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ANALYSIS OF PATHWAYS OF RESIDENTIAL LEAD EXPOSURE IN CHILDREN

Final Report

Program Assessment and Outreach Branch
National Program Chemicals Division
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
Washington, DC 20460

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The analysis that led to this report was funded and managed by the U.S. Environmental Protection Agency. The analysis was conducted by Battelle Memorial Institute. Each organization's responsibilities are listed below.

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The U.S. Environmental Protection Agency funded the task, managed the task, reviewed task documents, and managed peer review of this report. The EPA Work Assignment Manager was John Schwemberger. The Project Officer was Sineta Wooten.

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EXECUTIVE SUMMARY

Despite reductions of the amount of lead in various sources over the past few decades, elevated blood-lead concentrations in children continue to be a public health concern. Using data from three environmental lead studies (the Comprehensive Abatement Performance (CAP) Study [9, 10, 11], the Baltimore Repair and Maintenance (R&M) study [12], and the Rochester Lead-In-Dust study [13]), the relationships among environmental lead levels and children's blood lead concentrations were examined using structural equation models (SEM). SEM was used for this analysis because the method accounts for the covariance among variables that allow direct and, in particular, indirect effects of various sources of lead to be assessed. Traditional multiple regression only assesses the direct effects.

The primary analysis of this report focused on two types of structural equation models: environmental-lead pathway models and blood-lead pathway models. The environmental-lead pathway models were structured to assess the direct and indirect impact of several environmental variables such as soil lead, window sill dust-lead, and window well dust-lead on floor dust-lead so that comparisons could be made across the three studies (CAP, R&M, and Rochester). The blood-lead pathway models were structured to focus on the direct and indirect impact of soil lead, paint-lead, window sill dust-lead, window well dust-lead, and floor dust-lead on childhood blood-lead concentration and to allow comparisons between R&M and Rochester. (The CAP Study did not collect blood-lead data and therefore could not be included in the blood-lead pathway model analysis). Because the three studies were not designed or conducted in the exact same manner, there was some information collected in one study that was not collected in the others. To take advantage of having additional information in the studies, several secondary sub-analyses were performed. The sub-analyses focused on specific pathways of lead exposure within either the environmental-lead pathway models or the blood-lead pathway models. Note that for all analyses separate models were fit using dust-lead loading vacuum samples and dust-lead concentration vacuum samples.

In the <u>environmental-lead pathways</u> analysis, three statistically significant direct pathways of lead contamination were found for all three studies: 1) window well dust-lead loading to window sill dust-lead loading, 2) window well dust-lead concentration to window sill dust-lead concentration, and 3) exterior entryway dust-lead concentration to interior entryway dust-lead concentration. There were several indirect pathways which were the same for two out of the three studies: 1) soil-lead concentration to window well dust-lead loading to window sill dust-lead loading, 2) soil-lead concentration to window well dust-lead concentration to window sill dust-lead concentration, 3) window well dust-lead loading to window sill dust-lead loading to the interior entryway dust-lead loading or the floor dust-lead loading, and 4) window well dust-lead concentration to window sill dust-lead concentration to floor dust-lead concentration. Despite the different study designs and dust vacuum collection methods, the results are quite similar across the three studies.

The blood-lead pathways models fitted to the two data sets with blood lead measurements (R&M and Rochester) had fewer consistent, statistically significant pathways across the studies. In the lead loading models *consistent* pathways included direct pathways of lead exposure from 1) floor dust-lead and 2) children's mouthing habits to the blood, and indirect pathways from 1) interior entryway dust-lead, 2) dust on window wells and 3) dust on window sills to blood. However, no consistent significant pathways to blood were found in the lead concentration models. In the R&M concentration model, significant pathways included a direct pathway from interior entryway dust-lead concentration to blood, and indirect pathways of exposure to the blood from exterior entryway dust, window well dust, and the window sill dust-lead concentration. In the Rochester concentration model, the only statistically significant pathway to blood was a direct pathway from children's mouthing behavior to blood. There were no statistically significant indirect pathways to blood in the Rochester concentration model.

An analysis of the Rochester data included a statistically significant hand dust-lead pathway in the blood-lead pathways model. Hand dust-lead was a statistically significant pathway to blood-lead in other studies analyzed by structural equations modeling. An analysis of the Rochester data indicated that hand dust-lead was one of the direct pathways of lead exposure to a child's blood, with environmental pathways directly and indirectly to the child's hand dust-lead.

1.0 INTRODUCTION

Although Federal and state regulatory agencies have succeeded in reducing lead in paint, food, and ambient air, approximately one million children in the United States, ages one to five years, have a blood lead concentration equal to or above the CDC threshold of 10 µg/dL [22].

The purpose of the work presented in this document is to understand the sources and routes by which children are exposed to lead in their residences so that the optimal prevention and remediation action can be carried out. A pathways analysis using structural equation models (SEM) was performed to assess the different pathways by which a child may be exposed to lead. Data from three studies, the Comprehensive Abatement Performance Study (CAP Study) [9, 10, 11], the Baltimore Lead-Based Paint Abatement and Repair and Maintenance Study (R&M) [12], and the Rochester Lead-In-Dust Study (Rochester) [13] were used to assess the pathway models. Structural equation modeling was used for this analysis because the method takes into account the covariance among the environmental and blood-lead variables. Taking into account the covariance among the variables allows for the assessment of the direct effect or indirect effect of one lead source on another lead source. Multiple regression, the traditional analysis method, does not take into account the covariance structure among the variables. (An explanation of direct and indirect effects is provided below).

1.1 DEFINITIONS

Throughout the document there are several terms which will be used. For clarity, the definition of each term is given below.

Window Sill

"The portion of the horizontal window ledge that protrudes into the interior of the room, adjacent to the window sash when closed [16]." Also referred to as "window stool."

Window Well

"The portion of the horizontal window sill that receives both the upper and lower window sashes when they are lowered, often located between the storm window and the interior window sash [16]." Also referred to as "window channel" or "window trough."

Structural Equation Models

Consider the pathway diagramed in Figure 1-1. This diagram shows directional pathways of lead exposure as follows:

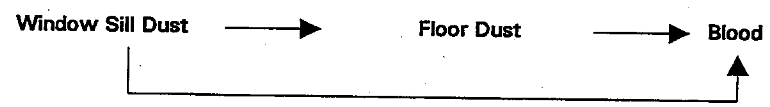


Figure 1-1. Pathways Diagram Assessing the Role of Floor Dust Lead as a Route for Lead Dust from the Window Sill to the Child's Blood.

- Window sill dust is being assessed as to whether it directly impacts floor dust and/or blood-lead (i.e., the arrows which point to blood and floor dust from window sill dust),
- Floor dust is being evaluated as to whether it is directly impacting blood-lead, and
- Finally, window sill dust is being assessed as to whether it indirectly impacts blood-lead via floor dust (i.e., the arrow which goes from window sill dust to floor dust and then the arrow which goes to blood from floor dust).

These directional relationships illustrated in the diagram are represented by the following two equations:

(1) Blood Lead = Floor Dust Lead + Window Sill Dust Lead
(2) Floor Dust Lead = Window Sill Dust Lead.

and a covariance matrix of all the variables in the diagram.

The directional nature of the diagram is illustrated through the equations by starting with the highest numbered equation and working upwards, i.e., (2) and then (1). Equation (2) represents the arrow from window sill dust to floor dust. Equation (1) represents the arrow from floor dust to blood and the arrow from window sill dust to blood. Finally, the indirect relationship of window sill dust to blood via floor dust is represented by both equations (1) and (2) and the covariance matrix.

Evaluating equations (1) and (2) separately is similar to multiple regression or ANOVA, i.e., both these methods can assess the direct effect of floor dust on blood in equation (1) and window sill dust on floor dust in equation (2). What these methods cannot assess is the indirect effect of window sill dust on blood via the floor dust. By evaluating both equations (1) and (2) simultaneously and accounting for the covariance between these variables, SEM allows for an assessment of the indirect effect.

Environmental-Lead Pathways Model

The environmental-lead pathways model is a set of structural equation models that assess the direct and indirect effects of lead in environmental media, such as soil, window sill dust, window well dust, floor dust, and paint. This model was developed for the R&M, Rochester, and CAP Study data.

Blood-Lead Pathways Model

The blood-lead pathways model is a set of structural equation models that assess the direct and indirect effects of lead in environmental media, such as soil, window well dust, window sill dust, floor dust, water, and paint; child modifier variables, such as a child's mouthing behavior; and indicator variables, such as the presence or absence of carpeting in the entryway, on the blood-lead concentration of the child in the home. This model was developed for the R&M and Rochester data.

Statistical Significance of Variables in the Structural Equation Models

A t-test was used to determine if the variable included in the model was statistically significant. If the absolute value of the t-value was greater than or equal to 1.96 then the parameter was considered to be statistically significant since the probability of observing this extreme value (-1.96 or +1.96) for the t-test statistic is 0.05.

1.2 PEER REVIEW

Prior to publication, this report was reviewed by three individuals with knowledge and expertise in the subject matter of the report. These reviewers were not involved in the development of the report, and conducted their reviews independently of each other. The following is a summary of comments and responses to those comments which had an important impact on the report or which are important for understanding and interpreting the report.

One reviewer strongly recommended that prediction limits be developed for the estimates of percent change in lead levels that resulted when the geometric mean of model input variables was decreased. An appropriate methodology was developed and implemented, and prediction limits were added to all tables which included a percent change. In response to another review comment, an appendix was added to the report which describes the types of calculations made in the pathways analysis and how the associated standard errors were estimated. This same appendix include a discussion of goodness-of-fit statistics for the pathways models, in response to comments by the reviewers.

A reviewer pointed out that hand wipe data were available for children in the Rochester Study. A pathways analysis that included these data was added to the report. Another reviewer asked whether bare soil or other "modifiers" should be included in the models. The Rochester Study included a variable on vegetative soil cover, and an additional analysis was added which incorporated this variable as a modifier to the soil lead level, in a manner similar to what was done previously in the report for paint lead levels and paint condition.

Two reviewers commented on statements in the report about renovation and remodeling in the Rochester Study. In fact, none of the houses in the Rochester Study had any renovation and remodeling work done on them in the twelve months immediately prior to initiation of that study. The language in the report was clarified on this point. However, information related to renovation and remodeling was found for one of the other studies in the report. This information was used to develop pathways analyses germane to the impact of renovation and remodeling for a second study, using the same approach presented in the report at the time of peer review. These additional pathways analyses were included in the final report.

Other review comments mentioned references for other lead pathway analyses that were not included in the report. These other references were added to the discussion section of the report, with appropriate text. Moreover, a reviewer pointed out that a published journal article contained results which conflicted with the results of one of the pathway analyses in this report, and requested double checking of the results in the report. An investigation showed that differences in methodology were the reason for the differences between the two analyses. The discussion section was revised to list the methodological differences.

One reviewer commented on the large number of pathways analyses, and stated that there should be one environmental pathway analysis and one blood pathway analysis per study. The same reviewer commented on the omission of lead from paint in a lead pathways analysis, indicating that it would be far preferable to include lead from paint. The reviewer also stated that there appeared to be a bias toward lead from soil. However, the report does contain analyses for the Rochester study and for the Repair and Maintenance study which do include a measure of lead in paint for windows and doors. The text in the report was changed to clarify the goals of the report. One of the primary objectives of the report was to examine lead pathways for three different studies, and compare the results across the different studies. A secondary objective was to examine other variables of interest that were not necessarily common to all three studies, and

to conduct pathways analyses with these additional variables. Paint and soil data were both used in the report.

EPA has established a public record for the peer review under Administrative Record 207. The administrative record is available in the TSCA Nonconfidential Information Center, which is open from noon to 4 PM Monday through Friday, except legal holidays. The TSCA Nonconfidential Information Center is located in Room NE-B607, Northeast Mall, 401 M Street SW, Washington, D.C.

1.3 STRUCTURE OF THE REPORT

Section 2 discusses the conclusions drawn from the structural equation modeling. Section 3 lists the quality assurance information for the data included in the analysis. Background information specific to each study is provided in Section 4. Statistical methodology used to assess the pathways models is discussed in Section 5. Results from the pathways analysis are discussed in Section 6, and a discussion of the conclusions and results from this report in comparison to published results is provided in Section 7. References are provided in Section 8. Appendices A, B, and C present selected results from the CAP Study, R&M, and Rochester data, respectively. Appendix D illustrates several pathway models which have been analyzed and published in the literature. Finally Appendix E presents a discussion of model specification, estimation criteria and goodness-of-fit tests associated with structural equation modeling.

2.0 FINDINGS AND CONCLUSIONS

This section presents conclusions drawn from the pathways models described in Section 5 and the analysis results presented in Section 6. Though much of the same type of information was collected in each of the three studies included in the analysis, there were a number of variables not collected in some of the studies. For example, no blood-lead or water-lead measurements were taken in the CAP Study. As a result, pathways including blood lead and water lead could not be examined using the CAP Study data. When applicable, such exceptions are noted. Because of these data limitations, there may be pathways other than those included in the models which are significant contributors to either dust-lead levels or blood-lead concentrations but were not investigated. Note that all the dust-lead samples included in the analysis were all collected via vacuum.

2.1 CORRELATION ANALYSIS

Note: All correlations were calculated within a study. The findings within a study are compared across studies.

- Correlation coefficients between window well and window sill dust-lead loadings were larger than 0.5 for all three studies. Similarly, correlation coefficients for window well and window sill dust-lead concentrations were larger than 0.5 for all three studies. For one study, these correlation coefficients were larger than 0.8.

- Water-lead samples in the R&M study were collected after a 2-hour fixed time stagnation while the Rochester study water samples were collected after an 8-hour stagnation period. The water-lead concentrations within the R&M study and within the Rochester study were not highly correlated with any respective environmental measure, or blood-lead concentration. [Note: Water and blood samples were not collected in the CAP Study.]

- For the Rochester study, blood-lead concentrations typically had a higher correlation coefficient with dust-lead loadings than with dust-lead concentrations. For the R&M study, blood-lead concentrations typically had a higher correlation coefficient with dust-lead concentration than with dust-lead loading.

- For the Rochester study, the environmental variables that had the highest correlation coefficients with blood-lead were hand dust-lead (0.43), window well dust-lead loading (0.37), soil-lead concentration (0.37), and door paint hazard score (0.36). For the R&M study, the environmental variables that had the highest correlation coefficients with blood-lead were interior entryway dust concentration (0.56), floor dust concentration (0.53), and floor dust-lead loading (0.50). A number of other environmental variables in the R&M study had correlation coefficients with blood-lead that were larger than 0.40. (Hand dust-lead and soil-lead concentration were not available for the R&M study.)

- For the CAP study, floor dust-lead loadings were most highly correlated with interior entryway dust-lead loadings (0.36). For the R&M study, floor dust-lead loadings were most highly correlated with window sill dust-lead loadings (0.63). (The correlation between floor dust-lead loading and blood-lead concentration was 0.50 for the R&M study.) For the Rochester study, floor dust-lead loadings were most highly correlated with hand dust-lead (0.36) and window sill dust-lead loading (0.35). (The correlation between floor dust-lead loading and blood-lead concentration was 0.32 for the Rochester study.)

2.2 ENVIRONMENTAL-LEAD PATHWAYS ANALYSIS

Note: The primary environmental-lead SEM was structured for comparison across the three studies (CAP, R&M, and Rochester). The pathways to floor dust that were assessed were interior entryway dust, exterior entryway dust, window sill dust, window well dust, and soil. Because the CAP Study did not have paint data collected and more than half of the R&M study homes did not have paint data, paint was not included as a pathway in the primary analysis.

- In all three studies, the significant direct pathways of lead exposure were: window well dust lead to window sill dust lead for both loadings and concentrations, and exterior entryway dust-lead concentration to interior entryway dust-lead concentration.

- In the R&M study, window well dust lead was an indirect pathway to interior entryway dust lead via the window sill for both loadings and concentrations. In addition, for the R&M study, window well dust-lead was an indirect pathway to floor dust for both loadings and concentrations. In the Rochester study, window well dust lead was an indirect pathway of lead exposure to floor dust lead via the window sill for both loadings and concentrations. In the CAP study, window well dust-lead concentration directly contributed to floor dust-lead concentration, while neither window sill nor window well dust-lead loading were direct or indirect pathways of lead exposure to floor dust-lead loading or interior entryway dust-lead loadings.

- In the R&M study, exterior entryway dust lead loading was an indirect pathway to floor dust lead via the interior entryway loadings. In the Rochester study, exterior entryway dust-lead concentration was an indirect pathway to floor dust via the interior entryway concentration. In the CAP study the exterior entryway dust-lead loadings and concentrations were neither direct nor indirect pathways to the floor dust-lead loadings or concentrations.

- In the CAP and Rochester studies, where soil-lead concentrations could be assessed, soil-lead concentration was found to be an indirect pathway of lead to window sill dust lead through the window well for both loadings and concentrations. (As noted above, very few soil samples were collected in the R&M study and could not be included as a pathway in the analyses.)

The following conclusions are drawn from the estimated environmental-lead pathways models. These pathways models contained all variables, not just those that were significant. For each study and model, one variable was assumed to have a 50% reduction in its geometric mean lead level while all the other variables were held constant at their geometric mean lead levels.

- In the CAP study, the largest reduction in floor dust-lead loadings or concentrations occurred when the geometric mean soil-lead concentration was reduced 50%. In the R&M study, the greatest decrease in the floor dust lead occurred when window well dust lead was reduced by 50% for both loadings and concentrations. In the Rochester study, a 50% reduction in the geometric mean soil-lead concentration had the greatest effect on floor dust-lead loadings while a reduction in interior entryway dust-lead concentration had the largest effect on reducing the floor dust-lead concentrations.

- In the CAP and Rochester studies, generally, the 50% reduction in the geometric mean soil-lead concentration produced the largest reductions in the other environmental-lead levels (floor, interior entryway, window sill, and window well dust-lead levels). In the R&M study, the largest reductions were achieved in window sills when window well levels were reduced.

2.3 BLOOD-LEAD PATHWAYS ANALYSIS

Note: The primary blood-lead SEM was structured for comparison across the R&M and Rochester studies. The pathways to blood that were assessed were floor dust, interior entryway dust, exterior entryway dust, window sill dust, window well dust, water, mouthing behavior, and soil. The CAP study data were not included because no blood data were collected in the study. Paint pathways were not included in the primary analysis because more than half the homes in the R&M study did not have paint data collected.

- In the R&M study, child's mouthing behavior, floor dust-lead loading, and interior entryway dust-lead concentration were direct pathways of lead exposure to the child's blood-lead concentration. In the Rochester study, the floor and window well dust-lead loadings and child's mouthing behavior were direct pathways of lead to the child's blood-lead concentration.

- For the R&M study, there were four indirect pathways of lead exposure to the blood 1) window well dust-lead loading to window sill dust-lead loading to interior entryway dust-lead loading to floor dust-lead loading, 2) window well dust-lead concentration to window sill dust-lead concentration to interior entryway dust-lead concentration, 3) exterior entryway dust-lead loading to interior entryway dust-lead loading to floor loading, and 4) exterior entryway concentration to interior entryway concentration. For the Rochester study, two indirect pathways of lead exposure to blood were 1) soil-lead concentration to window well dust-lead loading to window sill dust-lead loading to floor dust-lead loading and 2) soil-lead concentration to interior entryway dust-lead loading to floor dust-lead loading.

The following conclusions are drawn from the estimated blood-lead pathways models. For each study and model, one variable was assumed to have a 50% reduction in its geometric mean while all the other variables were held constant at their geometric means. For the mouthing variable, a 50% reduction in mouthing activity was assessed.

- For both the R&M and Rochester studies, the most significant reductions in blood-lead concentration occurred when a child's mouthing habits were changed from frequent mouthing behavior to infrequent mouthing behavior. For the Rochester study only, the next largest reduction in blood-lead concentrations occurred when the geometric mean window sill concentrations were reduced by 50%.

2.4 ASSESSMENT OF PAINT-LEAD INDICATORS

Paint-lead pathways were added to the environmental-lead pathways models discussed above for both the R&M and Rochester studies and to the blood-lead pathways models for the Rochester study. The paint-lead pathways were not added to the blood-lead pathways models for the R&M data due to insufficient data. No paint information was collected in the CAP study.

- The paint-lead pathways were represented by two types of paint-lead indicators: paint-lead hazard score and average XRF measurement. For the Rochester study, generally, the same statistically significant pathways were observed when either the paint-lead hazard scores or the average XRF measurements were used as the paint-lead indicator. For the R&M study, the number of statistically significant pathways was the same when either average XRF measurements or paint-lead hazard scores were used in the concentration model. For the loading model, there were no significant pathways with average XRF measurements in the model, whereas there were two significant pathways when paint-lead hazard scores were used.

- In the Rochester study, the door paint hazard score was a direct pathway of lead to interior entryway dust-lead loading and concentration and the window paint hazard score was a direct pathway to floor dust-lead concentration and both window well and window sill dust-lead loadings and concentrations. In the R&M study, door paint and window paint hazard scores were direct pathways of lead to floor dust-lead loading, and window paint hazard score was a direct pathway to interior entryway dust-lead concentration.

- In the Rochester study, door paint score was an indirect pathway of lead to floor dust-lead loading and concentration via interior entryway dust and window paint score was an indirect pathway of lead to floor dust lead via window sill dust. No significant indirect effects of paint scores to floor dust-lead were found in the R&M study.

- In the Rochester study, both door paint score and window paint score were direct pathways to blood-lead. Door paint score was also an indirect pathway to blood-lead concentration through interior entryway dust-lead loading and floor dust-lead loading. Window paint score was an indirect pathway to blood-lead concentration through window well dust-lead loading, window sill dust-lead loading, and floor dust-lead loading and through window well dust-lead concentration.

2.5 ASSESSMENT OF HAND DUST-LEAD

Hand dust-lead was collected only in the Rochester study. This pathway was added to the Rochester study blood-lead pathways model which included paint hazard scores.

- The hand dust-lead pathway explained additional variation in the model.

- Hand dust-lead was found to be a direct pathway of lead exposure to blood.

- Floor dust-lead loadings and window well dust-lead concentrations were direct pathways of lead to the hands.

2.6 ASSESSMENT OF SOIL-LEAD COVERAGE

In the Rochester study only, a variable was available that described the soil coverage (i.e., grassy, bare soil, etc.) at the location where each soil sample was taken. Combining the soil coverage and the soil-lead concentration variables, a soil-lead coverage variable was created. This variable replaced the soil-lead concentration variable in the Rochester blood-lead models that included the paint hazard score.

- Replacing the soil-lead concentration variable with the soil-lead coverage variable did not change most of the statistically significant pathways.

- In the model with soil-lead coverage replacing the soil-lead concentration variable, the pathway from soil to interior entryway dust-lead loading is no longer significant.

- In the model with soil-lead coverage, the pathways from soil to window well dust-lead loading and soil to window well dust-lead concentration have much lower parameter estimates than is the case in the model with the soil-lead concentration variable.

These changes are interesting, but should be viewed with caution. Changing the input variables to the model is not as convincing as, for example, estimating of the effects of bare versus grass covered soil through a controlled study.

2.7 ASSESSMENT OF CARPETED FLOORS

The results of this section must be viewed with extreme caution since potential confounding effects such as age of the home, type of home, or other socioeconomic variables were not taken into account in the analysis.

Using the blood-lead pathway models discussed above, the effect of carpeting on floors in the homes and blood-lead concentration was assessed for both the R&M and Rochester studies. For the R&M study, an indicator variable of the proportion of rooms sampled in the home with carpeted floors was added as a pathway in the models. The analysis using the Rochester study data included a pathway that accounted for the proportion of carpeted floors sampled in the home and also an indicator of whether the interior entryway was carpeted. There was no information available on the absence or presence of carpeting at the interior entryway for the R&M study. Also, a separate analysis of the Rochester study data was conducted that included only homes which had carpeted bedrooms and play areas.

- For the R&M study, the proportion of carpeted floors was a direct pathway to blood lead for both the loading and the concentration models. For the Rochester study, the proportion of carpeted floors was a direct pathway to blood for the loading model. Also for the Rochester study, the indicator of whether the interior entryway was carpeted was a direct pathway to blood-lead in both the loading and concentration models.

- In the Rochester study, the presence or absence of interior entryway carpeting was a direct pathway to interior entryway dust-lead loading, and the proportion of carpeted floors was a direct pathway of lead to the floor dust-lead loading.

- In the Rochester study, when only homes with carpeted bedrooms and play areas were included, the significant pathways of lead exposure generally remained the same. The notable absent pathway was the floor dust-lead loading pathway. When only homes with carpeted floors were included in the analysis, floor dust-lead loading was no longer a statistically significant pathway of lead exposure to blood.

The following conclusions were drawn from the estimated pathways models that included the carpeted floors indicator variables. For each study and model, each environmental variable was assumed to have a 50% reduction in its geometric mean while all other environmental variables were held constant at their geometric means. Also, a 50% reduction in average proportion of carpeted floors and the presence or absence of interior entryway carpeting was assessed when each of the other environmental variables was held constant.

- In the R&M study, decreasing the proportion of carpeted floors in the home by 50% produced a large predicted increase in the blood-lead concentration. For the Rochester study, decreasing the proportion of carpeted floors increased the predicted blood-lead concentration. Moreover, for the Rochester study, going from a carpeted interior entryway to an uncarpeted entryway also increased the predicted blood-lead concentration.

- In the R&M study, reducing the proportion of carpeted floors increased both the floor dust-lead loadings and concentrations. In the Rochester study, reducing the proportion of carpeted floors produced decreases in floor dust-lead loading and increases in floor dust-lead concentration. Moreover, going from a carpeted to uncarpeted interior entryway also produced decreases in floor dust-lead loading and increases in floor dust-lead concentration.

As indicated above, these results for carpets should be viewed with extreme caution. Furthermore, adding or changing input variables to the model is not as convincing as estimating the effects of carpets through a controlled study.

2.8 ASSESSMENT OF RECENT RENOVATION AND REMODELING

Both the R&M and CAP studies collected information that indicated whether renovation or remodeling had taken place in the home six months prior to sampling at the home. An indicator variable of whether renovation or remodeling had taken place in the home was included in the environmental-lead pathways model for both the R&M and CAP studies and in the blood-lead pathways models for the R&M study. Since the occurrence of major renovation and

remodeling in the home within twelve months of attempted recruitment into the study was an exclusion criterion for the Rochester study, a renovation and remodeling pathway was not assessed for the Rochester study.

- Renovation and remodeling in the six months prior to environmental sampling was a direct pathway of lead exposure to floor dust loadings and concentrations in the CAP study. For the R&M study renovation and remodeling in the six months prior to sampling was neither a direct nor indirect pathway of lead exposure to environmental-lead loadings or concentrations.

- In the R&M blood-lead pathway model, renovation and remodeling in the six months prior to environmental and blood sampling was neither a direct nor indirect pathway of lead exposure to environmental-lead loadings or concentrations or to blood-lead concentration.

2.9 ASSESSMENT OF RACE

In the Rochester study, the race of the children was available for analysis. A pathways model was fitted to two subsets of the Rochester study data, African-American children and all other children in the study (e.g., Caucasian, Hispanic, and Puerto Rican children).

- For African-American children, significant pathways of direct lead exposure to blood were mouthing behavior in the concentration model and window well dust-lead loading in the loading model. For all other race groups, window well dust-lead loading and concentration, interior entryway dust-lead loading, floor dust-lead loading, window paint hazard score and door paint hazard score were direct pathways of lead exposure to blood.

- Window paint hazard score and soil concentration were indirect pathways to blood-lead concentration via both window well dust-lead loading and concentration for the other race group. In addition, exterior entryway dust-lead loading and door paint hazard score were indirect pathways to blood-lead concentration via the interior entryway dust-lead loading for the other race group. There were no indirect pathways of lead to blood-lead concentration for the African-American children.

Note that the differences observed in this analysis could be due solely to the limited sample sizes that resulted when the data was subsetted by race group.

2.10 ASSESSMENT OF AIR DUCTS

Air duct dust-lead loadings and concentrations were collected in the CAP study. An air duct dust-lead pathway was added to the CAP environmental pathways models. In neither the Rochester nor the R&M studies was air duct dust lead available for inclusion as a pathway.

- The air duct dust-lead pathway was neither a direct nor indirect pathway of lead to dust-lead measurements in the CAP study.

3.0 OVERALL QUALITY ASSURANCE

For all aspects of data management and statistical analysis, the SAS® software package was used. All procedures and routines in this software have passed rigorous quality control testing.

As discussed earlier, the data from three studies, CAP, R&M, and Rochester were included in this report. These data sources are considered secondary data sources since the data included in the analysis have already been subjected to quality assurance checks by the respective study coordinators. For each study a report has been published discussing the management of the data during the study and the results of the statistical analysis of the data [9, 10, 11, 12, 13].

The data were available as SAS data sets. To prepare the data for the analysis conducted in this report, the data were compared to the published results. For the CAP study, summary statistics generated using the in-house data were compared to Table 1-7 in [10], for R&M, the data were compared to tables in [12], and for Rochester, results were compared to tables presented in [13]. Any differences were noted and resolved.

Next, several variables in each study were combined to allow similar comparisons across the three studies. For the CAP study, a principal components analysis indicated that the mass-weighted average of the exterior entryway, foundation, and boundary of the property soil samples was a reasonable representation of the soil lead at each home in the study.

For the R&M and Rochester data, five similar variables were created to aid in the comparison of the analysis results. For each study, a variable indicating children's mouthing behavior was calculated from the available mouthing information. A categorical water-lead variable was created for each study. The proportion of carpeted floors in each home was calculated. Finally, two indicators of lead in the window paint and door paint were calculated for each study. The first indicator was a hazard score which took into account the condition of the paint as well as the XRF reading on the sampled surface. The second indicator was just the average XRF reading from the windows in the home and the average XRF reading from the doors in the home. Further descriptions of each of these variables are provided in Sections 4 and 5.

For each of the created variables, a hand check of the accuracy of the calculations was conducted, and frequency, summary statistic, and graphical validations were performed.

As the statistical analysis was performed, validations of the data included in the analysis were periodically performed using frequency counts and summary statistics. PROC CALIS of the SAS® software system was used as the primary analysis procedure.

All tables and figures in the report were validated through visual inspection. When possible, direct processing from SAS® output to WordPerfect tables or figures was employed to reduce any chances of error.

4.0 DESCRIPTION OF ENVIRONMENTAL FIELD STUDIES

Data from the Baltimore Lead-Based Paint Abatement and Repair and Maintenance Study (R&M), the Rochester Lead-In-Dust Study, and the Comprehensive Abatement Performance Study (CAP) were used in the analysis. Brief descriptions of each data source are provided below. Included in the descriptions are the purpose of the study, the data collected in the study, the data used in the pathways analysis, and summary statistics for the data included in the pathways analysis.

4.1 BALTIMORE LEAD-BASED PAINT ABATEMENT AND REPAIR AND MAINTENANCE STUDY (R&M)

The purpose of the Lead-Based Paint Abatement and Repair and Maintenance (R&M) study was to compare short-term (2 to 6 months) and long-term (12 to 24 months) efficacy of comprehensive lead-paint abatement and repair and maintenance interventions for reducing lead in settled house dust and children's blood. Five categories of vacant and occupied homes were recruited into the study. The first three categories were Repair and Maintenance (R&M) I, R&M II, and R&M III homes signifying the level of repair and maintenance efforts that would be applied to the home. The repair and maintenance intervention homes were older, low-income rental properties in Baltimore City. By study design, the R&M intervention homes were required to be structurally sound, not excessively furnished, 800 to 1200 square feet in size, and containing either lead-based paint ($\geq$ 0.7 mg Pb/cm^2 or $\geq$ 0.5 percent Pb by weight) on at least one surface in a minimum of two rooms or be built prior to 1941. The other two categories included "control" homes: modern urban and previously abated. The modern urban homes were built after 1979 and were identified by house-to-house visits in areas where these newer homes were clustered. The previously abated homes were chosen from homes that were abated in past years as part of either the City of Baltimore or Kennedy Krieger Research Institute lead-based paint abatement demonstration projects. The majority of the homes in all five groups were rowhouses.

For all five groups of homes, questionnaire data, blood-lead samples, and environmental-lead samples were collected between January 1993 and November 1994. The data analyzed in this report are "pre-intervention" data, collected prior to the implementation of the repair and maintenance interventions in the study. Venous blood-lead samples were collected at Kennedy

Krieger Research Institute Lead Clinic by a pediatric phlebotomist using 3 mL vacutainers. In many homes, multiple children had blood samples taken. For the pathways analysis, only the blood-lead sample of the youngest child in each home was considered. The average age of these children was 2.2 years ranging from 6 months to 4.8 years of age. The settled house dust samples were collected using the Baltimore Repair and Maintenance (BRM) vacuum. Three composite floor dust samples – one across rooms with windows on the first story, one across rooms with windows on the second story, and one from first and second story rooms without windows – were collected in each home. Composite window sill and window well samples were collected separately from all first and second story windows. Individual samples of settled dust were collected from the interior entryway and exterior entryway. Two-hour fixed-time stagnation drinking water samples were collected from the kitchen faucet – the cold water was run for at least two minutes to flush the pipes, then a sample from the first flush after a stagnation period of two hours was collected. XRF measurements were taken on surfaces such as windows, doors, walls and ceilings. Generally, in each home an XRF measurement from at least one window and one door surface was taken. The other components were not consistently sampled in each home. Therefore, for the pathways analysis only XRF samples from the windows and doors were included in the analysis. Note that paint samples for this study were collected only for the R&M I, II, and III homes. Of the 75 R&M I, II, and III homes, 72 homes had paint samples collected. Thirty-six of the 72 homes were not occupied, therefore only the 36 occupied homes were included in the paint analyses. Additional details regarding the sampling protocol are available in [12]. Table 4-1 provides descriptions of the variables used in the R&M pathways analysis. Tables 4-2 and 4-3 present summary statistics for the variables included in the pathways analysis.

The R&M homes, by definition, had lead-based paint on at least one surface in a minimum of two rooms or were constructed prior to 1941. The control homes on the other hand were previously abated or were built after 1979 [12]. Table 4-4 provides summary statistics for the R&M and control homes separately. The R&M homes have higher concentrations and loadings than the control homes for all media. The blood lead concentrations for the children in R&M homes are higher, on average, than those for the children in the control homes. The differences seen in the average levels were considered and assessed prior to the pathways analysis. The statistical analysis results are presented in Section 6.

Table 4-1. Description of Variables Used in the Baltimore Lead-Based Paint Abatement and Repair and Maintenance (R&M) Pathways Analysis.

Analysis Variable	Description
Blood	Venous blood sample collected from children between the ages of 6 months and 4.8 years.
Water	Individual sample collected from the kitchen faucet as a 2-hour fixed-time stagnation sample. *The sample value was coded as 0 if the sample was less than or equal to the limit of detection (LOD = 0.6 μg/L), 1 if the sample was greater than the LOD and less than or equal to 2.6 μg/L, and 2 if the sample was greater than 2.6 μg/L.*
Mouthing	Indicator of how often a child puts their fingers, dirt, or paint chips into their mouth or puts their mouth on the window sill. *The variable was coded as 0 if the child infrequently puts fingers, dirt, or paint into mouth or mouth on the window sill (≤ 1 day/week) or 1 if the child frequently puts fingers, dirt, or paint into mouth or mouth on window sill (> 1 day/week).*
Renovation & Remodeling Exposure	Indicator of the renovation & remodeling activity in the home as indicated during initial interview. *The variable was coded as 0 if no renovation or remodeling occurred in the 6 months previous to the interview and 1 if renovation or remodeling occurred within the 6 months previous to the interview.*
Window Paint Hazard Score	Arithmetic average of the product of the paint condition score and the XRF readings taken from window wells, sashes, and sills in rooms throughout the house. *The paint condition score was 0 for intact paint and 1 for non-intact paint.*
Door Paint Hazard Score	Arithmetic average of the product of the paint condition score and the XRF reading taken from doors and door jambs throughout rooms in the home. *The paint condition score was 0 for intact paint and 1 for non-intact paint.*
Proportion of Floors that are Carpeted	For all interior floors from which floor dust samples were collected, excluding the interior entryway, this is the proportion of those floors which were carpeted.
Dust[(a)]	
Floor	Arithmetic average of composite dust samples collected: 1 in rooms with windows on the first floor, 1 from rooms with windows on the second floor, and 1 from first and second floor rooms without windows.
Interior Entryway	Arithmetic average of individual samples collected from the interior entryway of the home.
Exterior Entryway	Arithmetic average of individual samples collected from the exterior entryway of the home.
Window Sill	Arithmetic average of composite dust samples collected from the window sills in rooms on the first and second floors.
Window Well	Arithmetic average of composite dust samples collected from the window wells in rooms on the first and second floors.

Note: All dust lead loadings are area-weighted averages in $\mu g/ft^2$ and dust lead concentrations are mass-weighted averages in μg/g.
(a) Samples collected using the BRM vacuum.

Table 4-2. Summary Statistics for the Baltimore Lead-Based Paint Abatement and Repair and Maintenance (R&M) Variables Included in the Pathways Analysis.

Location of Sample	N	Loadings (μg/ft²)		Concentrations (μg/g)**	
		Geometric Mean (GSD)*	Minimum - Maximum	Geometric Mean (GSD)*	Minimum - Maximum
Dust Levels					
Floor	87	210 (5.63)	2.09 - 24,726	1,118 (4.48)	40.4 - 64,109
Interior Entryway	87	329 (8.28)	3.47 - 26,417	1,459 (4.50)	39.8 - 42,625
Exterior Entryway	85	405 (9.44)	7.25 - 196,752	1,570 (5.20)	17.6 - 89,505
Window Sill	87	1,229 (17.6)	2.10 - 122,368	5,411 (8.65)	7.25 - 141,057
Window Well	86	37,035 (21.0)	36.2 - 2,496,630	8,452 (7.32)	108 - 191,480
Other Levels					
Blood	87			8.35 (2.08)	0.90 - 41.9
Water	87			2.25 (3.98)	0.15 - 29.7

* GSD = Geometric standard deviation
** Blood-lead concentration is in μg/dL and the water-lead concentration is in μg/L.

Table 4-3. Summary of the Other Variables Included in the Baltimore Lead-Based Paint Abatement and Repair and Maintenance (R&M) Pathways Analysis.

Indicator Variable	Levels	Description	% of Population
Water-Lead Level	0	≤ LOD (0.6 μg/L)	21
	1	> LOD and ≤ 2.6 μg/L	35
	2	> 2.6 μg/L	44
Mouthing Behavior	0	Infrequently puts fingers, dirt, or paint chips in mouth or mouth on the window sill	64
	1	Frequently (> 1 day/week) puts fingers, dirt, or paint chips in mouth or mouth on the window sill	36
R&R Exposure Indicator	0	No renovation or remodeling occurred in 6 months previous to interview	91
	1	Remodeling or renovation occurred 6 months previous to interview	9

Table 4-3. Summary of the Other Variables Included in the Baltimore Lead-Based Paint Abatement and Repair and Maintenance (R&M) Pathways Analysis (Continued).

Indicator Variable		Summary Statistics				
Variables		Mean	Min	Max	Std	N
Door Paint	Hazard Score	1.29	0.0	15.0	2.97	36[a]
	XRF Measurement[b]	6.70	0.50	23.8	5.45	36[a]
	Paint Condition	0.18	0.00	1.00	0.28	36[a]
Window Paint	Hazard Score	5.19	0.00	21.8	5.05	36[a]
	XRF Measurement[b]	7.16	0.90	38.7	6.71	36[a]
	Paint Condition	0.71	0.00	1.00	0.31	36[a]
Proportion of Floors that are Carpeted[c]		0.29	0.0	0.88	0.29	87

(a) 72 of the 75 R&M homes had XRF measurements collected. Only 36 of the homes were occupied resulting in only 36 R&M homes being included in paint summaries.
(b) The XRF measurements were not substrate corrected.
(c) On average 73% of the floors in a modern urban home were carpeted, while 20% of floors in a previously abated home and 19% of floors in an R&M home were carpeted.

Table 4-4. Geometric Mean Lead Loadings (μg/ft²) and Concentrations (μg/g) for the R&M and Control Homes Included in the R&M Pathways Analyses.

Location of Sample	Loadings (μg/ft²)		Concentrations (μg/g)	
	R&M Homes (N=56)	Control Homes (N=31)	R&M Homes (N=56)	Control Homes (N=31)
Dust - Geometric Mean (GSD)*				
Floor	398 (3.66)	66.4 (6.24)	2,219 (2.69)	324 (4.39)
Interior Entryway	520 (6.44)	144 (10.1)	2,575 (3.52)	522 (3.96)
Exterior Entryway	668 (8.95)	155 (7.82)	2,810 (3.59)	510 (5.58)
Window Sill	7,144 (3.35)	51.1 (8.66)	19,663 (2.42)	526 (5.97)
Window Well	285,722 (2.71)	987 (6.10)	29,428 (2.16)	924 (4.46)
Other Levels				
Blood (μg/dL)			9.98 (1.87)	5.97 (2.27)

* GSD = Geometric standard deviation.

4.2 ROCHESTER LEAD-IN-DUST STUDY

The Rochester Lead-In-Dust Study was designed to address several objectives: "to determine whether dust-lead loading (µg/ft^2) or dust-lead concentration (µg/g) is a better predictor of children's blood lead levels; to investigate whether dust sampling using vacuum methods or a wipe method is more predictive of children's blood lead levels; to identify which interior household surface(s) should routinely be sampled for dust lead measurements; and to estimate the probability of a child having an elevated blood lead level on the basis of a known level of lead in house dust, controlling for other potential exposures. [13]"

Children 12 to 30 months of age who lived in the city of Rochester and had no known history of elevated blood-lead concentrations were eligible for the study. Children were excluded from the study if they had taken a prescribed iron supplement 2 months prior to recruitment or if there had been major renovation in their residence 12 months prior to recruitment. The location of a child's residence, the blood-lead history of the child, and other eligibility criteria were applied to control for the possibility of non-residential, non-typical sources of lead affecting blood-lead concentrations [13]. Two hundred and five children were enrolled into the study. To summarize the children and homes in the study, Table 4-5 shows the distribution of the year in which a home was built, the average percentage of carpeted floors, and the age of the child at blood collection. This table shows that 84% of the homes in the study were built prior to 1940 and that 44% of the children in the study were between 12 months and 18 months of age.

Collection of questionnaire data, blood-lead samples, and environmental-lead samples was performed between August and November, 1993. Venous blood samples were obtained by a certified pediatric phlebotomist during a home visit using lead-free containers provided by the New York State Department of Health Clinical Laboratory Evaluation Program. Three dust collection methods (one wipe method and two vacuum methods) were used to sample settled house dust: wipe sampling, Dust Vacuum Method (DVM) sampling, and Baltimore Repair and Maintenance (BRM) vacuum sampling [13]. To aid in comparisons with the CAP and R&M results, only samples collected using the BRM vacuum sampling method were used in the pathways analyses.

Table 4-5. Distribution of the Year Homes were Built, Average Percentage of Carpeted Floors, and Age of the Children for the Rochester Lead-In-Dust Study Data.

	N	Percent of Population	Average Percentage of Carpeted Floors
Year in which home was built			
Pre - 1900	19	9%	36%
1900 - 1909	32	16%	34%
1910 - 1919	40	20%	38%
1920 - 1929	61	30%	38%
1930 - 1939	20	10%	48%
1940 - 1959	19	10%	32%
1960 - 1979	4	2%	48%
Post - 1979	10	5%	36%
Age of children at time of blood collection			
12 - 18 months	90	44%	
18 - 24 months	57	28%	
24 - 30 months	58	28%	

Dust samples were collected from the window well, interior window sill, and floor in the child's bedroom; the window well and floor in the kitchen; the window well, interior window sill, and floor in the child's principal play area; the interior window sill and floor in the living room; the interior entryway floor; and the exterior entryway floor. Floor samples were collected over a 1-ft^2 area. Window well and interior window sill samples were collected over one-third of the available surface area. Soil core samples, taken at a depth of ½ inch, were collected in two distinct areas: the perimeter of the foundation and the child's principal outside play area. Because a significant number of homes did not have play area soil samples taken, only the foundation soil samples were used in the pathways analyses. Three core soil samples were taken on each side of the house around the perimeter of the foundation and combined for a composite foundation sample. The composite samples were sieved into fine and coarse samples. In addition, the amount of bare soil in the immediate area of the soil sample was characterized as 1=no bare soil, 2=small amount bare, 3=half bare, 4=mostly bare, and 5=all bare. A pair of composite hand dust-lead samples were taken from each child in the study. One was taken at the beginning of the home visit, before any hand washing was done and the other was taken at the end of the home visit or two hours after the child's hands were washed, whichever came first. Each composite hand dust-lead sample consisted of two wipe samples, one from each hand. Two water samples were taken at each home. One sample was a first draw after a minimum 8-hour stagnation period. The other was collected after a one minute flush. XRF paint measurements were taken from components in a number of areas, such as the child's bedroom, the child's principal play area, the kitchen, and the living room. Three XRF measurements were taken on each surface and were averaged together. XRF measurements were not substrate corrected for the pathways analysis. A visual inspection of each surface was also performed, and the paint condition rated as poor, average, or good.

Floor dust-lead samples were collected from both carpeted and uncarpeted floors in some homes. In order to account for potential differences in dust-lead exposure from carpeted floors and uncarpeted floors, two average floor dust-lead values were calculated – one for carpeted floors and one for uncarpeted floors. These two average values were then combined, weighting the average floor dust-lead on carpeted floors by the proportion of rooms that were carpeted and weighting the average floor dust-lead on uncarpeted floors by the proportion of rooms that were uncarpeted. In addition, two variables related to the presence of carpeting in the home were calculated and included in the pathway models: 1) the proportion of rooms that were carpeted and 2) an indicator of the presence of carpeting at the interior entryway. Table 4-6 provides a description of the variables that were selected to be included in the pathways analysis.

Tables 4-7 and 4-8 provide summary statistics for the variables included in the pathways analysis.

Note that some homes did not have all samples collected, resulting in less than 205 samples for many of the environmental variables. In the pathways analysis, if the value for a variable in the model was missing for a home, the home was not included in the pathways analysis.

Table 4-6. Description of Variables Used in the Rochester Pathways Analysis.

Analysis Variable	Description
Blood	Venous blood sample collected from children between the ages of 12 and 30 months.
Water	Two individual water samples were collected from the kitchen faucet. One sample was a first draw collected after an 8-hour stagnation period. The other sample was collected after a one minute flush. *The sample value was coded as 0 if the sample was less than 0.5 µg/L and 1 if the sample was greater than or equal to 0.5 µg/L*[(a)].
Mouthing	Indicator of how often a child puts their thumb, paint chips, or dirt into their mouth or puts their mouth on the window sill. *The variable was coded as 0 if the child never, rarely, or sometimes puts their thumb, paint chips, or dirt into their mouth or puts their mouth on the window sill and 1 if the child often or always puts their thumb, paint chips, or dirt into their mouth or puts their mouth on the window sill.*
Indicator of whether the Interior Entryway is Carpeted	Indicates whether the interior entryway was carpeted. *The variable was coded as 0 if the interior entryway was not carpeted and 1 if the interior entryway was carpeted.*
Proportion of Floors that are Carpeted	For all interior floors from which floor dust samples were collected, excluding the interior entryway, this is the proportion of those floors which were carpeted.
Window Paint Hazard Score	Arithmetic average of the product of XRF paint measurements and paint condition score from window sills, wells, and sashes. *The paint condition score was coded as 0 if 0 % to less than 5% of paint on surface characterized as deteriorated, 1 if greater than 5% of paint on the surface is characterized as deteriorated.*
Door Paint Hazard Score	Arithmetic average of the product of XRF paint measurements and paint condition score from interior doors and jambs. *The paint condition score was coded as 0 if 0 % to less than 5% of paint on surface characterized as deteriorated, 1 if greater than 5% of paint on the surface is characterized as deteriorated.*
Soil[(b)]	Composite samples collected from the foundation of the home.
Soil-Lead Coverage	Arithmetic average of the product of soil lead measurements and soil cover score. *The soil cover score was 1=no bare soil, 2=small amount bare, 3=half bare, 4=mostly bare, and 5=all bare.*
Dust[(c)]	
Floor	Individual samples collected from carpeted and uncarpeted floors in the bedroom, play area, kitchen, or living room.
Interior Entryway	Individual samples collected from the interior entryway of the home.
Exterior Entryway	Individual samples collected from the driveway and porch.
Hand[(d)]	Composite samples collected from the children's hands.
Window Sill	Individual samples collected from the interior window sills in the bedroom, play area, or living room.
Window Well	Individual samples collected from the interior window wells in the bedroom, play area, or kitchen.

Note: All dust-lead loadings are area-weighted averages in µg/ft² and dust-lead concentrations are mass-weighted averages in µg/g.

(a) 72% of the one minute flush water lead samples were ≤ 0.5 µg/L. The other 28% of the samples ranged from 1 µg/L to 24 µg/L with the exception of one sample at 157 g/L. Note that the definition of the presence of lead in water for the Rochester data differs from that for the R&M data.

(b) Composite of up to 12 samples taken at a depth of 0.5 inch sieved into coarse and fine fractions for analysis. An average of the fine and coarse samples was used in the analysis.

(c) Samples were collected using the BRM vacuum method. Floor samples were collected from 1-ft² sample areas. Window well and window sill samples were collected from ⅓ of the available surface area.

(d) Pre and post interview samples were each a composite of two samples, one from each hand. An average of the pre and post interview samples was used in the analysis.

Table 4-7. Summary Statistics for the Rochester Variables Included in the Pathways Analyses.

Location of Sample	N**	Loadings (µg/ft²) Geometric Mean (GSD)*	Loadings (µg/ft²) Minimum - Maximum	N**	Concentrations (µg/g) Geometric Mean (GSD)*	Concentrations (µg/g) Minimum - Maximum
Dust						
Exterior Dust	164	515 (7.34)	0.08 - 51,012	172	656 (5.35)	0.16 - 44,854
Floor Dust	166	100 (4.34)	3.49 - 37,093	162	563 (4.05)	21.9 - 57,346
Interior Entryway Dust	177	88.6 (13.5)	0.30 - 32,040	174	468 (4.90)	1.62 - 20,785
Hand Dust (µg)	197	2.26 (2.12)	0.38 - 25.85	197		
Window Sill Dust	197	345 (10.5)	0.68 - 117,821	199	2,787 (8.44)	3.15 - 368,111
Window Well Dust	189	22,584 (21.6)	6.86 - 3,030,214	188	8,676 (10.7)	5.15 - 207,181
				N**	Concentrations Geometric Mean (GSD)*	Concentrations Minimum - Maximum
Other						
Blood (µg/dL)				205	6.38 (1.85)	1.4 - 31.7
Soil (µg/g)				187	852 (3.83)	19.8 - 27,143

* GSD = Geometric standard deviation.
** N = number of homes at which the sample was collected.

Table 4-8. Summary of Other Variables Included in the Rochester Pathways Analysis.

Indicator Variable	Levels	Description	% of Population
Water-Lead Level	0	> 0.5 µg/L	27
	1	≤ 0.5 µg/L	73
Mouthing Behavior	0	Infrequently puts thumb, dirt, or paint chips in mouth or mouth on the window sill	81
	1	Frequently puts thumb, dirt, or paint chips in mouth or mouth on the window sill	19
Indicator of Whether the Interior Entryway is Carpeted	0	Uncarpeted interior entryway	64
	1	Carpeted interior entryway	36
Soil Coverage	1	No bare	1
	2	Small amount bare	86
	3	Half bare	13
	4	Mostly bare	0
	5	All bare	0

Variable	N**	Mean	Min	Max	Std Dev
Door Paint Hazard Score	196	0.97	0.00	24.8	3.61
Door Paint XRF Measurements	196	3.47	0.50	48.4	6.54
Door Paint Condition Score	196	0.16	0.00	1.00	0.31
Window Paint Hazard Score	199	3.48	0.00	33.0	4.83
Window Paint XRF Measurements	199	5.81	0.50	33.0	5.64
Window Paint Condition Score	199	0.44	0.00	1.00	0.39
Proportion of Sampled Floors that are Carpeted[a]	205	0.38	0	1	0.21

** N = number of homes at which the sample was collected.
[a] On average, 39% of sampled floors in a home built before 1940, 32% of the sampled floors in a home built between 1940 and 1959, 48% of the sampled floors in a home built between 1960 and 1979, and 36% of the sampled floors in a home built after 1979 were carpeted (Table 4-5).

4.3 COMPREHENSIVE ABATEMENT PERFORMANCE (CAP) STUDY

There were four objectives for the Comprehensive Abatement Performance (CAP) study. They were:

(1) Assess the long-term efficacy of two primary abatement methods;

(2) Characterize lead levels in household dust and exterior soil in unabated homes and homes abated by different abatement methods;

(3) Investigate the relationship between lead in household dust and lead from other sources, in particular, exterior soil and air ducts, and

(4) Compare dust lead loading results from cyclone vacuum sampling and wipe sampling protocols [9, 10, 11].

This study was a follow-up to the HUD Lead-Based Paint Abatement Demonstration [5] project which assessed the costs and short-term efficacy of alternative methods of lead-based paint abatement in 169 homes in five urban areas: Washington/Baltimore, Birmingham, Denver, Indianapolis, and Seattle/Tacoma. The CAP study, conducted two years after the completion of the HUD Abatement Demonstration, evaluated the longer-term performance of the abatement strategies employed in the Demonstration project.

Thirty-five homes which were abated in the HUD Abatement Demonstration project and were located in Denver were included in the CAP study. To assess the performance of the abatement methods, pre- and post-abatement soil and dust-lead levels were needed. Only foundation soil samples and a limited number of dust samples were collected prior to abatement in these 35 homes. Therefore, to provide a comparison of the abatement performance lead levels with other environmental levels, 17 unabated homes in Denver that were previously tested by XRF in the HUD Demonstration and were found to be relatively free of lead-based paint were included in the CAP study. For these 52 homes, 35 abated homes plus 17 unabated homes, environmental samples were collected during March and April of 1992.

In general, two to three rooms in each home were selected for testing. Dust samples were collected on the perimeter of the floors, from the window sills, the window troughs, and the air ducts in each of these selected rooms. Additionally, dust samples were collected from inside and outside the entryways. Most dust samples were collected by a vacuum method, and only vacuum dust samples were included in the analysis for this report. Soil core samples were collected from the entryways adjacent to the home, the foundation of the home, and the boundary of the property. The lead in the dust samples were reported both as loadings (µg/ft²) and concentrations (µg/g) while the lead from the soil samples were reported as concentrations (µg/g). In addition, the information on whether renovation and remodeling had taken place in the home six months prior to the environmental sampling was collected. Additional sampling protocol details are available in [9, 10, 11].

The samples included in the pathways analysis are described in Table 4-9. Since the CAP study houses were vacant prior to the performance of the abatements, no blood-lead measurements were collected.

Table 4-9. Description of Variables Used in the Comprehensive Abatement Performance (CAP) Study Pathways Analysis.

Analysis Variable	Description
Dust[a]	
Floor	Arithmetic average of dust samples collected from the perimeter of carpeted or uncarpeted floors in the kitchen, bedroom, living room, etc. *Note: Two to three rooms, in general, were chosen for each home.*
Interior Entryway	Arithmetic average of dust samples collected immediately inside the front and rear entryways of the home.
Air Duct	Arithmetic average of dust samples collected from the air ducts in the rooms selected for sampling.
Window Sill	Arithmetic average of dust samples collected from the window sills in the rooms selected for sampling.
Window Well	Arithmetic average of dust samples collected from the window wells in the rooms selected for sampling.
Exterior Entryway	Arithmetic average of dust samples collected immediately outside the front and rear entryways of the home.
Soil[b]	
Exterior Entryway	Arithmetic average of soil samples collected immediately outside of the front and rear entryways.
Foundation	Arithmetic average of soil samples collected at the foundation of the home.
Boundary	Arithmetic average of soil samples collected at the property boundary

Note: Dust-lead loadings are area-weighted averages in µg/ft² and dust-lead concentrations are mass-weighted averages in µg/g.

[a] Samples were collected using a cyclone style vacuum. Floor and entrance samples were collected from 1- ft² sample areas. Other samples were collected from the entire accessible surface.

[b] At each location, a composite of three core samples was collected. The three composite soil samples were averaged together for this analysis using a mass-weighted average as indicated by a principal components analysis.

For each analysis variable and each home in the study, an average lead level in the home was calculated. This was done to provide comparable information from each home. Summary statistics over all 52 homes are provided in Table 4-10, while Table 4-11 presents summary statistics for the unabated and abated homes separately. The geometric mean dust-lead loadings and concentrations are lower in the unabated homes than in the abated homes. The same holds true for the soil-lead concentrations. Note that the abated homes generally had paint lead levels greater than or equal to 1 mg/cm² prior to being abated while the unabated homes were found to be relatively free of lead-based paint. In addition, the abated homes on average were built in 1926 while the average year in which the unabated homes were built was 1943 [10]. The differences seen in the average levels were considered prior to the pathways analysis. This is covered in Section 6.1.

Table 4-10. Summary Statistics for the Lead Loadings (µg/ft²) and Concentrations (µg/g) for All Homes Included in the CAP Study Pathways Analysis.

		Loadings (µg/ft²)		Concentrations (µg/g)	
Location of Sample	N**	Geometric Mean (GSD)*	Minimum - Maximum	Geometric Mean (GSD)*	Minimum - Maximum
Dust					
Floor	52	48.8 (5.01)	2.02 - 2,640	174 (2.91)	37.9 - 5420
Interior Entryway	52	342 (4.57)	1.66 - 4,870	201(2.44)	9.65 - 4,940
Air Duct	52	156 (8.16)	4.13 - 25,400	485 (2.23)	122 - 2,920
Window Sill	52	107 (6.81)	2.76 - 16,700	778 (4.08)	45.8 - 17,000
Window Well	49	3,230 (6.32)	45.0 - 93,500	1,577 (4.65)	133 - 22,900
Exterior Entryway	51	574 (4.00)	17.2 - 10,700	261 (2.68)	20.7 - 2,820
Soil					
Exterior Entryway	52			157 (2.24)	19.7 - 644
Foundation	52			196 (2.52)	11.0 - 1810
Boundary	52			132 (1.94)	24.1 - 606
Indicator Variable	**Levels**	**Description**			**% of Population**
R&R Exposure Indicator	0	No renovation or remodeling occurred in 6 months prior to interview			75
	1	Remodeling or renovation occurred 6 months prior to interview			25

*GSD = Geometric standard deviation.
** N = Number of homes at which the sample was collected.

Note: Average levels were calculated for each home separately. The summary statistics were then calculated using the average levels. This differs from the results presented in Table 1-7 in the CAP study report [10] where the summary statistics were calculated using all samples individually.

Table 4-11. **Geometric Mean Lead Loadings (μg/ft²) and Concentrations (μg/g) for Abated and Unabated Homes Included in the CAP Study Pathways Analyses.**

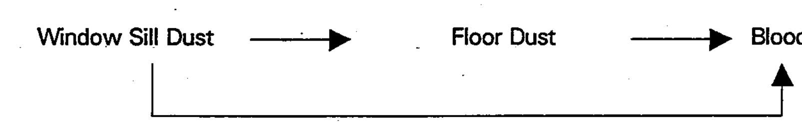
Location of Sample	Loadings (μg/ft²)		Concentrations (μg/g)	
	Unabated Homes* (N=17)	Abated Homes* (N=35)	Unabated Homes* (N=17)	Abated Homes* (N=35)
Dust				
Floor	42.3 (6.24)	52.4 (4.55)	143 (2.66)	192 (3.03)
Interior Entryway	200 (7.40)	444 (3.22)	164 (2.25)	222 (2.52)
Air Duct	58.3 (7.24)	252 (7.48)	449 (2.38)	503 (2.18)
Window Sill	52.7 (5.14)	152 (7.17)	487 (3.95)	977 (3.99)
Window Well	2,600 (6.46)‡	3,588 (6.38)†	1,050 (4.15)‡	1,923 (4.82)†
Exterior Entryway	351 (4.43)‡	718 (3.67)	204 (2.67)‡	292 (2.66)
Soil				
Exterior Entryway			122 (2.47)	177 (2.09)
Foundation			107 (2.43)	263 (2.22)
Boundary			99.1 (2.06)	151 (1.82)

* Geometric standard deviation is given in parentheses.
‡ Only 16 samples were included in the calculations.
† Only 33 samples were included in the calculations.

5.0 STATISTICAL METHODOLOGY

Structural equation modeling (SEM) is similar to multiple regression, factor analysis, and analysis of variance (ANOVA) approaches in that these approaches are based on linear statistical models. A difference between SEM and these other approaches is that SEM requires the formal specification of a model that includes both direct and indirect effects. The other approaches require specification of only direct effects.

A direct effect is a directional relation between two variables, typically the type of relationship evaluated using ANOVA or multiple regression. Within a model, the direct effect characterizes the relationship between an independent variable and the dependent variable in the equation. The indirect effect, which can be specified in a SEM, characterizes the effect of an independent variable on a dependent variable through intervening or mediating variables [3]. For example, consider the following pathway diagram:



This diagram shows directional pathways of lead exposure as follows:

- Window sill dust is being assessed as to whether it directly impacts floor dust and/or blood-lead (i.e. the arrows which point to blood and floor dust from window sill dust.),
- Floor dust is being evaluated as to whether it is directly impacting blood-lead, and
- Finally, window sill dust is being assessed as to whether it indirectly impacts blood-lead via floor dust (i.e., the arrow which goes from window sill dust to floor dust and then the arrow which goes to blood from floor dust).

The directional relationships illustrated in the diagram are represented by the following two equations:

(1) Blood Lead = Floor Dust Lead + Window Sill Dust Lead
(2) Floor Dust Lead = Window Sill Dust Lead

and a covariance matrix of all the variables in the diagram.

The directional nature of the diagram is illustrated through the equations by starting with the highest numbered equation and working upwards, i.e., (2) and then (1). Equation (2) represents the arrow from window sill dust to floor dust. Equation (1) represents the arrow from floor dust to blood and the arrow from window sill dust to blood. Finally, the indirect relationship of window sill dust to blood via floor dust is represented by both equations (1) and (2) and the covariance matrix.

Evaluating equations (1) and (2) separately is similar to multiple regression or ANOVA, i.e., both these methods can assess the direct effect of floor dust on blood in equation (1) and window sill dust on floor dust in equation (2). What these methods cannot assess is the indirect effect of window sill dust on blood via the floor dust. By evaluating both equations (1) and (2) simultaneously and accounting for the covariance between these variables, SEM allows for an assessment of the indirect effect.

SEM has been used to examine pathways of lead in a number of studies. Section 5.1 discusses several examples published in the literature that illustrate pathway models analyzed using SEM. Section 5.2 presents the various environmental-lead and blood-lead pathway models assessed in this report using SEM.

Note that the mechanism by which lead is transported from one location to another is beyond the scope of this report. The analyses are designed only to evaluate the association between lead at one location with lead at another location, not how the lead is transported via the statistically significant pathway.

5.1 OVERVIEW OF THE PATHWAYS THAT HAVE BEEN INVESTIGATED IN THE LITERATURE

Several structural equation models describing the pathways by which environmental lead exposure occurs during childhood have been published in the literature. Table 5-1 below lists several papers that were identified as having assessed pathway models associated with an environmental-lead study. The first column in the table lists the title of the paper and the author, the second column lists the study from which the analyzed data were obtained, and the third column identifies the pathway diagram in Appendix D. The diagrams in Appendix D illustrate all pathways considered in each analysis. The significant pathways are indicated by solid lines

Table 5-1. Identified Papers Which Assessed Pathways.

Title of Paper /Author(s)	Field Study(s) Used to Assess the Hypothesized Pathways	Pathway Diagram Figure Number
Exterior Surface Dust Lead, Interior House Dust Lead and Childhood Lead Exposure in an Urban Environment [2] Bornschein RL, Succop PA, Kraft KM, Clark CS, Peace B, and Hammond PB	Cincinnati Lead Study	D-1
Soil Lead - Blood Lead Relationship in a Former Lead Mining Town [17] Bornschein RL, Clark CS, Grote J, Peace B, Roda S, and Succop P.	Telluride, Colorado	D-2
The Influence of Social and Environmental Factors on Dust Lead, and Blood Lead Levels in Young Children [1] Bornschein RL, Succop PA, Dietrich KN, Clark CS, Que Hee S, and Hammond PB.	Cincinnati Lead Study	D-3
Pathways of Lead Contamination for the Brigham and Womens Hospital Longitudinal Lead Study [7] Menton R, Burgoon DA, and Marcus AH.	Boston Hospital for Women Lead Study	D-4
Dust Lead Contribution to Lead in Children [18] Sayre J	Rochester Lead Study (1973)	D-5
Racial Differences in Urban Children's Environmental Exposures to Lead [6] Lanphear, BP, Weitzman, M, and Eberly, S	Rochester Lead Study (1993)	NA
Pathways of Lead Exposure in Urban Children [19] Lanphear, BP, and Roghmann, KJ	Rochester Lead Study (1991-92)	D-6
Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program [20] U.S. Department of Housing and Urban Development, Fifth Interim Report	Field studies conducted in Alameda County, CA, Baltimore, MD, Boston, MA, California, Chicago, IL, Cleveland, OH, Massachusetts, Minnesota, New Jersey, New York City, NY, Rhode Island, Vermont, Wisconsin, and Milwaukee, WI, during 1996-1997.	NA

Note: The Sayre paper and the Lanphear paper on racial differences utilized multiple regression and not structural equation modeling to analyze the data.

while the pathways not found to be significant in the analysis are indicated by a dotted line. Tables D-1 through D-6 in Appendix D explain each of the variables used in the pathways analysis. Because the report *Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program* [20] is an interim report, its analyses will not be covered in this report.

Among these studies, pathways of exposure from lead in paint, dust, and soil were often found to be statistically significant. Moreover, lead dust on children's hands was a statistically significant direct pathway to blood lead in each study where hand lead data were collected. A direct pathway of lead exposure from renovation and remodeling activities (also called "Refinishing") to a child's blood-lead concentration was found to be significant in one of the papers (Figure D-4). Similarly, several child modifiers such as age of child (Figure D-2), pica habits (Figure D-5 and D-6), and socioeconomic status (Figure D-3) were found to be direct pathways of lead exposure to blood. A pathway of lead exposure from air was addressed in two papers (Figure D-4 and Figure D-5). Because each study was designed differently, the pathways investigated varied somewhat from study to study.

Based on the various pathway models described in the literature and common perceptions, a general pathway diagram was designed. This diagram is presented in Figure 5-1.

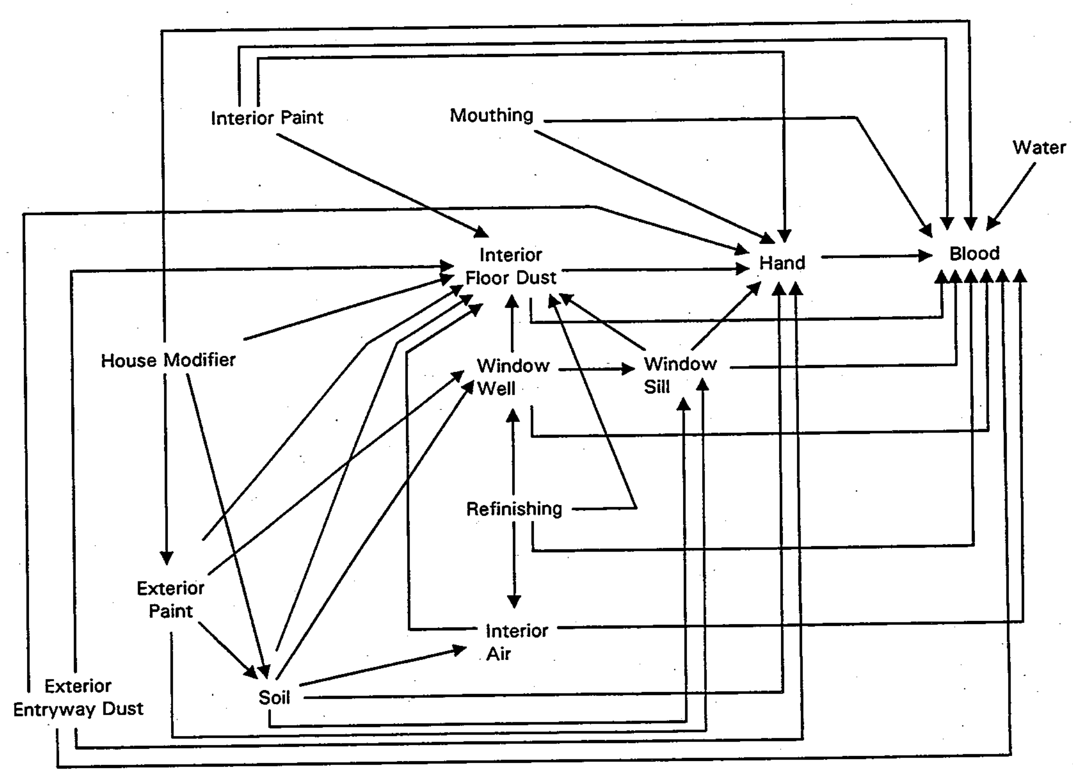


Figure 5-1. General Pathway Diagram Based on Literature Review.

The diagram in Figure 5.1 forms the basis for the pathway models analyzed in this report. Many of the illustrated pathways could not be included in the analyses because data necessary for those pathways were not available.

5.2 PATHWAYS TO BE INVESTIGATED

As mentioned earlier, the data used for the pathway analysis in this report were collected in three separate studies with three different objectives. Pieces of information collected in one study were not necessarily collected in another study. For instance, no blood-lead or water-lead concentrations were collected in the CAP study; very few soil samples and air duct dust-lead samples were collected in the R&M study; and no air duct dust-lead samples were collected in the Rochester study.

Because of the differences in the data collected among the studies, several pathways that can be tested using data from one study cannot be tested using data from another study. Below are descriptions of the pathways that were tested. The primary analysis centered around two sets of pathways models: environmental-lead and blood-lead pathways models. The environmental-lead pathways were designed to be similar across studies so that comparisons could be made among the CAP, R&M, and Rochester data. Similarly, the blood-lead pathways for the R&M and Rochester data were similar to facilitate comparisons.

In addition to the environmental and blood-lead pathway models, several sub-analyses were conducted. For the R&M data and the Rochester data, sub-analyses were conducted to compare the effect of using a paint hazard score versus an average XRF measurement and to assess whether an indicator of carpeting in the home is informative. The significance of an air duct dust-lead pathway was addressed using the CAP data and the significance of recent renovation and remodeling in the home was analyzed using the CAP and R&M study data. Finally, differences in exposure pathways for African American children and children from all other races, the effect of hand dust-lead, and the significance of soil vegetative cover were examined using the Rochester data.

All of the pathway models described below were analyzed using SEM, and the results of the analyses are presented in Section 6.

5.2.1 Environmental-Lead Pathways Equations

As discussed previously, because of the differences in data collection, the pathways that could be statistically evaluated were restricted. Equation Sets 5-1, 5-2, and 5-3 present the environmental-lead pathway models evaluated using the CAP, R&M, and Rochester data, respectively. To allow comparisons between the studies, the pathways for each study were the same with one major exception. Because very few samples were collected, the soil pathway was not included in the R&M model.

Equation Set 5-1. CAP Environmental-Lead Pathways Model

Floor Dust	= Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil
Interior Entryway Dust	= Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil
Window Sill Dust	= Window Well Dust + Soil
Window Well Dust	= Soil

Equation Set 5-2. R&M Environmental-Lead Pathways Model

Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill + Window Well Dust
Window Sill Dust	=	Window Well Dust

Equation Set 5-3. Rochester Environmental-Lead Pathways Model

Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil
Window Sill Dust	=	Window Well Dust + Soil
Window Well Dust	=	Soil

5.2.2 Blood-Lead Pathways Equations

Child blood-lead concentrations were not collected in CAP study. Therefore, pathway models to assess the pathway of environmental lead sources to a child's blood were developed only for the R&M and Rochester studies and are presented in Equation Sets 5-4 and 5-5, respectively.

Equation Set 5-4. R&M Blood-Lead Pathways Model

Blood	=	Floor Dust + Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Water + Mouthing Behavior
Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust
Window Sill Dust	=	Window Well Dust

Equation Set 5-5. Rochester Blood-Lead Pathways Model

Blood	=	Floor Dust + Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Water + Mouthing Behavior
Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil
Window Sill Dust	=	Window Well Dust + Soil
Window Well Dust	=	Soil

As discussed above, no soil pathway is included in the R&M model because of limited soil data. The main difference between the blood-lead pathways and the environmental-lead pathways is the inclusion of an equation in the blood pathways model which assesses the direct effect of the environmental dust-lead levels on the childhood blood-lead concentration. Included in this equation are the mouthing behavior of the child and water-lead concentration.

5.2.3 Paint-Lead Indicators

Two types of paint indicators were considered for this analysis. The first included paint hazard scores for interior windows and doors, while the second was the average XRF measurement for interior windows and doors. This analysis was carried out for the environmental-lead models for both the R&M data and the Rochester data and for the blood-lead pathway model for the Rochester data. There were not enough occupied homes with XRF measurements to be able to carry out the blood-lead pathway model for the R&M data.

The CAP data were not included in this paint analysis. In the CAP study, the 17 unabated homes had relatively few cases of lead-based paint and the 35 abated homes had the lead-based paint abated two years prior to the environmental sampling. Equation Sets 5-6 and 5-7 show the environmental-lead pathway models that included window and door paint for the R&M and Rochester data, respectively. Equation Set 5-8 shows the Rochester blood-lead pathway model that included window and door paint.

Equation Set 5-6. R&M Environmental-Lead Pathways Model – Assessing the Impact of Paint-Lead Pathways.

Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Window Paint + Door Paint
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Window Paint + Door Paint
Window Sill Dust	=	Window Well Dust + Window Paint
Window Well Dust	=	Window Paint

Equation Set 5-7. Rochester Environmental-Lead Pathways Model – Assessing the Impact of Paint-Lead Pathways.

Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Window Paint + Door Paint
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust +Soil + Window Paint + Door Paint
Window Sill Dust	=	Window Well Dust + Soil + Window Paint
Window Well Dust	=	Soil + Window Paint

Equation Set 5-8. Rochester Blood-Lead Pathways Model – Assessing the Impact of Paint-Lead Pathways.

Blood	=	Floor Dust + Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust +Water + Mouthing Behavior + Window Paint + Door Paint
Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Window Paint + Door Paint
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust +Soil + Window Paint + Door Paint
Window Sill Dust	=	Window Well Dust + Soil + Window Paint
Window Well Dust	=	Soil + Window Paint

The results from the SEM analysis of Equation Sets 5-6 and 5-7 were compared to Equation Sets 5-2 and 5-3 to assess the effect the paint pathways have on the environmental-lead pathway models. Similarly, results for Equation Set 5-8 were compared to results for Equation Set 5-5. In addition, results for models with paint hazard scores were compared to results for models with average XRF measurements.

5.2.4 Hand Dust-Lead

The average of pre- and post-interview hand dust-lead levels was included as a pathway in the Rochester study blood-lead pathway models that included the paint-lead pathways. This pathways model is similar to Equation Set 5-8, except a separate equation for the average hand dust-lead level and a pathway from hand dust-lead to blood-lead are included. Equation Set 5-9 illustrates the hand dust-lead model evaluated for the Rochester study data. No hand dust-lead was collected in the R&M and CAP studies.

Equation Set 5-9. Rochester Blood-Lead Pathways Model – Assessing the Impact of Hand Dust-Lead.

Blood	=	Hand Lead + Floor Dust + Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust +Water + Mouthing Behavior + Window Paint + Door Paint
Hand Lead	=	Floor Dust + Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Mouthing Behavior + Window Paint + Door Paint
Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Window Paint + Door Paint
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust +Soil + Window Paint + Door Paint
Window Sill Dust	=	Window Well Dust + Soil + Window Paint
Window Well Dust	=	Soil + Window Paint

The results from the SEM analysis of Equation Set 5-9 were compared to the results for Equation Set 5-8.

5.2.5 Soil-Lead Coverage

A variable indicating the extent of grass covering at the site of each soil sample was available in the Rochester study data. To assess how the grass covering may affect the pathways of soil-lead exposure, a variable that was a combination of the soil coverage variable and the associated soil-lead concentration replaced the soil-lead variable in the blood-lead pathways model of Equation Set 5-8. A comparison of the parameter estimates of the two sets of models was made.

5.2.6 Carpeted Floors

Equation sets for an assessment of the effect of carpeting on floor dust-lead loading and concentration and blood-lead concentration are presented in this section. Equation Sets 5-10 and 5-11 illustrate the models evaluated for the R&M and Rochester data, respectively. These models are very similar to the blood-lead pathways described in Equation Sets 5-4 and 5-5, but they include an indicator of the proportion of floors from which samples were taken that were carpeted. For the Rochester data, the window and door paint hazard scores and a variable indicating whether the interior entryway was carpeted were included as pathways. Information on the presence of carpeting in the interior entryway was not available for the R&M data, and only a subset of R&M homes were both occupied and had paint information available. Hence because of these data limitations, the indicator of whether the interior entryway was carpeted and the door and window paint pathways were not included in the R&M model.

An additional analysis using only homes in the Rochester study in which the floors in the bedroom and play area were carpeted was conducted. The equations for this pathway analysis are illustrated in Equation Set 5-12. The results from this analysis were compared to the results for Equation Set 5-11 to assess the effect of sampling only from carpeted surfaces.

Equation Set 5-10. R&M Blood-Lead Pathways Model – Assessing the Impact of a Carpeted Floors Pathway.

Blood	=	Floor Dust + Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Water + Mouthing Behavior + Proportion Carpeted
Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Proportion Carpeted
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust
Window Sill Dust	=	Window Well Dust

Equation Set 5-11. Rochester Blood-Lead Pathways Model – Assessing the Impact of a Carpeted Floors Pathway.

Blood	=	Floor Dust + Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Water + Mouthing Behavior + Window Paint Hazard Score + Door Paint Hazard Score + Proportion Carpeted + Indicator Interior Entrance Carpeted
Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Window Paint Hazard Score + Door Paint Hazard Score + Proportion Carpeted + Indicator Interior Entrance Carpeted
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Window Paint Hazard Score + Door Paint Hazard Score + Indicator Interior Entrance Carpeted
Window Sill Dust	=	Window Well Dust + Soil + Window Paint Hazard Score
Window Well Dust	=	Soil

Equation Set 5-12. Rochester Blood-Lead Pathways Model – Assessing the Impact of Carpeted Bedroom and Play Area Floors.

Blood	=	Floor Dust(Bed/Play Carpeted) + Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Water + Mouthing Behavior + Window Paint Hazard Score + Door Paint Hazard Score + Indicator Interior Entrance Carpeted
Floor Dust (Bed/Play Carpeted)	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Window Paint Hazard Score + Door Paint Hazard Score + Indicator Interior Entrance Carpeted
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Window Paint Hazard Score + Door Paint Hazard Score + Indicator Interior Entrance Carpeted
Window Sill Dust	=	Window Well Dust + Soil + Window Paint Hazard Score
Window Well Dust	=	Soil

5.2.7 Renovation and Remodeling Activities

A variable indicating whether renovation and remodeling had been performed in the home six months prior to environmental sampling was collected in the R&M and CAP studies. In the Rochester study, the occurrence of renovation and remodeling any time twelve months prior to recruitment into the study was an exclusion criterion.

To compare the effect of recent renovation and remodeling in the R&M and CAP studies, the renovation and remodeling variable was included in the environmental-lead pathways model. In addition, to assess the effect of recent renovation and remodeling on a child's blood-lead concentration, the renovation and remodeling variable was included in the R&M blood-lead pathways model that included proportion of carpeting.

Equation Set 5-13 and 5-14 show the environmental pathways models; these models are similar to those presented in Equation Sets 5-1 and 5-2, respectively. Equation Set 5-15 presents the blood-lead pathway models evaluated for the R&M data. The results from this model were compared to those from Equation Set 5-10.

Equation Set 5-13. CAP Environmental-Lead Pathways Model – Assessing the Impact of Recent Renovation and Remodeling Activities.

Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Recent R&R
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Recent R&R
Window Sill Dust	=	Window Well Dust + Soil
Window Well Dust	=	Soil

Equation Set 5-14. R&M Environmental-Lead Pathways Model – Assessing the Impact of Recent Renovation and Remodeling Activities.

Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Recent R&R
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill + Window Well Dust + Recent R&R
Window Sill Dust	=	Window Well Dust

Equation Set 5-15. R&M Blood-Lead Pathways Model – Assessing the Impact of Recent Renovation and Remodeling Activities.

Blood	=	Floor Dust+ Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Water+ Mouthing Behavior + Proportion Carpeted + Recent R&R
Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Proportion Carpeted + Recent R&R
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Recent R&R
Window Sill Dust	=	Window Well Dust

5.2.6 Race

Using the Rochester data and multivariate regression, Lanphear et al. [6] reported a racial difference in the sources of environmental-lead exposures in urban children. A pathways analysis, subsetting the Rochester data into two racial groups, African-American children and children of all other races, was performed to estimate whether there is a difference in the pathways of lead exposure between different race groups. The model used in this analysis is described in Equation Set 5-16.

Equation Set 5-16. Rochester Blood-Lead Pathways Model – Assessing Pathways for Different Races.

Blood	=	Floor Dust + Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust +Water + Mouthing Behavior + Window Paint Hazard Score + Door Paint Hazard Score
Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Window Paint Hazard Score + Door Paint Hazard Score
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust +Soil + Window Paint Hazard Score + Door Paint Hazard Score
Window Sill Dust	=	Window Well Dust + Soil + Window Paint Hazard Score
Window Well Dust	=	Soil + Window Paint Hazard Score

5.2.7 Air Ducts

No air duct dust samples were collected in the Rochester study and very few samples were collected in the R&M study. Only the CAP study had enough air duct dust samples to perform a pathways analysis. Equation Set 5-17 presents the pathways to evaluate the effect of air duct dust-lead. The pathways are very similar to the pathways presented in Equation Set 5-1. The results from this analysis were compared to the results of the Equation Set 5-1 analysis.

Equation Set 5-17. CAP Study Environmental-Lead Pathways Model-Assessing the Effect of an Air Duct Dust-Lead Pathway.

Floor Dust	=	Interior Entryway Dust + Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Air Duct Dust
Interior Entryway Dust	=	Exterior Entryway Dust + Window Sill Dust + Window Well Dust + Soil + Air Duct Dust
Window Sill Dust	=	Window Well Dust + Soil
Window Well Dust	=	Soil

6.0 FINDINGS AND RESULTS

Presented in this section are the results and findings from the analysis of the pathway models illustrated in Section 5. Detailed tables of the results for the CAP, R&M, and Rochester data are presented in Appendices A, B, and C, respectively. Note that log-transformed dust-lead loadings and concentrations, soil-lead concentrations, and blood-lead concentrations are used in the analyses.

6.1 CORRELATION ANALYSIS RESULTS

Prior to performing the structural equation modeling, an assessment of the correlation structure of the data included in the analysis was conducted for each study individually. The Pearson correlation coefficients for the CAP data are presented in Tables A-4a and A-4b. Tables B-7a and B-7b list the correlation results for the R&M data and Tables C-11a and C-11b present correlation results for the Rochester data. Note that the first table for each study contains correlations for the dust-lead loadings while the second table includes correlations for the dust-lead concentrations. All other variables are the same.

After a visual assessment of the CAP study data, it was decided that data from both abated and unabated homes in the CAP study would be included in the pathway analysis. The visual assessment indicated similar relationships among the media for both types of homes.

The largest correlations for the CAP data occurred among the three soil-lead concentrations: exterior entryway and foundation soil had a Pearson correlation coefficient (r) of 0.53; exterior entryway and boundary soil had a coefficient of 0.64; and foundation and boundary soil had a correlation of 0.56. Other correlated variables included the window well and window sill dust-lead loadings ($r = 0.55$) and concentrations ($r = 0.59$) and the interior and exterior entryway dust-lead concentrations ($r = 0.56$). Because of the high correlation seen among the soil samples, a principal components analysis of the three log-transformed soil-lead concentrations was performed to represent the information from the soil samples with a single linear combination. Over seventy percent of the variability in the soil samples was explained by the first principal component which weighted each soil sample nearly equally. Therefore a mass-weighted average soil-lead concentration of exterior entryway, foundation, and boundary soil-lead concentration was used in the analysis. Table A-5 in Appendix A lists the results of the principal components analysis.

Similarly, a decision on whether to include the control homes in the analysis with the R&M homes was made. Figures 6-1 and 6-2 illustrate the relationship between blood-lead concentration and floor dust-lead loading and concentration, respectively. Though Table 4-4 shows that the control homes have consistently lower floor dust-lead levels and blood-lead concentrations than the R&M homes, the figures illustrate that the relationships between the floor dust-lead levels and the blood-lead concentrations are similar for both types of homes. Hence both sets of homes were included in the analysis.

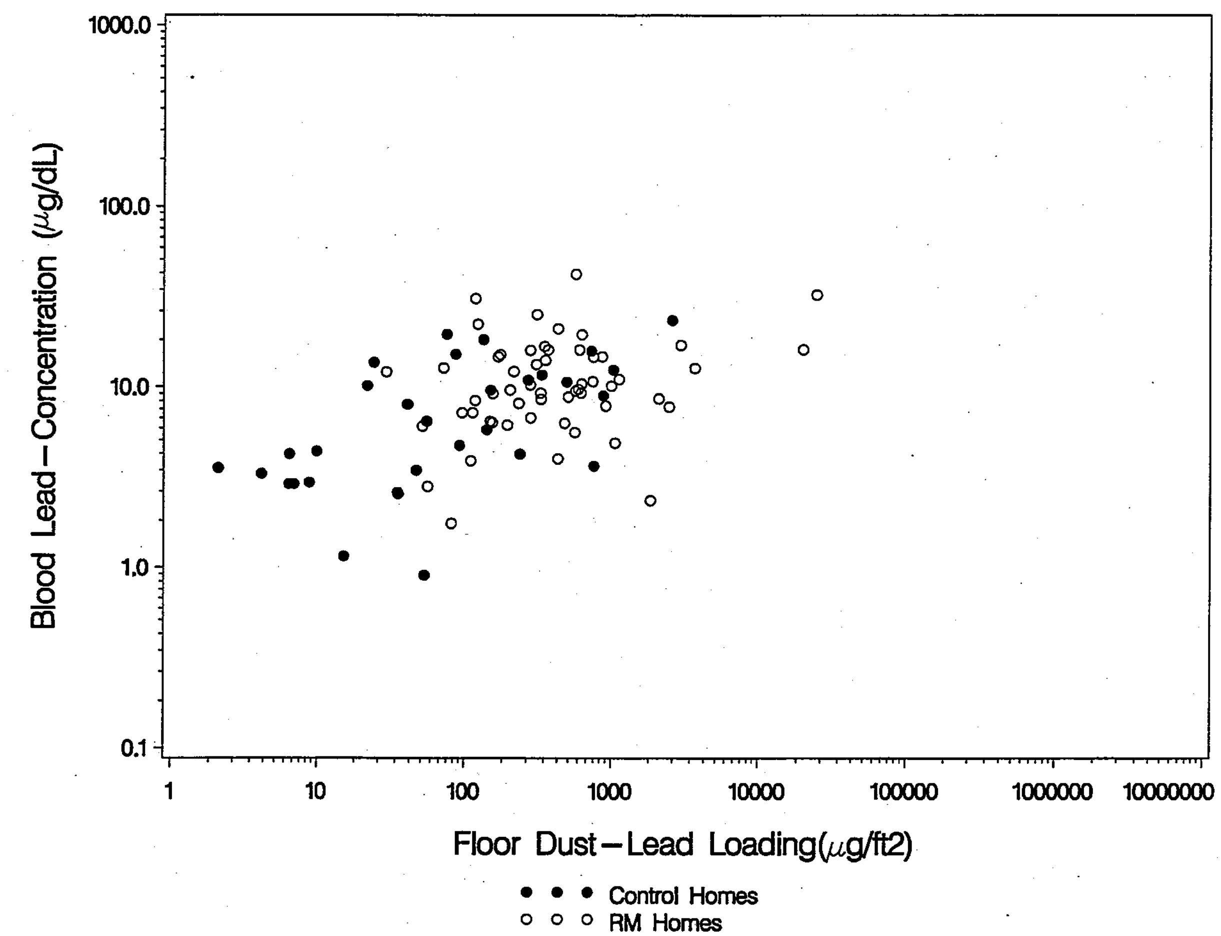


Figure 6-1. Relationship of Blood-Lead Concentration (µg/dL) and Average Floor Dust-Lead Loading (µg/ft²) for the R&M Data.

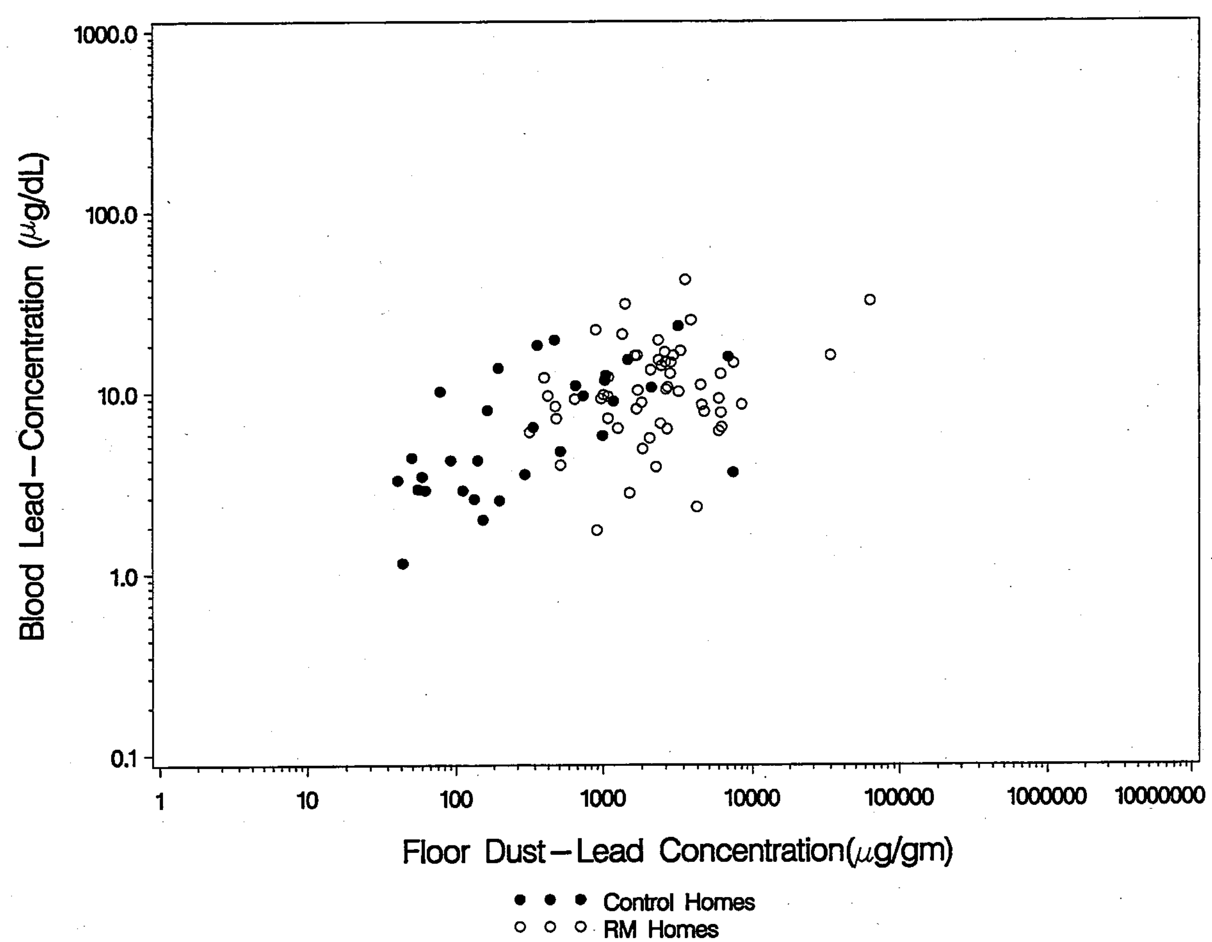


Figure 6-2. Relationship of Blood-Lead Concentration (µg/dL) and Average Floor Dust-Lead Concentration (µg/g) for the R&M Data.

The R&M analysis included the dust-lead concentrations and loadings and water-lead concentration. The largest correlations occurred between window well and window sill dust loadings ($r = 0.84$) and concentrations ($r = 0.83$). Blood-lead was moderately correlated with the dust measures (r was between 0.34 and 0.50 for loadings and between 0.40 and 0.56 for concentrations).

The highest correlations in the Rochester data occurred between window well and window sill dust loadings ($r = 0.56$) and window well and window sill dust concentrations ($r=0.55$). Blood-lead was somewhat correlated with sills and wells (r between 0.34 and 0.37 for loadings and between 0.21 and 0.24 for concentrations), soil ($r = 0.37$), and door paint hazard score ($r = 0.36$).

6.2 ENVIRONMENTAL-LEAD PATHWAYS RESULTS

The environmental-lead pathway models, presented in Equation Sets 5-1, 5-2, and 5-3 of Section 5 were analyzed for the CAP Study, R&M, and Rochester data, respectively. Parameter estimates for each of the data sets are listed in Tables 6-1, 6-2, and 6-3 for the CAP study, R&M, and Rochester data, respectively. Note that two sets of models were run for each study. One set of models utilized dust-lead loadings and the other employed dust-lead concentrations. All other variables remained the same in the two analyses. For comparison purposes, the significant pathways in the dust loading and the dust concentration models are illustrated below in Figures 6-3 and 6-4.

Across all three studies, the dust loading models indicated one consistent, statistically significant direct pathway of lead contamination: window well dust directly impacted the window sill dust. An additional statistically significant direct pathway from the interior entryway dust to the floor dust was observed in the R&M analysis and the Rochester analysis. In the R&M Study, a statistically significant indirect pathway of lead contamination from exterior entryway dust to floor dust through interior entryway dust was observed. In both the CAP and Rochester data, the indirect pathway of lead contamination from soil to window well dust to window sill dust was found to be statistically significant. A statistically significant indirect pathway from window well dust to window sill dust to interior entryway dust to floor dust was observed in R&M, while window well dust indirectly impacted floor dust through window sill dust and soil indirectly impacted floor dust via interior entryway dust, as well as through window wells and sills, in Rochester.

Similar statistically significant pathways were observed when the dust-lead concentrations were included in the analysis. For all three data sets, two significant direct pathways, 1) window well dust to window sill dust and 2) exterior entryway dust to interior entryway dust, were observed. For the CAP and Rochester studies, a statistically significant indirect pathway of lead contamination from soil to window well dust to window sill dust was observed. Note that when the dust-lead concentrations were included in the analysis the direct pathway from interior entryway dust to floor dust was no longer statistically significant for the R&M data.

Using the parameter estimates presented in Tables 6-1, 6-2, and 6-3, the estimated decreases in environmental lead-loadings and concentrations when the geometric mean of each environmental variable is decreased by 50% were calculated and provided in Tables 6-4, 6-5, and 6-6 below.

Table 6-1. Structural Equation Modeling Results for the CAP Study Environmental Pathways — Dust-Lead Loadings (μg/ft²) and Dust-Lead Concentrations (μg/g).

Variables: Independent / Dependent	Direct Effect Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Soil	R^2
Dust-Lead Loadings (μg/ft²)						
Floor	0.2942 (1.91)	0.1504 (1.05)	-0.0610 (-0.42)	0.1224 (0.75)	0.0979 (0.28)	0.17
Interior Entryway Dust		0.2330 (1.78)	-0.0109 (-0.08)	0.2145 (1.43)	0.3512 (1.08)	0.18
Window Sill			**0.5291* (4.06)**		0.4513 (1.29)	0.33
Window Well					**0.8059* (2.15)**	0.09
Dust-Lead Concentrations (μg/g)						
Floor	0.2275 (1.15)	-0.1807 (-1.45)	**0.2647* (2.18)**	-0.0838 (-0.48)	0.1694 (0.71)	0.16
Interior Entryway Dust		0.0007 (0.01)	0.0207 (0.23)	**0.4580* (4.09)**	0.1960 (1.13)	0.34
Window Sill			**0.5389* (4.56)**		0.0810 (0.31)	0.35
Window Well					**0.8479* (2.81)**	0.14

Notes:
1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-values ≥ 1.96 and ≤ -1.96 are significant at the 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations and soil-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9996, and 0.9934 for the dust-lead concentration model.

Table 6-2. Structural Equation Modeling Results for the R&M Environmental Pathways — Dust-Lead Loadings (μg/ft²) and Dust-Lead Concentrations (μg/g).

Variables: Independent / Dependent	Direct Effect Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	R^2
Dust-Lead Loadings (μg/ft²)					
Floor	**0.2114* (2.77)**	0.1577 (1.71)	0.1507 (1.75)	0.0325 (0.47)	0.46
Interior Entryway		**0.3943* (3.13)**	-0.1432 (-1.17)	**0.2210* (2.30)**	0.25
Window Sill			**0.7958* (13.86)**		0.70
Dust-Lead Concentrations (μg/g)					
Floor	0.2035 (1.88)	**0.3082* (3.51)**	0.1737 (1.71)	-0.0281 (-0.29)	0.59
Interior Entryway		**0.1870* (2.16)**	-0.0415 (-0.40)	**0.5486* (6.95)**	0.57
Window Sill			**0.9059* (13.38)**		0.68

Notes:
1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥ 1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations and soil-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9569, and 0.9001 for the dust-lead concentration model.

Table 6-3. Structural Equation Modeling Results for the Rochester Environmental Pathways — Dust-Lead Loadings ($\mu g/ft^2$) and Dust-Lead Concentrations ($\mu g/g$).

Variables: Independent / Dependent	Direct Effect Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Soil	R^2
Dust-Lead Loadings ($\mu g/ft^2$)						
Floor	**0.1743*** **(3.29)**	**0.1795*** **(2.73)**	-0.0118 (-0.22)	0.0383 (0.62)	0.1424 (1.24)	0.21
Interior Entryway		0.0077 (0.07)	0.0595 (0.66)	0.1950 (1.95)	**0.4767*** **(2.58)**	0.12
Window Sill			**0.4121*** **(6.56)**		0.2057 (1.4067)	0.34
Window Well					**1.1057*** **(6.20)**	0.23
Dust-Lead Concentrations ($\mu g/g$)						
Floor	**0.3795*** **(5.17)**	**0.2002*** **(3.14)**	-0.0338 (-0.54)	-0.0828 (-1.24)	-0.0938 (-0.92)	0.25
Interior Entryway		-0.0284 (-0.37)	**0.1862*** **(2.50)**	**0.2006*** **(2.54)**	0.0942 (0.76)	0.16
Window Sill			**0.4695*** **(6.26)**		0.1591 (1.15)	0.35
Window Well					**0.9787*** **(7.05)**	0.28

Notes:
1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥1.96 or ≤-1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations and soil-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9878, and 0.9869 for the dust-lead concentration model.

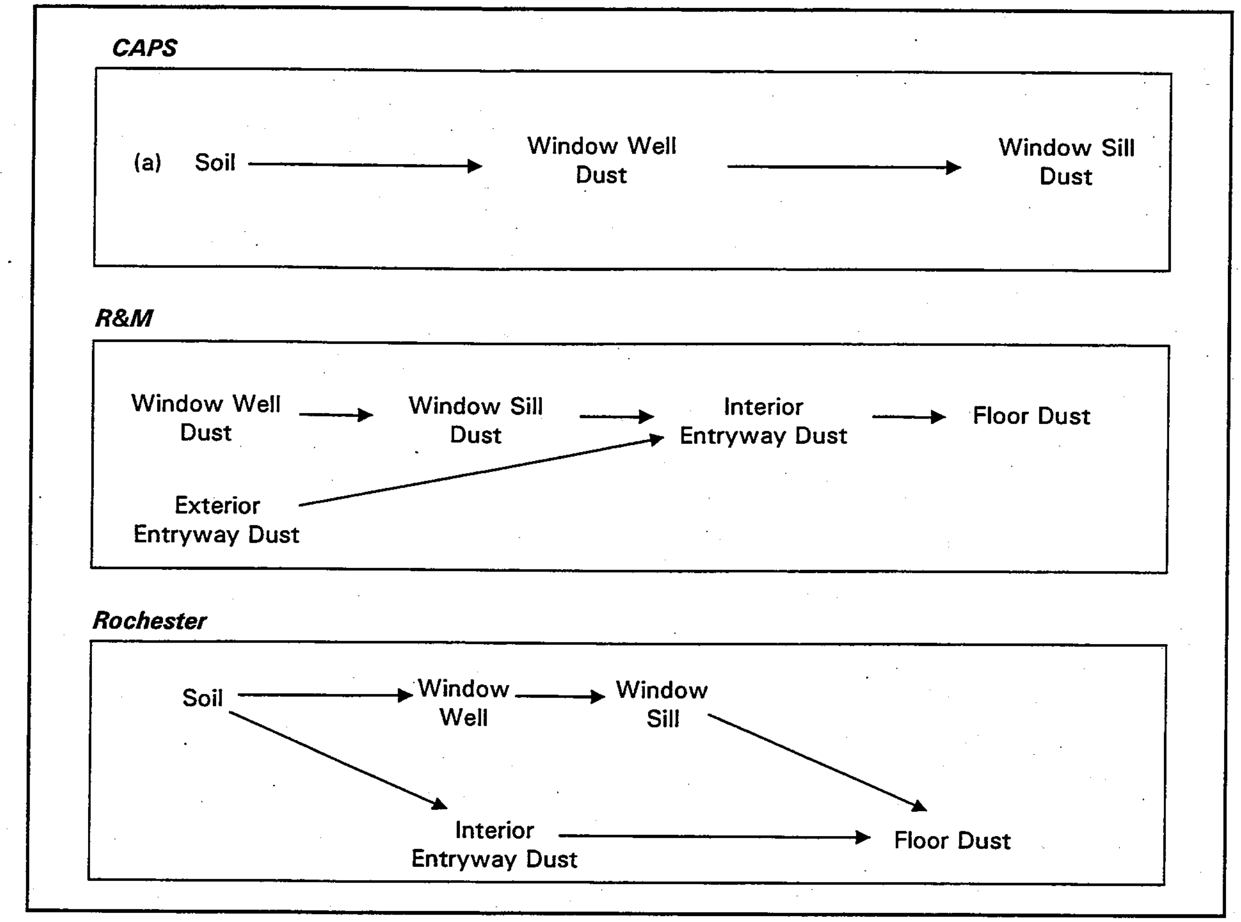


Figure 6-3. Significant Pathways for the CAP, R&M, and Rochester Environmental-Lead Pathway Models — Dust-Lead Loadings ($\mu g/ft^2$).

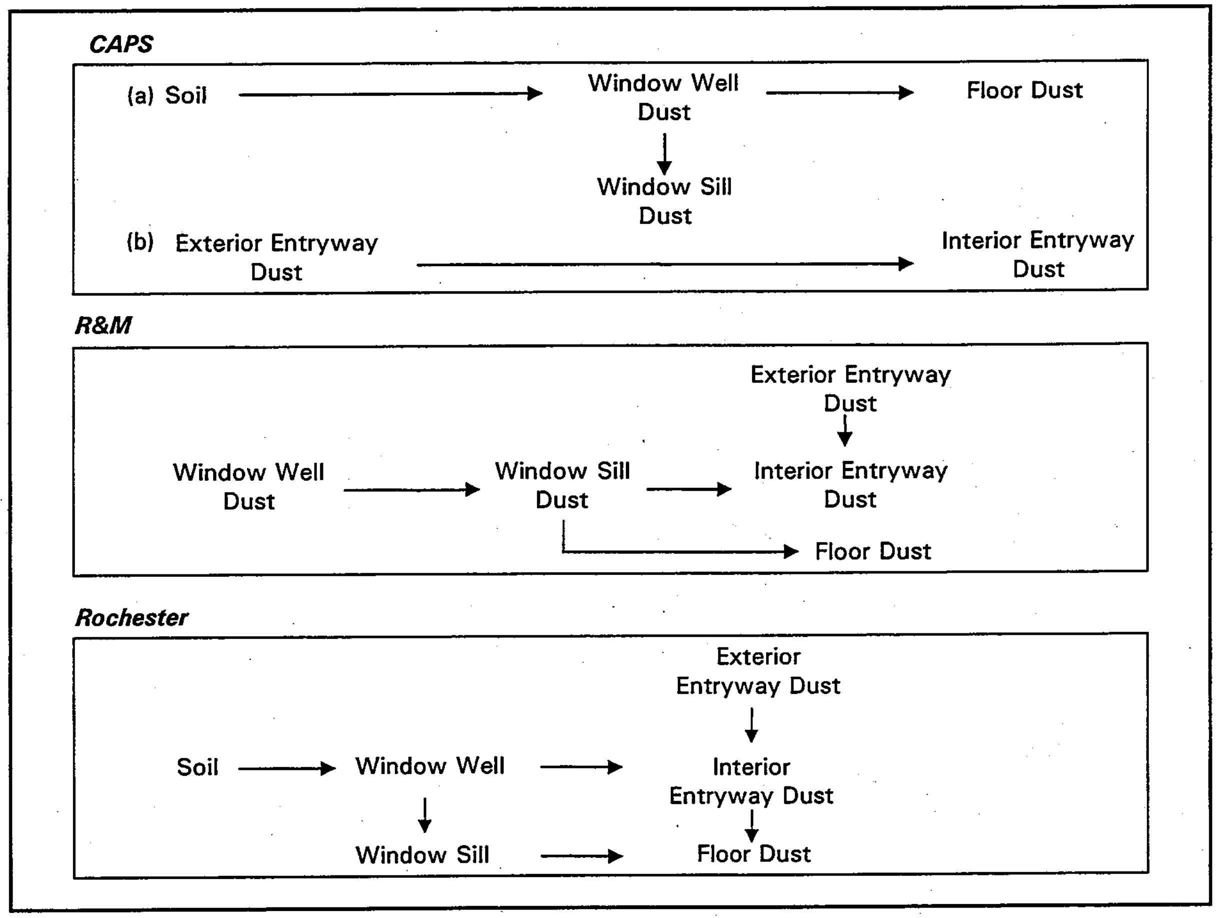


Figure 6-4. Significant Pathways for the CAP, R&M, and Rochester Environmental-Lead Pathway Models — Dust-Lead Concentrations (μg/g).

Table 6-4. Predicted Effect of a 50% Decrease in Environmental-Lead Loadings (μg/ft²) and Concentrations (μg/g) Based on the Environmental-Lead Pathways SEM for the CAP Study Data.

Sample Location	Geometric Mean	50% Decrease in GM	Predicted Percent Change (%) (95% Lower Prediction Bound, 95% Upper Prediction Bound) [b]			
			Floor	Interior Entryway	Window Sill	Window Well
Dust-Lead Loading (μg/ft²)						
Interior Entryway	342	171	-18 (-40,13)	*NA*	*NA*	*NA*
Window Sill	107	54	-14 (-36,16)	-15 (-34, 10)	*NA*	*NA*
Window Well	3,230	1,615	-4 (-29, 30)	-7 (-29, 22)	-31(-48, -8)	*NA*
Exterior Entryway	574	287	-12 (-37, 24)	-14 (-36, 16)	*NA*	*NA*
Soil[a]	157	79	-21 (-62, 63)	-32 (-64, 30)	-46(-75, 17)	-43 (-77, 44)
Dust-Lead Concentration (μg/g)						
Interior Entryway	201	101	-15 (-35, 12)	*NA*	*NA*	*NA*
Window Sill	778	389	-13 (-27, 3)	0 (-9, 10)	*NA*	*NA*
Window Well	1,577	789	-11 (-25, 5)	-1 (-10, 9)	-31 (-43, 16)	*NA*
Exterior Entryway	261	131	-7 (-27, 19)	-27 (-35, 18)	*NA*	*NA*
Soil[a]	157	79	-21 (-43, 10)	-14 (-28, 3)	-31 (-55, 6)	-44 (-69, 2)

[a] Average soil-lead concentration in μg/g.
[b] The prediction intervals or forecasting intervals presented are confidence intervals for the actual or future value of a response. Note that the upper and lower 95% prediction bounds are based on the direct effects only.
NA Indicates that the fitted pathway model did not include this variable.

As seen in Table 6-4, for the CAP data, the largest reduction in floor dust loading or concentration, a 21% reduction, occurred when the geometric mean of the soil was reduced by 50%. Similar results were seen for floor dust loading in the Rochester model, as shown in Table 6-6. For the Rochester floor dust concentration, only a 6% reduction in concentration was seen when the soil was reduced by 50%, but a 23% reduction was seen when the interior entryway dust concentration was lowered. Generally, for both the CAP and Rochester data, a 50% reduction in the geometric mean soil-lead concentration produced the largest reductions in lead levels for floors, interior entryways, window sills, and window wells, ranging from a 6% decrease in floor dust concentration to a 54% decrease in window well dust loading for the Rochester data, and a 14% decrease in interior entryway dust concentration to a 46% decrease in window sill dust loading for the CAP data.

Table 6-5. Predicted Effect of a 50% Decrease in Environmental-Lead Loadings ($\mu g/ft^2$) and Concentrations ($\mu g/g$) Based on the Environmental-Lead Pathways SEM for the R&M Data.

Sample Location	Geometric Mean	50% Decrease in GM	Predicted Percent Change (%) (95% Lower Prediction Bound, 95% Upper Prediction Bound) [b]		
			Floor	Interior Entryway	Window Sill
Dust-Lead Loading ($\mu g/ft^2$)					
Interior Entryway	329	165	-14 (-25, -2)	*NA*	*NA*
Window Sill	1,229	615	-15 (-28, 0)	-24 (-44, 4)	*NA*
Window Well	37,035	18,518	-19 (-30, -6)	-11 (-35, 21)	-42 (-49, -34)
Exterior Entryway	405	203	-5 (-16, 7)	-14 (-32, 9)	*NA*
Dust-Lead Concentration ($\mu g/g$)					
Interior Entryway	1,459	730	-13 (-24, 0)	*NA*	*NA*
Window Sill	5,411	2,706	-21 (-30, -11)	-12 (-22, -1)	*NA*
Window Well	8,452	4,226	-28 (-37, -18)	-8 (-20, 5)	-47 (-53, -41)
Exterior Entryway	1,570	785	-6 (-17, 7)	-32 (-39, -25)	*NA*

[a] The prediction intervals or forecasting intervals presented are confidence intervals for the actual or future value of a response. Note that the upper and lower 95% prediction bounds are based on the direct effects only.
NA Indicates that the fitted pathway model did not include this variable.

Because very few soil samples were available for analysis from the R&M homes, a comparison to the CAP and Rochester reductions was difficult. In R&M study, the exterior entryway dust, considered to be a surrogate for soil, does show decreases in other environmental variables when its geometric mean was reduced, although not to the same degree as seen for soil in the CAP and Rochester studies. The largest decreases in floor dust-lead levels, 28% and 21%, occur when window well dust-lead concentration and window sill dust-lead concentration were decreased.

Table 6-6. Predicted Effect of a 50% Decrease in Environmental-Lead Loadings ($\mu g/ft^2$) and Concentrations ($\mu g/g$) Based on the Environmental-Lead Pathways SEM for the Rochester Data.

Sample Location	Geometric Mean	50% Decrease in GM	Predicted Percent Change (%) (95% Lower Prediction Bound, 95% Upper Prediction Bound) [b]			
			Floor	Interior Entryway	Window Sill	Window Well
Dust-Lead Loading ($\mu g/ft^2$)						
Interior Entryway	88.6	44.3	-11 (-20, -1)	*NA*	*NA*	*NA*
Window Sill	345	173	-12 (-23, 0)	-1 (-30, 40)	*NA*	*NA*
Window Well	22,584	11,292	-5 (-15, 6)	-4 (-28, 28)	-25 (-36, -12)	*NA*
Exterior Entryway	521	258	-5 (-16, 7)	-13 (-37, 20)	*NA*	*NA*
Soil[a]	852	426	-21 (-37, -1)	-32 (-62, 23)	-37 (-57, -8)	-54 (-76, -13)
Dust-Lead Concentration ($\mu g/g$)						
Interior Entryway	468	234	-23 (-32, -13)	*NA*	*NA*	*NA*
Window Sill	2,787	1,394	-12 (-21, -2)	2 (-13, 19)	*NA*	*NA*
Window Well	8,676	4,338	-8 (-17, 2)	-11 (-23, 3)	-28 (-39, -14)	*NA*
Exterior Entryway	656	328	0 (-10, 12)	-13 (-26, 2)	*NA*	*NA*
Soil[a]	852	426	-6 (-20, 11)	-16 (-34, 7)	-35 (-53, -11)	-49 (-65, -25)

[a] Average soil-lead concentration in $\mu g/g$.
[b] The prediction intervals or forecasting intervals presented are confidence intervals for the actual or future value of a response. Note that the upper and lower 95% prediction bounds are based on the direct effects only.
NA Indicates that the fitted pathway model did not include this variable.

6.3 BLOOD-LEAD PATHWAYS RESULTS

The results of the SEM for the blood-lead pathway models illustrated in Equation Sets 5-4 and 5-5 are presented in Tables 6-7 and 6-8 using the R&M and Rochester data, respectively. The significant pathways observed in Tables 6-7 and 6-8 are diagramed in Figures 6-5 and 6-6 for easy comparison.

Four similar direct pathways of lead exposure/contamination were observed in Figure 6-5 (i.e., dust-lead loading model): 1) window well dust to window sill dust, 2) interior entryway dust to floor dust, 3) floor dust to blood, and 4) mouthing habits of the child to the blood. For the Rochester data, there was another significant direct pathway from window well dust to blood. No additional significant direct pathways to blood were observed in the R&M data.

Table 6-7. Structural Equation Modeling Results for the R&M Blood-Lead Pathways — Dust-Lead Loadings ($\mu g/ft^2$) and Dust-Lead Concentrations ($\mu g/g$).

Variables	Direct Effect Parameter Estimates (t-value)							
Independent / Dependent	Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Floor Dust	Water	Mouthing	R^2
Dust-Lead Loadings ($\mu g/ft^2$)								
Blood	0.0591 (1.57)	-0.0089 (-0.20)	0.0587 (1.42)	0.0269 (0.81)	**0.1144* (2.21)**	-0.0400 (-0.34)	**0.3603* (2.08)**	0.35
Floor	**0.2114* (2.77)**	0.1577 (1.71)	0.1507 (1.75)	0.0325 (0.47)				0.46
Interior Entryway		**0.3943* (3.13)**	-0.1432 (-1.17)	**0.2210* (2.30)**				0.25
Window Sill			**0.7958* (13.86)**					0.70
Dust-Lead Concentrations ($\mu g/g$)								
Blood	**0.1620* (2.41)**	0.0507 (0.89)	-0.0190 (-0.30)	-0.0017 (-0.03)	0.1251 (1.88)	-0.0850 (-0.75)	0.2979 (1.82)	0.38
Floor	0.2035 (1.88)	**0.3082* (3.51)**	0.1737 (1.71)	-0.0281 (-0.29)				0.59
Interior Entryway		**0.1870* (2.16)**	-0.0415 (-0.40)	**0.5486* (6.95)**				0.57
Window Sill			**0.9059* (13.4)**					0.68

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥ 1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations, soil-lead concentrations, and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9575, and 0.9126 for the dust-lead concentration model.

Table 6-8. Structural Equation Modeling Results for the Rochester Blood-Lead Pathways — Dust-Lead Loadings ($\mu g/ft^2$) and Dust-Lead Concentrations ($\mu g/g$).

Variables	Direct Effect Parameter Estimates (t-value)								
Independent / Dependent	Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Soil	Floor Dust	Water	Mouthing	R^2
Dust-Lead Loadings ($\mu g/ft^2$)									
Blood	-0.0275 (-1.26)	0.0233 (0.87)	**0.0620* (2.97)**	-0.0101 (-0.41)		**0.1096* (3.19)**	-0.0691 (-0.64)	**0.3933* (3.11)**	0.27
Floor	**0.1813* (3.39)**	**0.1726* (2.61)**	-0.0182 (-0.32)	0.0406 (0.66)	0.1671 (1.41)				0.22
Interior Entryway		0.0146 (0.13)	0.0748 (0.81)	0.1909 (1.90)	**0.4273* (2.25)**				0.12
Window Sill			**0.4186* (6.44)**		0.2067 (1.37)				0.35
Window Well					**1.1669* (6.64)**				0.25
Dust-Lead Concentrations ($\mu g/g$)									
Blood	-0.0283 (-0.67)	0.0273 (0.80)	0.0386 (1.27)	0.0204 (0.59)		0.0654 (1.40)	0.0083 (0.07)	**0.4788* (3.37)**	0.15
Floor	**0.3854* (5.20)**	**0.1917* (3.00)**	-0.0437 (-0.69)	-0.0862 (-1.29)	-0.0596 (-0.57)				0.25
Interior Entryway		-0.0196 (-0.25)	**0.1794* (2.39)**	**0.1948* (2.46)**	0.0868 (0.69)				0.16
Window Sill			**0.4595* (6.00)**		0.1884 (1.33)				0.35
Window Well					**1.0160* (7.30)**				0.30

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥ 1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations, soil-lead concentrations, and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9751, and 0.9661 for the dust-lead concentration model.

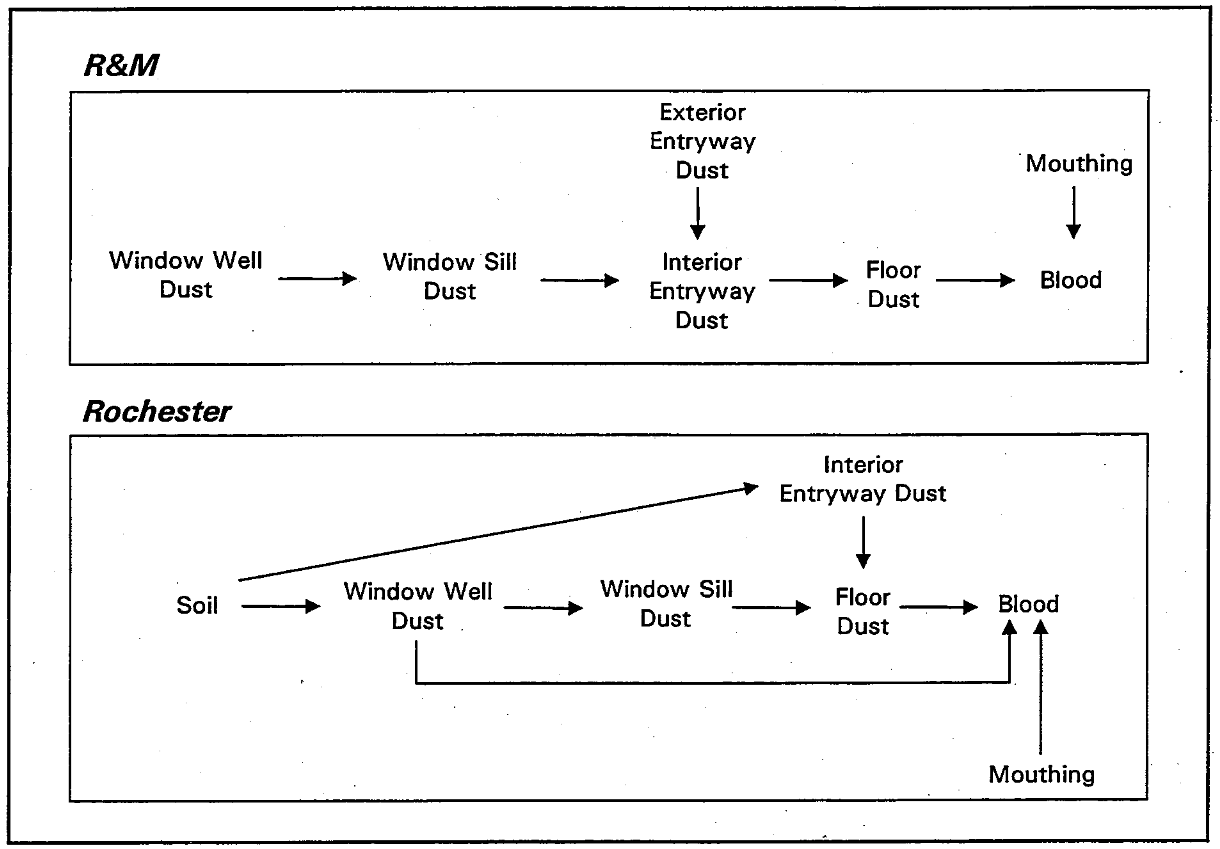


Figure 6-5. Significant Pathways for the R&M and Rochester Blood-Lead Pathway Models — Dust-Lead Loadings (μg/ft²).

A comparison of Figure 6-6 (i.e., dust-lead concentration model) to Figure 6-5 (i.e., dust-lead loading model) shows that there were some common statistically significant pathways in the concentrations and loadings models. For instance, the R&M data had three direct pathways that were the same for dust loadings and concentrations: 1) exterior entryway dust to interior entryway dust, 2) window well dust to window sill dust, and 3) window sill dust to interior entryway dust. The Rochester data shows three pathways which were the same for the dust loadings and concentrations: 1) children's mouthing to blood, 2) interior entryway dust to floor dust, and 3) soil to window well dust to window sill dust to floor dust.

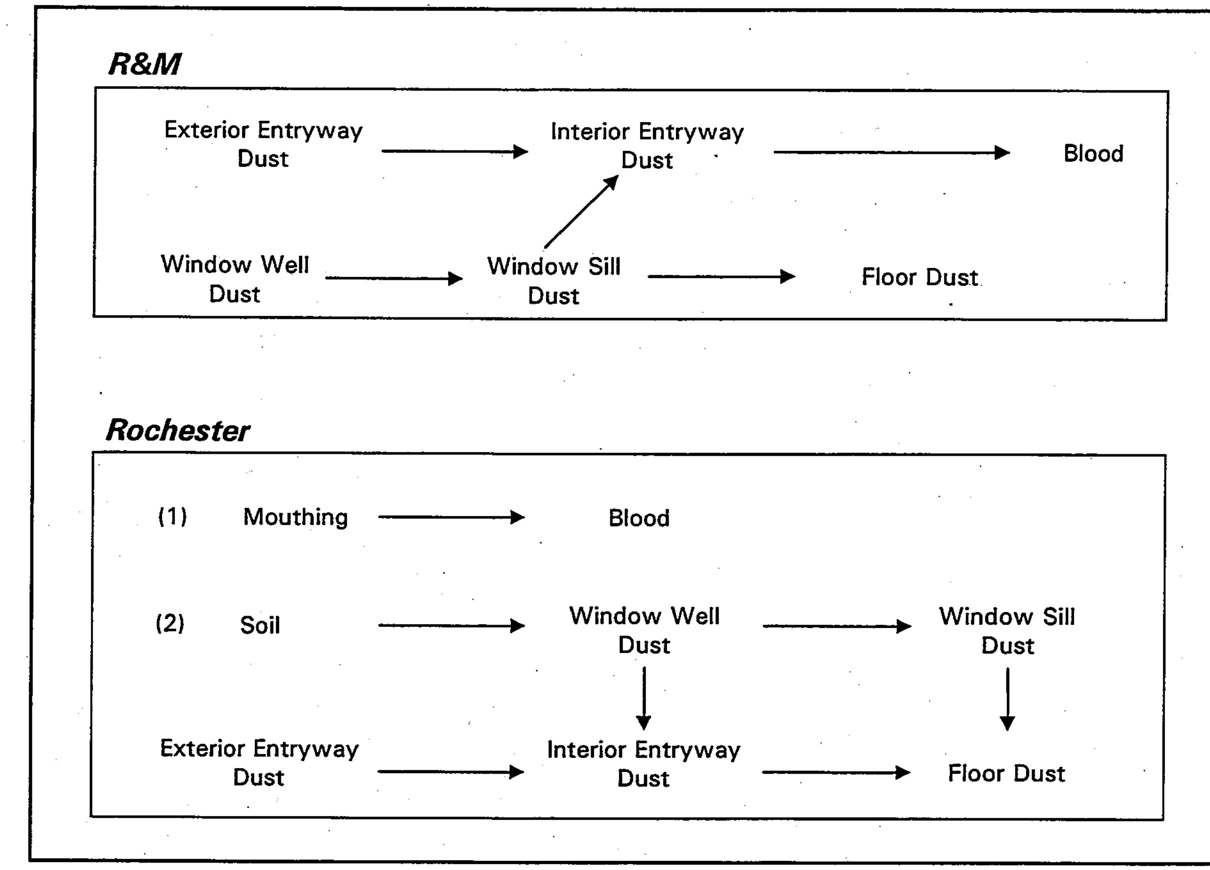


Figure 6-6. Significant Pathways for the R&M and Rochester Blood-Lead Pathway Models — Dust-Lead Concentrations (μg/g).

One notable difference between the loading and concentration models occurred in the Rochester data. In the loading model the floor dust, window well dust, and child mouthing directly impacted the blood. In the concentration model only the child mouthing directly impacted the blood.

Tables 6-9 and 6-10 list the predicted effect of a 50% decrease in the geometric means of the environmental variables on the blood-lead concentrations and the environmental-lead loadings and concentrations. The parameter estimates from Tables 6-7 and 6-8 were used to calculate the predictions. Also listed in the table are the 95% prediction intervals about the predicted effect. The prediction intervals are based only on the direct effects.

Table 6-9. Predicted Effect of 50% Decrease in Environmental-Lead Loadings ($\mu g/ft^2$) and Concentrations ($\mu g/g$) and Blood-Lead Concentrations ($\mu g/dL$) Based on the Blood-Lead Pathways SEM for the R&M Data.

Sample Location	Geometric Mean	50% Decrease in GM	Predicted Percent Change (%) (95% Lower Prediction Bound, 95% Upper Prediction Bound) [b] Blood	Floor	Interior Entryway	Window Sill
Dust-Lead Loadings ($\mu g/ft^2$)						
Floor	210	105	-8 (-12, -4)	*NA*	*NA*	*NA*
Interior Entryway	329	165	-6 (-9, -3)	-14 (-25, 2)	*NA*	*NA*
Window Sill	1,229	615	-3 (-6, 1)	-18 (-30, 4)	-23 (-44, 5)	*NA*
Window Well	37,035	18,518	-6 (-9, -3)	-14 (-26, 0)	-19 (-40, 10)	-43 (-50, -35)
Exterior Entry	405	203	-3 (-6, 0)	-5 (-16, 7)	-14 (-32, 9)	*NA*
	Exposure	**No Exposure**				
Mouthing[a]	1	0	-30 (-40, -19)	*NA*	*NA*	*NA*
Water[a]	1	0	4 (-6, 15)	*NA*	*NA*	*NA*
Dust-Lead Concentrations ($\mu g/g$)						
Floor	1,118	559	-8 (-13, -3)	*NA*	*NA*	*NA*
Interior Entryway	1,459	730	-12 (-16, -7)	-13 (-24, 0)	*NA*	*NA*
Window Sill	5,411	2,706	-8 (-12, -4)	-21 (-30, -11)	-12 (-22, 1)	*NA*
Window Well	8,452	4,226	-6 (-11, -1)	-20 (-30, -9)	-11 (-22, 2)	-47 (-53, -41)
Exterior Entry	1,570	785	-7 (-11, -3)	-6 (-17, 8)	-32 (-39, -25)	*NA*
	Exposure	**No Exposure**				
Mouthing[a]	1	0	-26 (-35, -16)	*NA*	*NA*	*NA*
Water[a]	1	0	9 (0, 19)	*NA*	*NA*	*NA*

[a] Variables were treated as categorical.
[b] The prediction intervals or forecasting intervals presented are confidence intervals for the actual or future value of a response. Note that the upper and lower 95% prediction bounds are based on the direct effects only.
NA Indicates that the fitted pathway model did not include this variable.

Table 6-10. Predicted Effect of 50% Decrease in Environmental-Lead Loadings ($\mu g/ft^2$) and Concentrations ($\mu g/g$) and Blood-Lead Concentrations ($\mu g/dL$) Based on the Blood-Lead Pathways SEM for the Rochester Data.

Sample Location	Geometric Mean	50% Decrease in GM	Predicted Percent Change (%) (95% Lower Prediction Bound, 95% Upper Prediction Bound) [b] Blood	Floor	Interior Entryway	Window Sill	Window Well
Dust-Lead Loading ($\mu g/ft^2$)							
Floor Dust	100	50	-7 (-9, -5)	*NA*	*NA*	*NA*	*NA*
Interior Entryway Dust	89	45	-1 (-3, 1)	-12 (-21, -2)	*NA*	*NA*	*NA*
Window Sill	345	173	-3 (-5, -1)	-11 (-22, 1)	-1 (-30, 40)	*NA*	*NA*
Window Well	22,584	11,292	-4 (-6, -2)	0 (-11, 11)	-5 (-29, 28)	-25 (-37, -11)	*NA*
Soil[a]	852	426	NA	-13 (–31, 10)	-7 (-50, 71)	-38 (-58, -8)	-55 (-76, -17)
Exterior Dust	515	258	0 (-2, 2)	-5 (-16, 7)	-12 (-36, 21)	*NA*	*NA*
	Exposure	**No Exposure**					
Mouthing [b]	1	0	-33 (-39, -26)	*NA*	*NA*	*NA*	*NA*
Water[b]	1	0	7 (-2, 16)	*NA*	*NA*	*NA*	*NA*
Dust-Lead Concentrations ($\mu g/g$)							
Floor Dust	563	282	-4 (-8, 0)	*NA*	*NA*	*NA*	*NA*
Interior Entryway Dust	468	234	0 (-4, 4)	-23 (-32, -13)	*NA*	*NA*	*NA*
Window Sill	2,787	1,394	-31 (-33, -29)	-12 (-21, -2)	1	*NA*	*NA*
Window Well	8,676	4,338	-21 (-23, 19)	-11 (-20, -1)	-12 (-24, 2)	0 (-16, 19)	*NA*
Soil	852	426	NA	-13 (-27, 3)	-11 (-31, 14)	-51 (-65, -32)	-51 (-66, -29)
Exterior Dust	656	328	-1 (-4, 2)	1 (-9, 13)	-13 (-26, 2)	*NA*	*NA*
	Exposure	**No Exposure**					
Mouthing [b]	1	0	-38 (-45, -30)	*NA*	*NA*	*NA*	*NA*
Water [b]	1	0	-1 (-11, 10)	*NA*	*NA*	*NA*	*NA*

[a] Soil lead is measured as a concentration.
[b] Variables were treated as categorical.
[c] The prediction intervals or forecasting intervals presented are confidence intervals for the actual or future value of a response. Note that the upper and lower 95% prediction bounds are based on the direct effects only.
NA Indicates that the fitted pathway model did not include this variable.

Tables 6-9 and 6-10 show that for both data sets, the largest decreases in blood-lead occurred when the mouthing variable was changed from exposure to no exposure, ranging from an estimated 26% decrease to a 38% decrease. Reduction of all other variables, in general, produced lower decreases in blood-lead levels, less than 12% and typically in the single digits. In a few cases there were no decreases or small positive increases in the blood-lead concentration. Two exceptions to the general rule of small predicted percent change occurred in the concentration model for the Rochester data. Reducing the geometric mean window sill dust-lead concentration by 50% resulted in a 31% reduction in blood-lead concentration. Reducing the geometric mean window well dust-lead concentration by 50% resulted in a 21% reduction in blood-lead concentration.

6.4 RESULTS OF ASSESSING THE PAINT-LEAD INDICATORS

The results of two analyses that assessed two types of paint-lead indicators are presented below. The first set of results assessed the impact of paint in the R&M and Rochester data environmental pathway models described in Equation Sets 5-2 and 5-3. The second set of analysis results assessed the impact of paint in the Rochester data blood-lead pathway model illustrated in Equation Set 5-8.

The parameter estimates for the environmental pathway models for R&M and Rochester are given in Tables B-1 and B-2 of Appendix B and Tables C-1, C-2, C-3, and C-4 of Appendix C for the R&M and Rochester data, respectively.

Hazard Score versus XRF Measurement

The tables listed above show several differences in the statistically significant pathways when the paint pathway in the model was the paint hazard score versus the average XRF measurement. As shown in Table B-1, when the hazard scores were used in the R&M loading model, both the window paint and the door paint were statistically significant pathways of lead to floor dust. However, when the average XRF measurement was used in the R&M loading model, there were no statistically significant pathways to floor dust, as shown in Table B-2. In the R&M concentration model, the statistically significant pathways were generally the same regardless of the type of paint pathway.

For the Rochester data, comparisons of Tables C-1 to C-2 and C-3 to C-4 show that significant pathways were generally the same when either paint hazard score or average XRF measurement was used in the model.

The small sample size available for the R&M data may explain the differences observed in the R&M results. Since the hazard score is thought to be more representative of the paint hazard present at the time of blood sampling and since the significant pathways in the Rochester analysis were generally the same whether hazard score or average XRF measurement was included, the paint hazard scores were included in all subsequent models that had a paint pathway.

Note that in some cases estimated coefficients for the XRF variables or the paint hazard scores were statistically significant and negative. The negative parameter estimates may seem non-intuitive since paint-lead has been shown to be a leading cause for increases in blood-lead concentration. Perhaps these negative parameter estimates are due to not having substrate corrected XRF measurements, not sampling all painted surfaces in the residence, or having subjectivity in the evaluation of paint condition.

Environmental-Lead Pathways

Figures 6-7 and 6-8 present the significant pathways for the environmental pathway model paint assessment using results for the models which included paint hazard score as pathways. The figures show that there were far more significant pathways for the Rochester data than for the R&M data. This may be due to the fact that there were only 36 homes available for paint analysis in the R&M data and there were up to 205 homes available for analysis in the Rochester data.

For the Rochester data, window paint directly impacted window sill and window well dust loading and concentration and floor dust concentration. Door paint directly impacted interior entryway dust loading and concentration. All other significant pathways remain unchanged to those illustrated in Figures 6-3 and 6-4.

For the R&M data, window paint directly impacted the floor dust loading and interior entryway dust concentration while the door paint directly impacted floor dust loading. Note that inclusion of the paint hazard score in the R&M environmental models and the decrease in sample size resulted in major changes in the statistically significant pathways as presented in Figures 6-3 and 6-4.

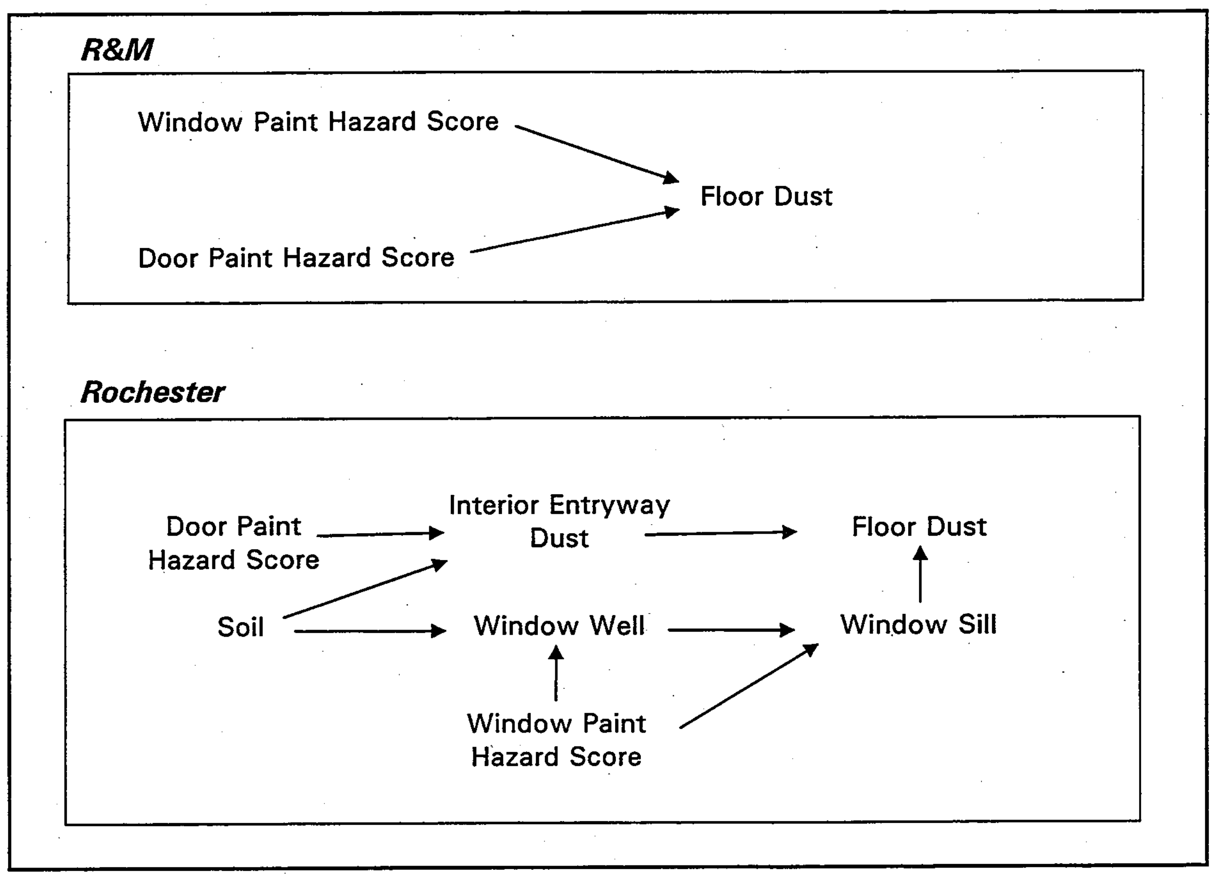


Figure 6-7. Significant Pathways for the R&M and Rochester Environmental-Lead Pathway Models Including Window and Door Paint Hazard Score Pathways — Dust-Lead Loadings (µg/ft²).

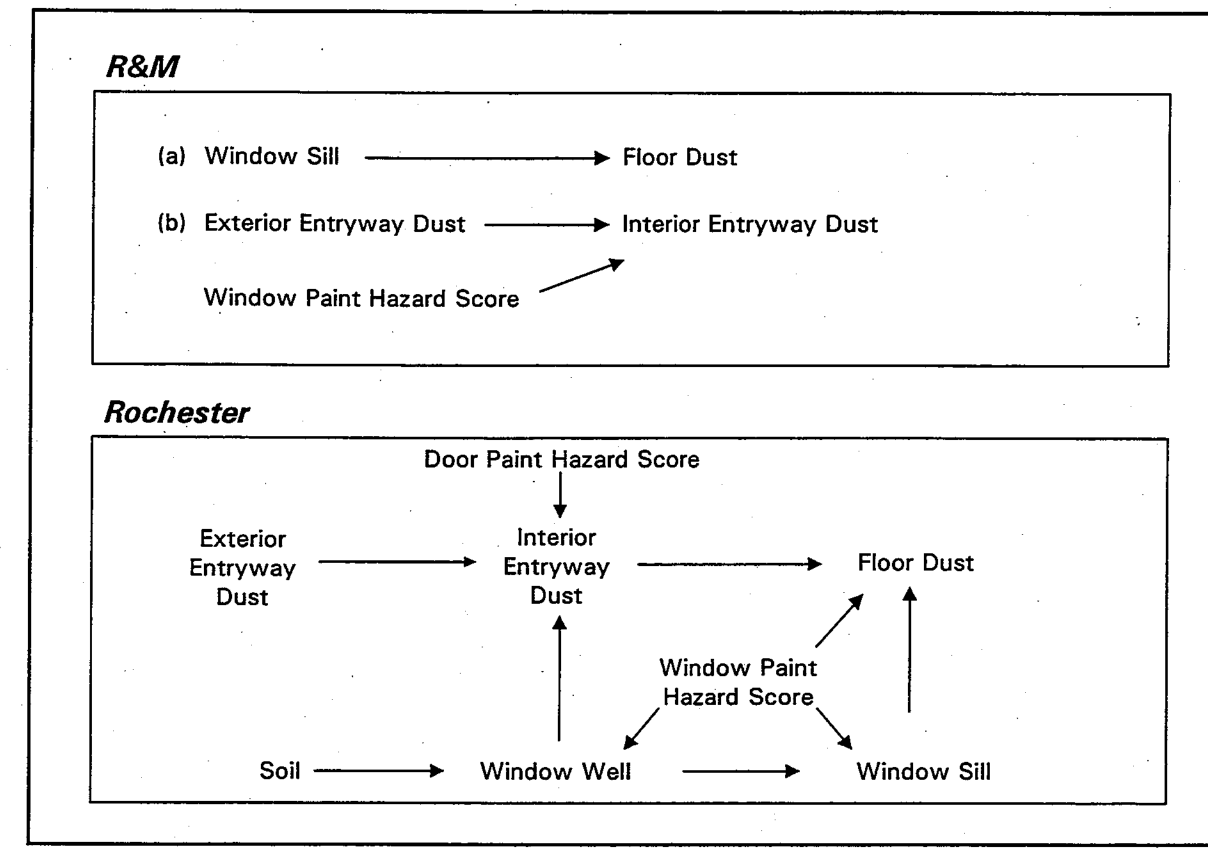


Figure 6-8. Significant Pathways for the R&M and Rochester Environmental-Lead Pathway Models Including Window and Door Paint Hazard Score Pathways — Dust-Lead Concentrations (µg/g).

Blood-Lead Pathways

Figure 6-9 presents the significant pathways for the blood-lead pathways assessed for the Rochester data and Table C-3 in Appendix C presents the model parameter estimates.

Figure 6-9 illustrates that the window and door paint directly impacted the blood in the loading model while only the door paint contributed directly to blood in the concentration model. In addition, for both the loading and concentration models the window paint directly impacted the window sills and window wells dust while the door paint directly impacted the interior entryway dust.

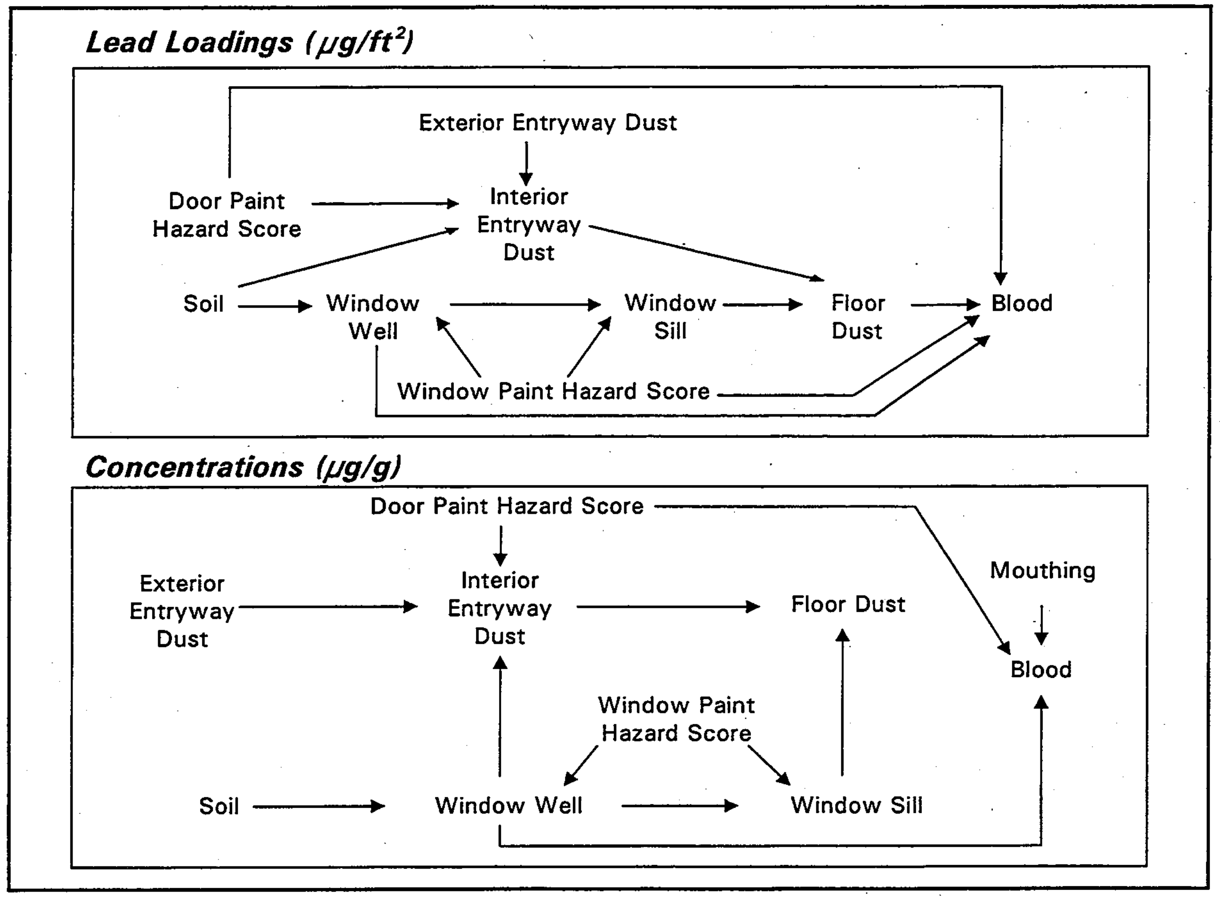


Figure 6-9. Significant Pathways for the Rochester Blood-Lead Pathway Model Including Window and Door Paint Hazard Score Pathways — Dust-Lead Loadings (μg/ft²) and Concentrations (μg/g).

6.5 RESULTS OF ASSESSING THE HAND DUST-LEAD

Since only the Rochester study had hand dust-lead information, this analysis assesses the impact of including hand dust-lead as a pathway in the Rochester blood-lead pathways model that includes paint. The pathways model assessed was described in Equation Set 5-9, the parameters are presented in Table C-5 in Appendix C, and Figure 6-10 presents the statistically significant pathways. Comparing Figure 6-10 to Figure 6-9 shows that when hand dust-lead is included in the analysis, the pathways in Figure 6-10 are almost the same as those in Figure 6-9, but hand-lead is now a direct pathway to blood-lead in both the loading and concentration models. In addition, in the loading model, floor dust-lead is a direct pathway to hand dust-lead. In the concentration model, window well dust-lead concentration is a direct pathway to hand dust-lead.

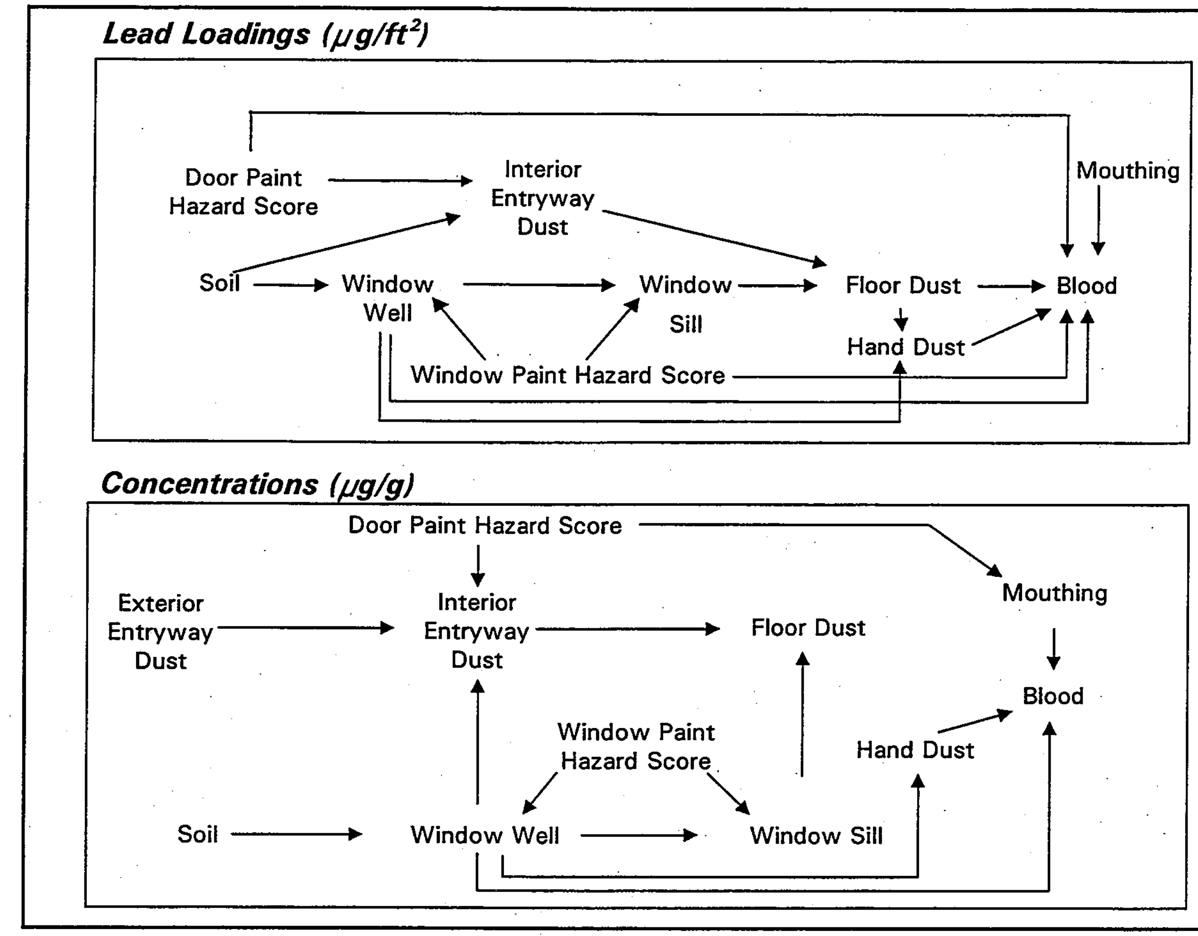


Figure 6-10. Significant Pathways for the Rochester Blood-Lead Pathway Model Including a Hand Lead and Window and Door Paint Pathways — Dust-Lead Loadings (μg/ft²) and Concentrations (μg/g).

Finally, comparing the blood-lead equation in Table C-3 to Table C-5 shows that the R^2 for the blood-lead equation increases when hand dust-lead is added as a pathway, indicating that additional variability is explained when the hand dust-lead variable is included in the model.

6.6 RESULTS OF ASSESSING SOIL-LEAD COVERAGE

A variable was collected in the Rochester study which described the soil coverage at the site of the soil sample, i.e., whether the area was grass covered, bare, etc. This variable was combined with the soil-lead concentration by multiplying the coverage indicator times the soil-lead concentration. This new variable was then substituted for the soil-lead concentration in the Rochester blood-lead pathways model illustrated in Equation Set 5-8. Table C-6 in Appendix C lists the parameter estimates. The significant pathways were similar to those shown in Figure 6-9, the original model that included soil-lead concentration. However, in the model with the soil-lead coverage variable replacing the soil-lead concentration variable, the pathway from soil to interior entryway dust-lead loading is no longer significant. Moreover, in the model with soil-lead coverage, the pathways from soil to window well dust-lead loading and soil to window well dust-lead concentration have much lower parameter estimates than is the case in the model with soil-lead concentration.

6.7 RESULTS OF ASSESSING CARPETED FLOORS

This section discusses the effect of carpeting. *Note that the results in this section must be viewed with extreme caution since potential confounding effects such as age of the home, type of home, or other socioeconomic variables were not taken into account in the analysis.*

For the R&M model, a pathway for the proportion of floor samples which were carpeted was included in the blood-lead pathway model. Equation Set 5-10 presents the exact model assessed. Table B-3 in Appendix B lists the parameter estimates and Figure 6-11 illustrates the statistically significant pathways for the loading and concentration models.

A comparison of Figure 6-11 to Figures 6-5 and 6-6 shows that the statistically significant pathways generally remained the same. The carpet indicator was an added pathway of lead exposure to blood in both the loading and concentration models. All other pathways in the loading model remained the same. In the concentration model, the window sill dust to floor dust pathway was replaced by the window well to floor dust pathway while all other pathways remained the same. Most of the parameter estimates in Table 6-7 remained about the same when the carpet indicator was included in the model, as can be seen by comparing Table 6-7 to Table B-3.

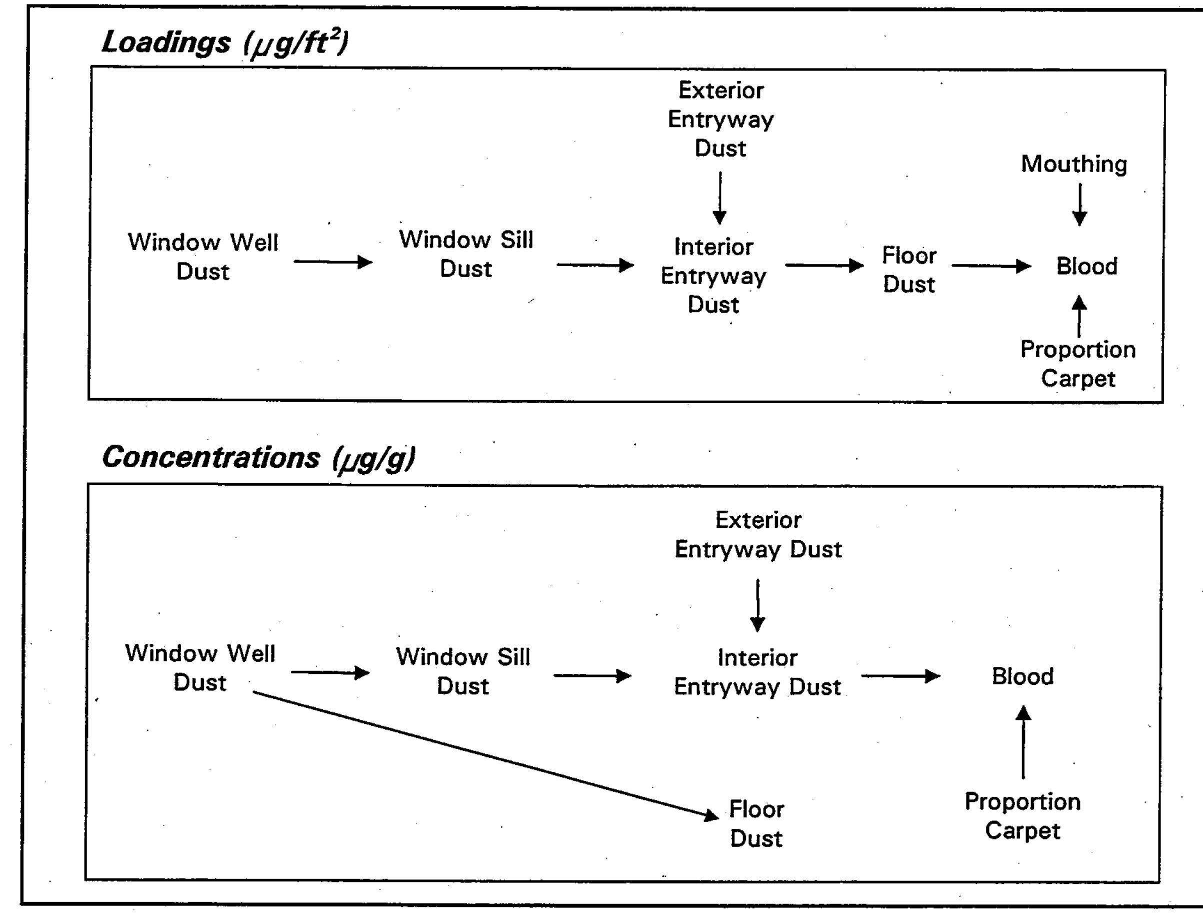


Figure 6-11. Significant Pathways for the R&M Blood-Lead Pathway Model Including a Proportion of Carpeting Pathway — Dust-Lead Loadings ($\mu g/ft^2$) and Concentrations ($\mu g/g$).

The models were used to assess the effect of a 50% decrease in geometric mean environmental-lead levels on blood-lead concentrations and other environmental levels. Table B-6 in Appendix B presents the results for the R&M study data and shows the largest decreases in blood-lead concentrations, a 27% decrease for the loading model and a 25% decrease for the concentration model, occurred when the mouthing habits of the child were reduced. There was an estimated 104% increase, for the loading model, and an 81% increase, for the concentration model, in the blood-lead concentration when the proportion of carpeted floors in the home was reduced. Again, extreme caution should be exercised in drawing any conclusions from this result. The results may be highly confounded. The R&M homes had higher lead levels and on average 20% of the sampled floors were carpeted. The control homes had lower lead levels and about 47% of the sampled floors in a control home were carpeted. Moreover, 73% of the sampled floors in the modern urban control homes were carpeted

Two additional analyses were run for the Rochester data. The first analysis (see Equation Set 5-11) added a variable for the proportion of floors carpeted and an indicator variable of whether the interior entryway was carpeted to the blood-lead pathway model illustrated in Equation Set 5-8. The second analysis (see Equation Set 5-12) essentially applied the blood-lead pathway model, which included the door and window paint hazard score variables, to a subset of homes that had both a carpeted bedroom and a carpeted play area. For the subset of homes, the average floor dust sample for each home was the average of the bedroom and the play area floor dust samples only. Presence of carpeting in the interior entryway was accounted for by an indicator variable. The purpose of the analysis of the subset data was to determine if carpeting in the rooms where a child spends a lot of time reduces the child's blood-lead concentration. Figures 6-12 and 6-13 diagram the statistically significant pathways for the two analyses. Tables C-7 and C-8 in Appendix C present the parameter estimates for the models.

Comparing Figure 6-12 to Figure 6-9 shows the statistically significant pathways were nearly the same. However, in Figure 6-12, the indicator of interior entryway carpet and the proportion carpet variable are now direct pathways to blood-lead in the loading model. The indicator of entryway carpet is a direct pathway to blood-lead in the concentration model. In the loading model, the indicator of entryway carpet is a direct pathway to entryway dust-lead, and the proportion carpet variable is a direct pathway to floor dust-lead.

The results of the second analysis on the subset of homes are presented in Figure 6-13 and Table C-8. Note that the proportion carpet indicator was omitted from the second analysis since all floors other than entryways were carpeted in the analysis. Comparison of Figure 6-13 to Figure 6-12 shows that floor dust-lead loading is no longer a direct pathway to blood-lead when only carpeted (non-entry) floors are included in the model. Additionally, interior entryway and window sill dust concentrations are no longer direct pathways to floor dust concentration.

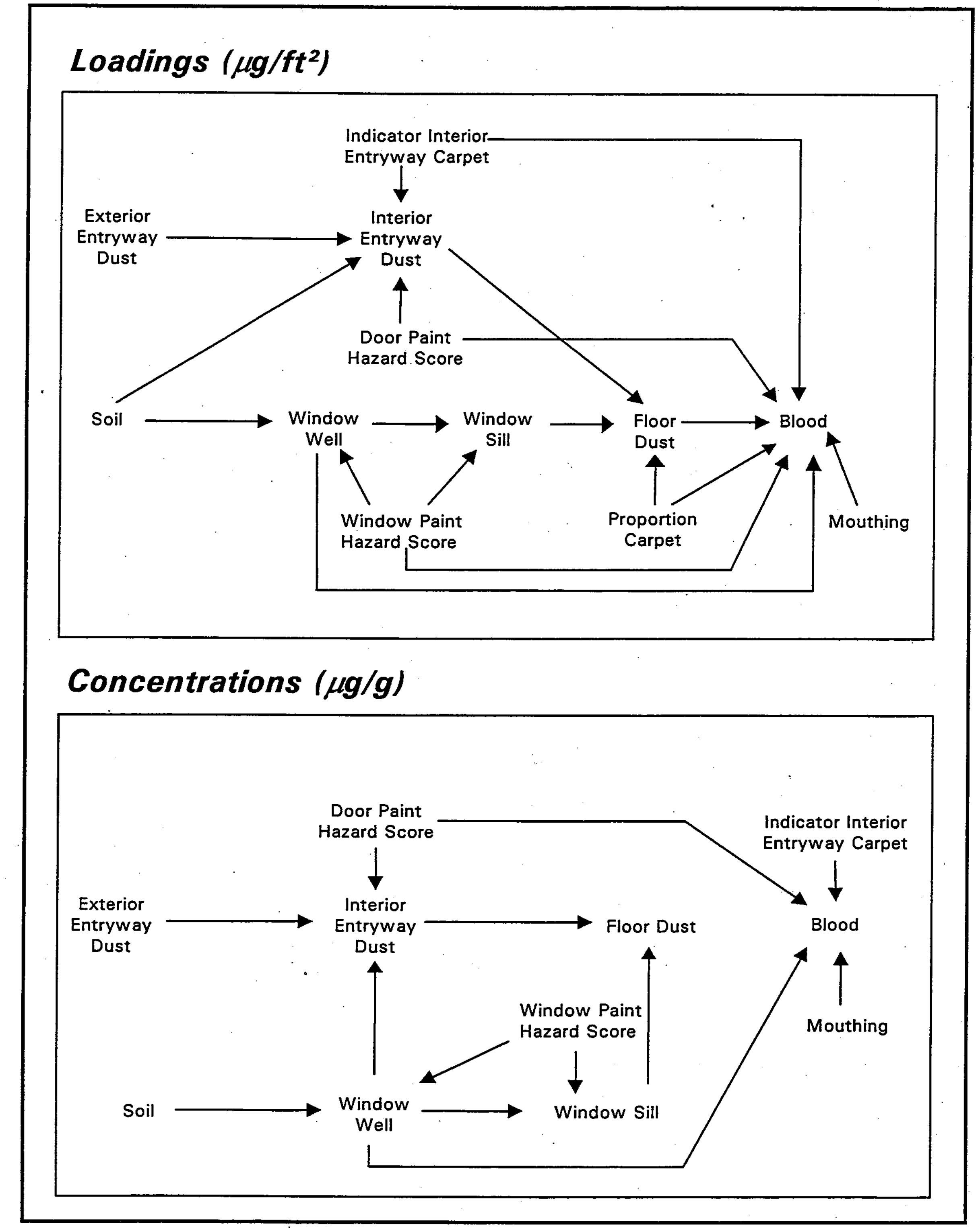


Figure 6-12. Significant Pathways for the Rochester Blood-Lead Pathway Models Including Proportion of Carpeting and Indicator of Interior Entryway Carpet Pathways — Dust-Lead Loadings (µg/ft²) and Concentrations (µg/g).

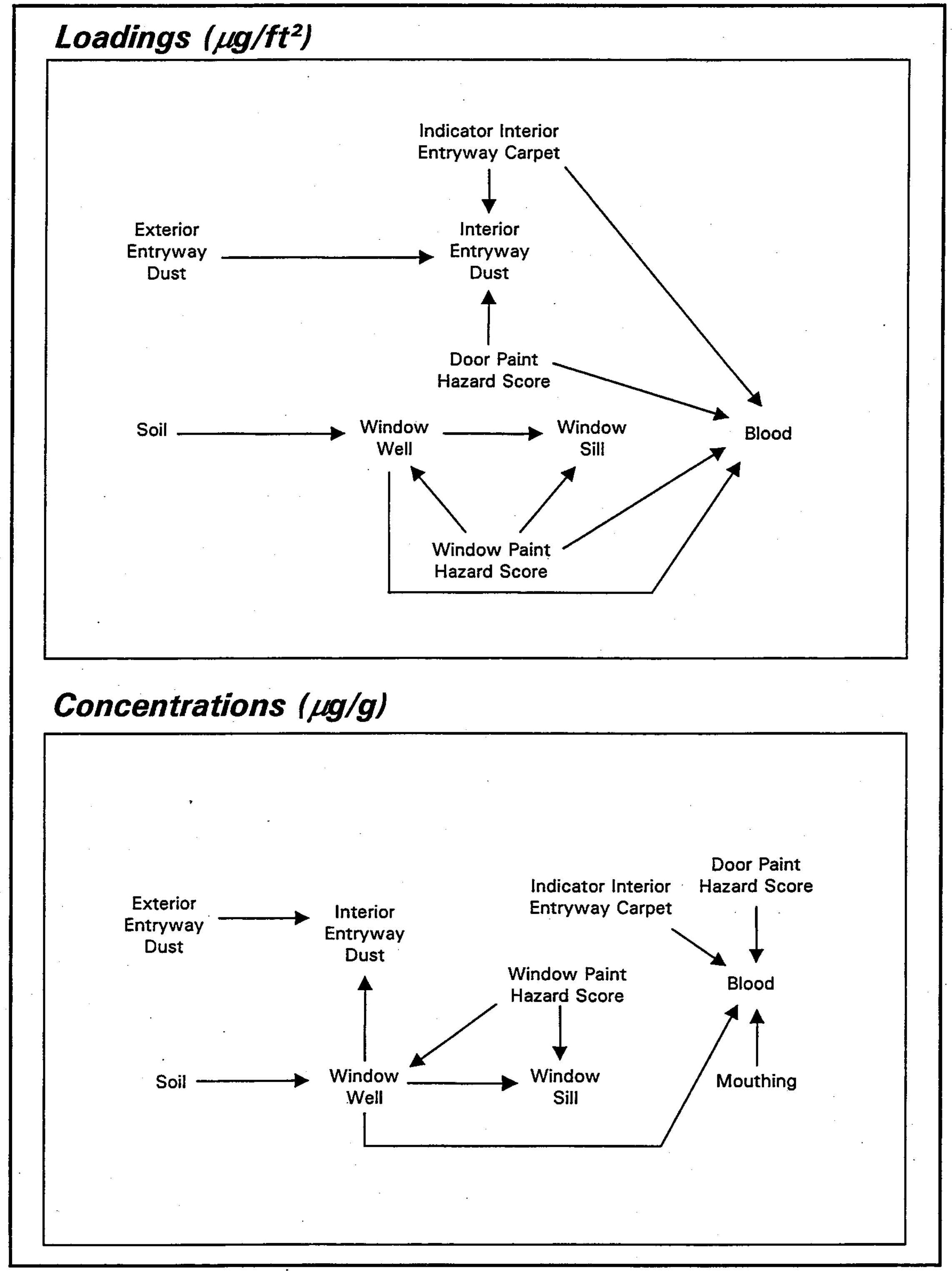


Figure 6-13. Significant Pathways for the Rochester Blood-Lead Pathway Model For Homes with Carpeted Bedrooms and Play Areas — Dust-Lead Loadings (µg/ft²) and Concentrations (µg/g).

To assess the effect of the carpeting and paint pathways, an analysis of the effect of 50% decreases in the reported geometric means of environmental variables was performed. Table C-9 in Appendix C shows that for both the loading and the concentration models, when the proportion of carpeting is reduced (i.e., more uncarpeted floors) the blood-lead concentration increased: a 27% increase for the loading model and a 40% increase for the concentration model. The similarities between the models of the effect of decreasing carpeting in the home did not hold for floor dust. Decreasing the proportion of carpeting *decreased* the floor dust-lead loading by 81% but *increased* the floor dust-lead concentration by 19%.

These results must be interpreted cautiously. They do not necessarily mean that children's blood-lead concentrations are higher in homes with uncarpeted floors. There may be socioeconomic variables which have not been included in the analysis that could be confounding the analysis results. In particular, for the R&M homes, the modern urban control homes are likely to be heavily influencing the outcome. Also, the BRM vacuum may collect dust deep in carpet piling that is not normally accessible to a child. A controlled study would likely be necessary to determine the effect of carpeting.

6.8 RESULTS OF ASSESSING RENOVATION AND REMODELING

The R&M and CAP studies collected information on the conduct of renovation or remodeling (R&R) in the home, where the R&R activities were performed six months prior to the environmental sampling. A pathway for the R&R activities was included in the environmental pathway models for CAP and R&M studies. In addition, a pathway for R&R activities was included in that R&M blood-lead pathway model which had the proportion of carpeting as a pathway. Equation set 5-13, 5-14, and 5-15 present the exact models assessed. Tables A-1 in Appendix A, and Tables B-4 and B-5 in Appendix B list the parameter estimates.

For the CAP study, renovation and remodeling was a significant pathway to both floor dust loading and concentration, whereas for R&M environmental model, R&R was not a significant pathway to floor dust. Recent R&R recent activities occurred among 25% of the homes for the CAP study, but only 10% of R&M homes had recent renovation and remodeling activities performed. This may explain the difference in results between the two studies.

The parameter estimates for the blood-lead model with R&R activity for R&M, shown in Table B-5 of Appendix B, indicate that the R&R pathway was not a significant pathway of lead exposure. Not surprisingly, the significant pathways highlighted in Table B-5 are nearly the same as those highlighted in Table B-3. There is a change in the loading model and a change in the concentration model. In the loading model, window sill dust to floor dust becomes a significant pathway when R&R activity is included in the model. In the concentration model, a significant pathway of window sill dust-lead concentration to floor dust-lead concentration replaces a pathway from window well dust-lead concentration to floor dust-lead concentration when R&R activity is included in the model.

Note that the nonsignificant R&R pathway in the R&M blood-lead pathway model is different from published results for the Brigham and Women's Hospital Longitudinal Lead Study [7] which indicated a statistically significant R&R (or "Refinishing") pathway to blood-lead concentration. Differences in the results could be due to study differences, such as the percentage of houses with recent renovation and remodeling activities (10% for the R&M data and 25% for the Brigham and Women's data) or the number of observations used in the analysis (84 for R&M and about 180 for Brigham and Women's).

6.9 RESULTS OF ASSESSING RACE

This section discusses the significant direct and indirect pathways of lead exposure in the Rochester study for two different race groups: African-American children and children from all other race groups, including Caucasian, Hispanic and Puerto Rican. The average blood-lead concentrations were 9.2 µg/dL for African-American children and 4.9 µg/dL for children of all other races, so it was conjectured there may be different pathways of lead exposure.

Equation Set 5-16 presents the pathways model analyzed for the two race groups. Figures 6-14 and 6-15 present the statistically significant pathways for the lead loading and lead concentration models, respectively. The parameter estimates for the models are provided in Tables C-10 and C-11 of Appendix C.

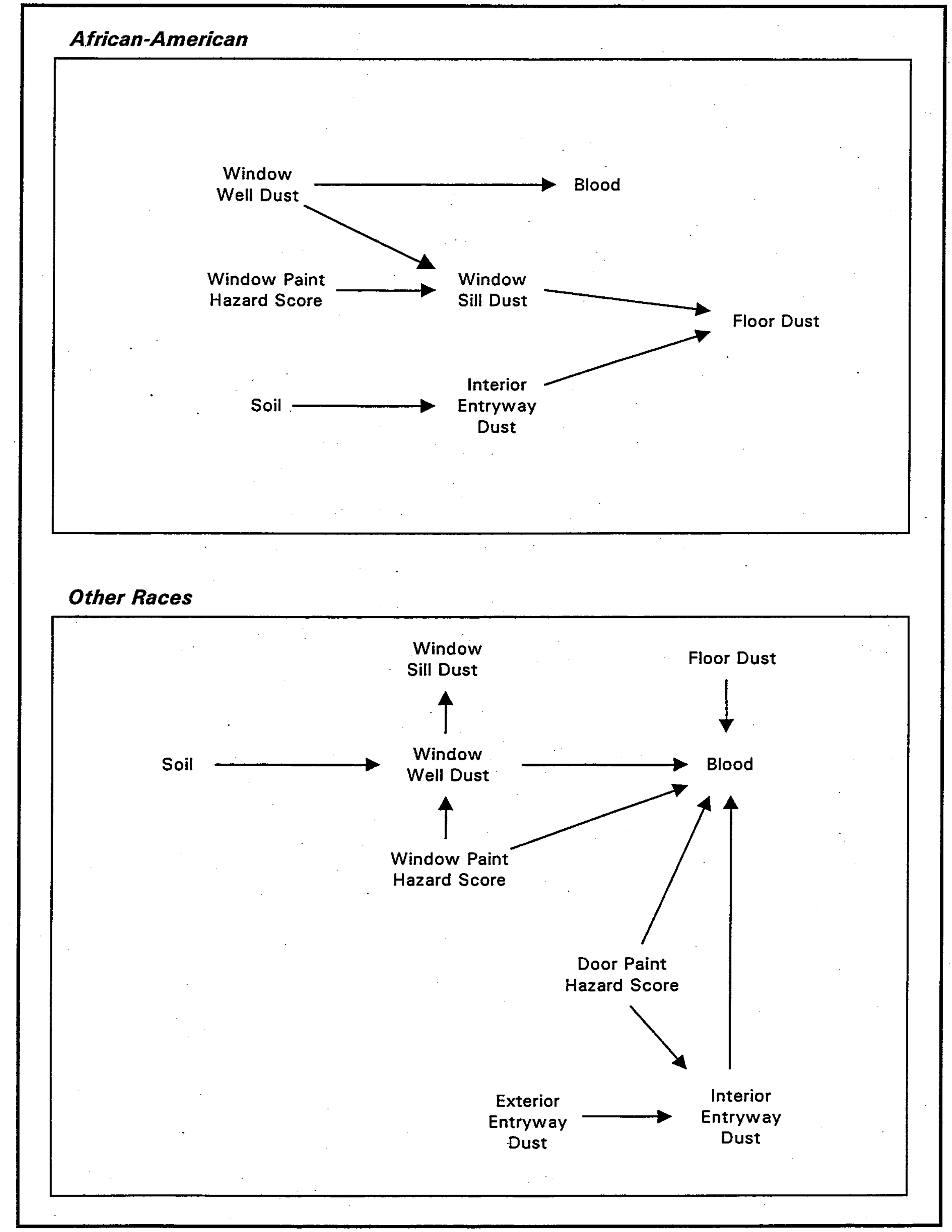


Figure 6-14. Significant Pathways for the Rochester Blood-Lead Pathway Models For African-American and Other Race Children – Dust-Lead Loadings (µg/ft²).

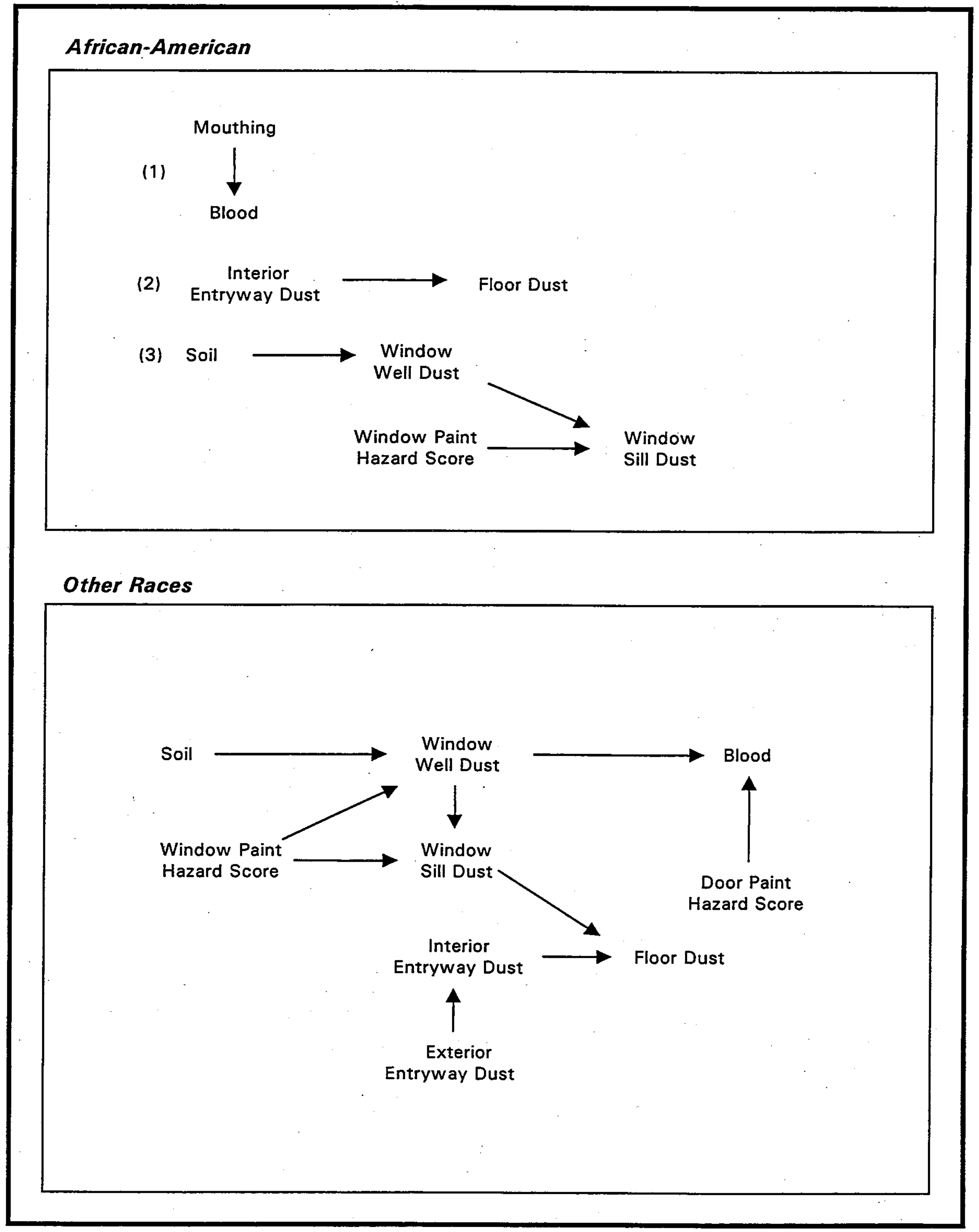


Figure 6-15. Significant Pathways for the Rochester Blood-Lead Pathway Models For African-American and Other Race Children — Dust-Lead Concentrations (μg/g).

For the loading models, the statistically significant direct pathways of lead exposure to the blood are different for the two race groups. For the African-American children, window well dust-lead loading was the only direct pathway of lead to blood, while for the other race children, the statistically significant direct pathways to blood included interior entryway dust, window well dust, floor dust, window paint hazard score, and door paint hazard score. Blood-lead was indirectly impacted by exterior entryway dust and soil for other race children. There were no statistically significant indirect pathways of lead to blood for African-American children.

In the concentration model, the mouthing behavior was the only direct pathway of lead to blood for the African-American children and there were no statistically significant indirect pathways. For the other race children, window well dust and door paint hazard score were statistically significant direct pathways to blood. Soil and window paint hazard score indirectly impacted blood via window well dust for these children.

Note that there were 86 African-American children and 119 children in the other race group. The differences observed in this analysis could be due solely to the limited sample sizes that resulted when the data was subsetted by race group.

6.10 RESULTS OF ASSESSING AIR DUCTS

The results of an analysis using air duct data are presented in Table A-2 of Appendix A and show that the air duct dust-lead pathway is not significant. A comparison of the parameter estimates presented in Tables 6-1 and A-2 show that there were minimal changes when the air duct dust-lead pathway was added to the model.

The estimated change in environmental lead levels are presented in Table A-3 of Appendix A. This table shows that the reduction of the soil-lead concentration geometric mean by 50% is estimated to produce the greatest reductions in floor dust-lead – a 21% reduction for both the loading and concentration models.

7.0 DISCUSSION

In the environmental-lead pathways analysis, three statistically significant direct pathways of lead contamination were found for all three studies: 1) window well dust-lead loading to window sill dust-lead loading, 2) window well dust-lead concentration to window sill dust-lead concentration, and 3) exterior entryway dust-lead concentration to interior entryway dust-lead concentration. There were several indirect pathways which were the same for two out of the three studies: 1) soil-lead concentration to window well dust-lead loading to window sill dust-lead loading, 2) soil-lead concentration to window well dust-lead concentration to window sill dust-lead concentration, 3) window well dust-lead loading to window sill dust-lead loading to the interior entryway dust-lead loading or the floor dust-lead loading, and 4) window well dust-lead concentration to window sill dust-lead concentration to floor dust-lead concentration. Despite the different study designs and dust vacuum collection methods, the results are quite similar across the three studies.

The blood-lead pathways models fitted to the two data sets with blood lead measurements (R&M and Rochester) had fewer consistent, statistically significant pathways across the studies. In the lead loading models *consistent* pathways included direct pathways of lead exposure from 1) floor dust-lead and 2) children's mouthing habits to the blood, and indirect pathways from 1) interior entryway dust-lead, 2) dust on window wells and 3) dust on window sills to blood. However, no consistent significant pathways to blood were found in the lead concentration models. In the R&M concentration model, significant pathways included a direct pathway from interior entryway dust-lead concentration to blood, and indirect pathways of exposure to the blood from exterior entryway dust, window well dust, and the window sill dust-lead concentration. In the Rochester concentration model, the only statistically significant direct pathway to blood was a pathway from children's mouthing behavior to blood. There were no statistically significant indirect pathways to blood in the Rochester concentration model.

In one of the sub-analyses, two paint-lead metrics were separately included in the models as interior door and window paint-lead pathways: 1) a *hazard score* defined as the product of paint condition and XRF measurement, and 2) an *average XRF measurement*. In the concentration models for the R&M and Rochester data, the hazard score and the average XRF measurement generally yielded the same statistically significant pathways, indicating little difference in the explanatory power of either metric. In the loading model for Rochester, again,

similar statistically significant pathways were observed when either metric was included in the model. In contrast, in the loading model for the R&M data, no statistically significant pathways were observed when the average XRF measurement was used, but both the door and window paint were statistically significant pathways of lead exposure to blood when the hazard scores were used.

A sub-analysis of the effect of interior entryway carpeted floors in blood-lead concentrations was performed using the Rochester study data. An indicator variable representing whether the interior entryway was carpeted or not was included in the analysis. The analysis showed that the presence of interior entryway carpeting in a home was associated with lower blood-lead concentrations. Although the result should be interpreted with caution, this result may indicate the usefulness of interior entryway mats in the home for reducing the soil and dust tracked into the home. A study by Roberts et al., discussed in an EPA literature review which identified 59 articles on dust and lead exposures associated with residential carpet, indicated that a walk-off mat present at the entry resulted in a 6.4-fold reduction in dust-lead loadings in carpets [21].

In the Rochester data, floor dust-lead loadings were on average higher on carpeted surfaces than on uncarpeted surfaces and the floor dust-lead concentrations were lower on the carpeted surfaces than on the uncarpeted surfaces. In the EPA literature review report, it was found that carpets can have high dust-lead loadings relative to other surfaces but only moderate dust-lead concentrations. One study reported geometric mean dust-lead loadings from carpet to be approximately 18 times higher than loadings from uncarpeted floors and reported lower dust-lead concentrations on carpets relative to other surfaces [21].

For both the R&M and Rochester studies, a variable representing the proportion of sampled floors that were carpeted was a significant pathway to blood; as the proportion of carpeted floors increased the blood-lead concentration decreased. In the Rochester analysis discussed above, an indicator of interior entryway carpet was found to be a significant direct pathway to blood. In an effort to further address the carpeted versus uncarpeted floors issue, an analysis was performed on Rochester homes where both the bedroom and play area floors were carpeted. The analysis showed that the floor dust-lead loading was no longer a significant pathway of lead exposure to blood. These results should be interpreted cautiously. There may be socioeconomic variables which have not been included in the analysis that could be confounding the analysis results. In particular, for the R&M houses it seems likely that the modern urban control homes are strongly influencing the outcome. Also, the BRM vacuum may be collecting dust from carpets that is not normally accessible to a child. It is likely a controlled study would be necessary to estimate the effect of carpets.

As discussed earlier, there have been several studies in which pathways of lead exposure to blood have been examined. Six sets of pathways, as reported in the literature, are diagramed in Appendix D and the variables used in the analysis are described in the tables in Appendix D.

There were three sets of analyses performed by Bornschein, et al., using environmental lead, demographic, and blood lead information for 18-month old children in the Cincinnati Lead Study (2 sets of analyses) and 6 to 72-month old children in the Telluride, Colorado smelter study. Menton, et al., assessed pathway models for 24-month old children in Boston. Using stepwise multiple regression techniques, Sayre assessed the blood lead, environmental lead, and demographic information for 18 to 71-month old children living in central Rochester, New York. An SEM analysis was performed by Lanphear et al. using data from the 1991-1992 Rochester study.

In all five of the analyses which included hand dust-lead in the analysis, hand dust-lead was found to be a statistically significant direct pathway of lead exposure to the blood, and interior dust was an indirect pathway to blood via hand dust. Similarly, the sub-analysis of the Rochester hand dust-lead performed for this report indicated significant pathways of hand lead to the blood-lead concentration and interior dust to hand lead. No other sub-analyses could be run for hand dust-lead since hand dust-lead was not available for assessment in the R&M study.

Both the Sayre and Lanphear analyses found pica habits to be statistically significant direct pathways of lead exposure to blood. This is similar to results seen for mouthing behavior in the blood-lead pathway models analysis for the R&M and Rochester study data. These similarities are observed even though the definition of pica was slightly different across the analyses. Lanphear defined his pica variable as putting soil or dirt in the mouth, and Sayre used finger sucking, mouthing of toys, coins, pencils, or articles of clothing as his pica variable. Pica was defined in R&M and Rochester for this report by an indicator of how often a child puts a thumb, paint chips, or dirt into his/her mouth or mouths a window sill.

In Bornschein (see Figure D-1), the paint hazard score was a direct pathway to floor dust and an indirect pathway to blood-lead through floor dust and hand-lead. However, when

maximum XRF measurements were used in another Bornschein pathways model (see Figure D-2), an indirect pathway from exterior XRF to floor dust or blood-lead through soil was observed. In the Lanphear pathways analysis, paint lead, the average of XRF measurements, contributed to blood-lead levels indirectly through dust-lead and hand-lead. Significant pathways in the Rochester analyses in this report were generally the same whether hazard score or average XRF was included. But in the R&M analyses, both the window and door paint hazard scores were statistically significant pathways of lead to floor dust loading. However, when the average XRF measurements was used in the R&M loading model, there were no statistically significant pathways. The small sample size available for the R&M data may explain the differences observed in the R&M results.

In the Rochester data, the average blood-lead concentrations for African-American children were 9.2 µg/dL and 4.9 µg/dL for children of all other races (Caucasian, Hispanic, and Puerto Rican). Because of these differences in blood-lead concentrations, it was thought that there may be different pathways of lead exposure for each race group. One pathway model was assessed separately for the African-American children and for the children of all other races. This assessment showed one common direct pathway of lead exposure to blood-lead concentration and several different statistically significant pathways for each race. For African-American children, the loading model had just one direct pathway to blood, window well dust loading. The concentration model had only mouthing as a direct pathway to blood. There were no indirect pathways to blood for the African-American children. For the analysis of all other race groups, the loading model included the following direct pathways to blood: floor dust loading, window well dust loading, window paint hazard score, door paint hazard score, and interior entryway dust loading. In the concentration model, window well concentration and door paint hazard score were the only direct pathways to blood. There were a number of indirect pathways to blood in both the loading and concentration models for the other race group.

Lanphear, et al. [6, 19] also assessed the relationship of race group to blood-lead concentrations. Two types of analysis were performed to address this issue: SEM [19] and multivariate regression [6]. Lanphear's SEM model did not split the data into two distinct data sets as was done for the Rochester analysis performed here, but assessed the data for African-American children and Caucasian children together by including an indicator variable for race in the model. In the multivariate regression analysis Lanphear split the data into separate data sets:

African-American children and Caucasian children. In the multivariate regression analysis, Lanphear found that for African-American children, lead interior to the homes--dust-lead loadings, condition and lead content of the painted surfaces, and water lead concentrations--were the most significant predictors of blood-lead concentration. For Caucasian children, lead exterior to the home--soil lead concentration, mouthing of dirt or soil, and the amount of time spent outdoors-- were significant predictors of blood-lead concentration. In the SEM analysis, Lanphear showed that African-American race was a significant direct pathway to blood-lead concentration.

A comparison between Lanphear's multivariate results and SEM analysis performed here indicates that the exposure from lead interior to the home for African-American children and exposure from lead exterior to the home for Caucasian children found in Lanphear's multivariate regression analysis [6] work did not hold in the SEM analysis performed in this report. Methodological differences between Lanphear's multivariate regression analysis and the SEM analysis in this report are the likely explanation for the differences in results. Besides the difference between multivariate regression analysis and structural equations modeling, there are the following differences: 1) Lanphear's analysis relies on wipe samples while the analysis in this report used vacuum samples, and 2) the sample size in Lanphear's analysis was 86 African-American children and 86 White children whereas the sample size for the analysis in this report was 86 African-American children and 119 children from all other race groups. Finally, the differences in pathways between the African-American children and the children of all other race groups that were observed in the SEM analysis in this report could be due to the smaller sample sizes that resulted from subsetting by race group.

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APPENDIX A

Results from the Pathways Analyses of the CAP Study Data

Table A-1. Structural Equation Modeling Results for the CAP Study Environmental Pathways, Including an R&R Exposure Pathway — Dust-Lead Loadings ($\mu g/ft^2$) and Dust-Lead Concentrations ($\mu g/g$).

Variables: Dependent \ Independent	Direct Effect Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Soil	R&R Exposure	R^2
Dust-Lead Loadings ($\mu g/ft^2$)							
Floor	**0.2911*** **(1.98)**	0.1296 (0.95)	0.0099 (0.07)	0.1062 (0.68)	-0.0194 (-0.06)	**1.9042*** **(2.13)**	0.24
Interior Entryway Dust		0.2323 (1.77)	-0.0086 (-0.06)	0.2140 (1.42)	0.3475 (1.05)	0.0344 (0.07)	0.18
Window Sill			**0.5450*** **(4.08)**		0.4154 (1.17)	0.2918 (0.52)	0.14
Window Well					**0.8831*** **(2.41)**	-0.9733 (-1.63)	0.34
Dust-Lead Concentrations ($\mu g/g$)							
Floor	0.0923 (0.47)	-0.2099 (-1.78)	**0.3395*** **(2.88)**	-0.1164 (-0.70)	0.1224 (0.54)	**0.8651*** **(2.42)**	0.26
Interior Entryway Dust		-0.0174 (-0.20)	0.0653 (0.74)	**0.3994*** **(3.62)**	0.1504 (0.89)		0.39
Window Sill			**0.5498*** **(4.55)**		0.0584 (0.22)	0.1688 (0.41)	0.19
Window Well					**0.9074*** **(3.05)**	-0.7523 (-1.55)	0.36

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T- values ≥ 1.96 and ≤ -1.96 are significant at the 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations and soil-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9869, and 0.9772 for the dust-lead concentration model.

Table A-2. Structural Equation Modeling Results for the CAP Study Environmental Pathways, Including an Air Duct Pathway — Dust-Lead Loadings ($\mu g/ft^2$) and Dust-Lead Concentrations ($\mu g/g$).

Variables: Dependent \ Independent	Direct Effect Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Air Duct	Soil	R^2
Dust-Lead Loadings ($\mu g/ft^2$)							
Floor	0.2968 (1.93)	1.428 (1.0)	-0.0617 (-0.43)	0.1109 (0.67)	0.0330 (0.29)	0.0985 0.28	0.17
Interior Entryway Dust		0.2424 (1.86)	-0.0097 (-0.07)	0.2294 (1.49)	-0.0449 (-0.42)	0.3491 (1.07)	0.19
Window Sill			**0.5291*** **(4.06)**			0.4513 (1.29)	0.33
Window Well						**0.8059*** **(2.15)**	0.09
Dust-Lead Concentrations ($\mu g/g$)							
Floor	0.2128 (1.070)	-0.1934 (-1.56)	**0.2627*** **(2.17)**	-0.0806 (-0.46)	0.0980 (0.54)	0.1726 (0.72)	0.17
Interior Entryway Dust		-0.0167 (-0.18)	0.0176 (0.20)	**0.4531*** **(4.09)**	0.1352 (1.02)	0.1964 (1.14)	0.35
Window Sill			**0.5389*** **(4.56)**			0.0810 (0.31)	0.35
Window Well						**0.8479*** **(2.81)**	0.14

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-values ≥ 1.96 and ≤ -1.96 are significant at the 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations and soil-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9538, and 0.9918 for the dust-lead concentration model.

Table A-3. Predicted Effect of a 50% Decrease in Environmental-Lead Levels Based on the CAP Study Environmental-Lead Structural Equation Model, Including the Air Duct Pathway - Dust-Lead Loading (μg/ft²) and Concentrations (μg/g).

Sample Location	Geometric Mean	50% Decrease in GM	Predicted Percent Change (%) (Lower Prediction Interval, Upper Prediction Interval) [b]			
			Floor	Interior Entryway	Window Sill	Window Well
Dust-Lead Loading (μg/ft²)						
Interior Entryway	342	171	-19 (-41 , 12)	*NA*	*NA*	*NA*
Window Sill	108	54	-14 (-36 , 16)	-15 (-34 , 10)	*NA*	*NA*
Window Well	3,229	1,615	-3 (-28 , 31)	-8 (-21 , 20)	-31 (-48 , -8)	*NA*
Air Duct	156	78	-1 (-22 , 26)	-3 (-22 , 20)	*NA*	*NA*
Soil[a]	157	79	-21 (-62 , 64)	-32 (-64 , 30)	-46 (-75 , 17)	-43 (-77, 44)
Exterior Entryway	572	287	-12 (-38 , 25)	-15 (-37, 15)	*NA*	*NA*
Dust-Lead Concentration (μg/g)						
Interior Entryway	201	101	-14 (-34 , 13)	*NA*	*NA*	*NA*
Window Sill	778	389	15 (-3 , 36)	1 (-8 , 11)	*NA*	*NA*
Window Well	1,577	789	-11 (-24 , 5)	-17 (-24 , -9)	-3 (-20 , 17)	*NA*
Air Duct	485	243	-8 (-28 , 18)	-9 (-20 , 4)	*NA*	*NA*
Soil[a]	57	79	-21 (-43 , 9)	-13 (-27 , 3)	-31 (-55 , 5)	-44 (-69 , 1)
Exterior Entryway	261	130	-1 (-22 , 26)	-27 (-35 , -18)	*NA*	*NA*

(a) Average soil-lead concentration in μg/g.
(b) A prediction interval or forecasting interval is a confidence interval for the actual or future value of a response, which is the mean value plus error. Here the upper and lower 95% prediction intervals are based on the direct effects only.
NA Indicates that the fitted pathway model did not include a pathway from the sample.

Table A-4a. Correlations for Log-Transformed Dust-Lead Loadings (μg/ft²) and Soil-Lead Concentrations (μg/g) Used in the CAP Study Pathways Analysis.

	Floor Dust	Air Duct Dust	Interior Entryway Dust	Window Well Dust	Window Sill Dust	Exterior Entryway Dust	Exterior Entryway Soil	Foundation Soil	Boundary Soil	Mass Weighted Average Soil
Floor Dust	1.00000 0.0 52	0 .15743 0 .2650 52	0 .35648 0 .0095 52	0.10123 0.4889 49	0.21898 0.1188 52	0.18105 0.2036 51	0 .20107 0 .1529 52	0.06759 0.6340 52	0.23057 0.1001 52	0.18763 0.1829 52
Air Duct Dust	0.15743 0.2650 52	1.00000 0.0 52	0.05862 0.6798 52	0.13728 0.3469 49	0.11246 0.4273 52	0.24169 0.0875 51	0.14830 0.2941 52	0.05701 0.6881 52	0.20016 0.1548 52	0.17672 0.2101 52
Interior Entryway Dust	0.35648 0.0095 52	0.05862 0.6798 52	1.00000 0.0 52	0.19758 0.1736 49	0.32992 0.0169 52	0.22004 0.1208 51	0.28452 0.0409 52	0.13223 0.3501 52	0.18554 0.1879 52	0.25688 0.0660 52
Window Well Dust	0.10123 0.4889 49	0.13728 0.3469 49	0.19758 0.1736 49	1.00000 0.0 49	0.55256 0.0001 49	0.02957 0.8419 48	0.28873 0.0442 49	0.15568 0.2854 49	0.25439 0.0777 49	0.29788 0.0376 49
Window Sill Dust	0.21898 0.1188 52	0.11246 0.4273 52	0.32992 0.0169 52	0.55256 0.0001 49	1.00000 0.0 52	0.00309 0.9829 51	0.22846 0.1033 52	0.12126 0.3918 52	0.29352 0.0347 52	0.24304 0.0825 52
Exterior Entryway Dust	0.18105 0.2036 51	0.24169 0.0875 51	0.22004 0.1208 51	0.02957 0.8419 48	0.00309 0.9829 51	1.00000 0.0 51	0.19018 0.1813 51	0.18760 0.1874 51	-0.02470 0.8634 51	0.20299 0.1531 51
Exterior Entryway Soil	0.20107 0.1529 52	0.14830 0.2941 52	0.28452 0.0409 52	0.28873 0.0442 49	0.22846 0.1033 52	0.19018 0.1813 51	1.00000 0.0 52	0.52970 0.0001 52	0.64037 0.0001 52	0.85763 0.0001 52
Foundation Soil	0.06759 0.6340 52	0.05701 0.6881 52	0.13223 0.3501 52	0.15568 0.2854 49	0.12126 0.3918 52	0.18760 0.1874 51	0.52970 0.0001 52	1.00000 0.0 52	0.55853 0.0001 52	0.80579 0.0001 52
Boundary Soil	0.23057 0.1001 52	0.20016 0.1548 52	0.18554 0.1879 52	0.25439 0.0777 49	0.29352 0.0347 52	-0.02470 0.8634 51	0.64037 0.0001 52	0.55853 0.0001 52	1.00000 0.0 52	0.79196 0.0001 52
Mass Weighted Average Soil	0.18763 0.1829 52	0.17672 0.2101 52	0.25688 0.0660 52	0.29788 0.0376 49	0.24304 0.0825 52	0.20299 0.1531 51	0.85763 0.0001 52	0.80579 0.0001 52	0.79196 0.0001 52	1.00000 0.0 52

Notes: 1. Correlations were calculated for the natural logarithm transformed dust-lead loadings and soil-lead concentrations.
2. First number is the Pearson correlation coefficient, the second number is the p-value, and the third number is the number of observations.

Table A-4b. Correlations for Log-Transformed Dust-Lead Concentrations (μg/g) and Soil-Lead Concentrations (μg/g) Used in the CAP Study Pathways Analysis

	Floor Dust	Air Duct Dust	Interior Entryway Dust	Window Well Dust	Window Sill Dust	Exterior Entryway Dust	Exterior Entryway Soil	Foundation Soil	Boundary Soil	Mass Weighted Average Soil
Floor Dust	1.00000 0.0 52	0.14612 0.3013 52	0.22249 0.1129 52	0.28349 0.0484 49	0.01190 0.9333 52	0.09858 0.4913 51	0.19160 0.1736 52	0.13421 0.3428 52	0.33594 0.0149 52	0.21932 0.1182 52
Air Duct Dust	0.14612 0.3013 52	1.00000 0.0 52	0.19240 0.1718 52	0.17034 0.2419 49	0.20521 0.1445 52	0.05998 0.6759 51	0.18726 0.1837 52	-0.01820 0.8981 52	0.18599 0.1868 52	0.12774 0.3668 52
Interior Entryway Dust	0.22249 0.1129 52	0.19240 0.1718 52	1.00000 0.0 52	0.14587 0.3173 49	0.00561 0.9685 52	0.55763 0.0001 51	0.37130 0.0067 52	0.17489 0.2150 52	0.23164 0.0985 52	0.33668 0.0147 52
Window Well Dust	0.28349 0.0484 49	0.17034 0.2419 49	0.14587 0.3173 49	1.00000 0.0 49	0.59493 0.0001 49	0.11442 0.4387 48	0.39132 0.0054 49	0.14883 0.3074 49	0.30910 0.0307 49	0.36555 0.0098 49
Window Sill Dust	0.01190 0.9333 52	0.20521 0.1445 52	0.00561 0.9685 52	0.59493 0.0001 49	1.00000 0.0 52	-0.04710 0.7428 51	0.24320 0.0823 52	0.08412 0.5532 52	0.23619 0.0918 52	0.21682 0.1226 52
Exterior Entryway Dust	0.09858 0.4913 51	0.05998 0.6759 51	0.55763 0.0001 51	0.11442 0.4387 48	-0.04710 0.7428 51	1.00000 0.0 51	0.31996 0.0221 51	0.18571 0.1920 51	0.03995 0.7807 51	0.31660 0.0236 51
Exterior Entryway Soil	0.19160 0.1736 52	0.18726 0.1837 52	0.37130 0.0067 52	0.39132 0.0054 49	0.24320 0.0823 52	0.31996 0.0221 51	1.00000 0.0 52	0.52970 0.0001 52	0.64037 0.0001 52	0.85763 0.0001 52
Foundation Soil	0.13421 0.3428 52	-0.01820 0.8981 52	0.17489 0.2150 52	0.14883 0.3074 49	0.08412 0.5532 52	0.18571 0.1920 51	0.52970 0.0001 52	1.00000 0.0 52	0.55853 0.0001 52	0.80579 0.0001 52
Boundary Soil	0.33594 0.0149 52	0.18599 0.1868 52	0.23164 0.0985 52	0.30910 0.0307 49	0.23619 0.0918 52	0.03995 0.7807 51	0.64037 0.0001 52	0.55853 0.0001 52	1.00000 0.0 52	0.79196 0.0001 52
Mass Weighted Average Soil	0.21932 0.1182 52	0.12774 0.3668 52	0.33668 0.0147 52	0.36555 0.0098 49	0.21682 0.1226 52	0.31660 0.0236 51	0.85763 0.0001 52	0.80579 0.0001 52	0.79196 0.0001 52	1.00000 0.0 52

Notes: 1. Correlations were calculated for the natural logarithm transformed dust-lead concentrations and soil-lead concentrations.
2. First number is the Pearson correlation coefficient, the second number is the p-value, and the third number is the number of observations.

Table A-5. Principal Components Analysis of the Entryway, Foundation, and Boundary Soil-Lead Concentrations (μg/g) from the CAP Study.

Simple Statistics

	WCBDY	WCFDN	WCEWY
Mean	4.881270657	5.278522566	5.053991088
StD	0.664755800	0.923506587	0.806544484

Correlation Matrix

	WCBDY	WCFDN	WCEWY
WCBDY	1.0000	0.5585	0.6404
WCFDN	0.5585	1.0000	0.5297
WCEWY	0.6404	0.5297	1.0000

Eigenvalues of the Correlation Matrix

	Eigenvalue	Difference	Proportion	Cumulative
PRIN1	2.15371	1.66475	0.717903	0.71790
PRIN2	0.48896	0.13162	0.162986	0.88089
PRIN3	0.35733	.	0.119111	1.00000

Eigenvectors

	PRIN1	PRIN2	PRIN3
WCBDY	0.592676	-.297676	-.748415
WCFDN	0.554944	0.824371	0.111578
WCEWY	0.583757	-.481457	0.653778

WCBDY = Mass-weighted boundary soil concentration
WCFDN = Mass-weighted foundation soil concentration
WCEWY = Mass-weighted exterior entryway soil concentration

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APPENDIX B

Results from the Pathways Analyses of the R&M Data

Table B-1. Structural Equation Modeling Results for the R&M Environmental Pathways, Including the Window Paint and Door Paint Hazard Score Pathways — Dust-Lead Loadings (μg/ft²) and Concentrations (μg/g).

Variables: Dependent \ Independent	Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Window Paint Hazard Score	Door Paint Hazard Score	R^2
Dust-Lead Loadings (μg/ft²)							
Floor	0.0121 (0.11)	0.0458 (0.33)	0.2983 (1.73)	-0.0497 (-0.58)	**0.0960* (2.59)**	**-0.1652 * (-2.67)**	0.31
Interior Entryway		0.1796 (0.83)	0.0940 (0.35)	0.0582 (0.44)	0.0065 (0.11)	-0.0364 (-0.38)	0.03
Window Sill			-0.0216 (-0.10)		0.0144 (0.32)		0.003
Window Well					0.0013 (0.04)		0.00004
Dust-Lead Concentrations (μg/g)3							
Floor	0.0200 (0.15)	**0.3463* (2.25)**	0.2774 (1.54)	-0.1292 (-0.90)	0.0525 (1.67)	-0.0894 (-1.87)	0.28
Interior Entryway		-0.2012 (-1.03)	-0.1843 (-0.80)	**0.6414* (4.33)**	**-0.0793* (-2.08)**	-0.0439 (-0.72)	0.40
Window Sill			-0.1940 (-0.97)		0.0142 (0.45)		0.03
Window Well					0.0199 (0.73)		0.02

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥ 1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9768, and 0.9053 for the dust-lead concentration model.

Table B-2. Structural Equation Modeling Results for the R&M Environmental Pathways, Including the Average Window Paint and Door Paint XRF Measurement Pathways — Dust-Lead Loadings (μg/ft²) and Concentrations (μg/g).

Variables: Dependent \ Independent	Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Window Paint XRF Measurement	Door Paint XRF Measurement	R^2
Dust-Lead Loadings (μg/ft²)							
Floor	0.0453 (0.37)	-0.0045 (-0.03)	0.2657 (1.41)	-0.0395 (-0.43)	0.0631 (1.70)	0.0019 (0.04)	0.16
Interior Entryway		0.1589 (0.75)	0.1280 (0.48)	0.0603 (0.46)	0.0286 (0.55)	-0.0815 (-1.29)	0.08
Window Sill			-0.0203 (-0.09)		0.0034 (0.10)		0.001
Window Well					-0.0066 (-0.24)		0.002
Dust-Lead Concentrations (μg/g)							
Floor	0.0350 (0.23)	**0.4161* (2.49)**	0.2627 (1.37)	-0.1401 (-0.89)	0.0259 (0.91)	0.0001 (0.004)	0.22
Interior Entryway		-0.2907 (-1.63)	-0.2363 (-1.14)	**0.6516* (4.87)**	-0.0233 (-0.75)	**-0.0927* (-2.50)**	0.53
Window Sill			-0.1830 (-0.93)		0.0112 (0.47)		0.03
Window Well					0.0002 (0.01)		0.000002

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥ 1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9810, and 0.9097 for the dust-lead concentration model.

Table B-3. Structural Equation Modeling Results for the R&M Blood-Lead Pathways, Including a Proportion of Carpeting Pathway — Dust-Lead Loadings (μg/ft²) and Dust-Lead Concentrations (μg/g).

Variables	Direct Effects Parameter Estimates (t value)								
Dependent \ Independent	Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Proportion Carpet	Floor Dust	Water	Mouthing	R^2
Dust-Lead Loadings (μg/ft²)[4]									
Blood	0.0472 (1.36)	0.0333 (-0.81)	0.0212 (0.52)	0.0439 (1.43)	**-1.0059*** **(-3.84)**	**0.1048*** **(2.18)**	-0.0489 (-0.45)	**0.3152*** **(1.97)**	0.44
Floor	**0.2075*** **(2.73)**	0.1400 (1.51)	0.1504 (1.63)	0.0367 (0.53)	-0.2813 (-0.47)				0.46
Interior Entryway		**0.3943*** **(3.13)**	-0.1432 (-1.17)	**0.2210*** **(2.30)**					0.25
Window Sill			**0.7958*** **(13.86)**						0.70
Dust-Lead Concentrations (μg/g)[4]									
Blood	**0.1292*** **(2.04)**	0.0300 (0.56)	-0.0591 (-0.94)	0.0183 (0.32)	**-0.8432*** **(-3.21)**	0.1005 (1.58)	-0.1053 (-0.97)	0.2930 (1.89)	0.43
Floor	-0.5533 (-1.24)	0.1793 (1.67)	**0.2890*** **(3.32)**	0.1455 (1.36)	-0.0154 (-0.16)				0.59
Interior Entryway		**0.1870*** **(2.16)**	-0.0415 (-0.40)	**0.5486*** **(6.95)**					0.57
Window Sill			**0.9059*** **(13.37)**						0.68

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥ 1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9524, and 0.9106 for the dust-lead concentration model.

Table B-4. Structural Equation Modeling Results for the R&M Environmental Pathways, Including the R&R Exposure Pathways — Dust-Lead Loadings (μg/ft²) and Concentrations (μg/g).

Variables	Direct Effects Parameter Estimates (t-value)					
Dependent \ Independent	Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	R&R Exposure	R^2
Dust-Lead Loadings (μg/ft²)[3]						
Floor	**0.2222*** **(2.96)**	**0.1853*** **(2.05)**	0.1063 (1.25)	0.0282 (0.42)	0.8665 (1.82)	0.48
Interior Entryway		**0.3753*** **(2.99)**	-0.1158 (-0.93)	**0.2222*** **(2.32)**	-0.5179 (-0.75)	0.25
Window Sill			**0.7958*** **(13.86)**			0.70
Dust-Lead Concentrations (μg/g)[3]						
Floor	**0.2186*** **(2.0288)**	**0.3221*** **(3.71)**	0.1258 (1.20)	-0.0128 (-0.13)	0.4953 (1.30)	0.60
Interior Entryway		**0.1739*** **(2.02)**	-0.0035 (-0.03)	**0.5302*** **(6.45)**	-0.3877 (-1.00)	0.58
Window Sill			**0.9059*** **(13.39)**			0.68

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥ 1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. Goodness-of-fit index (GFI) for dust-lead loadings is 0.9538 and GFI for dust-lead concentration is 0.9120

Table B-5. Structural Equation Modeling Results for the R&M Blood-Lead Pathways, Including a Proportion of Carpeting and Renovation and Remodeling Pathway — Dust-Lead Loadings ($\mu g/ft^2$) and Dust-Lead Concentrations ($\mu g/g$).

Variables (Independent / Dependent)	Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Proportion Carpet	Floor Dust	Water	Mouthing	R&R Exposure	R^2
	Direct Effects Parameter Estimates (t-value)									
Dust-Lead Loadings ($\mu g/ft^2$)										
Blood	0.0467 (1.33)	-0.0343 (-0.84)	0.0223 (0.54)	0.0439 (1.43)	**-1.0084* (-3.85)**	**0.1058* (2.17)**	-0.0507 (-0.46)	**0.3162* (1.97)**	-0.0250 (-0.11)	0.44
Floor	**0.2194* (2.93)**	**0.1802* (2.00)**	0.1001 (1.09)	0.0310 (0.46)	-0.1828 (-0.31)				0.8529 (1.80)	0.48
Interior Entryway		**0.3753* (2.99)**	-0.1158 (-0.93)	**0.2222* (2.32)**					-0.5179 (-0.75)	0.25
Window Sill			**0.7958* (13.85)**							0.70
Dust-Lead Concentrations ($\mu g/g$)										
Blood	**0.1417* (2.24)**	0.0409 (0.76)	-0.0810 (-1.28)	0.0250 (0.44)	**-0.8123* (-3.12)**	0.0901 (1.42)	-0.0879 (-0.82)	0.2847 (1.86)	0.2744 (1.23)	0.44
Floor	0.1955 (1.83)	**0.3037* (3.53)**	0.1046 (0.96)	-0.0027 (-0.03)	-0.4973 (-1.12)				0.4529 (1.21)	0.60
Interior Entryway		**0.1739* (2.02)**	-0.0035 (-0.03)	**0.5302* (6.50)**					-0.3877 (-1.02)	0.58
Window Sill			**0.9059* (13.40)**							0.68

Notes:
1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥ 1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9512, and 0.9155 for the dust-lead concentration model.

Table B-6. Predicted Effect of 50% Decrease in Environmental-Lead Loadings ($\mu g/ft^2$) and Concentrations ($\mu g/g$) and Blood-Lead Concentrations ($\mu g/dL$) Based on the Blood-Lead Pathways SEM for the R&M Data, Including Proportion of Carpet.

Sample Location	Geometric Mean	50% Decrease in GM	Predicted Percent Change (%) (Lower Prediction Interval, Upper Prediction)[b]			
			Blood	Floor	Interior Entryway	Window Sill
Dust-Lead Loadings ($\mu g/ft^2$)						
Floor	210	105	-7 (-10, -4)	*NA*	*NA*	*NA*
Interior Entryway	319	165	-5 (-8, -2)	-14 (-25, -2)	*NA*	*NA*
Window Sill	1,229	615	1 (-2, 4)	-12 (-25, 3)	0 (-27, 37)	*NA*
Window Well	37,035	18,518	-1 (-4, 2)	-14 (-27, 1)	8 (-20, 47)	-42 (-49, -34)
Exterior Entry	405	203	-4 (-6, -2)	-5 (-16, 7)	-14 (-32, 9)	*NA*
Proportion Carpet	0.29	0.15	104 (67, 148)	149 (59, 219)	NA	*NA*
	Exposure	No Exposure				
Water[a]	1	0	5 (-3, 14)	*NA*	*NA*	*NA*
Mouthing[a]	1	0	-27 (-35, -18)	*NA*	*NA*	*NA*
Dust-Lead Concentrations ($\mu g/g$)						
Floor	1,118	559	-6 (-10, -1)	*NA*	*NA*	*NA*
Interior Entryway	1,459	730	-10 (-14, -6)	-13 (-24, 0)	*NA*	*NA*
Window Sill	5,411	2,706	-5 (-9, -1)	-19 (-28, -9)	0 (-11, 12)	*NA*
Window Well	8,452	4,226	1 (-4, 6)	-23 (-33, -12)	0 (-13, 15)	-47 (-53, -41)
Exterior Entry	1,570	785	-7 (-11, -3)	-7 (-18, 5)	-31 (-38, -23)	*NA*
Proportion Carpet	0.29	0.15	81 (49, 120)	41 (-21, 150)	NA	*NA*
	Exposure	No Exposure				
Water[a]	1	0	9 (1, 18)	*NA*	*NA*	*NA*
Mouthing[a]	1	0	-25 (-33, 16)	*NA*	*NA*	*NA*

[a] Variables were treated as categorical.
[b] A prediction interval or forecasting interval is a confidence interval for the actual or future value of a response, which is the mean value plus error. Here the upper and lower 95% prediction intervals are based on the direct effects only.
NA Indicates that the fitted pathway model did not include a pathway from the sample location.

Table B-7a. R&M Data Correlation of Log-Transformed Blood-Lead Concentrations (µg/dL), Dust-Lead Loadings (µg/ft²), and Water-Lead Concentrations (µg/L).

	Blood	Floor Dust	Interior Entryway Dust	Window Well Dust	Window Sill Dust	Exterior Entryway Dust	Water	Door Paint Hazard Score	Door Paint XRF	Window Paint Hazard	Window Paint XRF
Blood	1.00000 0.0 87	0.49977 0.0001 87	0.40889 0.0001 87	0.41655 0.0001 86	0.43834 0.0001 87	0.33690 0.0016 85	-0.05243 0.6296 87	-0.17675 0.3024 36	-0.14461 0.4001 36	-0.11413 0.5075 36	-0.30488 0.0706 36
Floor Dust	0.49977 0.0001 87	1.00000 0.0 87	0.48834 0.0001 87	0.57258 0.0001 86	0.62981 0.0001 87	0.36254 0.0007 85	-0.06280 0.5633 87	-0.30151 0.0739 36	0.20076 0.2404 36	0.28776 0.0888 36	0.29448 0.0813 36
Interior Entryway Dust	0.40889 0.0001 87	0.48834 0.0001 87	1.00000 0.0 87	0.31023 0.0036 86	0.46245 0.0001 87	0.39209 0.0002 85	0.04191 0.6999 87	-0.04979 0.7731 36	-0.20211 0.2372 36	-0.01012 0.9533 36	-0.06624 0.7011 36
Window Well Dust	0.41655 0.0001 86	0.57258 0.0001 86	0.31023 0.0036 86	1.00000 0.0 86	0.83763 0.0001 86	0.37982 0.0004 84	0.07790 0.4759 86	0.10948 0.5313 35	0.08804 0.6150 35	0.00600 0.9727 35	-0.04169 0.8120 35
Window Sill Dust	0.43834 0.0001 87	0.62981 0.0001 87	0.46245 0.0001 87	0.83763 0.0001 86	1.00000 0.0 87	0.47593 0.0001 85	0.09091 0.4024 87	0.14931 0.3848 36	-0.01875 0.9136 36	0.05881 0.7333 36	0.02234 0.8971 36
Exterior Entryway Dust	0.33690 0.0016 85	0.36254 0.0007 85	0.39209 0.0002 85	0.37982 0.0004 84	0.47593 0.0001 85	1.00000 0.0 85	-0.08369 0.4464 85	-0.00524 0.9758 36	0.03416 0.8432 36	0.14555 0.3970 36	0.13428 0.4349 36
Water	-0.05243 0.6296 87	-0.06280 0.5633 87	0.04191 0.6999 87	0.07790 0.4759 86	0.09091 0.4024 87	-0.08369 0.4464 85	1.00000 0.0 87	0.28190 0.0958 36	0.02113 0.9026 36	-0.20182 0.2379 36	-0.20550 0.2292 36
Door Paint Hazard Score	-0.17675 0.3024 36	-0.30151 0.0739 36	-0.04979 0.7731 36	0.10948 0.5313 35	0.14931 0.3848 36	-0.00524 0.9758 36	0.28190 0.0958 36	1.00000 0.0 36	0.51022 0.0015 36	0.16400 0.3392 36	0.02130 0.9019 36
Door Paint XRF	-0.14461 0.4001 36	0.20076 0.2404 36	-0.20211 0.2372 36	0.08804 0.6150 35	-0.01875 0.9136 36	0.03416 0.8432 36	0.02113 0.9026 36	0.51022 0.0015 36	1.00000 0.0 36	0.63836 0.0001 36	0.59231 0.0001 36
Window Paint Hazard Score	-0.11413 0.5075 36	0.28776 0.0888 36	-0.01012 0.9533 36	0.00600 0.9727 35	0.05881 0.7333 36	0.14555 0.3970 36	-0.20182 0.2379 36	0.16400 0.3392 36	0.63836 0.0001 36	1.00000 0.0 36	0.86920 0.0001 36
Window Paint XRF	-0.30488 0.0706 36	0.29448 0.0813 36	-0.06624 0.7011 36	-0.04169 0.8120 35	0.02234 0.8971 36	0.13428 0.4349 36	-0.20550 0.2292 36	0.02130 0.9019 36	0.59231 0.0001 36	0.86920 0.0001 36	1.00000 0.0 36

Notes: 1. Correlations were conducted on the natural logarithm transformed dust-lead loadings and blood-lead and water-lead concentrations.
2. First number is the Pearson correlation coefficient, the second number is the p-value, and the third number is the number of observations

Table B-7b. Correlaton of Lg-Transormed Blood-Lead (µg/dL), Dust-Lead (µg/g), and Water-Lead (µg/L) Concentrations.

	Blood	Floor Dust	Interior Entrway Dust	Window Well Dust	Window Sill Dust	Exterior Entryway Dust	Water	Door Paint Hazard	Door Paint XRF	Window Paint Hazard	Window Paint XRF
Blood	1.00000 0.0 87	0.53302 0.0001 87	0.56015 0.0001 87	0.40277 0.0001 86	0.48946 0.0001 87	0.46745 0.0001 85	-0.05243 0.6296 87	-0.17675 0.3024 36	-0.14461 0.4001 36	-0.11413 0.5075 36	-0.30488 0.0706 36
Floor Dust	0.53302 0.0001 87	1.00000 0.0 87	0.60667 0.0001 87	0.68940 0.0001 86	0.74478 0.0001 87	0.58587 0.0001 85	0.01357 0.9007 87	-0.27486 0.1047 36	0.01775 0.9181 36	0.22005 0.1972 36	0.15373 0.3707 36
Interior Entryway Dust	0.56015 0.0001 87	0.60667 0.0001 87	1.00000 0.0 87	0.52726 0.0001 86	0.65675 0.0001 87	0.75587 0.0001 85	0.01781 0.8700 87	-0.13834 0.4210 36	-0.38511 0.0204 36	-0.18070 0.2916 36	-0.22767 0.1817 36
Window Well Dust	0.40277 0.0001 86	0.68940 0.0001 86	0.52726 0.0001 86	1.00000 0.0 86	0.83469 0.0001 86	0.59699 0.0001 84	0.00512 0.9627 86	0.21543 0.2139 35	0.09517 0.5865 35	0.12491 0.4746 35	0.00126 0.9943 35
Window Sill Dust	0.48946 0.0001 87	0.74478 0.0001 87	0.65675 0.0001 87	0.83469 0.0001 86	1.00000 0.0 87	0.73108 0.0001 85	0.05961 0.5834 87	-0.21133 0.2160 36	-0.15752 0.3589 36	0.09436 0.5841 36	0.11403 0.5079 36
Exterior Entryway Dust	0.46745 0.0001 85	0.58587 0.0001 85	0.75587 0.0001 85	0.59699 0.0001 84	0.73108 0.0001 85	1.00000 0.0 85	0.07175 0.5140 85	0.01723 0.9206 36	0.09880 0.5665 36	0.29418 0.0816 36	0.25049 0.1406 36
Water	-0.05243 0.6296 87	0.01357 0.9007 87	0.01781 0.8700 87	0.00512 0.9627 86	0.05961 0.5834 87	0.07175 0.5140 85	1.00000 0.0 87	0.28190 0.0958 36	0.02113 0.9026 36	-0.20182 0.2379 36	-0.20550 0.2292 36
Door Paint Hazard Score	-0.17675 0.3024 36	-0.27486 0.1047 36	-0.13834 0.4210 36	0.21543 0.2139 35	-0.21133 0.2160 36	0.01723 0.9206 36	0.28190 0.0958 36	1.00000 0.0 36	0.51022 0.0015 36	0.16400 0.3392 36	0.02130 0.9019 36
Door Paint XRF	-0.14461 0.4001 36	0.01775 0.9181 36	-0.38511 0.0204 36	0.09517 0.5865 35	-0.15752 0.3589 36	0.09880 0.5665 36	0.02113 0.9026 36	0.51022 0.0015 36	1.00000 0.0 36	0.63836 0.0001 36	0.59231 0.0001 36
Window Paint Hazard Score	-0.11413 0.5075 36	0.22005 0.1972 36	-0.18070 0.2916 36	0.12491 0.4746 35	0.09436 0.5841 36	0.29418 0.0816 36	-0.20182 0.2379 36	0.16400 0.3392 36	0.63836 0.0001 36	1.00000 0.0 36	0.86920 0.0001 36
Window Paint XRF	-0.30488 0.0706 36	0.15373 0.3707 36	0.22767 0.1817 36	0.00126 0.9943 35	0.11403 0.5079 36	0.25049 0.1406 36	-0.20550 0.2292 36	0.02130 0.9019 36	0.59231 0.0001 36	0.86920 0.0001 36	0.00000 0.0 36

Notes: 1. Correlations were conducted on the natural logarithm transformed dust-lead, blood-lead, and water-lead concentrations.
2. First number is the Pearson correlation coefficient, the second number is the p-value, and the third number is the number of observations

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APPENDIX C

Results from the Pathways Analyses of the Rochester Data

Table C-1. Structural Equation Modeling Results for the Rochester Environmental-Lead Pathways, Including the Window Paint and Door Paint Hazard Score Pathways — Dust-Lead Loadings (μg/ft²) and Dust-Lead Concentrations (μg/g).

Variables: Independent / Dependent	Direct Effect Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Soil	Window Paint Hazard Score	Door Paint Hazard Score	R^2
Dust-Lead Loadings (μg/ft²)								
Floor	**0.1909* (3.48)**	**0.2014* (2.94)**	0.0033 (0.06)	0.0399 (0.63)	0.1511 (1.24)	0.0102 (0.38)	-0.0476 (-1.33)	0.25
Interior Entryway		-0.0642 (0.57)	0.0560 (0.60)	0.1978 (1.95)	**0.5000* (2.57)**	0.0206 (0.47)	**0.1292* (2.25)**	0.16
Window Sill			**0.3450* (5.09)**		0.1115 (0.72)	**0.0907* (2.69)**		0.33
Window Well					**0.7866* (4.09)**	**0.1591* (3.77)**		0.25
Dust-Lead Concentrations (μg/g)								
Floor	**0.4103* (5.29)**	**0.1582* (2.27)**	-0.0486 (-0.73)	-0.0855 (-1.25)	-0.1314 (-1.23)	**0.0456* (1.97)**	-0.0280 (-0.90)	0.26
Interior Entryway		-0.0513 (-0.62)	**0.1915* (2.48)**	**0.1803* (2.27)**	0.0940 (0.75)	-0.0233 (-0.85)	**0.1084* (3.05)**	0.19
Window Sill			**0.3740* (4.75)**		0.0115 (0.08)	**0.0965* (3.38)**		0.33
Window Well					**0.6619* (4.43)**	**0.0945* (2.93)**		0.24

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations and soil-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9845, and 0.9897 for the dust-lead concentration model.

Table C-2. Structural Equation Modeling Results for the Rochester Environmental Pathways Model, Including Window and Door Paint XRF Measurement Pathways — Dust-Lead Loadings (μg/ft²) and Dust-Lead Concentrations (μg/g).

Variables: Independent / Dependent	Direct Effect Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Soil	Window Paint XRF	Door Paint XRF	R^2
Dust-Lead Loadings (μg/ft²)								
Floor	**0.1786* (3.22)**	**0.1943* (2.86)**	0.0081 (0.14)	0.0408 (0.64)	0.1785 (1.40)	-0.0072 (-0.26)	-0.0043 (-0.16)	0.23
Interior Entryway		0.0218 (0.20)	0.0604 (0.66)	0.1700 (1.67)	**0.5836* (2.92)**	-0.0712 (-1.64)	**0.1055* (2.49)**	0.16
Window Sill			**0.3705* (5.51)**		0.0778 (0.48)	**0.0597* (1.96)**		0.32
Window Well					**0.7549* (3.69)**	**0.1131* (2.88)**		0.22
Dust-Lead Concentrations (μg/g)								
Floor	**0.3923* (5.05)**	**0.1627* (2.38)**	-0.0494 (-0.74)	-0.0941 (-1.37)	-0.1481 (-1.35)	0.0399 (1.71)	-0.0029 (-0.12)	0.26
Interior Entryway		-0.0126 (-0.16)	**0.1647* (2.12)**	**0.1729* (2.17)**	0.1402 (1.08)	-0.0437 (-1.60)	**0.0802* (3.04)**	0.18
Window Sill			**0.3936* (4.89)**		-0.0080 (-0.06)	**0.0645* (2.42)**		0.30
Window Well					**0.6169* (3.98)**	**0.0847* (2.87)**		0.24

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations and soil-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9909, and 0.9884 for the dust-lead concentration model.

Table C-3. Structural Equation Modeling Results for the Rochester Blood-Lead Pathways, Including the Window Paint and Door Paint Hazard Score Pathways — Dust-Lead Loadings (µg/ft²) and Dust-Lead Concentrations (µg/g).

Variables: Dependent \ Independent	Direct Effects Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Floor Dust	Soil	Window Paint Hazard Score	Door Paint Hazard Score	Water	Mouthing	R^2
Dust-Lead Loadings (µg/ft²)											
Blood	-0.0405 (-1.90)	0.0022 (0.08)	**0.0877*** **(4.20)**	-0.0177 (-0.74)	**0.1125*** **(3.38)**		**-0.0236*** **(-2.30)**	**0.0687*** **(4.28)**	-0.0924 (-0.90)	0.2307 (1.83)	0.35
Floor	**0.1941*** **(3.49)**	**0.1975*** **(2.85)**	-0.0058 (-0.10)	0.0401 (0.63)		0.1763 (1.40)	0.0087 (0.32)	-0.0405 (-0.96)			0.25
Interior Entryway		-0.0843 (-0.75)	0.0841 (0.88)	**0.2016*** **(1.99)**		**0.4648*** **(2.32)**	0.0188 (0.42)	**0.1543*** **(2.30)**			0.16
Window Sill			**0.3532*** **(5.04)**			0.1121 (0.70)	**0.0895*** **(2.65)**				0.34
Window Well						**0.8601*** **(4.50)**	**0.1483*** **(3.57)**				0.27
Dust-Lead Concentrations (µg/g)											
Blood	-0.0665 (-1.57)	0.0045 (0.13)	**0.0621*** **(1.96)**	0.0111 (0.33)	0.0667 (1.46)		-0.0138 (-1.17)	**0.0704*** **(3.83)**	-0.0093 (-0.08)	**0.3236*** **(2.24)**	0.21
Floor	**0.4094*** **(5.28)**	**0.1515*** **(2.16)**	-0.0586 (-0.87)	-0.0898 (-1.31)		-0.0974 (-0.89)	0.0436 (1.86)	-0.0233 (-0.64)			0.26
Interior Entryway		-0.0514 (-0.61)	**0.1905*** **(2.42)**	**0.1799*** **(2.24)**		0.0963 (0.73)	-0.0234 (-0.83)	**0.1079*** **(2.56)**			0.17
Window Sill			**0.3676*** **(4.58)**			0.0360 (0.25)	**0.0949*** **(3.30)**				0.32
Window Well						**0.7035** **(4.65)**	**0.0886*** **(2.75)**				0.25

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥ 1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations, soil-lead concentrations, and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9649, and 0.9635 for the dust-lead concentration model.

Table C-4. Structural Equation Modeling Results for the Rochester Blood-Lead Pathways Model, Including Window and Door Paint XRF Measurement Pathways — Dust-Lead Loadings (µg/ft²) and Dust-Lead Concentrations (µg/g).

Variables: Dependent \ Independent	Direct Effects Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Floor Dust	Soil	Window Paint XRF	Door Paint XRF	Water	Mouthing	R^2
Dust-Lead Loadings (µg/ft²)											
Blood	-0.0314 (-1.41)	0.0331 (1.21)	**0.0803*** **(3.62)**	-0.0164 (-0.65)	**0.0993*** **(2.85)**		**-0.0233*** **(-2.22)**	0.0159 (1.45)	-0.0776 (-0.72)	**0.3291*** **(2.53)**	0.29
Floor	**0.1813*** **(3.25)**	**0.1877*** **(2.74)**	0.0008 (0.01)	0.0411 (0.64)		0.2111 (1.61)	-0.0113 (-0.41)	0.0056 (0.19)			0.24
Interior Entryway		0.0190 (0.17)	0.0847 (0.89)	0.0713 (1.67)		**0.5451*** **(2.64)**	-0.0750 (-1.68)	**0.1075*** **(2.37)**			0.15
Window Sill			**0.3755*** **(5.37)**			0.0872 (0.53)	0.0581 (1.90)				0.32
Window Well						**0.8233*** **(4.10)**	**0.1142*** **(2.99)**				0.25
Dust-Lead Concentrations (µg/g)											
Blood	-0.0436 (-0.99)	0.0310 (0.86)	0.0570 (1.70)	0.0156 (0.44)	0.0669 (1.39)		-0.0169 (-1.40)	0.0142 (0.13)	-0.0066 (-0.05)	**0.4362*** **(2.94)**	0.14
Floor	**0.3935*** **(5.08)**	**0.1532*** **(2.24)**	-0.0641 (-0.95)	-0.0997 (-1.45)		-0.1053 (-0.94)	0.0387 (1.63)	0.0034 (0.14)			0.26
Interior Entryway		-0.0117 (-0.14)	**0.1628*** **(2.06)**	**0.1725*** **(2.14)**		0.1337 (1.00)	-0.0402 (-1.43)	**0.0742*** **(2.61)**			0.17
Window Sill			**0.3807*** **(4.63)**			0.0245 (0.17)	**0.0652*** **(2.43)**				0.30
Window Well						**0.6565*** **(4.23)**	**0.0852*** **(2.92)**				0.26

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥1.96 or ≤-1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations, soil-lead concentrations, and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9759, and 0.9673 for the dust-lead concentration model.

Table C-5. Structural Equation Modeling Results for the Rochester Blood-Lead Pathways, Including Hand Lead and Window and Door Paint Pathways — Dust-Lead Loadings (μg/ft²) and Dust-Lead Concentrations (μg/g).

Variables: Dependent \ Independent	Direct Effects Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Floor Dust	Hand Lead	Soil	Window Paint Hazard Score	Door Paint Hazard Score	Water	Mouthing	R^2
Dust-Lead Loadings (μg/ft²)												
Blood	-0.0264 (-1.27)	0.0162 (0.63)	0.0805* (3.81)	-0.0272 (-1.16)	0.0825* (2.51)	0.2163* (3.27)		-0.0278* (-2.78)	0.0578* (3.57)	-0.0591 (-0.59)	0.2563* (2.06)	0.40
Hand Lead	-0.0321 (-1.10)	-0.0311 (-0.87)	0.0510 (1.69)	0.0527 (1.63)	0.1049* (2.32)		0.0518 (0.81)	0.0105 (0.75)	0.0371 (1.64)		-0.0566 (-0.33)	0.17
Floor	0.2029* (3.56)	0.2037* (2.87)	0.0122 (0.20)	0.0459 (0.70)			0.1714 (1.33)	0.0030 (0.10)	-0.0473 (-1.04)			0.25
Interior Entryway		-0.0918 (-0.80)	0.0598 (0.59)	0.1940 (1.85)			0.4653* (2.26)	0.0239 (0.52)	0.1694* (2.35)			0.15
Window Sill			0.3362* (4.49)				0.1097 (0.67)	0.0927* (2.66)				0.31
Window Well							0.7485* (3.93)	0.1529* (3.74)				0.26
Dust-Lead Concentrations (μg/ft²)												
Blood	-0.0523 (-1.26)	0.0195 (0.59)	0.0316 (1.00)	-0.0022 (-0.07)	0.0484 (1.13)	0.3135* (4.33)		-0.0187 (-1.68)	0.0593* (3.26)	0.0458 (0.41)	0.3457* (2.48)	0.31
Hand Lead	-0.0308 (-0.56)	-0.0390 (-0.91)	0.0843* (2.01)	0.0422 (1.00)	0.0519 (0.93)		0.0701 (1.04)	0.0118 (0.80)	0.0345 (1.45)		-0.0918 (-0.50)	0.12
Floor	0.4228* (5.07)	0.1441* (2.01)	-0.0594 (-0.84)	-0.0888 (-1.27)			-0.1084 (-0.97)	0.0473* (1.96)	-0.0356 (-0.91)			0.25
Interior Entryway		-0.0226 (-0.28)	0.1235 (1.55)	0.1708* (2.19)			0.1255 (1.00)	-0.0267 (-0.98)	0.1311* (3.05)			0.16
Window Sill			0.3804* (4.45)				0.0263 (0.18)	0.0949* (3.22)				0.32
Window Well							0.6311* (4.23)	0.0904* (2.87)				0.24

Notes:
1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥1.96 or ≤1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations, soil-lead concentrations, hand-lead measurements, and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9666, and 0.9660 for the dust-lead concentration model.

Table C-6. Structural Equation Modeling Results for the Rochester Blood-Lead Pathways Model, Including Soil Coverage and Window and Door Paint Pathways — Dust-Lead Loadings (μg/ft²) and Dust-Lead Concentrations (μg/g).

Variables: Dependent \ Independent	Direct Effects Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Floor Dust	Soil Coverage	Window Paint Hazard Score	Door Paint Hazard Score	Water	Mouthing	R^2
Dust-Lead Loadings (μg/ft²)[4]											
Blood	-0.0405 (-1.90)	0.0022 (0.08)	0.0877* (4.20)	-0.0177 (-0.75)	0.1125* (3.39)		-0.0236* (-2.31)	0.0687* (4.29)	-0.0924 (-0.90)	0.2307 (1.83)	0.36
Floor	0.2036* (3.68)	0.2066* (2.98)	0.0099 (0.17)	0.0449 (0.71)		0.0000 (0.81)	0.0115 (0.42)	-0.0499 (-1.19)			0.24
Interior Entryway		-0.0617 (-0.54)	0.1236 (1.32)	0.2206* (2.16)		0.0001 (1.62)	0.0260 (0.58)	0.1320 (1.94)			0.13
Window Sill			0.3715 * (5.59)			0.0000 (0.02)	0.0922* (2.74)				0.33
Window Well						0.0002* (2.33)	0.1808* (4.21)				0.18
Dust-Lead Concentrations (μg/g)[4]											
Blood	-0.0600 (-1.30)	0.0055 (0.16)	0.0602 (1.88)	0.0089 (0.26)	0.0647 (1.40)		-0.0135 (-1.14)	0.0698* (3.79)	-0.0080 (-0.07)	0.3256* (2.25)	0.21
Floor	0.4482* (5.33)	0.1552* (2.21)	-0.0867 (-1.33)	-0.1122 (-1.64)		0.0000 (-0.33)	0.0425 (1.83)	-0.0227 (-0.63)			0.26
Interior Entryway		-0.0594 (-0.77)	0.2045* (2.94)	0.2077* (2.83)		0.0001 (1.37)	-0.0256 (-0.99)	0.0993* (2.55)			0.21
Window Sill			0.3767* (4.96)			-0.0000 (-0.02)	0.0958* (3.34)				0.32
Window Well						0.0001* (2.37)	0.1180* (3.52)				0.16

Notes:
1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations, soil coverage values, and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9686, and 0.9705 for the dust-lead concentration model.

Table C-7. Structural Equation Modeling Results for the Rochester Blood-Lead Pathways, Including Proportion of Carpeting and Indicator of Interior Entryway Carpet Pathways — Dust-Lead Loadings (µg/ft²) and Dust-Lead Concentrations (µg/g).

Variables: Dependent \ Independent	Direct Effects Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Floor Dust	Soil	Window Paint Hazard Score	Door Paint Hazard Score	Water	Mouthing	Proportion Carpet	Indicator Interior Entryway Carpet	R^2
Dust-Lead Loadings (µg/ft²)													
Blood	0.0071 (0.28)	0.0114 (0.47)	0.0789* (4.08)	-0.0395 (-1.74)	0.1428* (4.41)		-0.0246* (-2.58)	0.0455* (2.91)	-0.0496 (-0.52)	0.2795* (2.39)	-0.6866* (-2.78)	-0.3368* (-2.65)	0.45
Floor	0.1862* (2.69)	0.1624* (2.47)	0.0117 (0.21)	0.0660 (1.07)		0.1933 (1.61)	0.0084 (0.32)	-0.0033 (-0.08)			2.3914* (3.68)	-0.2026 (-0.58)	0.32
Interior Entryway		-0.0801 (-0.93)	0.0436 (0.60)	0.2350* (3.03)		0.3190* (2.07)	0.0187 (0.55)	0.1943* (3.78)				3.1860* (9.40)	0.51
Window Sill			0.3532* (5.04)			0.1121 (0.70)	0.0895* (2.65)						0.34
Window Well						0.8601* (4.50)	0.1483* (3.57)						0.27
Dust-Lead Loadings (µg/ft²)													
Blood	-0.0665 (-1.63)	0.0058 (0.17)	0.0792* (2.61)	0.0006 (0.02)	0.0554 (1.27)		-0.0133 (-1.18)	0.0599* (3.36)	0.0289 (0.25)	0.3570* (2.58)	-0.4672 (-1.69)	-0.2732* (-2.29)	0.30
Floor	0.4076* (5.21)	0.1514* (2.17)	-0.0507 (-0.75)	-0.0953 (-1.37)		-0.0964 (-0.87)	0.0434 (1.85)	-0.0279 (-0.76)			-0.2565 (-0.44)	-0.1047 (-0.41)	0.27
Interior Entryway		-0.0527 (-0.64)	0.2036* (2.62)	0.1781* (2.24)		0.1084 (0.83)	-0.0231 (-0.83)	0.1026* (2.45)				-0.4282 (-1.53)	0.19
Window Sill			0.3676* (4.58)			0.0360 (0.25)	0.0949* (3.30)						0.32
Window Well						0.7035* (4.65)	0.0886* (2.75)						0.25

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations, soil-lead concentrations, and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9665, and 0.9611 for the dust-lead concentration model.

Table C-8. Structural Equation Modeling Results for the Rochester Blood-Lead Pathways for Homes with Carpeted Bedrooms and Play Areas — Dust-Lead Loadings (µg/ft²) and Dust-Lead Concentrations (µg/g).

Variables: Dependent \ Independent	Direct Effects Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Carpeted Floor Dust	Soil	Window Paint Hazard Score	Door Paint Hazard Score	Water	Mouthing	Indicator Interior Entryway Carpet	R^2
Dust-Lead Loadings (µg/ft²)												
Blood	0.0523 (1.82)	0.0406 (1.50)	0.0858* (4.02)	-0.0343 (-1.39)	-0.0456 (-1.39)		-0.0296* (-2.83)	0.0790* (3.68)	0.0780 (0.71)	0.2298 (1.80)	-0.5029* (-3.49)	0.41
Floor – Carpeted	-0.0813 (-0.96)	0.0708 (0.89)	-0.0257 (-0.39)	0.0807 (1.14)		-0.1007 (-0.69)	0.0037 (0.12)	-0.0243 (-0.40)			0.7413 (1.79)	0.05
Interior Entryway		-0.1383 (-1.55)	0.0391 (0.53)	0.2178* (2.82)		0.3086 (1.91)	-0.0277 (-0.82)	0.1683* (2.49)			3.3162* (9.64)	0.54
Window Sill			0.3288* (4.52)			0.1754 (1.03)	0.0933* (2.73)					0.35
Window Well						0.9342* (4.54)	0.1375* (3.20)					0.28
Dust-Lead Concentrations (µg/g)												
Blood	-0.0481 (-1.26)	-0.0019 (-0.06)	0.0721* (2.31)	-0.0017 (-0.05)	0.0195 (0.44)		-0.0140 (-1.19)	0.1028* (4.30)	0.1543 (1.21)	0.3316* (2.27)	-0.3938* (-3.25)	0.29
Floor – Carpeted	0.0868 (1.03)	0.0846 (1.12)	-0.0486 (-0.65)	-0.0461 (-0.62)		0.1304 (1.04)	0.0108 (0.42)	-0.0195 (-0.37)			0.5005 (1.89)	0.08
Interior Entryway		0.0024 (0.03)	0.2144* (2.57)	0.1762* (2.08)		0.0092 (0.06)	-0.0161 (-0.54)	0.0929 (1.55)			-0.2101 (-0.69)	0.16
Window Sill			0.3220* (3.67)			0.0654 (0.41)	0.1019* (3.33)					0.30
Window Well						0.7592* (4.70)	0.0813* (2.44)					0.27

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations, soil-lead concentrations, and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9713, and 0.9809 for the dust-lead concentration model.

Table C-9. Predicted Effect of 50% Decrease in Environmental-Lead Loadings (μg/ft²) and Concentrations (μg/g) and Blood-Lead Concentrations (μg/dL) Based on the Blood-Lead Pathways SEM for the Rochester Data, Including Carpet and Paint Pathways.

Sample Location	Geometric Mean	50% Decrease in GM	Predicted Percent Change (%) (Lower Prediction Interval, Upper Prediction Interval) [b]				
			Blood	Floor	Interior Entryway	Window Sill	Window Well
Dust-Lead Loading (μg/ft²)							
Floor Dust	100	50	-9 (-11, 7)	*NA*	*NA*	*NA*	*NA*
Interior Entryway Dust	89	45	-2 (-4, 0)	-12 (-23, 0)	*NA*	*NA*	*NA*
Window Sill	345	173	-2 (-4, 0)	-10 (-20, 2)	6 (-14, 30)	*NA*	*NA*
Window Well	22,584	11,292	-6 (-7, -5)	-5 (-14, 5)	-1 (-17, 18)	-22 (-35, -7)	*NA*
Soil[a]	852	426	NA	-21 (-37, -1)	-20 (-45, 16)	-25 (-50, 13)	-45 (-71, 4)
Exterior Dust	515	258	2 (0, 4)	-7 (-17, 4)	-15 (-30, 3)	*NA*	*NA*
Window Paint	4.9	2.5	0 (-1, 1)	-2 (-7, 3)	-1 (-9, 8)	-9 (-17, -1)	-10 (-27, 3)
Door Paint	1.5	0.75	-4 (-5, -3)	-2 (-9, 6)	-13 (-23, -1)	*NA*	*NA*
Proportion Carpet	0.38	0.19	27 (8, 50)	-81 (-94, -36)	*NA*	*NA*	*NA*
	Presence	**Absence**					
Indicator Interior Entryway Carpet	1	0	29 (19, 40)	-32 (-65, 30)	-96 (-98, -91)	*NA*	*NA*
	Exposure	**No Exposure**					
Mouthing	1	0	-24 (-30, -18)	*NA*	*NA*	*NA*	*NA*
Water	1	0	5 (-2, 12)	*NA*	*NA*	*NA*	*NA*
Dust-Lead Concentrations (μg/g)							
Floor Dust	563	282	-4 (-7, -17)	*NA*	*NA*	*NA*	*NA*
Interior Entryway Dust	468	234	3 (-4, 0)	-25 (-34,-15)	*NA*	*NA*	*NA*
Window Sill	2,787	1,394	-1 (-4, 2)	-9 (-19, 2)	4 (-12, 22)	*NA*	*NA*
Window Well	8,676	4,338	-5 (-7, -3)	-5 (-15, 6)	-12 (-24, 3)	-22 (-35, -7)	*NA*
Soil	852	426	NA	-1 (-17, 19)	-15 (-34, 10)	-18 (-40,12)	-39 (-58, -11)
Exterior Dust	656	328	1 (-2, 4)	2 (-9, 14)	-12 (-25, 3)	*NA*	*NA*
Window Paint	4.9	2.5	0 (-1, 1)	-4 (-8, 0)	1 (-4, 7)	-8 (-14, -2)	-6 (-13, 2)
Door Paint	1.5	0.75	-4 (-5, -3)	-1 (-7, 5)	-7 (-14, 1)	*NA*	*NA*
Proportion Carpet	0.38	0.19	40 (13, 74)	19 (-55, 213)	*NA*	*NA*	*NA*
	Presence	**Absence**					
Indicator Interior Entryway Carpet	1	0	30 (19, 43)	32 (-13, 100)	53 (-11, 164)	*NA*	*NA*
	Exposure	**No Exposure**					
Mouthing	1	0	-30 (-37, -22)	*NA*	*NA*	*NA*	*NA*
Water	1	0	-3 (-11, 6)	*NA*	*NA*	*NA*	*NA*

(a) Soil lead is measured as a concentration.
(b) A prediction interval or forecasting interval is a confidence interval for the actual or future value of a response, which is the mean value plus error. Here the upper and lower 95% prediction intervals are based on the direct effects only.
NA Indicates that the fitted pathway model did not include a pathway from the sample location.

Table C-10. Structural Equation Modeling Results for the Rochester Blood-Lead Pathways Model For African-American Children — Dust-Lead Loadings (μg/ft²) and Dust-Lead Concentrations (μg/g).

Variables: Dependent \ Independent	Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Floor Dust	Soil	Window Paint Hazard Score	Door Paint Hazard Score	Water	Mouthing	R^2
	Direct Effects Parameter Estimates (t-value)										
Dust-Lead Loadings (μg/ft²)											
Blood	-0.0061 (-0.18)	-0.0015 (-0.04)	**0.0630*** (2.15)	0.0017 (0.05)	0.0596 (1.04)		0.0019 (0.07)	0.0439 (1.54)	-0.2349 (-1.22)	0.3693 (1.87)	0.38
Floor	**0.3301*** (4.09)	**0.2725*** (2.88)	-0.0525 (-0.68)	-0.0399 (-0.51)		0.0267 (0.14)	0.1158 (1.82)	-0.0736 (-1.08)			0.50
Interior Entryway		-0.2919 (-1.70)	0.0678 (0.47)	-0.0158 (-0.11)		**0.9957*** (2.96)	0.1315 (1.13)	0.0156 (0.12)			0.24
Window Sill			**0.2588*** (2.15)			0.2138 (0.74)	**0.2110*** (2.82)				0.32
Window Well						0.5628 (1.60)	0.1431 (1.57)				0.13
Dust-Lead Concentrations (μg/g)											
Blood	-0.0164 (-0.31)	0.0210 (0.39)	0.0232 (0.57)	0.0170 (0.40)	0.0661 (1.06)		0.0161 (0.59)	0.0339 (1.09)	-0.3033 (-1.42)	**0.4809*** (2.24)	0.35
Floor	**0.2906*** (2.32)	0.0318 (0.23)	0.0644 (0.62)	-0.0802 (-0.83)		-0.1594 (-0.80)	0.0599 (0.95)	0.0043 (0.06)			0.21
Interior Entryway		-0.1649 (-1.00)	0.2081 (1.68)	0.1035 (0.88)		0.2844 (1.18)	-0.0517 (-0.67)	0.1541 (1.86)			0.24
Window Sill			**0.2345*** (2.13)			0.2057 (0.93)	**0.1287*** (2.37)				0.34
Window Well						**0.7935*** (2.80)	0.1407 (1.93)				0.26

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations, soil-lead concentrations, and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9508, and 0.9000 for the dust-lead concentration model.

Table C-11. Structural Equation Modeling Results for the Rochester Blood-Lead Pathways Model For Children of All Other Races — Dust-Lead Loadings ($\mu g/ft^2$) and Dust-Lead Concentrations ($\mu g/g$).

Variables: Dependent \ Independent	Direct Effects Parameter Estimates (t-value): Interior Entryway Dust	Window Sill Dust	Window Well Dust	Exterior Entryway Dust	Floor Dust	Soil	Window Paint Hazard Score	Door Paint Hazard Score	Water	Mouthing	R^2
Dust-Lead Loadings ($\mu g/ft^2$)											
Blood	**-0.0684*** (-2.82)	0.0036 (0.12)	**0.0828*** (3.40)	-0.0335 (-1.05)	**0.1478*** (4.13)		**-0.0215*** (-2.23)	**0.0640*** (3.41)	-0.1719 (-1.62)	0.1941 (1.44)	0.43
Floor	0.0958 (1.26)	0.1387 (1.43)	0.0649 (0.79)	0.1163 (1.18)		0.1612 (1.01)	-0.0211 (-0.69)	-0.0703 (-1.21)			0.20
Interior Entryway		0.1043 (0.72)	0.0210 (0.17)	**0.4522*** (3.28)		0.1922 (0.81)	0.0320 (0.70)	**0.1766*** (2.09)			0.22
Window Sill			**0.4270*** (5.09)			-0.0038 (-0.02)	0.0456 (1.30)				0.40
Window Well						**0.9828*** (4.44)	**0.1500*** (3.38)				0.36
Dust-Lead Concentrations ($\mu g/g$)											
Blood	-0.0685 (-1.32)	-0.0414 (-1.14)	**0.1409*** (3.89)	-0.0539 (-1.17)	0.0950 (1.88)		-0.0198 (-1.85)	**0.0587*** (2.84)	-0.1160 (-0.97)	0.1828 (1.22)	0.28
Floor	**0.5122*** (4.90)	**0.2076*** (2.58)	-0.1575 (-1.79)	-0.1075 (-0.99)		-0.0491 (-0.36)	0.0388 (1.56)	-0.0526 (-1.12)			0.34
Interior Entryway		0.0412 (0.46)	0.0976 (1.00)	**0.4095*** (3.65)		0.0005 (0.00)	-0.0109 (-0.39)	0.0912 (1.77)			0.23
Window Sill			**0.4901*** (4.31)			-0.1025 (-0.55)	**0.0848*** (2.49)				0.34
Window Well						**0.6872*** (3.97)	**0.0701*** (2.06)				0.27

Notes: 1. Bolded and a * indicate parameter estimates are significant at the 0.05 level. T-value ≥ 1.96 or ≤ -1.96 significant at 0.05 level.
2. Pathways analyses were conducted on the natural logarithm transformed dust-lead loadings/concentrations, soil-lead concentrations, and blood-lead concentrations.
3. First number is estimated parameter; second number is corresponding t-value.
4. The goodness-of-fit index (GFI) for the dust-lead loading model is 0.9388, and 0.9541 for the dust-lead concentration model.

Table C-12a. Rochester Data Correlation of Log-Transformed Blood-Lead ($\mu g/dL$), Dust-Lead Loadings ($\mu g/ft^2$), Soil-Lead ($\mu g/g$) Concentrations, and Child and Housing Characteristic Variables.

	Blood	Hand Lead	Floor Dust	Interior Entry Dust	Window Sill Dust	Window Well Dust	Exterior Entry Dust	Indicator of Proportion Carpeted	Soil	Door Paint Hazard Score	Door Paint XRF	Window paint Hazard Score	Window Paint XRF	Water
Blood	1.00000 0.0 205	0.43006 0.0001 197	0.32454 0.0001 203	0.15113 0.0446 177	0.34288 0.0001 197	0.37437 0.0001 189	0.11389 0.1357 173	-0.22194 0.0014 205	0.36924 0.0001 187	0.36258 0.0001 196	0.17198 0.0159 196	0.11088 0.1190 199	0.07151 0.3155 199	0.04832 0.4947 202
Hand Lead	0.43006 0.0001 197	1.00000 0.0 197	0.36410 0.0001 195	0.15941 0.0379 170	0.25869 0.0003 189	0.32547 0.0001 181	0.25563 0.0009 166	0.03467 0.6286 197	0.33040 0.0001 179	0.23871 0.0010 188	0.22575 0.0018 188	0.27208 0.0001 191	0.24014 0.0008 191	0.04415 0.5410 194
Floor Dust	0.32454 0.0001 203	0.36410 0.0001 195	1.00000 0.0 203	0.31822 0.0001 177	0.34589 0.0001 196	0.24292 0.0008 188	0.21412 0.0049 171	0.23506 0.0007 203	0.26879 0.0002 185	0.13810 0.0548 194	0.14096 0.0499 194	0.23847 0.0007 197	0.16850 0.0179 197	-0.06289 0.3763 200
Interior Entryway Dust	0.15113 0.0446 177	0.15941 0.0379 170	0.31822 0.0001 177	1.00000 0.0 177	0.22144 0.0035 172	0.21090 0.0067 164	0.21183 0.0088 152	-0.00978 0.8972 177	0.33916 0.0001 161	0.22591 0.0031 169	0.25711 0.0007 169	0.18080 0.0180 171	0.14346 0.0612 171	0.00412 0.9569 175
Window Sill Dust	0.34288 0.0001 197	0.25869 0.0003 189	0.34589 0.0001 196	0.22144 0.0035 172	1.00000 0.0 197	0.55848 0.0001 184	0.26942 0.0004 169	-0.08404 0.2403 197	0.37066 0.0001 181	0.25226 0.0005 188	0.22337 0.0021 188	0.38279 0.0001 193	0.41298 0.0001 193	0.05496 0.4454 195
Window Well Dust	0.37437 0.0001 189	0.32547 0.0001 181	0.24292 0.0008 188	0.21090 0.0067 164	0.55848 0.0001 184	1.00000 0.0 189	0.23358 0.0030 160	-0.13024 0.0741 189	0.44630 0.0001 174	0.16490 0.0270 180	0.12814 0.0865 180	0.44204 0.0001 186	0.41139 0.0001 186	-0.06286 0.3940 186
Exterior Entryway Dust	0.11389 0.1357 173	0.25563 0.0009 166	0.21412 0.0049 171	0.21183 0.0088 152	0.26942 0.0004 169	0.23358 0.0030 160	1.00000 0.0 173	-0.12940 0.0897 173	0.20777 0.0082 161	0.12076 0.1223 165	0.19326 0.0129 165	0.11331 0.1436 168	0.17624 0.0223 168	0.01958 0.7999 170
Indicator of Proportion Carpeted	-0.22194 0.0014 205	0.03467 0.6286 197	0.23506 0.0007 203	-0.00978 0.8972 177	-0.08404 0.2403 197	-0.13024 0.0741 189	-0.12940 0.0897 173	1.00000 0.0 205	-0.09477 0.1970 187	-0.14334 0.0450 196	-0.15836 0.0266 196	-0.06647 0.3509 199	-0.10256 0.1494 199	0.04522 0.5228 202
Soil	0.36924 0.0001 187	0.33040 0.0001 179	0.26879 0.0002 185	0.33916 0.0001 161	0.37066 0.0001 181	0.44630 0.0001 174	0.20777 0.0082 161	-0.09477 0.1970 187	1.00000 0.0 187	0.10603 0.1578 179	0.17742 0.0175 179	0.24743 0.0008 182	0.35131 0.0001 182	0.07652 0.3006 185
Door Paint Hazard Score	0.36258 0.0001 196	0.23871 0.0010 188	0.13810 0.0548 194	0.22591 0.0031 169	0.25226 0.0005 188	0.16490 0.0270 180	0.12076 0.1223 165	-0.14334 0.0450 196	0.10603 0.1578 179	1.00000 0.0 196	0.53604 0.0001 196	0.26511 0.0002 190	0.19748 0.0063 190	-0.06131 0.3970 193
Door Paint XRF	0.17198 0.0159 196	0.22575 0.0018 188	0.14096 0.0499 194	0.25711 0.0007 169	0.22337 0.0021 188	0.12814 0.0865 180	0.19326 0.0129 165	-0.15836 0.0266 196	0.17742 0.0175 179	0.53604 0.0001 196	1.00000 0.0 196	0.30336 0.0001 190	0.36710 0.0001 190	-0.05903 0.4148 193
Window Paint Hazard Score	0.11088 0.1190 199	0.27208 0.0001 191	0.23847 0.0007 197	0.18080 0.0180 171	0.38279 0.0001 193	0.44204 0.0001 186	0.11331 0.1436 168	-0.06647 0.3509 199	0.24743 0.0008 182	0.26511 0.0002 190	0.30336 0.0001 190	1.00000 0.0 199	0.77743 0.0001 199	-0.00707 0.9216 196
Window Paint XRF	0.07151 0.3155 199	0.24014 0.0008 191	0.16850 0.0179 197	0.14346 0.0612 171	0.41298 0.0001 193	0.41139 0.0001 186	0.17624 0.0223 168	-0.10256 0.1494 199	0.35131 0.0001 182	0.19748 0.0063 190	0.36710 0.0001 190	0.77743 0.0001 199	1.00000 0.0 199	0.01139 0.8742 196
Water	0.04832 0.4947 202	0.04415 0.5410 194	-0.06289 0.3763 200	0.00412 0.9569 175	0.05496 0.4454 195	-0.06286 0.3940 186	0.01958 0.7999 170	0.04522 0.5228 202	0.07652 0.3006 185	-0.06131 0.3970 193	-0.05903 0.4148 193	-0.00707 0.9216 196	0.01139 0.8742 196	1.00000 0.0 202

Notes: 1. Correlations were conducted on the natural logarithm transformed hand-lead measurements, dust-lead loadings, and blood-lead, soil-lead and water-lead concentrations.
2. First number is the Pearson correlation coefficient, the second number is the p-value, and the third number is the number of observations

Table C-12b. Rochester Data Correlation of Log-Transformed Blood-Lead (µg/dL), Dust-Lead (µg/g), and Soil-Lead (µg/g) Concentrations, and Child and Housing Characteristic Variables.

	Blood	Hand Lead	Floor Dust	Interior Entry Dust	Window Sill Dust	Window Well Dust	Exterior Entry Dust	Indicator of Proportion Carpeted	Soil	Door Paint Hazard Score	Door Paint XRF	Window Paint Hazard Score	Window Paint XRF	Water
Blood	1.00000 0.0 205	0.43006 0.0001 197	0.13216 0.0602 203	0.08323 0.2749 174	0.23639 0.0008 199	0.21112 0.0036 188	0.11436 0.1352 172	-0.22194 0.0014 205	0.36924 0.0001 187	0.36258 0.0001 196	0.17198 0.0159 196	0.11088 0.1190 199	0.07151 0.3155 199	0.04832 0.4947 202
Hand Lead	0.43006 0.0001 197	1.00000 0.0 197	0.12492 0.0819 195	0.13622 0.0783 168	0.19449 0.0070 191	0.30279 0.0001 180	0.15863 0.0419 165	0.03467 0.6286 197	0.33040 0.0001 179	0.23871 0.0010 188	0.22575 0.0018 188	0.27208 0.0001 191	0.24014 0.0008 191	0.04415 0.5410 194
Floor Dust	0.13216 0.0602 203	0.12492 0.0819 195	1.00000 0.0 203	0.34997 0.0001 173	0.29123 0.0001 197	0.21547 0.0031 186	0.13863 0.0714 170	-0.07530 0.2857 203	0.09887 0.1806 185	0.07819 0.2785 194	0.11357 0.1149 194	0.21859 0.0020 197	0.23000 0.0011 197	0.06806 0.3383 200
Interior Entryway Dust	0.08323 0.2749 174	0.13622 0.0783 168	0.34997 0.0001 173	1.00000 0.0 174	0.24679 0.0012 170	0.23814 0.0024 160	0.23838 0.0035 148	-0.08393 0.2709 174	0.24524 0.0018 159	0.23521 0.0023 166	0.31201 0.0001 166	0.08317 0.2838 168	0.09677 0.2121 168	0.11659 0.1277 172
Window Sill Dust	0.23639 0.0008 199	0.19449 0.0070 191	0.29123 0.0001 197	0.24679 0.0012 170	1.00000 0.0 199	0.55223 0.0001 183	0.27469 0.0003 168	-0.03245 0.6491 199	0.33537 0.0001 182	0.22162 0.0021 190	0.19938 0.0058 190	0.37154 0.0001 194	0.33780 0.0001 194	0.02750 0.7013 197
Window Well Dust	0.21112 0.0036 188	0.30279 0.0001 180	0.21547 0.0031 186	0.23814 0.0024 160	0.55223 0.0001 183	1.00000 0.0 188	0.21672 0.0062 158	-0.00234 0.9745 188	0.49852 0.0001 173	0.10959 0.1442 179	0.12936 0.0844 179	0.36497 0.0001 185	0.35457 0.0001 185	0.03503 0.6359 185
Exterior Entryway Dust	0.11436 0.1352 172	0.15863 0.0419 165	0.13863 0.0714 170	0.23838 0.0035 148	0.27469 0.0003 168	0.21672 0.0062 158	1.00000 0.0 172	-0.15739 0.0392 172	0.28968 0.0002 160	0.10459 0.1826 164	0.14948 0.0561 164	0.07633 0.3269 167	0.14292 0.0654 167	0.03524 0.6492 169
Indicator of Proportion Carpeted	-0.22194 0.0014 205	0.03467 0.6286 197	-0.07530 0.2857 203	-0.08393 0.2709 174	-0.03245 0.6491 199	-0.00234 0.9745 188	-0.15739 0.0392 172	1.00000 0.0 205	-0.09477 0.1970 187	-0.14334 0.0450 196	-0.15836 0.0266 196	-0.06647 0.3509 199	-0.10256 0.1494 199	0.04522 0.5228 202
Soil	0.36924 0.0001 187	0.33040 0.0001 179	0.09887 0.1806 185	0.24524 0.0018 159	0.33537 0.0001 182	0.49852 0.0001 173	0.28968 0.0002 160	-0.09477 0.1970 187	1.00000 0.0 187	0.10603 0.1578 179	0.17742 0.0175 179	0.24743 0.0008 182	0.35131 0.0001 182	0.07652 0.3006 185
Door Paint Hazard Score	0.36258 0.0001 196	0.23871 0.0010 188	0.07819 0.2785 194	0.23521 0.0023 166	0.22162 0.0021 190	0.10959 0.1442 179	0.10459 0.1826 164	-0.14334 0.0450 196	0.10603 0.1578 179	1.00000 0.0 196	0.53604 0.0001 196	0.26511 0.0002 190	0.19748 0.0063 190	-0.06131 0.3970 193
Door Paint XRF	0.17198 0.0159 196	0.22575 0.0018 18	0.11357 0.1149 194	0.31201 0.0001 166	0.19938 0.0058 190	0.12936 0.0844 179	0.14948 0.0561 164	-0.15836 0.0266 196	0.17742 0.0175 179	0.53604 0.0001 196	1.00000 0.0 196	0.30336 0.0001 190	0.36710 0.0001 190	-0.05903 0.4148 193
Window Paint Hazard Score	0.11088 0.1190 199	0.27208 0.0001 191	0.21859 0.0020 197	0.08317 0.2838 168	0.37154 0.0001 194	0.36497 0.0001 185	0.07633 0.3269 167	-0.06647 0.3509 199	0.24743 0.0008 182	0.26511 0.0002 190	0.30336 0.0001 190	1.00000 0.0 199	0.7774 0.0001 199	-0.00707 0.9216 196
Window Paint XRF	0.07151 0.3155 199	0.24014 0.0008 191	0.23000 0.0011 197	0.09677 0.2121 168	0.33780 0.0001 194	0.35457 0.0001 185	0.14292 0.0654 167	-0.10256 0.1494 199	0.35131 0.0001 182	0.19748 0.0063 190	0.36710 0.0001 190	0.77743 0.0001 199	1.00000 0.0 199	0.01139 0.8742 196
Water	0.04832 0.4947 202	0.04415 0.5410 194	0.06806 0.3383 200	0.11659 0.1277 172	0.02750 0.7013 197	0.03503 0.6359 185	0.03524 0.6492 169	0.04522 0.5228 202	0.07652 0.3006 185	-0.06131 0.3970 193	-0.05903 0.4148 193	-0.00707 0.9216 196	0.01139 0.8742 196	1.00000 0.0 202

Notes: 1. Analyses were conducted on natural logarithm transformed hand-lead measurements, and dust-lead, soil-lead, and blood-lead concentrations.
2. First number is the Pearson correlation coefficient, and the second number is the number of observations.

APPENDIX D

Pathway Diagrams Identified in the Literature

Table D-1. Description of Variables for Pathway Model from *Exterior Surface Dust Lead, Interior House Dust Lead and Childhood Lead Exposure in an Urban Environment*, by Bornschein, et al [2].

Variable	Description
XRF Hazard	Paint hazard score derived from a linear combination of the product of a maximum of 15 XRF measurements and the condition code (0 to 10) value for the painted surface.
PbSS	Soil surface scrapes were taken from 1) surfaces either paved with asphalt, 2) concrete or brick, or 3) were composed of hard-packed soil devoid of vegetation. Collected from areas where child played and/or immediately outside the dwelling unit entry.
PbD	Floor dust lead in $\mu g/g$.
PbH	Hand lead samples taken from the surface of the child's hands by three repeated wipings of each hand with a total of six wet wipes.
PbB	Blood lead concentrations collected by venipuncture.

Table D-2. Description of Variables for Pathway Model from *Soil-Lead – Blood Lead Relationship in a Former Lead Mining Town*, by Bornschein, et al [17].

Variable	Description
XRF-EXT	Maximum exterior XRF/house in mg/cm^2
XRF-INT	Maximum interior XRF/house in mg/cm^2
PbSS	Median soil surface scrapings from exposed soil in play areas, paths through yards or playgrounds, and from paved areas immediately outside the house entry.
PbSC	Median 1 inch soil core lead in $\mu g/g$.
DIST. 2	Location of dwelling-proximity to the old railway right of way which originated at the mill on the east side of town and ran parallel to the San Migual river on the southern boundary of town.
PbD Floor	Floor dust lead in $\mu g/g$.
PbD Window	Window sill dust lead in $\mu g/g$.
Age (yr)	Age of child in years.
PbH	Hand lead in μg for two hands from handwipes.
Age x PbH	Interaction between hand lead and age of the child.
PbB	Blood lead concentrations collected by venipuncture.

Table D-3. Description of Variables for Pathway Model from *The Influences of Social and Environmental Factors on Dust Lead, Hand Lead, and Blood Lead Levels inYoung Children*, by Bornschein, et al [1].

Variable	Description
House	Housing quality including the age, type of home, and condition of the home.
H.O.M.E.	Home Observation for Measurement of the Environment (HOME) used to quantitate various aspects of the child's rearing environment.
SES	Socioeconomic status (SES) of families made through the use of the Hollingshead Four-Factor Scale.
PbD	Interior surface dust collected by three sweeps of a defined area using a 2-liter/min vacuum.
PbH	Hand lead recovered from surface of child's hands by repeated wipings of both hands with a total of six wet wipes.
PbB	Blood lead concentration obtain via venipuncture.

Table D-4. Description of Variables for Pathway Model from *Pathways of Lead Contamination for the Brigham and Women's Hospital Longitudinal Study*, by Menton, et al [7].

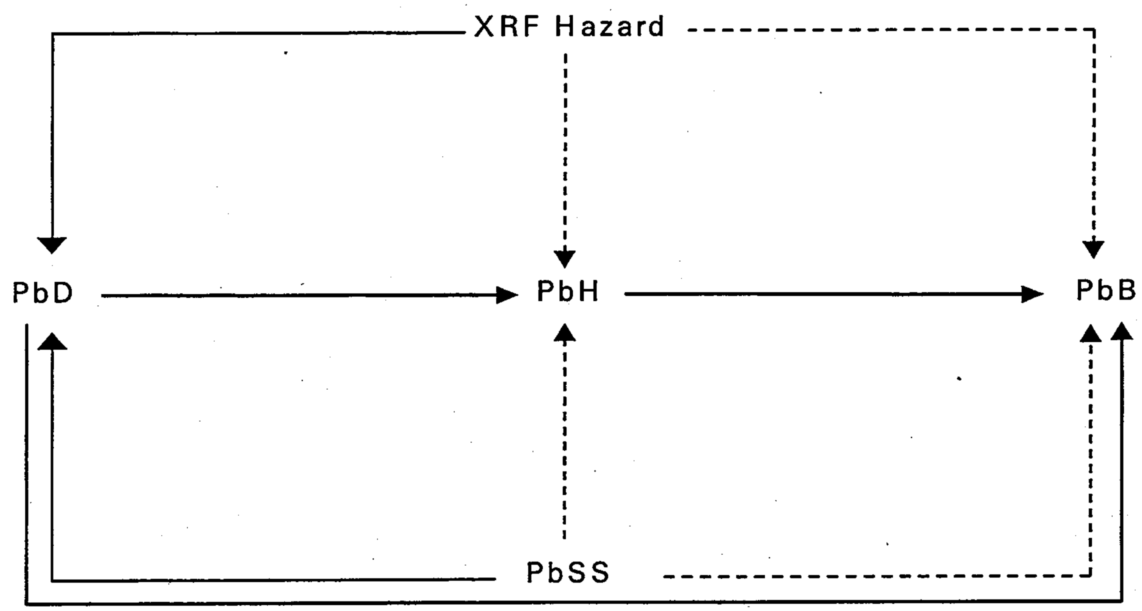
Variable	Description
Refinishing	An indication of the presence of any refinishing or renovation and remodeling activity within the preceding 6 months.
Pb Air	Amount of particulate lead ($\mu g/m^3$) in air sampled at 24 months.
Pb Dust Floor	Amount of lead (μg) in floor dust wipe at 24 months.
Pb Dust Window Sill	Amount of lead (μg) in window sill dust wipe at 24 months.
Pb Soil	Average concentration of lead ($\mu g/g$) in soil.
Pb Blood	Concentration of lead in blood ($\mu g/dL$) at 24 months.

Table D-5. Description of Variables for Pathway Model from *Dust Lead Contribution to Lead in Children*, by Sayre[18].

<table>
<tr><th>Variable</th><th colspan="2">Description</th></tr>
<tr><td rowspan="2">Pb-Containing Paint</td><td rowspan="2">Loose or peeling paint from any area where loose paint could be seen, regardless of its accessibility to the child.</td><td>Pica: Parent indicated the child ate paint chips.</td></tr>
<tr><td>Paint containing lead becomes dust which contributes to the interior house dust.</td></tr>
<tr><td>Airborne Pb</td><td colspan="2">Explanation not provided.</td></tr>
<tr><td rowspan="2">Pb-Contaminated Outside Dirt</td><td rowspan="2">Soil taken from area reported to be used most frequently by the child.</td><td>Parent indicated child ate dirt.</td></tr>
<tr><td>Soil containing lead which contributes to the interior house dust.</td></tr>
<tr><td>Interior Dust</td><td colspan="2">Towel wipe taken from window sill and floor in area child commonly plays.</td></tr>
<tr><td>Hands</td><td colspan="2">Towel wipe, rubbing both front and back surfaces of both hands of child.</td></tr>
<tr><td>Play Objects</td><td colspan="2">Explanation not provided.</td></tr>
<tr><td>Pb B</td><td colspan="2">Blood lead concentration collected at health center within one year prior to environmental sampling.</td></tr>
</table>

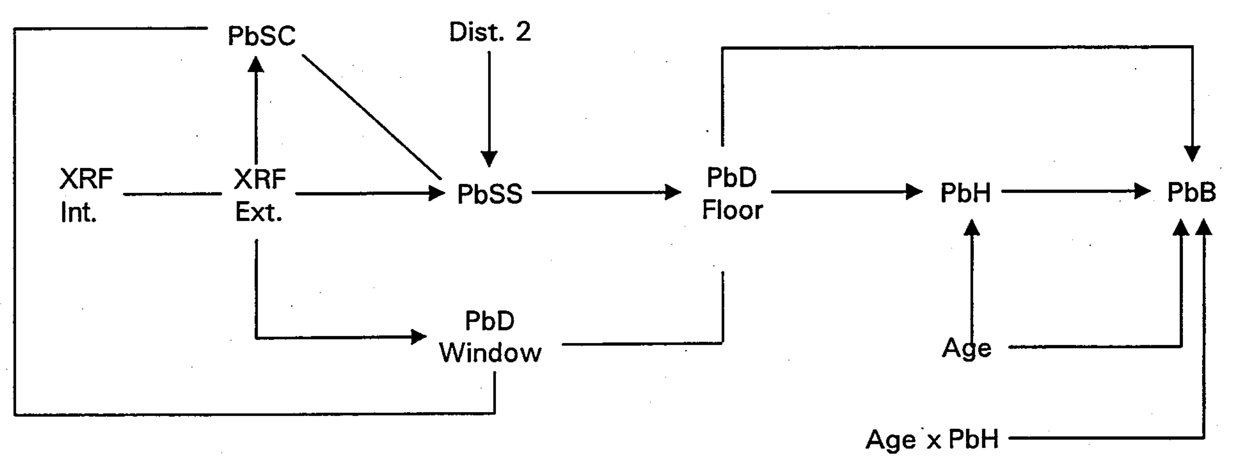
Table D-6. Description of Variables for Pathway Model from *Pathways of Lead Exposure in Urban Children*, by Lanphear [19].

Variable	Description
Dust Lead	Dust lead level, as measured by wipe sampling, was the average of all transformed measures across the four surfaces (carpeted floors, uncarpeted floors, interior window sills, and window troughs).
Hand Lead	Explanation not provided.
Soil Lead	Composite sample of three core samples taken on each side of the house around the perimeter of the foundation.
Paint Lead	Average of all interior paint XRF values.
Blood Lead	Venous blood sample collected from children between the ages 12 and 30 months.
Black Race	An indicator variable coded 1 for African American and 0 for Caucasian.
Income Level	Gross Income levels were categorized as income below $15,000, and above $15,000.
Playing Outside	The amount of time spent playing outdoors (# hours).
Ingestion of Soil	How often a child puts dirt or sand in his/her mouth.



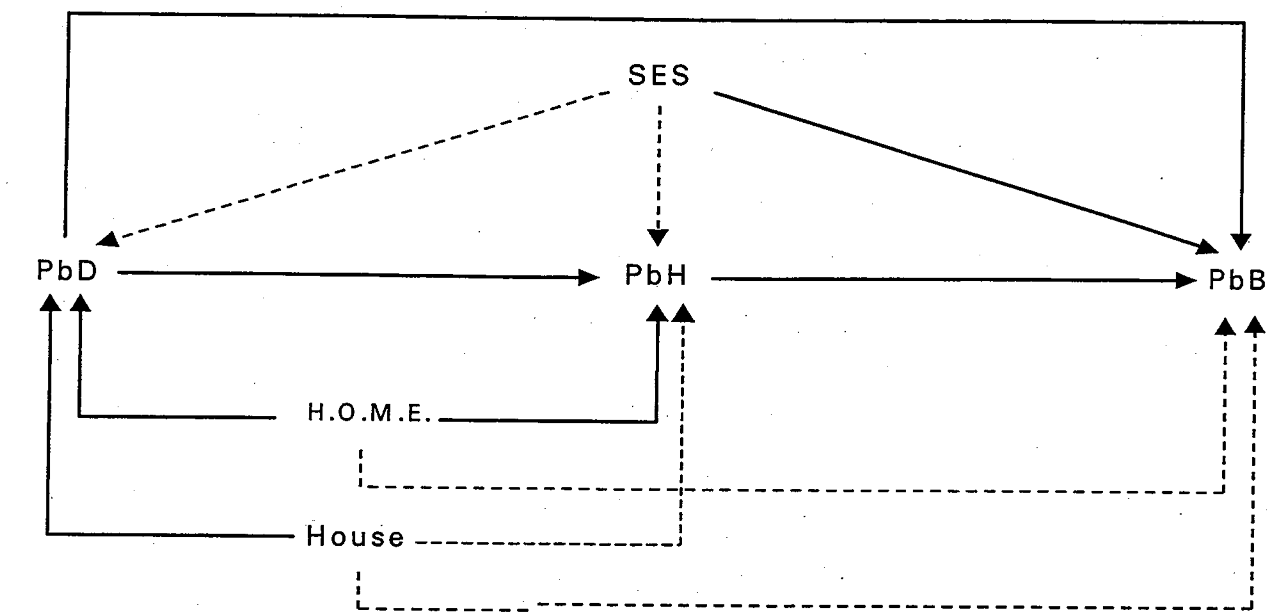
Note: Solid lines represent significant pathways and dotted lines represent non-significant pathways.

Figure D-1. Statistically Significant Pathways from *Exterior Surface Dust Lead, Interior House Dust Lead and Childhood Lead Exposure in an Urban Environment,* by Bornschein, et al. [2]



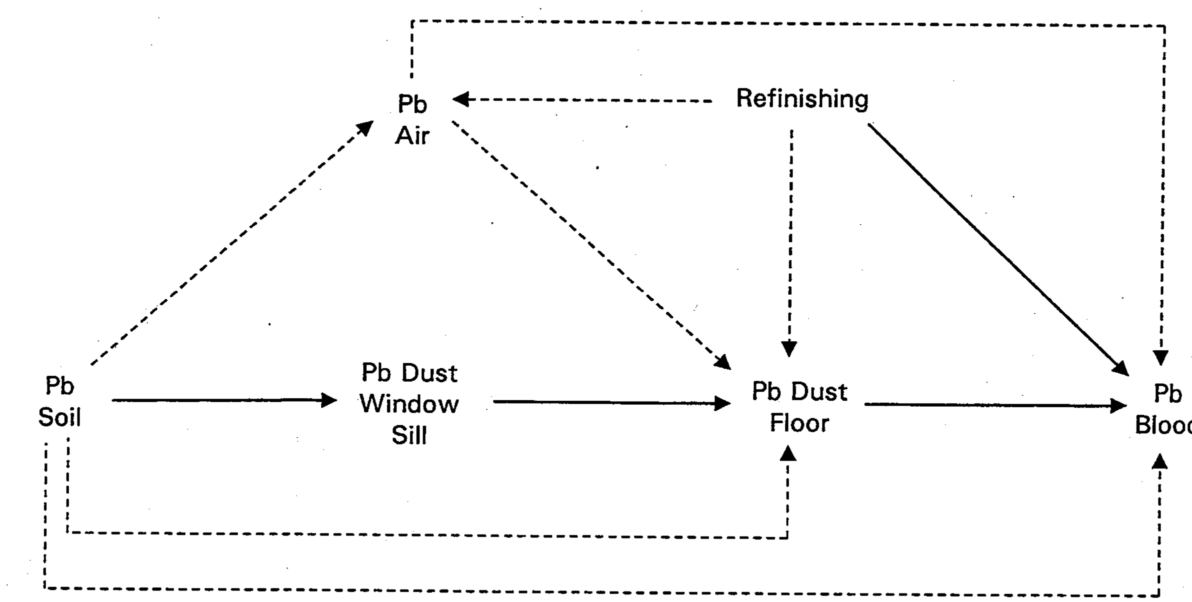
Note: Solid lines represent significant pathways. Arrows represent presumed direction. No arrow means no direction was presumed. No line means the pathway was not significant.

Figure D-2. Statistically Significant Pathways from *Soil-Lead – Blood Lead Relationship in a Former Lead Mining Town,* by Bornschein, et al. [17].



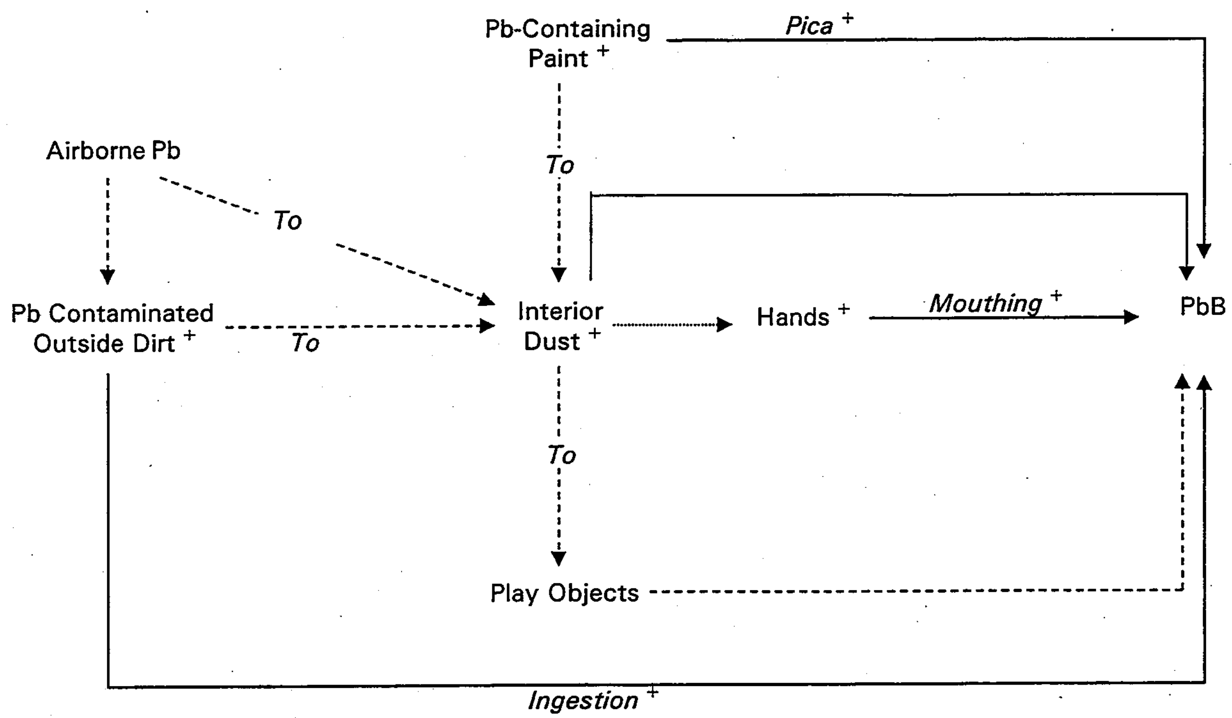
Note: Solid lines represent significant pathways and dotted lines represent non-significant pathways.

Figure D-3. Statistically Significant Pathways from *The Influence of Social and Environmental Factors on Dust Lead, Hand Lead, and Blood Lead Levels in Young Children*, by Bornschein, et al. [1].



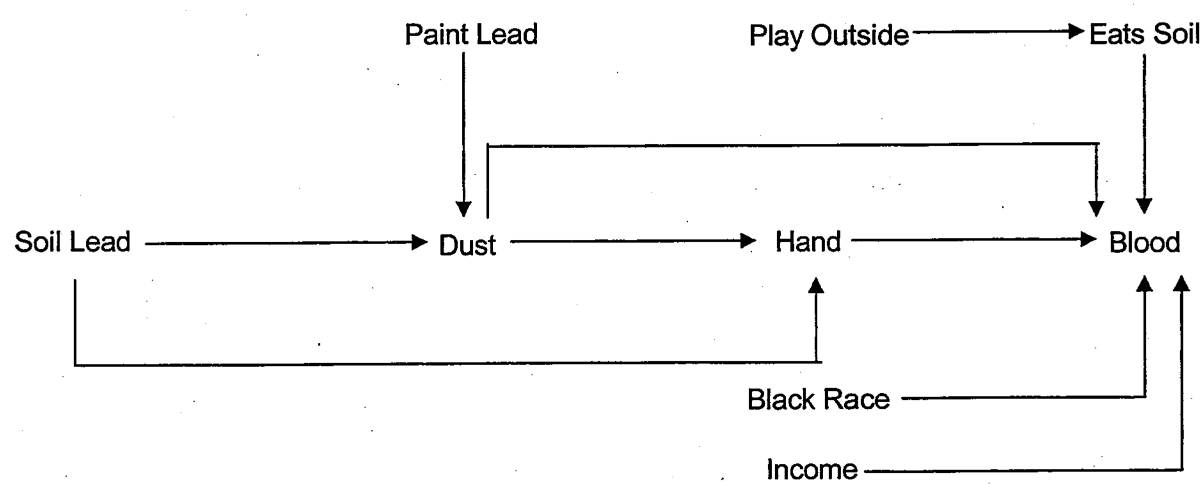
Note Diagram was selected as most representative of the analyses done in this article. Solid lines represent significant pathways and dotted lines represent non-significant pathways.

Figure D-4. Statistically Significant Pathways from *Pathways of Lead Contamination for the Brigham and Women's Hospital Longitudinal Study*, by Menton, et al. [7].



Note: Diagram was selected as most representative of the analyses done in this article. Solid lines and plus signs represent significant correlations and dotted lines represent hypothesized pathways.

Figure D-5. Statistically Significant Pathways from *Dust Lead Contribution to Lead in Children*, by Sayre [18].



Note: Solid lines represent the pathways represented and assumed to be statistically significant.

Figure D-6. Statistically Significant Pathways from *Pathways of Lead Exposure in Urban Children*, by Lanphear et al. [19].

APPENDIX E

Structural Equation Modeling (The CALIS Procedure)

This section briefly describes the SAS procedure, PROC CALIS (CALIS), that was used in all the structural equation modeling (SEM) for this report.

Background

The SEM models divide the explanatory variables into exogenous and endogenous variables. The endogenous variables in the analyses of this report were blood-lead, hand dust-lead, floor dust-lead, interior entryway dust-lead, window sill dust-lead and window well dust-lead, while the exogenous variables were exterior entryway dust-lead, soil-lead, mouthing habits of children, an indicator of water-lead, an indicator of renovation and remodeling activities, air duct dust-lead, paint-lead indicators, and the carpeting indicator variables.

The Model

In CALIS there are several options for calculating the parameter estimates in the model. For this analysis, the LINEQS method was chosen using the Newton-Raphson optimization method with maximum likelihood estimation. The structure of the SEM is

$$\eta = \beta\eta + \gamma\xi$$

where β and γ are coefficient matrices and η and ξ are vectors of random variables. The components of η correspond to the endogenous variables expressed as a linear combination of the remaining endogenous variables, of the exogenous variables of ξ, and of a residual component in ξ. The coefficient matrix β describes the relationships among the endogenous variables in η. The coefficient matrix γ explains the relationships between the endogenous variables of η and the exogenous and error components of ξ.

The parameters are estimated using maximum likelihood estimation (MLE) criterion and an iterative a non-linear optimization algorithm (Newton-Raphson) that optimizes a goodness-of-fit criterion F. The fit criterion for the maximum likelihood estimation is

$$F_{ML} = Tr\,[SC^{-1}] - n + \ln \det\,[C] - \ln \det\,[S]$$

where n is the number of variables, S is the sample covariance matrix, and C denotes the predicted moment matrix. This can also be expressed by the generally weighted least-squares criterion:

$$F_{GWLS} = \frac{1}{2}\,Tr[W^{-1}(S-C)^2]$$

where W is the weight matrix, S is the sample covariance matrix, and C is the predicted moment matrix. For the normal theory maximum-likelihood, W is the iteratively updated predicted moment matrix C. The values of the maximum-likelihood function F_{ML} and the generally weighted least-squares criterion F_{GWLS} with W = C are asymptotically equivalent. Then the approximate standard errors can be computed as the diagonal elements of the matrix

$$\frac{c}{NM} * \left[H^{-1}\right]$$

where N is the sample size, NM = N - 1 if the correlation or covariance matrix is analyzed, H is the approximate Hessian matrix of F evaluated at the final estimates, and c = 2 for the maximum likelihood method. If a given correlation or covariance matrix is singular, PROC CALIS computes a generalized inverse of the information matrix either by the Moore-Penrose inverse or a G2 inverse method, depending on the G4 specification. The Moore-Penrose inverse uses an eigenvalue decomposition and the G2 inverse is produced by sweeping the linearly independent rows and columns and zeroing out the dependent ones.

Goodness-of-Fit

To evaluate the models, a goodness-of-fit index (GFI) was calculated and assessed. The GFI computed by CALIS for the maximum likelihood estimation method is given by

$$GFI = \frac{1 - Tr[W^{-1}(S-C)^2]}{Tr[W^{-1}S]^2}$$

If the GFI is between 0 and 1 then the fit is considered to be good. If the GFI is negative or much larger than 1 then the data is considered to not fit the specified model.

Prediction Interval

The prediction intervals presented in Tables 6-4, 6-5, 6-6, 6-7, etc. are confidence intervals for the estimates of percent change in blood-lead levels that resulted when the geometric mean of one of the model input variables was decreased by 50%. Due to the complexity of the pathway models, the confidence bounds were based on the direct effects only. A two-sided 100(1-α)% confidence interval for the estimated percent change in blood-lead level was calculated as

$$[Y_L, Y_U] = K\hat{\beta} \pm K\hat{\sigma}\ S(\hat{\beta})$$

where

$K\hat{\beta}$ = Estimated percent change in blood-lead level.

$\hat{\beta}$ = Estimated value of the regression coefficient for the model input variable.

$S(\hat{\beta})$ = Standard error of $\hat{\beta}$.

$\hat{\sigma}$ = Residual Mean Square (MSE)

K = log(D) with D being the ratio of the model input variable value at a 50% reduction of the geometric mean to the geometric mean.

The upper and lower bounds were transformed back to the original scale to facilitate physical interpretation.

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This report presents the results of the pathways analysis of data from three major studies: the Rochester Study, the Repair and Maintenance Study, and the Comprehensive Abatement Performance Study. Data from the studies were analyzed via structural equations models to determine the significant pathways of lead in residential settings. Both environmental-lead pathways and blood-lead pathways were analyzed. Results of the environmental-lead pathways modeling were quite similar across all three studies. Blood-lead pathways results were less similar across studies. For the blood pathways models, results for models with lead loadings were very different from results for models with lead concentration. Additional analyses were conducted to examine pathways from paint on windows and doors, renovation and remodeling, carpeted floors, air ducts, and other variables for which data was available from at least one but not all of the three studies.

14. SUBJECT TERMS
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