49)	(N=47)	(N=148)
Minimum	0	0	0	0
25%	4.75	4.75	3.75	4.75
50%	6.75	5.75	5.75	6.75
75%	10.25	8.75	10.75	9.75
Maximum	54.7	44.75	37.75	54.75
Mean	8.79	7.79	8.75	8.45
Standard Deviation	8.33	7.20	7.51	7.67
POST1	(N=51)	(N=48)	(N=46)	(N=145)
Minimum	0	0	0	0
25%	1.5	2.5	1.3	1.5
50%	3.5	5.5	3.5	4.5
75%	8.5	8.5	9.5	8.5
Maximum	30.5	22.5	64.5	64.5
Mean	6.30	5.96	7.89	6.69
Standard Deviation	6.80	4.86	12.68	8.64
POST2	(N=52)	(N=49)	(N=46)	(N=147)
Minimum	0	0	0	0
25%	0	0	0.5	0
50%	3.5	2.5	4.5	3.5
75%	8.0	6.5	12.5	9.5
Maximum	58.5	96.5	63.5	96.5
Mean	6.04	6.58	9.42	7.28
Standard Deviation	9.34	16.82	14.31	13.74

*Negative levels were assigned the value zero.

15.4 ENVIRONMENTAL LEAD LEVELS

Tables 15-19 through 15-25 describe the distributions of soil, dust, water, and paint lead levels among the Study and Control Groups. Table 15-26 describes the QA/QC results for the soil and dust analyses. Median soil and dust lead levels, maximum first flush water lead levels and maximum wall and woodwork paint lead levels were used to characterize

TABLE 15-16. CRUDE CHANGES* IN HAND LEAD LEVELS (μg/pair of hands)* EXCLUDING CHILDREN WHO BECAME LEAD POISONED**

STUDY PHASE	STUDY GROUP	CONTROL GROUP A	CONTROL GROUP B
Pre-Abatement (Sept. '89-Dec. '89)	6.67 (N=52)	5.67 (N=49)	6.60 (N=47)
	-3.81 p =0.002	-2.96 p=0.01	-1.95 P=0.35
Post-Abatement POST1 (Mar. '90 - July '90)	2.90 (N=52)	2.10 (N=48)	4.57 (n=46)
	+0.22 p=0.86	+2.13 p=0.30	+1.59 P=0.45
POST2 (July '90 - Jan. '91)	3.06 (N=52)	4.14 (N=49)	6.15 (n=46)

each child's unit or premises. Detection limits for soil and dust were each 100 PPM, for water it was 1 μg/L, and for paint it was 0.5 mg/cm^2. The soil and dust concentrations were adjusted using weighing factors designed to make the Boston project's soil and dust lead levels comparable to those of the Cincinnati and Baltimore Lead-In-Soil Demonstration projects. These weighing factors (1.0370 for soil and 1.1527 for dust) were derived from the results of the intercalibration study conducted under the supervision of Dr. Robert Elias. Dr. Elias is with the U.S. EPA Environmental Criteria Assessment Office and has the responsibility to facilitate the successful completion of the Lead-In-Soil Demonstration Projects.

15.4.1 Soil

At baseline the median surface soil lead levels were slightly higher in Control Group A (2,230 PPM) than the Study Group and Control Group B (2,074 and 2,100 PPM). Sampling

TABLE 15-17. CRUDE CHANGES IN HAND LEVELS (μg/pair of hands)* EXCLUDING CHILDREN WHO BECAME LEAD POISONED**

STUDY PHASE	STUDY GROUP	CONTROL GROUP A	CONTROL GROUP B
Pre-Abatement (Sept. '89-Dec. '89)	8.79 (N=52)	6.74 (N=49)	8.14 (N=47)
	2.53 p=0.05	-1.29 p=0.31	-0.77 P=0.73
Post-Abatement POST1 (Mar. '90 - July '90)	6.30 (N=52)	5.98 (N=48)	7.89 (n=46)
	0.25 p=0.86	+0.69 p=0.75	+1.53 P=0.52
POST2 (July '90 - Jan. '91)	6.04 (N=52)	6.98 (N=49)	9.80 (n=46)

conducted within a few weeks of the soil abatement documented the reduction in lead levels in the Study Group. The drop in median soil lead levels ranged from 166 to 5,558 PPM, the average drop was 1,856 PPM. However, many samples still had detectable lead levels at post-abatement sampling (Median Post Abatement Level: 109 PPM).

About nine months after soil abatement, median surface soil lead levels in the Study Group had not increased but several properties had evidence of recontamination. Eight properties (23%) had median soil lead levels ranging from 156 to 1,867 PPM. The concentration of lead in soil for these eight properties in PPM, were 156, 171, 202, 228, 249, 259, 389, and 1,867. The surface soil lead levels in Control Groups A and B did not change substantially over this period.

TABLE 15-18. CRUDE AND ADJUSTED CHANGES IN HAND LEAD LEVELS (μg/pair of hands) EXCLUDING CHILDREN WHO BECAME LEAD POISONED*

	S POST2 Blood Lead Levels	A	B	S-A	S-B	Overall[3] Group Effect
Crude**	3.06	4.14	6.15	-2.62	-3.25	
Adjusting for Pre-Abatement Hand Lead Level**	2.90	4.47	6.04	-1.56	-3.14	p=.48
Crude***	6.04	6.58	9.42	-2.07	-3.51	
Adjusting for Pre-Abatement Hand Lead Level***	5.86	6.95	9.29	-1.08	-3.43	p=.43

*Two children in the Study Group became poisoned between POST1 and POST2 sampling rounds.
**Adjusts for maximum field handwipe blank lead level.
***Adjusts for median field handwipe blank lead level.

15.4.2 Dust

Tables 15-20 through 15-22 describe the distribution of interior floor dust lead concentration (PPM), dust loading (mg/m^2), and dust lead loading (μg/m^2) over time in the Study and Control Groups. At baseline median dust lead concentrations were similar across the three groups (2,513-2,651 PPM). Median floor dust lead concentrations in the Study Group and Control Group A were reduced by 53% and 49%, respectively, an average of 4-5 weeks after the interior dust abatement (Post Abatement). Floor dust lead levels remained substantially below baseline levels an average of 33 weeks after interior dust abatement for both the Study Group (67%) and Control Group A (54%) (Recontamination 2). During this period Control Group B experienced a comparable decline (42%) in floor dust lead levels. (Control Group B received loose paint abatement but not interior dust abatement.)

At baseline the median floor dust loading was higher in Control Group B than in the other two groups (40 vs. 24 and 25 mg/m^2). In the Study Group median floor dust loading increased by 50% an average of 4-5 weeks after the interior dust abatement. (Mean floor dust loading was essentially unchanged.) Median dust loading in the Study Group then

TABLE 15-19. DISTRIBUTION OF SURFACE SOIL LEAD CONCENTRATIONS* OVER TIME AND ACCORDING TO GROUP

	S	A	B	Total
Pre Abatement (Aug.'89 - June '90)	(N=34)	(N=36)	(N=30)	(N=100)
Minimum	415	747	985	415
25%	1,556	1,374	1,452	1,452
50%	2,074	2,230	2,100	2,152
75%	2,644	3,215	3,422	3,163
Maximum	5,704	6,948	4,563	6,948
Mean	2,255	2,524	2,401	2,395
Standard Deviation	1,165	1,381	1,195	1,248
Post (Oct.'89 - Dec.'89) Abatement	(N=25)	N/A	N/A	(N=25)
Minimum	52			52
25%	83			83
50%	109			109
75%	166			166
Maximum	249			249
Mean	123			123
Standard Deviation	56			56
Recontamination (June '90 - July '90) Assessment	(N=34)	(N=34)	(N=30)	(N=98)
Minimum	52	622	954	52
25%	52	1,556	1,556	52
50%	52	2,23	1,970	1,556
75%	109	3,007	3,059	2,385
Maximum	1,867	5,755	5,081	5,755
Mean	145	2,437	2,315	1,605
Standard Deviation	315	1,226	1,144	1,443

*Adjusted using the weighing factor derived from the intercalibration study. The median soil concentration was used to characterize the premises. Detection limit was 100 PPM. Undetectable levels were assigned the value 50 PPM. N/A = Not Applicable.

TABLE 15-20. DISTRIBUTION OF INTERIOR FLOOR DUST LEAD CONCENTRATIONS* OVER TIME AND ACCORDING TO GROUP

	S	A	B	Total
Pre Abatement (Aug.'89 - Jan.'90)	(N=41)	(N=40)	(N=36)	(N=117)
Minimum	150	646	496	150
25%	1,164	1,406	1,354	1,303
50%	2,651	2,513	2,542	2,547
75%	4,288	4,369	5,314	4,380
Maximum	107,201	22,823	46,108	107,201
Mean	6,623	4,202	5,178	5,350
Standard Deviation	16,786	5,075	8,272	11,291
Post (Oct.89 - March '90) Abatement	(N=31)	(N=34)	N/A	(N=65)
Minimum	450	519		450
25%	807	865		865
50%	1,233	1,274		1,268
75%	2,190	2,121		2,132
Maximum	12,680	5,141		12,680
Mean	2,420	1,822		2,107
Standard Deviation	3,058	1,352		2,327
Recontamination 1 (March '90 - June '90)				
	(N=40)	(N=35)	(N=37)	(N=112)
Minimum	334	426	184	184
25%	657	807	807	795
50%	939	1,279	1,095	1,095
75%	1,712	1,568	1,499	1,562
Maximum	49,566	6,052	4,253	49,566
Mean	3,108	1,458	1,493	2,059
Standard Deviation	8,257	1,108	1,084	5,033
Recontamination 2 (July '90 - Dec.'90)				
	(N=33)	(N=35)	(N=34)	(N=102)
Minimum	346	311	288	288
25%	692	749	968	784
50%	876	1,153	1,475	1,193
75%	1,349	1,568	2,017	1,694
Maximum	4,841	3,804	10,374	10,374
Mean	1,294	1,300	1,886	1,494
Standard Deviation	1,094	774	1,777	1,300

*Adjusted using the weighing factor derived from the intercalibration study. A single composited floor dust sample was used to characterize a child's living unit. N/A = Not Applicable.

TABLE 15-21. DISTRIBUTION OF INTERIOR FLOOR DUST LOADING* (mg/m^2) OVER TIME AND ACCORDING TO GROUP

	S	A	B	Total
Pre-Abatement (Aug.'89 - Jan.'90)	(N=41)	(N=40)	(N=35)	(N=116)
Minimum	4	7	5	4
25%	13	11	15	12
50%	24	25	40	29
75%	69	51	71	67
Maximum	363	246	141	363
Mean	51	41	47	46
Standard Deviation	67	46	36	52
Post (Oct.89 - March '90) Abatement	(N=31)	(N=34)	N/A	(N=65)
Minimum	9	3		3
25%	15	9	31	12
50%	36	19	31	29
75%	59	37	31	45
Maximum	254	117	31	254
Mean	52	30	31	41
Standard Deviation	58	31	31	47
Recontamination 1 (March '90 - June '90)	(N=40)	(N=35)	(N=37)	(N=112)
Minimum	2	3	2	2
25%	14	15	12	13
50%	24	28	32	27
75%	62	48	56	55
Maximum	366	195	278	366
Mean	57	41	47	49
Standard Deviation	74	43	53	59
Recontamination 2 (July '90 - Dec.'90)	(N=32)	(N=33)	(N=33)	(N=98)
Minimum	2	2	2	2
25%	9	10	11	9
50%	16	17	19	17
75%	32	41	32	35
Maximum	136	153	115	153
Mean	27	31	29	29
Standard Deviation	31	36	29	32

*A single composited floor dust sample was used to characterize a child's living unit. N/A = Not Applicable.

TABLE 15-22. DISTRIBUTION OF INTERIOR FLOOR DUST LEAD LOADING* ($\mu g/m^2$) OVER TIME AND ACCORDING TO GROUP

	S	A	B	Total
Pre-Abatement (Aug.'89 - Jan.'90)	(N=41)	(N=40)	(N=35)	(N=116)
Minimum	9	9	3	3
25%	35	36	38	36
50%	61	68	87	75
75%	126	203	208	153
Maximum	7,976	437	3,354	7,976
Mean	344	117	291	250
Standard Deviation	1,280	113	623	836
Post (Oct.89 - March '90) Abatement	(N=31)	(N=34)	N/A	(N=65)
Minimum	10	3		3
25%	22	12		17
50%	47	27		41
75%	74	71		71
Maximum	2,547	191		2,547
Mean	145	49		94
Standard Deviation	452	50		315
Recontamination 1 (March '90 - June '90)	(N=40)	(N=35)	(N=37)	(N=112)
Minimum	1	6	1	1
25%	13	14	11	13
50%	28	32	31	31
75%	80	67	82	77
Maximum	3,087	259	929	3,087
Mean	236	53	83	128
Standard Deviation	658	58	156	410
Recontamination 2 (July '90 - Dec.'90)	(N=32)	(N=33)	(N=33)	(N=98)
Minimum	2	1	2	1
25%	7	9	14	9
50%	18	21	25	21
75%	28	46	62	46
Maximum	224	226	527	527
Mean	38	39	65	47
Standard Deviation	60	50	107	77

*Adjusted using the weighing factor derived from the intercalibration study. A single composited floor dust sample was used to characterize a child's living unit. N/A = Not Applicable.

TABLE 15-23. DISTRIBUTION OF INTERIOR WINDOW WELL DUST LEAD CONCENTRATIONS* OVER TIME AND ACCORDING TO GROUP

	S	A	B	Total
Pre-Abatement (Aug.'89 - Jan.'90)1	(N=40)	(N=41)	(N=34)	(N=115)
Minimum	231	1,153	58	58
25%	3,458	3,170	2,594	3,170
50%	11,815	15,907	13,429	13,832
75%	28,818	38,039	28,818	33,428
Maximum	121,034	74,926	147,546	147,546
Mean	19,481	22,429	27,285	22,839
Standard Deviation	23,039	20,722	37,314	27,299
Post (Oct.89 - March '90) Abatement	(N=32)	(N=32)	N/A	(N=64)
Minimum	58	58		58
25%	2,795	778	11,166	1,037
50%	7,550	2,190	11,166	3,400
75%	16,138	3,689	11,166	10,778
Maximum	46,108	63,399	11,166	63,399
Mean	10,789	4,766	11,166	7,777
Standard Deviation	10,492	11,166	11,166	11,168
Recontamination 1 (March '90 - June '90)	(N=41)	(N=35)	(N=36)	(N=112)
Minimum	1,153	1,383	692	692
25%	4,323	5,418	3,977	4,409
50%	12,103	10,086	11,527	11,181
75%	18,443	25,359	32,276	23,486
Maximum	44,955	55,330	98,844	98,844
Mean	12,493	15,671	21,464	16,370
Standard Deviation	10,559	14,156	22,998	16,806
Recontamination 2 (July '90 - Dec.'90)	(N=34)	(N=32)	(N=30)	(N=96)
Minimum	807	865	548	548
25%	3,573	5,418	2,900	3,631
50%	8,213	13,832	9,942	10,807
75%	27,665	29,207	42,650	34,581
Maximum	109,507	96,827	103,743	109,507
Mean	19,815	20,674	24,761	21,647
Standard Deviation	23,830	23,123	27,604	24,676

*Adjusted using the weighing factor derived from the intercalibration study. The median window well dust concentration was used to characterize a living unit. N/A = Not Applicable.

TABLE 15-24. DISTRIBUTION OF INTERIOR WINDOW WELL LOADING* (mg/m^2) OVER TIME AND ACCORDING TO GROUP

	S	A	B	Total
Pre-Abatement (Aug.'89 - Jan.'90)	(N=40)	(N=41)	(N=34)	(N=115)
Minimum	20	23	0	0
25%	52	68	89	63
50%	155	280	216	219
75%	525	578	401	547
Maximum	2,722	6,542	5,701	6,542
Mean	339	564	443	450
Standard Deviation	472	1,100	968	884
Post (Oct.89 - March '90) Abatement	(N=32)	(N=32)	N/A	(N=64)
Minimum	0	0		0
25%	27	16	244	18
50%	79	29	244	39
75%	162	122	244	160
Maximum	2,018	1,293	244	2,018
Mean	185	115	244	150
Standard Deviation	372	244	244	314
Recontamination 1 (March '90 - June '90)	(N=41)	(N=35)	(N=36)	N=(112)
Minimum	32	22	9	9
25%	123	176	85	118
50%	387	284	213	278
75%	646	542	558	615
Maximum	3,431	3,207	8,905	8,905
Mean	513	489	634	545
Standard Deviation	615	601	1,509	984
Recontamination 2 (July '90 - Dec.'90)	(N=34)	(N=32)	(N=30)	(N=96)
Minimum	30	38	15	15
25%	125	216	158	153
50%	295	438	418	341
75%	546	760	744	700
Maximum	3,310	2,867	3,457	3,457
Mean	559	562	641	585
Standard Deviation	726	559	837	707

*The median window well loading was used to characterize a child's living unit. N/A = Not Applicable.

TABLE 15-25. DISTRIBUTION OF INTERIOR WINDOW WELL LEAD LOADING* ($\mu g/m^2$) OVER TIME AND ACCORDING TO GROUP

	S	A	B	Total
Pre-Abatement (Aug.'89 - Jan.'90)	(N=40)	(N=41)	(N=34)	(N=115)
Minimum	5	32	0	0
25%	213	351	279	282
50%	2,262	3,825	2,236	3,145
75%	9,298	17,122	11,465	12,829
Maximum	56,614	451,193	657,170	657,170
Mean	7,861	25,545	26,976	19,817
Standard Deviation	12,606	73,487	111,910	75,178
Post (Oct.89 - March '90) Abatement	(N=32)	(N=32)	N/A	(N=64)
Minimum	0	0		0
25%		13		27
50%	114	68		249
75%	687	381		1,398
Maximum	3,280	11,561		46,529
Mean	46,529	674		1,942
Standard Deviation	3,211	2,073		6,114
	8,267			
Recontamination 1 (March '90 - June '90)	(N=41)	(N=35)	(N=36)	(N=112)
Minimum	98	83	9	9
25%	1,066	644	672	803
50%	3,547	3,810	3,503	3,531
75%	7,817	13,293	8,683	8,711
Maximum	19,869	38,116	173,592	173,592
Mean	5,007	8,544	11,955	8,346
Standard Deviation	4,961	10,416	29,861	18,210
Recontamination 2 (July '90 - Dec.'90)	(N=34)	(N=32)	(N=30)	(N=96)
Minimum	41	44	6	6
25%	1,754	1,540	1,340	1,549
50%	5,102	5,104	5,318	5,186
75%	11,234	12,797	18,690	13,434
Maximum	169,584	80,981	52,078	169,584
Mean	12,443	10,750	11,406	11,555
Standard Deviation	28,946	16,129	14,160	20,920

*Adjusted using the weighing factor derived from the intercalibration study. The median window well dust concentration, and loading were used to characterize a child's living unit. N/A = Not Applicable.

TABLE 15-26. QA/QC RESULTS FOR SOIL AND DUST ANALYSES

	EMSL RESULTS*			BOSTON RESULTS*		
	Consensus Mean	Biweight Mean	95% Biweight Distribution Bounds	Mean	Range	% of Results Within EMSL 95% Bounds
SOIL**						
CINL	290	315	204-426	399	207-570	61.3
BALH	934	1,017	847-1,187	1,044	747-1,244	73.3
BOSM	5,759	6,219	4,742-7,696	6,786	6,015-7,549	100.0
CINH	12,376	12,729	11,361-14,096	14,074	11,407-16,592	50.0
DUST**						
CIN02	242	233	93-372	331	115-461	64.7
BAL03	1,334	1,438	1,091-1,786	1,232	980-1,441	92.0
CIN01	2,933	2,617	1,422-3,812	2,671	2,075-3,228	100.0
BOS01	***	***	***	11,783	10,374-15,561	***

*Adjusted using the weights derived from the intercalibration study.
**Acronyms stand for the source of the sample.
***BOS01 was not included in the intercalibration study because of lack of material.

decreased to a level 33% below baseline by the end of the recontamination assessment period. In Control Group A median floor dust loading decreased by 24% after dust abatement and remained substantially below baseline levels during subsequent sampling. Median levels in Control Group B decreased by 53% from baseline levels over this time period.

At baseline floor dust lead loading was higher in Control Group B than the other groups (87 vs. 61 and 68 $\mu g/m^2$). An average of 4-5weeks after the interior dust abatement, lead loading had decreased by 23% in the Study Group and by 60% in Control Group A. By the end of the recontamination assessment period, floor lead loading had declined by 70% in the Study Group and 69% in Control Group A. Control Group B declined by 71% over this time period.

Tables 15-23 through 15-25 describe the distribution of interior window well dust lead concentration, dust loading, and dust lead loading over time in the Study and Control Groups. At baseline median dust lead concentrations were higher in Control Group A than the Study Group and Control Group B (15,907 vs. 11,815 and 13,429 PPM). Median window well dust lead concentrations in the Study Group and Control Group A were reduced by 36% and 86%, respectively, an average of 4-5 weeks after the interior dust abatement (Post Abatement). Window well dust lead levels increased in these groups over the recontamination assessment period but were still below baseline levels (13-30%) an average of 33 weeks after interior dust abatement (Recontamination 2). During this period the window well dust lead concentrations in Control Group B declined by 26%.

At baseline the median window well dust loading (mg/m^2) was higher in Control Group A than in the other groups (280 vs. 155 and 116 mg/m^2). An average of 4-5 weeks after the interior dust abatement, the median window well dust loading levels decreased by 49% in the Study Group and 90% in Control Group A. Over the recontamination assessment period, median window well dust loading substantially rose in both groups and were 56-90% above baseline by the end of this period. Median levels in Control Group B also rose by 94% by the end of this period.

At baseline the median window well dust lead loading was higher in Control Group A than the other groups (3,825 vs. 2,262 and 2,236 $\mu g/m^2$). An average of 4-5 weeks after the interior dust abatement, lead loading had decreased by 70% in the Study Group and by 98% in Control Group A. Over the recontamination assessment period window well lead loading rose (from baseline levels) by 126% in the Study Group and 33% in Control Group A. Control Group B increased by 138% over this time period.

Lastly, no dose-response relationship was seen when we modeled the second recontamination assessment floor and window well dust measures as a function of the change in soil lead concentration.

The results of the external audit sample analyses conducted by EMSL, the external QA/QC contract laboratory in Las Vegas, indicate that our soil and dust lead data were generally of good quality (Table 15-26). While our mean soil concentrations were consistently higher than the consensus and biweight means, the majority of our results fell within the 95% biweight distribution bounds provided by EMSL. The best agreement was

seen for lead levels that encompassed most of our soil samples (BALH and BOSM). Our dust lead results were also in good agreement with those of the EMSL laboratory; the majority of our results also fell within the 95% biweight bounds and the best agreement was seen for lead levels that encompassed most of our floor dust samples (BAL03 and CIN01). Because of the lack of material, no EMSL data are available for the highest dust lead category (BOS01) where a large portion of our window well dust samples fell.

15.4.3 Water

Table 15-27 describes the distribution of water lead levels in the Study and Control Groups. The maximum levels in two first flush tap water samples was used to characterize each living unit. Water lead levels ranged from undetectable to 560 μg/L. The median concentration in Control Group B was higher than the other two groups (36 vs. 20 and 18 μg/L).

TABLE 15-27. DISTRIBUTION OF WATER LEAD CONCENTRATIONS* (μg/L) ACCORDING TO GROUP

	S (N=34)	A (N=34)	B (N=29)	Total (N=97)
Minimum	1	UD	2	UD
25%	11	8	11	9
50%	20	18	36	20
75%	43	58	61	57
Maximum	350	387	560	560
Mean	43	54	76	56
Standard Deviation	68	84	115	90

*The maximum of two first flush samples was used to characterize the living unit of the child. UD means undetectable. The detection limit was 1.0 μg/L. To calculate the mean and standard deviation, 0.5 μg/L was used to characterize undetectable levels.

15.4.4 Paint

Table 15-28 describes the distribution of wall and woodwork paint lead concentrations among the Study and Control Groups. The maximum XRF readings for the wall and woodwork were used to characterize each living unit. A smaller proportion of units in Control Group B had detectable lead paint on walls (20.0%) than the Study Group and Control Group A (30.6% and 47.4%, respectively). Almost all units had detectable lead paint on woodwork.

Table 15-29 describes the amount of chipping paint that was present at baseline inside subjects' living units Case managers conducted the chipping paint assessments by visual inspection in all but 20 units. A larger proportion of units in the Study Group had significant amounts (>200 square inches) of chipping and peeling paint compared to Control Groups A and B. All groups received loose paint abatement as part of the intervention.

TABLE 15-28. DISTRIBUTION (%) OF WALL AND WOODWORK PAINT LEAD CONCENTRATIONS* (mg/cm^2) ACCORDING TO GROUP

	S (N=39)	A (N=40)	B (N=36)	Total (N=115)
Wall				
Undetectable	30.6	47.4	20.0	33.7
0.5-1.0	25.0	18.4	33.3	25.0
1.1-9.9	25.0	10.5	16.7	17.3
10.0	19.4	23.7	30.0	24.0
Woodwork				
Undetectable	5.1	0.0	11.1	5.2
0.5-1.0	10.3	15.0	27.8	17.4
1.1-9.9	25.6	30.0	22.2	26.1
10.0	59.0	55.0	38.9	51.3

*The maximum XRF level for the wall and woodwork were used to characterize the living unit of the child. Detection limit was 0.5 mg/cm^2

TABLE 15-29. DISTRIBUTION (%) OF AMOUNT INTERIOR CHIPPING PAINT* AT BASELINE ACCORDING TO GROUP

	S (N=34)	A (N=36)	B (N=32)	Total (N=102)**
Amount of Chipping Paint at Baseline (Square Inches)				
0 - 50	55.9	58.3	46.9	53.9
51-200	14.7	22.2	34.4	23.5
> 200	29.4	19.4	18.8	22.5

*The presence of interior chipping paint at baseline was assessed by visual inspection of all rooms in the living unit.

**The chipping paint assessment was not performed on 20 units (8 in S, and 6 each in A and B). Percentages exclude units with missing data.

15.5 COST OF ABATEMENT ACTIVITIES

15.5.1 Soil Abatement

In this section the actual cost of soil abatement is presented, along with the cost breakdown for the various components of the abatement including soil sampling, excavation, disposal and replacement. Costs are described separately for abatements conducted in 1989 and 1990 because of differences in contractors and abatement requirements. Average cost per property, per square meter, and per cubic yard of soil excavated and replaced are presented. These figures must be interpreted with caution given the many unique conditions under which the abatements were conducted for this study. Alternative cost estimates are also provided that perhaps better reflect future costs of lead contaminated soil abatement.

Lead contaminated soil was abated from thirty-six properties in 1989. The abated areas of these properties averaged 2,141 square feet, or 199 square meters and ranged from 12 to 702 square meters. It is estimated that an average of 41 cubic yards of soil were excavated and replaced at each site. This estimate is crude since 12 of the 36 abatements were conducted after the ground had frozen and consequently large slabs of earth were often removed that were difficult to measure. In some cases, measurements were not possible. Since the yard sizes were somewhat smaller, on average, for the premises abated in 1990

(178 versus 199 square meters), and since the measurement of cubic feet excavated in 1990 was easier and more accurate and resulted in an estimate of 44 cubic yards per property, we have assumed that the cubic feet abated per property were similar in 1989 and 1990, Thus, the estimated cost per cubic meter in 1989 is probably greater than the actual cost incurred.

The costs of soil abatements are shown in Tables 15-30 and 15-31.

Many of the soil abatement related costs incurred in both 1989 and 1990 may not be applicable to future soil abatement activities in this and other communities. In 1989, for example, $69,668 was spent for contract development and supervision by Applied Occupational Health Systems. This cost was incurred because of lack of experience with lead contaminated soil abatement. Probably only the $19,401 spent for abatement supervision is applicable for other settings. Other portions of the Contract Development/Supervision expenses might be applicable as one time costs for future soil abatement activities. Similarly, of the $52,307 spent for miscellaneous extra costs ($1,453/property), only the $2,425 ($67/property) spent for pre-abatement yard cleaning may be applicable for future soil abatement activities, although it might be argued that the cost for hoses, sprinklers, and tarps may also be needed for future soil abatements. If these costs are included miscellaneous costs totalled $7,627, or $220/property.

While $26,190 was spent on soil disposal in 1989 ($725/property), soil disposal is likely to be the most variable and unpredictable expense associated with future abatements and it may be more useful to estimate abatement costs without including the cost of soil disposal.

For the 36 properties abated in 1989, the total cost for soil sampling and analysis ($10,933), pre-abatement yard cleaning ($2,425), soil excavation and replacement ($186,420), and supervision of abatement activities was $219,179 or approximately $6,100 per property. The cost per square meter of soil abated and replaced was $31, and the cost per cubic yard of soil replaced was $140. In 1990, the total cost of soil sampling and analysis ($17,535), pre- abatement yard cleaning ($1,550), soil excavation and replacement ($307,995), and supervision of abatements ($39,247) was $366,327, or $6,315 per property. The cost per square meter of soil abated and replaced was $35, and the cost per cubic yard of soil replaced was $143. Thus, the average costs were quite similar in 1989 and 1990.

TABLE 15-30. 1989 SOIL ABATEMENT COSTS

1. Soil Sampling and Analysis	$ 3,780
Labor, Sampling 36 Properties @ $105 Each	36
2 Core Sampling Tubes @ $17.95 Each	74
2 Core Sampling Tubes @ $36.80 Each	25
1,000 Plastic Bags @ $25 Per 1,000	200
Miscellaneous Supplies	6,818
Analyses of Approximately 20 Samples/Site @ $9.47 Each x 36	$ 10,933
Total for Soil Sampling and Analysis	
2. Contract Development/Supervision by Applied Occupational Health Systems (AOHS)	
Development	$ 20,503
Pilot Abatement	9,450
Abatement Supervision	19,401
Dosimeters	365
Final Report	2,449
LFK Field Operations Coordinator 6 Months	17,500
Total Contract Development/Supervision	$ 69,668
3. Abatement Contract	157,740
33 Properties @ $4,780 Each	28,680
3 Properties @ 2 x $4,780 Each	$ 186,420
Total Abatement Contract	
4. Soil Disposal	
Use of Barry's Quarry	
Mattapan Costs, Prep, Clean-up	
Total Soil Disposal	
5. Miscellaneous Extra Costs	$ 2,425
Yard Cleaning Pre-abatement	1,402
Hoses and Sprinklers	3,800
Extra Poly Tarps, 19 Sites	30,795
Cold Weather Abatement	13,885
Asphalt, 4 Properties	
Total Miscellaneous Extra Costs	
Total Cost for 36 Soil Abatements in 1989	$345,518
Average Cost Per Property, including all factors listed above	$ 9,598
Cost Per Square Meter of Soil Abated	$ 48
Cost Per Cubic Yard of Soil Replaced	$ 218

TABLE 15-31. 1990 SOIL ABATEMENT COSTS

1. Soil Sampling and Analysis	
Labor, 58 Sites Sampled @ 105 Per Site	$ 6,090
2 Core Sampling Tubes @ 17.95 Each	36
2 Core Sampling Tubes @ 36.80 Each	74
2,000 Plastic Bags @ $25 Per 1,000	50
Miscellaneous Supplies	30
Analyses of approximately Samples/Site	0
@ $9.47 Each x 58	10,985
Total for Soil Sampling and Analysis	$ 17,535
2. Supervision of Abatements	
3 Site Monitors 3 Months Each	$ 25,550
Travel for Site Monitors	1,697
LFK Field Operations Coordinator 4 Months	12,000
Total for Supervision	$ 39,247
3. Abatement Contract	
51 Properties @ $4,738.38 Each	$241,657
7 Properties @ 2 x $4,738.38 Each	66,337
Total Abatement Contract	$307,995
4. Soil Disposal	
Use of Barry's Quarry	$ 2,500
Materials for Temporary Storage	1,724
Taking Stored Soil to Quarry	1,400
Site Monitor at Quarry	1,528
Gravel for Quarry Driveway	485
Bulldozer Rental for Covering Soil - 3 Months	9,350
Total Soil Disposal	$ 16,987
5. Miscellaneous Extra Costs	$ 1,550
Yard Cleaning/Change Orders	655
Hoses and Sprinklers	795
Transit Level Rental	$ 3,000
Total Miscellaneous Extra Costs	
Total Cost of 58 Soil Abatements in 1990	$384,764
Average Cost Per Property, Including all Factors Listed Above	$ 6,634
Cost Per Square Meter of Soil Abated	$ 37
Cost Per Cubic Yard of Soil Replaced	$ 150

15.5.2 Interior Loose Paint and Dust Abatement

Actual cost for units that received interior paint abatement alone, and for units that received both interior paint and dust abatement are presented. Actual cost of dust abatement alone cannot be provided as no units in the study received dust abatement in the absence of interior loose paint abatement. Possible cost for dust abatement alone is estimated using two different approaches. Costs are provided for the abatement activities, and for the costs associated with pre-abatement preparation, abatement monitoring, and the costs associated with cancellations. The contractor who performed the interior loose paint and dust abatements charged different unit rates depending on unit size. Actual costs for loose paint abatement and loose paint and dust abatement, and estimates of costs for dust abatement alone are therefore provided by the cost category charged by the contractor. Average costs are also provided.

A total of 129 units had interior abatements: 40 units had only loose paint abatement, and 89 units had loose paint and dust abatement.

While participants were asked to prepare their units for abatement activities it quickly became apparent that most could not accomplish this. Thus, the contractor hired to do the interior abatements was paid to prepare the units at a rate of $20/hour. This included moving all furniture items to the middle of the room. A total of 407.25 hours at $20/hour ($8,145) was spent on preparation activities for the 129 units that received interior abatements. In calculating cost estimates we have used the average unit preparation cost as $63/unit ($8,145/129 units). This assumes that these costs did not vary by size of unit.

All interior abatement activities were monitored by study staff. It is estimated that the total cost of monitoring was $15,832. Although the monitoring cost may have varied by unit size and abatement category (loose paint abatement alone took approximately 1/2 day per unit whereas loose paint and dust abatement took approximately one day per unit to complete) the average cost of monitoring was used ($15,832/129 or $123/unit).

Interior Loose Paint Abatement Costs

Abatement Work -	32 units @ 499/unit	$15,968
	8 units @ $988/unit	7,904
	Total for 40 units	$23,872
Preparation -	40 units @ $63/unit	$ 2,520
Monitoring -	40 units @ $123/unit	$ 4,920
Cancellations -	4 units @ $499/unit	$ 1,996

Thirty-two units were abated at a cost of $499 per unit. Eight units were considered oversized and were abated at a cost of $988 per unit. Thus, for 75% the cost of loose paint abatement was $499 and for 25% the cost was $988. The average cost for all 40 units was $597/unit. These figures do not include the costs of preparation work, monitoring, or the cancellations.

If the costs of preparation work ($63/unit) and monitoring ($123/unit) are included, the cost for interior loose paint abatement was $685/unit for 75% of the units, $1,174/unit for 25%, and the average cost was $783/unit.

If the costs of cancellations are added, then each figure would be increased by $50 ($1,996/40).

Interior Loose Paint and Dust Abatement Costs

Abatement Work -	84 units @ $873/unit	$73,332
	4 units @ $1,748/unit	6,992
	1 unit @ $1,310	1,310
	Total for 89 units	$81,634
Cancellations -	9 units @ 873/unit	$ 7,857

For 84 units the cost of loose paint and dust abatement combined was $873, for four units the cost was $1,748/unit, and for one unit the cost was $1,310. The average cost for all 89 units was $917/unit. These figures do not include the costs of preparation work, monitoring, or cancellations.

If the costs of preparation work and monitoring are included the respective costs are $1,059, $1,934, and $1,496 with an average cost of $1,103. If the costs of cancellations are added, and cancellations were common, occurring in 10% of cases, then each figure above should be increased by $50.

15.5.3 Interior Dust Abatement Costs

No units in the study underwent dust abatements without associated loose paint abatement. The figures presented therefore represent hypothetical cost estimates of interior dust abatements. Estimates are provided of costs estimated in two different ways.

First, the cost per unit for loose paint and dust abatement was divided in half as it took approximately 1/2 day to do loose paint abatements alone and approximately one day to do loose paint and dust abatement. Among the 89 units that had both loose paint and dust abatements, the estimated cost of dust abatements alone were: $437 each for 84 units, $674 each for four units, and $650 for one unit. The estimated average cost was $458 overall not including the costs of preparation and monitoring. If preparation and monitoring costs are included the respective costs were $525, $867, and $748 with an average cost of $552 overall.

Secondly, the average cost for dust abatement was estimated by subtracting the average cost of loose paint abatement alone, with and without the costs of preparation and monitoring ($783 and $597, respectively), from the average cost of loose paint and dust abatement combined, again with and without the cost of preparation and monitoring included ($1,103 and $917, respectively). By this method, the average cost of dust abatement was $134 without including preparation and monitoring costs and $320 if they were included.

All estimates provided for the cost of interior loose paint, loose paint and dust, and dust abatement do not include costs associated with identifying units in need of abatement, recruiting landlords, making arrangements for families to be off the premises during abatement activities, and pre or post-environmental sampling.

15.5.4 Deleading Costs

Interior and exterior deleading activities are described in detail in another section of the report. The study offered to pay in full the cost of exterior and interior deleading for owner occupied units, and $2,000 towards the cost of these activities for non-owner occupied units. Non-owner occupied properties were viewed as businesses and therefore were believed to be responsible for bringing their properties into compliance with the Massachusetts Lead Law and so were not offered full coverage of the deleading costs. A total of 46 exterior and 46 interior deleading operations were facilitated and paid for in total or in part. These

92 operations were performed by four licensed deleading contractors under eight separate contracts. One contractor subcontracted some of the work to a fifth licensed deleader.

The study incurred a variety of costs that may or may not be relevant to or included in cost estimates of deleading activities, such as those associated with lead based paint inspections, including the purchase of a portable XRF machine, respirator use by inspectors while monitoring deleading (monitoring is not currently required in Massachusetts), clearance sampling to assure that the units were free of lead contaminated dust (this is also not required in Massachusetts but it is conducted if dust is discernible on visual inspection), moving and furniture storage charges, and alternate housing for families during deleading. Many of these costs may not be applicable to deleading activities undertaken as part of the environmental management of children with elevated lead levels, and they may in large part reflect idiosyncrasies associated with this study. Many of these costs may, however, be quite relevant to future endeavors where deleading is undertaken on a large scale or as part of a comprehensive approach to the primary prevention of low level lead toxicity among children. All actual cost estimates are presented.

Costs Associated with Lead Paint Inspections

Development of the inspection process	
$1,800/wk × 10 weeks	$18,000
Conducting Inspections of units	
$2,000/wk × 12 weeks	24,000
Monitoring Deleading Activities	
$2,000/wk × 24 weeks	48,000
Cost of One Portable XRF Machine	4,147
Total Cost of Inspecting and Monitoring	$94,147

As described earlier, for the purposes of this study it was necessary to hire private lead paint inspectors. In other situations, code enforcement inspectors may work for public regulatory agencies, such as health departments, or families who do not have children with elevated lead levels but want inspections may hire licensed private inspectors. Three lead paint inspectors and one assistant accomplished the inspection related activities. They had the additional assistance of an intern inspector who worked on the project.

The total cost of inspector related activities for this study was $94,147, or approximately $1,000 per deleading operation. This figure is probably substantially higher than usual because of factors unique to this study. For example, the $18,000 spent to develop the inspection process is most likely best viewed as a cost idiosyncratic to this study, or as a one time cost that might be incurred by other cities or projects that were starting up large scale deleading activities. Similarly, private lead inspectors do not typically monitor deleading activities, but rather perform lead inspections to determine the need for deleading and to issue certificates of compliance after deleading has been completed. The cost of the portable XRF could also be viewed either as a one time cost, or not included as a cost since any lead related regulatory agency must have this type of equipment. Therefore, it is probably most realistic to include only the costs of actually conducting inspections of units in arriving at the total cost of deleading.

Ninety-two deleading operations were performed, and the cost of lead paint inspections associated with these operations was $24,000, or approximately $260 per operation. Since certificates of compliance are issued only after both interior and exterior deleadings in Massachusetts, a more accurate estimate of this inspection/compliance cost might be $520 per unit deleaded.

Costs Associated With Actual Deleadings

46 Exterior Deleading Operations	$262,278
46 Interior Deleading Operations	343,242
Total Cost of Exterior and Interior Deleading	$605,520

The average cost of an exterior deleading operation was $5,702 and the average cost of an interior deleading operation was $7,462. Thus the average total cost per unit of both interior and exterior deleading operations was $13,164.

Cost of Respirators

4 PAPT Respirators @ 546/each	$ 2,186

Respirators were purchased for use by inspectors during deleading monitoring. While it would be accurate to factor their cost into the study related deleading costs, this is a one-time cost and is not regularly required for lead paint inspectors. Deleaders are required to wear respirators while performing deleading operations.

Cost Associated With Moving and Storage

41 Moves @ 720/each	$29,520
5 Cancellations @ 360/each	1,800
Extra Storage	2,346
Total Cost	$33,666

$33,666 was spent on moving and storing the property of 41 families. Five other families were able to find alternative housing without any financial assistance from the project. Thus, to accomplish 46 interior and 46 exterior deleading operations, 41 required financial assistance with temporary moves and the average cost for those requiring moving assistance was $820 per family.

Cost Associated With Alternative Housing

Seven families could not locate suitable alternative housing and the study identified and paid for temporary housing for those individuals. A total of 78 nights of alternative housing was provided for these seven families at a total cost of $11,612, or approximately $1,650/family.

Cost Associated With Clearance Samples

Materials (centrifuge tubes and wash and drys)	$ 1,476
Acid dispenser and centrifuge shaker	997
Analyses of 619 samples at $14.50/each	8,975
Total Cost	$11,448

A total of $11,448 was spent obtaining and analyzing clearance samples. No estimate is available of the cost associated with the inspectors' time involved in obtaining clearance samples. The average cost of performing clearance sampling for the 46 interior units is therefore approximately $250/unit deleaded. Since it is not currently standard public health

practice to conduct clearance sampling with all interior deleading operations, it may be best to exclude the cost of clearance sampling in estimating total costs of deleading operations.

15.5.4.1 Total Deleading Costs

$741,712 was spent for the 46 interior and 46 exterior deleading operations. This includes the cost associated with inspecting and monitoring deleading activities, the actual deleading activities, financial assistance with moving and storage, alternative housing for selected families and clearance samples for all interior deleading operations. Thus, the average cost per combined interior and exterior deleading operation was $741,712/46, or approximately $16,124 per combined operation. If the cost of moving, storage, and alternative housing are removed, the total cost was $696,434/46, or approximately $15,000 per combined operation. If the cost of moving, storage, alternative housing, and inspections and clearance samples are removed, the total cost was $594,072/46, or approximately $13,000 per combined operation. This cost may be likened to the cost of deleading a single family home, or one interior operation and an exterior deleading operation in a multiunit home. Deleading of subsequent units in multiunit homes would have costs closer to that of interior unit deleading alone.

Separate costs associated with exterior deleading operations may be about $5,700/exterior operation, although there is no data to suggest how comparable costs would be in other cities with different sizes or types of homes. The average cost per interior deleading activity, not including the costs associated with the unique situations of this study (e.g., moving, storage, alternative housing, inspections, monitoring, and clearance samples) was $7,500/interior deleading operation. If one assumes that many of the unique costs are applicable to future large scale deleading activities in other communities, the actual cost may be closer to $10,000-$10,500 per unit.

16. DISCUSSION

One of the most difficult aspects of the childhood lead problem is identifying the sources of lead and determining their relative contribution to children's lead burden. Lead based paint and household dust have received most of the attention to date. Far less attention has been paid to urban outdoor sources of lead, especially soil, except in cases of stationary sources such as smelters. Our findings suggest that lead contaminated soil does contribute to the blood lead levels of urban children. We found that soil abatement alone (Study vs. Control Group A) was associated with a 0.8 to 1.4 μg/dL decline in blood lead levels and that soil and interior dust abatement combined (Study Group vs. Control Group B) was associated with a 1.2 to 1.6 μg/dL decline. (These numbers are the range of adjusted point estimates.) These blood lead changes were observed approximately one year following soil abatement in which surface soil lead levels were dropped an average of 1,856 PPM.

Numerous previous studies have shown that soil and dust lead levels are correlated with children's blood lead levels.[4,6-10,12-14,19-21] These studies have relied largely on cross-sectional data, often from communities with point sources of lead such as smelters, where soil lead concentrations were far greater than those typically found in urban settings. Many of the smelter area studies were conducted in response to crises and were not designed as research studies so that important design features such as study size and timing of intervention could not be planned. These studies have produced widely differing results with slope estimates of the soil lead - blood lead relationship that vary over nearly an order of magnitude.[25]

Removal of lead contaminated soil in this study was associated with a 0.8-1.6 μg/dL reduction in children's blood lead levels, suggesting that urban soil lead is biologically available and contributes to low level lead absorption in children. The clinical and public health implications of a reduction of this magnitude are not readily apparent. The magnitude of reduction in blood lead observed suggests that lead contaminated soil abatement may not be a particularly useful clinical intervention for children with low level lead exposure. It might be extremely useful, however, in specific situations, such as if soil lead were extremely high or the particular child had pica for soil. It is also a relatively inexpensive

and low technology intervention. Although there are no data regarding the relative safety of soil and lead based paint abatement, it seems unlikely that soil abatement is as dangerous to children, families, and workers as lead based paint abatement can be.[26-31]

16.1 STUDY PROBLEMS AND THEIR RESOLUTION

16.1.1 Recruitment and Retention of Study Participants

A potential problem was the recruitment and retention of study participants. The success of the study depended, in part, on recruiting and retaining sufficient numbers of participants who were representative of the general population of urban preschool children who are at risk for low level lead exposure. These concerns were important so as to provide a large enough sample so that we had sufficient power to test the study hypothesis and be generalizable to other children. The issue of generalizability was addressed by using the Boston Childhood Lead Poisoning Prevention Program (BCLPPP) for identification of children. This program has data on the majority of children screened in the neighborhoods of Boston of interest (i.e., those neighborhoods with the highest rates of lead poisoning). We also attempted to improve generalizability by choosing as wide a range of blood lead levels as was practical. That is, we could not choose children with blood lead levels greater than 24 μg/dL because of concern that they would receive medical and possibly environmental interventions that might confound study results. We chose as a lower limit blood lead values of 7 μg/dL because of concern that it would be difficult to ascertain the effect that soil abatement would have on lower blood lead levels. Our range for blood lead levels at entry was therefore 7-24 μg/dL. A related concern was that the BCLPPP screening data were derived from fingerstick lead tests. We addressed this by confirming all potential subjects' blood lead levels with venous blood samples before final enrollment.

Recruitment of participants was further supported by six approaches:

1. An active and visible community relations program and subject education effort was mounted. This ensured that residents of the target communities were aware of the lead poisoning problem in their communities, the risks that lead poisoning posed for their children, and of the program at the time that study staff attempted to recruit them. In addition, study staff were educated in the epidemiology, long-term effects, prevention, and treatment of childhood lead poisoning so that they could discuss these issues with potential subjects and convince them of the importance of the study and its potential benefits to their children and community.

2. Each month families were given $25 gift certificates for local supermarkets and general purpose stores as long as they participated in the study. Even if they moved they were eligible for these incentives as long as they stayed in touch with the study staff and agreed to provide access for environmental and biologic sampling and study interviews. All families completing the study were given a $150 gift certificate.

3. Study staff were enthusiastic, well trained, well supported by the study's management, often experienced in home visitation, and frequently came from the target communities. This led to a close and effective rapport with participating families.

4. Families were not enrolled if during intake they stated that they had plans to move during the next three months.

5. Study activities were very intrusive and disruptive to families and we made every effort to minimize family disruption by scheduling study activities at their convenience, taking children to museums and restaurants during interior abatement work, and offering alternative housing if necessary during interior lead paint abatement.

6. There was great concern about landlord consent to participate and the early stages of recruitment supported this concern. That is, landlords were initially reluctant to participate because of concern that if lead paint were found on the interior surfaces of their houses, they would be forced to pay for deleading. This problem was addressed by offering landlords of non-owner occupied premises $2,000 towards the cost of interior lead paint deleading and landlords of owner occupied premises the full cost of interior lead paint deleading. Moreover, we pointed out that (1) these properties were not in compliance with Massachusetts law and that at some time in the future they would have to be deleaded; (2) the study would facilitate and pay for part or all of the cost; and (3) if the landlords did not delead at the end of the study and a child became lead poisoned, they might be found liable if the family chose to sue them. We also pointed out that the soil contained high levels of lead and that we would remove this soil at no cost to them.

16.1.2 Lead Contaminated Soil Disposal

A great deal of energy went into identifying a location to dispose of lead contaminated soil. After exploring multiple options, some of which were not used because of distance from the excavation site or political concerns, a quarry was identified that abutted a cemetery in a Boston neighborhood not involved in the study. This worked well until the City councillor from that neighborhood raised concerns about the potential hazard of this soil to this neighborhood. This problem was resolved by temporarily storing the abated soil on a city-owned property while the EPA Project Manager, the principal investigator and other

members of the Lead Free Kids Staff, and representatives from the Mayor's Office met with the City councillor and concerned citizens and convinced them that dumping the soil in the quarry and covering it with unleaded soil posed no risk to residents of this community.

16.1.3 Limited Funding

Early in the study the Boston Lead-In-Soil Project was subjected to a cut in funds available from the EPA due to the other projects having budgetary needs that had to be addressed. This was dealt with by calculating the minimum number of families who needed to be recruited and retained to have sufficient power to test the study hypothesis. The CDC was helpful in supporting these estimates. This budget cut, plus the need to offer landlords substantial incentives to participate, led us to abandon the cluster arm of the Study Group and focus only on the effects of abating individual properties.

16.1.4 Concerns About Ethical, Legal, and Logistical Constraints

A series of very complicated ethical, legal and logistical constraints, documented in detail in documents produced by Region I of the EPA, submissions to and correspondence with the Institutional Review Board of the Trustees of Health and Hospitals, and correspondence with the Massachusetts Department of Public Health, led to great concern about the feasibility of carrying out a scientifically rigorous study in Boston. This problem, or series of problems, was dealt with by assembling a credible and capable leadership team with an established and respected record of scientific and public health accomplishment. The team assumed leadership for all aspects of the study, met regularly, provided daily oversight of all study activities, and worked closely and effectively with local and national EPA and public health officials, lead advocates, and nationally renowned leaders in the field of childhood lead poisoning research and treatment. This is a very truncated discussion of a substantial number of very complicated legal and ethical issues.

16.1.5 Frozen Ground During Soil Abatement of the Study Group

The ground froze during lead contaminated soil abatement of the Study Group in the Winter of 1989-1990. The study had a very narrow window of time in 1989 in which to accomplish soil abatement for the Study Group. Before these abatements were completed the

soil froze, as Boston experienced the coldest December in recorded history. This problem was addressed by using jack hammers to loosen soil so that abatements could proceed.

16.2 LIMITATIONS

Although designed and conducted to produce rigorous results, the study has a number of limitations that deserve mention:

16.2.1 Relatively Small Sample Size

Despite a sample size with adequate power to detect the hypothesized overall effect of the intervention, the relatively small sample size did result in a number of limitations:

1. Randomization was undertaken to maximize the probability that all three groups were comparable as regards measured and unmeasured characteristics. Because of the small sample size, randomization did not result in groups that were entirely comparable at baseline. In the analyses, we adjusted for the measured variables that were potential confounders.

2. Outliers had a greater influence on the study results. Two siblings in the Study Group had significant increases in blood lead levels between the first and second post-abatement sampling rounds. We hypothesized that they became poisoned because they were spending time at the father's home that had lead-based paint and was being renovated. The crude analysis was conducted both with and without these children and all results are reported. If the sample size were larger, however, the influence of the outliers would have been attenuated.

3. The relatively small sample size limited the stability of our stratified analyses on children with particular characteristics. For example, the small sample size resulted in a limited number of children with blood lead levels of 15 μg/dL and greater at baseline. Thus, our estimates are unstable regarding the effectiveness of soil abatement among children with lower versus higher starting blood lead levels.

16.2.2 Follow-up Limited To One Year

There are virtually no data available on the rate of change in children's blood lead levels following a change in lead exposure. It is possible that the intervention would have been associated with a greater reduction in children's blood lead levels had we followed them for a longer period of time. We have consequently applied to the EPA for a no cost

extension to obtain blood lead levels on participants who remained on the study premises during the summer of 1991. This will allow us to compare the blood lead levels of children who had soil abatement two years ago to those who had soil abatement during the fall of 1990.

16.2.3 Mobility Of Families

Twenty two families (14.5%) moved by the second post-abatement blood sampling round, and more families from the Study Group moved (20.4%) than families from Control Group A (15.7%) or Control Group B (6.4%). We followed all of these families for the duration of the study and obtained blood and environmental samples whenever possible. In addition it did not appear that the movement of the families reduced the magnitude of the treatment effect. Children who lived on the study premises for at least 300 days had a similar reduction in blood lead levels as the entire group.

16.2.4 Limitations Resulting From Study Design

Several aspects of the design of the study may have limited the observed effectiveness of the intervention.

1. All children in the study, irrespective of group assignment, were exposed to lead contaminated soil prior to enrollment. An alternative study design which would have been logistically more difficult to execute would have involved conducting lead contaminated soil abatement prior to birth. Such a design would have enabled us to investigate whether exposure to lead contaminated soil abatement in the first year of life is associated with lower blood lead levels.

   This study provides information about soil abatement as a secondary prevention strategy, that is the benefit to children already exposed to lead derived, in part, from contaminated soil. It can not be used to estimate the primary prevention effect of soil abatement. Since children's post-abatement blood lead levels reflect both recent exposure and body burdens from past exposure, the benefit observed is probably less than the primary prevention benefit, that is the benefit of abating lead contaminated soil before children are exposed to it so as to prevent increases in blood levels and body stores.

2. Lack of Cluster Groups - Due to budgetary constraints and difficulties enrolling landlords, we abandoned our original plan to study clusters as the unit of abatement. We therefore evaluated only the effect of single premises abatements. It is possible that the effect of lead contaminated soil abatement on children's blood lead levels would be even greater had we abated lead contaminated soil from properties that surrounded Study Group children's premises.

3. Study staff regularly visited all participating families and provided education about lead poisoning, and while educational efforts were identical among the groups, this may have resulted in decreased group differences.

4. Children were already 31 months old, on average, at the outset of the study, well above the age at which mean blood leads are highest.[32,33]

These limitations all would tend to drive the results toward the null (Type II error), rather than produce false positive results (Type I error), making it likely that the study underestimates the full impact of urban soil abatement.

16.2.5 Limitations To Generalizability

There are limitations to the generalizability of the results stemming from the characteristics of the study population. For example, the abatement might have had a different effect among children with more or less exposure to soil lead. It might also have been different among children of higher socioeconomic status because of better diets, foundation shrubbery, more grass cover, or other reasons. The results therefore can be generalized to inner city children 1 to 4 years of age who have soil lead levels greater than 1,500 PPM, blood lead levels of 7 to 24 μg/dL, whose families' place of residence are reasonably stable (only 15% moved during the course of this study), and whose exterior lead paint is in fairly good condition. The study provides no information about the effect of lead contaminated soil abatement for children with lead levels outside of the eligible range (7 to 24 μg/dL). Similarly, the results may not be generalizable to children who live in communities with smelters or other stationary sources where soil lead levels are substantially higher than those seen in this study, or where differences in particle size result in differences in bioavailability.[5]

16.2.6 Misclassification

Errors in the sampling and measurement of lead in the environmental media and the blood and handwipes may have resulted in exposure and outcome misclassification. Because these errors were just as likely to occur in the Study Group as the Control Groups, they are more likely to result in bias toward the null than toward falsely positive results. We suspect that handwipe data was subject to non-differential misclassification because of sampling problems (e.g. the parent may have washed the child's hands shortly before sampling), and the highly variable background lead levels in the wipes (ranging from 2 to 18 μg).

Deficiencies in parental memory and report may have led to inaccuracies in the interview data. Most of the variables collected at interview were considered potential confounders of the relationship between soil abatement and blood and hand lead levels. Therefore any misclassification would have reduced our ability to control for confounding.

16.3 IMPLICATIONS OF FINDINGS

Although the average benefit associated with abatement of lead-contaminated soil is modest, the societal impact may be substantial. Consider, for example, the impact on the blood lead distribution of an average decline of 1 or 2 μg/dL in the mean blood lead level of a population of children assuming a starting mean blood lead level of 12 μg/dL, a standard deviation of 4, and a normal distribution (Table 16-1). We also assume that the amount of change (as opposed to the percentage of change) is constant for all starting values, as we observed in our own sample in which the distribution of starting values was truncated. A decline of 2 μg/dL in the mean blood lead level results in 72% as many children with levels exceeding 10 μg/dL, 47% as many children with levels exceeding 15 μg/dL, and 26% as many children with levels exceeding 20 μg/dL (values of 10, 15, and 20 μg/dL were chosen because they correspond to the new CDC definition of lead poisoning, the new screening guideline, and the new action level for medical intervention). Even a 1 μg/dL decline in mean blood lead level results in 87%, 70%, and 52% as many children with levels of 10, 15, and 20 μg/dL, respectively. The percentage shifts may differ somewhat in a more representative sample in which the distribution of starting values is likely to be log normal.

TABLE 16-1. PERCENTAGE OF CHILDREN EXPECTED TO HAVE BLOOD LEAD LEVELS EXCEEDING 10, 15, AND 20 μg/dL ASSUMING VARIOUS MEAN BLOOD LEAD LEVELS *

Mean	% > 10 μg/dL	% > 15 μg/dL	% > 20 μg/dL
12	69.1	22.7	2.3
11	59.9	15.9	1.2
10	50.0	10.6	0.6

*A constant standard deviation of 4 μg/dL is assumed for all mean blood lead levels.

The results of this study suggest that lead contaminated soil contributes to the lead burden of urban children and that abatement of lead contaminated soil around their homes results in a modest decline in blood lead levels. Thus it may be prudent to include soil inspection and abatement as part of primary prevention strategies in communities with high rates of childhood lead poisoning and as part of the environmental intervention on behalf of selected lead poisoned children.

Policy decisions regarding urban lead contaminated soil abatement as a lead control strategy will require numerous considerations. For example, are other types of remediation (e.g., planting grass cover and shrubs) equally effective but less expensive and intrusive? How does the cost effectiveness of soil abatement compare to other lead exposure reduction activities, such as paint abatement? Will it be practical to perform large scale abatements without encountering problems regarding the disposal of lead contaminated soil? Will future research help specify whether changes in children's blood lead levels of the magnitude seen in this study are clinically relevant or prudent from a public health or societal perspective? And will we develop and sustain the resolve and commit the resources needed to prevent what remains the most important environmental health problem of children in the United States?

16.4 ONE YEAR EXTENSION

In December, 1990 the investigators requested that unexpended funds that resulted from paint deleading refusals be used to support a no cost extension for one year. In May 1991

the extension was granted and signed. The extension will be used to accomplish a number of related objectives.

The first objective is to conduct detailed analyses of data already collected that are vital to our understanding of how lead contaminated soil abatement affects children's blood lead levels. A great deal of environmental and child based data were collected as part of this study. As anticipated from the outset of the project, only a selected number of analyses directed at answering the primary hypothesis posed by the project, that is, in the aggregate, did lead contaminated soil abatement result in significant reductions in children's blood lead levels, could be conducted by the end of May, 1991. The extension will enable the investigators to complete more detailed analyses regarding the impact of behavioral and environmental variables on the change in blood lead levels.

Second, analyses conducted to date suggest that soil abatement was associated with a 0.8-1.6 μg/dL reduction in children's blood lead levels, somewhat less than what was originally hypothesized. The clinical and public health implications of a reduction of this magnitude are not readily apparent. It is possible that larger differences in mean blood lead levels between the experimental and Control Groups may be found at two years post-abatement. If this is the case, then it might imply that this environmental intervention is prudent public policy. The one year extension enabled the investigators to obtain an additional blood and hand lead level measurement among children who still live at their original premises. This will also allow the investigators to examine the impact of paint deleading on blood lead levels. Additional soil and dust samples will also be obtained and analyzed for lead content so that recontamination can be further studied. The possibility of obtaining a fourth blood lead level if the results were inconclusive or if the financial resources were available was discussed in the original grant application submitted in August, 1988.

A one year extension also enables this project to be completed simultaneously with the other projects in Baltimore and Cincinnati and will facilitate our input in understanding how the data from each of the three projects complement each other. It also ensures that the investigators will be available to work with EPA officials in writing the final report to Congress combining the results of all three projects.

The Trustees of Health and Hospitals of the City of Boston has agreed to continue housing the grant. Michael Weitzman, M.D., although having moved to the University of Rochester School of Medicine and Dentistry, will continue to be the principal investigator, and in that capacity will continue to be responsible for the overall operation of the project during the extension period. Ann Aschengrau, Sc.D. at Boston University will continue to oversee the day-to-day data collection and analyses and she, along with Michael Weitzman, M.D., David Bellinger, Ph.D. of Harvard Medical School, and Alexa Beiser, Ph.D. at Boston University, will collaborate on the production of all reports.

Boston Lead Free Kids Study

Protocols and Other Documents

A. Protocols

1. Blood Sampling and Processing
2. Blood Lead Analysis
3. Erythrocyte Protoporphyrin Analysis
4. Handwipe Sampling
5. Handwipe Analysis
6. Child Height Measurement
7. Child Weight Measurement
8. Soil Sampling
9. Soil Lead Analysis
10. Interior Dust Sampling
11. Interior Dust Lead Analysis
12. Water Sampling
13. Water Lead Analysis
14. Lead Paint and Site Inspection
15. Interior Dust Abatement
16. Interior Loose Paint Abatement
17. Quality Assurance Plan: Soil and Dust Analyses
18. CDC External Quality Assurance Plan: Blood Lead Analyses
19. US EPA/EMSL External Quality Assurance Plan: Soil, Dust, and Handwipes

BOSTON LEAD FREE KIDS STUDY

PROTOCOL FOR SAMPLING BLOOD FOR LEAD ANALYSIS

Venipuncture Method

1. Make sure the consent form is signed.
2. Educate the patient according to their level of comprehension, with parent present.
3. Assure the patient of minimal discomfort.
4. Inspect the patient's arm and hands for best venipuncture site.
5. Determine the best method of venipuncture for the patient (butterfly 18 ga. or conventional needle 21 ga. assembly).
6. Clean venipuncture site using Becton Dickinson (B-D) alcohol prep until alcohol prep shows clean. Let air dry or dry with clean gauze.
7. Be sure the patient is properly restrained.
8. Apply tourniquet.
9. Don gloves.
10. Palpate for vein.
11. Clean site again and dry after palpating.
12. Insert needle assembly.
13. Draw 2 B-D pediatric 3 ml vacutainer evacuated tubes with EDTA preservative. Mix well; invert 3-5 times.
14. Loosen tourniquet before last tube is full or before withdrawing needle.
15. Withdraw needle.
16. Apply pressure to venipuncture site until bleeding is stopped, then apply band-aid.
17. Write in patient's name, other coded information, and sign labels. Attach labels to tubes.
18. Put tubes in cooler.

Processing Equipment:

1. Consent form
2. Butterfly 18 ga. or 21 ga. by 3/4", 12" tubing infusion set, vacutainer multiple sample Luer-Adapter, Becton Dickinson vacutainer with EDTA preservative, and vacutainer holder.
3. Becton Dickinson (B-D) alcohol swab.
4. Tourniquet
5. Cooler with "Blue Ice" packs to keep sample cool.
6. Trained and qualified person to obtain blood samples (i.e., medical technician, nurse, etc.).

All waste materials should be **red-tagged.** Upon failure to achieve venipuncture, the alternative fingerstick procedure as described by CDC may be used.

Revised 8/89

Boston Lead-In-Soil Demonstration (Lead Free Kids) Project

Whole Blood Collection and Processing Protocol

For Blood Lead and FEP determinations

Blood

↓

One 7 ml Lavender Top Vacutainer

↓

Invert Several Times To Ensure Proper Mixing

↓ ↓

Blood Lead Blood FEP

↓

Initiate Chain Of Custody Document

↓

Refrigerate at 4°C Within 30 Minutes Of Collection
And Store At Same Temperature Until Shipment

↓

Pack Blood in Styrofoam Shipping Containers Provided By Laboratory

↓

Transport Blood Via Lead Free Kids Messenger
to Environmental Science Associates (E.S.A.) Laboratories
of Bedford, Massachusetts

LEAD FREE KIDS STUDY

BLOOD LEAD ANALYSIS

ANALYTE: Lead

MATRIX: Blood

LABORATORY: ESA Laboratories, Bedford, MA

PROCEDURE: Graphite Furnace Atomic Absorption (GFAAS)

METHOD: A 1:12 dilution with a Matrix Modifier, FGAAS

RANGE: 0-50 μg/dL

DATE:

1. PRINCIPLE OF THE METHOD

1.1 A 100 μL aliquot of well mixed blood is diluted to 1.2 mL with a matrix modifier.

1.2 The sample is then run by GFAAS using polarized Zeeman background correction.

2. RANGE AND SENSITIVITY

2.1 The sensitivity of this method is 1 μg/dL. The upper range is 50 μg/dL, samples above this range should be diluted and re-run.

3. INTERFERENCES

3.1 Normal constituents of blood and urine do not interfere. Zeeman background correction will adequately correct for all background interference at this dilution.

4. REAGENTS

4.1 Triton X-100

4.2 Dibasic ammonium phosphate (NHA) 2HP04

4.3 16 M nitric acid

4.4 Matrix Modifier - To approximately 1000 mL of DIW stir in 20 mL of Triton-X and 4 grams of dibasic ammonium phosphate. Then add 4mL of NHO3 and dilute to 2000 mL with DIW.

5. STANDARDS

5.1 Stock Standard - 1000 μg/mL Pb Fisher certified or equivalent.

5.2 Working Standard - 10 μg/mL Pb - Dilute 1 mL of the Stock Standard to 100 mL with DIW.

5.3 Curve Standard - 5, 10, 20 and 50 μg/dL - Dilute 0.5, 1.0, 2.0 and 5.0 mL of the Working Standard to 100 mL with the Matrix Modifier.

6. SAMPLE PREP

6.1 Using a micromedic pumping system, draw up 100 uL of well mixed blood, and dispense along with 500 μL of Matrix Modifier into a sample cup.

6.2 Draw up 100 μL of Matrix Modifier and dispense along with 500 μL of Matrix Modifier into the same sample cup from 6.1.

6.3 Controls - Follow Steps 6.1 - 6.2 using a known blood control.

6.4 Calibration Curve - Using a micromedic pumping system, draw up 100 μL of a <5 μg/dL blood sample, and dispense along with 500 μL of Matrix Modifier into a sample cup.

6.5 Draw up 100 μL of the lowest Curve Standard and dispense along with 500 μL of Matrix Modifier into the same sample cup from 6.4. Continue steps 6.4 -6.5 with remaining standards. Run the Matrix Modifier at the beginning of the run to ensure it is lead free.

7. INSTRUMENT PARAMETERS

HITACHI SIMULTANEOUS MULTIELEMENT ATOMIC ABSORPTION SPECTROPHOTOMETER

Element: Pb
Sample: Blood
Analyst: Lee

Date: 89.10.26

A/S PROGRAM

Signal Mode:	BKG Corrected
Measurement Mode:	Absorbance
Sample Blank:	No
STD Replicates:	1
Sample Replicates:	2
Statistics:	Mean, SD, RSD
Auto Sampling:	Yes
Sample Volume:	20 μL
Dilution:	Off (Sample)
Conc. Times:	1
Modif. Add.:	No
Stop Position:	16
Reslope -Standard:	No
-Interval:	1
Result on Record:	Yes (Conc. +Abs)
Chart Speed:	1

GROUP 1

Calculation Pb:	Peak Height
Slicing Height (Peak width only) Pb:	10%
Carrier Gas Int.:	Yes
Opt. Temp. Contr.:	On

GROUP 2

Calculation	
Slicing Height (Peak width only)	
Carrier Gas Int.:	Yes
Opt. Temp. Contr.:	On

STANDARD SAMPLE

S1 S2 S3 S4 S5 S6 S7 S8 S9 Pb

INSTRUMENTAL CONDITION

Unit:	ppb
Time Constant:	0.2 sec
Cuvette:	Pyro

Carrier Gas: 200 Ml/min
Interrupted Gas: 30 Ml/min

TEMPERATURE PROGRAM

Stage	No.	Temperature (C) Start	End	Time (Sec)	
Dry	1	50	120	60	Group 1:Pb
Ash	2	120	720	30	
Ash	3	720	720	30	
Atom	4	2400	2400	5	
Clean	5	3000	3000	5	

	W.L.	Lamp	Dimension
Pb	283.3 nm	7.5 mA	Linear

8. QUALITY CONTROL

8.1 A calibration curve composed of a minimum of reagent blank and three standards is prepared.

8.2 If a large number of samples are to be run, run a set of standards at the beginning and the end of the run. Average standards.

8.3 Run at least one known control, QC material, NBS or Quebec, etc. with every set of standards and every 10 samples.

8.4 At least one duplicate sample should be run every 10 samples.

8.5 At least one spiked sample should be run every 10 samples.

9. REFERENCE RANGES

BEI Lead in Blood - 50 μg/100 mL

10. NOTES

10.1 All plasticware used in this procedure must be soaked in 5% HNO3 and rinsed several times with DIW.

10.2 A well seasoned pyro-coated cuvette seems to work better for this method. It reduces the carbon buildup and minimizes the splattering of the sample.

11. REFERENCE

Miller DT, Paschal DC, Gunter EW, Stroud PE, and D'Angelo J: Analyst 1982, 112, 1701.

ACCURACY AND PRECISION OF LABORATORIES

QC Sample TV	Boston ESA
"Low Bench" 1.6	0.2 (0.5)
"High Bench" 45.6	47.1 (1.6)
"Low Blind" 4.3	4.0 (0.6)
"High Blind" 10.3	10.6 (0.7)

LEAD FREE KIDS STUDY

ERYTHROCYTE PROTOPORPHYRIN PROCEDURE
(Hematofluorometer)

A. Principle

Erythrocyte Protoporphyrin (EP) is beneficial in identifying a biological response to lead (Pb) absorption (causing increased blood lead levels), as well as iron-deficiency anemia. A simple dedicated portable fluorometer, which is called a hematofluorometer, measures the zinc protoporphyrin level by using front surface illumination of a drop of blood on a glass microscope cover slip.

The instrument measures the ratio between zinc protoporphyrin (ZnP) and hemoglobin (oxyhemoglobin) in blood. Consequently, the raw data from the instrument is presented in ZnP/Hgb. The instrument has been calibrated to take the raw reading and convert it electronically to units or equivalent up EPP/100mL of whole blood at a fixed hematocrit (42) to conform to the CDC definition of the Modified Piomelli Technique (see manufacturer's manual for more detail).

B. Apparatus

1. ZnP Manual 4000 Hematofluorometer.
2. 25 - μL micropipet, Eppendorf.
3. Oxygenation apparatus.
4. Glass cover slips.
5. Wood applicator sticks.

C. Basic Operation

1. Introduction

   a. Gloves, safety glasses, and lab coats are to be worn in the blood lead laboratory at all times.

   b. Power to the unit is on at all times.

   c. Handle the calibration slides by the edge only.

2. Calibration Procedure

   a. Checker slides and internal calibration

1. Pull the slide assembly forward to the stop position. Place a low-level (green) calibration slide into the assembly. Push the slide assembly until it engages the first detent position. The "wait" indicator light will immediately light for a period of approximately one second and then go out. The "advance slide" indicator light will light. Push the slide assembly into the second position and wait until the "advance slide" indicator light again lights. Now push the slide assembly into the third position; take the digital reading when the "read" light illuminates.

2. Record three digital readings for the green checker slide in the Hematofluorometer Daily QC notebook. The average of these three readings should be within the range given by the manufacturer. If the average value is out of range, refer to Section C.2.c. of this procedure to calibrate the instrument.

3. Record the values for the medium level (yellow) and high level (red) checker slides following the above procedure.

4. Record the values for internal calibration: with no slide in the assembly, advance to the detent position. The digital display is the value for the internal low calibration. Advance to the second position and record the internal high calibration value. Advance to the third position and record the dark current. If the internal calibration values differ greatly from the previously recorded values and the checker slides are out of range, refer to Section C.2.b. of this procedure.

b. Cleaning the internal slides.

Periodically it may be necessary to remove dust that has accumulated on the internal slides. If you feel this process must be completed, notify the laboratory supervisor at once. If she/he sees fit, **PROCEED WITH GREAT CARE**. The internal slides are extremely fragile. They cannot be repaired or replaced so don't break them!

Remove the black cover on the right side panel of the hematofluorometer. Loosen the small screw within and pull out the slide assembly. You will notice that the top side of the assembly is very dusty. That is not our concern. On the underside, you will see portion of the internal slides that is exposed to the radiation. If there is dust on this portion, remove it in the following manner.

Moisten a cotton swab with methanol and **VERY CAREFULLY** attempt to remove the dust particles. Allow the slides to dry completely.

Replace the slide assembly and tighten the screw to the desired tension.

With no slide in the assembly, advance to the first, second, and third positions

and make note of the digital readings at each position. If the problem seems to have been rectified, analyze the checker slides and continue. Record in the QC notebook that this section was taken.

If the problem persists, notify the lab supervisor and if necessary, notify the ESA, Inc., Service Department.

c. Recalibration

If the internal calibration values are acceptable but one or more of the checker slides is out of range, complete the following. Record in the QC notebook that recalibration was done.

Zero Offset Calibration

If the low level check slide is out of range, place the slide in the assembly and advance to the third position. Depress the "Push to Cal" button on the front panel and hold while adjusting the "Zero Control" located on the rear panel until the desired reading is obtained. Check the low value calibration two or three times.

Slope Correction (High Value Calibration)

Place the high level (red) calibration slide into the assembly. Advance the slide to its third position. If calibration is necessary, depress the "Push to Cal" button and hold while adjusting the "Cal" control on the front panel.

Recheck the zero and high calibration points. Repeat calibration procedure if necessary. When the green and red slides are within range, the yellow slide must be within range since the calibration curve is linear. If it is not, notify the lab supervisor.

3. Sampling Procedure

a. Rock venous samples on an aliquot mixer for one hour to insure they are completely mixed and have reached room temperature.

NOTE: Protoporphyrin is light sensitive. Protect samples from excessive light exposure.

b. Turn on oxygen by turning the small black knob on the tank gauge. Turn until the water tap bubbles gently.

c. Place 25 μL of whole blood on a 25 X 25 mm coverslip. Spread blood to completely cover a 3/8 inch diameter spot on the center of the slide using the pipet tip or a wood applicator stick.

NOTE: Use a new pipet tip for each specimen.

d. Ensure that no clots, air bubbles, or other debris are located on the cover slip.

e. Place coverslip in oxygenation chamber for at least one minute.

f. Place the coverslip on the slide assembly and advance to the third position. The EP value expressed in μg EP/100mL will appear on the digital readout.

Continue to take readings until the value has stabilized. (The blood may continue to oxygenate causing the value to drop. The value will stabilize when the blood is completely oxygenated.)

g. Record the last three readings taken on the green worksheet.

The digital readout represents EP or FEP. To convert EP to ZPP, multiply the EP value by 1.1.

h. NOTE:

1. Lysed blood will give questionable data.

2. Elevated bilirubin concentration will give increased EP.

3. Previously frozen samples will give questionable data due to lysed red blood cells. The same may happen with blood over two weeks old.

4. Quality Control

a. Analyze a high, medium, and low control daily and record the values in the Hematofluorometer Daily QC notebook.

b. These controls are taken from client samples, selected by the lab supervisor.

c. If the QC values differ by more than 15 μg/100mL from the previous value, see the lab supervisor.

5. Maintenance

The hematofluorometer must be calibrated by the manufacturer (ESA, Inc.) once a year. At that time, values will be assigned to the checker slides.

Updated 2/90

LEAD FREE KIDS STUDY

PROTOCOL FOR HAND LEAD DETERMINATIONS (HAND WIPES)

Testing of hand lead will be conducted each time a blood sample is taken for lead analysis. There will be a total of three hand lead determinations: the first baseline test will be done before any abatement activities occur, and the second and third follow-up tests will occur 4-6 months and 9-12 after abatement activities are completed.

Since studies indicate that hand dust reaches equilibrium within two hours after washing, case managers will make every effort to conduct the hand lead testing more than two hours after the last hand washing reported by the parent or guardian.

Case managers will wear disposable gloves when obtaining a hand wipe. Lead in dust on children's hands will be sampled by wiping each hand of the child with three separate commercial wet-wipes. The Walgreen's brand wet-wipes will be used for the LFK study. All surfaces of the hands, front and back up to the wrists will be wiped thoroughly with each of the three wet-wipes. All six wet wipes will be placed inside the container provided by the analytic laboratory. The container will be labeled with the child's name and LFK number.

Each case manager team will also prepare hand wipe blanks at regular intervals during the sampling period (i.e. every tenth child). The hand wipe blank will be prepared by removing six wipes from the wet-wipe container and handling them in such a manner as to simulate wiping the child's hands. These wipes will be placed into a container labeled "BLANK", dated and submitted to the laboratory along with the regular samples. Blind external quality control samples prepared by the EPA with dummy (seemingly correct) identifiers will also be submitted to the lab.

Chain of custody forms will be initiated when hand wipe samples are taken. All samples will be transported to Dennison Laboratories of Woburn, Massachusetts by the Lead Free Kids Study driver.

The six wipes will be composited for chemical analysis. The method of extraction of the lead from the wet wipes is currently being determined. The total quantity of lead found will be reported as ug/pair of hands.

LABORATORY ANALYSIS OF HANDWIPES

Report of Analysis
Method

1 M Nitric Acid Extraction

1. Place each sample in a labeled, acid-washed 800 ml beaker.
2. To each sample, add 100 ml of 1 M nitric acid prepared with deionized water.
3. Swirl each sample for 10 seconds.
4. Cover each sample with a watchglass and allow it to extract at room temperature for 2 hours.
5. Decant the acid solution from the handwipes into a labeled, acid-washed 250 ml beaker.
6. Add 50 ml of 1 M nitric acid to the handwipes in the 800 ml beaker.
7. Swirl the sample for 10 seconds.
8. Decant the acid solution into the same 250 ml beaker to composite the acid rinse.
9. Repeat steps 6, 7, and 8 a second time for a total acid solution of about 200 ml.
10. Cover the samples with a watchglass which is elevated above the beaker rim with glass hooks. (The watchglass must be elevated to prevent "bumping" of the sample during evaporation).
11. Place the samples on the hotplate at about 250°C.
12. Evaporate the samples to dryness.
13. Add about 3-5 ml of 1 M nitric acid to each sample, rinsing the watchglass and the sides of the beaker.
14. Heat the samples gently on a hotplate at 120-150°C to redissolve lead.
15. a. Filter the samples using Whatman, rinsing the beaker/filter paper/funnel with IM $HN0_3$.
    b. Evaporate to about 5 mL on a hotplate.
16. Transfer to an acid-washed 10 mL graduated volumetric flask, rinsing and diluting with IM HNO_3.
17. Shake sample well and transfer to borosilicate test tube and cover.
18. Measure lead concentrations using a Varian 1475 Atomic Absorption Spectrometer. Report results in total μg/sample.

LEAD FREE KIDS STUDY

PROTOCOL FOR MEASURING THE LFK CHILD'S HEIGHT

The LFK child should be in his/her stocking feet when you measure his/her height. First, find an open wall in a room that has no carpeting or thin pile carpeting (the kitchen may be best). Place the yardstick up against the wall with the centimeter side facing you. Make sure that the bottom of the yardstick is resting squarely on the floor and that numbers on the yardstick are increasing as you look up from the floor. Have the child stand straight (no slouching!) up against the yardstick and measure his/her height to the nearest one-half centimeter (i.e. 40.0, 40.5, 41.0, 41.5). This means that you should round up to the nearest one-half centimeter if the height is in between half-centimeters. Thus, 40.25 should be rounded to 40.5 and 40.75 should be rounded to 41.0. The height measurement should be taken right at the top of his/her head (big hairdos should not be counted!!). A small ruler held across the top of the child's head may help you read the correct number on the yardstick. If the child is taller than the yardstick, mark his/her height on the wall with a light pencil and measure the distance from the floor to the mark with the yardstick. Record the height IN CENTIMETERS on the form provided.

LEAD FREE KIDS STUDY

PROTOCOL FOR MEASURING LFK CHILD'S WEIGHT USING THE SECA INTEGRA SCALE

SETTING UP THE SCALE

The scale is already assembled for use with the digital indicator head fitted at the back of the platform and the connecting cable stored in the compartment underneath the head.

INSTALLING THE BATTERY

The seca integra operates with a standard 9-V alkaline battery. Remove the digital display head from the bracket or base in order to open the battery compartment underneath. Connect the battery terminals, then insert the battery and close the cover. Replace the head on the bracket or base.

HOW TO WEIGHT CORRECTLY

Selected lbs. or kg measurement using the switch on the underside of the digital display.

- Switch on the scale by pressing the ON button.
- Weight yourself when display switches to 0.0
- Your weight is indicated after a short time (approximately 4 seconds).

The scale switches off automatically after 30 seconds.

How to use the seca integra when you wish to weight a small child for instance who cannot stand alone on the scale:

- First, weigh yourself as described above.
- Remain standing on the scale and press the ON button once again. 000.0 lb (or tArE kg) appears on the digital display.
- Wait until the display switches to 0.0 and then take the child in your arms.
- After a few seconds, the child's weight appears in the display.

StOP lbs (or SUP kg) signals that the scale has been overloaded.

WHAT TO DO IF....

...No weight display appears under load?
- Remove load from scale

...---appears?
- Press the ON button

...Err appears?
- Remove load from scale, press ON and wait for 0.0

...bAt appears?
- Change battery.

LEAD FREE KIDS STUDY

SUPERFUND SOIL LEAD ABATEMENT DEMONSTRATION PROJECT PROTOCOL FOR SOIL SAMPLING AND ANALYSIS

1. SOIL SAMPLING

1.1. SITE DESCRIPTION

1.1.1. General Site Description

For each location, a detailed drawing should be made that shows the boundary of the lot, the position of the main building and any other buildings such as storage sheds or garages, the position of the sidewalks, driveways, and other paved areas, the position of the play areas if obvious, and the position of the areas with exposed soil (grassy or bare) (See attachment A). Show down spouts and general drainage patterns. Identify each soil subarea by letter or number. If a large soil area needs to be divided into smaller patches for sampling convenience, show how this division was made.

In addition to the diagram, briefly describe the location, including the following information:

Type of building construction
Condition of main building
Condition of lot (debris, standing water, vegetation cover)
Nature of adjacent property
Presence and type of fence
Animals on property
Apparent use of yard (toys, sandbox, children present)
Underground utilities

1.1.2. Subarea Description

For each soil subarea identified on the general diagram, draw a full page diagram showing the approximate dimensions and position relative to the building foundation (see Attachment A). Indicate vegetation and bare soil areas, as well as obvious traffic patterns. Identify the category of landuse, such as roadside, property boundary, adjacent to foundation, play area. Select an appropriate sampling scheme and mark the sample locations on the diagram.

1.1.3. Sampling Schemes. The sample scheme selected for each subarea must adequately characterize the potential exposure of children to lead in the dust

from this soil. It must identify the areas of high lead concentrations, and the general distribution pattern of lead concentrations at the soil surface. For abatement purposes, the depth to which lead has penetrated the soil profile must be determined. Consequently, selected the most appropriate sampling scheme is the critical element in the site description. Several options are offered for the best judgement of the investigator.

Line Source Pattern. This pattern can be used whenever the source of the lead is thought to be linear, such as along a building foundation, a fencerow, a street, or beside a garage. Draw a line parallel to the source, such as the foundation of the main building, approximately 0.5 meters (20 inches) from the foundation. Repeat at the property boundary if the subplot is more than three meters wide (10 ft), and add a third parallel line between the first two if the subarea exceeds five meters (16 ft) in width. Divide each line into segments that do not exceed 7 meters (20ft) in length. Take one composite of 5-10 cores along each line segment. A subarea, for example, that is at the side of the main building and measures 12 X 7 meters would have three lines of two segments each. The lines would be parallel and approximately three meters apart. They would be 12 meters long and consist of two 6 meter segments each, making a total of six samples, each being a composite of at least five cores divided into a top 2 cm sample and a bottom 2 cm sample.

Targeted Pattern. This method is intended to be used in conjunction with the line source or grid patterns as a means of sampling obvious areas that would be missed by the regular patterns. In using the targeted pattern, the investigator should select those locations within the subarea that are likely to reflect potential exposure to lead in soil dust. These may be play areas, paths, drainage collection areas, or areas that are likely to contribute dust to other surfaces that children use. Determine the number of samples to be taken by identifying distinctive landuse characteristics (path, swingset, sandbox), and take a composite of 5-10 cores for each sample.

Small Area Pattern. When the subarea is less than two meters in each dimension, or when the accessible area of a larger plot is less than four square meters, a single composited sample may be taken if it appears that such a sample would adequately represent the subarea.

Grid Pattern. Establish a rectangular grid of intersecting lines 2-10 meters apart, and sample each rectangular area. For larger areas, randomly select the rectangles to be sampled. In each rectangular area, mark three lines parallel to the longest axis, and composite 5-10 cores along each line. Since the rectangle should not exceed four meters, there is no need to divide the line into segments. Therefore, each rectangle should have six samples of 5-10 composites each. Use this pattern when the subarea is generally uniform and there is no reason to suspect large variations in lead concentrations.

When the sample sites have been located on the subarea diagram and the sample collection is ready to proceed, locate each sample with a flag and visually confirm an even and representative distribution of sample locations.

1.2. SAMPLE COLLECTION

The flags or other markers represent the center of the sample location for the targeted and small area patterns. For the line source and grid patterns, the flags indicate the sampling lines. Take at least five but not more than ten cores randomly selected from within the sampling area of the targeted and small area sampling patterns. For the line source sampling pattern, select a random location on each line and take subsamples within a 2' by 2' square area. Take these subsamples from the four corners and the middle of the square with the middle point being on the line. When the line exceeds 7 meters and is broken into segments, take a composited sample in the above manner on each segment. The cores make a composite identified as a single sample. A sample record sheet is used to record information about the composite.

The corer should be clean and free of lead contamination. Vegetation and debris can be removed at the point of insertion, but do not remove any soil or decayed litter. The corer should be driven into the ground to a depth of at least 10 cm, 15 cm if possible. If the 10 cm depth cannot reached, the corer should be extracted and cleaned, and another attempt made nearby. If the second attempt does not permit a 10 cm core, the sample should be taken as deep as possible, and the maximum depth of penetration noted on the sample record sheet. Every effort should be made to take all cores of a composited sample at the same depth.

The cores of each plot should be examined for debris, artifacts, and any other evidence of recent soil disturbance. These should be noted on the subarea description sheet, as should a brief description of the soil color and soil type.

For each sample location, the top 2 cm segment of each of the cores are composited into one sample, and the bottom 2 cm segment combined into a second. For the surface segment, debris and leafy vegetation should not be included with the sample. However, no soil or decomposed litter should be removed, as this is the most critical part of the soil sample and is likely to be the highest in lead concentration.

The soil core segments should be composited in sealable polyethylene containers suitable for prevention of contamination and loss of the sample. The sample identification number should be placed on the container and the sample record sheet. After each sample composite, the corer should be cleaned by reinsertion in the next sampling area. Store the composited soil sample at ambient temperature until returned to the lab.

A field blank should be taken for each sample crew day. This is normally done by taking a sample container with clean quartz sand into the field, opening it to expose the container for a period of time representing normal sample procedures, then returning the container to the lab in the same manner as other soil samples. The purpose of the field

blank is to detect accidental or incidental contamination during the sampling process.

1.3 SAMPLING HANDLING AND STORAGE

The sample containers should be sealed to prevent loss or contamination of the sample. Shipping containers should also be airtight. Storage should be in a cool, dry location.

1.4 RECORD-KEEPING AND SAMPLE CUSTODY

Soil sample records for each location consist of a location diagram and description, a plot diagram for each distinct soil plot, and sample record sheet for each sample in a plot. The sample record sheets should also contain space for chain-of-custody documentation (See Attachment B).

Samples should be sequentially numbered within each subarea. Each location diagram, subarea description, and sample record sheet should bear all sample numbers and the signature of the person responsible for verifying the quality of the information collected. This signature certifies that there has been no misuse of the sample protocol, no mistake in recording the information, and that the information is sufficient to clearly identify these samples for comparison with other types of samples taken at the same location, such as street dust, house dust, house paint, blood, and hand dust. These documents also establish the chain of custody required for the Quality Assurance Plan.

When the sample is delivered to the laboratory, custody is relinquished by the field investigator and received by the lab supervisor by signatures on the sample record form.

2. SAMPLE ANALYSIS

2.1 METHOD OF ANALYSIS

Three methods of analysis have been considered. They are Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma Emission Spectroscopy (ICP), and X-Ray Fluorescence (XRF). The XRF method is the approved method for routine analyses, whereas the AAS method should be used for standardization.

2.1.1. Sample Definition. The representative urban soil sample is defined as the soil from 0-2 cm depth that passes a 250 μm stainless steel sieve. This fraction is comprised of small particles, and the concentration of lead believed to be closely related to that of particles on the hands of children. The fraction is also homogenous enough to allow reliable analysis by X-Ray fluorescence.

2.1.2 Sample Preparation. Sample preparation requires that the sample be air dried and separated by particle size before being digested by wet chemistry. Drying is done at room temperature overnight, or until the sample can be easily

disaggregated by hand or with a rolling pin. The full sample should be brought to complete disaggregation by passing through a 2 mm sieve, using the fingers or a stainless steel tool to crush the larger soil particles. Material larger than 2 mm should be discarded. Soil should not be milled to a fine powder with a mortar and pestle or any other grinding device.

The fraction that passes the 2 mm sieve is now called the total soil fraction. A portion of this sample is retained for possible reference analysis, but the larger fraction is passed through a #60 mesh sieve (250 µm), giving a fine soil fraction identified as the "Urban Soil Sample." The portion that does not pass the #60 mesh sieve should be discarded, as only the total soil fraction (<2 mm) and the fine soil fraction will be analyzed.

About 5-10% of the retained total soil samples should be analyzed. An aliquot is ground so that it all passes a #60 mesh (250 µm) sieve, mixed well and analyzed. Grinding is necessary to provide low/appropriate variance in XRF analysis.

During the processing of the sample, it should be remembered that small soil particles may individually be as high as 50,000 µg Pb/g, and paint fragments as high as 300,000 µg/g. Care should be taken to clean equipment between samples. The sieves may be cleaned by tapping on a hard surface to remove residual particles, or any other dry method. Wet washing is not recommended as this will interfere with the size calibration.

Care should also be taken to thoroughly homogenize the separated sample before removing the aliquot for analysis. Shaking will cause separation. Tumbling or stirring is recommended.

2.1.3. Atomic Absorption Spectroscopy (To be used for primary standards)

2.1.3.1. Wet Digestion. The extraction procedure used for solubilizing soil lead is critical to the interpretation of the results of the Superfund Soil Lead Abatement Demonstration Projects. Even in the absence of analytical errors, the data may not represent the same lead concentrations from sample to sample unless the correct extraction procedure is used. The method selected here does not represent the total extraction of lead, but the breakdown of the organic material and the leaching of lead from the inorganic soil fraction. The methods measure total non-matrix soil lead, because no other extractable fraction has been experimentally shown to measure bioavailable, or non-HF extractable, soil lead. Hot HNO_3 has been repeatedly shown to extract total non-matrix soil lead, or at least >95% of soil lead, compared to a total soil dissolution method (HF). The 1.0 .N HNO_3 cold shake method has been shown to extract as much lead as the hot HNO_3 extract, except for unpolluted

soils where a higher fraction of the total soil lead is within the matrix of soil particles.

The sample should be oven dried at 105°C for 24 hours or until a constant weight is achieved. The aliquot should be placed in a 150 ml beaker and covered with a watch glass. Class A borosilicate glassware and stainless steel tools should be used throughout the sample processing. Low density conventional polyethylene containers may be used to store the solution prior to analysis.

An aliquot of 1 g soil is normally considered representative of the whole sample if the soil is well mixed. Prior to removing the aliquot, the sample should be stirred with a spatula or rod. Shaking the container can cause the sample to separate by particle size.

2.1.3.1.1 Hot HNO_3 Extraction. Add 50 ml 7N HNO_3, cover and digest gently at 95°C for 2 hours, stirring occasionally. If excessive foaming occurs, remove from the heat periodically until foaming subsides. Maintain at least 25 ml in the beaker by adding 7N HNO_3 as necessary.

Cool and dilute with 10 ml 1N HNO_3. Filter through Whatman No. 42 filter paper into a volumetric flask. Rinse filter and labware with 1N HNO_3, and dilute to volume.

2.1.3.1.2. Cold HNO_3 Extraction. Weight the 1 g aliquot into a 4 oz. urinalysis cup. Add 50 mL 1.0 N HNO_3 to each cup. Screw the lid on tightly and place on a reciprocal shaker. Adjust the speed of the shaker to maintain a suspension of the soil particles. Shake for one hour, then filter through a Whatman 111-V filter. Rinse with 1.0 N HNO_3. Dilute to standard volume.

2.1.3.2. Analysis. Analysis by flame AAS should be at 283.3 nm, with background correction. Working standards should be prepared fresh daily, in the range of 2-50 µg/g, in a 1.0 N HNO_3 matrix.

2.1.4. XRF Analysis. Approximately 2 g of loose soil sample are poured into sample cups (Somar Labs, Inc., Cat No. 340), fitted with windows of 1/4 mil thick X-ray polypropylene film (Chemplex Industries, Inc., Cat No. 425). The sample cup should be at least half full. The sample cup is sealed with a sheet of microporous film (Spex Industries, Inc., Cat No. 352A) held in place by the snap-on sample cup cap. The exact weight of the sample is not important, but should be in the range of 2-6 g.

The instrument configuration for the Kevex Delta Analyst Energy Dispersive

X-ray Spectrometer is:

1. Kevex Analyst 770 Excitation/Detection Subsystem:

   a. X-ray tube: Kevex high output rhodium anode
   b. Power supply: Kevex 60 kV, 3.3 mA.
   c. Detector/cryostat: Kevex Quantum - UTW lithium, drifted silicon. 165 eV FWHM resolution at 5.9 KeV.

2. Kevex Delta Analyzer:

   a. Computer mainframe: Digital Equipment Corporation, PDP 11/73
   b. Computer software: Kevex XRF Toolbox II, Version 4.14
   c. Disk drives: Iomega Bernoullik box, dual drives, 10 MB
   d. Pulse processor: Kevex 4460
   e. Energy to digital converter: Kevex 5230

3. Operating Conditions:

   a. Excitation mode: Mo secondary target with 4 mil thick Mo filter.
   b. Excitation conditions: 30 kV, 1.60 mA
   c. Acquisition time: 300 livetime seconds
   d. Shaping time constant: 7.5 microseconds
   e. Sample chamber atmosphere: air
   f. Detector collimator: Ta

4. Analytical Conditions:

   a. Escape peaks, but not background be removed from all spectra.
   b. The intensity ratio, defined as the integral of counts in the Pb (LA) window divided by the integral of the counts in the Mo (KA) Comptom scatter window, should be determined for each spectrum
   c. The intensity ratios for the standards should be used to determine a linear least squares calibration curve.

   The acquisition time (3c) may be reduced at the discretion of the lab supervisor.

2.1.5. QA/QC. By blind insertion into the sample stream (where possible), the QA/QC officer will provide the following blanks at the indicated frequency. At the discretion of the project director, the field team will collect one blank per day by carrying a sample of clean quartz sand into the field in a normal sample container. The sample container will be opened and exposed during the collection of one sample, then closed and returned to the lab. The field blank can be split into two aliquots. One aliquot, the field blank, can be analyzed directly with no further treatment. The second aliquot (the sample blank) can

be analyzed after it has passed through the sample stream (except seiving). The field blank represented contamination added in the field, the sample blank represents contamination added in the field and during storage and sample preparation.

A project standard soil sample will be prepared and distributed at the beginning of the study. This will be used as a lab control. For XRF analysis, there is no need for a reagent blank.

Field blank	1/field sampling day
Sample blank	1/field sampling day
Lab control	1/20 samples
Reagent blank	3/reagent batch

Additionally, split sample (duplicate) analyses and spiked samples will be determined as follows:

Split soil	1/20 samples
Spiked soil	1/20 samples

The spiked soil samples will be prepared by mixing dried and sieved soil of known concentration with the sample. Spiked soil samples may be used at the discretion of the project director. Additional split soil samples will be sent to a designated QA/QC laboratory for analysis using the hot HNO_3 method, one for each 40 samples.

An interlaboratory comparison, similar to the soil pilot study, will be conducted during each six month period, with 10-20 samples from each laboratory, including the QA/QC lab. These samples will be dried, but not sieved.

LEAD FREE KIDS STUDY

Additional Soil Sampling Methods

Protocol for Preliminary Soil Sampling

The goal of the preliminary sampling is to determine whether the soil surrounding the premise of a potential participant contains high levels of lead. For a premise to be eligible, two or more samples must contain at least 1500 parts per million, or the mean of all the samples must be 1500 parts per million or greater.

A total of up to five samples will be taken, which in most cases represents the four sides of the house and a separate play area if one exists. To start, draw a rough sketch of the house and surrounding property. Indicate areas that are paved and those with soil or grass. Label the sides of the house F, L, R, and B, for front, left, right, and back, respectively. Right and left are always from the perspective of standing on the sidewalk looking at the front of the house. Take one sample from each side of the house where there is soil. If there is an area of soil that is not directly adjacent to the house, but appears to be a potential play area, a sample should be taken there as well. Areas of soil that are on the same side of a house but are separated by a porch or stairs may be sampled separately, or combined as one sample.

Sampling Instructions:

Materials needed:

Trowel
paper towels
plastic bucket
zip-lock sandwich bags
marker
labels for bag
Chain-of-custody forms

To get a representative sample, you will use a technique called "composite sampling". This involves taking several sub-samples in an area and then mixing them together to make one composite sample.

For areas adjacent to the house, take five sub-samples along a line parallel to the house, at a distance of one meter from the foundation. The subsamples should be fairly evenly spaced along the foundation for the length of that side, or as much of that side as is not paved. Each subsample should consist of scoop of soil 5 cm in diameter and 2 cm deep. Mix the five sub-samples together in the bucket to make the composite sample from that side of the house. Put the composite sample in a zip-lock bag and place the identifying label on the bag. Fill out the label, giving premise address, premise ID, and sample letter. The sample identification number will consist of the premise number, followed by the letter corresponding to the side of the house. If more than one sample is taken on a side, then follow the letter with a number, for

example, F1, F2, etc. Indicate all sample locations on sketch.

For play areas that are not adjacent to the house, follow the composite sampling guidelines, treating the area as a rectangle or a square. Take sub-samples from the four corners and the middle of this area. Label samples from such play areas "P".

For each sample, initiate a chain-of-custody form. Between samples, wipe the trowel and bucket with paper towels to remove any residual soil.

LEAD FREE KIDS STUDY

Additional Sampling Methods

Protocol for Soil Recontamination Sampling

For each property that was in the project after the baseline blood sample, soil samples need to be taken to check for changes in soil lead. Some of the properties have been abated, and others have not. You will get a sampling pattern for each property. Recontamination samples will be taken at every other location where a detailed sample was taken before. In other words, you will take half the number of samples. The locations which need to be sampled will be highlighted on the map. Locations which are not highlighted can be ignored.

At each location on the map, there will be a number and a little box like this □ Sometimes the box will be on a line, like this _□_ . The box is where the sample should be taken. It represents an area of about two square feet. At each location, get as close as you can to where the box appears on the map, and take five surface scoops of soil in an area of about two square feet. Mix these samples in the plastic container and put about a 1/2 cup of the mixed soil in the sample bag.

The sample bags can be written on using an indelible marker. Put the address, premid, and sample number on each bag. You can do these in advance to save time in the field. Please use a separate paper bag and chain-of-custody form for each property. If you are unable to take a sample or if there is some other problem with a property, please write a note separate from the chain-of-custody form and put it in the paper bag with the samples.

Samples should be numbered using the number on the sample plan, with the addition of the letters "RE". For example, RE2, RE4, RE6, etc.

Revised 2/90

LEAD FREE KIDS STUDY

HOUSEHOLD DUST SAMPLING PROTOCOL*

For this study, the household dust samples are defined as the samples that are most likely to come into contact with a child's hands during indoor activity. This would include dust on upfacing surfaces accessible to the child such as bare floors, carpets, window sills and wells, furniture, as well as dust on toys and other objects likely to be handled by children.

Dust sampling has two components that are important to interpreting lead exposure: the concentration of lead in the dust and the amount of dust or loading on the surface. The concentration of lead in dust appears to be closely related to the amount of lead on children's hands whereas the amount of dust on surfaces is an indicator of the importance of this route of human exposure.

Dust Collection and Sample Handling

There is no standard procedure for collecting dust samples. The following protocol was decided upon after reviewing other available methods (such as the personal air pump) and finding them inadequate. The dust sampling method chosen was the Sirchee-Spittler modified dust buster. We believe that it is the best method for collecting numerous household dust samples within a reasonable amount of sampling time. Other necessary equipment to conduct the sampling are a ruler to measure the sampling area, a 25" by 25" template for designating the floor sampling area, paper envelopes to which the dust samples will be transferred, tape to seal the envelopes, and a cylinder of compressed air for cleaning the sample collection screen.

Before collection, make certain that the Sirchee-Spittler modified dust buster is fully charged. You can tell this by running the dust buster for a few seconds and listening for a high pitched sound from the motor. Another way to monitor the charge in the dust buster is to keep track of the number of samples taken on a change. A maximum of 18 samples (roughly three households) should be taken on one charge. Also, when starting a sampling round in a household make sure that the sample collection screen is clean. Use the compressed air cylinder to blow the screen clean.

Seven dust samples should be taken in each LFK household from each of the following locations: entry floor (i.e. right inside the front door of the house or apartment), LFK child's bedroom window well and floor, kitchen window well and floor, and living room window well and floor. You may choose which window to sample in a room. The floor samples should be taken roughly from the center of the room. Sometimes it will not be possible to get all six samples in a household because of windows that are nailed shut, obstructed by air conditioners, etc. In these instances, obtain as many samples as possible from the designated locations.

Once the individual sampling locations are decided upon, the size of the sampling area must be measured. For the window wells, measure the sampling area with a ruler. For the floors, set down the 25" x 25" template. If the floor is very clean, it may be necessary to vacuum a surface area larger than 25" x 25". In these cases, vacuum an area whose size is double or triple the template area. Be sure to obtain an amount of dust that is adequate for analysis (at least 5 mg).

The sampling sequence should be as follows: Collect the bedroom, kitchen and living room floor samples first. Then, collect the floor sample from the entry way. Finally, collect the window well samples.

To collect a dust sample, switch on the dust buster and vacuum the designated area with back and forth strokes about 1-2 inches in width. The vacuum is most efficient if the head is held parallel to the ground and titled about 5 degrees in the direction of the motion. When the surface has been vacuumed, keep your finger on the switch while raising the vacuum to an upright position. The constant air flow will prevent loss of dust from the filter before it is in an upright position. Switch off the power and carefully remove the vacuum head without tilting it significantly. Reach in and remove the filter screen with a gentle clockwise motion.

Transfer the dust sample to the paper envelope in the following way. Empty the contents of the filter screen into the paper envelope. Tap the envelope to cause the sample to collect in one end. Next, tap the filter ring several times into the open envelope on a hard surface.

Tap the dust to the bottom of the envelope and then seal the envelope and fold over 1/2 inch of the top of the envelope and crease carefully. Tape the folded part of the envelope down with at least a 10 inch long piece of Scotch tape. Each envelope should be labelled with the following information: LFK child's name, LFK number, sample location (i.e. bedroom window well) and size of sample area. It would be best if these envelopes and labels were prepared beforehand. Remember to handle the dust containing envelopes carefully; keep them upright in an envelope box. We want to avoid any loss of dust from the envelopes.

Replace the filter screen with a counterclockwise motion, attach the vacuum head and collect the other samples in the household using the same method. When you are finished sampling a household, clean out the filter screen and the vacuum head with a blast of compressed air.

* Parts of this protocol were adapted from Dr. Tom Spittler's 12/88 protocol "Instructions for Operation and Maintenance of Sirchee-Spittler Hand-Held Dust Vacuum Units".

Updated 1/90

LEAD FREE KIDS STUDY

WATER SAMPLING PROTOCOL

We wish to obtain a tap water sample that will be predictive of the child's blood lead level. Since a standing water sample (i.e. water that has been standing in the pipes for at least 8 hours) is thought to be most predictive, it will be necessary for the parent or guardian to take the water sample. The case managers should give the following instructions to this individual:

The tap water sample should be taken from the cold water faucet of the kitchen. It should be a first flush sample of water that has been standing in the pipes from 8 to 18 hours. We foresee two main options for the time a sample is taken: (1) it can be taken first thing in the morning, or (2) if all of the residents of the household have been out of the house for the entire day it can be taken at the end of the day (i.e. dinner time).

We will provide a labelled plastic bottle for the sample. The bottle should be completely filled with the water. The bottle contains a small amount of acid preservative and so you should store it unopened in a safe place until you take the sample. We will return to pick up the sample at a convenient time.

Before dropping off a water collection bottle case managers will fill out and affix the label provided by the laboratory. The chain of custody form will be initiated when case managers pick up the water sample. The water samples will be shipped to the Hall-Kimbrell laboratory in Lawrence Kansas by U.S. Postal Service.

LEAD FREE KIDS STUDY

WATER ANALYSIS PROTOCOL

A. Reference: Method 239.2 (Atomic Absorption, furnace technique) EPA - 600/4-79-020

Optimum Concentration Range: 5-100 μg/L

Detection Limit: 1 μg/L

B. Application:

Tests for lead are carried out using the graphite furnace atomic absorption technique as described herein. Samples, blanks, quality control, replicate, and spike test solutions are prepared as described and placed in trays for automatic sampling. This instrument setup and analysis steps are performed using the parameters defined.

C. Preparation of Standard Solution:

1. Stock lead solution: Commercially available containing 1000 mg/L (1000 ppm) of lead.

2. Matrix modifier - ammonium monobasic phosphate + magnesium nitrate solution: Transfer 4 grams of $NH_4H_2PO_4$ monobasic Ultrex reagent and 0.2 grams of Mg $(NO^3)^2$, Suparapure, to a 100-mL volumetric flask and makeup to mark with deionized distilled water (DW) containing 0.5% (v.v) HNO_3.

3. Working lead solution: Dilute the stock solution to the ratios needed as calibration standards at the time of analysis. The calibration standards and reagent blank must be prepared with the same acid, i.e., 0.5% (v/v) HNO_3. The reagent blank used in all subsequent dilutions is prepared by diluting 5 mL conc. HNO^3 to 1 L with DW. A 1-ppm solution is prepared by dilution of the 1000-ppm stock solution with reagent blank. This 1-ppm solution is used to obtain calibration standards of 0, 5, 10, 25, 50, and 100 ppb lead. To obtain the calibration standards, withdraw appropriate aliquots of the 1 ppm solution and dilute to 100 mL with reagent blank.

D. Sample Preparation

All samples solutions for analysis are acidified in the field and contain 0.5% (v/v) conc. HNO_3.

E. Instrument Parameters for Lead Analysis

1.	Drying Time and Temp:	40 sec. - 120 degrees C
2.	Charring Time and Temp:	40 sec. - 1000 degrees C
3.	Atomizing Time and Temp:	5 sec. - 1800 degrees C
4.	Cleaning Time and Temp:	5 sec. - 2600 degrees C
5.	Cooling Time and Temp:	20 sec. - 25 degrees C
6.	Purge Gas Atmosphere:	Argon
7.	Wavelength:	283.3 nm
8.	Slit:	0.7 nm
9.	Tub/site:	Pyro coated tube with L'vov platform
10.	Matrix Modifier Setting:	5 μL
11.	Sample and Standard Quality Setting:	20 μL
12.	Max power:	30
13.	Background correction mode:	On
14.	Lamp:	Electrodeless discharge lamp (EDL)

Note: Parameters 1, 2, 4, and 5 use 1 second ramp time. Parameter 3 uses 0 second ramp time and gas stop flow.

F. INSTRUMENT USED

Perkin-Elmer Zeeman model 5100 atomic absorption spectrophotometer equipped with a model AS-60 autosampler and an HGA model 600 graphite analyzer.

G. LABORATORY USED

Hall-Kimbrell Laboratory, Kansas City, Kansas

Drafted June 1990
Revised August 1990

LEAD FREE KIDS STUDY

LEAD PAINT AND SITE INSPECTION PROTOCOL

LFK participants' homes will be inspected to provide information on the extent of leaded paint to deleading contractors and the project epidemiologist. The contractors will be given this information so that they can make informed estimates on the cost of interior and exterior deleading. The project epidemiologist will use the measurements for scientific purposes to estimate the contribution of leaded paint to participant children's blood and hand lead levels.

The first part of this document describes how lead paint inspections will be conducted to gather information for the deleading contractors. The second part describes how this and additional information will be used for scientific purposes.

Lead Paint Inspection

Lead paint inspections will be performed according to current Massachusetts Department of Public Health requirements by registered inspectors. The following forms will be used to record the needed information on all properties:

1. Adapted Massachusetts lead paint inspection forms
2. LFK interior deleading information form
3. LFK exterior deleading information form

Instructions for filling out these forms are as follows:

Make sure the address of each property is recorded on each page of each form and that the participant child's room is designated on the appropriate form. Also record which machine (PGT or Microlead) was used to measure the amount of leaded paint. The sides of the house will be labelled as follows: A - front, B - left, C - rear, and D - right. Window and doors in each room will be numbered from left to right. Window measurements should be taken from the header to the sill and from casing to casing. A list of definitions and abbreviations that may be used on these forms is attached.

Lead Paint Measurements

Lead in paint will be measured using x-ray fluorescence (XRF). Two different brands of XRF machines will be used to measure lead in paint for the deleading contractors: Princeton Gamma-Tech (PGT) XK-3 and Microlead. The two different brands will be used because they are the only machines that are available to the study and both are needed to conduct the inspections in a timely fashion. Only PGT XK-3 measurements will be used for the scientific study data since the two machines are not sufficiently comparable for research purposes.

Differences between the machines are as follows: The possible measurements on the PGT range from 0 to 10 mg/cm^2 and those on the Microlead range from 0 to approximately 50 mg/cm^2. In general, the Microlead XRF reads leaded paint many more inches below the surface than the PGT does. When we tested the comparability of the two machines, we observed that repeated Microlead readings of the LFK conference room windowsill were 2.5, 2.2, 2.2 and 2.9 and repeated PGT readings of the same spot were 0.2, 0.7, 1.4, and 0.6. (Note: the first two readings were taken on one day and the second two readings were taken two days later).

XRF Machine Calibration

Both machines will be calibrated twice a day: once in the morning and again in the early afternoon. An XRF calibration form will be filled out each time a machine is calibrated (see attached). Calibration will involve making two sets of ten readings. The first set of ten readings will be done using a zero standard and the other set will be done using known lead standards of various levels (i.e. 1.45, 3.5 mg/cm^2).

XRK Machine Use in the Field

XRF readings of lead paint concentrations are read directly from the digital read-out on the machine. If the reading is 2.0 mg/cm^2 or less, three readings will be taken and the average will be recorded on the lead paint inspection form. If the inspector believes that there is lead present on a surface despite a negative or very low XRF reading, sodium sulfide will be used to test for leaded paint. The results of both the XRF measurement and the sodium sulfide test will be recorded on the inspection form.

XRF measurements will be taken on painted and on (non-vinyl) wallpapered surfaces. The determination of what constitutes an appropriate surface will be made by the inspector. Measurements will be taken on the interior and exterior of the participant's dwelling. The interior is defined as the apartment or living quarters of the LFK participant. The exterior is defined as the common hallways, stairs, entrances, porches, accessible basements as well as the exterior walls of the building. The exterior may also include any other buildings (i.e. garages) and fences on the property. Interior measurements will be taken on walls and woodwork including baseboards, windowsill, etc. in each room of the participant's unit. Ceiling measurements will be taken only if the paint on the ceiling is peeling.

Additional Deleading Information and Instructions

Besides taking the lead paint readings, the inspectors will record other pertinent information/instructions for the deleading contractors. Examples of such instructions are:

1. In general, baseboards will be made intact and capped with quarter round moldings. When lead painted decorative moldings are present, record the width that will be needed for replacement.

2. When porch rails or other items require replacement, specify materials and workmanship common to the area. Also note that this will require further negotiation with the landlord.

3. Indicate whether the door and window trim are decorative or flat. Flat boards will be replaced with #2 pine. Decorative moldings will be dipped off-site.

4. Ceilings will be tested for lead only if they are peeling. If peeling ceilings are not accessible, note that they should be made intact on the comment sheet.

5. Lead painted basement windows wherever possible will be covered with plexiglass.

6. Measure rails and count ballisters on exterior porches.

7. Exterior window sills and wells will be covered with aluminum and caulked.

Lead Paint Measurements for Scientific Purposes

Since the Microlead and PGT XRF machines are not sufficiently comparable, only the PGT measurements taken by the lead paint inspectors will be used for the project's scientific data. Thus, only about 50% of the properties initially inspected will have measurements useful to test the study hypothesis. Once the lead paint inspectors finish gathering all the data needed for deleading, they will return to the properties where the Microlead was used to take the measurements and will re-take six measurements using the PGT XK-3.

The six measurements will re-taken in each of the following rooms since it is likely that the participant child spends most of his/her time there: the child's bedroom, the kitchen, and the living room. One measurement will be taken on the lower part of the wall and one on the window sill (i.e. woodwork) in each of these rooms. The calibration and

measurement procedures described previously will also be followed during this round of measurements. Special study data collection forms will be developed for recording these data. These same data will be abstracted from the inspection forms for the properties that were originally tested using the PGT.

Abbreviations and Definitions for Lead Paint Inspections

n/a = not accessible
cov = covered
rep = replace
y = yes
n = no
dip = off-site removal of lead from surface by an approved method
R & R = remove and replace (unless otherwise noted, the replacement material will be #2 pine)
neg = negative
pos = positive
upper walls = walls above five feet
lower walls = walls below five feet
mit = make intact

porch = the area extending from the house, the wall the porch is attached to is the exterior of the house.

scrape = delead on-site

interior = the apartment or living quarters of only the LFK participant, excludes common areas within the building.

exterior = the common hallways, stairs, entrances and porches as well as the exterior walls of the building, and all other buildings and fences located on the property.

All other abbreviations are described on the individual forms.

LEAD FREE KIDS STUDY

INTERIOR DUST ABATEMENT

Description of abatement process

The purpose of the dust abatement is to significantly reduce the amount of lead-bearing dust in the treated homes. It follows the loose paint abatement in the Study Group and the Control Group A. The methods used are similar to those used during the loose paint abatement. The most important distinction is that no loose paint is removed during the dust abatement. This clean-up focuses on cleaning dust off surfaces where it accumulates.

The two primary activities involved in this process are vacuuming with a HEPA vacuum and wiping surfaces with either a wet cloth or an oil-treated rag(for furniture). The surfaces treated in this manner are floors, woodwork, walls, and furniture. For the dust abatement, the vacuuming on floors is timed. Carpets are vacuumed for 3 minutes per sqare yard. Wood and tiled floors are vacuumed for 2 minutes per square yard and washed with a TSP solution. Area rugs are vacuumed on each side, then rolled up so that the floor beneath can be vacuumed and washed.

Because the loose paint abatement and the dust abatement are so similar, checklists are used in both cases to document that all necessary steps are taken. In the dust abatement no tyvek suits and plastic dropcloths are required, but care is taken to do the rooms in such an order that no dust is tracked from an uncleaned area to a cleaned area.

Summary of dust abatement

1. Furniture is moved as needed to expose floor.

2. Top (horizontal) surfaces of woodwork(doorframes, windowsills, etc.) are HEPA vacuumed.

3. Walls and other vertical surfaces are HEPA vacuumed.

4. Vertical surfaces are wiped wiped with wet cloths(TSP solution). Cloths are used once and thrown away.

5. Horizontal surfaces are wiped with wet cloths.

6. Furniture is wiped with oil-treated cloths.

7. Area rugs are vacuumed on both sides and rolled up to expose floor.

8. Floors:

   Wood, tile, or linoleum floors are vacuumed for 2 minutes per square yard, then washed with wet cloths.

   Carpeted floors are vacuumed for 3 minutes per square yard.

9. Furniture is moved back to original positions. Tyvek foot coverings are used by anyone who needs to enter a cleaned area.

LEAD FREE KIDS STUDY

INTERIOR PAINT ABATEMENT

Description of abatement process

The purpose of the interior paint abatement is to safely remove any very loose, chipping paint from the inside of the home without generating dust, or leaving behind any small chips of paint. The techniques used for the interior paint abatement are simple in principle. Loose paint will be vacuumed using a HEPA vacuum. HEPA stands for "high efficiency particle accumulator". This vacuum is equipped with a special filter which catches dust that would pass through an ordinary vacuum. The peeling surfaces are then washed off using disposable cloths and a solution of Trisodium Phosphate (TSP) and water. TSP is a detergent which is good for picking up lead.

Obviously only very loose paint will come off during this process. This abatement is not "deleading". We are only trying to remove the paint most readily available to the children living in the house, and most likely to fall off and contribute to lead in the house dust.

Summary of loose paint abatement process

NOTE: This work is monitored by the case managers to ensure that no steps are skipped. All children are absent from the house during the abatement. All workers put on tyvek suits and overshoes before entering a work area and remove the tyvek overshoes before leaving the work area.

1. A case manager walks through premise with the contractor to identify areas to be washed. All window wells and trim are washed even if loose paint is not evident. In some cases, the window wells and trim are the only areas needing abatement. In others, walls and trim also need work. In general, we do not remove any ceiling paint, because ceiling paint rarely contains lead. A work plan for the premise is agreed upon, including the order in which the rooms will be worked on, what furniture will be moved, etc.. The entire floor of the apartment is HEPA vacuumed, and all toys are put in plastic trash bags.

2. Work proceeds room by room, starting from the far end of the unit and working back towards the entrance. In each room, furniture is moved away from windows, baseboards, or any other area of chipping paint. The floor around these areas is vacuumed to pick up paint that may already have fallen. Furniture and floors are then covered over with plastic sheets as needed to provide a work area within which paint can be contained. The plastic should be attached to walls or baseboards below any areas needing abatement, and should extend out into the room from the point of

attachment. In some cases the plastic may be put up under a window, run out to the middle of the room, and up over furniture or up a wall to form a basin.

3. Workers vacuum with a HEPA vacuum all areas of chipping paint. They do not use the vacuum to chip or scrape paint, simply to pick up whatever paint readily comes off. They then wash down chipping surfaces with disposable cloths soaked with a solution of water and sodium sulfide. The cloth may be folded over carefully for a second pass over one area, but the last time a surface is cleaned a new cloth should be used. Cloths will be thrown away after each use to prevent spreading dust and chips.

4. When all the surfaces to be cleaned in a room are finished, all plastic dropcloths are wiped off. The cleaned surfaces and the plastic are then cleaned with a HEPA vacuum. Window wells are painted with primer paint to "lock down" any remaining paint and dust.

5. All equipment is decontaminated by washing. The plastic is taken up. The workers start at the edges, and carefully roll the plastic inward towards them from all sides, until they stand in the center of a ring of rolled-up plastic. They step off the plastic, leaving behind the tyvek overshoes. The plastic can then be placed in a trash bag. The floor will be HEPA vacuumed to catch any residual dust. Any furniture that the contractors had to move will be moved back into place.

6. All rooms are treated in this manner. For Control Group B this concludes the abatement process for the fall of 1989. The Study Group and Control Group A have dust abatement immediately following the loose paint abatement.

LEAD FREE KIDS STUDY

Interior Paint and Dust Abatement
Site Documentation Form

Address_____

Premise ID _____

Date_____

Monitor(s)_____

Please check appropriate circle to indicate that each step has been completed.

Part A:	Completed
1. Walkthrough with contractor to assess work to be done	[ ]
2. HEPA vacuum entire floor of residence	[ ]
3. All toys sealed in plastic bags	[ ]

Part B.

Note: In all activities of washing or wiping surfaces with cloths, the cloth should never be put into the wash water after use. All cloths are to be disposed of in a plastic bag immediately after use. A bag should be placed close to the work area to avoid unnecessarily tracking dust from immediate area.

Comments and Notes on Interior Paint abatement. Please note any unusual circumstances or conditions in this house:

On the next page, fill in one of the following room codes at the top of each column.
K = Kitchen P = Pantry LR = Living Room DR = Dining Room BR = Bedroom (BR2 = 2nd Bedroom, etc.) BT = Bathroom

O = Other (specify below)

O_____

O2_____

O3_____

Check steps when completed

Room Codes	___	___	___	___	___	___
1. Shades\curtains removed	[]	[]	[]	[]	[]	[]
2. Furniture moved away from loose paint paint abatement areas	[]	[]	[]	[]	[]	[]
3. Polyethylene in place for loose paint abatement	[]	[]	[]	[]	[]	[]
4. Workers wearing Tyvek suits, respirators and foot covering	[]	[]	[]	[]	[]	[]
5. Procedure observed for leaving or entering work area	[]	[]	[]	[]	[]	[]
6. Initial vacuuming of areas of loose paint	[]	[]	[]	[]	[]	[]
7. Washing of loose paint areas with TSP and water solution	[]	[]	[]	[]	[]	[]
8. Final HEPA vacuuming of loose paint areas	[]	[]	[]	[]	[]	[]
9. Wipedown of polyethylene sheets to collect any paint and dust	[]	[]	[]	[]	[]	[]
10. Workers removed foot coverings, and head covering, etc. when leaving work area	[]	[]	[]	[]	[]	[]
11. Floor coverings rolled up and removed in such a way that no paint could fall outside plastic	[]	[]	[]	[]	[]	[]
12. Floor area under poly vacuumed	[]	[]	[]	[]	[]	[]
13. Window wells painted with primer paint	[]	[]	[]	[]	[]	[]
14. Return furniture and other articles to original position	[]	[]	[]	[]	[]	[]
OR						
15. Proceed to Dust Abatement(Part C.)		[ ]				

Part C. Interior Dust Abatement Checklist

Note: If it is not possible to move furniture to the next room before the dust abatement, the room may be cleaned one half at a time. The furniture can be moved to one half of the room while the other half is cleaned. If a piece of furniture can't be moved at all, every attempt should be made to vacuum and or wash as far under it as possible.

	Check steps when completed					
Room Codes	___	___	___	___	___	___
1. Move furniture as needed to clean floor	[]	[]	[]	[]	[]	[]
2. HEPA vacuum top surface of woodwork and other horizontal surfaces	[]	[]	[]	[]	[]	[]
3. HEPA vacuum walls and other vertical surfaces	[]	[]	[]	[]	[]	[]
4. Damp wipe horizontal surfaces (except floors)	[]	[]	[]	[]	[]	[]
5. Damp wipe vertical surfaces (trim, etc.)	[]	[]	[]	[]	[]	[]
6. Wipe furniture with oil-treated rags	[]	[]	[]	[]	[]	[]
7. HEPA vacuum area rugs on both sides (top and bottom)	[]	[]	[]	[]	[]	[]
8. Floors (see part D. also)						
A. Wall-to-wall carpets: HEPA vacuum (with beater bar) 3 minutes per square yard	[]	[]	[]	[]	[]	[]
B. Wood, tile, etc.						
1. Wash with clean rags using TSP solution	[]	[]	[]	[]	[]	[]
2. HEPA vacuum at a rate of 2 minutes per square yard (see schedule for each room part D)	[]	[]	[]	[]	[]	[]
C. Area Rugs HEPA vacuum on both sides, roll up rug, clean floor	[]	[]	[]	[]	[]	[]
9. Move articles back to original positions wearing foot covering	[]	[]	[]	[]	[]	[]

INTERIOR ABATEMENT DOCUMENTATION

PART D.

Room Code	Primary floor type Wood, carpet, linoleum, etc.	Area Rugs Check if Yes	HEPA vacuum time required Rugs sq. yds. X 3 Others sq. yd X 2	HEPA vacuum timed and completed

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May 29, 1991
K-1-05-11

Mr. Scott Clifford
ESAT Deputy Project Officer
Environmental Services Division
U.S. EPA Region I
60 Westview Street
Lexington, Massachusetts 02173

Re: TID No. 01-9104-50
Standard Operating Procedure
Columbia X-MET 820 XRF

Dear Mr. Clifford:

Environmental Services Assistance Team (ESAT) member Paul Killian has completed the Standard Operating Procedure (SOP) for the Columbia X-MET 820 x-ray fluorescence instrument. The task was requested by Beverly Fletcher and Scott Clifford, EPA Task Monitors, and authorized under Technical Instruction Document (TID) Number 01-9104-50.

Enclosed is the SOP. The ESAT demonstration on how to operate the instrument has been scheduled for June 7, 1991 at 10:00 am. Please contact Paul Killian at 617/229-2050 should you have any questions or comments.

Very truly yours,

ROY F. WESTON, INC.

Paul F. Killian
Associate Project Scientist

John J. Hagopian, P.G.
Team Manager
ESAT Region I

/pfk
Enclosures

cc: Beverly Fletcher

Effective Date:	Initiated By:	Reviewed By:	Approved By:	SP No.
May 29, 1991				ESAT-01-0083

Environmental Services Assistance Team
EPA Region I

STANDARD OPERATIONS for the COLUMBIA X-MET 820 X-RAY FLUORESCENCE INSTRUMENT

TABLE OF CONTENTS

1.0 PURPOSE

To enable the operator to analyze soils samples for lead content using the Columbia X-MET 820 X-Ray Fluorescence Instrument.

2.0 SCOPE

This SOP will allow the operator to determine the concentration of lead in soil samples. This SOP covers the preparation of soil samples, operation of the Columbia X-MET 820 XRF instrument, and calculation of the results from the printed spectra. Modifications to this SOP can be made to determine lead content in other matrices as well as other elements in various matrices.

3.0 DEFINITIONS AND ACRONYMS

EPA	Environmental Protection Agency
ESAT	Environmental Services Assistance Team
LCS	Laboratory Control Sample
ppm	Parts Per Million
RTN	Hard Return on the Terminal
SOP	Standard Operating Procedures
SPL	Sample
X-MET	Columbia X-MET 820 X-Ray Fluorescence Instrument
XRF	Energy Dispersive X-ray Fluorescence

4.0 PRINCIPLES OF OPERATION

When an atom is bombarded with x-rays from a radioisotope x-ray source, it looses an electron from its inner shell. As a result, one of the atom's outer electrons is repositioned to the inner shell and emits energy. The energy emitted is at a specific Kiloelectron Volt (KeV) depending on which element and which outer electron was repositioned. The concentration of each element can be determined by examining the height of the peak at the specified KeV. This process is know as Energy Dispersive X-ray Fluorescence.

The advantage of the Energy Dispersive X-ray Fluorescence (XRF) technique is that the sample is not destroyed in the analysis. The sample remaining in a stable state, enables the analyst to reanalyze the sample at a later date, or digest and analyze the sample using other techniques such as inductively coupled plasma (ICP) or atomic absorption (AA) spectroscopy. Other advantages include the quick turnaround of sample results, and the ease of operating the instrument.

5.0 APPARATUS AND MATERIALS

5.1 SAMPLE PREPARATION

Sample cups, plastic, spectro-cup, Cat. No. 340, Somar Lab. Inc., New York or equivalent.

Mylar film, 6 micron

60 Mesh sieve

Sample weigh boats

Powder funnel

5.2 SAMPLE ANALYSIS

Columbia X-MET 820 X-Ray Fluorescence Instrument, with:
- Cm-244 source
- Texas Instrument 703 Data Terminal.

Printer paper - Thermal Fax Paper

6.0 PROCEDURES

6.1 SAMPLE PREPARATION

6.1.1 Sample Container Preparation

6.1.1.1 Invert cup and place a piece of 6 micron mylar film over the bottom aperture.

6.1.1.2 Snap a retaining o-ring over the film onto the base of the cup (o-ring teeth down).

6.1.1.3 Place cup upright and add enough soil to uniformly cover the mylar film bottom of the cup.

6.1.1.4 Snap cap into place on top of the cup.

6.1.1.5 Label the sample cup with the sequential laboratory Identification number and record that in the instrument logbook.

6.1.2 Sample Preparation

6.1.2.1 An aliquot of the soil, 2 to 3 table spoons (10 to 15 grams), is removed with a spoon or spatula and placed in a sample weigh boat.

6.1.2.2 The weigh boat is marked with the laboratory identification number and allowed to air dry under a hood overnight at ambient laboratory temperature.

6.1.2.3 The dried soil sample is manually shaken in a 60 mesh sieve until approximately 1 gram of fines have been collected. (Typically 10 to 15 seconds is adequate.)

6.1.2.4 The fines are then transferred to the analysis sample container using a glass powder funnel placed over the sample container. The cap is then placed on the sample container.

6.1.2.5 All excess soils from sample preparation are discarded in the waste barrel in the preparation hood.

6.1.2.6 The powder funnel, sieve, and spoon (or spatula) will be cleaned between samples to remove soil particles. The funnel and sieve will be blown free of dust with compressed air. The spoon will be wiped with disposal tissues.

6.2 SAMPLE ANALYSIS

6.2.1 Definition of Fields

6.2.1.1 >

This field details the type of sample analyzed. If the instrument is being recalibrated, STD (Standard) would be entered. Since the curves are prepared separately, no STD should be entered. The analyst should enter SPL, for sample. There is no default value for this field.

6.2.1.2 **LATEST?**

This field details which spectra to print. Since the spectra are not named, only the latest measurement may be recalled. Therefore, the field should be left blank and the hard return key pressed. The default for this field is the last sample.

6.2.1.3 **FIRST CHANNEL: 0 ?**

This field details which point the spectra is to start. The total spectra goes from Channel 0 to Channel 255. Since the Lead peak is located around Channel 166, the spectra should be viewed from Channel 140 to Channel 190. Therefore the proper input for this field is 140. The default for this field is 0.

6.2.1.4 **LAST CHANNEL: 255 ?**

This field details which point the spectra is to stop. The total spectra goes from Channel 0 to Channel 255. Since the Lead peak is located around Channel 166, the spectra should be viewed from Channel 140 to Channel 190. Therefore the proper input for this field is 190. The default for this field is 255.

NOTE: If you enter a Last Channel that is lower than the First Channel, the instrument will print out an error message and ask you to reenter the Last Channel value.

6.2.1.5 **WINDOW: 1 ?**

This field details how frequent the channels will be printed in the spectra. The choices are from 1 to 4. If 1 is chosen then every channel will be printed. If 4 is chosen then every fourth channel will be printed. The proper input for this field is 2. The default for this field is 1.

6.2.1.6 **RANGE,lower: 0 ?**

This field details the lower scale of the curve. Since the baseline of the peak is drawn from the two low points on either side of the peak, the graph does not need to extend below these two points. Therefore, the lower range is set at 250. The default for this field is 0.

NOTE: On occasions, one or both of the low points may fall below the 250 mark. When this occurs, the graph should be reprinted with the RANGE,lower set at 200. If the points still fall below 200, the sample is to be reported as non-detected.

6.2.1.7 **RANGE,upper: *###* ?**

This field details the upper scale of the curve. Since the Lead peak is the highest point from Channel 140 to Channel 190, the curve does not have to extend any farther than just above the value of the peak. The value *###* is the highest point on the graph from Channel 140 to Channel 190. Therefore, the upper range is set at the next higher multiple of 25. (i.e. if *###* equals 459, then enter 475.) The default for this field is *###*.

6.2.1.8 **40 CHARACTER PER LINE ?**

This field details the size of the print. When a larger Character Per Line is entered, the graph expands over more of the paper. Therefore, the Character Per Line is set at 80. The default for this field is 40.

6.2.2 Instrument Operation

6.2.2.1 Turn on the instrument by pressing the switch on the back left face of the instrument.

6.2.2.2 Turn on the printer by pressing the switch on the back right face of the printer.

6.2.2.3 Allow the instrument to warm up for 30 minutes.

6.2.2.4 Place the sample into the instrument by:
A. sliding the holder towards you;
B. opening the holder by lifting the top;
C. placing the sample into the open holder and closing the top;
D. sliding the holder back into place.

6.2.2.5 Type in sample identification (i.e. 300 STD)

6.2.2.6 Press the START 1 key on the instrument.

Instrument will respond:

DATE: dd,mm,yy TIME: hh-mm-ss
MEASURING:
MODEL 10 PROBE 1 50 SECONDS

After 50 seconds the analysis is complete, the instrument will signal by beeping. The instrument prints:

ASSAYS: PB ##.##
>

6.2.2.7 Type the following:

	Instrument response	Analyst Response
a.	>	SPL <RTN>
b.	LATEST?	<RTN>
c.	FIRST CHANNEL: 0 ?	140 <RTN>
d.	LAST CHANNEL: 255 ?	190 <RTN>
e.	WINDOW: 1 ?	2 <RTN>

f. **RANGE,lower: 0 ?** 250 <RTN>
g. **RANGE,upper: ### ?** next higher multiple of 25 <RTN>
(i.e. if ### = 408 then enter 425)
h. **40 CHARACTERS PER LINE ?** 80 <RTN>

The spectra for the sample is printed, and the instrument responds:

LATEST?

If all the points on the spectra fall above the baseline (250), proceed to step 6.2.2.8. Otherwise, reprint the spectra with the baseline (RANGE, lower) set at 200. This is done by repeating steps 6.2.2.7.b - 6.2.2.7.h, and entering 200 at step 6.2.2.7.f instead of 250. Regardless of whether or not the points still fall below the baseline (200), proceed to step 6.2.2.8.

6.2.2.8 Press the ESCAPE key twice.

6.2.2.9 Follow steps 6.2.2.4 through 6.2.2.7 for the remaining samples to be analyzed.

6.2.3 LFK Order of analysis

6.2.3.1 The following standards are run from low to high:

a.	blank		standard	(Empty sample cup)
b.	300	ppm	standard	(Laboratory # 5103)
c.	900	ppm	standard	(Laboratory # 5113)
d.	1600	ppm	standard	(Labeled as 1600 STD)
e.	6000	ppm	standard	(Laboratory # 4873)
f.	13000	ppm	standard	(Laboratory # 4903)
g.	Laboratory Control Sample (LCS)			(Labeled as 880 STD)

6.2.3.2 Ten laboratory samples are analyzed. (Both duplicates and replicates are considered laboratory samples.)

NOTE: Duplicates are prepared during sample preparation at a rate of one per twenty. Replicates are analyzed at a rate of one per twenty.

6.2.3.3 One of the standards (b - e) is analyzed.

6.2.3.4 Steps 6.3.2.2 and 6.3.2.3 are repeated until the analysis batch is complete, rotating the standards (b - e).

6.2.3.5 Once the analysis batch is complete, all standards are analyzed, including the LCS, as in step 2.2.1.

6.3 SAMPLE QUANTITATION

6.3.1 Determination of Peak Height

6.3.1.1 A straight line is drawn connecting the two low points on either side of the peak.

6.3.1.2 The peak height is then measured, in millimeters, from the straight line to the highest point on the peak.

6.3.1.3 The corresponding number of counts is then determined by:

$$\frac{\text{(RANGE, upper - RANGE, lower)}}{\text{132.5 mm (Length of full scale)}} \times \text{peak height (mm)} = \text{Counts}$$

6.3.2 Determination of Sample Concentration

6.3.2.1 The analysis results (counts and concentration) of all standards, except the LCS results, are tabulated.

6.3.2.2 Two standard curves are then created using linear regression. A low concentration curve consisting of the blank, 300, 900, 1600, and 6000 standards are used for all sample results less than 6000 ppm. The high concentration curve consisting of blank, 1600, 6000, and 13000 standards are used for all sample results greater than 6000 ppm. Both standard curves are plotted through the point zero, zero.

6.3.2.3 The slope of the appropriate curve is then multiplied by the sample's counts to determine the sample concentration.

6.3.2.4 The LCS results are determined as in 6.3.2.3 (using the low standard curve). The results must fall within 20% of the true value (880 ppm).

7.0 ATTACHMENTS

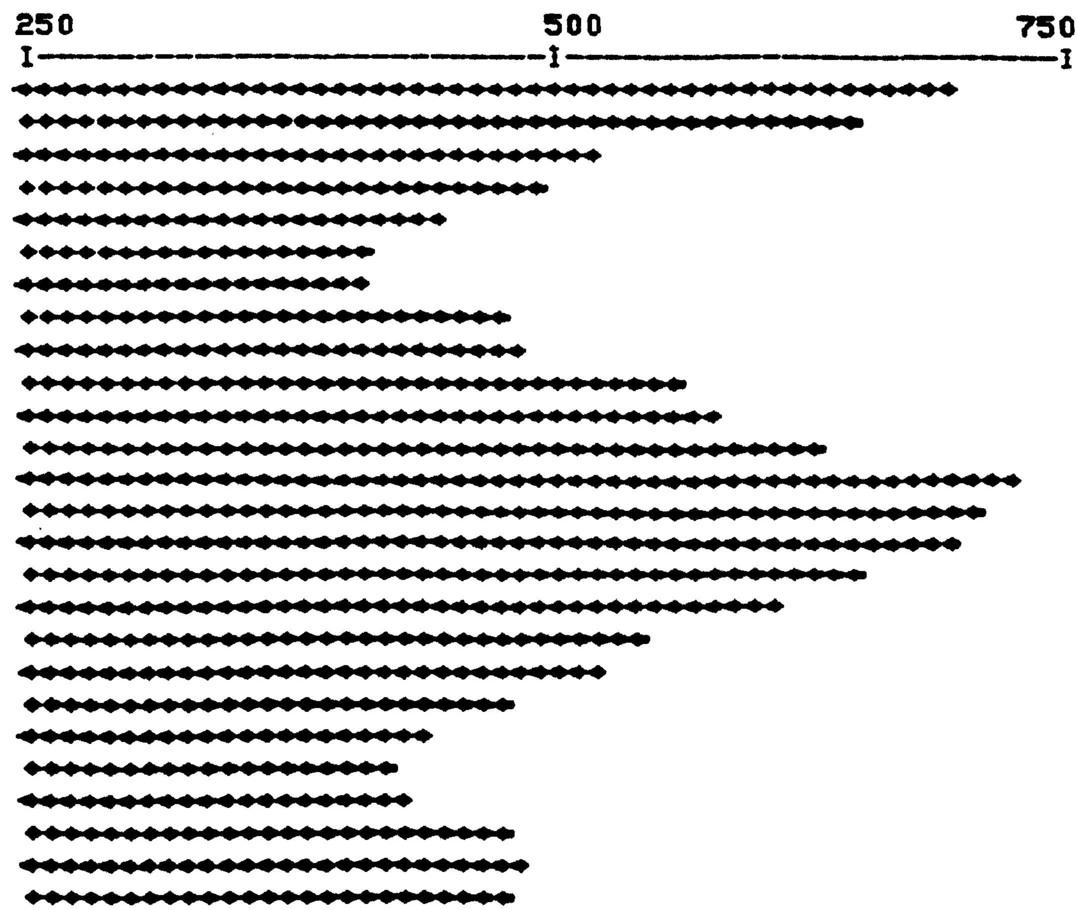
Enclosed are two copies of the spectra of a Laboratory Control Sample analysis. The first is the copy is unmarked. The second copy details steps from the SOP for printing the spectra and calculating the peak height in counts.

```
WHAT?

> LCS
DATE: 14.05.91  TIME: 13-21-47
MEASURING:
MODEL 10 PROBE 1 50 SECONDS
ASSAYS:PB 85.97

> SPL
LATEST?
FIRST CHANNEL: 0 ? 140
LAST CHANNEL: 255 ? 190
WINDOW: 1 ? 2
RANGE,lower: 0 ? 250
RANGE,upper: 725 ? 750
40 character per line ?80
♦♦♦♦ LATEST SPECTRUM   MEAS.TIME: 50  DATE: 14.05.91   13-23-25
```

CHANNEL	COUNTS
140	692
142	647
144	531
146	502
148	453
150	421
152	416
154	478
156	491
158	565
160	586
162	629
164	725
166	703
168	690
170	650
172	615
174	546
176	527
178	478
180	449
182	423
184	431
186	478
188	490
190	485



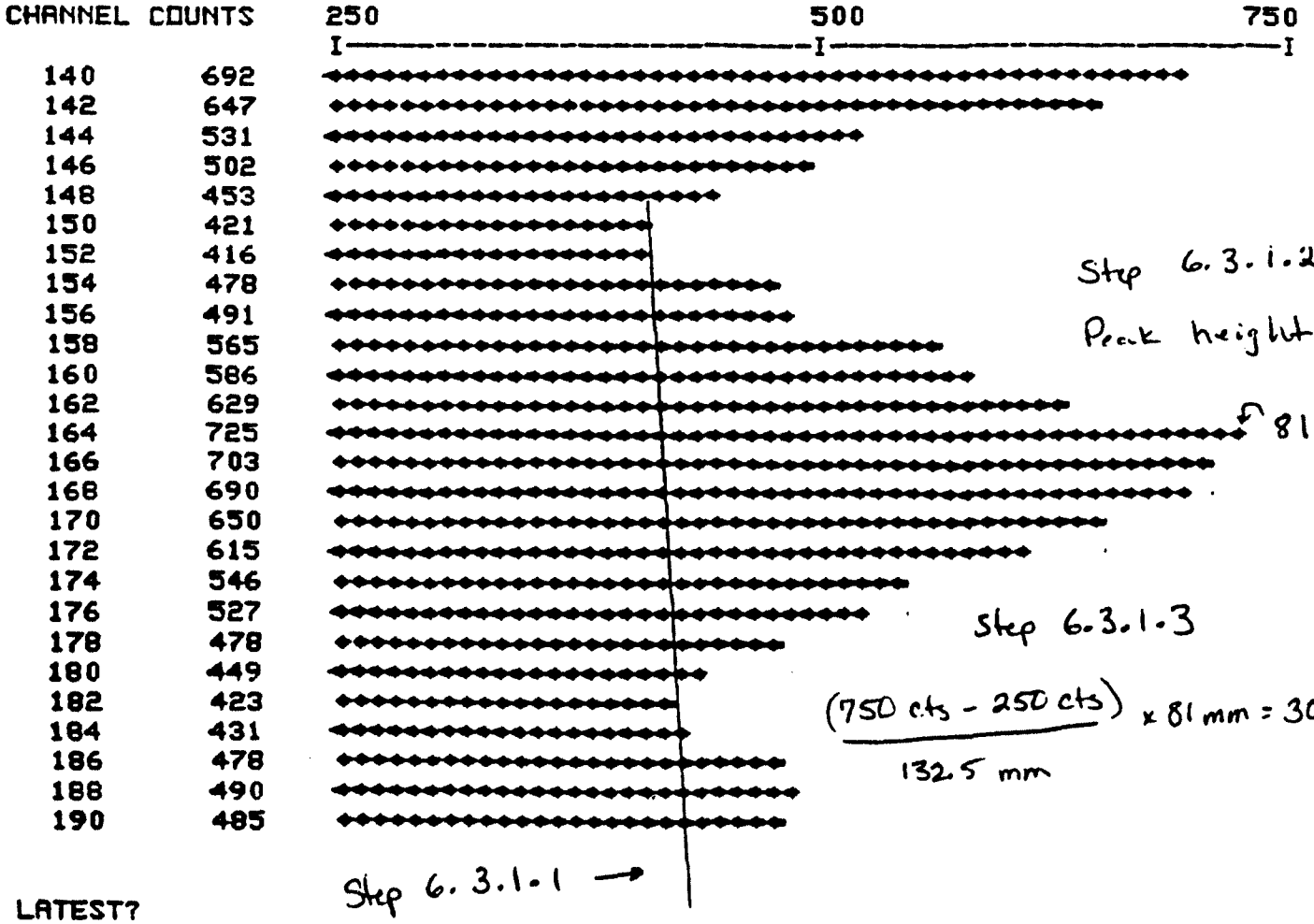

```
LATEST?
```

```
WHAT?
> LCS
DATE: 14.05.91  TIME: 13-21-47
MEASURING:
MODEL 10 PROBE 1 50 SECONDS
ASSAYS:PB 85.97

> SPL
LATEST?
FIRST CHANNEL: 0 ? 140
LAST CHANNEL: 255 ? 190
WINDOW: 1 ? 2
RANGE,lower: 0 ? 250
RANGE,upper: 725 ? 750
40 character per line ?80
◆◆◆◆ LATEST SPECTRUM   MEAS.TIME: 50  DATE: 14.05.91   13-23-25
```

Step 6.2.2.5

Step 6.2.2.7



Step 6.3.1.2

Peak height

81 mm

Step 6.3.1.3

$\frac{(750 \text{ cts} - 250 \text{ cts})}{132.5 \text{ mm}} \times 81 \text{ mm} = 305.7$

Step 6.3.1.1

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February 12, 1991
K-1-02-05

Mr. Scott Clifford
ESAT Deputy Project Officer
Environmental Services Division
U.S. EPA Region I
60 Westview Street
Lexington, Massachusetts 02173

Re: TID No. 01-9102-17
Lead Free Kids Project
Review of the LFK Protocols Report

Dear Mr. Clifford:

Environmental Services Assistance Team (ESAT) member Paul Killian has completed the review of the Lead Free Kids (LFK) Project Protocols. The request was made by Beverly Fletcher, EPA Task Monitor, and authorized under Technical Instruction Document (TID) number 01-9102-17. The requested start date was February 11, 1991. The estimated completion date was February 12, 1991.

The task was initiated on February 11, 1991, and completed on February 12, 1991. The task required reviewing the LFK Protocols Report, Section II Soil Analysis Protocol, pages A-4 through A-7, and Section IV Dust Analysis pages A-11 through A-13. The methods were compared to the methods submitted by ESAT on February 8, 1991 (Correspondence Number 01-9102-17). The following discrepancies were noted:

Soil Analyses

- The procedure in which ESAT received soil samples is slightly different than the procedure presented on Page A-4 of the LFK Protocols Report. The procedure ESAT followed is: The samples are received from LFK staff. The Chain-of-Custodies (COCs) are checked to verify that all samples are present. The COCs are signed and dated, noting the time of sample receipt. The COCs are then copied, returning the original COC to the LFK staff. Laboratory Identification numbers are then placed on the sample bags and on the laboratory copy of the COCs.

- The procedure in which ESAT prepared soil samples is not the same as the procedures presented in the LFK Protocols Report, steps 3 - 14, pages A-4 through A-6. The procedures that ESAT followed are outlined in Appendix B-4, sections 6.3 and 6.4. (Attachment I)

- ESAT did not use the Kevex X-Ray Fluorescence (XRF) instrumentation to analyze the soil samples. Soil samples were analyzed using the Oxford LAB-X 1000 until May 1990; then analyses were performed using the Columbia X-MET 800 XRF. The procedures followed by ESAT for the analysis of soil samples on the Oxford LAB-X 1000 XRF are presented in section 7.0 of Appendix B-4. The procedures followed by ESAT for the analysis of soil samples on the Columbia X-MET 800 XRF are presented in Attachment II.

Dust Analyses

- The procedure in which ESAT received dust samples is slightly different than the procedure presented on Page A-11 of the LFK Protocols Report. The procedure ESAT followed is: The samples are received from LFK staff. The Chain-of-Custodies (COCs) are checked to verify that all samples are present. The COCs are signed and dated, noting the time of sample receipt. The COCs are then copied, returning the copied COC to the LFK staff. Laboratory Identification numbers are then placed on the sample bags and on the laboratory copy of the COCs. The original COCs are returned when analysis has been completed.

- The procedure in which ESAT prepared dust samples is similar to the procedures presented in the LFK Protocols Report, steps 2 - 6, pages A-11 through A-12. However, step 5a, page A-12, states that "The minimum acceptable sample is 20 mg." In actuality there was no minimum acceptable amount of sample. Several of the samples had only 1 mg of sample.

- The procedure in which ESAT analyzed dust sample is more detailed than the procedures presented in the LFK Protocols Report, pages A-12 through A-13. ESAT followed section 7 of Appendix B-3. (Attachment III)

- The LFK Protocols Report, step 3c, page A-13, states an acquisition time of 100 seconds; however, ESAT used an acquisition time of 30 seconds.

- The LFK Protocols Report, step 4c, page A-13, states that standards should be used to determine a linear least squares calibration curve; however, ESAT determined sample concentrations by directly comparing the sample peak height to appropriate standard peak height. ESAT followed the procedure detailed in section 7.6 of Appendix B-3.

ESAT reviewed the remaining sections of the LFK Protocol Report; however, no comments were made because the sections pertained to areas of the project with which ESAT was not involved. Please contact Paul Killian at 617/229-2050 should you require any additional information.

Very truly yours,

ROY F. WESTON, INC.

Paul F. Killian
Associate Project Scientist

John J. Hagopian, P.G.
Team Manager
ESAT Region I

/pfk
Enclosures

cc: Beverly Fletcher

ATTACHMENT I

APPENDIX B-3

STANDARD OPERATING PROCEDURE: LABORATORY SCREENING METHOD FOR LEAD IN HOUSE DUST

USING ENERGY DISPERSIVE X-RAY FLUORESCENCE (KEVEX 0700)

CATEGORY:	TITLE:	
Field	Lead Free Kids	No.
Technical	Demonstration Project	Date: 3/90
		Revision: 0

1.0 SCOPE AND APPLICATION

1.1 Lead in household dust may be determined by energy dispersive X-ray fluorescence (XRF) spectrometry. This method is simple, rapid, and applicable to Lead in various matrices with little or no sample preparation (i.e., digestion is not required prior to analysis).

1.2 Detection limits, sensitivity, and optimum ranges of the metals will vary with regard to sample matrix as well as the model of XRF instrument utilized.

1.3 This method is applicable for use by Region I ESD and ESAT staff for performing XRF screening analyses in lead in house dust samples as part of the LFK Demonstration Project.

2.0 SUMMARY OF METHOD

This method may be used for the semi-quantitative screening analysis of house dust samples for lead. The dust sample is thoroughly sieved, and placed in a plastic sample cup for XRF analysis. The intensity of the sample response at the L-alpha energy region of lead is compared to known lead reference standards for quantitation.

3.0 INTERFERENCES

Certain elements, such as _____, if present in the soil at concentrations _____ times that of lead, could present difficulties in the identification and quantitation of lead.

4.0 APPARATUS AND MATERIALS

4.1 Energy Dispersive X-Ray Fluorescence Spectrometer

A Kevex Model 7000 XES equipped with:

(a) _____ source;

(b) _____ detector;

(c) sixteen (16) place rotating sample holder; and

(d) computerized data system for analyzing, comparing and storing sample spectra.

4.2 8 inch Floppy Data diskettes, IBM, or equivalent.

4.3 Sample cups, plastic, consisting of cup, o-ring, and cap, Spectra-Cup, Cat. No. 340, Somar Labs. Inc., New York, or equivalent.

4.4 Mylar film, 6 micron.

5.0 REAGENTS

5.1 U.S. Department of Commerce, National Bureau of Standards, Standard Reference Materials

SRM	Unit Type	Certified Lead Size	Concentration
1579	Powdered Lead Base Paint	35g	11.87%
1633a	Coal Fly Ash	75g	72.4 ug/g
1645	River Sediment	70g	714 ug/g
1646	Estuarine Sediment	75g	28.2 ug/g
1648	Urban Particulate	2g	0.655%

5.2 US EPA, Environmental Monitoring and Surveillance Laboratory (EMSL), Quality Control Reference Standards

5.3 Instrument Calibration Standards

Dust M-10	2500 ppm	10 mg.
Dust M-50	2500 ppm	50 mg.
Dust H-10	25,000 ppm	10 mg.
Dust H-50	25,000 ppm	50 mg.

6.0 Sample Collection and Transfer of Custody to the U.S. EPA

Samples are collected in the field by Lead-Free-Kids staff, placed in labeled individual envelopes, and submitted with chain-of-custody (COC) documentation to the U.S. EPA New England Regional Laboratory (NERL) for XRF analysis. U.S. EPA personnel or their contractors will acknowledge receipt of custody by signing and dating the COC document in the presence of the LFK dust sample courier. The COC document is retained until sample analysis has been completed and results have been entered onto it. Then the original COC is returned to LFK with a cover letter.

6.1 Sample Preparation

6.1.1 Samples are assigned unique laboratory identification numbers, a sequential five-digit number, which is subsequently recorded on the sample envelope, chain-of-custody document, XRF Dust preparation worksheet, XRF analytical result summary sheet, and on the cover of the sample analysis container.

6.1.2 Under the ventilation hood, the sample envelope is carefully opened at one end (with scissors) and the dust is placed into a 60 mesh sieve.

6.1.3 The sieve is manually shaken for approximately 15 to 20 seconds.

6.1.4 All the fines are then transferred to the pre weighed sample analysis container using a glass powder funnel centered over and touching the center of the mylar window of the sample container.

6.1.5 Information from the chain-of-custody, including weight of sample, and laboratory ID number is recorded on the analytical results summary form.

6.1.6 All of the excess (non-filtered) soil/dust from the sample preparation is discarded in a special barrel in the laboratory. In some cases filtered

dust may be removed for the analysis container if the quality of dust interferes with container fabrication. However, all the dust ~~amount~~ be weighed before excess dust is removed. MUST

6.1.7 The powder funnel and sieve are cleaned between samples to remove soil and dust particles, using clean, compressed breathing air (grade D), or the like.

6.1.8 The sampling cup is sequentially placed in the sample tray according to the laboratory ID number for XRF analysis. Empty envelopes are retained and returned to LFK staff along with sample results.

6.2 Sample Container Preparation

The sample containers consist of two small o-rings with tabs, two pieces of 6 micron mylar film, a sample cup (which is slightly larger than the o-rings), and a container cap.

6.2.1 Place a piece of 6 micron mylar film over one o-ring (tabs down).

6.2.2 Snap the sample cup into place on top of the o-ring.

6.2.3 Weigh sample cup parts excluding cap and round to 4 decimal places.

6.2.4 Place dust sample onto mylar film via glass powder funnel. Be sure that sample is centered on film.

6.2.5 Place another piece of mylar onto sample cup over the dust and snap the second o-ring onto the top of the cup (tabs up).

6.2.6 Reweigh sample container and round to 4 decimal places.

6.2.7 Snap container cap into place on top of cup.

Note: The container cap is only used for identification and handling of the sample. All analyses must be performed with container cap removed.

6.2.8 Label the sample container cap with the correct sequential laboratory sample ID number.

6.3 Standards Preparation

Study Control standards are prepared from previously analyzed and concentration verified house dust samples. Standard concentrations should be prepared at concentration levels and weigh ranges as presented below.

			Std.	Sample Calibration Weight Range
Dust M-10	2500 ppm	10 mg	M-10 or	0.0 - ~~0.24g~~ 0.024g
Dust M-50	2500 ppm	50 mg	H-10	
Dust H-10	25,000 ppm	10 mg	M-10 or	~~0.25g~~ 0.025g or greater
Dust H-50	25,000 ppm	50 mg	H10	

6.4 Sample Preservation and Handling

No preservation is required. Handling of the sample, once it is placed in the analysis cup, must be done in a gentle manner to keep the sample centered in the middle of the mylar. This is especially important for samples requiring replicate analysis.

7.0 ANALYSIS PROCEDURE

7.1 The use of the Kevex 7000 XRF is relatively straightforward. The Kevex is normally left in the standby mode (target .8, 30 kV, and 0.5 mA) between analyses to prevent x-ray tube damage. House dust samples for lead are analyzed under the following instrumental conditions: target .4, 30 kV, .5 mA. (Detailed instructions can be found in the User's Manual for Kevex XRF Software.)

7.2 Instrument Set-Up

7.2.1 Turn the video monitor and plotter power on.

7.2.2 Insert the Master floppy disk into disk drive No. 0 (DY0)

7.2.3 Insert formatted floppy disk into disk drive No. 1 (DY1).

7.2.4 Boot the operating system by pressing the "Shift" and "Reset" keys simultaneously. Next, press the "Q Vantx" and then the "Enter" key.

7.2.5 When prompted on the screen, enter the current date.

7.2.6 After the current date has been entered, the spectral region of interest for lead must be established. This is accomplished by pressing the blue double-headed arrow (<------->) key. The region of interest that should be obtained is from 7.04 Kilo-electron Volts (KeV) to 17.28 KeV, where the lead L-alpha (L-a) peak is 10.25 KeV and the lead L-beta (L-b) is 10.___ KeV. After the spectral region has been established for lead analysis, wait for the asterisk (*) prompt and type in ATO, PBSOIL4. Type in sample ID Numbers as 5 digit numbers followed by -D- for each number at the end.

ex: Lab ID # 143 entered as 00143-D-

7.2.7 The first carousel run on the Kevex for the day must contain all four calibration standards. Each additional carousel run must include one of the four study control standard on a rotating basis. Calibration standards are run manually and not on the ATO program.

7.3 Loading the Kevex Sampler (Carousel)

7.3.1 Push the "Reset" key (red) to shut-off the x-ray beam. (As a safety precaution, the lid will not open when the x-ray beam is functioning).

7.3.2 Open the Kevex top and place sample cups into the sixteen (16) available slots (numbered 0 through 15) on the circular carousel.

7.3.3 Set the Kevex XES to ATO (white key). Then proceed with the analysis.

7.4 Manual Analysis of Dust Samples

The analysis will be performed using the ATO and manual modes. The manual method requires that the operator be presented while performing this type of analysis.

Keyboard commands required to initiate and perform XRF analyses are detailed below:

7.4.1 Await (*); type "Clr", then press the "Enter" key.

7.4.2 Make sure white switch is on manual position.

7.4.3 Push yellow key next to sample number. Use numbered key pad on KEVEX to enter desired position then hit enter.

7.4.4 Push yellow key to target display and enter 4 using numbered key pad again.

7.4.5 Continue in this manner and enter 30 for KEV and .5 for mA.

7.4.6 On the screen keyboard hit the yellow ACQ button. When running the standards you will manually stop them at their designated ppm concentration (2500 for medium and 25,000 ppm for high) using the yellow stop key next to the acquire key. Using the blue arrows (up and down) to increase and shrink the size of the peak, let the sample run for between 20 and 30 seconds. Stop the peak when it reaches the 2.5 mark designated by the numbered lines on the left side of the viewing screen.

7.4.7 When you have stopped the peak at its desired height (2.5) type SMO to smooth the curve. If the peak now falls below 2.5 it may be necessary to continue acquiring the peak for a couple more seconds and again hit stop to halt peak. Alternating between acquire, stop and smooth may be done an unlimited number of times until the peak appears in the right position as long as the time count is below 30 seconds. Time of analysis may not run over 30 seconds.

Note: Only calibration standards will be run on manual not dust samples.

7.4.8 Await (*); type "REA"d, press "Enter".

7.4.9 Await (*); type "SAV"e, press "Enter".

7.4.10 Prompt: General Comments.

7.4.11 Response: Section is ignored, press "Enter".

7.4.12 Prompt: Enter Unit: (1) or (2).

7.4.13 Response: Type "1", press "Enter".

* 7.4.14 Prompt: Enter Sample ID":

7.4.15 Response: type in Sample ID as assigned in XRF dust preparation worksheet.

* Manual analysis does not automatically add a 4 onto the end of the identification label and therefore the 4 is not needed for recall purposes.

7.5 Automatic Analysis Procedure

7.5.1 At asteric on screen type ATO.PBSOIL4 Enter.

7.5.2 Enter the last sample position but do not include standards that will run manually.

7.5.3 Enter lab ID numbers for each corresponding position.

7.5.4 As the program runs you must be present to observe each lead sample peak as it acquires for 30 seconds.

7.5.5 With screen parameters of <7.04 and 17.28> the compton scatter peak will be the last peak visible on the right hand side. The lead peak will appear directly above the blue arrow at the bottom of the screen.

7.5.6 If the lead peak rises faster then the compton peak it will be calibrated using the high standard. If the lead sample peak does not rise above the compton peak, the medium standard will be used.

7.5.7 To determine if the 10 standard or the 50 standard is to be used, identify the weight of the sample. The sample is:

0.00g - 0.024g use 10 standard
0.025g - 0.100g or above use 50 standard.

7.6 Manual Quantitation and Comparison of Dust Samples

7.6.1 Await (*); type "RCL" (recall), press "Enter".

NOTE: The RCL (recall) command is used to recall a previously analyzed spectra that has been stored on the floppy diskette (DY1). In this case, a previously analyzed lead in dust calibration or reference standard for comparison to the various dust samples analyzed and stored on the same diskette.

7.6.2 Prompt: Enter Unit: 1 or 2.

7.6.3 Response: Type "1", press "Enter".

7.6.4 Prompt: Enter ID:

7.6.5 Response: Type the standard/label ID, press "Enter".

7.6.6 Prompt: Smooth Recalled Spectrum (Y/N)?

7.6.7 Response: Press "Enter".

7.6.8 Await (*); type "OVR" (overlay), press "Enter". The overlay command is used to compare and normalize spectra from the disk. The normalization feature (OVR) allows the operator to mark regions within the displayed spectrum as a basis for normalization. This feature aids in the visual interpretation of data and reduces channel-to-channel statistical fluctuations.

7.6.9 Prompt: Enter ID: add -D-4 to the end of each ID.

7.6.10 Response: Enter the sample ID, press "Enter".

7.6.11 Prompt: Smooth Recalled Spectrum (Y/N)?

7.6.12 Response: Press "Enter".

7.6.13 Prompt: Mark Peak(s) or Region(s) Hit Enter When Ready a cursor will appear on the screen.

7.6.14 Response: Mark the regions to be used for normalization by moving the cursor with the left and right green arrow function keys. The peak to be painted is the compton scatter peak. The screen parameters should be 9.60 - 19.84 use the green" equal (=) key to paint the desired area. Note: the paint cursor will move in the direction it was last set. Press the "Enter" key when finished.

7.6.15 The screen display will now include the standard spectrum overlaid by the sample spectrum normalized to the same energy region of the spectrum. Direct comparison of the lead (L-a) peaks can be made and a concentration (in ppm) can be determined.

Note: The red peak is the standard peak which should read 2.5 (use the Blue up and down arrows to set this). The white peak is the sample peak. Use the blue up and down arrows to best compare the sample peak value ppm. Although the height of

the red and white peaks will change the ppm value of the red (standard) will always remain the same 2500 ppm or 25,000 ppm depending on the standard used.

7.6.16 The OVR sequence can be repeated for each sample on the disk (DY1).

7.7 A Modified Quantitation Procedure - This is basically the same procedure as described above.

Dr. T. Spittler, USEPA Region I, Technical Services Branch Chief, Lexington, Massachusetts initiated the use of a quick and easy method for the semi-quantitative analysis of lead in soil samples.

Dr. Spittler has determined that, when acquiring data for the 2000 ppm lead in soil standard at an attenuation of 512 and the energy level for the compton's back scattering energy peak at 15 KeV is at 50 percent intensity, each horizontal screen division is equivalent to the response of ca. 800 ppm lead. To utilize this technique for dust, follow the XRF instrument set-up guidelines as previously described in Sections 7.2, 7.3, and 7.4 (7.4.1 to 7.4.5). To acquire, quantify, and store data, utilize the following procedure:

7.7.1 Check sampler position at "0".

7.7.2 Await (*); press the yellow "ACQ" key.

7.7.3 Wait for energy level at 15.- KeV to reach 50 percent scale at a range of 512.

7.7.4 Press the yellow "Stop" key.

7.7.5 Await (*); type "SMO", press "Enter".

7.7.6 Await (*); type "REA", press "Enter".

7.7.7 Await (*); type "SAV", press "Enter".

7.7.8 Prompt: General Comments.

7.7.9 Response: Section is ignored, press "Enter".

7.7.10 Prompt: Enter Unit: (1) or (2).

7.7.11 Response: Type "1", press "Enter".

7.7.12 Prompt: Enter Sample ID:

7.7.13 Response: type in sample ID as assigned in the XRF logbook.

7.7.14 Quantify the L(a) lead peak using the following scale:

Attenuation	Concentration Range of Lead (vertical scale division concentration)
64	0 to 700 (100 ppm)
128	0 to 1400 (200 ppm)
256	0 to 2800 (400 ppm)
512	0 to 5600 (800 ppm)
1024	0 to 11,200 (1600 ppm)

7.7.15 Await (*); type "CLR" (clear), press "Enter".

7.7.16 Advance the sample tray one space and repeat the analysis procedure.

8.0 QUALITY CONTROL

8.1 All quality control data should be maintained and available for easy reference or inspection.

8.2 At the beginning of each operating shift all 4 study control standards are analyzed on the first carousel. On following carousel runs analyze one standard (one per sixteen) This is done to assess method accuracy and to correct for normal standard drift and results should agree within ± 20 percent of the true value.

8.3 At least one laboratory replicate should be analyzed for every 20 samples to verify precision of the method. Replicate samples may be run at the end of an analytical day in their own carousel.

8.4 At least one laboratory replicate should be analyzed at a frequency of 1 per 20 samples to verify precision of

the method. Replicate samples maybe run at the end of an operation shift.

NOTE: True replicates of soil and dust samples are usually not possible since chemicals such as lead are typically not uniformly distributed in these materials. Additional handling of the sample may cause the dust to migrate away from the center of the mylar. Care must be taken when handling samples. Care must be taken in the interpretation of soil and dust replicate analytical results.

9.0 METHOD REFERENCE

9.1 Precision and accuracy data are not available at this time.

9.2 The performance characteristics for a dust sample free from interferences are:

Optimum Concentration Range: N/A ug/g
Detection Limit: NA ug/g
N/A: not available at this time.

ATTACHMENT II

Columbia X-MET 800 XRF

Standard Operating Procedures

1.0 SAMPLE PREPARATION

All procedures detailed in section 6.0 of Appendix B-4 were followed for sample preparation.

2.0 SAMPLE ANALYSIS

2.1 Instrument Operation

2.1.1 Turn on the instrument by pressing the switch in back left face of the instrument.

2.1.2 Turn on the printer by pressing the switch in back right face of the printer.

2.1.3 Allow the instrument to warm up for 30 minutes.

2.1.4 Place the sample into the instrument by:
- A. sliding the holder towards you;
- B. opening the holder by lifting the top;
- C. placing the sample into the open holder and closing the top;
- D. sliding the holder back into place.

2.1.5 Turn the printer off line by alternating the ON LINE switch away from the ".".

2.1.6 Type in sample identification (i.e. 300 STD)

2.1.7 Turn the printer on line by aternating the ON LINE switch towards the ".".

2.1.8 Press the START 1 key on the instrument.

Instrument will respond:

```
DATE:  dd,mm,yy        TIME:  hh-mm-ss
MEASURING:
MODEL 10  PROBE 1 50 SECONDS
```

After 50 seconds the analysis is complete, the instrument will signal by beeping. The instrument prints:

```
ASSAYS:  PB  ##.##
>
```

2.1.9 Type the following:

	Instrument response	Analyst Response
a.	>	SPL <RTN>
b.	LATEST?	<RTN>
c.	FIRST CHANNEL: 0 ?	140 <RTN>
d.	LAST CHANNEL: 255 ?	190 <RTN>
e.	WINDOW: 1 ?	2 <RTN>
f.	RANGE, lower: 0 ?	250 <RTN>
g.	RANGE, upper: ### ?	next higher multiple of 25 <RTN>
	(i.e. if ### = 108 then enter 125)	
h.	40 CHARACTERS PER LINE ?	80 <RTN>

The spectra for the sample is printed, and the instrument responds:

LATEST?

If all the points on the spectra fall above the baseline (250), proceed to step 2.1.10. Otherwise, reprint the spectra with the baseline (RANGE, lower) set at 200. This is done by repeating steps 2.1.9.b - 2.1.9.h, and entering 200 at step 2.1.7.f instead of 250. Regardless of whether or not the points still fall below the baseline (200), proceed to step 2.1.10.

2.1.10 Press the ESCAPE key twice.

2.1.11 Follow steps 2.1.4 through 2.1.8 for the remaining samples to be analyzed.

2.2 LFK Order of analysis

2.2.1 The following standards are run from low to high:

a.	blank		standard	(Empty sample cup)
b.	300	ppm	standard	(Laboratory # 5103)
c.	900	ppm	standard	(Laboratory # 5113)
d.	1600	ppm	standard	(Labeled as 1600 STD)
e.	6000	ppm	standard	(Laboratory # 4873)
f.	13000	ppm	standard	(Laboratory # 4903)
g.	Laboratory Control Sample (LCS)			(Labeled as 880 STD)

2.2.2 Ten laboratory samples are analyzed. (Both duplicates and replicates are considered laboratory samples.)

NOTE: Duplicates are prepared during sample preparation at a rate of one per twenty. Replicates are analyzed at a rate of one per twenty.

2.2.3 One of the standards (b - e) is analyzed.

2.2.4 Steps 2.2.2 and 2.2.3 are repeated until the analysis batch is complete, rotating the standards (b - e).

2.2.5 Once the analysis batch is complete, all standards are analyzed, including the LCS, as in step 2.2.1.

3.0 SAMPLE QUANTITATION

3.1 Determining Peak Height

3.1.1 A straight line is drawn connecting the two low points of the curve.

3.1.2 The peak height is then measured, in millimeters, from the straight line to the highest point on the peak.

3.1.3 The corresponding number of counts is then determined by:

$$\frac{\text{(RANGE, upper - RANGE, lower)}}{\text{132.5 mm (Length of full scale)}} \times \text{peak height (mm)} = \text{Counts}$$

3.2 Determining Sample Concentration

3.2.1 The analysis results (counts and concentration) of all standards, except the LCS results, are tabulated.

3.2.2 Two standard curves are then created using linear regression. A lower curve consisting of the blank, 300, 900, 1600, and 6000 standards are used for all sample results less than 6000 ppm. The high curve consisting of blank, 1600, 6000, and 13000 standards are used for all sample results greater than 6000 ppm. Both standard curves are plotted through the point zero, zero.

3.2.3 The slope of the appropriate curve is then multiplied by the sample's counts to determine the sample concentration.

3.2.4 The LCS results are determined as in 3.2.3 (using the low standard curve). The results must fall within 20% of the true value (880 ppm).

ATTACHMENT III

APPENDIX B-4

STANDARD OPERATING PROCEDURE: LABORATORY SCREENING METHOD FOR LEAD IN SOIL USING ENERGY DISPERSIVE X-RAY FLUORESCENCE OXFORD LX1000

CATEGORY:	TITLE:	
Field	Lead Free Kids	No.
Technical	Demonstration Project	Date: 3/90

1.0 SCOPE AND APPLICATION

1.1 Metals in a solution may be readily determined by energy dispersive x-ray fluorescence (XRF) spectrometry. The method is simple, rapid, and applicable to a large number of metals in various matrices with little or no sample preparation (i.e., digestion is not required prior to analysis).

1.2 Detection limits, sensitivity, and optimum ranges of the metals will vary with the sample matrices and the models of XRF spectrometers utilized.

1.3 This method is applicable to Region I ESD and ESAT staff performing laboratory screening analyses for lead in soil samples collected as part of the LFK Demonstration project.

2.0 SUMMARY OF METHOD

This method is used for the semi-quantitative screening of lead in soil. The soil sample is homogenized, an aliquot is removed and placed in a sampling container. The sample is then analyzed using XRF.

3.0 INTERFERENCES

Certain elements, such as _____, present in the soil sample could interfere with the analysis, if present in concentrations greater than _____ times that of lead.

4.0 APPARATUS AND MATERIALS

4.1 Energy Dispersive X-Ray Fluorescence

An Oxford Analytical Instrument LAB-X 1000 equipped with:

- excitation source: Cadmium 109
  typical activity: 3 milli Curies (3MCi)
  half life: 1.3 years
  principal energy level: silver, K, 22 KeV
  atomic no range:(K) spectra, 24-42; (L) spectra, 72-92
- detector: xenon filled proportional counter
- six (6) position motorized turntable
- microprocessor control consisting of:

- display: 40 column, 2 line liquid crystal display
- printer: 40 column, 2 color dot matrix with graphics, uses 70mm wide plain paper
- keypad: 20 key alphanumeric membrane pad.

4.2 Printer paper, 70mm wide.

4.3 Printer ribbon.

4.4 Sample cups, plastic, spectro-cup, Cat. No. 340, Somar Lab. Inc,, New York or equivalent.

4.5 Mylar film, 6 micron

4.6 A stable power supply, whose requirements of 100-120 volt AC, 45-165 Hz, 50 VA maximum consumption are critical to instrument performance. Extreme temperature ranges also effect instrument performance.

5.0 REAGENTS

5.1 U.S. Department of Commerce, National Bureau of Standards, Standard Reference Materials

SRM	Type	Unit Size	Certified Lead Concentration
1579	Powdered Lead Base Paint	35g	11.87%
1633a	Coal Fly Ash	75g	72.4 ug/g
1645	River Sediment	70g	714 ug/g
1646	Estuarine Sediment	75g	28.2 ug/g
1648	Urban Particulate	2g	0.655%

5.2 US EPA, Environmental Monitoring and Surveillance Laboratory (EMSL), Quality Control Reference Standards

5.3 Instrument Calibration Standards

Not available at this time.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 Samples are collected in the field, placed in labelled, individual, zip-lock plastic bags, and submitted to the ESD laboratory for analysis. Samples are logged into the laboratory logbook and assigned a laboratory identification number.

6.2 Soil samples are thoroughly mixed (homogenized) in the zip-lock bag. An aliquot of the soil, 2 to 3 table spoons (10 to 15 grams), is removed with a spoon or spatula and placed in a wang dish or appropriate drying vessel. The dish is marked with the laboratory identification number and allowed to air dry overnight at ambient laboratory temperature.

6.2.1 Excess sample in the zip lock bag will be stored until the analytical report has been finalized then discarded. However, selected soil samples maybe kept longer for additional testing.

6.3 Sample Preparation

Dried soil samples will be passed through a 60 mesh sieve until approximately 1 gram of fines have been passed. The sieve will be manually shaken, typically 10 to 15 seconds is adequate. The fines are then transferred to the analysis sample container using a glass powder funnel which is placed over the sample container.

6.3.1 All excess soils from sample preparation will be discarded in a special barrel in the laboratory.

6.3.2 The powder funnel, sieve, drying vessel, and spoon (or spatula) will be cleaned between samples to remove soil particles. The funnel and sieve will be blown free of dust with compressed air. The spoon will be wiped with disposal tissues and drying vessel washed vigorously with hot water.

6.4 Sample Container Preparation

6.4.1 Invert cup and place a piece of 6 micron mylar film over the bottom aperture.

6.4.2 Snap a retaining o-ring over the film onto the base of the cup (o-ring teeth down).

6.4.3 Place cup upright and add enough soil to uniformly cover the mylar film bottom of the cup.

6.4.4 Snap cap into place on top of the cup.

6.4.5 Label the sample cup with the sequential laboratory I.D. No. and record that in the XRF instrument logbook.

NOTE: Information to be recorded in the XRF logbook would include:

- field identification numbers;
- laboratory identification numbers;
- date samples prepared;
- date samples and analyzed;
- analysis parameters; and
- analyst's initials affiliation and date.

6.5 Standards Preparation

Calibration standards are prepared from previously analyzed and concentration verified soil samples or known reference standards. Standard concentrations should be prepared at concentration levels of lead at approximately:

- 50 - 100 ppm (ug/g)
- 100 - 500 ppm
- 500 - 1000 ppm
- 1000 - 2000 ppm
- 2000 - 5000 ppm

6.6 No special preservation or handling procedures are required.

7.0 ANALYSIS PROCEDURE

The use of the Oxford Analytical Instrument Model LAB-X 1000 XRF is relatively simple. (Detailed instructions for its use can be found in the LAB-X 1000 Instruction Manual.)

7.1 Instrument Set-Up

7.1.1 Turn power on.

7.1.2 Wait for menu to appear in video display.

7.1.3 Press key "3" to select Utilities routine.

7.1.4 The instrument will print the date and time and display the menu:

1 = Position Turntable
2 = Set Date and Time
3 = Printer Check
4 = Turn Page

Select option 3 to check correct function of printer

Press key "3".

7.1.5 If date and time printed at the start of these routines are incorrect, they can be reset by pressing key "2".

7.1.6 Exit from the utilities routine by pressing option 4 until the main menu (as shown below) is displayed.

1 = Analyses 2 = Calibrate
3 = Utilities 4 = Turn Page

The LAB-X is now ready to begin analyses.

7.2 Manual Analysis of Soil Samples

7.2.1 Place one of the assembled safety windows in position 0 in the sample loading port.

7.2.2 Place the sample cup into the cell or secondary window holder which fits into the safety window of the sample loading port. The cell assembly should be lightly tapped on a clean, hard surface to settle the contents of the cup (i.e., evenly distribute the soil on the mylar film).

7.2.3 Selection option 1, Analyses, on the Main Menu. Press key "1".

7.2.4 Another menu appears, select option 2, Spectrum Scan. Press key "2".

7.2.5 Prompt: enter "Analysis Head".

7.2.6 Response: press key "2".

7.2.7 Prompt: enter "Sample Label".

7.2.8 Response: enter sample ID from XRF log.

7.2.9 Prompt: Is "Sample Label" Inserted?

7.2.10 Response: press "Yes" key.

7.2.11 The measurement cycle now begins. The turntable will rotate 60 degrees, carry out an Energy Lock for Ca. 10 seconds prior to further rotation which transports the sample to the required sampling head. The operator may terminate a measurement by pressing the "Esc"ape key before the programmed time has elapsed.

7.2.12 After completion of the measurement cycle, select option 2, Print Scan. Press key "2".

7.2.13 After the scan has been printed, determine if the lead L-alpha peak is on scale and measurable. If not, select one of the three (3) scaling options: 5, 10, or 20. Press the appropriate key.

7.2.14 After the scale scan has been printed, select option 4, Turn Page, to return to the Analyses Menu. Press key "4".

7.2.15 Place another sample into the sample holder and repeat the analysis process.

7.3 Quantification

7.3.1 A series of calibration standards are analyzed at each scaling factor; 0, 5, 10, and 20. An average response factor (RF) is determined using a minimum of three (3) concentrations and one (1) reagent blank analyzed at least three times.

7.3.2 The peak height of the lead L-alpha (at _____) is measured for each sample. This peak height is multiplied by the RF to determine the concentration of lead (ppm) in the sample.

8.0 QUALITY CONTROL

8.1 All quality control data should be maintained and available for easy reference or inspection.

8.2 A set of calibration standards at each scaling factor should be analyzed in the laboratory prior to initiating field studies. These calibration standards should consist of a minimum of three (3) standards and one (1) reagent blank ("clean soil").

8.3 A minimum of one (1) reagent blank and one (1) standard at or near the mid-range of the calibration curve should be analyzed daily to verify instrument reproducibility. These values should agree within ± 20 percent of the initial calibration.

8.4 If forty-five (45) or more samples per day are analyzed or if samples from more than one site are to be analyzed in one day, then the working standard curve must be verified by analyzing a mid-range standard for every thirty (30) samples or for each site, whichever is more frequent. These check standard results must be within ± 20 percent of the true value.

8.5 At least one (1) field laboratory duplicate sample should be analyzed with every twenty (20) samples to verify the precision of the method.

NOTE: True replicates of soil samples are usually not possible since chemicals such as lead are typically not uniformly distributed in these materials. Care must be taken in the interpretation of soil replicate analytical results.

8.6 At least one (1) lead-in-soil standard reference sample should be analyzed daily or per site, which ever is more frequent. The result should agree within ± 20 percent of the true value.

9.0 METHOD PERFORMANCE

9.1 Precision and accuracy data are not available at this time.

9.2 The performance characteristics for a soil sample free from interferences are:

Optimum Concentration Range: N/A ug/g

Detection Limit: N/A ug/g

NA: not available at this time.

ROY F. WESTON, INC.
LANDMARK ONE
ONE VAN DE GRAAFF DRIVE
BURLINGTON, MA 01803
(617) 229-2050

March 1, 1990
D-0-2-30

Mr. Scott Clifford
ESAT Deputy Project Officer
Environmental Services Division
US EPA - Region I
60 Westview Street
Lexington, Massachusetts 02173

Re: TID No. 01-9001-25
LFK Demonstration Project
Quality Assurance Project Plan
Revisions to Interim DRAFT

Dear Mr. Clifford:

Environmental Service Assistance Team (ESAT) member Jay Markarian prepared an interim revised draft of the Boston Lead Free Kids Demonstration Project Quality Assurance Project Plan (QAPjP). The task, requested by David McIntyre, EPA task monitor, was authorized under Technical Instruction Document (TID) No. 01-9001-25. The requested start date was January 29, 1990. An interim revised draft QAPjP was requested for submission on February 27, 1990 with the final version due on April 27, 1990.

The first revision of the April 28, 1989 QAPjP was initiated on January 29, 1990. J. Markarian met with D. McIntyre on February 8, 1990 to discuss the scope of revisions required. After this meeting D. McIntyre edited sections 1.0 through 6.0 of the QAPjP, addressing program changes, which included addition of the dust sampling and analysis elements of the project. J. Markarian has reviewed the edits made by D. McIntyre and edited the remaining sections of the QAPjP, which included the following:

- All tables and figures;
- Sections 7.0 through 11.0;
- the Detailed Sampling SOP;
- Deletion of former Appendices B-2, B-3, B-5 and B-6;

- Development of a dust sample preparation and analysis SOP and;
- Incorporation of a dust sampling SOP developed by LFK staff, into the sampling guidelines found in Appendix A of the QAPjP.

The enclosed diskette contains a merger of edits provided by D. McIntyre and J. Markarian under the file name QAPP3B1.Jay. "Redline" and "Strikeout" modes, available on WordPerfect software version 5.0, have been used to assist D. McIntyre with the QAPjP's review.

Current status of this TID is summarized below:

- The interim draft QAPjP has been submitted by ESAT to USEPA for comment;
- 76 of the 120 assigned labor hours have been expended (approximately 64 percent);
- The task appears to be on schedule and on budget, barring extensive comments by the US EPA.

Please contact Jay Markarian at 617/229-2050 should you require any additional information.

Very truly yours,

ROY F. WESTON, INC.

Jay Markarian, P.G., CHMM
Senior Investigation Coordinator

Joseph D. Mastone
Team Manager
ESAT Region I

JSM/dam

cc: D. McIntyre, US EPA

1.0 QUALITY ASSURANCE PROJECT PLAN

Project Title: Lead Free Kids (LFK) Demonstration Project

EPA Project Manager: David McIntyre

LFK Principal Investigator: Michael Weitzman, M.D.

Performing Organization: Trustees of Health and Hospitals of the City of Boston, Inc. (Trustees)

Lead Free Kids Project, Department of Health and Hospitals City of Boston

Duration: 2 years (See Project Design)

Type of Project: Superfund Epidemiological/Soil Abatement Demonstration Project

Supporting Organization: EPA Region I

Approvals:

EPA, Region I
Name: David McIntyre Title: Project Manager

Signature _____ Date _____

Name: Carol Wood Title: Quality Assurance Coordinator

Signature _____ Date _____

Name: Dr. Thomas Spittler Title: Technical Project Director

Signature _____ Date _____

LFK Project

Name: Michael Weitzman, M.D. Title: Principal Investigator

Signature _____ Date _____

Name: John L. Christian Title: VP Trustees of Health & Hospitals

Signature: _____ Date _____

2.0 TABLE OF CONTENTS

2.0 TABLE OF CONTENTS (continued)

2.0 TABLE OF CONTENTS (concluded)

Quality Assurance Project Plan

Distribution List

A copy of this Quality Assurance Project Plan has been provided to the following organizations and their project representatives:

Natalie Zaremba, LFK
Ann Aschengrau, LFK
Michael Wietzman, LFK
John Christian, ~~LFK~~ Trustee
Tom Spittler, U.S. EPA
Carol Wood, U.S. EPA
David McIntyre, U.S. EPA
Jay Markarian, Roy F. Weston, Inc.

LIST OF APPENDICES

LIST OF FIGURES

3.0 PROJECT DESCRIPTION

3.1 Introduction

The purpose of the Quality Assurance Project Plan (QAPjP) for the Boston Lead-in-Soil/LFK Demonstration Project is to indicate prime responsibilities and prescribe requirements for assuring that the project is planned and executed in a manner consistent with defined quality assurance objectives. This QAPjP provides guidance and specifications to assure that:

1. All field sampling, methodologies and documentation, sample preparation, handling, and transportation are conducted consistently according to established procedures;

2. All laboratory determinations and analytical results are valid through preventative maintenance, instrument calibration, and analytical protocols;

3. Samples are identified and controlled through sample tracking systems and chain-of-custody protocols;

4. Records are retained as documentary evidence of the sample integrity, applied processes, equipment used, and analytical results;

5. Generated data is validated and its use in calculations documented; and

6. Calculations and evaluations are accurate, appropriate, and consistent throughout the project.

the Lead Free Kids (LF project in

The requirements of this QAPjP apply to the EPA Region I (and its subcontractor activities) and to the Trustees (and its subcontractor activities) as appropriate for the Demonstration Project.

3.2 Project Summary

The following information summarizes the specific tasks required for this Demonstration Project as well as other pertinent information.

3.2.1 Project Background

In 1985, the Centers for Disease Control (CDC), Atlanta, Georgia, published a report entitled, Preventing Lead Poisoning in Young Children, which stated that "lead in soil and dust appears

to be responsible for blood lead levels in children increasing above background levels when the concentration in the soil or dust exceeds 500-1000 parts per million (ppm)."

Data from the City of Boston Childhood Lead Poisoning Prevention Program, coupled with the CDC report, led to the following conclusions:

a. Children playing in the area of exposed, lead-contaminated soil may ingest lead in the course of their normal hand-to-mouth activities.

b. Ingestion of lead ~~through~~ direct contact with lead-contaminated soil may result in an increased body burden of the contaminant.

c. Exposure of humans to lead through ingestion or inhalation can result in toxic effects in the brain, central and peripheral nervous system, kidney, and hematopoietic system. Anemia is an early manifestation of lead poisoning. Peripheral neuropathy also results from lead poisoning. Young children under the age of six are especially prone to the most profound and deleterious effects of lead exposure. Chronic exposure to low levels of lead can cause permanent learning disabilities in children.

3.2.2 Demonstration Project

The Boston Lead Free Kids Demonstration Project shall involve sampling approximately 150 selected children for blood lead levels to determine base line data, sampling their yards to establish soil lead levels, and their residences to determine dust lead levels, removing contaminated soil and dust, and resampling the children during the following year to observe the effects of the soil/dust removal. This QAPjP addresses the soil and dust sampling and analysis.

Preliminary soil sampling will be conducted during 1989, as necessary, at the selected children's properties. Should the preliminary sampling indicate lead concentrations equal to or greater than 1500 ppm in two or more samples, residents of those properties shall be contacted for enrollment in the project. Detailed soil sampling will be conducted at those sites enrolled in the project in order to define the nature and extent of the lead contamination. The surface of those properties which are included in the project will be removed to a depth of 15cm (six inches). Post abatement sampling and analysis will be conducted to evaluate the effectiveness of abatement activities, and to monitor the levels of lead in soil at the project properties at later dates. This is illustrated in the flow diagram presented as Figure 3-1.

Once the properties are signed on to the project, interior dust sampling and interior dust abatement (extensive vacuuming and cleaning) will commence. Dust samples will be analyzed at the EPA lab and the data forwarded to LFK. Dust abatement activity details are available in the project design document prepared by LFK.

Preliminary Soil Sampling to Determine Eligibility

Three to four composited surface samples will be collected from properties with children chosen to be potential study participants. One composited surface sample will also be taken from any obvious play areas. Sketches of the properties indicating key landmarks and sample locations will be made. Samples will be analyzed by XRF at the EPA Region I laboratory. The property will be eligible if two or more sample results are equal to or greater than 1500 ppm.

Detailed Soil Sampling

After properties are selected and signed up to be in the project, they will undergo detailed soil sampling. Soil samples will be collected at the surface and from corings 15 centimeters below surface by the project staff according to attached protocols, using one or more of the defined patterns: line source, targeted area, small area, or grid patterns. Pattern selection will be based upon the layout of the subject property at the discretion of the sample crew chief. Sketches indicating property details and sample locations will be made by the samplers. The samples will be transported to the EPA Region I laboratory as described in the protocols and analyzed on XRF. Results of the detailed sampling and analysis will be forwarded to LFK for interpretation.

Post Abatement Soil Sampling

Properties will be sampled after abatement activities. The purpose of this is two-fold. Firstly, to document the effectiveness of abatement activities, and establish a control point (i.e., the abated property). Secondly, to document lead concentrations in the soil at later dates in order to determine if lead concentrations in the soil have changed since abatement activities. Soil sampling conducted immediately after abatement will be confined to the abated areas, and be conducted in the same pattern as was previously used. Periodic, post abatement sampling will be conducted in areas which previously had the highest concentrations of lead, play areas, or any locations otherwise specified by the principal investigator. Soil sampling will follow the protocol utilized during the preliminary sampling phase of the project. Analysis will be by XRF at the EPA Region I laboratory.

Dust Sampling

Dust sampling will be conducted in interior areas on hard surfaces, according to the LFK protocol. Modified "Dust Busters" will be used to collect dust from areas identified by a template (24x24 or 25x25 inches), the sample will be placed in a paper, legal sized envelope, sealed, and delivered to the EPA lab for XRF analysis.

3.3 Project Objectives

The main objective of the Boston Lead-in-Soil Demonstration Project is: to determine the effects of lead contaminated soil removal from inner city residential areas on blood lead levels of children living on the contaminated properties. A secondary objective is to measure the effects, if any, on the blood lead levels of children after dust abatement on those same properties.

3.3.1 Major Task Summary

The Boston Lead-in-Soil Demonstration Project will include field and laboratory activities by EPA Region I and Trustees. A summary of tasks covered by this QAPjP is presented below.

- preparation of a Health and Safety Plan that will identify potential hazards associated with the planned field activities, establish the level of protection, and provide information and procedures needed to mitigate these hazards for on-site workers;

- preparation of Sampling and Analysis procedures to be utilized by personnel in obtaining soil and dust samples for analysis and for personnel conducting soil and dust analyses in the laboratory. For soil, this will include procedures for conducting site surveys for the purpose of preparing site grids, and obtaining preliminary, detailed and post-abatement soil samples, and procedures for laboratory analysis. For dust, this will include procedures for collecting and analyzing;

- conduct preliminary soil sampling at selected properties according to established protocols;

- conduct detailed soil sampling at selected properties with full site documentation as specified in the protocols;

- conduct dust sampling at selected properties as specified in the protocols;

Figure 3-1

Demonstration Project Flow Chart

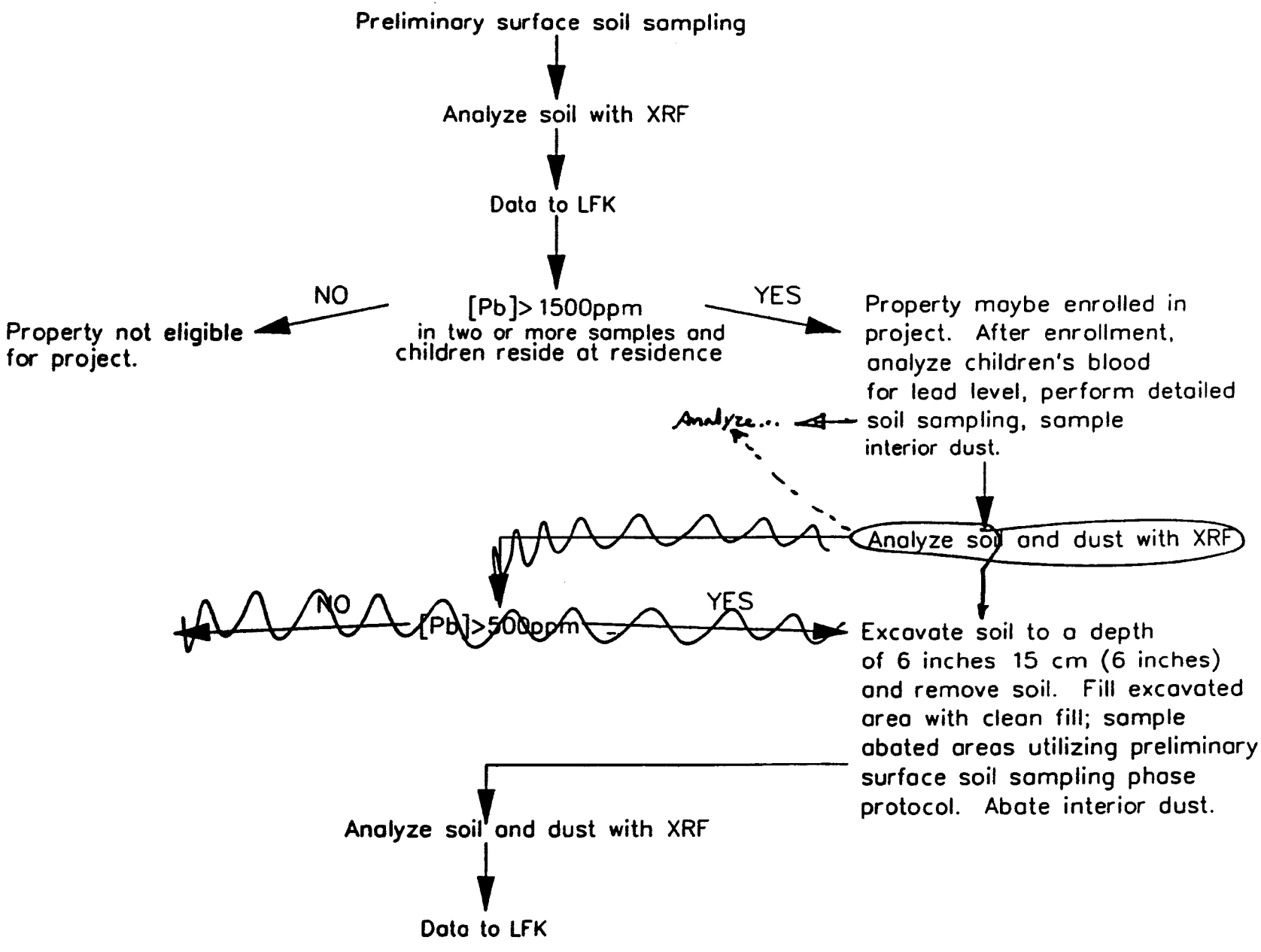
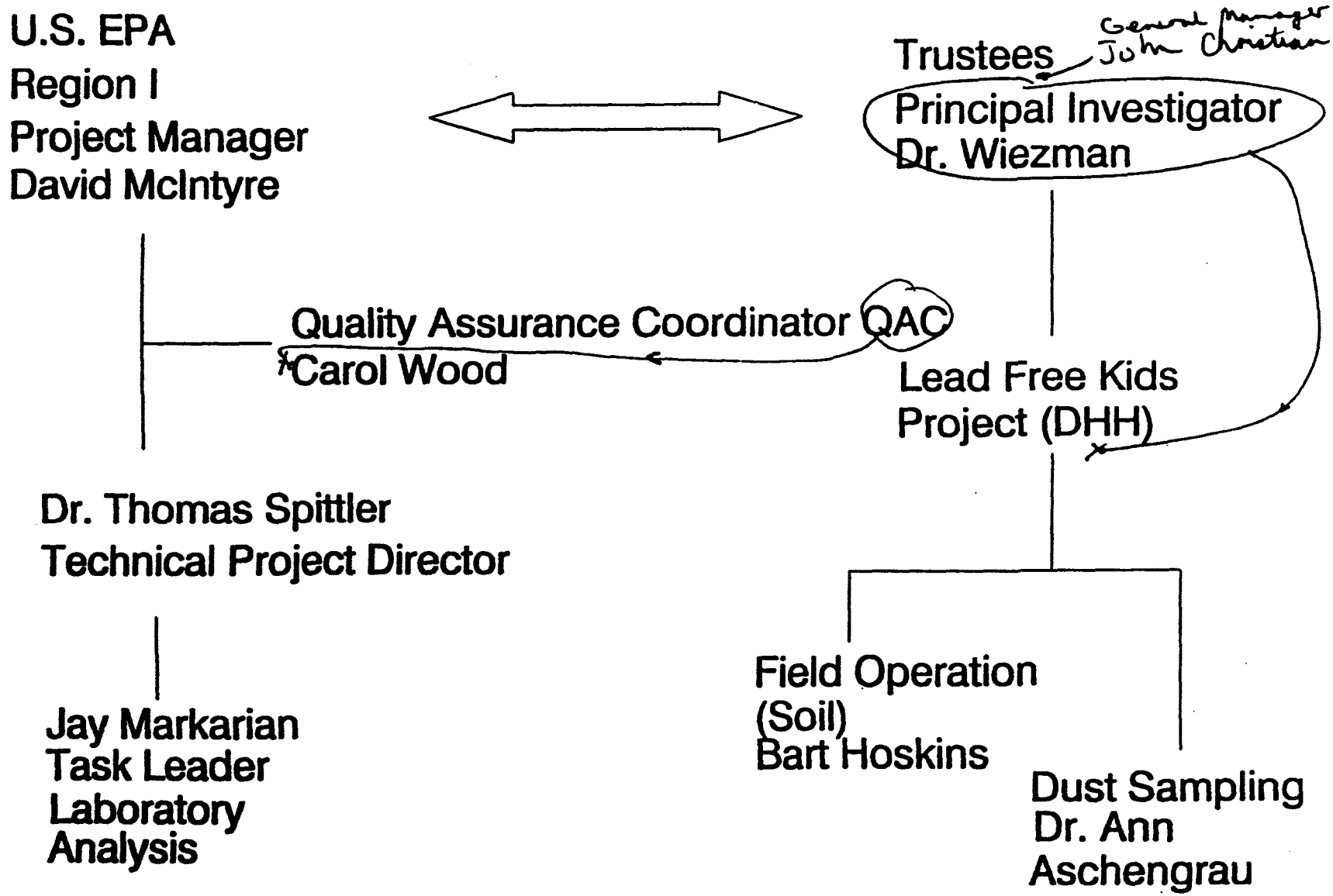


FIGURE 4-1
PROJECT ORGANIZATION



- analysis of all soil and dust samples using the techniques of energy dispersive X-ray fluorescence, and of a fraction of the samples using Inductively Coupled Plasma Emission Spectrophotometry; and

- post abatement soil sampling of properties according to protocols.

4.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

4.1 Organization

This project is being financed through the EPA under SARA as part of a three project effort to define the lead-in-soil/childhood lead poisoning relationship. Each of the three projects are responsible for their own operation and findings. EPA Region I and the Trustees of Health and Hospitals of the City of Boston, Inc. have entered into a cooperative agreement to conduct this Demonstration Project. The Trustees are responsible for the operation and findings of the Boston project, including all scientific and logistical facets. The EPA's responsibility, as a partner in the cooperative agreement with the Trustees, is to ensure that (1) the money allocated to the Boston project is spent appropriately according to federal regulations, (2) that involved federal agencies are coordinated, and (3) that EPA's input as defined in the Special Conditions is provided. It is Region I's position that it will closely monitor the activities of the Trustees and work with them on the project, but that the Trustees are running the project. The responsibilities and project organization are discussed below.

4.2 Responsibility for Quality Assurance

- EPA Support to the Project

  The Region I Environmental Services Division (ESD) Laboratory and their contractors will provide personnel and facilities for energy dispersive x-ray fluorescence spectrometry (XRF), and inductively coupled plasma spectroscopy (ICP) analyses for lead in soil.

  The ESD and their contractors will also provide technical guidance and services related to the collection and chemical analysis of soil samples obtained during field activities and will serve as sample custodian during sample analysis. In addition, they will provide support in developing the QAPjP, perform analytical data review and report generation.

- Trustees Support to the Project

  The Trustees will provide equipment, laboratory supplies and personnel necessary for on-site sampling soil removal activities, blood sampling, dust sampling, and all other project activity not specifically provided by EPA.

Figure 4-1 shows the project organization and its principal lines of communications. The responsibilities of the EPA and Trustees' project staff positions and support organizations are summarized below:

For the EPA:

- The Project Manager is responsible for:

  1. Maintaining coordination between the EPA and the Trustees.
  2. ~~Monitoring all project activities.~~ Ensuring completion of EPA responsibilities as specified in the special conditions of the cooperative agreement.
  3. Providing overall direction for preparation of work plans, sampling plans, and analytical procedures relative to soil and dust.
  4. Administering all contracts with EPA contractors.

  The Project Manager is David McIntyre.

- The Technical Project Director is responsible for:

  1. Approving, maintaining, and implementing this QAPjP for EPA-conducted activities, i.e., sample analysis.
  2. Indicating the types of QA records to be maintained for the analytical portion of the project.
  3. Approving analytical procedures and operating systems.

  The Technical Project Director is Dr. Thomas Spittler or designee.

- The Quality Assurance Coordinator (QAC) will be responsible for:

  1. Evaluating and approving this QAPjP.
  2. Scheduling and conducting systems and performance audits on-site and in the Laboratory.
  3. Providing QA reports to the Project Manager on the results of audits and the need for preventative or corrective actions.

4. Developing and initiating preventative and corrective actions as needed in conjunction with the Project Manager and the Technical Project Director.

The Quality Assurance Coordinator (QAC) is Carol Wood or designee.

For the Trustees:

- The Principal Investigator is responsible for staffing and conducting the project, except for activities having to do with sample analysis which will be provided by EPA. As part of his QA responsibilities he will:

  1. Approve, maintain, and implement this QAPjP as it relates to LFK activities, i.e., sample collection.

  2. Indicate the types of QA records to be retained for the LFK aspects of the project, and retain such records.

  3. Provide for QA audits by EPA.

  4. Approve task plans and operating systems.

  The Principal Investigator is Dr. Michael Weitzman.

- LFK Task Leaders are responsible for specific engineering and scientific operations. As part of this responsibility they will:

  1. Initiate, develop and check subtask plans including initiating, monitoring, and accepting support services and products.

  2. Identify safety hazards and ensure that the associated risks are at acceptable levels.

  3. Supervise and participate in operations, analyses, data collection, and data reduction.

  4. Maintain samples and their identification.

5. Develop site sketches, identify sample locations, buildings, and appropriate structures, identify notable site specific conditions and observations to include photographs, identify clean soil zones and those to be abated.

6. Generate required QA records.

7. Implement corrective actions, when required.

LFK Task Leaders will be named by the Principal Investigator.

TABLE 5-1

Data Quality Objectives for Lead in Soil Analyses

Method Detection Parameter	Method	Instrument	Reference[b]	Precision[d]	Accuracy[e]	Completeness[f]	Comparability	Method Limit[g]
Lead (Pb) -Soil	XRF[a]	Oxford LX1000	--	±20	±20	90	mg/kg dry wt.[h]	200 (mg/kg)
Lead (Pb) -Dust	XRF	Kevex 0700	—	±20	±10	90	mg/kg dry wt.[h]	100 (mg/kg)
	ICP[i]	Perkin Elmer	6010[c]	+10	±10	90	mg/kg dry wt.	42 (ug/L)

a. Energy dispersive x-ray fluorescence spectrometry

b. Copies of methods are attached as appendices

c. SW 846, 3rd Ed.

d. Percent relative standard deviation from mean or true value

e. Relative percent difference

f. Percent

g. Nominal detection limits, soil MDL estimated from sample size and concentration factors (units) mg/kg

h. Air dry overnight in laboratory hood at ambient temperatures

i. Inductively Coupled Plasma Emission Spectrophotometry

TBD = To be determined

5.0 QUALITY ASSURANCE OBJECTIVES

5.1 General

The quality of measurements made during this study will be determined by the following characteristics: accuracy; precision; representativeness; completeness; and comparability. Specific objectives for each characteristic are established to develop sampling protocols, to identify applicable documentation, and to perform sample handling and measurement procedures. These objectives are established based on site conditions, objectives of the project, and knowledge of available measurement systems. The subsequent use of these measurements in calculations and evaluations is also subjected to aspects of this QAPjP as described in the following sections. The Quality Assurance Objectives for chemical analyses conducted in conjunction with the Boston Lead Free Kids project are presented in Table 5-1.

The Trustees (Lead Free Kids) will collect all samples and provide site-specific field documentation and transport samples to the ESD Laboratory maintaining chain of custody from collection to delivery at the ESD Laboratory. Sample collection and field handling will be in accordance with the sampling protocols established in this QAPjP. Soil and dust samples will be analyzed at the EPA Region I ESD Laboratory in Lexington, Massachusetts. Analytical laboratory QA/QC discussion is presented in Section 9.0.

5.2 Representativeness

Sampling procedures (Section 6.0) will be used to assure that samples collected are representative of the media. Sample handling protocols (e.g., storage and transportation) protect the representativeness of the collected sample. Proper documentation will ensure that protocols have been followed and that sample identification and integrity are assured.

Sample preparation procedures (Section 9.3.1 - Soil and Dust) will be used to assure that the samples analyzed are representative of the fraction which poses the greatest risk to the public.

5.3 Precision and Accuracy

Precision, the ability to replicate a value, and accuracy, the ability to reproduce a true value, are addressed for all data generated by EPA. Data quality objectives for precision and accuracy are established for each major parameter to be measured at the site. These objectives are based on prior knowledge of the capabilities of the measurement system to be employed, and are in turn selected in accordance with the requirements of the project. The precision and accuracy requirements vary, dependent on their

intended use. For example, a screening tool to identify the general extent of chemical distribution will not require the same precision and accuracy required to define the exact nature and amount of chemicals present at specific locations.

5.4 Completeness

The characteristic of completeness is a measure of the amount of valid data obtained compared to the amount that was specified to be obtained under normal conditions. The amount of valid data specified is established based on the measurements required to accomplish project objectives. The extent of completeness must be reviewed on a relative basis for sample collection activities. Completeness of data handling systems is described in Sections 10.0, 11.0, 12.0, and 14.0. Examples of completeness objectives for specific measurement systems are also provided in Table 5-1.

5.5 Comparability

The characteristic of comparability reflects both internal consistency of measurements made at the site and expression of results in units and methodologies consistent with other organizations reporting similar data. Each value reported for a given measurement should be similar to other values within the same data set and within other related data sets. Comparability of data and measuring procedures must also be addressed. This characteristic implies operating within the calibrated range of an instrument and utilizing analytical methodologies which produce comparable results. (e.g., data obtained for lead (ICP) is not directly comparable to data obtained for lead (XRF). However, it is a Quality Assurance Objective to define the limits of comparability by submitting samples analyzed by XRF for ICP analysis and comparing their results).

5.6 Quality Assurance Objectives

The quality assurance objectives for the Demonstration Project are:

- to produce documented, traceable, and consistent data;
- to collect and analyze sufficient trip blank and field duplicate samples to allow an assessment of sample collection protocol precision;

- to provide sufficient laboratory duplicates, blanks, replicates, and reference standards to allow an assessment of analytical precision and accuracy. Sufficiency of analytical QC procedures is specified by the referenced methods (see Section 9.0);

- to produce documented, consistent, and technically defensible data reports; and

- to conduct site sampling and site-specific documentation according to established protocols.

Space →

- to define comparability of XRF and ICP obtained analytical data so as to allow XRF data to be compared to other organizations conducting similar studies.

6.0 SAMPLING PROCEDURES

6.1 General

Soil

Three soil sampling events will be conducted during the Demonstration Project. They are

- Preliminary Sampling;
- Detailed Sampling; and
- Post Abatement Sampling.

Preliminary sampling is the initial phase of sampling, and will qualify a property for further participation in the project. Detailed sampling will indicate the nature and extent of lead contamination. Post abatement sampling will indicate effectiveness of abatement, and provide additional data to be utilized in future lead abatement efforts.

All sampling locations will consist of a five point composite. The center point of the composite will fall upon the pre-determined sample station. Each sample location will consist of soil collected from the center point and four corners of the square. This is illustrated in Figure 6-1.

No preservatives will be required for soil samples. Sample containers will consist of plastic "Zip-Lock" bags. Sample collection schemes and field documentation will differ, based upon which phase of sampling (preliminary, detailed, or post abatement) is being conducted.

Dust

Dust sampling events will be conducted in conjunction with soil sampling and other scheduled activities on-going throughout the Demonstration Project.

For this study, the household dust samples are defined as the samples that are most likely to come into contact with a child's hands during indoor activity. This would include dust on upfacing surfaces accessible to the child such as bare floors, carpets, window sills, and wells, furniture, as well as dust on toys and other objects likely to be handled by children.

Dust sampling has two components that are important to interpreting lead exposure: the concentration of lead in the dust and the amount of dust or loading on the surface. The concentration of lead in dust appears to be closely related to the amount of lead on children's hands whereas the amount of dust on surface is an indicator of the importance of this route of human exposure.

All sampling locations within a home will consist of a measured surface area from which dust will be collected using a modified hand-held vacuum (Dust Buster).

No preservation will be required for dust samples. Sample transferred from the dust buster will be contained in a paper envelope.

6.2 Equipment List

Several items are required to collect soil and dust samples and document sampling events, site description, etc. Because many properties shall be investigated and several samples collected from each property, an adequate supply of equipment should be available at all times.

A list of equipment is provided in each of the four sampling protocols found in Appendix A. Additional equipment not on the list may be required on a site specific, as-needed basis.

6.3 Sample Collection

Soil

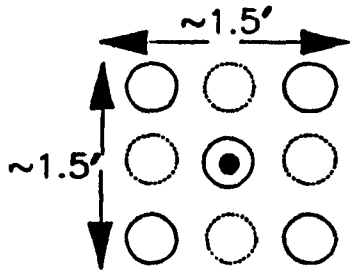
Each sampling point will consist of an approximate two-foot square area. The center of the square will fall upon the decided sampling point, and a composite sample will be collected, composed of soil taken from the four corners and center of the square. Preliminary Phase and Post Abatement Phase samples will be collected from 0 to 2 cm below the surface. Detailed Phase samples will be collected from 0 to 2 cm below the surface, and an additional core sample will be collected from 13 to 15 cm below the surface, from the same point. Figure 6-1 illustrates A - Preliminary and Post Abatement, and B - Detailed Soil Sample Collection. In depth discussion of sampling techniques, to be utilized during all phases of sampling, are provided in Appendices A-1, A-2, A-3 and A-4.

Dust

Each sampling point will be collected from a known square area using a modified Dust Buster. Floor and hallway areas will be sampled first using a 25" x 25" template. These samples will be collected from the center of the floor. Samples will then be collected from window wells and other areas with the square area sampled documented. A minimum of 5 milligrams of sample is

FIGURE 6-1

5 Point Composite Sample Scheme

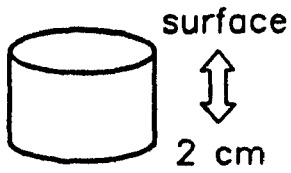


Legend

- ● Sampling Station
- ○ Sample Composite Location
- ○ Field Duplicate Sample Composite Locations

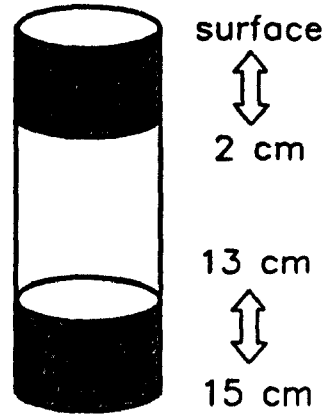
(At selected sampling stations duplicates will be collected at mid-points between sample composite locations.)

A
Preliminary and Post Abatement Phase Surface Sample Composite Location Schematic



Sample collected from surface to 2cm below surface.

B
Detailed Phase Surface and Subsurface Sample Composite Location Schematic

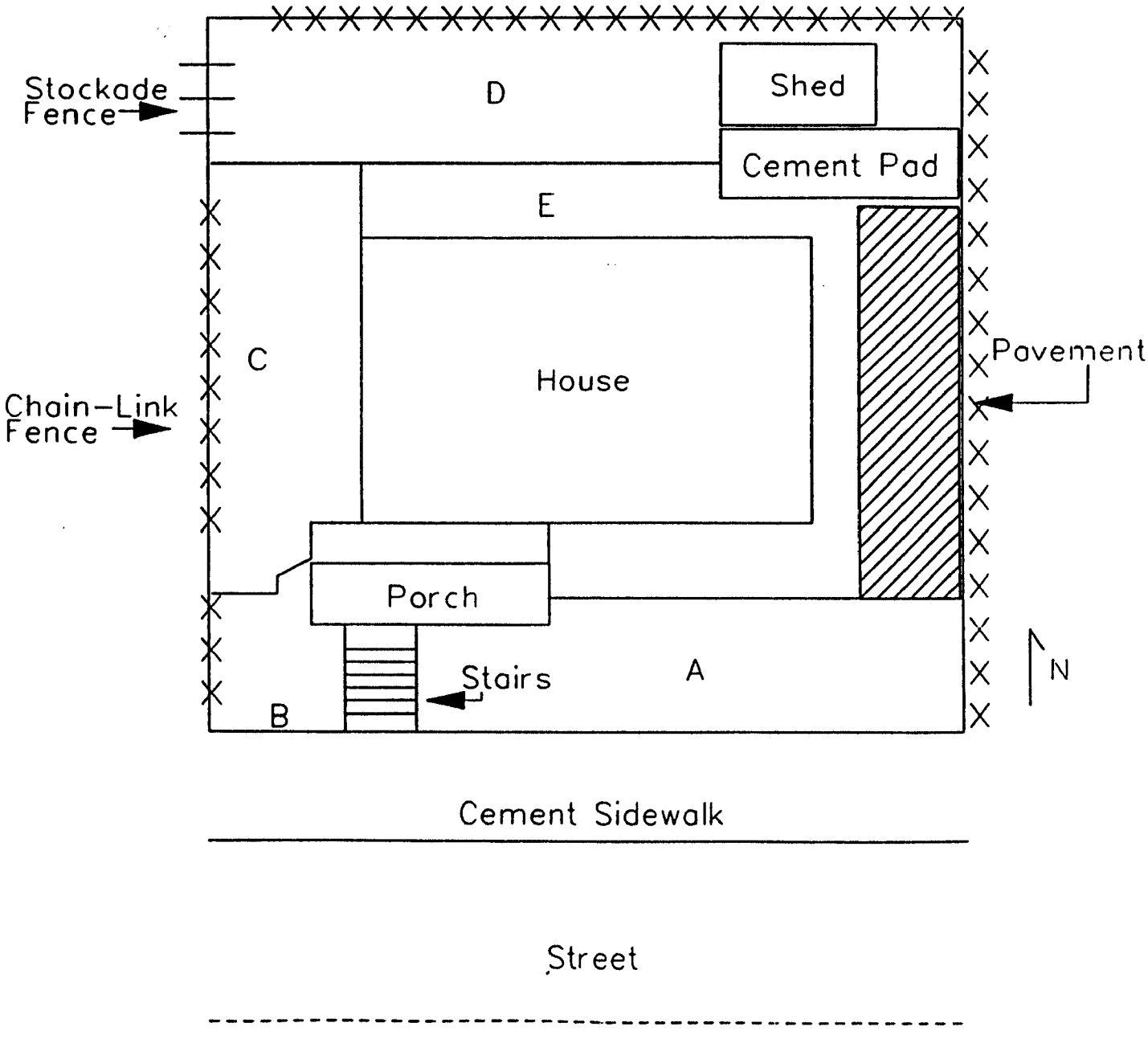


First sample collected from surface to 2 cm below surface.

Second sample collected from 13 cm to 15 cm below surface in same boring location.

FIGURE 6-2
Detailed Site Diagram

Address: _____ **Date:** _____



required for analysis. This may necessitate sampling and recording a larger floor or window well surface area. In-depth discussion of sampling procedures to be utilized during dust sampling are provided in Appendices A-4.

6.4 Sample Handling and Storage

The soil sample containers (polyethylene "Zip-Lock" bags, or equivalent) should be sealed to prevent loss or cross-contamination of the sample. Dust sample containers (paper envelopes) should be folder over 1/2 inch from the top and then taped down to prevent loss or cross contamination of the sample. No special considerations will be given to sample packaging or shipping papers as the samples will be delivered to Environmental Services Division (ESD) Laboratory by a member of the LFK staff. Pending delivery to EPA, samples should be stored in a cool, dry, and secure location with limited, controlled access. — Tom?

6.5 Record keeping

Sampling records, maintained by LFK, for each property will consist of a site sketch for soils and floor plan for dust with location descriptions and chain of custody record for each sample collected. Samples shall be assigned LFK field identification numbers to include premises identification number with a sequential alpha numeric designation, and located on the site sketch and summarized in a Blood Field Sampling log book. Chain of custody shall be established as described in Section 7.0.

6.6 Preliminary Soil Sampling

6.6.1 Site Description

During this phase of sampling, LFK will generate a detailed drawing that indicates the boundary of the lot, the position of the main building and any other buildings such as storage sheds or garages, the position of the side walks, driveways, and other paved areas, the position of the play areas, if obvious, and the areas with exposed soils, as illustrated in Figure 6-2. The property should be divided into separate sub-areas if necessary for clarity or detail and be identified with alpha designation. Sub-areas may include isolated areas of the site such as front, rear, and side yards. Sample locations will be identified on this drawing, indicating approximate distances from buildings and other landmarks. The resulting sketch will be placed in the property file at the LFK office.

In addition to the sketch, the following information will be included on the page:

- Address;
- Date and name of artist;.
- Apparent use of yard if any (toys, sandbox, children present);
- Debris, standing water, vegetation, cover and bare spots, animals on property; and
- Any notable unusual feature.

6.6.2 Sampling Schemes

The sampling scheme utilized for each property during the Preliminary Phase will be the same for each one, and will involve sampling in the immediate area of the house and in obvious play areas. This protocol is described in Attachment A-1.

6.7 Detailed Soil Sampling

6.7.1 Site Description

During the Detailed Soil Sampling Phase for each location, the project log should briefly describe the sampling locations and sampling schemes used, and include the following information if not provided by preliminary investigation:

- address;
- date and name of Artist;
- type of building construction;
- condition of main building;
- condition of lot (debris, standing water, vegetation cover);
- nature of adjacent property;
- presence and type of fence;
- animals on property;

- apparent use of yard (toys, sandbox, children present); and
- underground utilities.

6.7.2 Sampling Schemes

The sample scheme selected must adequately characterize the potential exposure of children to lead in the soil. The scheme utilized should reflect the size and proportions of the area to be sampled (see the protocols for details). Several options are offered for the best judgement of the investigator, and include:

- Line Source (LS) Pattern;
- Targeted Method (TM);
- Small Area (SA) Pattern; and
- Grid (G) Pattern.

Sampling Schemes are detailed in Appendix A-2.

6.8 Post-Abatement Sampling

Post-abatement sampling will be conducted in order to determine the effectiveness of abatement activities, and to monitor lead levels in the soil. Sampling shall be conducted in the same sampling locations as were used for the Preliminary Soil Phase Sampling (Section 6.6). The principal investigator will designate number of samples and specific location of these points. Detailed description of the sampling procedure is found in Appendix A-3.

7.0 CHAIN-OF-CUSTODY

7.1 General

EPA has established a program of sample chain-of-custody that is followed during sample handling activities in both field and laboratory operations.

Chain-of-custody procedures document the sample history and constitute a crucial part of sampling and analysis programs. Chain-of-custody documentation verifies the identification and history of a sample from collection through the time of analysis.

The objective of sample custody identification and control is to ensure that:

- all samples scheduled for collection, as appropriate for the data required, are uniquely identified;
- the correct samples are analyzed and are traceable to specific analysis records;
- important sample characteristics are preserved;
- samples are protected from loss or damage;
- any alteration of samples (e.g., filtration, preservation) is documented;
- a record of sample integrity is established for legal and technical purposes; and

The chain-of-custody record is used to:

- document sample handling procedures, including sample location, and sample number; and
- describe the chain-of-custody process.

The chain-of-custody description section requires:

- the sample number;
- the name(s) of the sampler(s) and the person shipping the samples;
- the date and time that the samples were delivered for shipping; and
- the names of those responsible for receiving the samples at the laboratory.

Samples of a chain-of-custody record for soils and dust samples are shown in Figure 7-1 and Figure 7-2 respectively.

As samples are collected, entries are made on the chain-of-custody forms. Data to be noted include:

- Date/Time;
- Samplers;
- Sample phase description ie. for soils: preliminary, detailed, post abatement or special study and for dust: post abatement, preabatement or other;
- Client/program;
- Analyses required;
- Special instructions/notes and
- Sample Identification information to include Premiss ID and Field ID numbers.

Soil and dust sample containers, will be labelled by LFK samplers with an indelible marker with station number/sample number and other appropriate information necessary to match the sample container to the Chain-of-Custody Record. (see Figure 7-3 and 7-4).

The station number/sample number shall be such as to allow tracking of the sample from its source of collection through analyses and be consistent with other site sample location identification systems.

When samples are received at the laboratory, the Laboratory Task Leader or Analyst will verify each and every sample against the chain-of-custody forms, note any discrepancies or losses of samples, and then sign for receipt of the samples. The laboratory task leader may also contact field personnel to resolve deficiencies, irregularities, discrepancies, etc., prior to accepting the samples. Samples will remain under the control of the laboratory task leader until samples are ultimately disposed of .

A sample is considered to be in custody if it:

- is in the physical possession of the responsible party;
- is in view of the responsible party;
- is secured by the responsible party to prevent tampering; or
- is secured by the responsible party in a restricted area.

Figure 7-1

- Soil -

Lead-In-Soil Demonstrtation Project

Chain-of-Custody Record

Prem. ID	Samp ID	Address	Dist.	Date Collected	Collected By

Relinquished By	Received By	Date	Time	Comments/Instructions

Figure 7-2
- Dust -
Lead-In-Soil Demonstrtation Project
Chain-of-Custody Record

DUST SAMPLES DATA FORM, STUDY PHASE _____

PREMID: _____ **Address:** _____ **Apt No.** _____

Date sample taken: _____ **Taken by:** _____

LFK children in this apartment: NAME, LFK NUMBER, and BEDROOM CODE(if needed)

_____ _____

_____ _____

	ROOM CODE	PLACE CODE	NOTE AREA		OR	CIRCLE TEMPLATE TYPE		SAMPLE WEIGHT	SAMPLE PPM	LABID
1.	____	____	____	x	____	25x25	24X24	_____	_____	_____
2.	____	____	____	x	____	25x25	24X24	_____	_____	_____
3.	____	____	____	x	____	25x25	24X24	_____	_____	_____
4.	____	____	____	x	____	25x25	24X24	_____	_____	_____
5.	____	____	____	x	____	25x25	24X24	_____	_____	_____
6.	____	____	____	x	____	25x25	24X24	_____	_____	_____
7.	____	____	____	x	____	25x25	24X24	_____	_____	_____
8.	____	____	____	x	____	25x25	24X24	_____	_____	_____
9.	____	____	____	x	____	25x25	24X24	_____	_____	_____
10.	____	____	____	x	____	25x25	24X24	_____	_____	_____

ROOM CODES:

K - Kitchen
L - Living Room
D - Dining Room
B1 - Bedroom 1
B2 - Bedroom 2 (etc.)
O1 - Other _____

PLACE CODES:

F - Floor
W - Window
O - Other _____

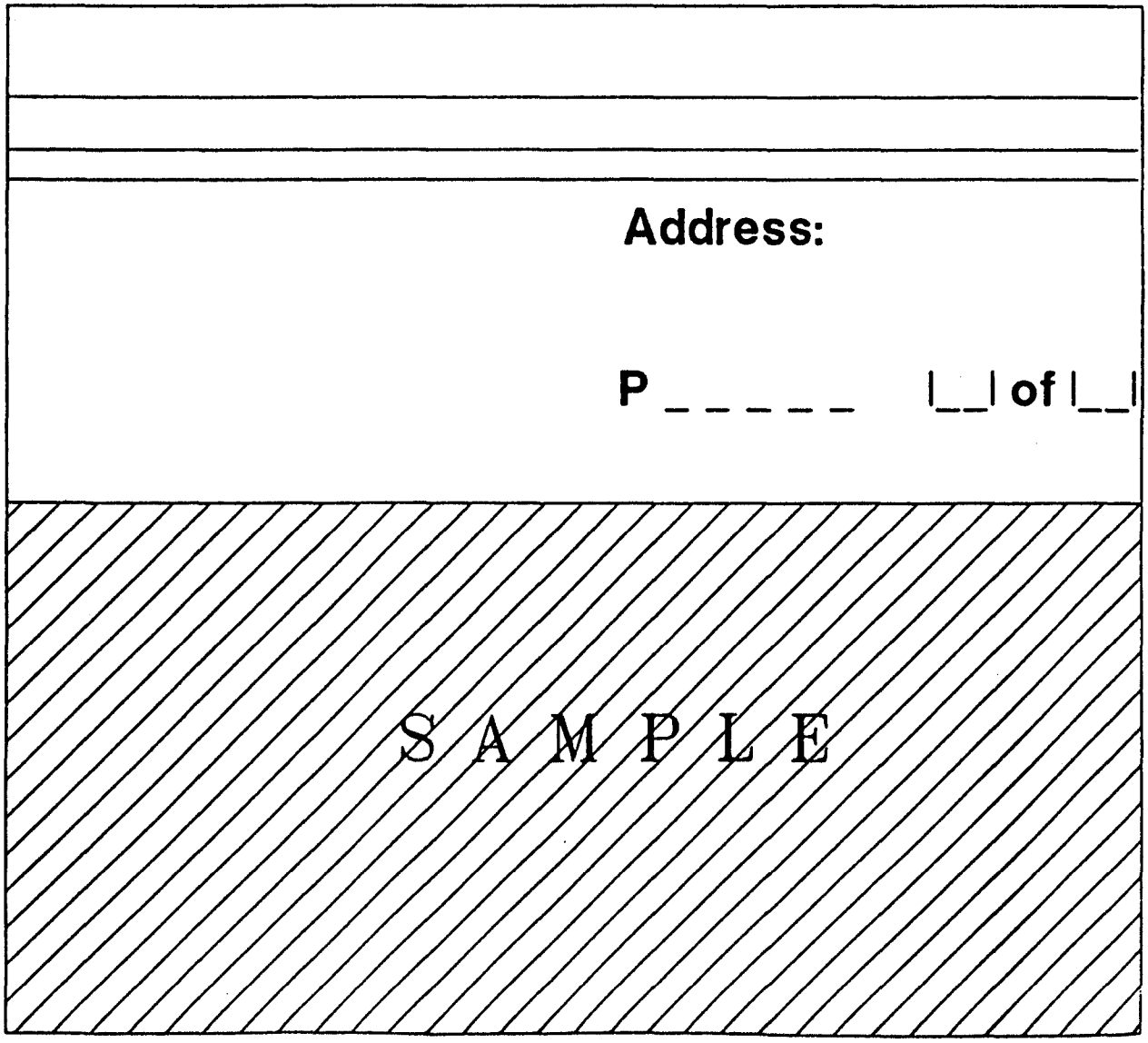
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)

Relinquished by: (Signature)	Date / Time	Received for Laboratory by: (Signature)	Date / Time	Remarks

FIGURE 7-3

Soil
Sample Container with
Sample Label

Plastic Ziplock Bag or Equivalent - Soil

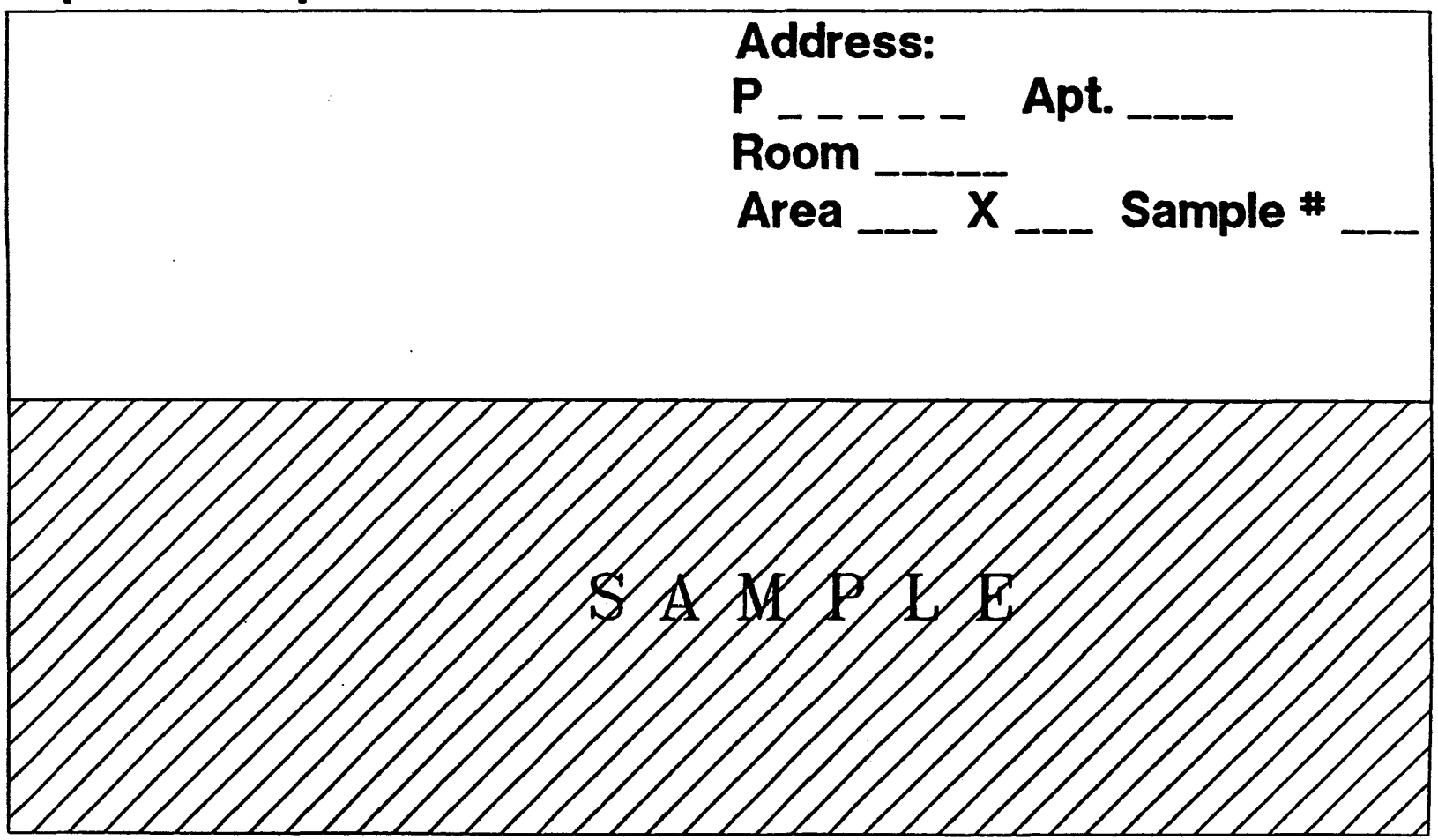


~ To Scale

FIGURE 7-4

Dust
Sample Container with
Sample Label

Paper Envelope - Dust



~ To Scale

7.1 Sample Receipt

All soil samples will be delivered to the Environmental Services Division Laboratory in Lexington, MA. by a member of the LFK field sampling team. Upon receipt chain-of-custody and sample integrity are to be checked and any problems recorded. Samples will then be logged in by EPA personnel or their contractors who will accept and sign the chain-of-custody record. The EPA project Manager will be informed of any deficiencies and will advise the laboratory on the desired disposition of the samples. Chain-of-custody forms and deficiency notices are maintained in the Laboratory's Project file.

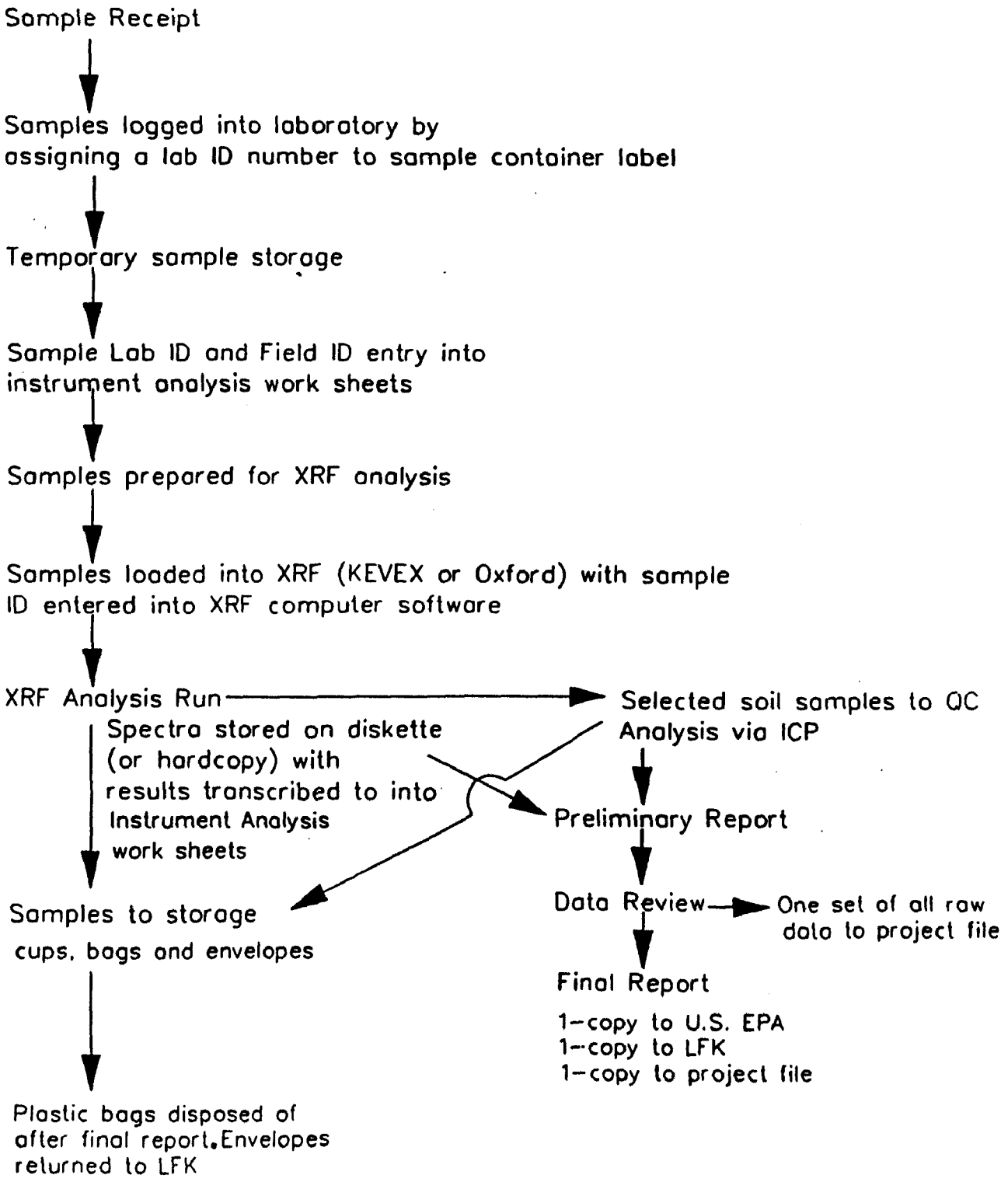
Each sample that is received by the laboratory is assigned a unique sequential Laboratory Identification number which will identify the sample in the laboratory's internal tracking system. The flow of samples and analytical data through the laboratory is shown in Figure 7-5 for soil and dust.

7.2 Sample Storage

All soil samples will be stored in a secure sample storage bank at the Region I ESD Laboratory facility.

Original sample containers (plastic baggies for soil and envelopes for dust), and laboratory analysis containers will be stored until each data report is finalized. Soil containers (plastic baggies) will be disposed of and envelopes returned to LFK staff. Analysis containers will be kept for duration of the project, a minimum of 3 years.

FIGURE 7-5
Sample and Data Progression Through Laboratory



8.0 CALIBRATION PROCEDURES AND FREQUENCY

8.1 Overview

Before any instrument can be used as a measurement device, the instrumental response to known reference materials must be determined. The manner in which the various instruments are calibrated depends upon the particular instrumentation and the intended use of the instrument. All sample measurements will be made within the calibrated range of the instrument. Preparation of all reference materials used for calibration will be documented in a standards preparation notebook. Good laboratory practices require general calibration procedures that should include:

- Preparation of standards that represent the range of concentrations of concern in the samples;
- For soil establishment of a concentration/response factor with a minimum of three points, using the standards prepared above and for dust, establishment of concentration/response spectra with a minimum of two points in both high and low sample weight ranges also using the standards prepared above;
- A set of secondary standards that can ultimately be traced to National Bureau of Standards (NBS) primary standards.

Inductively Coupled Plasma Spectrophotometry and X-ray Fluorescence are the two methods of analysis for the Demonstration Project. A separate discussion of calibration procedures and frequency for each of these measurement systems including each of the two X-Ray units used presented below.

8.2 Calibration and Frequency Procedures for Inductively Coupled Plasma Spectrophotometer

8.2.1 Calibration Procedures

The methods employed will be adapted from established EPA Methods as outlined in "Test Methods for Evaluating Solid Waste", SW 846, 3rd Ed., U.S. EPA Office of Solid Waste and Emergency Response, Nov. 1986. The quality assurance protocols are based upon the guidelines in "Handbook for Analytical Quality Control in Water and Wastewater Laboratories", EPA 600/4-79-0019, March 1979; "Methods for the Chemical Analysis of water and Wastewater", EPA 600/4-79-020, March 1983; and "Test Methods for Evaluating Solid Waste", EPA SW846, Nov. 1986.

Inductively Coupled Plasma spectrophotometer (ICP) will be calibrated each day before samples are analyzed. Calibration standards will be prepared from certified reference materials. Working calibration standards should exceed 6 month past date of preparation or exceed expiration date of the reference material. The working standards will include a blank and a minimum of three (3) concentrations to cover the anticipated range of measurement.

Duplicate injections will be made for each concentration. At least one of the calibration standards will be at the desired instrument detection limit. The correlation coefficient of the plot of known versus found concentrations will be at least 0.990 in order to consider the responses linear over the range to be tested. If a correlation coefficient of 0.990 cannot be achieved, the instrument will be recalibrated prior to analysis of samples. If a secondary wavelength is being used to detect lead a calibration must also conform with calibration procedures below.

Calibration data, to include the correlation coefficient, will be entered into laboratory notebooks to maintain a permanent record of instrument calibrations.

The following standards should be utilized for ICP analyses:

- Initial Calibration - ICP. New standards are prepared for each calibration sequence. Initial calibration is performed using a blank sample and at least three standards. A regression analysis is used to construct the calibration curve. Any regression with a coefficient of correlation below 0.990 is considered unacceptable and a re-calibration is required. Instrument calibrations are from microprocessor outputs, with chart-recorder graphs as supplemental documentation.

- Continuing Calibration. One of the calibration standards preferably at mid-range is analyzed every 10 samples to verify instrument stability. Results for the continuing calibration analysis must fall within the control limit of ±10 percent of the established mean value or re-calibration is required. Verify calibration every 10 samples and at the end of the analytical run, using a calibration and a single point check standard.

- Reference Standard. Independent reference standards traceable to NBS standards are analyzed to verify instrument performance. Any reference standard value outside the 95 percent confidence interval is considered suspect and re-calibration is required. This standard must be from a separate source than that of the certified reference material.

- Interference Check Solution. This solution should be analyzed at the beginning of each operating shift to verify the ability to detect lead at the specified wavelength without spectral interferences. The lead result should be within ± 20 percent of true value.

8.3 Calibration Frequency Procedures for X-Ray Fluorescence

8.3.1 Calibration Procedures for Soils Analysis using the Oxford XRF

The methods employed are based on accepted analytical procedures utilized in XRF analyses. The quality assurance protocols are based upon the guidelines outlined in "Test Methods for Evaluating Solid Wastes", EPA SW846, Nov. 1986.

The Oxford energy dispersive x-ray fluorescence spectrometer (XRF) will be calibrated prior to, during, and at the end of each day of use. A series of study control standards will be prepared from appropriate reference materials. Study control standards should include a blank and a minimum of four (4) concentrations spanning the anticipated range of measurement. Replicate analyses of study control standards will be performed for each concentration through the analysis day. At least one of the working study control standards will be at or below 1/2 the lowest action level. Calibration data to include calculation of the daily response factor will be entered into the laboratory analysis work sheets and placed in project files to maintain a permanent record of instrument calibration.

The following calibration standards should be utilized for Oxford XRF analyses:

- Study Control Standards (SCS). Daily calibration is performed using a blank sample and six SCS's. These will include the following concentrations of SCS's if available:

  0 ppm
  250 ppm
  400 ppm
  950 ppm
  1200 ppm
  2400 ppm
  4400 ppm

One of the SCS's is analyzed every 20 samples on a rotating basis to verify instrument stability. Results for this check sample must fall within the control limit of +/-20 percent of the day's established mean value or re-calibration is required.

- Reference Standard. Independent reference standards traceable to NBS standards are analyzed to verify instrument performance, (ia) available. Any reference outside of the 90 percent confidence interval is considered suspect and re-calibration is required.

8.3.2 - Calibration Procedures for Dust Analysis Using KEVEX 0700 XRF.

The methods employed are based on analytical procedures developed by Dr. Thomas Spittler USEPA for the KEVEX 0700 XRF analysis of dust. The quality assurance protocols are based upon the guidelines outlined in "test method for evaluating solid wastes", EPA SW846, Nov. 1986.

The KEVEX energy dispersive X-Ray Fluorescence Spectrometer (XRF) will be calibrated daily using a blank and a series of the four study control standards to generate calibration spectra for comparison to unknowns.

The first analysis run of the day will contain all four study control standards. In each of the following runs one of the 16 available analysis positions (in KEVEX Carousel) will contain one of these standards (* All standards are run manually).

Replicate analysis will be performed for each SCS through the analysis day. Calibration data to include results of the SCS analysis will be entered onto the laboratory analysis worksheets and the instrument software and placed in project files to maintain permanent record of instrument calibration.

Following calibration standards should be utilized for XRF analysis:

- Study Control Standards (SCS): Calibration is performed using a blank sample and the four SCS standards. These will include the following concentrations of standards and weight ranges.

Concentration	Weight	Name:	Samples to be used on
2500 ppm	10 mg	DustM-10-sequential #	0 - .024g
2500 ppm	50 mg	DustM-50-sequential #	> 0.25g
25,000 ppm	10 mg	DustH-10-sequential #	0 - .024g
25,000 ppm	50 mg	DustH-50-sequential #	> 0.25g

- Reference standard: Independent reference standards traceable to NBS standards are analyzed to verify instrument performance if available. Any reference outside of the 90 percent confidence interval is considered suspect and re-calibration is required.

SCS's have been prepared according to sample preparation procedures however, analysis is done manually as opposed to automatic analysis which is used for unknown samples. Daily calibration for each operating shift will contain all four standards and a blank. The set of SCS's will be run on the first carousel load of the day and will be used to generate comparison spectra used to calculate results of unknowns. The remaining 11 positions available in the carousel will be loaded will samples for analysis. In each of the following carousel runs, one of the 16 positions will contain one of these standards on a rotating basis. Results for this check control samples must fall within the control limit of $\pm$ 20 percent of the days established mean value or recalibration is required.

9.0 ANALYTICAL PROCEDURES

9.1 General

Analytical methods are routinely conducted as outlined in published sources (EPA, Standard Methods, ASTM, AOAC, etc.). Modifications to these methods may be necessary in order to provide accurate analyses of particularly complex matrices. When modifications to standard analytical methods are performed, the specific alternatives as well as the reason for the change will be reported with the results of analyses.

Laboratory reagents will be of a quality to minimize or eliminate background concentrations of the analyte to be measured. Reagents must also not contain other contaminants that will interfere with the analyte of concern.

9.2 Method of Analysis

The methods of analysis to be used in this project are Inductively Coupled Plasma (ICP) spectrometry and X-Ray Fluorescence (XRF). The XRF method is the suggested method for routine analyses. The ICP method should be used to verify lead concentrations in soil and dust and for other Quality Control/Quality Assurance determinations. All soil and dust samples for the LFK Demonstration Project will be prepared and analyzed according to the following procedures. A detailed description of sample analysis is found in Appendix B.

9.3 Sample Preparation (ICP/XRF)

A representative "urban soil sample" or "urban household dust sample" is defined as the sample fraction which passes through a 250 micron (#60 mesh) sieve.

Sample preparation requires that the samples be allowed to air dry overnight. Particle separation involves passing soil or dust through a 250 micron sieve. Light grinding of soils may be required to bring soils to disaggregation prior to the 250 micron sieving. This is necessary to provide low/appropriate variance in XRF analysis. For soil, aliquots of fines are then collected for both XRF and/or ICP analysis. Dust sample preparation will not require grinding prior to 250 micron sieving. However, the sample must be completely sieved and weighed. A minimum of 5 milligrams of dust is required for XRF analysis and no aliquots for ICP analysis will be prepared.

During the processing of the sample, it should be remembered that small soil and dust particles may individually be as high as 50,000 ug Pb/g, and paint fragments as high as 300,000 ug/g. Care should be taken to clean equipment (spatula, sieves, powder tunnels) between samples. The sieves and powder tunnels may be cleaned by tapping on a hard surface and blown free using compressed air to remove residual particles. Wet washing is not recommended as this will interfere with the sieving process. Detailed procedures for soil and dust sample preparation are found in Appendix B.

9.4 Atomic Emission Spectroscopy - ICP

9.4.1 Wet Digestion

The procedure used for digesting (solubilizing) the lead in soil is critical to the interpretation of the results of the Lead Free Kids Project - soil sample and dust sample analysis . EPA Method 3050, SW846 is a heated mineral acid digestion capable of leaching lead from the soil matrix and into aqueous matrix.

9.4.2 Analysis

Analysis by ICP, EPA Method 6010, SW846 3rd Edition, should be at 220.353 nm. This is the suggested protocol.

9.4.3 Quality Assurance/Quality Control (ICP)

The Laboratory Task Leader will provide the following QC samples:

- Laboratory Duplicates. One sample out of 20 is prepared and analyzed in duplicate. A control limit of +/-20 percent relative percent difference is used.

- Method Blanks. Procedural blanks are prepared and analyzed at a 5 percent frequency or one per batch digested if less than 20 samples.

- Matrix Spike/Matrix Spike Duplicate (MS/MSD). Duplicate samples are matrix spiked at ten times the detection limit prior to digestion at a frequency of 20 percent. Samples producing either spike recovery outside 75 to 125 percent control limits are re-analyzed by the "Method of Standard Additions". The matrix spike duplicate must fall within ±20 percent of true value.

- Laboratory Control Samples (LCS). Laboratory Control samples are prepared and analyzed according to each of the procedures applied to the samples. One LCS is prepared and analyzed once per operating shift. Percent recovery control limits of 80 to 120 percent must be attained. These maybe obtained through US EPA EMSL Las Vegas, Nevada and should be in a soil matrix.

- Field Blank. The field team will collect one blank per day by carrying a sample of clean quartz sand into the field in a normal sample container. The sample container will be opened and exposed during the collection of one sample, then closed and returned to the laboratory. The field blank represents contamination added in the field during storage and sample preparation.

- Study Control Standards (SCS). Project soil and dust study samples standards will be prepared and distributed at the beginning of the study. These will be analyzed in conjunction with LCS's. SCS samples will be used as calibration standards for XRF analysis. Their analysis via ICP will assist in assessing data quality of XRF data.

These QA/QC analysis will be performed at the frequency detailed below:

Field blank	1 per 20 samples
Laboratory control sample	1 per operating shift
Laboratory duplicate soil	1 per 20 samples
MS/MSD	1 per 20 samples
Method blank	1 per 20 samples or one per batch
SCS	1 per 20 samples

9.5 X-Ray Fluorescence

9.5.1 Sample Preparation for Dust and Soils.

Refer to Section 9.3 for overview and B Appendices for detailed procedures.

9.5.2 Analysis

The Oxford LX 1000 X-Ray Fluorescence Spectrophotometer is used for the identification and quantitation of lead in soil samples. The Kevex 0700 X-Ray Fluorescence Spectrophotometer is used for the

identification and quantitation of lead in dust samples. These protocols are presented in the appendices 3 and 4 respectively.

Quantification

The samples and standards are analyzed under identical conditions and the resulting peak heights of the standard and samples are compared for the Oxford, and after normalizing on the Compton scattering peak for the Mo target for the Kevex. The concentration of the lead in the sample is calculated by direct proportions of peak heights to standard concentrations.

9.5.3 Quality Assurance/Quality Control

Soil

The Laboratory Task Leader will provide the following QC samples:

- Study Control Standard (SCS). Project soil samples will be prepared and distributed at the beginning of this study. The SCS are prepared and analyzed according to the same procedure as applied to the samples. One set of SCS's are analyzed twice per operating shift once at the beginning and once at the end. During an operating shift individual SCS's, will be analyzed on a rotating basis,at the frequency of 1 per 20 samples. Percent recovery control limits of 80 to 120 percent should be attained.

- Method Blank. Procedural blanks consisting an empty analysis cup are analyzed at frequency of twice per operating shift.

- Laboratory Duplicates. One sample out of 20 is prepared and analyzed in duplicate. A control limit of 20 percent relative percent difference is suggested.

- Confirmatory ICP Analysis. Selected samples from XRF analysis will be submitted for ICP confirmatory analysis at the frequency of 1 per 20 samples analyzed. Selected samples will be include SCS's, Duplicate and Replicate samples, and field blanks. The frequency may be decreased to 1 per 40 or more if data suggests a good correlation between ICP and XRF results.

- Field Blank. The field team will collect one blank per day by carrying a sample of clean quartz sand into the field in a normal sample container. The sample container will be opened and exposed during the collection of one sample, then closed and returned to the laboratory. The field blank represents contamination added in the field during storage and sample preparation.

- Laboratory Replicate. One sample per 20 is analyzed in replicate. A control limit of 20 percent relative percent difference is suggested.

These QC analyses will be performed at the following frequency:

Laboratory control samples	At minimum one set if SCS analyzed twice per operating shift, at the beginning and end. Then, one SCS per 20 samples on a rotating basis during the shift.
Field blank	1 per field sampling day
Method blank	2 per operating shift
Laboratory duplicate	1 per 20 samples
Laboratory Replicate	1 per 20 samples
Confirmatory ICP Sample	1 per 20 samples (subject to change)

Dust

The Laboratory Task Leader will provide the following QC samples:

- Study Control Standards (SCS). Project dust samples will be prepared and distributed at the beginning of this study. The SCSs are prepared and analyzed according to the same procedure as applied to samples submitted for anlaysis. One set (consisting of 4 standards) of SCS's are analyzed at the beginning of an operating shift . During an operating shift individual SCS's, will be analyzed on a rotating basis, at the frequency of 1 per 16 samples. Percent recovery control limits of 80 to 120 percent should be attained.

- Method Blank. Procedural blanks consisting an empty analysis cup are analyzed at frequency of twice per operating shift.

- Laboratory Duplicates. Due to the small quantity of sample typically submitted for analysis laboratory duplicates analysis will not be performed.

- Confirmatory ICP Analysis. Selected samples may be submitted for ICP confirmatory analysis at the frequency of 1 per 20 samples analyzed if practical. Selected samples will include SCS's, and samples which contain sufficient quantity for analysis, a minimum of 1 gram requried for analysis. The frequency may be decreased if data suggests a good correlation between ICP and XRF results.

- Field Blank. No field blanks will be prepared for this study.

- Laboratory Replicate. One sample per 20 is analyzed in replicate. A control limit of 20 percent relative percent difference is suggested.

These QC analyses will be performed at the following frequency:

Laboratory control samples	At minimum one set of SCSs are analyzed at the beginning of a shift. Then, one of SCS's per 15 analysis on a rotating basis during the shift.
Method blank	2 per operating shift
Laboratory Replicate	1 per 20 samples
Confirmatory ICP Sample	1 per 20 samples (if applicable)

10.0 DATA ANALYSIS, VALIDATION, AND REPORTING

10.1 Data Analysis and Reduction

In addition to the data collected in the field and recorded on the chain-of-custody forms, data describing the processing and analysis of samples will be accumulated on the laboratory and recorded on laboratory Analytical work sheets. Laboratory analytical work sheet will contain:

- Date of processing or analysis;
- Laboratory sample identification numbers;
- Field identification sample number;
- Analyses or operation performed;
- Calibration data;
- Quality control samples data;
- Concentrations/dilutions required;
- Instrument readings;
- Special observations (operational); and
- Analyst's, reviewer's, and person making calculations signature.

Data reduction is performed by the individual analysts which consists of calculating concentrations in samples from the raw data obtained from the measuring instruments. The complexity of the data reduction will be dependent on the specific analytical method and the number of discrete operations (extractions, dilutions, weighing (dust) and concentrations) involved in obtaining a sample that can be measured.

ICP

For ICP the analytical method which utilizes a calibration curve, sample responses will be applied to the linear regression line to obtain an initial raw result which is then factored into equations to obtain the estimate of the concentration in the original sample. Rounding will not be performed until after the final result is obtained to minimize rounding errors. Results will not normally be expressed in more than two significant figures.

Soil

XRF analysis of soils using the Oxford utilizes a response factor methodology. A response factor is generated on a daily basis by analyzing the SCS. which fall in each of the four concentration ranges of the Oxford instrument. The response factor is calculated by measuring the peak height of the L-Alpha line (in millimeters) for the SCS and then dividing it into the SCS's assigned value. All other unknowns, for a specific concentration

range are then determined by multiplying their peak heights by the response factor. Rounding is performed for the response factor to the nearest 10. Rounding is performed on final results so they may be expressed in no more than two significant figures.

Dust

XRF analysis of dust using the Kevex utilizes a peak comparison methodology. In this procedure SCS Spectra are generated for comparison with unknowns. L-Alpha peaks of the SCS and unknown are overlayed on a video screen after normalizing for the compton scatter and concentrations are read directly by comparison using the screen's grid marks. Measurement of unknowns is dependent on sample weight and concentration. An unknown spectra is generated first, then based on weight and concentration, the appropriate SCS is selected for overlay and the concentration is determined. Rounding is done at the time concentration determination with results expressed in two significant figures.

Copies of all raw data and the calculations used to generate the final results will be retained on file to allow reconstruction of the data reduction process at a later date. ICP laboratory data and Kevex XRF diskettes containing spectra for dust analysis will be maintained by US EPA in Lexington, MA. All other data will be maintained in contractor files until project termination.

10.2 Data Validation and Review

Validation of measurements is a systematic process of reviewing a body of data to provide assurance that the data are adequate for their intended use. The process includes the following activities:

- editing,
- screening,
- checking,
- auditing,
- verification,
- certification, and
- review.

Data validation activities will be documented and records kept of any necessary corrective or remedial action.

System reviews are performed at all levels. The individual analyst constantly reviews the quality of data through calibration checks, quality control sample results, and performance evaluation

samples (ICP Analysis only). These reviews are performed prior to submission to the Data Reviewer or the Task Leader.

The Data Reviewer and/or the Task Leader review data for consistency and reasonableness with other generated data and determine if program requirements have been satisfied. Selected hard copy output of data (chromatograms, spectra, laboratory work sheets, etc.) will be reviewed to ensure that results are interpreted correctly. Unusual or unexpected results will be reviewed, and a resolution will be made as to whether the analysis should be repeated. In addition, the Task Leader or Data Reviewer will recalculate selected results to verify the calculation procedure.

The Region I ESD Quality Assurance Officer independently conducts a complete review of selected projects to determine if laboratory and quality assurance/quality control requirements have been met. Discrepancies will be reported to the Project Manager and/or Technical Project Director for resolution.

10.3 Data Reporting

Laboratory reports of data will be edited by comparing with original calculations. Subsequent data tabulations will be edited by comparing with the laboratory analytical work sheets.

Reports will contain final results (uncorrected for blanks and recoveries), methods of analysis, levels of detection (ICP Analysis only), and method blanks data. In addition, special analytical problems, and/or any modifications of referenced methods will be noted. The number of significant figures reported will be consistent with the limits of uncertainty inherent in the analytical method. Consequently, most analytical results will be reported to no more than two significant figures. Data are normally reported in units commonly used for the analyses performed. Concentrations in liquids are expressed in terms of weight per unit volume (e.g., milligrams per liter). Concentrations in solid or semi-solid matrices are expressed in terms of weight per unit weight of sample (e.g., milligrams/kilogram, ppm).

Reported detection limits will be the concentration in the original matrix corresponding to the low level instrument calibration standard after concentration, dilution, and/or extraction factors are accounted for.

Prior to issuance of a report for soil and dust analysis, results reported for each sample are verified to assure proper identification by comparing the chain-of-custody forms, laboratory analytical work sheets, and raw data. Based on the results of this

validation procedure, the laboratory certifies that the results are in compliance with the quality assurance objectives for accuracy and precision. Upon certification by the Task Leader, the report is reviewed by the QAC (if deemed necessary), then provided to the Project Manager for distribution.

ICP results reported for dust and soil analysis are verified and reported according to US EPA, Lexington, MA Laboratory procedures.

11.0 INTERNAL QUALITY CONTROL CHECKS

11.1 General

For each major measurement parameter, appropriate quality control checks shall be established. Field blanks should be taken to check for contamination introduced during sample collection and shipping. Study control samples should be analyzed to determine the accuracy of the analytical technique. Laboratory replicates and duplicates should be analyzed to determine the precision of the analysis. Spiked (fortified) samples should be used to determine the accuracy of the analysis (ICP only).

ICP Confirmatory Analysis of selected soil and dust will assist in assessing the comparability between XRF and ICP results.

11.2 Field Blanks

No field blanks for dust are required at this time. Field blank samples for soil/sediment matrices are not readily available, however quartz sand will be used. Field blanks will be prepared at the rate of one per sampling event day. Enough sample will be prepared for both XRF and ICP analysis. A Field Blank will be submitted for XRF analysis for each batch of samples associated with a sampling event day. Samples selected for ICP analysis will be accompanied by selected Field Blanks not necessarily representing their sampling event day(s).

11.3 Laboratory Duplicate

For soils and ICP analysis duplicate soil samples should be prepared in the laboratory at a rate of one per every 20 samples analyzed. For dust laboratory duplicate will not be prepared due to the small amount of sample typically collected.

11.4 Laboratory Control Samples (ICP only)

Laboratory control samples (LCS) consisting of secondary standards ultimately traceable to National Bureau of Standards (NBS) or EPA Environmental Monitoring and Surveillance Laboratory (EMSL) primary standards will be prepared for ICP. The LCS will be analyzed at least once per operating shift and should fall within the established recovery control limits of 80 to 120 percent.

11.5 Completeness

Completeness of scheduled sample collection will be controlled in the field by comparing predetermined sample locations on the gridded lot plan for each residential property with samples collected in the field at that site each day. Daily checking of site log books and chain-of-custody logs will provide further control on documentation and completeness. The determination of the completeness objective will be the responsibility of the QAC.

11.6 Study Control Standards (SCS)

XRF analysis Study Control standards for soil and dust have been made available by Dr. Thomas Spittler U.S. EPA. For soil analysis the SCS's are analyzed as a set twice per operating shift once at the beginning and once at the end with individual SCS's analyzed during the shift at a frequency of 1 per 20 samples analyzed on a rotating basis. The daily SCS results should fall within control limit of 80 to 120 percent of their respective concentrations. For dust SCS's are analyzed once at the beginning of the shift and results should also fall within 80 to 120 percent or their respective concentrations.

11.7 Laboratory Replicates

Replicate soil and dust samples analysis will be conducted at a rate of one per 20 samples analyzed.

11.8 Comparability - ICP Confirmatory Analysis

Selected soil and dust XRF samples will be submitted for confirmatory analysis using Inductively Coupled plasma Emission Spectrophotometry at a frequency of one per 20 samples analyzed (this frequency may be decreased at a later date). ICP and XRF analysis will be compared to define the limits of comparability between these two methods.

12.0 AUDITS

Quality assurance audits are performed to assure and document that quality control measures are being utilized to provide data of acceptable quality and that subsequent calculations, interpretation, and other project outputs are checked and validated.

The Quality Assurance Coordinator (QAC) will conduct system and performance audits and reviews of interpretations and reports based on the measurement system outputs. If any of the procedures to assess precision and accuracy described in Section 14.2 indicate potential data problems, an audit will be initiated, if appropriate.

12.1 Systems Audit

A systems audit will be conducted on all components of measurement systems to determine proper selection and utilization. The systems audit includes evaluation of both field and laboratory procedures.

Organization and personnel. The project organization is reviewed for compliance with the proposed organization and for clarity of assigned responsibility. Personnel assigned to the project will be reviewed to determine that assigned responsibility, skill, and training of the personnel are properly matched. The Technical Director maintains firsthand knowledge of his team's capabilities and will discuss the organization's efficacy with the QAC. Assigned personnel may be interviewed by the QAC during an audit.

Facilities and Equipment. The audit will address whether field tools and analytical instruments are selected and used to meet requirements specified by the project objectives stated in the QAPjP. Equipment and facilities provided for personnel health and safety will also be evaluated. Documentation procedures used in the field will receive special attention.

Analytical Methodology. Routine external performance evaluations as well as blind internal performance evaluations are generally conducted. A review of analytical methodology in regard to the data requirements for the project will also be performed. An in-laboratory observation of analyst technique, data reduction, and record keeping may be performed if determined necessary. Periodic review of precision and accuracy data is essential.

Sampling and Sample Handling Procedure. An audit of scheduled samples vs. samples collected vs. samples received for analysis may be performed. Field documentation will be reviewed. If deemed necessary, a site visit will be made to assure that designated control procedures are practiced during sampling activities.

Data Handling. During a systems audit, the QAC will review data handling procedures with the TD and Task Leaders. Accuracy, consistency, documentation, and appropriate selection of methodologies will be discussed.

12.2 Performance Audits

These audits are intended primarily for analytical and data generation systems. The EPA Region I ESD laboratory regularly participates in, and successfully completes U.S. EPA Performance Evaluations (WS and WP Series). Ongoing performance evaluations include duplicates, matrix spikes, QC check samples, etc., with regard to ICP analysis.

12.3 Project Audits

Project audits encompass the aspects of both the systems audit and the performance audits. The project audit typically occurs at least twice for a short-term project and more often during long-term projects. Timing is keyed to the systems involved and the project objectives.

12.4 Quality Assurance (QA) Audit Report

A written report (Figure 12-1) of the QA audit may be prepared to include:

- an assessment of project team status in each of the major project areas;
- clear statements of areas requiring improvement or problems to be corrected. Recommendations and assistance will be provided regarding proposed corrective actions or system improvements. If no action is required, the report will state that the QA audit was satisfactorily completed;
- a timetable for any corrective action required; and
- a follow-up to assure that recommendations have been implemented.

Figure 12-1
QUALITY ASSURANCE AUDIT REPORT

Project: _____

Project No.: _____

Quality Assurance Coordinator: _____

Project Aspects Audited: _____

Laboratory/Technical Director: _____

Audit Conducted By: _____

for the period _____ to _____

Date of Audit: _____

Personnel Interviewed: _____

1.0 Purpose and Objectives of the Project Aspects Audited
2.0 Brief Description of the Sampling and Analytical Requirements
3.0 Organization and Personnel
4.0 Facilities Utilized
5.0 Analytical Methodologies
6.0 Sampling and Sample Handling
7.0 Quality Control Measures Utilized
8.0 Data Handling
9.0 Quality Assurance Deficiencies
10.0 Recommended Correction Actions and Schedule

_____
Signed Date

_____
Title

Distribution:

_____
Reviewed by Date

_____
Title

13.0 PREVENTATIVE MAINTENANCE

Preventative maintenance of field equipment proceeds routinely before each sampling event. More extensive maintenance would be performed based on the number of hours in use. Preventative maintenance of EPA Region I ESD laboratory analytical equipment is the responsibility of that laboratory.

14.0 DATA ASSESSMENT

14.1 General

The purpose of data quality assessment is to assure that data generated under the program are accurate and consistent with project objectives. The quality of data will be assessed based on the precision, accuracy, consistency, and completeness of the data that are measured or generated.

Data quality assessment will be conducted in three phases:

14.1.1 Phase 1

Prior to data collection, sampling, and analysis, procedures are evaluated in regard to their ability to generate the appropriate, technically acceptable information required to achieve project objectives. This QA/QC Plan meets this requirement by establishing project objectives defined in terms of required sampling analysis protocols.

14.1.2 Phase 2

During data collection, results will be assessed to assure that the selected procedures are efficient and effective and that the data generated provide sufficient information to achieve project objectives. Precision and accuracy of measurement systems will also be evaluated. In general, evaluation of data will be based on performance audits, results of duplicate and reference sample analyses, and review of completeness objectives.

Documentation may include:

- number of duplicate and reference samples analyzed;
- identification of statistical techniques, if used, to measure central tendency, dispersion, or testing for outliers;
- use of historical data and its reference; and
- identification of analytical method.

14.1.3 Phase 3

Throughout the data collection activities, an assessment of the adequacy of the data base generated in regard to completing project objectives will be undertaken throughout the project. Recommendations for improved quality control will be developed, if appropriate. In the event that data gaps are identified, the QAC may recommend the collection of additional raw data to fully support the project's findings and recommendations.

14.2 Precision and Accuracy

Assessment of precision and accuracy of analytical data is accomplished via review of duplicate analyses (precision) and reference standard (accuracy) in soil. Precision is generally expressed as the relative percent difference (RPD). Accuracy is expressed as percent recovery. Precision must be assessed for each matrix, since distribution of contaminants may be non-homogeneous, especially in soil. Precision in samples must be reviewed with knowledge of the matrix and level of analyte present. Corrective action or documentation of substandard precision is the laboratory's responsibility. Accuracy is also impacted by matrix interferences. Each method which provides quality control requirements and acceptance criteria also specifies the method of generating the data to be reviewed. It is the laboratory's responsibility to attempt to identify the source of substandard recoveries and either take corrective action or document the cause.

Calculations are presented below:

Accuracy:

$$\%R = \frac{\text{observed value}}{\text{theoretical value}} \times 100$$

where: %R = percent recovery

Precision control requirements and acceptance criteria also specifies the method of generating the data to be reviewed. It is the laboratory's responsibility to attempt to identify the source of substandard recoveries and either take corrective action or document the cause.

Precision (as determined by Relative percent difference):

$$RPD = \frac{(A1 - A_2)}{(A_1 + A_2)/2} \times 100$$

where:

RPD = relative percent difference

A_1 = the value of the first sample

A_2 = The value for the duplicate sample

14.3 Completeness

Completeness is generally assessed as a percentage of data intended to be generated, and is most often utilized in Phase 3 of the data assessment process. Assessment of completeness will be undertaken by the QAC in co-operation with LFK staff.

15.0 CORRECTIVE ACTION

Corrective or preventative action is required when potential or existing conditions are identified that may have an adverse impact on data quantity or quality. Corrective action could be immediate or long-term. In general, any member of the program staff who identifies a condition adversely affecting quality can initiate corrective action by notifying in writing his or her supervisor and the QAC. The written communication will identify the condition and explain how it may affect data quality or quantity.

An analysis or analytical system is considered to be out-of-control when it does not conform to the conditions specified by the method or standard operating procedures which apply. To confirm that an analysis or analytical system is in control, the laboratory routinely performs instrument calibration checks, analysis of method blanks and method blank spikes. These results are compared to the results of quality control samples to laboratory control charts or analytical protocol criteria (e.g., U.S. EPA-CLP).

A Corrective Action Documentation Form, Figure 15-1, is to be completed for each out-of-control situation. The analyst, working with his or her supervisor or Task Leader, will attempt to determine the cause of the problem and take appropriate corrective action. Analysis may not resume until the problem has been corrected and it is determined that the analysis is back in control. Demonstration of the restoration of analytical control will normally be accomplished by generating satisfactory calibration and/or quality control sample data. This documentation will be attached to the corrective action documentation form to be placed in the project files.

15.1 Immediate Corrective Action

Immediate corrective action is applied to spontaneous, non-recurring problems, such as an instrument malfunction. The individual who detects or suspects nonconformance to specify the previously established criteria or protocol in equipment, instruments, data, methods, etc., will immediately notify his/her supervisor. The supervisor and the appropriate Task Leader will then investigate the extent of the problem and take the necessary corrective steps. If a large quantity of data is affected, the Task Leader must prepare a memorandum to the Project Manager, the Technical Project Director and the QAC. These individuals will collectively decide how to proceed. If the problem is limited in scope, the Task Leader will decide on the corrective action measure, document the solution in the appropriate workbook, and notify the Project Coordinator, the Technical Project Director, and the QAC.

15.2 Long-Term Corrective Action

Long-term corrective action procedures are devised and implemented to prevent the recurrence of a potentially serious problem. The QAC will be notified of the problem and will conduct an investigation to determine the severity and extent of the problem. The QAC will then file a corrective action request with the Project Manager.

Corrective actions may also be initiated as a result of other activities, including:

- Performance Audits;
- System Audits;
- Laboratory field/comparison studies; and
- QA Program Audits.

The QAC will be responsible for documenting all notifications, recommendations, and final decisions. The Project Coordinator and the QAC will be jointly responsible for notifying program staff and implementing the agreed upon course of action. The QAC will be responsible for verifying the efficacy of the implemented actions. The development and implementation of preventative and corrective actions will be timed, to the extent possible, so as to not adversely impact either project schedules or subsequent data generation/processing activities. However, scheduling delays will not override the decision to correct any data collection deficiencies or inaccuracies before proceeding with additional data collection. The QAC will also be responsible for developing and implementing routine program controls to minimize the need for corrective action.

FIGURE 15-1
CORRECTIVE ACTION DOCUMENTATION FORM

DESCRIPTION OF PROBLEM and when identified: _____

State cause of problem if known or suspected: _____

SEQUENCE OF CORRECTIVE ACTION: (If no responsible person is identified, bring this form directly to the QA Coordinator)

State date, person, and action planned: _____

CA Initially Approved By: _____

Date: _____

Follow-up dates: _____

Description of follow-up: _____

Final CA Approved By: _____

Date: _____

16.0 REPORTS TO MANAGEMENT

Periodic summary reports will be prepared to inform management of project status. The reports will include:

- periodic assessment of measurement data accuracy, precision, and completeness;
- results of performance audits and/or systems audits;
- significant QA problems and recommended solutions; and
- status of solutions to any problems previously identified.
- Periodic Analytical Summary Progress Reports which includes results for soil and dust sample analysis and an on-going status of samples received, analyzed and reported.

Additionally, any incidents requiring corrective action will be fully documented. Procedurally, the QAC will prepare the reports to management. These reports will be addressed to the Project Manager, with copies to the Technical Project Director and the QAC. The summary of findings shall be factual, concise, and complete. Any required supporting information will be appended to the report.

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