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LEAD-BASED PAINT ABATEMENT AND REPAIR AND MAINTENANCE STUDY IN BALTIMORE: PRE-INTERVENTION FINDINGS

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CONTRIBUTING ORGANIZATIONS

The study described in this report was funded by the U.S. Environmental Protection Agency (EPA). The study was managed by EPA and conducted collaboratively by several organizations undercontract to EPA. Each organization's responsibilities are listed below.

Kennedy Krieger Research Institute (KKRI)

KKRI was primarily responsible for the overall design and conduct of this study, including the field, laboratory and data analysis activities, and the preparation of this report.

Battelle Memorial Institute

Battelle managers and staff provided technical and administrative support during the planning phase of the study including planning, conducting and reporting on the pilot field study, the compilation of the Quality Assurance Project Plan for the main study, and the initiation of data collection.

Midwest Research Institute

Midwest Research Institute had substantive input to the Quality Assurance Project Plan and provided sampling and analysis support in the planning and pilot phases of the study.

Maryland Department of Housing and Community Development (MDDHUD)

MDDHCD reserved loan funds from a special residential lead paint abatement loan program to finance the Repair & Maintenance interventions in this study.

US Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA) was responsible for managing the study, for providing technical oversight, guidance and direction, and for overseeing the peer review and finalization of the report. The EPA Project Leader was Benjamin S. Lim. The EPA Work Assignment Managers were Benjamin S. Lim and Brad Schultz. The EPA Project Officers were Phil Robinson and Jill Hacker. Cindy Stroup was the Branch Chief of the Technical Programs Branch (TPB) who initiated this study and provided valuable input. Special Acknowledgment is given to Darlene Watford, the Acting Methods Section Chief, for her careful review and input.

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EXECUTIVE SUMMARY

The Lead-Based Paint Abatement and Repair and Maintenance (R&M) Study is a longitudinal study of housing intervention strategies designed to reduce children's exposure to lead in paint and in settled dust in their homes. The R&M study is design to characterize and compare the short-term (2 to 6 months) and longer-term (12 to 24 months) efficacy of comprehensive lead-paint abatement with less costly and potentially more cost-effective R&M interventions designed to reduce children's exposure to lead in residential paint and dust. The R&M Study may provide a practical means of reducing exposure for future generations of children who will occupy lead-painted housing. This study targets low-income housing where children are at high risk.

R&M Level I includes the following elements: wet scraping of peeling and flaking lead-based paint on interior surfaces; limited repainting of scraped surfaces; wet cleaning with a tri-sodium phosphate detergent (TSP) and vacuuming with a high efficiency particulate air (HEPA) vacuum to the extent possible in an occupied house; the provision of an entryway mat; the provision of information to occupants and owners; and stabilization of exterior surfaces to the extent possible given the budget cap. R&M Level II interventions include all elements in Level I plus floor treatments to make them smooth and more easily cleanable and in-place window and door treatments to reduce abrasion of lead painted surfaces. R&M Level III interventions include all of the elements in Levels I and II and window replacement and encapsulation of exterior window trim with aluminum coil stock as the primary window treatment, the encapsulation of exterior door trim with aluminum, and more durable floor and stairway treatments. All R&M Study households receive cleaning kits for their own wet cleaning efforts. The kits include a bucket, sponge mop, a replacement sponge mop head, sponges, a TSP cleaning agent, and the EPA brochure entitled "Lead Poisoning and Your Children."

This report is based on the initial data collection campaign, which was conducted between January 1993 and November 1994. The initial campaign provides pre-intervention baseline data for the study of changes in lead concentration in children's blood and in settled house dust associated with three levels of R&M interventions. These baseline data are cross-sectional in nature and complement another cross-sectional study of lead-contaminated house dust and children's blood lead concentration conducted in Rochester, New York.[1] The main conclusions and findings of this report are as follows:

- Enrollment and data collection goals were attained from five study groups: houses designated for the three R&M interventions (Levels I through III), previously abated control houses that received comprehensive abatement in the past, and modern urban control houses built after 1979, which are presumably free of lead-based paint. A total of 107 houses with 140 children were studied.

- Geometric mean blood lead concentrations and ranges by group were: R&M Level I, 10 µg/dL, R&M Level II, 14 µg/dL; R&M Level III, 14 µg/d previously abated, 13 µg/dL;

and modern urban. Blood lead concentrations were found to be statistically significantly lower in children within the modern urban group as compared to the other groups.

- Weighted measures of dust lead concentrations within an entire house were nearly two orders of magnitude higher in R&M houses (Levels I to III: 19,000, 14,400 and 17,500 µg/g, respectively) than in modern urban houses (235 µg/g). Differences were larger for lead loadings (R&M Levels I to III, 16,600, 24,000 and 47,500 µg/ft^2, respectively; modern urban houses, 83 µg/ft^2). Previously abated houses had intermediate lead concentrations (2,400 µg/g) and loadings (900 µg/ft^2). In these houses the geometric mean lead loadings for floors and window sills, but not window wells, remained at or below HUD's interim clearance standards (100, 500, and 800 µg/ft^2, respectively).

- Children's blood lead concentrations were significantly correlated with lead levels in house dust from entryway and six types of interior surfaces (correlations ranging from r=.27 to .64). Lead loadings and concentrations in dust from the various surface types were moderately to highly correlated with each other.

- Statistically significant differences were not found between R&M groups at the baseline in terms of blood lead concentration, environmental lead levels, and population demographics; however, lead levels tended to be highest in vacant R&M Level III houses, lowest in occupied R&M Level I houses, and intermediate in R&M Level II, which was a mix of vacant and occupied houses.

- No evidence was found for selection bias when R&M study houses were compared to houses that were considered for the study but later rejected for reasons explained herein.

- Laboratory performance and data quality objectives were met.

Future reports on the R&M study will include longitudinal data from multiple post-intervention sampling campaigns to be conducted during a two-year follow-up period.

1.0 INTRODUCTION

1.1 Report Objectives

The Lead-Based Paint Abatement and Repair & Maintenance (R&M) Study in Baltimore is a longitudinal study of housing intervention strategies designed to reduce children's exposure to lead in paint and in settled dust in their homes. This report is based on the initial data collection campaign, which was conducted between January 1993 and November 1994. The initial campaign provides pre-intervention baseline data for the study of changes in lead concentration in children's blood and in settled house dust associated with three levels of R&M interventions. These baseline data are cross-sectional in nature and complement another cross-sectional study of lead-contaminated house dust and children's blood lead concentration conducted in Rochester, New York.[1] Future reports on the R&M study will include longitudinal data from multiple post-intervention sampling campaigns to be conducted during a two-year follow-up period. The objectives of this report on the initial campaign are as follows:

- Describe the study objectives, design, and methodologies which are explained in detail in the Quality Assurance Project Plan.[2]

- Present descriptive statistics on baseline demographic, environmental, and biological data for the five groups of study houses, *i.e.*, houses designated for R&M intervention Levels I through III, modern urban control houses built after 1979, and previously abated control houses that received comprehensive abatement in the past, and the residents of these houses. The study includes a total of 107 houses and 140 children.

- Investigate potential selection bias by comparing the study houses designated for R&M interventions to houses that were considered for study but rejected for reasons explained herein.

- Assess the correlations between the lead levels in various types of environmental samples and between concentrations of lead in children's blood and these environmental samples.

- Report on compliance with data quality objectives and performance on laboratory quality control samples.

1.2 Purpose Of The R&M Study

Past studies have documented the short-term (2 to 6 months) and longer-term (12 to 24 months) effectiveness of comprehensive approaches to residential lead paint abatement.[3,4] The R&M study is designed to characterize and compare the short-term and longer-term efficacy of less costly and potentially more cost-effective R&M intervention strategies for reducing children's exposure to lead in residential paint and settled house dust. This research is important because house dust and residential paints containing lead have been identified as major sources of lead in U.S. children.[5-9] Exposure occurs primarily via the hand-to-mouth route of ingestion.[6, 10-13] Families with children less than seven years of age occupy approximately 10 million of the 57 million privately owned and occupied U.S. housing units which are estimated to contain some lead-based paint.[14] Children living in the nearly 4 million houses with deteriorating paint and elevated dust lead levels are at highest risk of exposure.[14] Given the extent and potential costs of remedying the lead abatement problem in U.S. housing, the preventive R&M approach may provide a practical means of reducing exposure for future generations of children who will continue to occupy housing containing lead paint. This study represents the first systematic examination of the R&M approach.

The research goal of the R&M study is to contribute to the existing scientific bases needed to develop a standard of care for lead-painted houses through the analysis of environmental and biological data from a longitudinal intervention study. Specific study objectives are as follows:

- Measure and compare the short-term and longer-term changes of lead concentration and loading in settled house dust and in children's blood lead concentrations associated with R&M intervention Levels I to III with houses that had undergone previous comprehensive abatement, as well as a group of modern urban houses presumably free of lead-based paint.

- Evaluate methodologies for the collection and analysis of lead in residential dusts, including wipe and cyclone methods. (This objective has been addressed in previous reports.[15-17])

- Characterize the nature of the relationship between lead in children's blood and settled house dust.

1.3 Peer Review

The draft report on the initial data collection campaign was reviewed by three independent external reviewers. A summary of their comments is presented below. Responses to comments are reflected in the report.

1. One reviewer commented that the report assumed that the reader was familiar with the study and recommended that the text be revised to provide more of an introduction. The report was reorganized to provide additional information (background, purpose, design, and methods) prior to the presentation of the findings.

2. Reviewers commented that a more detailed description was needed of the features and characteristics of the housing stock that was sampled in the intervention and control groups. It was pointed out that differences in housing characteristics may influence how dust travels into and within a dwelling and that these differences among the three R&M groups might confound later results in the post-intervention phase. Based on these comments, section 2.5 on housing characteristics was added to the report showing that study houses were generally similar in terms of characteristics that might be expected to influence patterns of dust movement into and within a house (*i.e.*, overall house size, number of windows, house type and design, condition, degree of setback from the street, and the presence of porches and yards). All five groups of study houses are primarily two-story rowhouses, which are common in Baltimore.

3. A related comment was made concerning the size of the group of modern urban control houses built after 1979 and their apparent location in neighborhoods with different ambient dust lead levels than the other groups. Additional text was added to the report explaining that the planned sample sizes of the two control groups were reduced from 25 to 16 houses each, due to reductions in the scope and funding of the project as originally planned. The number of control houses was reduced rather than the number of R&M houses because the former (and in particular the modern urban houses) were expected to have less inter-house variability with respect to both blood lead and dust lead. This assumption was borne out in the study findings. Furthermore, when the sample sizes were reduced, only houses in clusters of urban houses built after 1979 were included (as opposed to scattered-site housing) as the control group containing no lead paint because we expected this type of housing to reflect the lowest residential and ambient lead levels in the urban environment. While the study did not include street or playground dust, which would have been useful in comparing ambient lead levels, differences in lead levels in drip-line soil and exterior entryways between groups provided some evidence that the modern urban group, as anticipated, did differ from the other four study groups in terms of ambient lead levels.

4. A reviewer asked about the criteria for determining the need for additional cleanups/repairs in the R&M houses during the post-intervention follow-up period. The need for further cleanups/repairs during the entire follow-up period will be determined by a comparison of the follow-up dust lead loadings and blood lead concentrations in children to their corresponding levels prior to intervention (see section 2.1).

5. One reviewer asked whether the eligibility criterion for R&M houses regarding pre-intervention dust lead loadings was based on geometric mean lead loadings exceeding clearance loadings or a certain proportion of samples exceeding clearance loadings. Eligibility is based on houses having samples from a minimum of three locations with dust lead loadings that exceed Maryland's interim post-abatement clearance levels (*i.e.*, 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window wells). Since seven or eight interior dust samples were collected from each house from these three surfaces, then a minimum of 38 percent (3/8) to 43 percent (3/7) of the interior dust samples needed to exceed clearance levels in order for a house to qualify. Half or more of the dust samples in all R&M houses had lead loadings in excess of clearance levels.

6. A reviewer commented that information on the temporal relationship of blood lead collection to dust sampling would be helpful in interpreting the study findings. A section was added to the report explaining that the question of the temporal relationship of blood lead data to environmental lead data is relevant only for study houses that were occupied at the time of the intervention. The initial blood lead concentrations of the children moving into the vacant houses after R&M intervention would not reflect an equilibrium with their new environment. In occupied houses, the vast majority (72 to 93 percent by group) of the corresponding initial campaign blood and environmental samples were collected within three weeks of each other and, in nearly all cases, within 35 days of each other. The text also includes information on the time periods in which the environmental samples were collected by group.

It should be noted that EPA has established a public record for peer review under Administrative Record 159. The record is available in the TSCA Nonconfidential Information

Center located in Room NE-B607, Northeast Mall, 401 M Street, SW, Washington, D.C. The Center is open from 12:00 noon to 4:00 pm, Monday through Friday, except for legal holidays.

2.0 CONCLUSIONS

The enrollment and data collection goals of the initial campaign were attained, and the data are in compliance with laboratory performance objectives (see section 3.0). Therefore, the initial data collection campaign has produced valid baseline measurements for the longitudinal study of R&M interventions.

Houses that were candidates for R&M intervention were identified through the collaboration of private property owners and a housing organization. Additional field and laboratory efforts were required to attain the final study frame of 75 R&M houses. Twenty-seven R&M candidate houses were sampled and later excluded mainly due to the failure of owners to submit applications to the Maryland Department of Housing and Community Development for R&M loan funds, family moves, and concerns for the safety of field staff. Comparison of the excluded R&M-candidate houses to the 75 R&M houses showed no evidence of selection bias based on environmental lead concentrations, lead loadings, dust loadings, or the blood lead concentrations of resident children. Because of the apparent unwillingness of owners, as opposed to landlords, to apply for a state loan to do R&M work, the excluded group had a higher proportion of owner-occupants (19 percent) than did the R&M group (4 percent).

The three R&M groups under investigation were found to be comparable at the pre-intervention baseline. No patterns of statistically significant differences were found between R&M groups on environmental variables, children's blood lead concentrations, reported monthly rent/mortgage amounts, and ages of study children. However, R&M Level I houses tended to have the lowest baseline lead concentrations, lead loadings and dust loadings of the three R&M groups. R&M Level III houses tended to have the highest measurements, and R&M Level II houses registered intermediate measurements. This pattern may be due, in part, to the fact that at the time of sampling, all of the R&M Level I houses were occupied by study families, all of the R&M Level III houses were vacant, and the R&M Level II houses were a mix of occupied and vacant houses. Dust lead has been reported by others to accumulate in vacant houses.[25]

2.1 Environmental Lead

An examination of house dust data by surface type showed that within each study group window wells tended to have the highest dust lead concentrations and lead loadings; window sills and entryways had intermediate levels; and floor and upholstery items had the lowest levels. With regard to dust loadings, window wells and air ducts had the highest measurements across study groups, followed by interior entryways. These surfaces would be expected to be among those where dust accumulates in houses. In order to study houses in terms of overall dust lead levels and dust loadings, summary measures were calculated based on weighted averages of all sample types within a house.

Based on the overall weighted average measures of dust lead in a house, differences in lead concentrations of approximately one order of magnitude were found between modern urban and previously abated houses and between previously abated and R&M houses. Order of magnitude differences were also found between modern urban and previously abated houses in terms of overall lead loadings. Overall lead loadings in the R&M groups, however, were one to almost two orders of magnitude higher than those in previously abated houses and between two and three orders of magnitude higher than in the modern urban houses. The findings based on overall dust loadings had a similar ordering by group, but the relative differences between groups were much less pronounced. These patterns indicate that the higher dust lead loadings in R&M houses, relative to modern urban and previously abated houses, were due to higher dust lead concentrations in the R&M houses, and particularly in vacant units and on certain surface types (*e.g.*, window sills and wells), to a combination of higher lead concentrations and higher dust loadings.

Modern houses built after 1979 and located in clusters of urban housing were included in this study as a comparison group of houses that presumably contained little or no lead-based paint. Since 1978, the U.S. Consumer Product Safety Commission has limited the lead content of residential paints to only trace amounts for regulatory purposes (*i.e.*, to 0.06 percent by weight in the dried film[26]). This type of modern housing (located in clusters of similar housing as opposed to scattered site units built after 1979) is generally expected to reflect the lowest residential and ambient lead levels in the urban environment. This study did not include the collection of street dust or playground dust, which would be useful in comparing ambient lead levels. Lead concentrations measured in drip-line soil and exterior entryways, however, provided some evidence that the modern urban group did differ from the other four study groups in terms of ambient lead levels. In modern urban houses, lead concentrations in soil (geometric mean=63 µg/g; maximum=154 µg/g) and exterior entryway dust (geometric mean=137 µg/g; maximum=764 µg/g) were very low. In the other four groups, geometric mean dust lead concentrations in exterior entryway samples ranged from 2,200 to 7,000 µg/g, and the limited number of soil lead measurements ranged from 230 to 16,000 µg/g. The low soil lead concentrations in the modern urban group might be due to the use of replacement sod and soil around these houses at the time of construction, or at some other time in the past.

Like R&M houses, the previously abated houses are scattered-site properties located in older neighborhoods where, based on the age of the housing, houses are likely to contain lead-based paint. As mentioned above, these houses showed a pattern of intermediate dust lead concentrations and lead loadings relative to modern urban and R&M houses. The initial campaign data represent a point in time two to four years after the houses were abated using comprehensive methods. Notably, the study found that the geometric mean lead loadings for interior floors and window sills, but not window wells, remained below Maryland's interim clearance standards (200, 500, and 800 $\mu g/ft^2$ for interior floors, window sills and window wells, respectively) and the geometric floor levels were close to HUD's revised interim clearance standard for floors (100 $\mu g/ft^2$) (Table 16). (Note that lead loadings in this report are based on the use of the R&M cyclone, not wipe samples.) On average, most (58 percent) of the relevant dust samples per house in the previously abated houses had loadings below Maryland's interim clearance standards, although the range per house was wide (14 percent to 86 percent). These findings add to the scant information in the literature regarding the long-term effectiveness of comprehensive lead paint abatement in older housing.

2.2 Correlations Between Environmental Variables

The amount of lead in dust on various household surfaces was found to be moderately to highly correlated, whereas the amount of dust per unit area on the various surfaces was generally less well correlated. Dust lead on interior household surfaces was correlated with window well lead, exterior entryway lead, and exterior soil lead. These patterns of correlations suggest that there is some mixing of lead across surface types within houses and between interior and exterior sources and that an overall measure of dust lead exposure for houses should be investigated further. The directions of movement of lead and the sources of lead in dust cannot be determined, however, from an analysis of these cross-sectional data. An assessment of sources of lead in dust on various household surfaces would require additional work, such as analyses of stable lead isotope ratios of paint, soil, and dust. Toward this end, a pilot study is underway of stable lead isotopes using environmental samples from a small number of R&M houses.

2.3 Blood Lead

The geometric mean blood lead concentration in children living in the modern urban housing group, 4.8 µg/dL, falls between the national geometric mean of 3.6 µg/dL for U.S. children of the same age range (12 to 60 months) and the geometric mean for U.S. African American children in this age range, 5.6 µg/dL.[27] All children in the modern urban houses had blood lead concentrations equal to or less than the CDC level of concern of 10 µg/dL. The geometric mean blood lead concentrations in children in the other study groups ranged from 9.9 to 14.2 µg/dL and were higher than the national geometric mean of 9.7 µg/dL estimated for U.S. African American children aged 12 to 60 months from low-income families living in central cities with populations more than one million.[27] The maximum baseline blood lead concentration in this study was 42 µg/dL in a child in the R&M Level III group, the group with the highest baseline geometric mean blood lead level. Generally, higher blood lead concentrations were anticipated in this group because City Homes, Inc., a major source of R&M houses, has a policy of accepting families with lead-poisoned children as tenants in its improved properties.

When study groups were combined, blood lead concentrations and environmental lead levels were found to be correlated, with statistically significant correlation coefficients ranging from r=.36 to .64. Blood lead concentration was correlated with lead loadings and/or lead concentrations of every environmental sample type, except for air duct dust and water. Air ducts may not be accessible to children, and water was not found to be an important source of exposure due to low lead concentrations. The absence of statistically significant correlations between blood lead concentration and environmental lead levels within study groups is due to differences among groups, the smaller numbers of children per group, and the narrower ranges of environmental lead levels within groups, particularly in the modern urban houses.

3.0 QUALITY ASSURANCE

3.1 System Audit

Laboratory and field activities have been subjected to regular review to assure conformance with procedures prescribed in the QAPP.[2] This ongoing audit has focused on the sampling and analytical procedures used, their documentation, the training of field and laboratory personnel, and the adequacy of related facilities and equipment. Reports were prepared annually. Inadequacies were noted in these reports and subsequently corrected. Only minor problems, not directly related to data quality, were noted during the initial sampling campaign.

3.2 Data Audit

To verify the accuracy of the data used in this report, the quality control officer conducted a stratified random audit of 10 percent of the field and laboratory data generated during the initial sampling campaign. Prior to the audit, laboratory and data staff had completed three independent 100 percent checks of the data. The audit procedure involved the verification of information in the final data base against the original field and laboratory data. Samples to be audited were selected by computer using random number sequences. Sampling was stratified to ensure that samples were randomly selected to represent every analytical batch. Probably as a result of the extensive quality control effort prior to the audit by the quality control officer, the audit did not identify any errors.

3.3 Performance Audit

In order to assure that the sampling and analytical protocols employed in the R&M study yield data of sufficient quality, a number of different types of quality control samples were included in the study design. These samples were designed to control and assess data quality in each phase of the data collection and analysis process which was potentially subject to random and/or systematic error. Blank samples, including field blanks and method blanks, were included to assess procedural contamination by lead. Recovery samples, including standard reference materials, spiked samples, and calibration verification samples, were included to indicate the accuracy of analyses while duplicate samples indicated precision of analyses. Standard control charts were generated quarterly showing percent recovery of a standard reference material, percent recovery of spiked samples, spike/spike duplicate precision, initial calibration values, continuing calibration values, percent recovery of continuing calibration values, drift of continuing calibration values within a run, field blanks, and method blanks. Separate control charts were generated for each combination of sample matrix and analytical instrument used. Of the almost 3,900 quality control samples included in these analyses, the control limit was never exceeded for any quality control parameter.

In addition to these internal quality control efforts, the KKRI Trace Metals Laboratory has participated in external quality control programs for environmental lead samples and blood lead concentrations as a part of the R&M study. Beginning in September 1993, the laboratory has participated in the Environmental Lead Proficiency Analytical Testing (ELPAT) program for environmental samples. This program is administered through EPA's National Lead Laboratory Accreditation Program which recognizes laboratories which have demonstrated they are capable of performing adequate analyssis of lead in paint chips, dust, and/or samples. Blind samples are analyzed quarterly.The KKRI Trace Metals Laboratory has been rated as "proficient" for the evaluation of lead in paint chips, soil, and dust wipes every quarter since 1993. The KKRI Trace Metals Laboratory also participates in the HRSA/Wisconsin Blood Lead Proficiency Testing Program. Three blind blood samples are analyzed every month as a part of this program. The KKRI laboratory has achieved a 100% accuracy rating for GFAA analysis of blood lead since beginning this analysis in 1993.

Statistical Analyses of QC Data

Because of the overlapping nature of the sampling campaigns in this longitudinal study, samples from several campaigns are generated and analyzed concurrently. Consequently, there is no unique set of quality control data that can be attributed to the initial sampling campaign. As a result, the quality control data reported here represent all data submitted as a part of quarterly reports through October 18, 1995. These data include all of the samples from the initial sampling campaign plus varying numbers of samples from subsequent campaigns.

Statistical analyses of the quality control samples are included as Tables I through III. With the exception of soil samples, the percent recovery of standard reference material and the percent recovery of spike and spike duplicates all fell within a tolerance interval of 70 to 130 percent. Precision was very high, generally less than a 1 percent difference between spike and spike duplicate samples. Percent recovery of initial and continuing calibration samples fell within a tolerance interval of 90 to 110 percent. Drift was limited to an average of less than 2 percent over a run. On average field and method blanks showed extraneous lead contamination of the samples to be trivial. No systematic evidence of contamination was observed.

Table I: **Descriptive Statistics And Tolerance Limits For Percent Recovery For SRM And Spiked Samples And Percent Differences Between Spiked And Spike Duplicate Samples**

Sample Type	Type of Analysis	Number of Samples	Minimum (%)	Maximum (%)	Geometric Mean (%)	Standard Error
Standard Reference Material	ICP-DV[a]	277	78.01	153.64	97.17	0.66
	GFAA-DV	204	80.93	119.59	94.55	0.46
	GFAA-S[b]	9	81.48	108.39	96.03	2.99
	GFAA-W[c]	44	80.45	129.18	102.19	1.58
Spike/Spike Duplicate	ICP-DV SPIKE	276	84.67	119.92	97.56	0.29
	ICP-DV SPIKE DUPLICATE	276	83.91	121.03	97.36	0.30
	ICP-DV PERCENT DIFFERENCE	276	-20.99	13.29	0.20	0.18
	GFAA-DV SPIKE	205	81.50	118.00	100.11	0.47
	GFAA-DV SPIKE DUPLICATE	205	79.00	125.00	100.11	0.50
	GFAA-DV PERCENT DIFFERENCE	205	-20.33	19.12	0.04	0.34
	GFAA-S SPIKE	10	84.00	125.00	103.36	4.57
	GFAA-S SPIKE DUPLICATE	10	48.00	115.10	95.77	6.02
	GFAA-S PERCENT DIFFERENCE	10	-3.31	13.19	1.53	1.63
	GFAA-W SPIKE	45	72.80	117.80	96.45	1.48
	GFAA-W SPIKE DUPLICATE	45	74.40	120.60	96.48	1.58
	GFAA-W PERCENT DIFFERENCE	45	-7.41	13.51	-0.06	0.52

[a] DV = cyclone dust
[b] S = soil
[c] W= water

Table II: Descriptive Statistics And Tolerance Limits For Percent Recovery For ICV And CCV

Sample Type	Type of Analysis	Number of Samples	Minimum (%)	Maximum (%)	Geometric Mean (%)	Standard Error
ICV	ICP-DV[a]	177	94.30	109.98	101.29	0.24
	GFAA-DV	64	93.50	109.00	102.69	0.44
	GFAA-S[b]	21	97.50	107.50	102.60	0.54
	GFAA-Wc	42	96.00	108.50	103.24	0.52
CCV	ICP-DV % TRUE VALUE	1072	90.04	109.94	99.24	0.12
	ICP-DV % DRIFT	1072	-13.95	14.53	-2.25	0.14
	GFAA-DV % TRUE VALUE	231	91.00	112.50	102.13	0.27
	GFAA-DV % DRIFT	231	-12.04	11.39	-0.70	0.30
	GFAA-S % TRUE VALUE	47	89.00	109.00	100.70	0.71
	GFAA-S % DRIFT	47	-11.44	5.83	-1.36	0.58
	GFAA-W % TRUE VALUE	117	90.50	110.00	102.14	0.40
	GFAA-W % DRIFT	117	-12.80	11.68	-1.03	0.40

[a] DV = cyclone dust
[b] S = soil
[c] W= water

Table III: Descriptive Statistics For Field Blanks And Method Blanks

Sample Type	Type of Sample	Number of Samples	Minimum (mg/L)	Maximum (mg/L)	Geometric Mean (mg/L)	Standard Error
Field Blank	Dust[a]	135	39.00	621.00	18.40	5.56
	Soil	33	0.01	2.59	0.26	0.09
	Water	94	0.15	16.40	1.59	0.24
Method Blank	Dust	236	-152.00	549.00	12.64	3.80
	Soil	9	-0.40	14.00	3.37	1.76
	Water	42	-0.80	2.40	0.44	0.10

a Field blanks are analyzed by ICP or GFAA

4.0 STUDY DESIGN AND SAMPLE COLLECTION PROCEDURES

The R&M study targeted houses in low-income neighborhoods where children are at highest risk of lead-poisoning due to exposure in dust and in deteriorating paint. It is important to emphasize that the R&M study was not designed as an intervention study in the homes of lead-poisoned children *per se,* although some study children did have blood lead elevations at baseline. Instead, the study started by identifying eligible intervention and control houses with eligible children. The eligibility criteria for children were based on age and other criteria, but not blood lead concentration (see section 4.4). The sections below provide an overview of the study design followed by descriptions of the R&M interventions, recruitment and enrollment procedures, selection criteria for houses and children, selected characteristics of the study houses, and sample collection procedures.

4.1 Overview Of Study Design

The R&M study has two main components and five groups of study houses. The first component is designed to obtain serial measurements of lead in venous blood of children between the ages of six and 60 months at enrollment, as well as house dust, exterior soil, and drinking water in three groups of 25 houses (a total of 75 houses), each receiving one of three levels of R&M intervention. The second component is designed to collect a comparable set of measurements in two groups of control houses. Table 1 summarizes the types of data planned for collection by study group and by campaign (*i.e.*, pre-intervention, immediate post-intervention, two months, six months, 12 months, 18 months, and 24 months post-intervention). Blood lead and dust lead measurements are planned in all R&M study houses at each campaign, except for blood lead at the immediate post-intervention campaign. Measurements of lead in exterior soil were taken at baseline and are planned at immediate post-intervention, and at six and 18 months post-intervention. Measurements of lead in drinking water were made at baseline in occupied R&M houses, and are planned at immediate post-intervention in previously vacant R&M houses, and at six and 18 months post-intervention. The study questionnaire, designed to obtain information on demographics and covariates that could influence lead exposure in the home (*e.g.*, hobbies and child behavior), will be administered at six month intervals starting at enrollment.

R&M intervention houses (vacant and occupied) were identified in collaboration with owners and operators of low-income rental properties as explained in section 4.3. Occupied houses which were eligible for R&M intervention were randomly assigned to receive either R&M Level I (low level intervention) or R&M Level II (intermediate level intervention). Vacant houses which were eligible for R&M intervention were randomly assigned to receive either R&M Level II or R&M Level III (high level intervention). The R&M Level II intervention was designed to be performed in both occupied and vacant houses, and the randomization scheme was designed to ensure that equal numbers of houses (n=25) were assigned to each R&M intervention level. In order to allow for a better estimation of the post-intervention rate of re-accumulation of lead in dust and for periodic assessments of the need for further cleanups/repairs during the follow-up period, more frequent sampling campaigns are planned in all the R&M groups during the first year of follow-up (Table 1).

Table 1: Data Collection Plan For Lead Paint Abatement And Repair & Maintenance Study

Study Group	Type of Data	Pre-Intervention /Enrollment Campaign	Post-Intervention Campaigns					
			Immediate	2 Months	6 Months	12 Months	18 Months	24 Months
R&M Level I	Blood	√	√	√	√	√	√	√
	Dust	√	√	√	√	√	√	√
	Soil	√	√		√		√	
	Water	√			√		√	
	Questionnaire	√			√	√	√	√
R&M Level II	Blood	√[a]	√[a]	√	√	√	√	√
	Dust	√	√	√	√	√	√	√
	Soil	√	√		√		√	
	Water	√[a]	√[a]		√		√	
	Questionnaire	√[a]	√[a]		√	√	√	√
R&M Level III	Blood		√[a]	√	√	√	√	√
	Dust	√	√	√	√	√	√	√
	Soil	√	√		√		√	
	Water		√		√		√	
	Questionnaire		√[a]		√	√	√	√
Control Houses:	Blood	√			√	√	√	√
	Dust	√			√	√	√	√
Previously	Soil	√			√		√	
Abated and	Water	√			√		√	
Modern Urban	Questionnaire	√			√	√	√	√

Shading indicates data covered in this report

[a] Blood, questionnaire, and water samples cannot be collected in vacant houses until the family moves in

The need for additional cleanups/repairs during the entire follow-up period will be determined by a comparison of the follow-up dust lead loadings and blood lead concentrations with their corresponding pre-intervention levels. Further cleanups/repairs will be performed whenever dust lead loadings at most interior sites in a house re-accumulate to levels that exceed pre-intervention levels. This assessment will exclude interior sites with low baseline dust lead loadings (*e.g.*, <100 µg/ft^2) that remain low at follow-up despite small increases in their lead loadings. In contrast, clean-up/repair will be considered for sites with high levels at baseline and at follow-up (*e.g.*, >25,000 µg/ft^2) where the follow-up level approaches, but does not exceed, the corresponding baseline value.

The second component of the study is to obtain serial measurements of lead in venous blood of children six through 60 months of age at enrollment, and in house dust, soil, and drinking water in two groups of control houses. The first control group consists of 16 houses drawn from a group of houses that received comprehensive lead-paint abatement in demonstration projects in Baltimore between May 1988 and February 1991.[3,4] The second control group consists of 16 modern urban houses built after 1979 and presumably free of lead-based paint. The types and frequency of measurement are the same in the two control groups (Table 1). Measurements of lead in blood and settled dust were conducted at enrollment and are planned at six months, 12 months, 18 months, and 24 months post-enrollment. Measurements of lead in exterior soil and drinking water were conducted at enrollment and are planned at six months and 18 months post-enrollment. The study questionnaire will be administered at six month intervals starting at enrollment. The two years of follow-up in the previously abated control group will provide an opportunity to measure the efficacy of comprehensive abatement four to six years after abatement. Pre-abatement and immediate post-abatement data on dust lead loadings were collected in these houses as part of the previously mentioned demonstration project and are available for use in the R&M study.

It should be noted that the sample sizes of the control groups were reduced from 25 to 16 houses each due to reductions in the scope and funding of the project. The number of control houses, rather than the number of R&M houses, was reduced because the former (and in particular the modern urban houses) were expected to have less inter-house variability with respect to both blood lead and dust lead. This was borne out in the study findings. Furthermore, two types of houses were originally planned for inclusion in the modern urban control group: houses in clusters of urban houses built after 1979, and houses in scattered sites, which had been extensively rehabilitated after 1979. When the sample size of modern urban houses was reduced to 16 houses, only the former were included as the negative (no lead paint) control group (see section 4.5 for additional descriptive information). It was expected that this type of cluster housing would reflect the lowest residential and ambient lead levels in the urban environment.

4.2 Repair & Maintenance Interventions

The R&M interventions were financed by the Maryland Department of Housing and Community Development (DHCD) through a special loan program open to low-income owner-occupants and private property owners who rent their properties to low-income tenants. To meet DHCD loan eligibility requirements and the pre-requisites for R&M-type interventions imposed by the study, the three levels of R&M interventions were planned for study in lead-painted houses that had no structural defects and that were maintained according to the eligibility criteria listed in section 4.4. The R&M

intervention costs were capped by DHCD as follows: R&M Level I, $1,650; R&M Level II, $3,500; and R&M Level III, $6,000 to $7,000. The latter range is due to program criteria and pre-existing program agreements. The three levels of intervention, described in detail in the QAPP,[2] are described briefly below.

R&M Level I includes the following elements: wet scraping of peeling and flaking lead-based paint on interior surfaces; limited repainting of scraped surfaces; wet cleaning with a tri-sodium phosphate detergent (TSP) and vacuuming with a high efficiency particulate air (HEPA) vacuum to the extent possible in an occupied house; the provision of an entryway mat; the provision of information to occupants and owners; and stabilization of exterior surfaces to the extent possible given the budget cap. Two key additional elements in the R&M Level II interventions are floor treatments to make them smooth and more easily cleanable and in-place window and door treatments to reduce abrasion of lead painted surfaces. In addition to all of this, R&M Level III intervention includes window replacement and encapsulation of exterior window trim with aluminum coil stock as the primary window treatment, the encapsulation of exterior door trim with aluminum, and more durable floor and stairway treatments. All R&M households receive cleaning kits for their own wet cleaning efforts. The kits include a bucket, sponge mop, sponges, a replacement sponge mop head, a TSP cleaning agent, and the EPA brochure entitled "Lead Poisoning and Your Children."

4.3 Recruitment And Enrollment

R&M study houses were identified from lists of addresses provided by owners of private rental properties in low-income neighborhoods of Baltimore and by City Homes, Inc., a non-profit housing organization, which owns and operates low-income rental properties to demonstrate methods for managing and maintaining such properties. The small number of owner-occupant properties in the R&M intervention groups (n=4) were identified through the Kennedy Krieger Research Institute's Lead Poisoning Prevention Program and outside sources. The previously abated houses were identified from lists of houses abated in past years as part of lead paint abatement demonstration projects conducted by the City of Baltimore and the Kennedy Krieger Research Institute. The modern urban houses built after 1979 were identified by house-to-house visits conducted in multiple clusters of such housing in Baltimore.

The enrollment process was done in two stages: pre-enrollment and formal enrollment. These activities were undertaken by study field workers who conducted extensive home visits (1,100 visits to more than 650 modern urban, previously abated, and candidate R&M houses) during the spring and summer of 1992. More than 90 percent of households identified as potentially eligible for the study indicated an interest in participating. This pre-enrollment activity yielded 100 interested and eligible households for formal enrollment. Formal enrollment refers to the obtaining of signed informed consent statements for study participation from parents or legal guardians for both environmental and biological sampling. Separate consent statements were obtained for each child enrolled in the study using forms approved by the Joint Committee on Clinical Investigation of the Johns Hopkins Medical Institutions.

Between the time of formal enrollment and the commencement of the initial data collection campaign in January 1993, some enrolled households became ineligible, primarily due to the aging of the children and the moving of families to other dwellings. In some cases, the losses re-initiated pre-enrollment activity to identify an additional pool of potential study participants. The initial environmental sampling campaign in the modern urban and previously abated control houses was performed between January and July 1993. The baseline environmental sampling in R&M houses was conducted between March 1993 and November 1994.

4.4 Selection Criteria For Houses And Children

Houses and children were selected for participation in the study based on a rigid set of criteria. The first set of selection criteria listed below was applied to all five study groups. Additional selection criteria were applied to the three R&M groups and to the previously abated control group.

Selection criteria applied to all five study groups:

- House size was approximately 800 to 1,200 ft^2.

- The house was structurally sound without pre-existing conditions that could impede or adversely affect the R&M treatments and the safety of the workers and field staff (*e.g.*, roof leaks or unsafe floor structures). This criterion eliminated substandard housing in need of major renovation and, therefore, not suitable for R&M-type interventions and included housing that was somewhat maintained and suitable for the interventions under investigation. This criterion also allowed a house to qualify for the special state loans that were to finance the study interventions.

- Utilities (heat, electric, and water) were available to facilitate interventions and field sampling.

- The household included at least one child six through 60 months of age at enrollment who was not mentally retarded or physically handicapped with restricted movement and for whom the house was a primary residence (*i.e.*, child was reported to spend at least 75 percent of time at the address). Also, the child's family has no definite and immediate plans to move.

- The house was not excessively furnished. This criterion allowed dust collection in all houses, as well as the intervention and cleanup efforts in occupied R&M houses.

Additional selection criteria applied to R&M houses:

- The house contained lead-based paint (defined in Maryland as $\geq$0.7 mg Pb/cm^2 or $\geq$0.5 percent lead by weight as determined by wet chemical analysis) on at least one surface in a minimum of two rooms or, in the absence of testing, was constructed prior to 1941 (when lead-based paints were commonly used[14]).

- Interior house dust lead loadings prior to intervention exceeded Maryland's interim post-abatement clearance levels (*i.e.*, 200 µg/ft^2 for floors, 500 µg/ft^2 for window sills, and 800 µg/ft^2 for window wells) at a minimum of three locations.[18, a]

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[a] In 1990, these clearance levels were adopted as interim post-abatement clearance levels by the U.S. Department of Housing and Urban Development (HUD).[19] In 1995, HUD revised its interim clearance standard for floors to be 100 μg/ft^2.[20]

- The house had 12 or fewer windows needing R&M work. This is to allow for the implementation of the R&M interventions, given limited resources.

Additional selection criterion applied to previously abated houses:

- At least two pairs of pre-abatement and immediate post-abatement dust-wipe lead measurements from the same floor, window sill, and window well surfaces were available from previously collected data. This ensured that data were available to the R&M study on pre- and post-abatement baseline dust lead levels in these control houses.

4.5 Characteristics Of Study Houses

The R&M houses and the previously abated houses are all scattered-site houses located in older residential neighborhoods in Baltimore. All houses were built prior to 1941. More than 98 percent of the R&M houses and 100 percent of previously abated houses were rowhouses, which constitute the predominant type of housing in inner-city Baltimore neighborhoods. As mentioned previously, the 16 modern urban houses are rowhouses located in clusters of urban houses built after 1979. The clusters of modern urban houses, which served as the sampling frames for this study, were all located in, or are adjacent to, urban housing neighborhoods constructed prior to 1941. Each cluster had multiple rows of housing built after 1979 and the rows generally extended the length of a city block. The characteristics of the study houses were typical of housing in low-income neighborhoods in Baltimore. Unfortunately, data do not exist to allow a comparison of dust lead levels in study homes to those in city homes in general.

Study houses were generally similar in terms of housing characteristics that might influence patterns of dust movement into and within a house (*i.e.*, overall size and number of windows, house type and design, condition, degree of setback from the street, and the presence of porches and yards). The selection criteria ensured that the study houses would be similar in terms of size, number of windows, and, to some degree, overall condition. With regard to type and design, all five groups of study houses consisted primarily of two-story rowhouses (not located at the end of the row) with two or three rooms on each level. Floor plans were produced for each study house in order to facilitate the sample collection activities. The Appendix displays the floor plans of two typical study rowhouses (R&M #436, and modern urban #212).

Most study houses lacked porches (84 percent), were not located on narrow alleys (77 percent), and were minimally set-back from the street (77 percent). Houses with minimal set-back were those with no front yards and entryways leading directly from the sidewalk, or from stairs ascending directly from the sidewalk. The other 23 percent of study houses were more than minimally set-back from the street, primarily due to the presence of porches or small front yards. Only four houses (3 percent) were classified as being set-back from the street by more than a modest amount as described above. Unlike the other four groups of houses, most of the modern

Table 2: Selected Characteristics Of Houses By Study Group

Study Group	Soil Available for Sampling (%)	With Porch (%)	Setback from Street			Located on Alley (%)
			min. (%)	modest (%)	more (%)	
R&M Level I	20	32	56	32	12	12
R&M Level II	22	17	78	17	4	30
R&M Level III	4	4	96	4	0	30
Previously Abated	19	25	81	19	0	31
Modern Urban	69	0	69	31	0	13

urban control houses had yards in the front or back of the house. For this reason, exterior soil was available for collection from 69 percent of the modern urban houses as opposed to only 15 percent of the R&M houses and 19 percent of the previously abated houses.

Table 2 compares selected housing characteristics across the five study groups. R&M Level I houses were most likely to have a porch (32 percent) and to be more than minimally set-back from the street (44 percent). R&M Level I (12 percent) and modern urban houses (13 percent) were least likely to be located on narrow alleys. As shown in Table 3, the proportion of carpet samples in composites was on average very low - essentially zero - in R&M Level I, R&M Level II, R&M Level III, and previously abated houses. On average, the proportion of carpets making up floor dust composites in modern urban houses was very high, averaging close to 100 percent. In all groups, differences were noted in the distribution of carpets between first and second stories. The influence of these factors will be explored in future analysis of longitudinal trends in dust lead levels.

4.6 Sample Collection Procedures

Venous blood was collected from study children at the Kennedy Krieger Institute's Lead Poisoning Clinic by a pediatric phlebotomist into 3 mL Vacutainers® with EDTA added as an anticoagulant. Information on the study children and their households was collected using a structured interview questionnaire. Trained field teams administered the questionnaires and collected all environmental samples, including field quality control (QC) samples.

Settled house dust was collected using a modified high-volume cyclone sampler originally developed for EPA for the evaluation of pesticide residues in house dust. The modified device, referred to as the R&M cyclone, is described in detail and characterized elsewhere.[15,16] The device consists of a Teflon®-coated cast aluminum cyclone attached to hand-held Dirt Devil® vacuum as the air mover for the system. A 100 mL Teflon® microwave digestion liner was used as the sample collection container to eliminate a sample transfer step in the laboratory, thereby reducing the risk of sample loss.

The sampling plan for settled dust included the collection of three composite dust samples from the floors in each house at each campaign: one composite in rooms with windows on the first story, one composite in rooms with windows on the second story, and one composite in first and second story rooms without windows. Each composite was composed of samples collected from two randomly selected 1 ft^2 (929 cm^2) perimeter floor locations in each appropriate room. If a randomly selected location were carpeted or covered with an area rug, this information was recorded on the sample collection form and the carpet or rug was sampled using the R&M cyclone. Settled dust was also collected in two composite window sill samples and two composite window well samples in each house at each sampling campaign. Samples were composited by story from all windows available for sampling. Examples of windows not available for sampling were those with window air conditioners and those blocked by furniture. Settled dust was also collected as individual (*i.e.*, not composite) samples from horizontal portions of air ducts, interior and exterior entryways, and the main items of upholstered furnishing in each dwelling.

Three individual soil core samples were collected from the top 0.5 inch (1.3 cm) of soil from three randomly selected locations at the drip-line and then combined as one composite sample. Each soil core was collected into a polystyrene liner using a six-inch (15.2 cm) stainless steel recovery probe.

Drinking water samples were collected as two-hour fixed-time stagnation samples from the kitchen faucet. This procedure involved running the cold water for at least two minutes to flush the pipes and, after a two-hour interval, collecting the first flush of water in a 500mL polyethylene bottle. A list of field sample types is provided in Table 4.

Families were informed by letter of the results of all dust lead and blood lead tests. Results of dust tests were provided on a qualitative basis with recommendations for housekeeping priorities to address areas with high lead levels. Families in houses in which water and soil lead concentrations exceeded EPA guidance levels were provided with additional recommendations for avoiding lead exposure. Additionally, letters were sent to the parents/guardians of the study children with the results of the blood lead tests to be shared with the child's primary care provider. All blood lead test results were reported to the Maryland Blood Lead Registry as required by Maryland law. The effect of the provision of information to families will be considered in the interpretation of the study findings in subsequent reports.

Table 3: Distribution Of Percent Of Individual Samples Of Carpet Making Up Composite Dust Samples By Study Group And Story

Study Group	Story	n (Composites)	Percent Carpet Samples In Composite				
			Minimum	First Quartile	Median	Third Quartile	Maximum
R&M Level I	1st	25	0%	0%	0%	25%	67%
	2nd	25	0%	0%	25%	50%	100%
	Both	19	0%	0%	0%	25%	100%
	Basement	2	0%	0%	50%	100%	100%
R&M Level II	1st	23	0%	0%	0%	0%	67%
	2nd	23	0%	0%	0%	0%	100%
	Both	14	0%	0%	0%	0%	75%
R&M Level III	1st	27	0%	0%	0%	0%	0%
	2nd	27	0%	0%	0%	0%	50%
	Both	13	0%	0%	0%	0%	0%
Previously Abated	1st	16	0%	0%	0%	15%	63%
	2nd	16	0%	0%	33%	67%	100%
	Both	8	0%	0%	0%	0%	0%
Modern Urban	1st	16	50%	50%	50%	67%	75%
	2nd	16	100%	100%	100%	100%	100%
	Basement	1	0%	0%	0%	0%	0%
	Both	4	0%	0%	50%	100%	100%

Table 4: Types Of Field Samples

Sample Type	Sampling Locations/Specifics
Perimeter Floor Composite Settled Dust	First story and second story rooms with windows; rooms without windows
Window Sill Composite Settled Dust	First and second story
Window Well Composite Settled Dust	First and second story
Air Duct/Upholstery Settled Dust	Upholstery was sampled if air ducts were unavailable
Interior Entryway Settled Dust	Not directly on entryway mat
Exterior Entryway Settled Dust	Not directly on entryway mat
Soil Core	Drip-line composite
Drinking Water	Kitchen faucet
Field QC	Blanks and duplicates for all field sample types

5.0 LABORATORY ANALYSIS PROCEDURES

Interior and exterior settled dust, exterior soil, water and venous blood samples were analyzed at the Kennedy Krieger Research Institute's Trace Metal Laboratory using established analytical methods. Closed vessel microwave digestion was used for dust, soil, and water samples according to modified SW 846 Methods 3015 and 3051. Analysis of dust digestates was performed using Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP) according to SW 846 Method 6010 and/or Graphite Furnace Atomic Absorption Spectrometry (GFAA) according to SW 846 Method 7421. Soil and drinking water were analyzed by GFAA according to SW 846 Method 7421. Venous blood was analyzed by GFAA and ASV. [21] Table 5 summarizes these procedures.

Table 5: Summary Of Laboratory Procedures

Sample Type	Pre-Preparation	Preparation	Analysis
Dust	Drying and gravimetrics	Microwave digestion using 1:1 HNO_3: H_2O	ICP/GFAA[a]
Soil	Drying, sieving and homogenization	Microwave digestion using 1:1 HNO_3: H_2O	GFAA
Drinking Water	Acidified	Microwave digestion using 1:1 HNO_3: H_2O	GFAA
Blood	Stabilized in EDTA after collection	Addition of matrix modifier/Triton X-100 solution	GFAA/ASV[b]

[a] Samples with lead concentrations below the limit of quantitation of the ICP instrument were analyzed by GFAA.

[b] ASV was used in addition to GFAA for rapid reporting of blood lead

6.0 DATA PROCESSING AND STATISTICAL ANALYSIS PROCEDURES

6.1 Data Processing

Data analyzed as a part of this study were derived from the field collection forms, the laboratory instruments, and the questionnaires. Raw data of all types were transferred to the data manager who uploaded the data to a VAXStation 3100 computer for later analysis. A summary of the data processing steps employed for the three sources of data is presented below.

! The field data consist of all data recorded on the field collection forms for settled dust, soil, and drinking water samples, as well as room and window inventory data. Data were double entered for verification from the field forms into ASCII data files by a commercial data entry firm. These raw data files were transferred to the data management team for management, storage, and later analysis. Field data forms were checked for completeness and accuracy by the outreach coordinator and data manager prior to data entry. Data were verified again by laboratory staff from final SAS® file printouts.

! Laboratory data were electronically stored by each laboratory instrument. Gravimetric data (tared and loaded weights for dust and soil samples) were generated and stored by the Mettler Balance. Lead concentration measurements for dust samples were made and recorded by the ICP. Lead content in drinking water, soil, and blood, as well as dust samples with low lead concentrations were made by GFAA. Electronically stored laboratory data from the Mettler, ICP, and GFAA instruments were imported to Paradox® (v.4.0) by laboratory staff for tracking of samples. Paradox® data were then converted to ASCII files by the Data Management Team for uploading to the VAXStation. A SAS® program read in the laboratory data for environmental and blood samples and created SAS® data sets for data analysis. The data were verified again by laboratory staff from final SAS® file printouts.

! Questionnaire data forms were double entered for verification by a data entry firm into ASCII data files. These raw data files were verified in-house and transferred to the data manager. A SAS® program read in the raw data and created SAS® data sets for data analysis.

6.2 Data Summary

The study frame consisted of 107 houses occupied by 140 study children in the five groups (Table 6). It should be noted that the final total was 107 houses because an additional house was included in each control group (15 planned; 16 enrolled) due to concerns that some families might be moving soon after enrollment. Furthermore, two of the 25 houses originally assigned to the R&M Level II intervention group were reclassified as R&M Level III houses because of additional renovations at the time of the intervention. In both cases, the landlord independently undertook renovations beyond the scope defined by the R&M Level II criteria. Thus, this report is based on 25 R&M Level I houses, 23 R&M Level II houses, 27 R&M Level III houses, 16 modern urban houses, and 16 previously abated houses. The number of study children per household ranged from one to four. An additional 27 R&M candidate houses and 23 resident children were tested and subsequently excluded from further study for reasons listed in Table 7. The questionnaire was administered in every home at the time of enrollment.

In vacant homes, the questionnaire was administered when the family moved in. As part of the initial campaign, a total of 129 questionnaires were collected. A total of 1,370 environmental samples of 10 types (excluding field QC samples) and 163 blood samples were collected from these 134 houses. Table 8 provides information on the types and numbers of samples planned, collected, and analyzed for lead content in the 107 study houses and 27 excluded houses. Table 9 provides a summary of the numbers and types of samples by study group.

In the 107 study houses, 166 of the planned samples could not be collected because the sampling sites were inaccessible or nonexistent. Two of the 1,533 obtainable samples from potential study homes were missed and one other sample was not collected for no documented reason (Table 8). All environmental and blood samples collected in the initial data collection campaign were analyzed for lead content. Thus, this data collection effort met the data quality objective of having ≥95 percent (*i.e.*, 99.8 percent) of obtainable samples actually being collected, chemically analyzed, and available for data analysis. Section 7.0 reports on compliance with pre-established laboratory performance criteria.

6.3 Statistical Analysis Procedures

The purpose of this report is to summarize cross-sectional data using descriptive statistics. For data analysis purposes, lead measures less than the instrument detection limit (IDL) were calculated as the IDL divided by the square root of two (n=17).[22] For lead values less than the limit of quantification (LOQ) but greater than the IDL, the observed value was used in the data analysis (n=76).

Descriptive statistics were produced using SAS® software.[23] The Shapiro-Wilk test for normality indicated that the environmental and blood lead measurements were not normally distributed. As expected, use of the natural logarithm (ln) transformation reduced the amount of skewness; therefore, all exploratory data analyses were done on the transformed data. A further complication of the data set are the repeated measures from a house, which violate the assumption of independence invoked for most analyses. To overcome this problem, a mixed- effects model was used to account for the correlation of samples within a house. These calculations resulted in a better estimate of the mean and confidence interval for the settled dust from floors in rooms with windows, window sills, window wells, and children's blood. These calculations were done by study group and surface type.

Table 6: Numbers Of Houses And Children By Study Group

Study Group	No. Houses	No. Children
R&M Level I	25	33
R&M Level II	23[a]	32
R&M Level III	27[a]	33
Previously Abated using Comprehensive Methods	16[b]	23
Modern Urban - built after-1979	16[b]	19
TOTAL IN FINAL STUDY FRAME	107	140
Excluded R&M Candidate Houses:		
with paired environmental and blood lead data	19	23
with environmental data only	8	n/a
TOTAL EXCLUDED	27	23
TOTAL FOR INITIAL CAMPAIGN	134	163

[a] Two R&M Level II houses were reclassified to Level III on the basis of the actual work done in the house at the time of the intervention.

[b] One extra house was enrolled to help ensure adequate numbers of houses over time.

Table 7: Reasons For Exclusion Of Candidate R&M Houses

Reason for Exclusion	No. Houses
Non-cooperative landlord/owner-occupant; re: application for R&M loan funds	7
Family moved (including 3 evictions)	5
Concerns for safety of outreach staff (includes 3 houses that had R&M work)	7
Vacant house was vandalized	1
Owner received lead abatement notice	1
Tenant was suing landlord	1
Outreach staff unable to contact family	1
Family did not meet state loan program's income eligibility criterion for tenants	1
Family refused further participation	1
House was not child's primary residence	1
Landlord made house ineligible by replacing windows in a house assigned to R&M Level I intervention	1
TOTAL	27

Table 8: Types And Numbers Of Samples Collected And Analyzed For Lead (Excluding QC Samples) As A Part Of The Initial Campaign

Sample Type	Planned per House	Collected in 107 Study Houses	Collected in 27 Excluded Houses	Collected and Analyzed for Lead	Unavailable Samples in the 107 Houses
Perimeter Floor Dust Composite in Rooms with Windows	2[a]	217	54	271	0
Perimeter Floor Dust Composite in Rooms without Windows	1	58	13	71	49[c]
Window Sill Dust Composite	2[a]	212	54	266	2[d]
Window Well Dust Composite	2[a]	203	53	256	11[e]
Interior Entryway Dust	1	107	27	134	0
Exterior Entryway Dust	1	104	27	131	3[f]
Air Duct Dust	1[b]	29	10	39	18[g]
Upholstery Dust	-	60	16	76	0
TOTAL DUST	10	990	254	1244	83
Soil Core - drip line	1	25	7	32	82[h]
Drinking Water	1[i]	73	21	94	0
Venous Blood	1/child	140[j]	23	163[j]	1[k]
GRAND TOTAL	≥13	1228	305	1533	166[l]

a One composite sample was obtained per story.
b Upholstery sample was collected if air duct sample could not be obtained.
c 49 houses did not have rooms without windows.
d Sills on one story were inaccessible in 1 MU and 1 PA house.
e Wells on one story were inaccessible in 3 MU, 1 PA, 6 R&M I, and 1 R&M II house.
f Wet surfaces in 1 MU and 1 PA.
g Air duct & upholstery were inaccessible/not present in 1 PA, 1 R&M I, 6 R&M II, 8 R&M III, and 2 were missed (1 of which had no reason recorded as to why the sample was not collected).
h 80 houses had no drip-line soil; in 2 houses soil was inaccessible due to snow and ice.
i Drinking water is not part of the initial campaign sampling plan for vacant R&M houses; these samples will be collected at the post-intervention campaign.
j Includes 3 specimens (2 venous, 1 capillary) collected by primary provider and analyzed by outside laboratory.
k 1 family refused for one child.
l 164 of these 166 (99%) were not collected because the sampling sites were nonexistent or inaccessible.

Table 9: Types And Numbers Of Samples Collected By Study Group (Excluding QC Samples) As A Part Of The Initial Campaign

Sample Type	Collected in 16 Modern Urban Houses	Collected in 16 Previously Abated Houses	Collected in 25 R&M Level I Houses	Collected in 23 R&M Level II Houses	Collected in 27 R&M Level III Houses
Perimeter Floor Dust Composite in Rooms with Windows	33	32	52[a]	46	54
Perimeter Floor Dust Composite in rooms without windows	4	8	19	14	13
Window Sill Dust Composite	31	31	50	46	54
Window Well Dust Composite	30	31	43	45	54
Interior Entryway Dust	16	16	25	23	27
Exterior Entryway Dust	15	15	25	23	26
Air Duct Dust	0	1	1	12	15
Upholstery Dust	16	14	23	7	0
TOTAL DUST	145	148	238	216	243
Soil Core - drip line	11	3	5	5	1
Drinking Water	16	16	25	14	2
Venous Blood	19	23	33	32	33
GRAND TOTAL	191	190	301	267	279

a Includes two samples collected in basements used as living spaces.

In the correlation analyses, a single dust measure was required to represent each surface within a house, whereas two measures had been collected. Therefore, a weighted average measure was calculated as follows: for lead loadings the sum of the lead in the samples was divided by the sum of the areas of the sampling locations; for lead concentrations the sum of the lead across samples was divided by the sum of the sample weights; for dust loadings the sum of the sample weights was divided by the sum of the areas of the sampling locations. Similar calculations were made for the overall summary measures of dust lead concentrations, lead loadings, and dust loadings for houses based on the weighted averages of all dust sample types in a house.

The comparison of R&M study houses to excluded R&M-candidate houses was based on t-tests for normally distributed data and Chi-Square and Fisher's Exact Tests for binomially distributed data. Since the two groups were comparable, combined data from study houses and excluded houses were used to calculate the correlations among the various environmental variables and the correlations between blood lead and environmental lead variables. Only those children living in an occupied houses for at least two months prior to the initial campaign were included in the correlations of environmental variables with blood lead. Children who moved into the vacant R&M houses after intervention were excluded from the analysis since their blood lead concentrations would not reflect an equilibrium with their new environment. The correlation analysis was done twice, first using the youngest child in the house to avoid the problem of non-independence, and then using all eligible children per household. Future reports will take into account the clustering (non-independence) of children in the analysis of the blood lead changes.

7.0 RESULTS

The findings are presented below in the following order: demographics of the study population; blood lead concentrations; and dust, soil and water lead concentrations and lead and dust loadings. These sections are followed by results of the comparison of R&M houses to excluded R&M candidate houses and the analysis of correlations between environmental variables and between blood lead and environmental lead. Regarding the latter, it is important to bear in mind the temporal relationship of blood collection to environmental sampling, detailed below.

By design, all of the R&M Level III houses and half of the R&M Level II houses were vacant when the baseline environmental samples were collected. The initial blood lead measurements for the study children in the vacant houses were made close to the time of occupancy, which occurred, in all cases, after the completion of the R&M work. For this reason, the initial blood lead concentrations of these children would not reflect an equilibrium with their new environment. Thus, the question of the temporal relationship of blood lead concentrations to environmental lead levels is relevant only to houses that were occupied at the time of the intervention (*i.e.*, R&M Level I, some R&M Level II, and all control houses). In these relevant groups, the vast majority (72 to 93 percent by group) of the corresponding initial campaign blood and environmental samples across groups were collected within three weeks of each other and, in nearly all cases, within 35 days of each other (Figure 1).

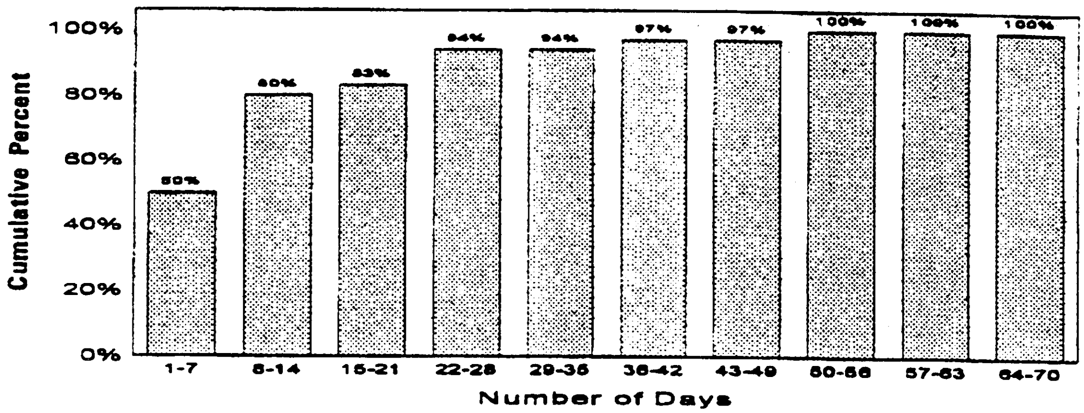
7.1 Demographics

The study was conducted in Baltimore households with reported low-to-moderate monthly rents and mortgages. All study participants were African-American. The overall mean reported monthly rent or mortgage payment was $324 (range $107 to $580, 10 missing values). Eighty percent of all households reported that they were renters, and 20 percent reported that they were owner-occupants. Household sizes ranged from two to 10 persons. Seventy-two percent of households had one child enrolled in the study. The remaining households had multiple children enrolled as follows: two study children in 24 percent of the households; three study children in 2 percent of the households; and four study children in 2 percent of the households.

Table 10 provides descriptive statistics by study group for the following variables: reported ownership, reported monthly housing payment (rent/mortgage amount), reported household size, number of study children per house, and ages of study children. The major differences between groups were in ownership status and monthly housing payments. These differences stem from differences between modern urban households and the four other study groups. Nearly all (94 percent) of the modern urban households are homeowners with higher reported monthly housing payments than the occupants of R&M and previously abated houses who are, for the most part, tenants (95 percent and 88 percent, respectively).

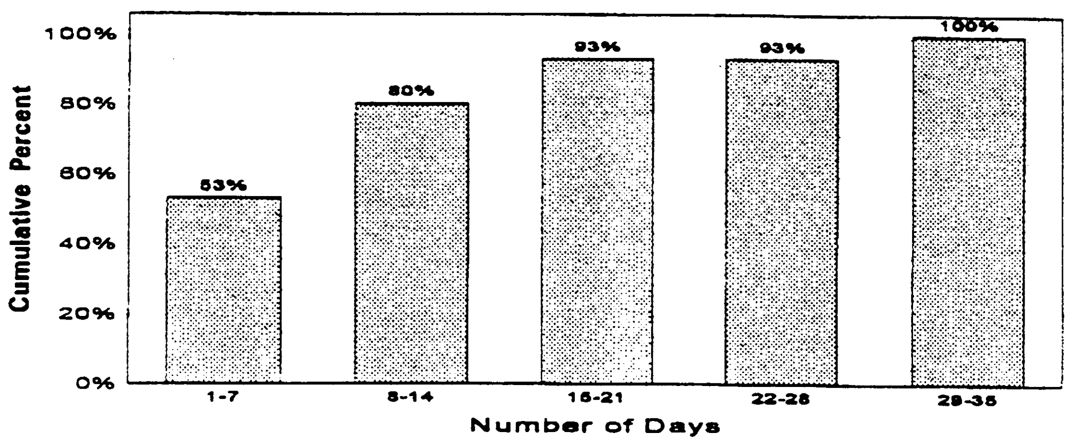
Figure 1: Temporal Relationship Of Blood Collection To Environmental Sampling

Time Between Initial Dust Collection And Initial Blood Collection For R & M Occupied Houses

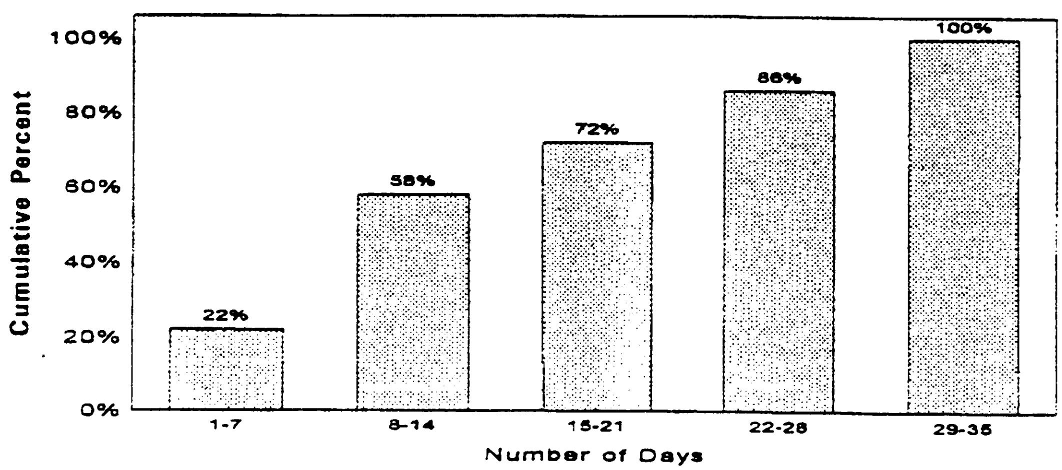


* Note: One blood collection was 129 days prior to the corresponding dust collection

Time Between Initial Dust Collection And Initial Blood Collection For Modern Urban Houses



Time Between Initial Dust Collection And Initial Blood Collection For Previously Abated Houses



* Note: One blood collection was 190 days after the dust collection and is not displayed here.

Table 10: Selected Demographic Characteristics Of Residents By Study Group

Study Group (no. households)	Reported Status: Rent/Own House		Reported Monthly Housing Payment ($)[a]		Household Size		No. Study Children per Household		Ages of Study Children (months)	
	Rent%	Own%	Mean range	(S.D.)	Mean range	(S.D.)	Mean range	(S.D.)	Mean range	(S.D.)
R&M Level I (n=25)	100	-	333 228 to 459	(12)	5.7 2 to 10	(.38)	1.4 1 to 3	(.13)	23.9 5 to 51	(2.3)
R&M Level II (n=23)	96	4	315 200 to 409	(11)	4.4 2 to 7	(.31)	1.4 1 to 4	(.16)	27.8 7 to 57	(2.6)
R&M Level III (n=27)	89	11	292 239 to 429	(10)	3.9 2 to 7	(.23)	1.2 1 to 2	(.08)	33.5 8 to 53	(2.1)
Previously Abated (n=16)	88	12	304 107 to 500	(30)	5.5 3 to 10	(.53)	1.7 1 to 4	(.25)	32.0 9 to 57	(2.8)
Modern Urban (n=16)	6	94	406 280 to 580	(21)	4.2 2 to 7	(.33)	1.25 1 to 3	(.14)	28.6 15 to 42	(2.2)

[a] Rent or mortgage amount. Data missing for 6 R&M, 2 previously abated, 2 modern urban houses.

Table 11: Descriptive Statistics For Blood Lead Concentrations By Group At Initial Campaign

Study Group	n	Minimum (µg/dL)	Maximum (µg/dL)	Geometric Mean[a] (µg/dL)	S.D. on log scale	Lower 95% CI for GM (µg/dL)	Upper 95% CI for GM (µg/dL)
R&M Level I	33	2.0	22.0	9.9	0.539	7.9	12.3
R&M Level II	32	3.5	36.0	13.8	0.531	11.2	16.9
R&M Level III	33	2.0	42.0	14.2	0.542	11.3	17.9
Previously Abated	23	3.5	28.0	12.8	0.495	10.2	16.1
Modern Urban	19	2.0	10.0	4.8	0.457	3.8	6.1

[a] GM values and confidence intervals were obtained from SAS® PROC MIXED

7.2 Blood Lead

Geometric mean blood lead concentrations in study children were 9.9 µg/dL in R&M Level I houses, 13.8 µg/dL in R&M Level II houses, 14.2 µg/dL in R&M Level III houses, 12.8 µg/dL in previously abated houses, and 4.8 µg/dL in modern urban houses (Table 11). The geometric mean blood lead concentration was statistically significantly lower in the modern urban group as compared to each of the other four groups. Differences between the geometric mean blood lead concentrations in the three R&M groups were not statistically significant. The ranges of blood lead concentrations by group were 2 to 22 µg/dL in R&M Level I, 4 to 36 µg/dL in R&M Level II, 2 to 42 µg/dL in R&M Level III, 4 to 28 µg/dL in previously abated, and 2 to 10 µg/dL in modern urban. Figure 2 displays box plots of children's blood lead concentrations by study group.

7.3 Environmental Lead

The environmental data are presented by study group in the following three formats:

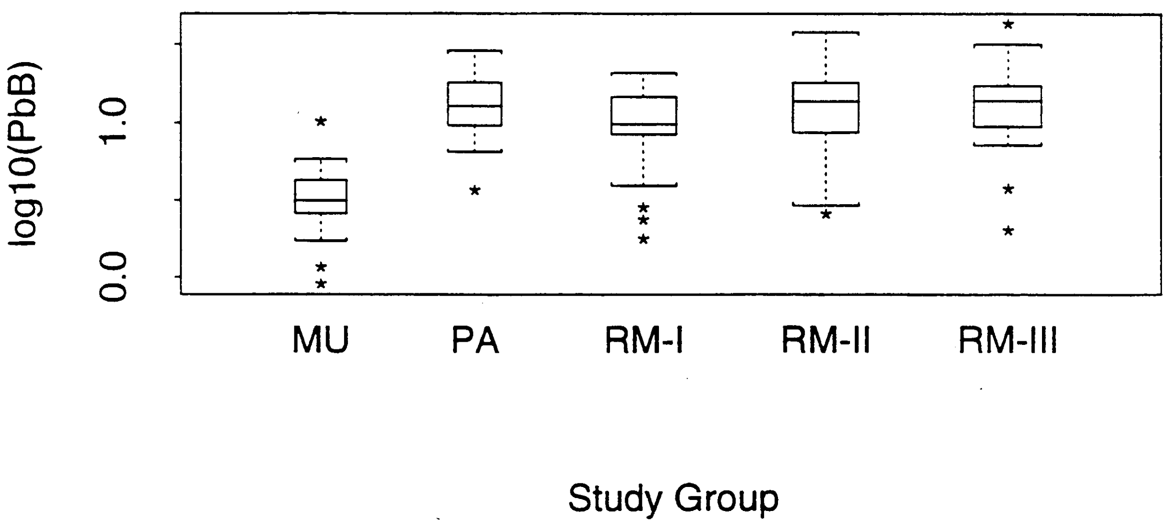
- Tables with descriptive statistics (n, minimum, maximum, geometric mean, standard deviation on the log scale, and 95 percent confidence interval for the geometric mean).
- Side-by-side bar graphs displaying geometric mean values.
- Side-by-side box plots displaying the distributions of log-transformed variables.

For comparison across study groups within surface types, side-by-side box plots are displayed for each surface type by study group (Figures 6 to 8). For comparisons across sample types within each study group, side-by-side box plots are displayed for each surface type by study group (Figures 9 to 11). In a box plot display, 50 percent of the data are contained in the box; the bottom of the box is the 25th percentile value and the top of the box is the 75th percentile value. The horizontal line inside the box represents the sample median. The vertical lines extending from the box show the range of data that falls within one-and-a-half inter-quartile ranges of the box. Extreme values are indicated by an asterisk.[24] The width of a box in any given side-by-side box plot is proportional to the number of observations.

7.3.1 Settled Dust

Tables 12 through 14 display descriptive statistics for baseline dust lead concentrations, dust lead loadings, and dust loadings, for the five study groups and eight surface types. The geometric mean concentrations and their 95 percent confidence intervals for floors in rooms with windows, window sills, and window wells are calculated by an analysis that takes clustering (non-independence of samples) into account (see section 4.3).

Figure 2: Blood Lead Concentrations By Study Group At Initial Campaign



The figures are grouped as follows:

- Figures 3 to 5 are bar graphs showing the geometric mean dust and soil lead concentrations, dust lead loadings, and dust loadings, respectively, for the five groups and eight surface types.

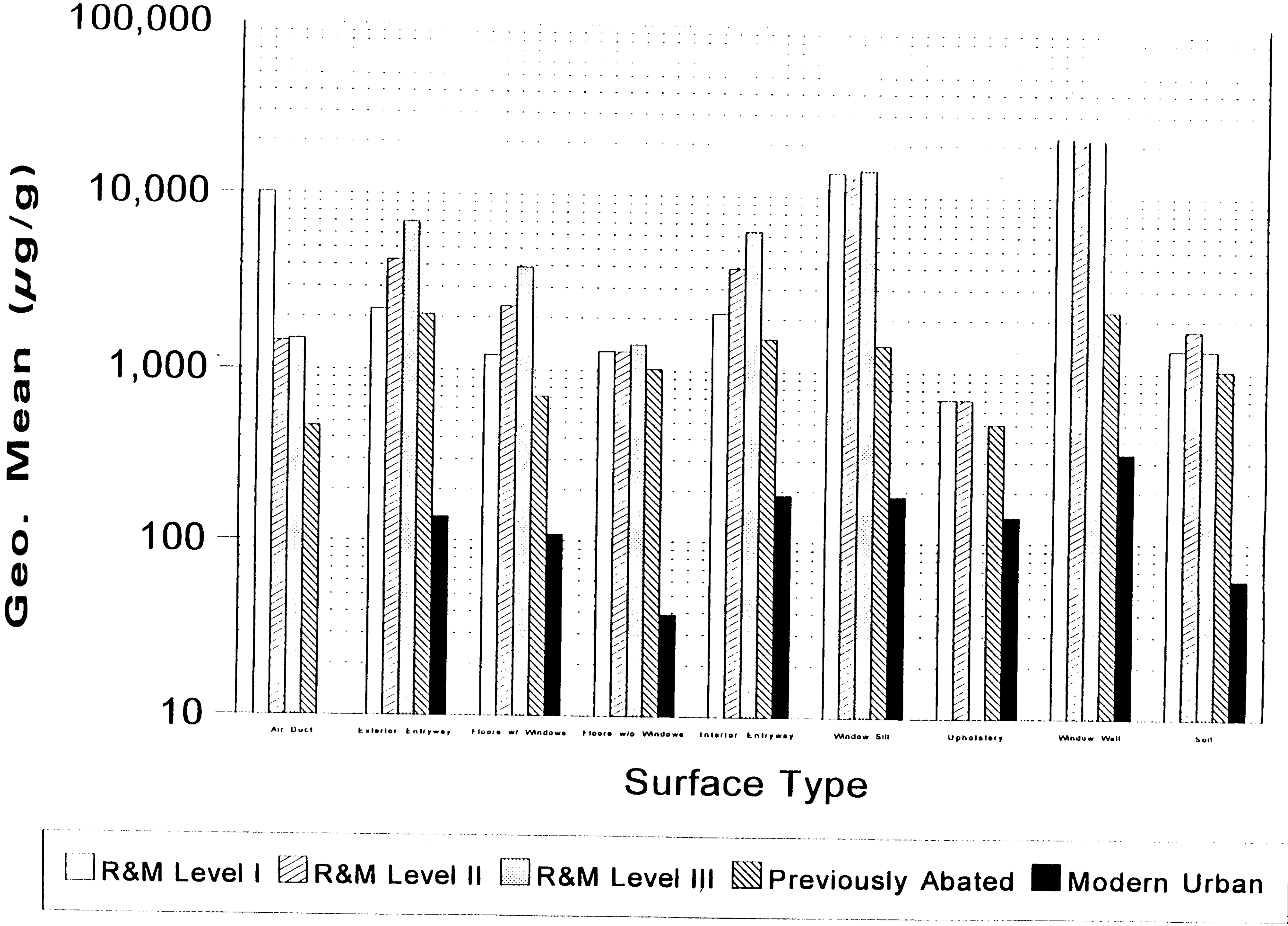
- Figures 6 to 8 are side-by-side box plots of distributions of log-transformed (log_{10}) lead concentrations, lead loadings and dust loadings, respectively for each surface type by study group. These figures are for comparison across groups.

- Figures 9 to 11 display side-by-side box plots of distributions of log-transformed (log_{10}) lead concentrations, lead loadings, and dust loadings for each study group by surface type. These figures are for comparison of sample types within each study group.

For dust lead loadings and lead concentrations, the measurements tended to be lowest in modern urban houses, intermediate in previously abated houses, and highest in the R&M houses (Figures 3, 4, 6, and 7). Across R&M groups, R&M Level I houses tended to have the lowest baseline lead measurements, R&M Level II houses had intermediate measurements, and R&M Level III houses had the highest measurements. The differences in geometric mean values across R&M Levels I to III generally were not found to be statistically different (Tables 12 and 13). In the case of dust loadings, the measurements across all groups tended to be more uniform, but were still higher in R&M groups, particularly on window sills and window wells (Figure 5). Pre-intervention dust samples from relevant sites indicated that 75 percent of the samples from R&M Level I homes, 85 percent of the samples from R&M Level II homes, and 98 percent of the samples from R&M Level III homes had lead loadings in excess of Maryland's interim clearance levels for floors, window sills, and window wells. Forty-two percent of the relevant samples in previously abated houses and 14 percent of the relevant samples in modern urban houses exceeded these guidelines (see section 4.4).

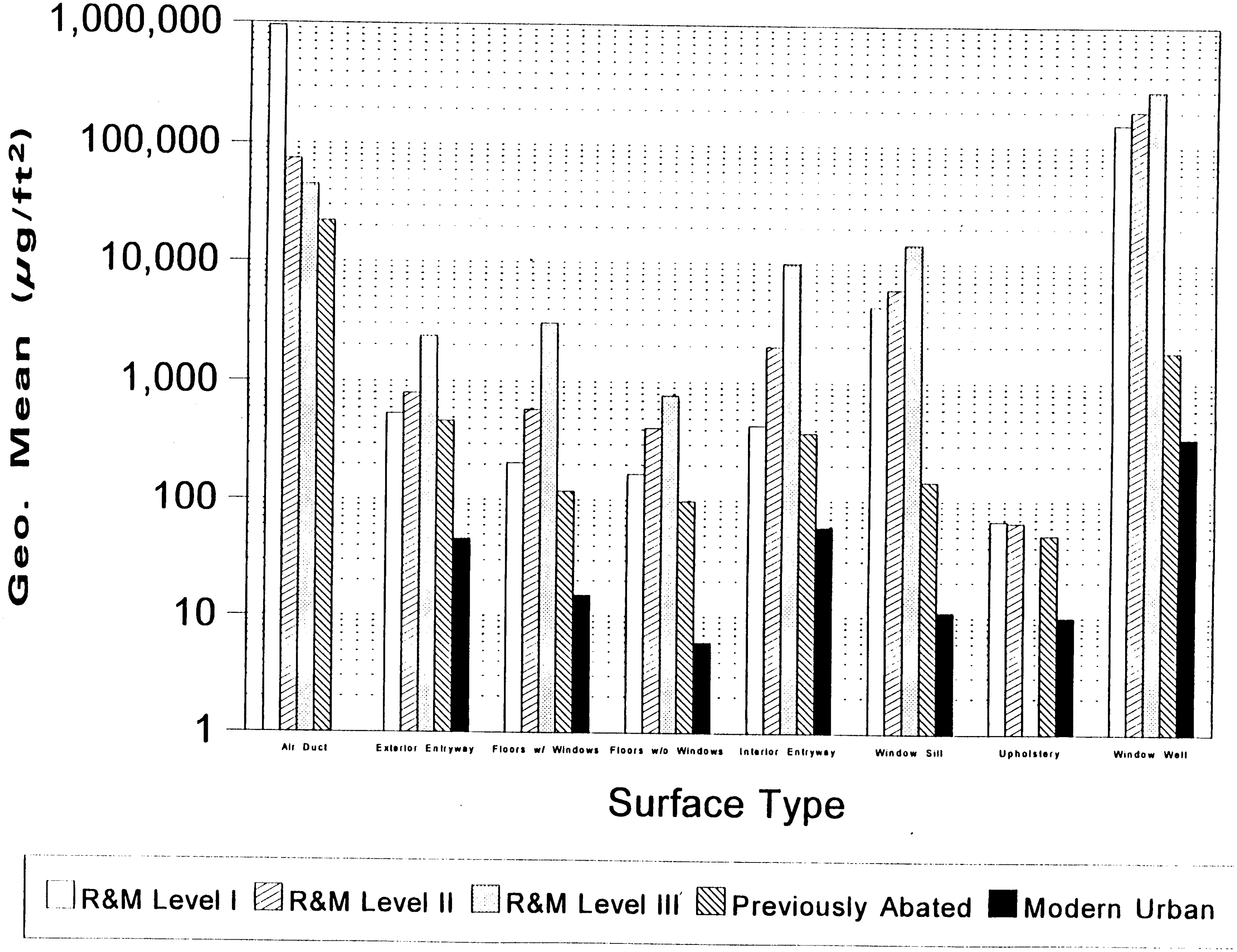
Across all surface types, geometric mean lead loadings and concentrations were substantially lower in modern urban houses than in the other four study groups (Tables 12 and 13). For all sample types with sufficient data for comparison, dust lead concentrations in modern urban houses were statistically significantly lower than those in the previously abated houses and than those in the three R&M levels (Table 12). Previously abated houses had significantly lower lead concentrations and lead loadings than R&M Level I to III houses for window sills and window wells (Tables 12 and 13). For all sample types with sufficient data for comparisons, dust lead loadings in the modern urban group were statistically significantly lower than those in the three R&M groups.

Figure 3: Geometric Mean Dust Lead And Soil Lead Concentrations By Sample Type And Study Group At The Initial Campaign



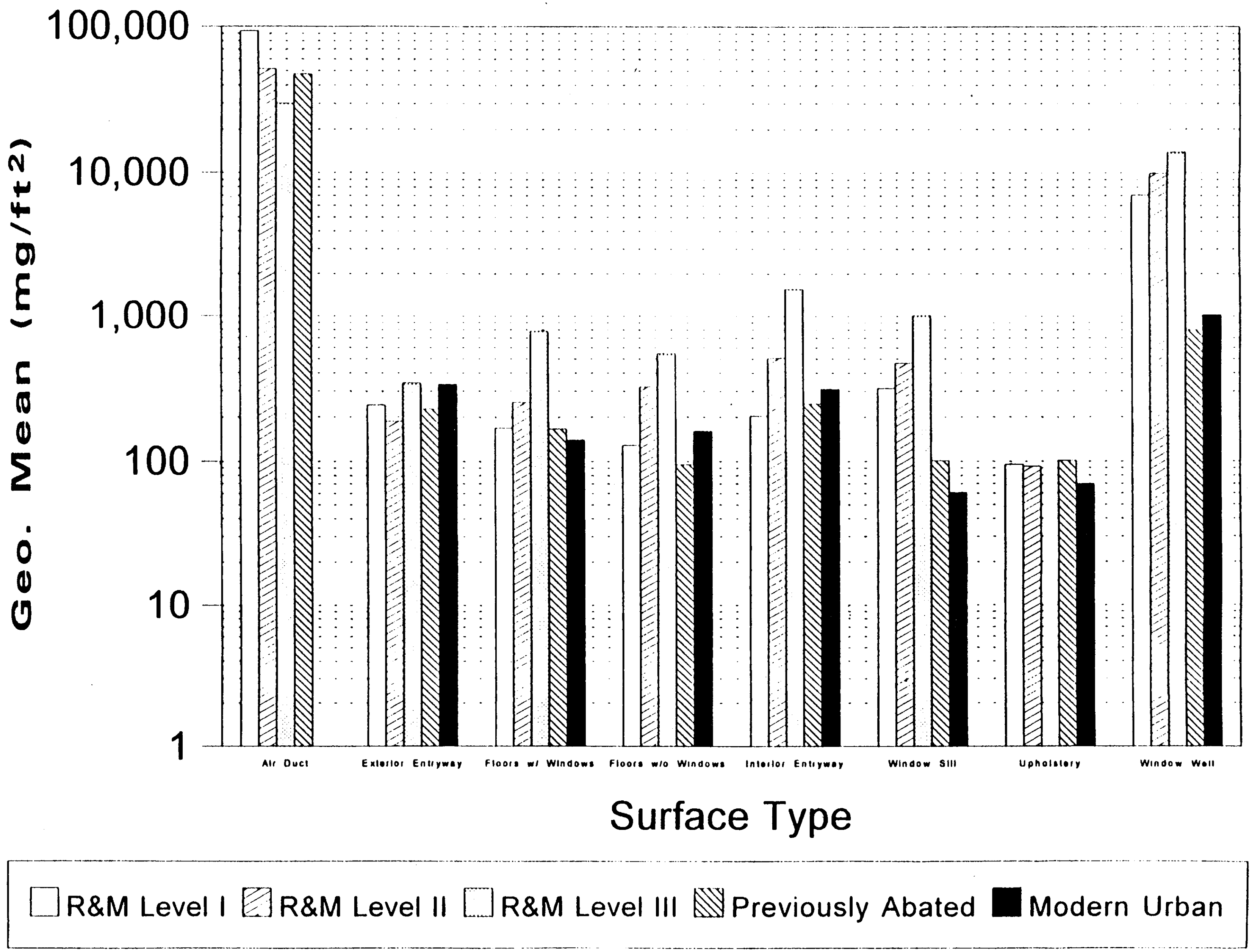
Geometric means for floors with windows, sills, and wells were obtained from PROC-MIXED analysis

Figure 4: Geometric Mean Dust Lead Loadings By Surface Type And Study Group At The Initial Campaign



Geometric means for floors with windows, sills, and wells were obtained from PROC-MIXED analysis

Figure 5: Geometric Mean Dust Loadings By Surface Type And Study Group At The Initial Campaign



Geometric means for floors with windows, sills, and wells were obtained from PROC-MIXED analysis

Figure 6: Lead Concentrations For Each Surface Type By Study Group At The Initial Campaign

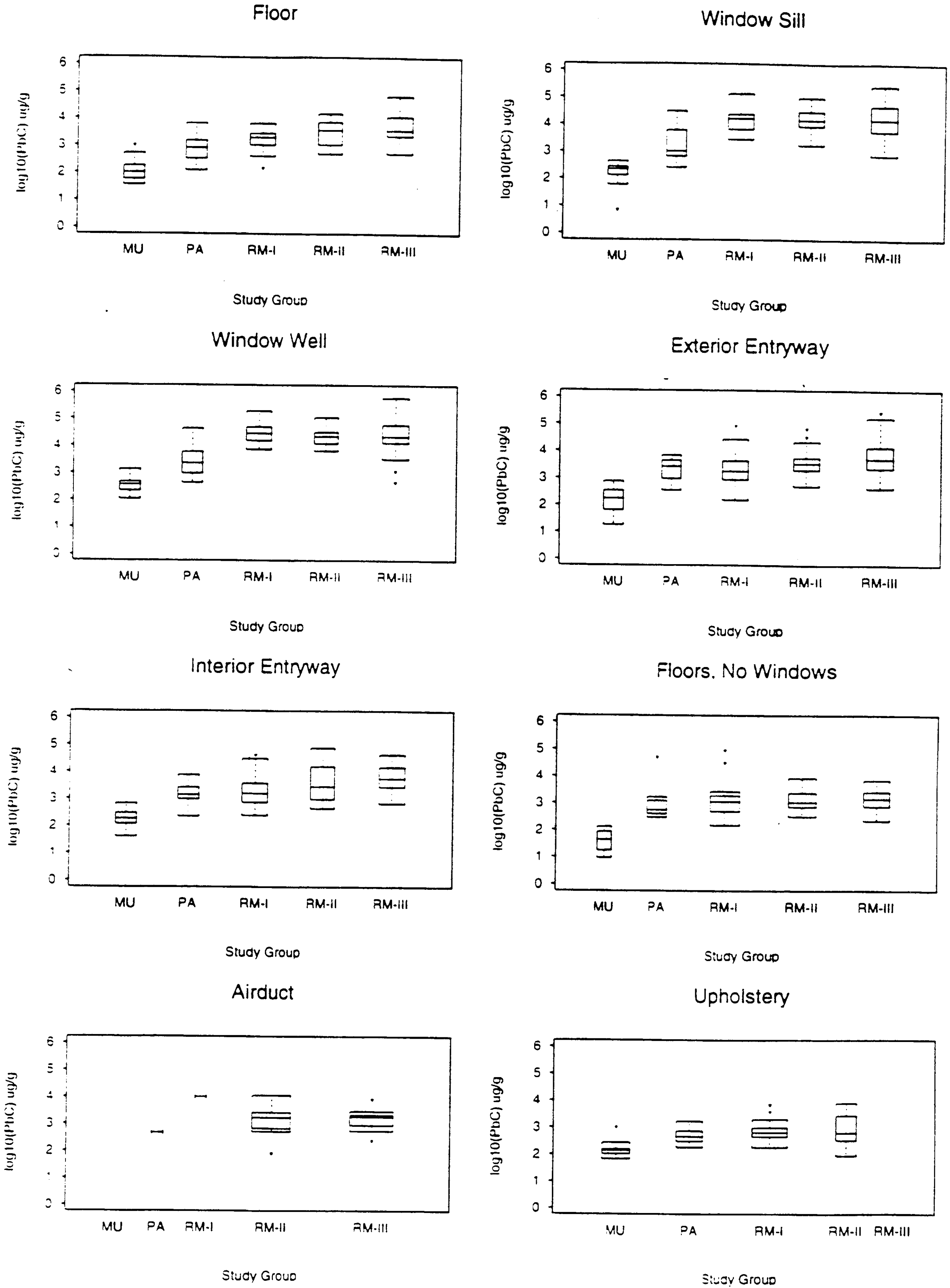


Figure 7: Lead Loading For Each Surface Type By Study Group At The Initial Campaign

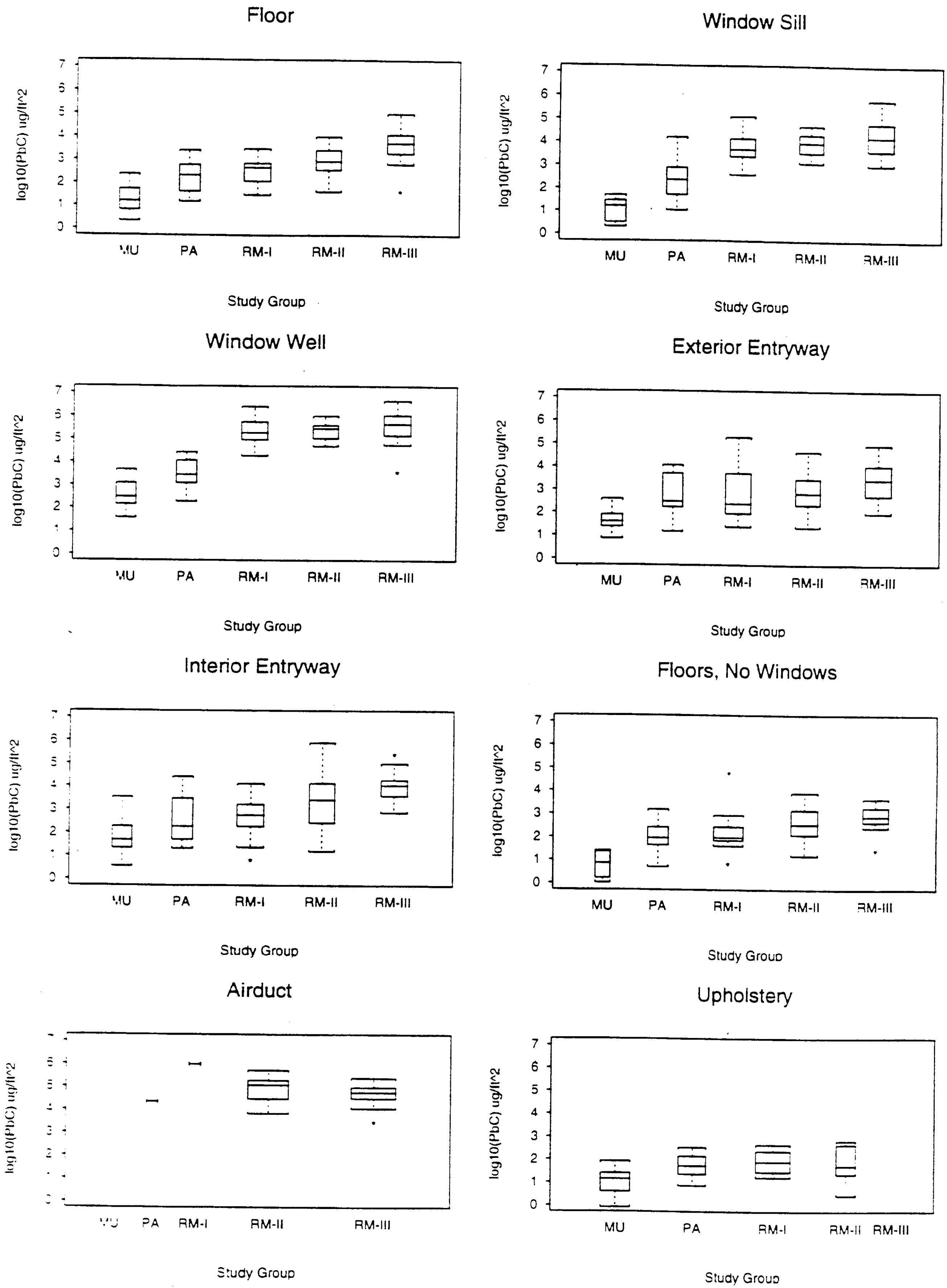


Figure 8: **Dust Loadings For Each Surface Type By Study Group At The Initial Campaign**

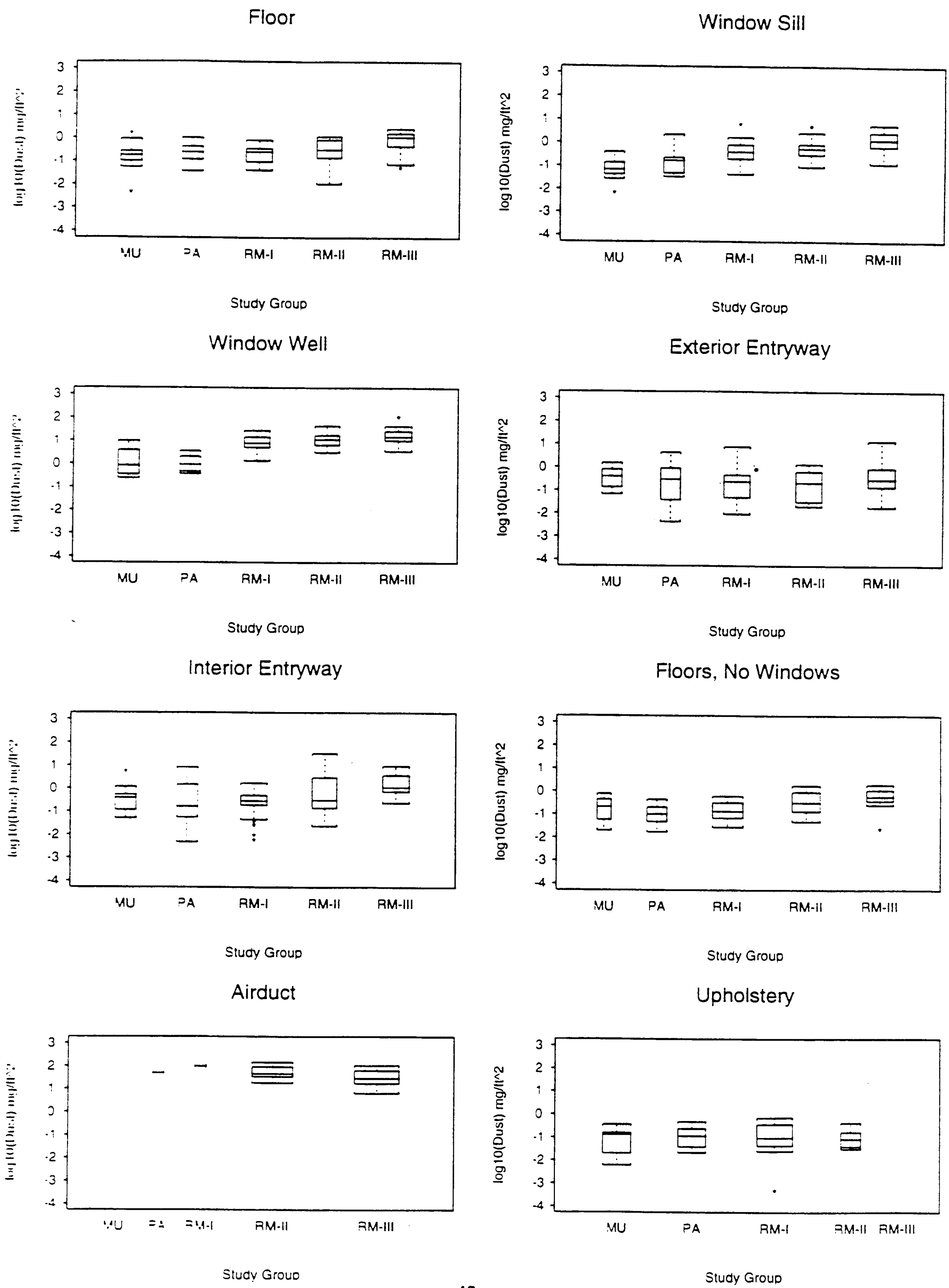


Figure 9: Lead Concentrations For Each Study Group By Surface Type At The Initial Campaign

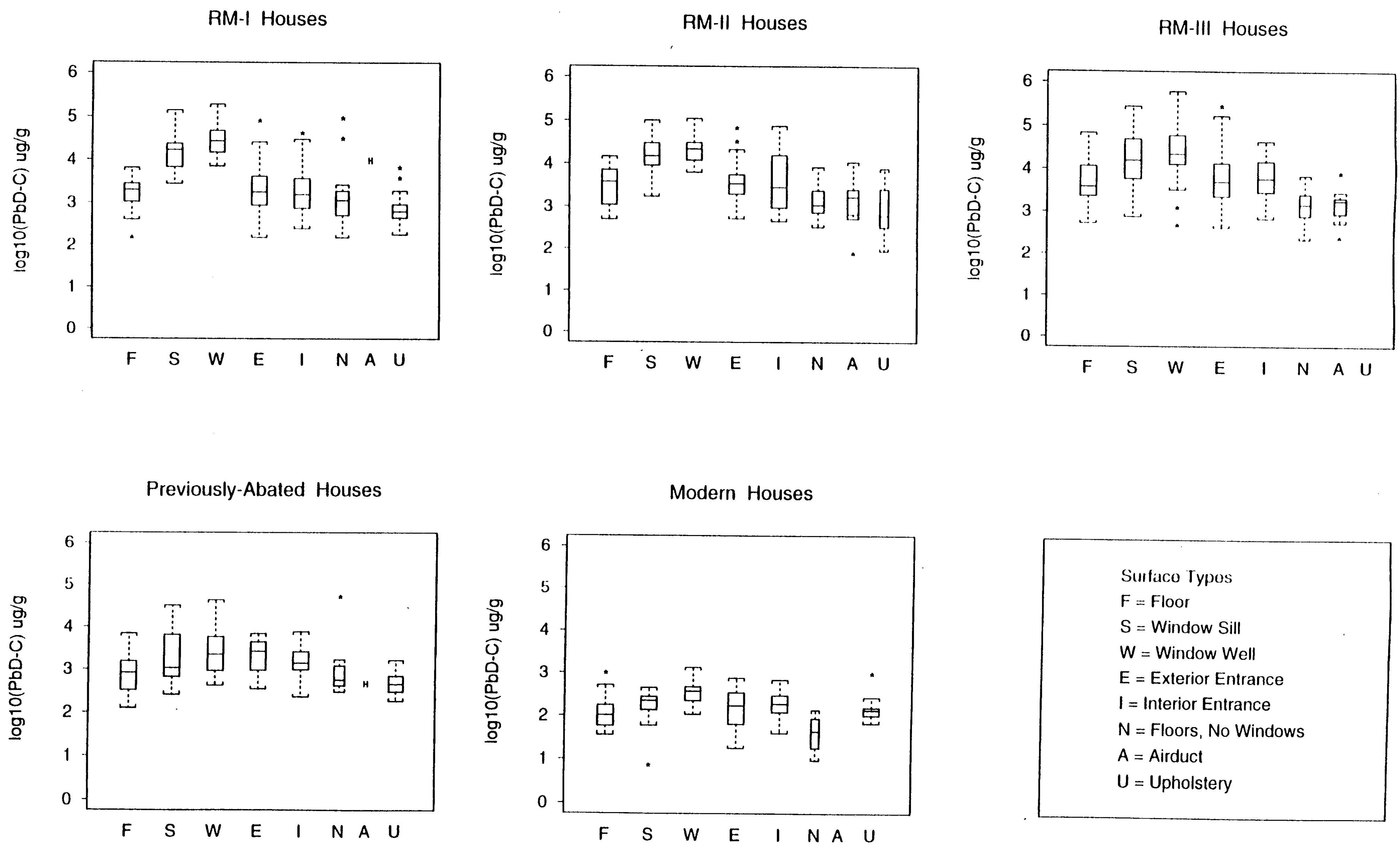


Figure 10: Lead Loadings For Each Study Group By Surface Type At The Initial Campaign

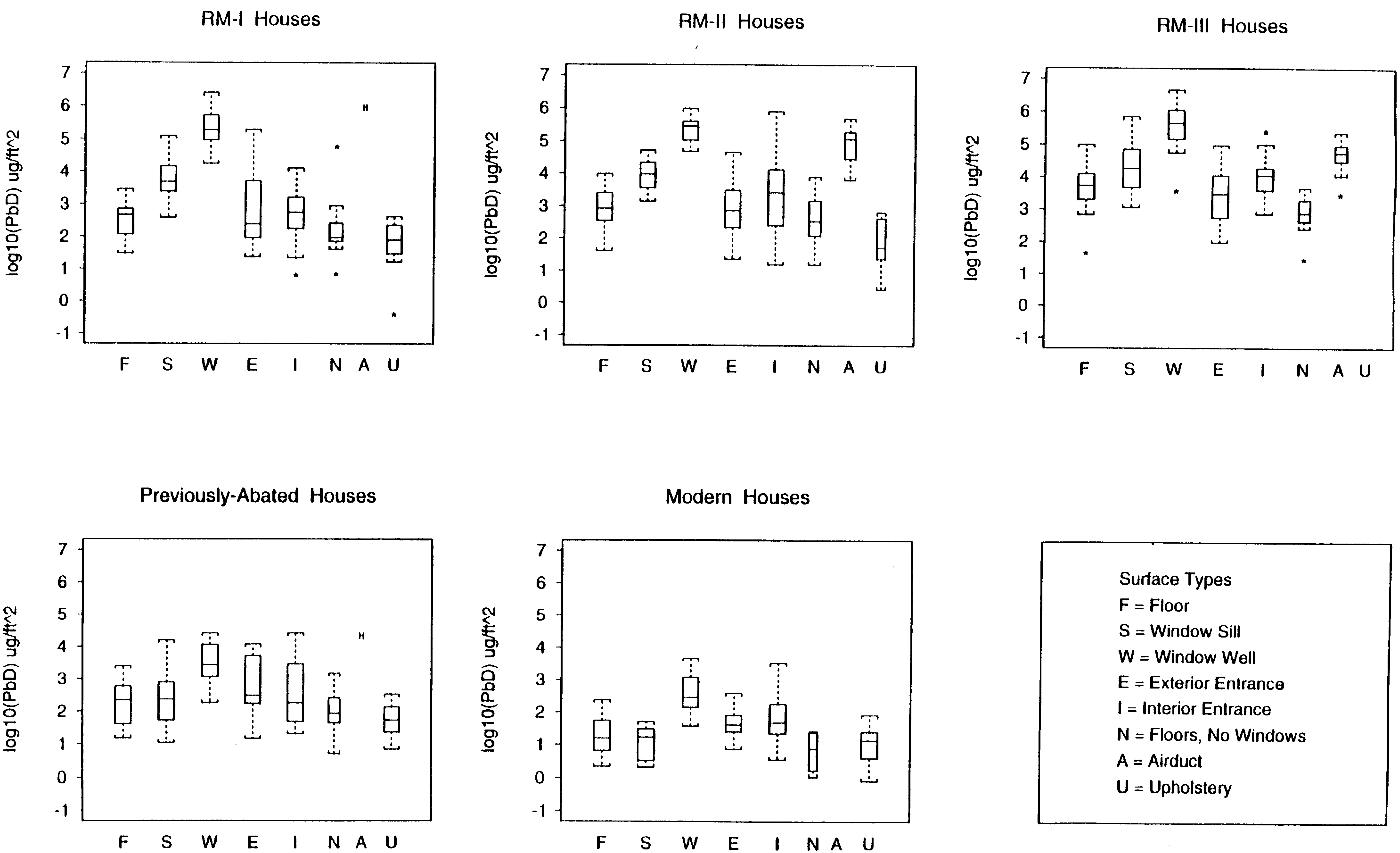


Figure 11: Dust Loadings For Each Study Group By Surface Type At The Initial Campaign

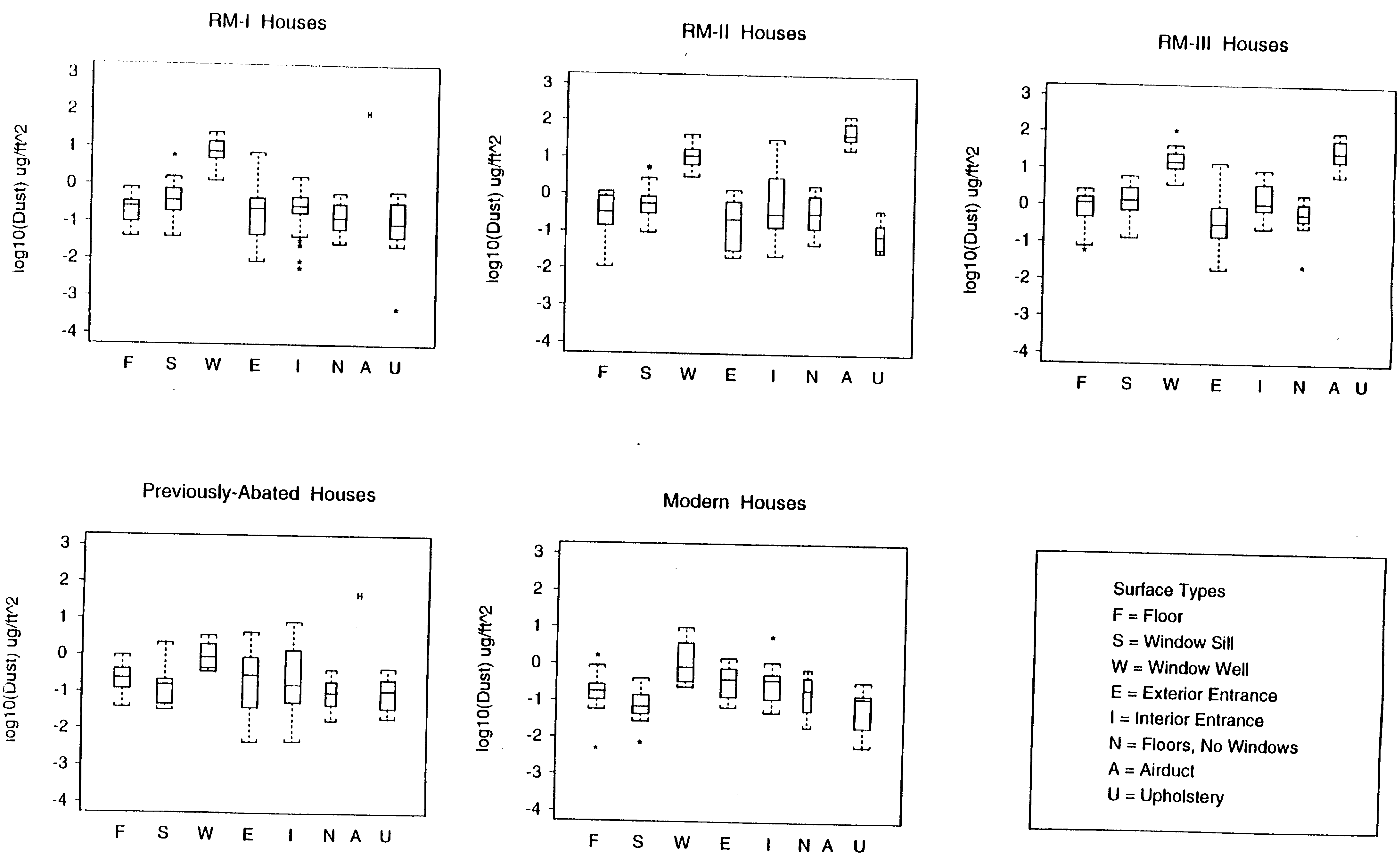


Table 12: Descriptive Statistics For Dust Lead Concentrations By Surface Type And Study Group At Initial Campaign

Surface Type	Study Group	n	Minimum (µg/g)	Maximum (µg/g)	Geometric Mean[a] (µg/g)	S.D. on log scale	Lower 95% CI for GM (µg/g)	Upper 95% CI for GM (µg/g)
Air Duct	R&M-I	1	10,092	10,092	-	-	-	-
	R&M-II	12	79	11,248	1,445	1.341	617	3,388
	R&M-III	15	245	8,125	1,491	0.825	945	2,354
	Previously Abated	1	466	466	-	-	-	-
	Modern Urban	0	-	-	-	-	-	-
Exterior Entryway	R&M-I	25	152	83,993	2,219	1.453	1,218	4,043
	R&M-II	23	516	69,321	4,265	1.155	2,588	7,029
	R&M-III	26	406	283,164	6,936	1.659	3,549	13,555
	Previously Abated	15	348	6,873	2,073	0.940	1,232	3,488
	Modern Urban	15	18	764	137	1.089	75	250
Floors in Rooms with Windows	R&M-I	52	26	7,249	1,216	1.141	861	1,717
	R&M-II	46	58	31,186	2,321	1.325	1,547	3,480
	R&M-III	54	477	84,863	3,900	1.304	2,550	5,965
	Previously Abated	32	65	21,267	709	1.155	435	1,155
	Modern Urban	33	15	1,978	109	1.047	74	160
Floors in Rooms without Windows	R&M-I	19	150	95,822	1,284	1.611	591	2,790
	R&M-II	14	325	8,568	1,281	0.936	746	2,198
	R&M-III	13	219	7,138	1,412	0.914	813	2,453
	Previously Abated	8	296	51,785	1,027	1.678	253	4,174
	Modern Urban	4	9	134	39	1.111	7	228
Interior Entryway	R&M-I	25	245	42,625	2,143	1.317	1,245	3,691
	R&M-II	23	445	75,535	3,922	1.523	2,030	7,580
	R&M-III	27	674	44,099	6,349	0.976	4,315	9,341
	Previously Abated	16	223	7,555	1,541	0.941	933	2,545
	Modern Urban	16	40	683	189	0.782	124	286
Window Sill	R&M-I	50	248	296,951	13,735	1.201	9,191	20,525
	R&M-II	46	1,115	107,030	12,888	1.111	8,997	18,462
	R&M-III	54	637	417,043	14,267	1.387	8,804	23,122
	Previously Abated	31	254	76,710	1,417	1.527	706	2,844
	Modern Urban	31	7	1,026	187	0.912	131	267
Upholstery	R&M-I	23	178	6,913	699	0.808	493	992
	R&M-II	7	90	7,879	700	1.468	180	2,722
	R&M-III	0	-	-	-	-	-	-
	Previously Abated	14	182	1,653	503	0.615	353	718
	Modern Urban	16	67	972	142	0.643	101	200
Window Well	R&M-I	43	570	215,811	22,144	1.216	15,091	32,495
	R&M-II	45	1,560	365,310	20,462	0.982	15,106	27,717
	R&M-III	54	384	817,029	21,600	1.488	12,751	36,590
	Previously Abated	31	399	48,470	2,251	1.287	1,247	4,062
	Modern Urban	30	106	1,555	338	0.674	239	479

[a] GM values and confidence intervals for floors (rooms with windows), window sills, and window wells were obtained from SAS® PROC MIXED

Table 13: Descriptive Statistics For Dust Lead Loadings By Surface Type And Study Group At Initial Campaign

Surface Type	Study Group	n	Minimum (µg/ft²)	Maximum (µg/ft²)	Geometric Mean[a] (µg/ft²)	S.D. on log scale	Lower 95% CI for GM (µg/ft²)	Upper 95% CI for GM (µg/ft²)
Air Duct	R&M-I	1	942,329	942,329	-	-	-	-
	R&M-II	12	6,489	496,080	74,296	1.326	31,985	172,579
	R&M-III	15	2,829	227,866	44,805	1.142	23,799	84,353
	Previously Abated	1	22,045	22,045	-	-	-	-
	Modern Urban	0	-	-	-	-	-	-
Exterior Entryway	R&M-I	25	24	196,752	538	2.434	197	1,469
	R&M-II	23	23	45,970	796	1.989	337	1,881
	R&M-III	26	97	92,289	2,373	2.008	1,054	5,340
	Previously Abated	15	15	11,691	470	2.152	143	1,548
	Modern Urban	15	7	392	46	1.048	26	82
Floors in Rooms with Windows	R&M-I	52	6	3,585	205	1.720	119	354
	R&M-II	46	5	11,154	585	1.829	304	1,125
	R&M-III	54	18	134,423	3,052	1.767	1,709	5,452
	Previously Abated	32	6	4,062	118	1.757	53	262
	Modern Urban	33	1	279	15	1.566	8	29
Floors in Rooms without Windows	R&M-I	19	7	59,074	166	1.780	70	391
	R&M-II	14	15	8,023	412	1.789	147	1,156
	R&M-III	13	27	4,432	773	1.344	343	1,742
	Previously Abated	8	5	1,526	98	1.700	24	406
	Modern Urban	4	1	26	6	1.586	1	78
Interior Entryway	R&M-I	25	6	12,782	435	1.784	208	908
	R&M-II	23	16	786,904	1,980	2.744	605	6,487
	R&M-III	27	719	251,881	9,877	1.341	5,811	16,789
	Previously Abated	16	21	26,417	379	2.446	103	1,396
	Modern Urban	16	3	3,308	59	1.718	23	147
Window Sill	R&M-I	50	111	335,248	4,305	1.700	2,358	7,862
	R&M-II	46	320	102,637	6,020	1.392	3,933	9,213
	R&M-III	54	332	1,222,676	14,438	1.864	7,530	27,683
	Previously Abated	31	4	24,472	145	1.920	65	324
	Modern Urban	31	1	74	11	1.193	6	19
Upholstery	R&M-I	23	0	441	67	1.494	35	127
	R&M-II	7	3	657	65	1.876	11	366
	R&M-III	0	-	-	-	-	-	-
	Previously Abated	14	7	336	51	1.241	25	104
	Modern Urban	16	1	83	10	1.345	5	20
Window Well	R&M-I	43	375	3,360,469	156,019	1.785	86,103	282,707
	R&M-II	45	23,407	2,183,020	203,916	1.022	138,994	299,160
	R&M-III	54	2,084	12,250,842	300,594	1.562	177,117	510,152
	Previously Abated	31	76	37,988	1,816	1.709	862	3,826
	Modern Urban	30	27	6,400	347	1.551	161	747

a GM values and confidence intervals for floors (rooms with windows), window sills, and window wells were obtained from SAS® PROC MIXED

Table 14: Descriptive Statistics For Dust Loadings By Surface Type And Study Group At Initial Campaign

Surface Type	Study Group	n	Minimum (mg/ft^2)	Maximum (mg/ft^2)	Geometric Mean[a] (mg/ft^2)	S.D. on log scale	Lower 95% CI for GM (mg/ft^2)	Upper 95% CI for GM (mg/ft^2)
Air Duct	R&M-I	1	93,373	93,373	-	-	-	-
	R&M-II	12	17,387	142,906	51,405	0.666	33,671	78,480
	R&M-III	15	6,371	102,673	30,046	0.886	18,399	49,066
	Previously Abated	1	47,333	47,333	-	-	-	-
	Modern Urban	0	-	-	-	-	-	-
Exterior Entryway	R&M-I	25	9	7,564	242	1.937	109	539
	R&M-II	23	20	1,353	187	1.390	102	340
	R&M-III	26	18	14,187	342	1.538	184	637
	Previously Abated	15	5	4,387	227	1.971	76	676
	Modern Urban	15	67	1,469	335	1.044	188	597
Floors in Rooms with Windows	R&M-I	52	14	953	168	1.058	119	238
	R&M-II	46	7	1,915	252	1.340	148	427
	R&M-III	54	20	3,778	783	1.107	535	1,146
	Previously Abated	32	9	1,110	166	1.310	97	286
	Modern Urban	32	4	2,044	140	1.407	71	277
Floors in Rooms without Windows	R&M-I	19	27	617	129	0.998	80	209
	R&M-II	14	48	1,795	321	1.270	154	669
	R&M-III	13	23	1,951	547	1.189	267	1,122
	Previously Abated	8	17	440	95	1.063	39	232
	Modern Urban	4	20	751	161	1.528	14	1,831
Interior Entrance	R&M-I	25	6	1,709	203	1.441	112	368
	R&M-II	23	23	32,606	505	1.960	216	1,179
	R&M-III	27	237	9,288	1,556	0.975	1,058	2,288
	Previously Abated	16	5	8,306	246	2.151	78	774
	Modern Urban	16	50	5,702	311	1.201	164	590
Window Sill	R&M-I	50	31	16,795	313	1.216	206	477
	R&M-II	46	21	10,164	467	1.311	290	751
	R&M-III	54	97	12,437	1,012	1.108	710	1,443
	Previously Abated	31	11	3,136	101	1.238	57	176
	Modern Urban	31	6	636	61	1.179	36	104
Upholstery	R&M-I	23	1	692	95	1.542	49	186
	R&M-II	7	30	408	92	0.930	39	218
	R&M-III	0	-	-	-	-	-	-
	Previously Abated	14	21	469	101	1.059	55	186
	Modern Urban	16	6	358	70	1.280	35	138
Window Well	R&M-I	43	613	52,356	7,051	1.008	4,896	10,156
	R&M-II	45	1,069	92,569	9,900	0.962	7,245	13,529
	R&M-III	54	1,783	137,744	13,916	1.008	10,104	19,167
	Previously Abated	31	42	5,254	802	1.136	501	1,284
	Modern Urban	30	111	12,166	1,021	1.400	515	2,024

[a] GM values and confidence intervals for floors (rooms with windows), window sills, and window wells were obtained from SAS® PROC MIXED

Geometric mean dust lead concentrations for all surface types in modern urban houses were <338 µg/g. In previously abated houses, geometric mean dust lead concentrations across all surface types were <2,252 µg/g. For each of the three R&M groups, geometric mean dust lead concentrations for all surface types were greater than the corresponding geometric mean values for the modern urban and previously abated houses. Maximum observed dust lead concentrations by study group were as follows: 1,978 µg/g in modern urban houses (floor); 76,710 µg/g in previously abated houses (window sill); 296,951 µg/g in R&M Level I houses (window sill); 365,310 in R&M Level II houses (window well); and 817,029 µg/g in R&M Level III houses (window well) (Table 12).

In the modern urban houses, geometric mean lead loadings for all surface types were below 60 µg/ft^2, except for window wells (geometric mean=347 µg/ft^2). In previously abated houses, geometric mean dust lead loadings for all surface types were $\leq$470 µg/ft^2, except for window wells (geometric mean=1,816 µg/ft^2). For all three R&M groups, baseline geometric mean dust lead loadings for all surface types were greater than the corresponding geometric mean values for modern urban and previously abated houses. Maximum dust lead loadings in all groups were found on window wells (6,400 µg/ft^2 in modern urban houses, 37,988 µg/ft^2 in previously abated houses, 3,360,469 µg/ft^2 in R&M Level I houses, 2,183,020 µg/ft^2 in R&M Level II houses, and 12,250,842 µg/ft^2 in R&M Level III houses) (Table 13).

Geometric mean dust loadings by group were <1,000 mg/ft^2 for all groups and surface types, except for air ducts, and window wells in R&M Level I to III houses (range of geometric means=7,051 to 13,916 mg/ft^2), interior entryways and window sills in R&M Level III houses (geometric means=1,556 mg/ft^2 and 1,012 mg/ft^2, respectively), and window wells in modern urban houses (geometric mean=1,021 mg/ft^2) (Table 14).

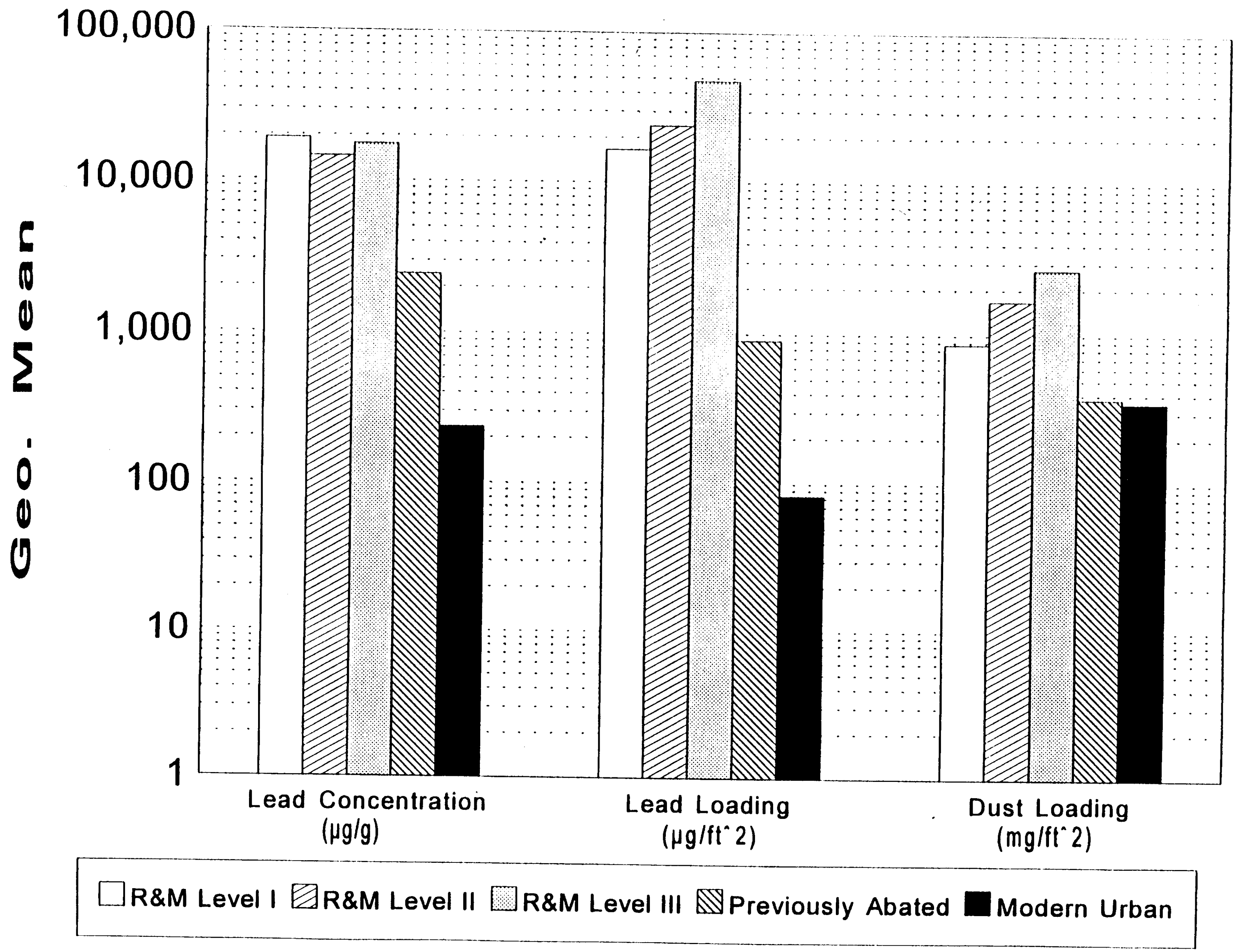
An examination of house dust data by surface type indicated a somewhat similar ordering of geometric mean lead levels across groups for both lead concentrations and lead loadings as shown in Table 15. Dust loadings tended to be highest for window wells, window sills, and air ducts and lowest for upholstery and floors in rooms without windows (Figure 5).

7.3.2 Overall Summary Measures Of Dust Lead And Dust Loading

To compare differences in overall dust measurements across study groups, descriptive statistics were developed for weighted average measurements calculated for each house across all eight surface types (see section 4.3). Descriptive statistics based on these overall lead loadings, lead concentrations, and dust loadings are presented by study group in Table 16. Figure 12 is a bar graph of geometric means for each of the three overall measures by study group.

For overall geometric mean dust lead concentrations, approximate order of magnitude differences were found between groups: modern urban (235 µg/g), previously abated (2,420 µg/g), R&M Level I houses (19,044 µg/g), R&M Level II houses (14,414 µg/g), and R&M Level III

Figure 12: **Overall Weighted Lead Concentrations, Lead Loadings, and Dust Loadings By Study Group At The Initial Campaign**



* Summary measures are based on weighted averages of all dust sample types within houses

Table 15: Rank[a] Of Geometric Mean Lead Concentrations And Lead Loadings By Surface Type At Initial Campaign

Surface Type	Loading					Concentration				
	R&M Level I	R&M Level II	R&M Level III	Previously Abated	Modern Urban	R&M Level I	R&M Level II	R&M Level III	Previously Abated	Modern Urban
Air Duct	3	6	6	8	n/a	1	2	2	1	n/a
Exterior Entryway	4	3	3	2	5	4	5	6	3	3
Floors in Rooms with Windows	7	5	5	6	6	6	6	5	6	4
Floors in Rooms without Windows	6	7	7	5	7	7	7	7	7	7
Interior Entryway	5	4	4	3	2	5	4	4	4	2
Window Sill	2	2	2	4	3	3	3	3	5	5
Upholstery	8	8	n/a	7	4	8	8	n/a	8	6
Window Well	1	1	1	1	1	2	1	1	2	1

[a] 1 = highest to 8 = lowest

Table 16: Descriptive Statistics For Overall Dust Lead Concentrations, Dust Lead Loadings, And Dust Loadings By Study Group At Initial Campaign

Variable	Units	Study Group	n	Minimum	Maximum	Geometric Mean	GM Lower 95 % CI	GM Upper 95% CI
Lead Concentration	µg/g	R&M Level I	25	3,256	105,232	19,044	13,697	26,479
		R&M Level II	23	5,509	43,222	14,414	11,227	18,505
		R&M Level III	27	1,042	160,298	17,548	10,766	28,602
		Previously Abated	16	475	14,086	2,420	1,405	4,168
		Modern Urban	16	88	498	235	170	325
Lead Loading	µg/ft^2	R&M Level I	25	1,270	146,428	16,574	11,514	23,857
		R&M Level II	23	3,010	112,836	23,997	16,937	33,998
		R&M Level III	27	3,495	404,814	47,480	30,837	73,104
		Previously Abated	16	139	4,886	908	475	1,737
		Modern Urban	16	9	526	83	45	152
Dust Loading	mg/ft^2	R&M Level I	25	311	3,107	870	688	1,101
		R&M Level II	23	362	3,907	1,665	1,280	2,166
		R&M Level III	27	936	7,512	2,706	2,187	3,348
		Previously Abated	16	152	1,541	375	259	543
		Modern Urban	16	52	1,568	351	222	557

houses (17,548 µg/g). Thus, overall dust lead concentrations were nearly two orders of magnitude higher in the R&M houses than in the modern urban houses. For dust lead loadings, order of magnitude differences were again found between modern urban (83 µg/ft^2) and previously abated (908 µg/ft^2) houses. Overall lead loadings in R&M Levels, however, were one to almost two orders of magnitude higher than those in previously abated houses, and between two and three orders of magnitude higher than in the modern urban houses.

Differences in overall dust loadings across groups were less pronounced. Overall geometric mean dust loadings were similar in modern urban (351 mg/ft^2) and previously abated (375 mg/ft^2) houses and lower than those found in R&M houses (870 to 2,706 mg/ft^2). Higher dust loadings in R&M II and R&M Level III houses may be due in part to the fact that most of these houses were vacant at the time of the initial environmental sampling campaign.

7.3.3 Drip-Line Soil

Only 25 of the 107 (23 percent) study houses had drip-line soil (five R&M Level I houses, five R&M Level II houses, one R&M Level III house, three previously abated houses, and 11 modern urban houses). Descriptive statistics on soil lead concentrations are displayed in Table 17. In modern urban houses, the soil lead concentrations ranged from 29 µg/g to 154 µg/g. In all other groups, the soil lead concentrations ranged from 233 µg/g to 15,968 µg/g. Figure 13 shows side-by-side box plots of soil lead concentrations by group.

7.3.4 Drinking Water

Collection of drinking water in the initial campaign was limited to occupied houses to allow time for any plumbing repairs that might be made by the owners of the vacant R&M houses at the time of intervention. Included in the descriptive statistics in Table 18 are three water samples collected in vacant houses (two R&M Level III houses and one R&M Level II house) before the decision was made to limit the initial water sampling to occupied houses. The water lead concentrations ranged from less than the instrumental limit of detection (<0.6 µg/L) to 44 µg/L. Overall, 50 percent of the water samples had lead concentrations less than the limit of quantification (LOQ, generally <3 µg/L). The geometric mean concentration of lead in water for the modern urban, previously abated, and R&M Level I and II houses was <3 µg/L. Figure 14 displays side-by-side box plots of water lead concentrations by study group.

7.4 Comparison of Study Houses And Excluded Houses

There were 27 excluded houses in which environmental data were collected but the houses were not selected for study; all were candidate houses for R&M interventions. These excluded houses were compared to the final group of 75 R&M houses to assess the possible selection bias. Both groups were a mix of occupied and vacant units at the time of sampling. No statistically significant differences were found between these two groups based on geometric mean dust lead concentrations, lead loadings, or dust loadings for the eight surface types (Tables 19 to 21).

Figure 13: **Box Plots Of Soil Lead Concentrations By Study Group At The Initial Campaign**

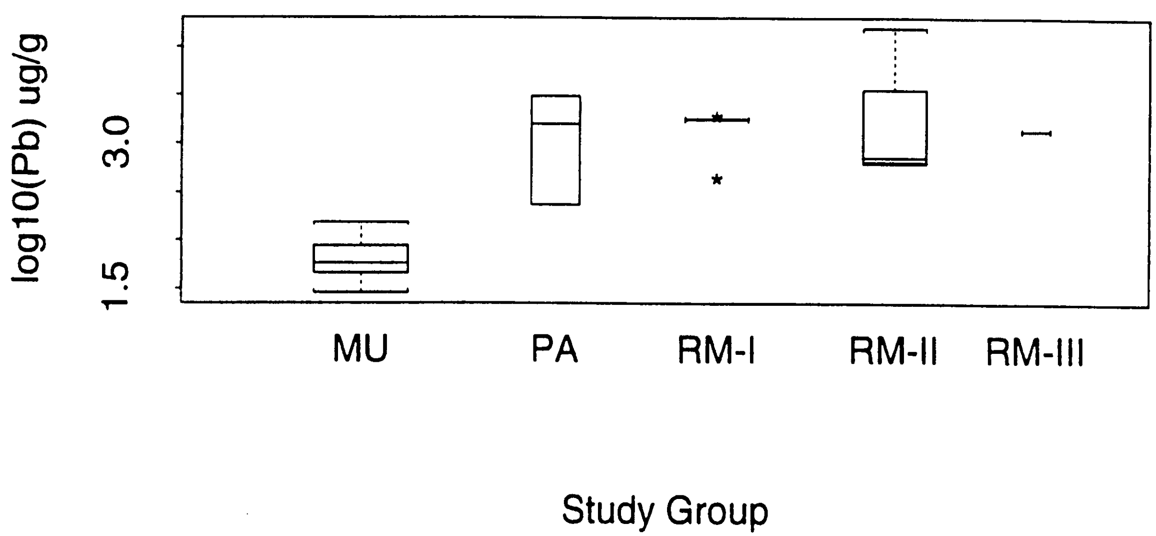


Figure 14: **Box Plots Of Water Lead Concentrations By Study Group At The Initial Campaign**

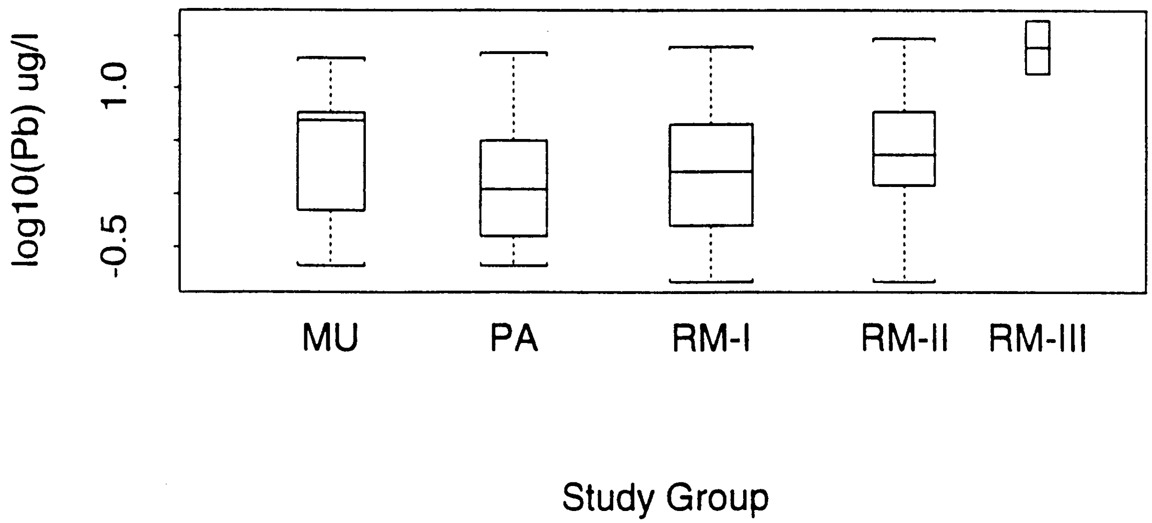


Table 17: Descriptive Statistics For Soil Lead Concentrations By Study Group At Initial Campaign

Study Group	n	Minimum (µg/g)	Maximum (µg/g)	Geometric Mean (µg/g)	S.D. on log scale	Lower 95% CI for GM (µg/g)	Upper 95% CI for GM (µg/g)
R&M Level I	5	435	1,879	1,355	0.635	616	2,981
R&M Level II	5	626	15,968	1,755	1.432	297	10,386
R&M Level III	1	1,350	1,350	-	-	-	-
Previously Abated	3	233	3,061	1,039	1.336	38	28,704
Modern Urban	11	29	154	63	0.489	45	88

Table 18: Descriptive Statistics For Water Lead Concentrations By Study Group At Initial Campaign

Study Group	n	Minimum (µg/L)	Maximum (µg/L)	Geometric Mean (µg/L)	S.D. on log scale	Lower 95% CI for GM (µg/L)	Upper 95% CI for GM (µg/L)
R&M Level I	25	<LOD[a]	25.0	1.8	1.499	1.0	3.3
R&M Level II	14	<LOD[a]	29.7	2.8	1.462	1.2	6.5
R&M Level III	2	13.7	44.2	24.6	0.828	0	41,966.8
Previously Abated	16	<LOD[a]	21.8	1.3	1.311	0.7	2.6
Modern Urban	16	<LOD[a]	19.5	2.4	1.437	1.1	5.1

[a] Generally <0.6 µg/L

Table 19: Comparison Of Mean Dust Lead Concentrations In The 75 R&M Houses To The 27 Excluded R&M Candidate Houses

Sample Type	ln Mean Lead Concentration for R&M Houses (n)	ln Mean Lead Concentration for Excluded Houses (n)	t-Test Value	Prob > |t|
Air Duct	7.36 (28)	6.86 (10)	-1.25	0.22
Exterior Entryway	8.31 (74)	8.39 (27)	0.26	0.80
Floors in Rooms with Windows	7.99 (75)	7.98 (27)	-0.04	0.97
Interior Entryway	8.25 (75)	8.32 (27)	0.26	0.80
Window Sill	9.69 (75)	10.13 (27)	1.85	0.07
Upholstery	6.55 (30)	6.91 (16)	1.24	0.22
Window Well	10.10 (74)	10.33 (27)	1.18	0.24
Floors in Rooms without Windows	7.17 (45)	7.61 (13)	1.19	0.24
Blood	2.48 (98)	2.50 (23)	0.15	0.88

Table 20: **Comparison Of Mean Dust Lead Loadings In The 75 R&M Houses To The 27 Excluded R&M Candidate Houses**

Sample Type	ln Mean Lead Loading for R&M Houses (n)	ln Mean Lead Loading for Excluded Houses (n)	t -Test Value	Prob > |t|
Air Duct	11.04 (28)	10.32 (10)	-1.44	0.16
Exterior Entryway	6.93 (74)	7.35 (27)	0.86	0.40
Floors in Rooms with Windows	7.02 (75)	6.66 (27)	-0.96	0.34
Interior Entryway	7.66 (75)	7.43 (27)	-0.44	0.66
Window Sill	9.26 (75)	9.39 (27)	0.50	0.62
Upholstery	4.19 (30)	4.77 (16)	1.31	0.20
Window Well	12.50 (74)	12.89 (27)	1.56	0.12
Floors in Rooms without Windows	5.85 (45)	6.11 (13)	0.46	0.65

Table 21: Comparison Of Mean Dust Loadings In The 75 R&M Houses To The 27 Excluded R&M Candidate Houses

Sample Type	ln Mean Dust Loading for R&M Houses (n)	ln Mean Dust Loading for Excluded Houses (n)	t -Test Value	Prob > |t|
Air Duct	10.58 (28)	10.37 (10)	-0.68	0.50
Exterior Entryway	5.53 (74)	5.87 (27)	0.93	0.35
Floors in Rooms with Windows	5.94 (75)	5.59 (27)	-1.41	0.16
Interior Entry	6.33 (75)	6.02 (27)	-0.81	0.42
Window Sill	6.48 (75)	6.17 (27)	-1.25	0.22
Upholstery	4.55 (30)	4.76 (16)	0.55	0.59
Window Well	9.30 (74)	9.48 (27)	1.21	0.23
Floors in Rooms without Windows	5.59 (45)	5.41 (13)	-0.43	0.67

Furthermore, there was no statistically significant difference between the genders or the blood lead concentrations of children living in study homes and excluded homes. When the monthly rental/mortgage payment was analyzed by R&M group, no significant differences were found between the excluded houses and the corresponding R&M houses. Because of the apparent unwillingness of owners, as opposed to landlords, to apply for a state loan to do R&M work, the excluded group had a higher proportion of owner-occupants (19 percent) than did the R&M group (4 percent).

7.5 Correlations Among Environmental Lead Variables

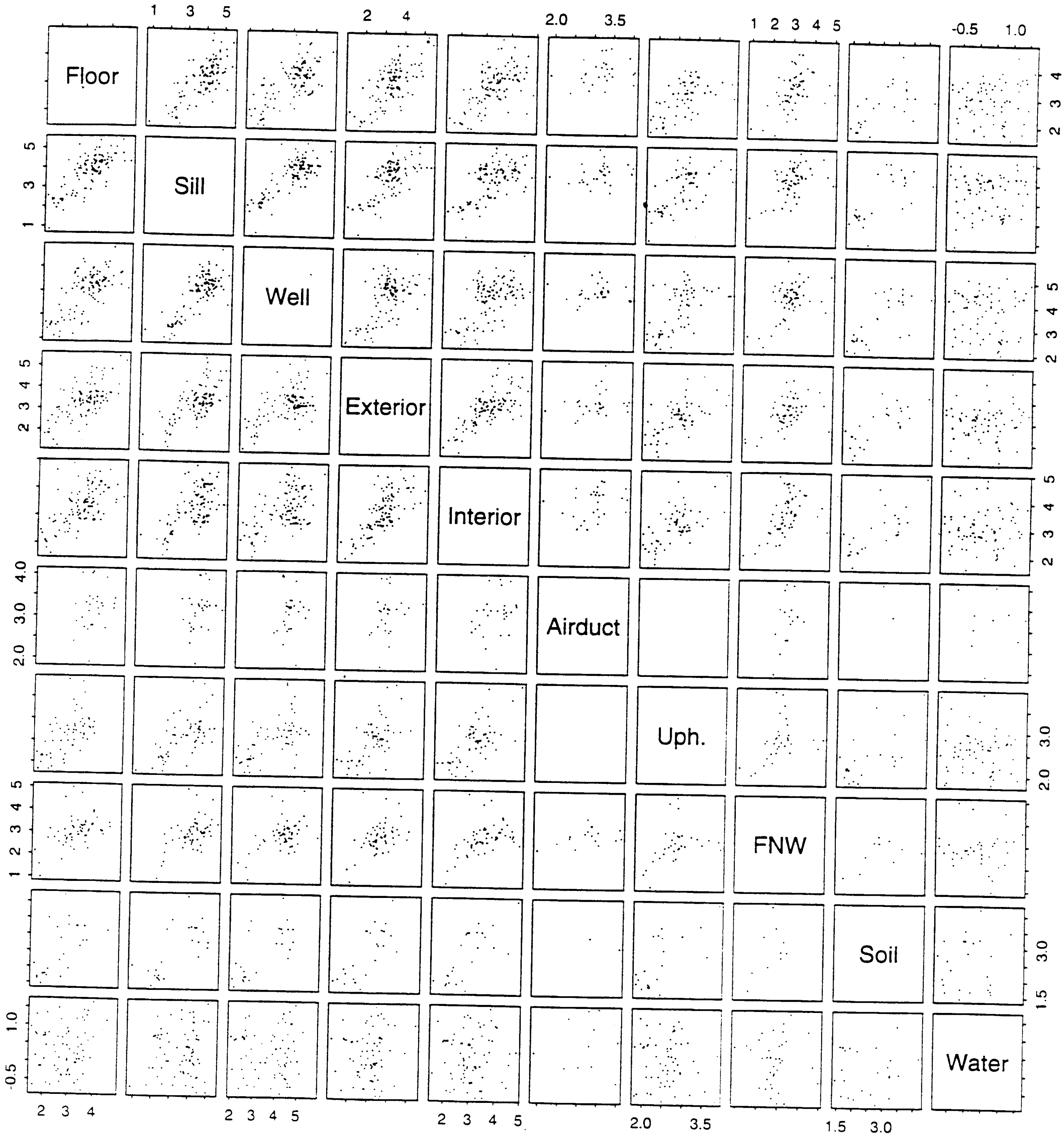
Tables 22 to 24 display the correlation matrices by sample type for lead concentrations, lead loadings, and dust loadings. Data from the 27 excluded houses were included in these analyses since no significant differences were found between R&M houses and the excluded houses.

For lead concentrations, the correlations between the various environmental sample types (exterior dust, interior dust on seven different surfaces, and drip-line soil) were statistically significant and in the range of r=.41 to .80, except for water and air ducts. Water lead concentration was not significantly correlated with any of the other environmental lead concentrations, and air duct dust lead concentration was correlated only with floor and interior entryway dust lead concentration. The highest correlation coefficient (r=.80) was found between lead concentrations on window wells and window sills. The next highest correlation coefficient (r=.77) was between dust collected in exterior entryways and drip-line soil. Figure 15 is a scatterplot matrix of lead concentration data showing the scatterplots for each possible pair of environmental sample types.

For lead loadings, the correlations among the dust sample types were statistically significant and in the range of r=.29 to .82, except for air ducts, which were significantly correlated with only the dust lead loadings found in interior entryways (r=.37). The highest correlation coefficient (r=.82) was between the lead loadings found on window wells and window sills. The next highest correlation coefficient for lead loadings (r=.72) was for floors in rooms with windows and window sills.

The correlations between dust loadings of the various surface types are weaker, and fewer are statistically significant, as compared to lead concentrations and lead loadings. The statistically significant correlations range from r=.25 to .55. Upholstery and air duct dust loadings were not correlated with any other surface types. Exterior entryways were correlated only with window sills. The highest correlation coefficient for dust loading measurements of (r=.55) is between floors in rooms with and without windows, followed by a correlation coefficient of r=.46 between window sills and floors in rooms with windows.

Figure 15: Scatterplot Matrix Between Environmental Lead Concentrations



FNW = Floors in rooms without windows

Table 22: **Correlations Between Environmental Dust Lead Concentrations At Initial Campaign**
Pearson Correlation Coefficients / Number of Observations

		Air Duct	Exterior Entryway	Floors in Rooms with Windows	Interior Entryway	Window Sill	Upholstery	Window Well	Floors in Rooms without Windows	Soil	Water
Air Duct	r	-	0.26	0.39*	0.38*	0.24	-	-0.11	0.38	-0.27	-0.15
	n		38	39	39	39	0	39	24	5	15
Exterior Entryway	r	-	-	0.63**	0.72**	0.66**	0.61**	0.55**	0.44**	0.77**	0.12
	n			131	131	131	75	130	68	32	92
Floors in Rooms with Windows	r	-	-	-	0.61**	0.73**	0.63**	0.65**	0.46**	0.63**	0.10
	n				134	134	76	133	70	32	94
Interior Entryway	r	-	-	-	-	0.60**	0.68**	0.55**	0.48**	0.72**	0.06
	n					134	76	133	70	32	94
Window Sill	r	-	-	-	-	-	0.65**	0.80**	0.51**	0.72**	0.11
	n						76	133	70	32	94
Upholstery	r	-	-	-	-	-	-	0.59**	0.41*	0.71**	-0.06
	n							75	38	26	76
Window Well	r	-	-	-	-	-	-	-	0.46**	0.72**	0.06
	n								69	32	93
Floors in Rooms without Windows	r	-	-	-	-	-	-	-	-	0.50	0.01
	n									12	45
Soil	r	-	-	-	-	-	-	-	-	-	0.18
	n										31
Water	r	-	-	-	-	-	-	-	-	-	-
	n										

* p-value is < .05
** p-value is < .01

Table 23: Correlations Between Environmental Dust Lead Loadings At Initial Campaign

Pearson Correlation Coefficients / Number of Observations

		Air Duct	Exterior Entryway	Floors in Rooms with Windows	Interior Entryway	Window Sill	Upholstery	Window Well	Floors in Rooms without Windows
Air Duct	r	-	0.12	0.09	0.37*	-0.02	-	-0.27	0.36
	n		38	39	39	39	0	39	24
Exterior Entryway	r	-	-	0.49**	0.49**	0.51**	0.34**	0.40**	0.29*
	n			131	131	131	75	130	68
Floors in Rooms with Windows	r	-	-	-	0.68**	0.72**	0.47**	0.61**	0.62**
	n				134	134	76	134	70
Interior Entryway	r	-	-	-	-	0.58**	0.37**	0.44**	0.58**
	n					134	76	133	70
Window Sill	r	-	-	-	-	-	0.52**	0.82**	0.54**
	n						76	133	70
Upholstery	r	-	-	-	-	-	-	0.48**	0.40*
	n							75	38
Window Well	r	-	-	-	-	-	-	-	0.43**
	n								69
Floors in Rooms without Windows	r	-	-	-	-	-	-	-	-
	n								

*   p-value is < .05
** p-value is < .01

Table 24: **Correlations Between Environmental Dust Loadings For The Initial Campaign**

Pearson Correlation Coefficients / Number of Observations

		Air Duct	Exterior Entryway	Floors in Rooms with Windows	Interior Entryway	Window Sill	Upholstery	Window Well	Floors in Rooms without Windows
Air Duct	r	-	-0.04	-0.15	0.29	-0.11	-	-0.18	-0.05
	n		38	39	39	39	0	39	24
Exterior Entryway	r	-	-	0.13	0.04	0.25**	-0.09	0.11	-0.06
	n			131	131	131	75	130	68
Floors in Rooms with Windows	r	-	-	-	0.35**	0.46**	0.01	0.41**	0.55**
	n				134	134	76	133	70
Interior Entryway	r	-	-	-	-	0.14	0.02	0.04	0.44**
	n					134	76	133	70
Window Sill	r	-	-	-	-	-	-0.07	0.35**	0.45**
	n						76	133	70
Upholstery	r	-	-	-	-	-	-	0.06	0.05
	n							75	38
Window Well	r	-	-	-	-	-	-	-	0.33*
	n								69
Floors in Rooms without Windows	r	-	-	-	-	-	-	-	-
	n								

* = p-value is < .05
** = p-value is < .01

7.6 Correlations Between Blood Lead And Environmental Lead

Children who had lived in a study house for at least two months prior to the initial blood lead measurement were included in the analysis of the correlation between blood lead and environmental lead (see section 6.3). Information on the temporal relationship of blood lead to environmental data is provided in section 7.0.

Correlations between blood lead concentrations and environmental lead variables were not found to be statistically significant when examined separately within each of the relevant groups of houses occupied at the time of the initial campaign. (See Table 11 for the range of blood lead concentrations by study group.) The analysis was then performed using combined data from all the relevant study houses, plus data from the 19 excluded houses, with paired blood and environmental data. The range of blood lead concentrations for the combined data set was 0.9 to 65.5 μg/dL. Figure 16 displays scatterplot matrices for blood lead concentration versus dust lead concentration and lead loading for floors, window sills, and window wells.

Table 25 displays the correlations between blood lead concentration of the youngest child in each household and lead loading, lead concentration, and dust loading by surface. The correlations between blood lead and environmental lead concentrations were all statistically significant and in the range of r=.36 to .64, except for air ducts and drinking water. The highest correlation coefficient found was r=.64 for upholstery followed by r=.56 for interior entryways, r=0.52 for floors in rooms with windows, and r=.49 for window sills. The correlations between blood lead and dust lead loadings were also statistically significant, except for air ducts and drinking water, but the correlations tended to be weaker than those for lead concentrations. The significant correlation coefficients ranged from r=.35 to .50. The highest coefficient was r=.50 for blood lead and lead loadings on upholstery, followed by r=.49 for blood lead and lead loadings on floors in rooms with windows. The only statistically significant correlations between blood lead and dust loadings were those between blood lead and upholstery (r=.24) and blood lead and window wells (r=.34). When all study children were considered in the analysis (Table 26), the correlations tended to be weaker than those obtained using the youngest child in each household.

Figure 16: **Scatterplot Comparisons Of Blood Lead Concentration And Environmental Lead Loadings And Concentrations By Surface**

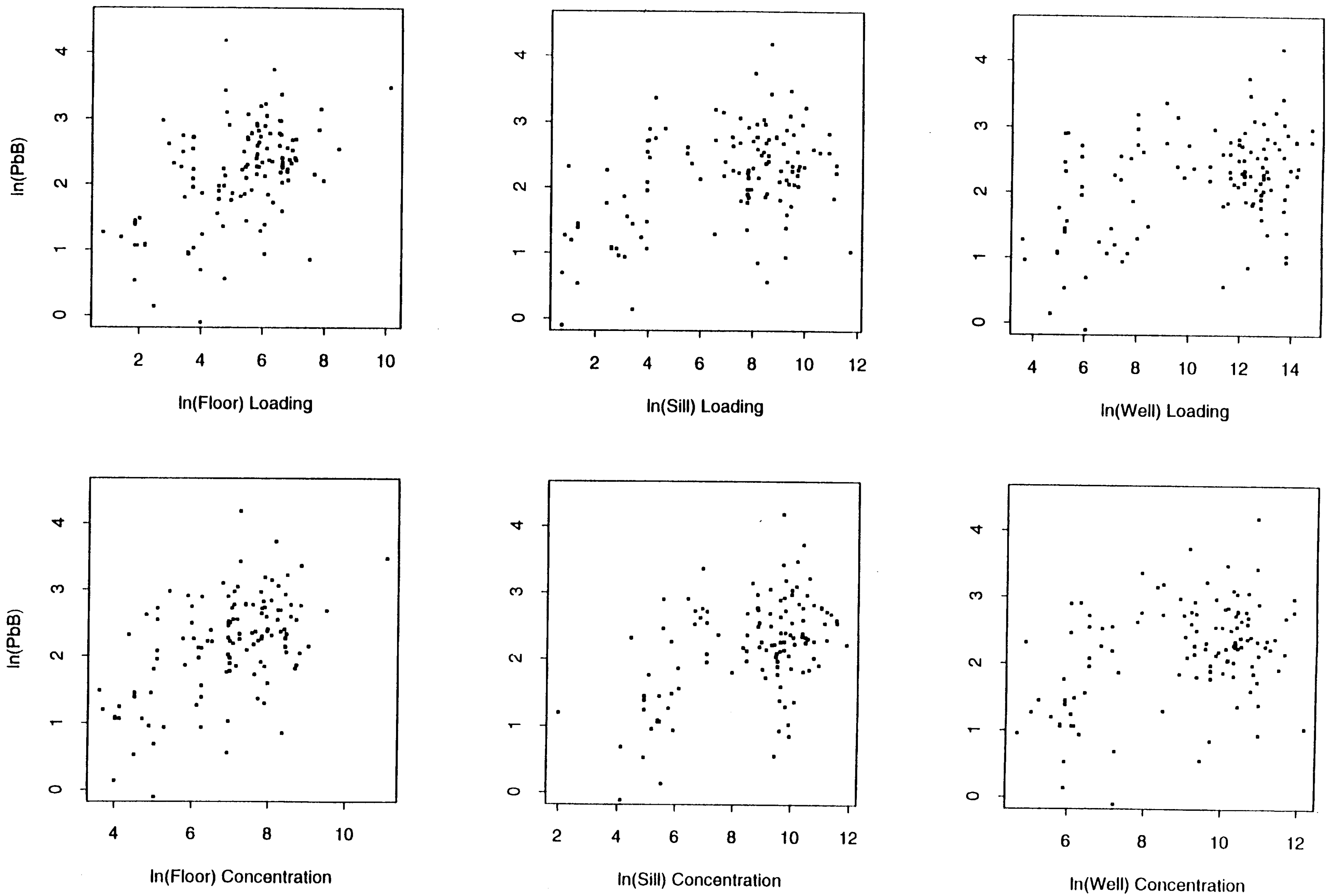


Table 25: Correlations Between Dust Lead Concentrations, Dust Lead Loadings, And Dust Loadings And Blood Lead Concentrations Of The Youngest Child Per Household In Continuing And Excluded Houses For The Initial Campaign

Pearson Correlation Coefficients / Number of Observations

DUST VARIABLE		SAMPLE TYPE									
		Exterior Entryway	Interior Entryway	Floors in Rooms with Windows	Floors in Rooms without Windows	Upholstery	Window Sill	Window Well	Air Duct	Soil	Water
log of lead concentration (µg/g)	r	0.48**	0.56**	0.52**	0.36*	0.64**	0.49**	0.42**	0.08	0.40*	-0.08
	n	85	87	87	41	73	87	86	11	29	87
log of lead loading (µg/ft²)	r	0.36**	0.40**	0.49**	0.35*	0.50**	0.43**	0.42**	0.12		
	n	85	87	87	41	73	87	86	11		
log of dust loading (mg/ft²)	r	0.07	0.04	0.01	-0.10	0.24*	-0.07	0.34**	-0.03		
	n	85	87	87	41	73	87	86	11		

* = p-value is < .05
** = p-value is < .01

Table 26: **Correlations Between Dust Lead Concentrations, Dust Lead Loadings, And Dust Loadings And Blood Lead Concentration Of All Children In Continuing And Excluded Houses For The Initial Campaign**

Pearson Correlation Coefficients / Number of Observations

DUST VARIABLE		SAMPLE TYPE									
		Exterior Entryway	Interior Entryway	Floors in Rooms with Windows	Floors in Rooms without Windows	Upholstery	Window Sill	Window Well	Air Duct	Soil	Water
log of lead concentration (µg/ft^2)	r	0.47**	0.56**	0.52**	0.41**	0.63**	0.47**	0.37**	-0.07	0.44**	0.01
	n	112	115	115	49	92	115	114	15	42	115
log of lead loading (µg/ft^2)	r	0.28**	0.36**	0.46**	0.34*	0.46**	0.42**	0.37**	-0.06		
	n	112	115	115	49	92	115	114	15		
log of dust loading (mg/ft^2)	r	0.05	0.03	-0.02	-0.17	0.18	-0.04	0.28**	-0.11		
	n	112	115	115	49	92	115	114	15		

* = p-value is < .05
** = p-value is < .01

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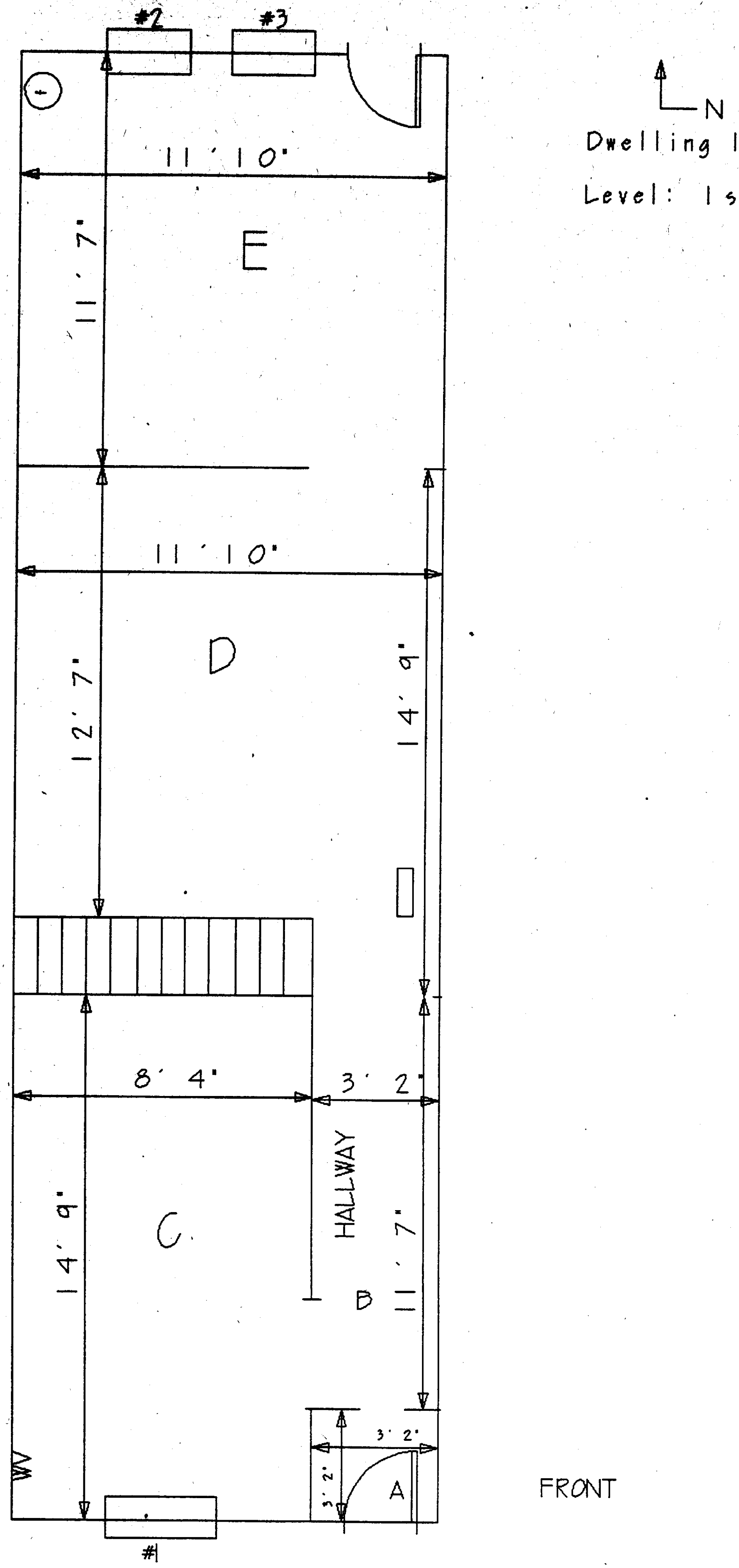
APPENDIX: Floor Plans of Two Typical Study Rowhouses

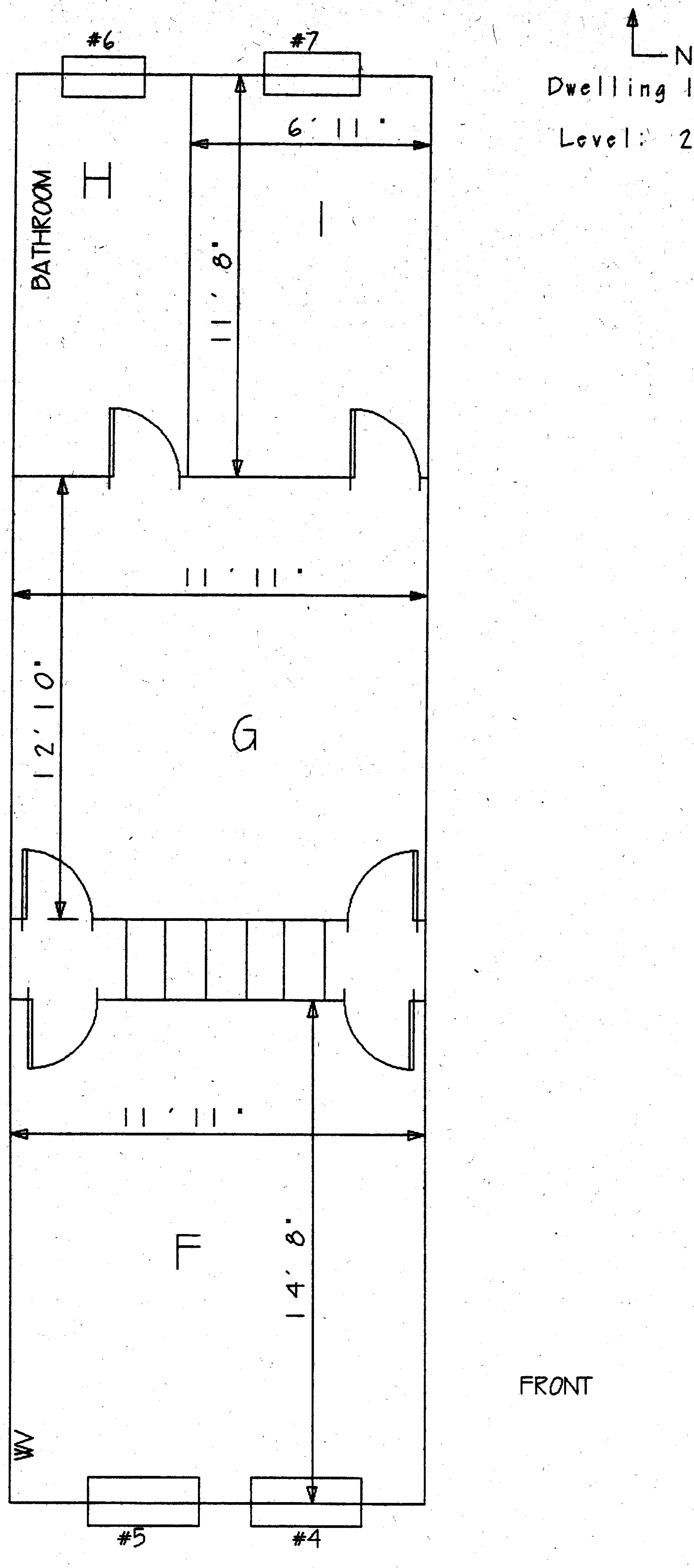


Dwelling ID #436

Level: 1st floor

Dwelling ID #436

Level: 2nd floor



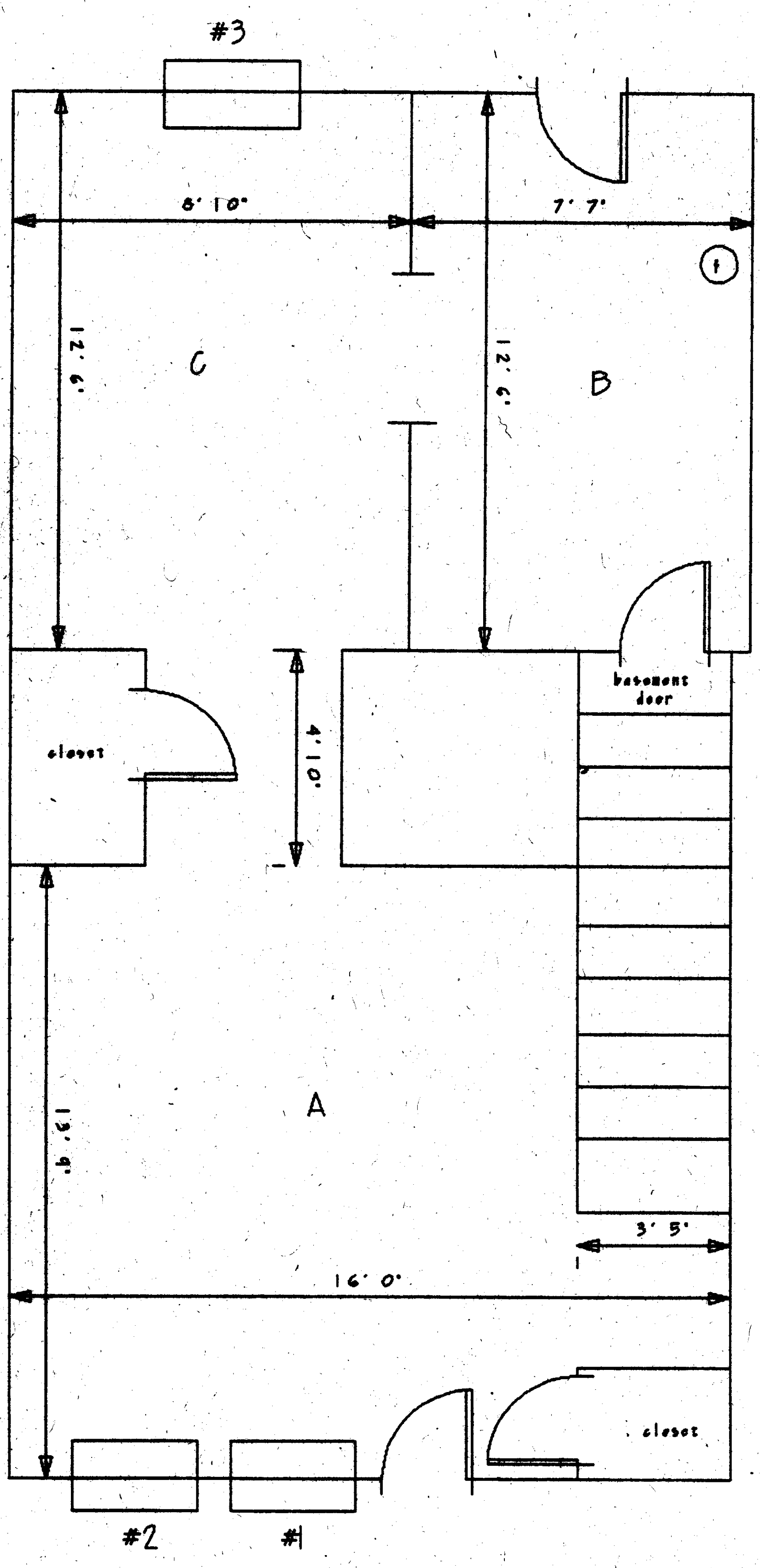
FRONT

← N

Dwelling #212

Level: 1st Floor

Carpet Throughout



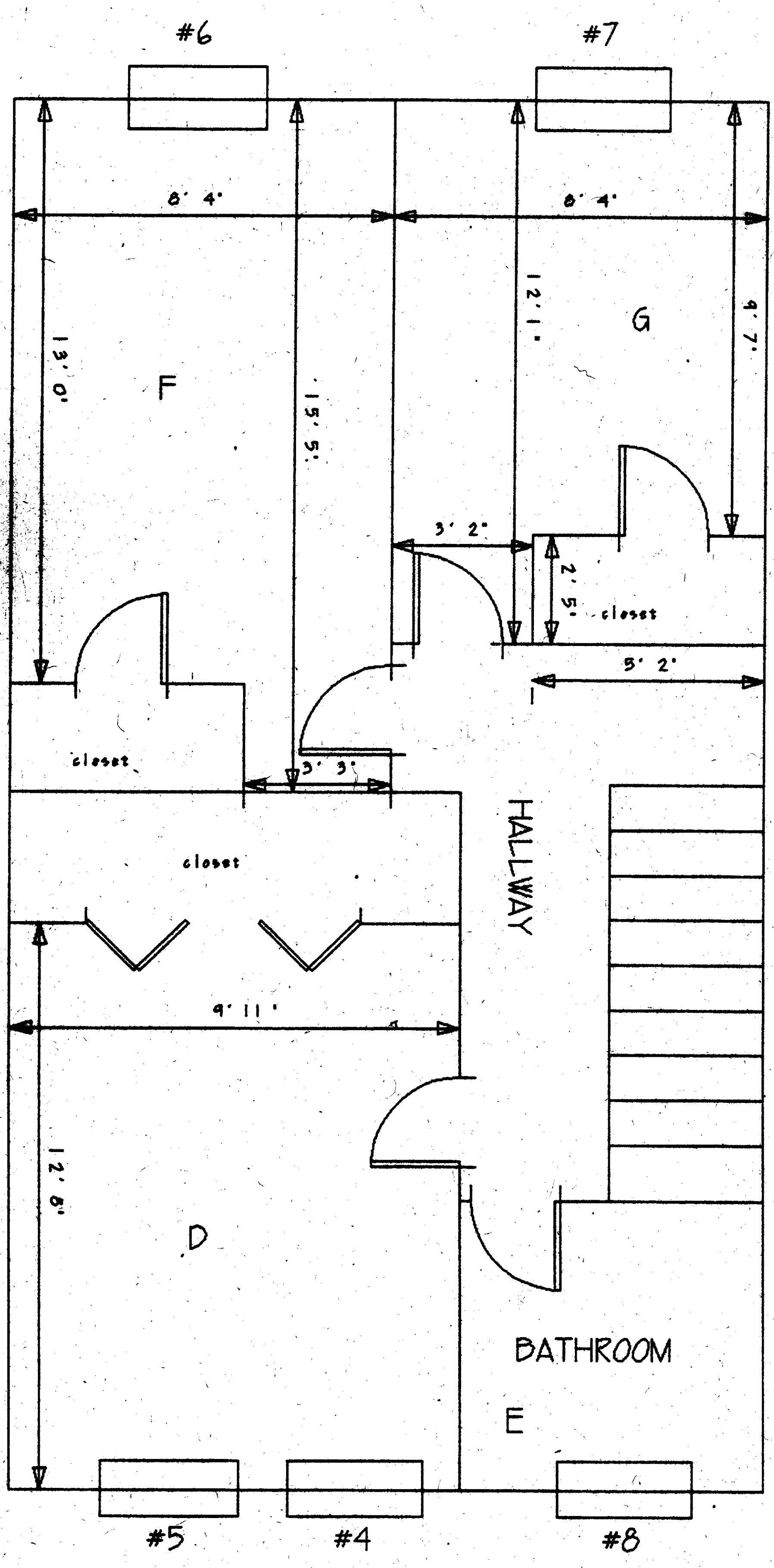
FRONT

← N

Dwelling #21 2

Level: 2nd Floor

Carpet Throughout



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16. Abstract (Limit: 200 words)
This report presents the results of the initial data collection of the Lead-Based Abatement and Repair and Maintenance (R&M) Study in Baltimore, MD. The R&M study is designed to characterize and compare the short (2-6 months) and long-term (12-24 months) efficacy of comprehensive lead abatement with less costly and potentially more effective R&M interventions. The R&M interventions are designed to reduce children's exposure to lead in residential paint and dust. The study targets low-income housing where children are at high risk. This report provides pre-intervention baseline data for the longitudinal study of changes in levels of lead in children's blood and in settled house dust associated with three levels of R&M intervention. The results showed that children's blood lead concentrations were significantly correlated with lead levels in house dust from entryway and six types of interior surfaces.

17. Document Analysis

a. Descriptors:
Kennedy Krieger Research Institute, lead, lead clinic, lead dust testing, blood lead testing, lead-based paint, lead-dust loading, lead-dust concentration, dust loading, low cost interventions, repair and maintenance, children's blood lead, lead exposure reduction in children, lead hazard reduction, blood lead-dust lead correlation.

b. Identifiers/Open-Ended Terms:
Lead poisoning, lead abatement, inductively coupled plasma emission spectroscopy (ICP-AES), flame atomic absorption spectroscopy (FAAS), graphite furnace atomic absorption spectroscopy (GFAAS), cyclone-based dust collector, Baltimore Repair and Maintenance dust collector (BRM).

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