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LEAD EXPOSURE ASSOCIATED WITH RENOVATION AND REMODELING ACTIVITIES:

SUMMARY REPORT

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for

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Contributing Organizations

This study was funded and managed by the U.S. Environmental Protection Agency. The study was conducted collaboratively by two organizations under contract to the Environmental Protection Agency, Battelle, and Midwest Research Institute. Each organization's responsibilities are listed below.

Battelle

Battelle was responsible for designing the study, recruiting participants, collecting worker questionnaire data and blood samples, creating and maintaining data bases, conducting statistical analysis, and producing the final report.

Midwest Research Institute (MRI)

MRI was responsible for field data collection of environmental samples, chemical analysis of environmental samples, and reporting of chemical analysis results.

U.S. Environmental Protection Agency

The Environmental Protection Agency was responsible for oversight in developing the study plan, managing and coordinating the study, and reviewing and editing this report. EPA Project Managers included Dan Reinhart, Darlene Watford, Susan Dillman, and Betsy Dutrow. Cindy Stroup was the Branch Chief of the Technical Programs Branch under whose direction the study was conducted.

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United Brotherhood of Carpenters

The United Brotherhood of Carpenters and Joiners of America (UBC) provided a list of current members that was used to develop the sampling frame for union carpenters for the Worker Characterization and Blood-Lead Study (WCBS). In addition, UBC reviewed the WCBS questionnaire, assisted in pretesting the questionnaire, provided assistance in recruiting their membership, and consulted in the design of the WCBS study. Special thanks go to John Repko, Sigurd Lucassen, Edward Coryell, and Terry Nelson.

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EXECUTIVE SUMMARY

The Residential Lead-Based Paint Hazard Reduction Act (Section 402; Title X) required the U.S. Environmental Protection Agency (EPA) to conduct a study of lead exposure associated with renovation and remodeling (R&R) activities (the R&R study). This study, conducted from 1993 to 1995, gathered information to be used to help determine which groups of people conducting R&R activities require training, certification, or educational materials. The study was designed to satisfy two objectives:

1. Determine the extent to which persons engaged in various types of R&R activities are exposed to lead.

2. Determine the extent to which persons engaged in various types of R&R activities disturb lead and create a lead-based paint hazard on a regular or occasional basis to building occupants or other exposed individuals.

The R&R study was conducted in several steps. The first step was an extensive literature review and information gathering effort directed at accumulating all currently available information on lead exposure related to R&R activities. The second step, EPA's first data collection effort on the study, focused on measuring environmental lead produced by the conduct of various R&R activities. This step, known as the Environmental Field Sampling Study, collected 90 personal air samples and 556 settled dust samples to assess potential exposure to R&R workers and building occupants resulting from selected R&R activities. In the third step, known as the Worker Characterization and Blood-Lead Study, blood-lead measurements and questionnaire information were collected from 585 R&R workers (a different set of workers from those participating in the Environmental Field Sampling Study) to (1) characterize blood-lead concentrations in specific worker groups, (2) determine if specific worker groups or specific R&R activities are associated with increases in blood-lead concentrations, and (3) provide information to develop worker activity profiles. An additional step in the R&R study, currently in the design stages, will be a retrospective study to evaluate the impact of the conduct of R&R activities on elevated blood-lead concentrations in children. This study, known as the Wisconsin Children's Study and conducted jointly with the University of Wisconsin and the State of Wisconsin Public Health Department, will compare the incidence of R&R activities in dwelling units containing a child with elevated blood-lead concentration to that in dwelling units not containing children with elevated blood-lead concentrations.

For many R&R activities conducted in the Environmental Field Sampling Study, airborne lead levels taken within workers' breathing zones, measured in micrograms lead per cubic meter ($\mu g/m^3$) of air, were often high when compared to the OSHA Permissible Exposure Limit (PEL) of 50 $\mu g/m^3$. These levels, representing an average exposure for a worker over the duration of performing R&R activity, averaged greater than 100 $\mu g/m^3$ for paint removal, interior demolition, and sawing activities, and greater than 49 $\mu g/m^3$ for interior surface preparation and central heating system maintenance/ repair. However, only one out of 581 workers whose blood-lead

concentrations were measured in the Worker Characterization and Blood-Lead Study had a blood-lead concentration greater than 40 micrograms per deciliter (µg/dL). In fact, blood-lead concentration exceeded 25 µg/dL in only 7 of the 581 workers (1.2%) and exceeded 10 µg/dL in only 50 of the 581 workers (8.8%). Thus, study results show little evidence of elevated blood-lead concentrations in workers (i.e., concentrations greater than 40 µg/dL, which is the current level set by the Occupational Safety and Health Administration (OSHA) at which full medical surveillance of a worker is required), despite the potential for high airborne lead levels within workers' breathing zones that can result from performing R&R activities.

Assessing occupant exposure is more difficult compared to worker exposure. In this study, occupant exposure was characterized by measuring lead levels in environmental dust. With the exception of carpet removal and drilling into plaster, all R&R activities deposited significant amounts of lead onto the floors, ranging from 328 micrograms per square feet (µg/ft^2) for sawing lead-based plaster to 42,900 µg/ft^2 for paint removal. These results indicate that there is a potential for significant amounts of lead to be disturbed by R&R activities, well over the current EPA guidance of 100 µg/ft^2 for floors. Occupants could be exposed to this lead if appropriate containment and cleanup practices are not employed. However, the extent to which this potential exposure translates into an actual internal dose for occupants, as well as any health effects, is unknown. The impact of R&R activities on children's blood-lead concentration will be investigated further in the Wisconsin Children's study.

In general, R&R activities that have the greatest potential for pronounced disturbance of lead-based paint have the highest potential for generating lead exposure. Paint removal and demolition activities resulted in the greatest exposure, while carpet removal was associated with the least exposure. This finding was consistent for both environmental and blood-lead measurements.

1.0 INTRODUCTION

Lead poisoning has long been recognized as one of this country's most important environmental health problems. With the phase-out of lead in gasoline in the United States that occurred from the late 1970s through the 1980s, lead-based paint is now considered the primary source of lead exposure, particularly for children and construction workers. Disturbing *intact* lead-based paint surfaces during R&R activities may result in significant lead exposure for both workers and building occupants. Extensive R&R is often performed in older homes or public buildings which have a high probability of containing lead-based paint.

On October 29, 1992, the United States Congress enacted the Residential Lead-Based Paint Hazard Reduction Act (Title X of HR 5334). This includes Title IV of the Toxic Substances Control Act that requires the U.S. Environmental Protection Agency (EPA) Administrator to conduct a study of lead exposure associated with R&R activities. In particular, paragraph (2) of Section 402 (c) states:

> *The Administrator shall conduct a study of the extent to which persons engaged in various types of renovation and remodeling activities in target housing, public buildings constructed before 1978, and commercial buildings are exposed to lead in the conduct of such activities or disturb lead and create a lead-based paint hazard on a regular or occasional basis.*

The results of the above study, hereafter referred to as the Renovation and Remodeling (R&R) study, are documented in three reports:

- "Lead Exposure Associated With Renovation and Remodeling Activities: Summary Report"

- "Lead Exposure Associated With Renovation and Remodeling Activities: Environmental Field Sampling Study," a technical report on environmental measurements of lead associated with renovation and remodeling. (This report also includes the results of the literature review and a summary of data collected from other extant sources.)

- "Lead Exposure Associated With Renovation and Remodeling Activities: Worker Characterization and Blood-Lead Study," a technical report on blood-lead levels and work practices of R&R workers.

This report, the R&R Summary Report, presents overall results and conclusions of the effort undertaken by EPA. Technical details concerning methodology and derivation of results can be found in technical reports for the Environmental Field Sampling Study, hereafter referred to as the Environmental Study, and the Worker Characterization and Blood-Lead Study, hereafter referred to as the Blood-Lead Study.

1.1 SCOPE AND OBJECTIVES

The scope of the study mandated by the Title X legislation called for an assessment of lead exposure for different categories of:

- Individuals (specifically R&R workers, building occupants, and other exposed individuals)

- Environments (specifically private housing constructed before 1978, public buildings constructed before 1978, and commercial buildings)

- R&R activities.

Public housing constructed before 1978, known as *target housing*, represented one environment category in which lead exposure was to be assessed, while public or commercial buildings were placed into one of two additional categories, according to whether or not children regularly inhabited the buildings.

After consulting with other government agencies, lead poisoning prevention experts, industry representatives, labor unions, and other concerned groups, the EPA identified eleven categories of R&R activities with potential for lead exposure that could be addressed by this study. These eleven categories of R&R activities, subsequently called ***target activities,*** were:

1. Paint removal
2. Surface preparation
3. Removal of large structures
4. Window replacement
5. Enclosure of exterior painted surfaces (i.e., siding)
6. Carpet or other floor covering removal
7. Wallpaper removal
8. HVAC (central heating system) repair or replacement including duct work
9. Repairs or additions resulting in isolated small surface disruptions
10. Exterior soil disruption
11. Major renovation projects involving multiple target activities.

The information collected under the scope of the R&R study is to be used to help determine which groups of people require training, certification, or educational materials because of the potential lead exposure associated with activities they perform. The study was designed to satisfy two objectives:

1. Determine the extent to which persons engaged in various types of R&R activities in target housing, public buildings constructed before 1978, and commercial buildings are exposed to lead.

2. Determine the extent to which persons engaged in various types of R&R activities disturb lead and create a lead-based paint hazard, on a regular or occasional basis, to occupants or other exposed individuals.

The R&R study addressed these objectives by collecting information that could be used to assess lead exposure associated both with specific R&R activities and with different R&R worker groups. Two data collection efforts were conducted in this study to collect the following information:

1. Environmental measurements of lead, primarily personal air and settled dust samples, to measure potential lead exposure to workers and occupants. Environmental measurements of lead were collected during the specific R&R activities in Baltimore, Maryland; Columbus, Ohio; Oakland, California; St. Louis, Missouri; and Denver, Colorado.

2. Blood-lead measurements and questionnaire information from R&R workers to assess worker exposure and help characterize R&R work practices. Blood-lead measurements were collected from 581 R&R workers in Philadelphia, Pennsylvania, and St. Louis, Missouri.

The environmental sampling process was independent of the worker blood and questionnaire data collection. No R&R workers participating in the blood and questionnaire data collection were involved in R&R activities associated with environmental sampling.

1.2 PEER REVIEW

The Summary Report, as well as both the Environmental Field Sampling Study (EFSS) report and the Worker Characterization and Blood-Lead Study (WCBS) report, were reviewed independently by members of a peer review panel. Comments which are important for interpreting the study results or which resulted in important modifications to the report are discussed below. All peer reviewers recommended publishing all reports with minor revisions.

A primary concern for a number of reviewers was the limited sample sizes, especially for the EFSS study. Both the Summary Report and the EFSS report include a separate section which discusses data gaps and data limitations. In addition, the sample size consideration has been highlighted through characterization of the EFSS independent monitoring jobs as case studies and through judicious use of language such as "potential for disturbing significant amounts of lead during R&R activities" that do not overstate conclusions that can be drawn from this data. Sample sizes are discussed and documented throughout all reports.

Related to the sample size issue, was concern over the number of statistical analyses conducted and the exploratory nature of some analyses. Additional cautionary language was added to the reports to warn of exploratory analyses, the effect of multiple statistical comparisons, and the limitation of small sample size on the ability to detect statistical significance.

Another concern expressed by reviewers was the relevance of abatement data to an exposure assessment for R&R workers, and similarly the effect of using trained abatement workers for some of the work conducted in the EFSS. Several sections of the EFSS report address these concerns directly. Section 2.1, Relevance of Information on Abatement, and Section 2.2, Characterization of Renovation and Remodeling, discuss the differences between abatement work and renovation and remodeling. Section 5.0, Overview of Recruitment, addresses the criteria applied in the EFSS for accepting jobs and workers as representative of typical R&R work. Professional abatement workers in the EFSS did wear respirators and follow abatement personal hygiene procedures to protect themselves. However, they did not follow standard abatement procedures, such as use of wet methods, and were instructed to perform the tasks as they are typically conducted in an unregulated environment. For example, demolition was conducted dry with hammers and crow bars, and sawing was conducted dry with a circular saw and no HEPA attachment. Since no dust minimization procedures were used, the work was considered representative of typical renovation and remodeling work. On the other hand, available data sources from professional abatement work that did involve dust minimization were not included in any data summaries.

Several comments related to clarification of the terms "surface preparation" and "paint removal." Although there is certainly overlap between the two activities, there was general concurrence among all parties consulted during the design of the study that it was important to distinguish between the two activities. These terms are defined throughout the report to make as clear as possible the exact type and duration of activity that took place.

Concern was also expressed over the inability to collect both blood-lead and environmental lead measurements from the same group of workers and/or occupants. Human subjects review, for both ethical and legal reasons, would not allow measuring blood-lead concentrations for occupants (young children) before and after conduct of an activity that was suspected of causing a hazard. For workers, the difficulty in this study was *recruiting* typical R&R workers operating in an unregulated environment. For this group of workers, employers were very reluctant to participate even as the study was conducted. Contractors were concerned over lawsuits by workers in the event that the study revealed a worker's blood-lead increased as a result of a specific job they were assigned to. We had very few contractors participating in either phase of the study. Employees participated in the WCBS largely because of either their own interest or the interest and encouragement of their national and local union. Gaining access to work sites for environmental and biological sampling would have required participation of the contractors, homeowners, and workers. If such sampling was conducted under forced cooperation, then the results may have been biased. If the study had focused on lead abatement workers this may not have been a problem, but with a focus on typical R&R workers who were not, at the time of this study, using worker protection practices, there were many problems recruiting contractors to participate. In short, the difficulty in recruiting contractors was in getting at the population of interest: unregulated R&R workers not specializing in lead abatement.

One reviewer requested more information to show that the QC data are consistent with the statistical analysis applications and results. As a result of this comment, more documentation

was added to the reports, including references to appendices and quality assurance project plans; and inconsistencies in the presentation of QC results were resolved and clarified.

EPA has established a public record for the peer review under administrative record AR152, "Lead Exposure Associated with Renovation and Remodeling Activities Peer Review." The 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.

2.0 CONCLUSIONS

This chapter presents conclusions drawn from the information obtained in the R&R Study. For a detailed presentation of study design and results, see Chapters 3 and 4, respectively.

Overall Conclusions

The results of this study indicate that R&R workers may be exposed to high levels of environmental lead while conducting certain activities in certain environments. However, there is little evidence of elevated blood-lead concentrations in a population of R&R workers who conduct a wide variety of activities. Elevated blood-lead concentrations are defined as concentrations above 40 µg/dL, the current Occupational Safety and Health Administration (OSHA) level at which full medical surveillance of a worker is required. It is possible that specialized groups of R&R workers exist who may be more highly exposed, for example, workers specializing in historic renovations. However, the R&R study included workers in cities with documented lead problems who were conducting a significant amount of work in older buildings. In this regard, study results were weighted toward highly exposed general R&R workers. However, only one out of 581 participating workers had a blood-lead concentration greater than 40 µg/dL. Only seven out of 581 participating workers had a blood-lead concentration greater than 25 µg/dL.

Because low blood-lead concentrations were observed among R&R workers, long-term occupant exposure should be stressed when determining the need for worker training, certification or educational materials. In this study, occupant exposure was characterized by measuring lead levels in environmental dust. This study indicates that there is a potential for disturbing significant amounts of lead during R&R activities which could result in occupant exposure if appropriate cleanup and contamination practices are not conducted. However, the extent to which this translates into an actual internal dose and the resultant health effects are unknown.

Worker Exposure

Airborne lead levels in a worker's breathing zone, representing an average exposure over the duration that R&R activity was performed, were often very high during many R&R activities. These levels averaged greater than 100 $\mu g/m^3$ (micrograms of lead per cubic meter of air) for paint removal, interior demolition, and sawing activities, and greater than 49 $\mu g/m^3$ for interior surface preparation and disturbance of the central heating system ductwork. Average levels were considerably lower (< 20 $\mu g/m^3$) for drilling, carpet removal, window replacement, and exterior surface preparation. Note that these personal exposure measurements reflect only the period of conducting the specific R&R activity and do not represent average exposures over an 8-hour day for a worker. In addition, results were based on selected case studies and small sample sizes.

Paint removal, window replacement, and interior demolition were associated with a statistically significant increase in workers blood-lead concentrations. Significance was determined at the 0.05 level, meaning that the probability that the increases were only due to

chance was no higher than 0.05. However, the estimated increase was so small that it is not meaningful from a practical standpoint.

In general, R&R activities that have the greatest potential for pronounced disturbance of lead-based paint have the highest potential for generating lead exposure. Paint removal and demolition activities resulted in the greatest exposure, while carpet removal was associated with the least exposure. This finding was consistent for both environmental and blood-lead measurements.

The environmental (airborne) and blood-lead results, however, produce divergent conclusions when making comparisons to current regulatory standards. In the Environmental Study, workers were exposed to high levels of airborne lead, often estimated to exceed the OSHA Permissible Exposure Limit (PEL) of 50 $\mu g/m^3$. On the other hand, blood-lead concentrations for workers in the Blood-Lead study were generally low, with less than 10% of the workers (52 of 581) having a blood-lead concentration greater than 10 µg/dL, less than 1.5% (7 of 581) with a blood-lead concentration greater than 25 µg/dL, and only one worker with a blood-lead concentration greater than 40 µg/dL, the level which requires full medical surveillance. Two factors may help explain this disparity in conclusions:

- R&R work is extremely varied, with exposure occurring sporadically and perhaps infrequently both within and across work days
- The study purposely selected buildings with substantial amounts of lead paint for collecting the environmental measurements.

A survey of 585 union carpenters and persons who worked for independent R&R contractors indicated that:

- The workers conducted a wide variety of R&R activities
- 90% of the workers did not use a respirator
- 89% of the workers did not use lead abatement cleanup methods, while 99% did use broom cleanup
- 97% of the workers used dry paint removal methods
- 67% of the workers had not received any materials on lead hazards, and 87% had received no lead exposure training.

Occupant Exposure

Occupant exposure to lead in buildings was assessed by analyzing samples of dust deposited as a result of R&R activities. With the exception of carpet removal and drilling into plaster, all monitored activities deposited considerable amounts of lead, well over the current EPA

guidance of 100 µg/ft^2 for floors. Paint removal, demolition, sawing, and disturbing central heating system ductwork were more likely to cause airborne lead to scatter and settle over a widespread area, while window replacement and drilling confined the disturbed lead to a smaller area. Simple broom and shop-vacuum cleanup resulted in substantial reduction in the total amount of lead available to occupants. However, as the distance from the activity increased, the cleanup left more lead in the dust left behind. In addition, the average amount of lead left behind after cleanup often remained above EPA's current guidance on bare floor dust levels (100 µg/ft^2).

3.0 DESIGN OF THE STUDY

The R&R study, conducted from 1993 to 1995, gathered information to address how R&R workers are exposed to lead while engaged in various types of R&R activities and how they disturb lead in the process, thereby creating a lead-based paint hazard to building occupants and other exposed individuals. The initial phase of the R&R study involved an extensive literature review and information-gathering process to uncover available information on lead exposure related to R&R. This phase was conducted in concert with the development of EPA guidelines for R&R — "Reducing Lead Hazard When Remodeling Your Home." In addition to the literature review, over 200 individuals or groups involved in lead research and/or policy-making were contacted. These contacts included national committees, major trade industries, published authors, federal and state agencies, academia, and medical institutions. With the exception of paint removal, little information was available for an exposure assessment of R&R activities. As a result, new data would be required to address the study objectives. Complete details of the literature review and information-gathering process are presented in Chapter 2 of the Environmental Study technical report.

Once the need for further data collection was identified, it was necessary to determine whether blood-lead or environmental lead would be measured, both of which have been used in the past to assess human exposure to lead. The advantages and disadvantages of each approach were considered. A study assessing blood-lead concentrations provides for direct measurement of an internal (absorbed) dose of lead. However, blood-lead concentrations are associated with many secondary factors (such as age, nutrition, and smoking) and by historical as well as recent exposure. A study assessing measurements of lead in the environment (dust, air, or soil) makes a direct link between R&R activities and measurements of lead disturbance. However, these measurements serve only as estimates of the amount of lead available for potential inhalation or ingestion, therefore representing only a potential internal dose to humans.

An optimal study design would involve measuring worker and occupant blood-lead concentrations and environmental-lead levels before, during, and after conducting R&R activities. However, measuring blood-lead concentrations before and after an activity was not feasible for ethical and legal reasons. Measuring environmental lead levels before and after an activity is complicated by serious recruitment and liability problems, because of the desire to target typical R&R jobs in an unregulated environment.

The study design approach circumvented these problems by defining two principal data collection efforts: one characterizing environmental lead disturbance resulting from R&R activities and the other focusing on the effect of R&R activity on worker blood-lead concentrations through a retrospective study. A follow-on study to assess the relationship between incidence of R&R activity and elevated blood-lead concentration in children is currently in the design stages.

The overall design and coordination of the R&R study is presented in Figure 1. All aspects of the field work involved in the R&R study were documented and submitted to both contractor and EPA Human Subjects Review Committees for approval. All procedures conducted in this study complied with the requirements of these committees, as specified in the study's Quality Assurance Project Plan.

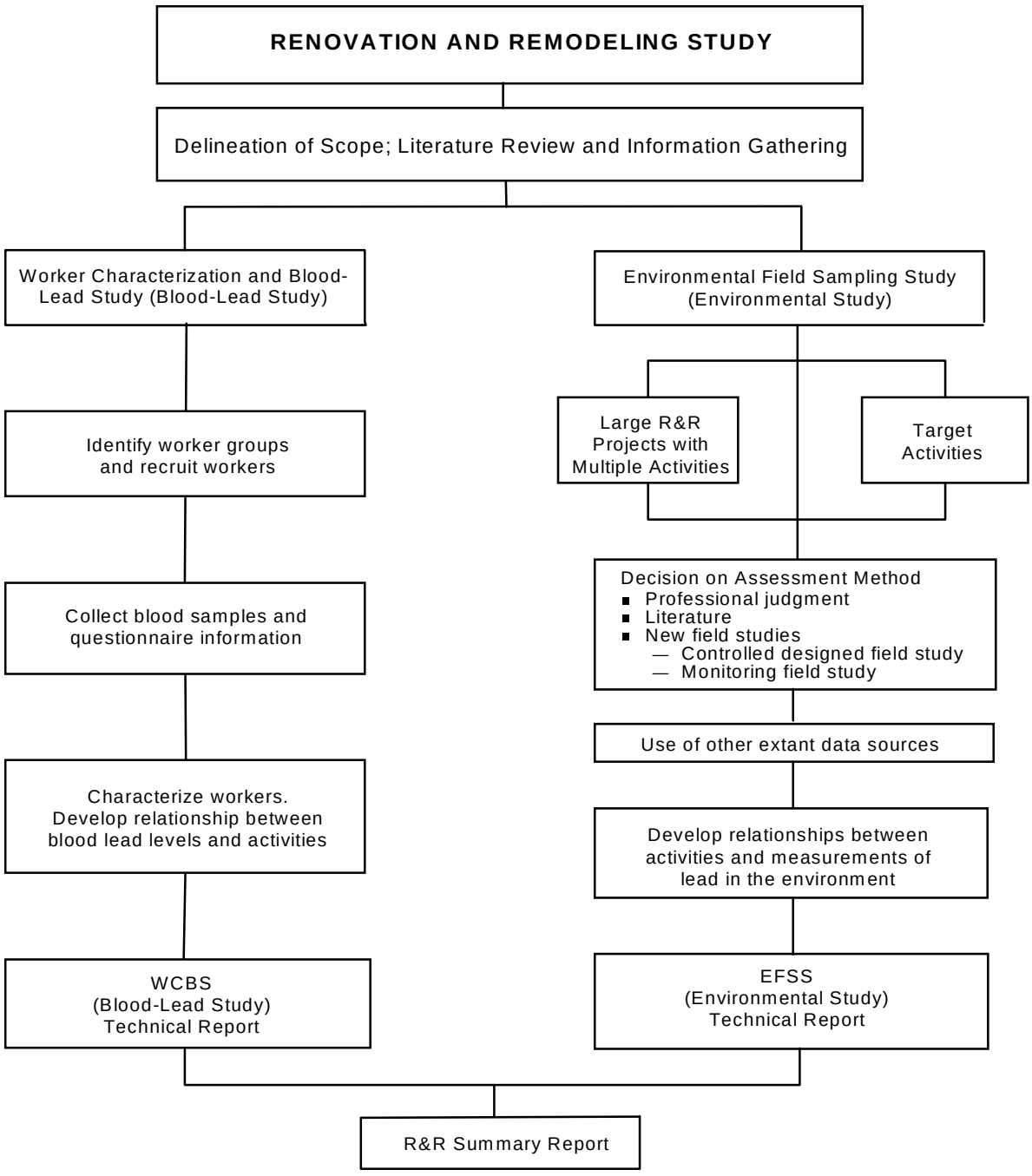


Figure 1. Overall Design Structure of the Renovation and Remodeling Study

3.1 DATA COLLECTION

Environmental Study

The first data collection effort of the R&R study was for the Environmental Study, which assessed the relative disturbance of exposure to lead created by selected R&R activities. The Environmental Study focused on monitoring specific R&R ***activities*** rather than specific ***worker groups*** for the following reasons:

1. Focusing on activities provided the best understanding of exactly what was causing the lead exposure.

2. Focusing on activities was the most efficient way to assess a wide variety of R&R worker groups. Exposure estimates based on worker groups would be applicable only to the monitored groups. Exposure estimates based on specific activities, on the other hand, could be combined with worker profile information for any given worker group to assess that group's exposure. ***Worker profile*** information includes information on the type of activities workers conduct, the type of work practices and worker protection they use, and the percent of time they work in buildings with lead-based paint.

3. Exposure estimates based on R&R activities provide information useful in developing subsequent guidelines for R&R.

Data collected for the Environmental Study focused on six of the ten target activities: removal of large structures (demolition), window replacement, carpet removal, HVAC repair or replacement, surface preparation, and repairs with small surface disruption. Exposure associated with paint removal was not addressed because it could be documented from the literature. Exposures from exterior siding, wallpaper removal, and exterior soil disruption were not evaluated, because they were considered of secondary importance by the study design team and the individuals consulted in the information-gathering phase. It is possible that inferences about exterior siding and exterior soil abatement may be made from professional judgment and comparison with other activities. Wallpaper removal is conducted primarily by painters, who were assessed based on other activities they perform — most notably surface preparation and paint removal.

The Environmental Study was supplemented by an extensive search for other sources of data that could be used either to fulfill data requirements for a specific activity or to confirm results obtained in the Environmental Study. A detailed discussion of the Environmental Study and other sources of data that were uncovered is presented in the Environmental Study technical report, "Lead Exposure Associated with Renovating and Remodeling Activities: Environmental Field Sampling Study."

Blood-Lead Study

The second data collection effort of the R&R study was the Blood-Lead Study. The Blood-Lead Study involved collecting questionnaire information and blood-lead measurements from R&R workers to (1) characterize blood-lead concentrations in specific worker groups, (2) determine if specific worker groups or specific R&R activities are associated with increases in blood-lead concentrations, and (3) collect information to be used to develop worker profiles. The Blood-Lead Study was intended to obtain information independent from the Environmental Study that would provide a direct measure of health effects on worker exposure to lead and to validate the results of the Environmental Study. Target R&R activities examined in the Blood-Lead Study included removal of large structures (demolition), window replacement, carpet removal, HVAC repair or replacement, and paint removal/surface preparation. Post-activity cleanup was also assessed. A detailed discussion of the Blood-Lead Study is available in the Blood-Lead Study technical report, "Lead Exposure Associated with Renovating and Remodeling Activities: Worker Characterization and Blood-Lead Study."

3.2 ENVIRONMENTAL STUDY DESIGN

The overall purpose of the Environmental Study was to assess lead disturbance and exposure associated with various types of R&R activities by measuring lead in air and dust. The Environmental Study was conducted in five locations (Baltimore, Maryland; Columbus, Ohio; Oakland, California; St. Louis, Missouri; and Denver, Colorado). A total of 90 personal exposure results were reported in this study, representing each execution of a particular R&R activity within a dwelling unit by one of the 31 participating R&R workers. A total of 556 settled dust samples were collected from floors and window components in the vicinity of an activity.

3.2.1 Objectives

The objectives of the Environmental Study were to:

1. Characterize personal exposure to airborne lead for workers during the performance of different R&R target activities and combinations of activities, and determine if worker exposure to airborne lead during those activities exceed 50 $\mu g/m^3$ (the OSHA Permissible Exposure Limit on the average micrograms of lead per cubic meter of air within the worker's personal breathing zone).

2. Characterize the amount of lead disturbed that settles on building surfaces within a specified period following completion of the R&R activity.

3. Characterize the extent that lead disturbance and exposure are affected by various factors such as distance from the activity and pre-activity measures of lead in the building environment.

3.2.2 Sampling

Although the activities, buildings, and, in some instances, types of samples differed for each category of activities, the design and protocol for all environmental sampling were similar.

In general, for each monitored R&R activity, buildings containing lead-based paint suitable for typical application of the activity were selected. Environmental measurements of lead were taken before, during, and after conducting the target activity. The measurements taken in the Environmental Study include:

1. ***Personal Air Samples.*** Measures of airborne lead concentration within each worker's personal breathing zone during the activity period were obtained by taking air samples through a cassette filter mounted on the worker's lapel. An air sampler pump was used to take the sample. The activity period was defined for each specific R&R activity, but generally included immediate preparing for the activity, conducting the activity, and cleaning up. For each worker, the average exposure over the duration of the activity period was calculated in $\mu g/m^3$.

2. ***Settled Dust Samples.*** Settled dust samples were taken either from stainless steel dustfall collectors or from selected areas, such as floors, window sills, window wells, and carpets. Samples were collected at varying distances from the surfaces disturbed by the activity. Lead loadings from settled dust samples were measured as indicators of the amount of lead disturbed by the activity and made available as a potential exposure to occupants.

Difficulties in recruiting workers in "real-world" R&R jobs, along with cost constraints and the wide variety of R&R work practices and building characteristics, made it impossible to obtain a statistically-based representative sample for exposed populations and defined jobs. Therefore, the Environmental Study focused on "case studies" that were "not atypical" of R&R work as it is currently conducted. Two different approaches were taken to characterize these case studies:

1. Monitoring "real-world" R&R jobs as they occurred in the field.

2. Monitoring controlled, experimentally designed simulations of specified R&R activities in vacant buildings.

In the latter approach, the type, quantity, and characteristics of the activity were specified by the design team. The activity was conducted in buildings in the field by experienced workers who were contracted to perform the work. In this environment, simulated target activities and generic R&R tasks (e.g., cutting and drilling) were conducted to measure the lead disturbed by these activities.

3.3 BLOOD-LEAD STUDY DESIGN

The Blood-Lead Study involved a targeted survey of two groups of workers (carpenters and employees of independent contractors) in two cities (Philadelphia, Pennsylvania, and St. Louis, Missouri). The collected data included:

1. Worker blood samples that were chemically analyzed for lead

2. Questionnaire data that were used to characterize the workers and understand differences in blood-lead concentrations among them.

3.3.1 Objectives

The primary goal of the Blood-Lead Study was to collect data that would permit an assessment of the relationship between R&R activities and actual human exposure. The objectives of the study were to:

1. Determine the relationship between blood-lead concentrations and work practices or activities performed by R&R workers, after controlling for other factors that may affect worker blood-lead concentrations.

2. Determine whether the blood-lead concentrations of R&R workers in specific worker groups differ after adjusting for other factors that may affect worker blood-lead concentrations.

3. Gather information on the types of work activities and work practices in which R&R workers engage.

3.3.2 Survey Design

The target population for the Blood-Lead Study consisted of two groups of R&R workers:

- Union carpenters
- Employees of independent, non-union contractors.

Carpenters were chosen because of the wide variety of R&R activities they perform. Carpenters represent the generalists of the R&R industry, considered by some to comprise the backbone of the industry. Independent, non-union contractors were chosen because a large portion of the R&R business is conducted by these workers, and their approaches and practices may differ from union contractors. Initially, laborers were targeted as a third group, as they can be considered among the most highly exposed groups of R&R workers. For example, tearing down a wall or ceiling (rip and strip) is often performed by general laborers using pick and sledge hammer techniques. However, their union, although initially cooperative, elected not to participate in the study. As a result, it was not possible to construct a sampling frame of laborers.

Time and resource constraints prevented a nationally representative sample of workers from being selected in the Blood-Lead Study. Instead, the study targeted workers in two cities: St. Louis and Philadelphia. These cities were selected because of the support and cooperation of local union leadership, and because a large number of children with elevated blood-lead concentrations have been found in both cities. Elevated blood-lead concentrations in children were taken as an indication of potential lead exposure to workers.

Sampling frames were defined separately for each group of workers. The sampling frame for the union carpenters was based on a list of current union members provided by the United Brotherhood of Carpenters and Joiners of America (UBC) leadership in each city. The list of potential respondents for employees of independent, non-union contractors was compiled by researching the local construction/remodeling market in each city. Information for potential independent workers was obtained from the National Association of Home Builders, phone books, newspaper advertisements, public service announcements, and referrals by other workers.

Sampling methods differed for union and non-union workers. Workers from union membership lists were randomly sampled for participation in the study. Most of the non-union workers were recruited from advertisements in local newspapers.

3.3.3 Data Collected

Two questionnaires were used in the Blood-Lead Study: a telephone screening interview and a self-administered questionnaire. The purpose of the telephone screening interview was to determine eligibility of the selected workers, to recruit workers for participation in the main study, and to collect preliminary information on targeted work activities. Eligible workers were initially requested to come to a centralized location for collection of blood samples and questionnaire information. If the subject was unwilling to come to a central location, an attempt was made to recruit that person for data collection in his or her home. The vast majority of participants were willing to travel to the centralized data collection centers.

Although the questionnaire was self-administered, an interviewer was available to help the respondent or to administer the entire questionnaire, if necessary. The questionnaire collected information relevant to a worker's potential lead exposure: (a) demographics, (b) current and past work history, (c) personal characteristics and habits, (d) non-work activities, (e) medical history, and (f) previous training or knowledge about potential lead hazards in the workplace. The questionnaire was reviewed for consistency and completeness before the respondent left the data collection center.

Blood was collected immediately following administration of the questionnaire. To minimize the potential for contamination and to insure comparability to data collected in other studies, blood samples were collected by venipuncture. Blood samples were taken by trained and licensed phlebotomists.

3.4 DATA GAPS AND LIMITATIONS

Due to the vast scope of the R&R study as defined by Title X legislation, combined with time and budget constraints, recruitment difficulties, and human subjects concerns, insufficient information was available to make inferences on certain areas of interest to the study. Data gaps that remain include:

1. ***The R&R study includes no information on the relationship between R&R and occupant (children) blood-lead concentration.*** It was originally hoped that the combination of environmental measurements and worker blood-lead concentrations could provide sufficient exposure information to address regulatory needs. However, the blood-lead concentrations of R&R workers were very low, while the amount of lead distributed in the environment was very high. These conflicting outcomes imply that environmental lead may be an inadequate surrogate for measuring worker blood-lead concentration. This, combined with difficulties in determining a health-based standard for acceptable environmental lead levels, places more importance on the relationship between R&R and occupant exposure as measured by blood-lead concentrations. Therefore, a follow-on study will be conducted to evaluate the impact of the conduct of R&R activities on elevated blood-lead concentrations in children. This study will be conducted jointly with the University of Wisconsin and the State of Wisconsin Public Health Department.

2. ***Exposure of people other than occupants and workers was not assessed.*** Other potentially exposed populations include workers' families and residents of neighboring buildings.

Limitations of the data collected include:

1. ***The Environmental Study field monitoring work represents a series of case studies that were not selected by a random sampling scheme***. Generalizing the results of the Environmental Study to a broader population must be based on a qualitative assessment of how representative the case studies are of that population. However, no reason was uncovered to believe that the case studies were atypical of general R&R work as it is conducted in an unregulated environment containing high levels of lead-based paint.

2. ***The Blood-Lead Study involved a targeted survey of selected groups of R&R workers in two cities.*** Generalizing the results of the Blood-Lead Study to a broader population must be based on a qualitative assessment of how representative the targeted surveys are of that population. Again, no reason was uncovered to suspect that the targeted surveys were atypical of R&R workers conducting a variety of R&R work in cities with a documented potential for lead exposure problems.

3. ***The non-union workers in the Blood-Lead Study were largely recruited through response to advertisements.*** Whereas the union members were randomly selected from a fairly complete sampling frame, non-union workers were recruited mainly through the use of advertisements in newspapers. The recruitment process included a telephone survey that collected preliminary data on target activities conducted by each worker.

4. ***Measurements of lead distributed into the occupants' environment were collected before cleanup.*** The effect of different cleanup methods was measured for two target activities in the Environmental Study, and data were collected in the Blood-Lead Study on typical cleanup methods employed by R&R workers. However, additional information on the extent of typical cleanup would be useful.

5. ***The focus of the data collected in the Environmental Study was on target housing.*** Exposure differences between building environments from a lead abatement perspective are discussed in EPA's proposed rule 40 CFR Part 745, "Requirements for Lead-Based Paint Activities," where an argument is made that public buildings and target housing represent similar exposure environments. However, there are no data at this time to assess whether environmental exposures monitored in target housing are representative of environmental exposures encountered in public or commercial buildings.

4.0 RESULTS: EXPOSURE RELATED TO SPECIFIC R&R ACTIVITIES

A primary focus of the R&R study was to assess potential lead exposures to workers and building occupants associated with specific R&R activities. Exposure results for R&R target activities and generic R&R tasks are presented in this chapter. In Chapter 5, information on lead exposure and worker group activities is combined to assess potential exposure for a variety of worker groups. This assessment can also be performed for worker groups not directly examined in the R&R Study.

4.1 WORKER EXPOSURE

The effect of specific R&R activities on lead exposure for workers was examined in two ways: (1) environmental measurement of airborne lead concentration in the personal breathing zone of workers during specific activities and (2) estimated change in blood-lead concentration attributable to conducting specific activities.

4.1.1 Summary Measures of Worker Exposure

Table 1 presents two measures that summarize worker airborne lead exposures associated with specific R&R activities:

- The estimated geometric mean of the distribution of average personal worker exposures over the duration of R&R activity and its associated 95% confidence interval.

- The estimated percentage of workers whose average lead exposures over the duration of R&R activity are expected to be greater than 50 $\mu g/m^3$, the OSHA PEL.

These statistics are obtained from airborne lead concentrations ($\mu g/m^3$) measured through personal exposure monitoring of participating workers while conducting the activity. The table includes both R&R target activities and R&R "generic tasks" (i.e., short tasks often conducted as part of a larger R&R job).

The exposure data summarized in Table 1 represent average airborne exposure for the worker during conduct of the activity. For the generic R&R tasks the period of activity was quite brief (as little as 15 minutes). OSHA exposure limits are based on an 8-hour time-weighted average (TWA), which is an average exposure over a full 8-hour work shift. However, very few R&R activities are conducted for a full 8-hour work day. Therefore, to measure exposure related to specific activities, the Environmental Study measured average exposures only for the duration of an activity. This measurement is equivalent to an 8-hour TWA for a worker only if it is assumed that the worker conducts the monitored activity for 8 hours in a day. However, a number of personal exposure measurements in the R&R study were high enough to imply that conducting the activity for even a short period of time, with no exposure during the rest of the work day, would result in an 8-hour TWA above the OSHA PEL. For each activity, Figure 2

presents the minimum duration of activity which, on average, would be necessary to achieve an 8-hour TWA of 50 µg/m^3, based on the limited personal exposure data collected in this study.

Table 1. Summary Measures of Worker Exposure to Airborne Lead

	Number of Workers Monitored	Estimated Geometric Mean Exposure[1] ($\mu g/m^3$)	95% Confidence Interval for Geometric Mean	Estimated Percentage of Workers With Exposures Expected to Exceed 50 $\mu g/m^3$[1]	95% Confidence Interval for the Estimated Percentage of Workers
R&R Target Activities					
Carpet Removal	14	7.54	(1.74, 32.6)	14%	(3%, 43%)
Window Replacement	8	7.48	(1.13, 49.3)	6.5%	(0%, 50%)
Paint Removal[2] (Hand)	6	254.00	(23.7, 2720)	94%	(41%, 100%)
(Power)	3	571.00	(42.9, 7600)	99%	(48%, 100%)
Large Structure Removal (Interior Demolition)	20	108.00	(26.6 435)	83%	(40%, 99%)
HVAC Work	4	49.60	(11.4, 216)	48%	(10%, 90%)
Surface Preparation[3] (Interior)	31	58.20	(2.27, 1490)	52%	(23%, 80%
(Exterior)	38	4.33	(0.408, 46.0)	11%	(0%, 49%)
Generic R&R Tasks[4]					
Drilling into Wood	7	15.10	(4.57, 50.2)	18%	(4%, 51%)
Drilling into Plaster	6	6.76	(3.00, 15.3)	0%	(0%, 21%)
Sawing into Wood	6	546.00	(366, 813)	99%	(99%, 100%)
Sawing into Plaster	2	110.00	(0, 2.32x10^6)	76%	(15%, 99%)

[1] Exposures represent the average lead exposure over the period in which the activity was conducted.
[2] Consists of continuous dry sanding activities (using hand or power methods).
[3] Based on data from other sources. Surface preparation consisted of a wide variety of activities including wet and dry scraping, feathering of edges, and wet and dry sanding to prepare a surface for repainting.
[4] It could not be determined from this study how much of the difference between wood and plaster substrates was due to differences in paint lead loading versus differences in substrate.

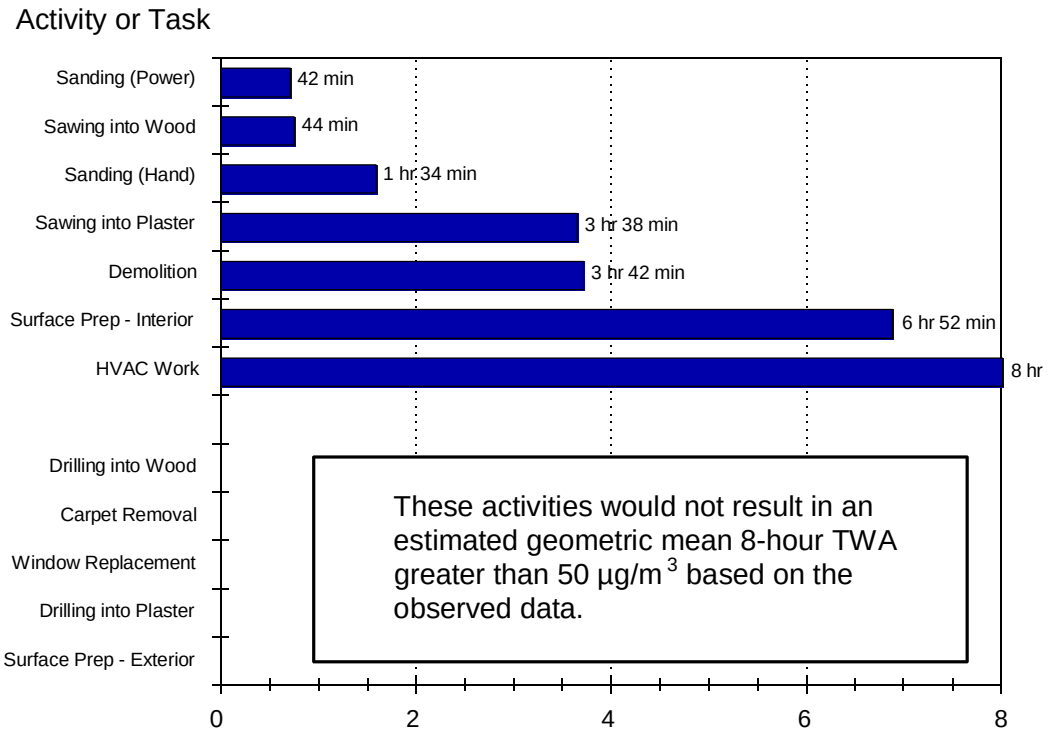


Figure 2. Hours of Activity That Would Result in an Estimated Geometric Mean 8-Hour TWA of 50 $\mu g/m^3$

Overall, average worker exposure to airborne lead over the duration of performing an activity was very high for paint removal (i.e., dry sanding), interior demolition, and sawing, and moderately high for interior surface preparation and disturbance of the central heating system ductwork. Exposures were lower for drilling, carpet removal, window replacement, and exterior surface preparation.

The last column of Table 1 presents the estimated percentage of workers performing a given activity whose average lead exposures over the duration of activity are expected to exceed 50 $\mu g/m^3$ (under the conditions of this study). Estimates range from zero percent of workers during drilling into plaster to 99 percent of workers during power sanding. High percentages were observed for activities having high disturbance potential, such as sanding, demolition, and sawing.

4.1.2 Relationship Between Blood-Lead Concentrations and Target Activities

4.1.2.1 Construction of Statistical Models

A series of statistical models were used to investigate the relationship between worker blood-lead concentration and how often a worker conducts a specific R&R activity. For each target activity, a regression model was fitted to the log-transformed blood-lead concentration using the number of days on which the activity was performed in pre-1950 housing as the primary independent variable.

Since worker blood-lead concentrations are associated with factors other than the conduct of specific target activities (e.g., age of worker or worker's home, race, or smoking practices), each regression model also incorporated these potential confounding factors. The worker questionnaire collected data on these factors, which were both related (e.g., respirator usage) and unrelated (e.g., age of worker's home) to R&R activities. Because of the large number of candidate confounding factors, preliminary analyses were first conducted to select the potential confounding factors for use in the statistical models.

When all factors were included in the regression model simultaneously, race, education level, smoking status, age of worker's home, recent R&R work in worker's home, and respirator usage were most related to worker blood-lead concentrations. In general, the estimated effect of each factor was anticipated: smokers, blacks, non-high school graduates, workers residing in older homes, and workers residing in homes that recently underwent R&R tend to have higher blood-lead concentrations. However, the observed effect associated with respirator usage was opposite of what was anticipated. The geometric mean of blood-lead concentrations of workers who wear a respirator was greater than that of workers who do not wear such respirators. One possible explanation for this result may be the fact that workers who report that they wear respirators are much more likely to be exposed to lead-based paint than those reporting otherwise.

4.1.2.2 Modeling Results

Table 2 displays, for each target activity, the estimated increase in blood-lead concentration associated with performing a target activity 10 days per month in pre-1950 buildings. Results are presented only for target activities with an estimated increase in blood-lead concentration. Results in Table 2 include an estimated base level (i.e., estimate for study workers who did not perform the given activity in pre-1950 buildings), followed by the estimated level for workers conducting the activity 10 days per month in pre-1950 buildings. Based on the covariate-adjusted model described in Section 4.1.2.1, a statistically significant relationship (at an alpha = 0.05 level) was found only for paint removal/surface preparation. Most importantly, the estimated increase in blood-lead concentration from the base level was very small (less than one µg/dL) for each target activity. The results indicate that even frequent conduct of these activities would be unlikely to raise worker blood-lead concentrations to a level that is currently considered a health risk.

Table 2. Summary Statistics Relating Worker Blood-Lead Concentration to the Frequency of Conducting Target R&R Activities

Target Activity	Change in Blood-Lead Concentration (μg/dL) for Work in pre-1950 Buildings	
	Base Level ➜	Level When Conducting the Activity 10 Days/Month
Carpet Removal	No estimated increase	
Window Replacement	4.4 ➜	4.8
Paint Removal/Surface Preparation	4.3 ➜	4.8*
HVAC Work	4.4 ➜	4.7
Large Structure Removal (Interior Demolition)	4.3 ➜	4.7

* Slope parameter estimate was significant at an alpha = 0.05 level.

4.2 OCCUPANT EXPOSURE

Potential exposures to building occupants were addressed by measuring lead in settled dust resulting from a target activity collected before cleanup activities. Pre-cleanup estimates of the lead distributed into the occupant's environment are considered bounding estimates that represent maximum levels of lead that may be left behind for potential occupant exposures.

Table 3 presents three columns of information that address potential occupant exposures. The first column is an estimate of the average amount of lead ($\mu g/ft^2$) deposited by the activity in a 6' x 1' region extending in a perpendicular direction from the activity. The relationship between the distance from the activity and the amount of lead deposited on the floor was statistically characterized for each activity and used to estimate the average amount of lead in the 6' x 1' region. The estimated amount of lead at 6 feet from the activity is presented in the second column of Table 3.

The third column of Table 3 shows the amount of activity that caused the lead loadings presented in the first two columns. In the case of window replacement, HVAC work, and large structure removal, the listed amount of activity is equivalent to the amount of activity monitored in the Environmental Study. For the other activities, however, the amount of activity (and the corresponding estimate of lead loading) has been scaled to a "standard unit of activity" chosen to be reasonably reflective of real-world R&R activity. The standard unit of activity is further discussed in the Environmental Study technical report.

Table 3. Summary Measures of Potential Occupant Lead Exposures that Can Result from Conducting Target and Generic R&R Activities

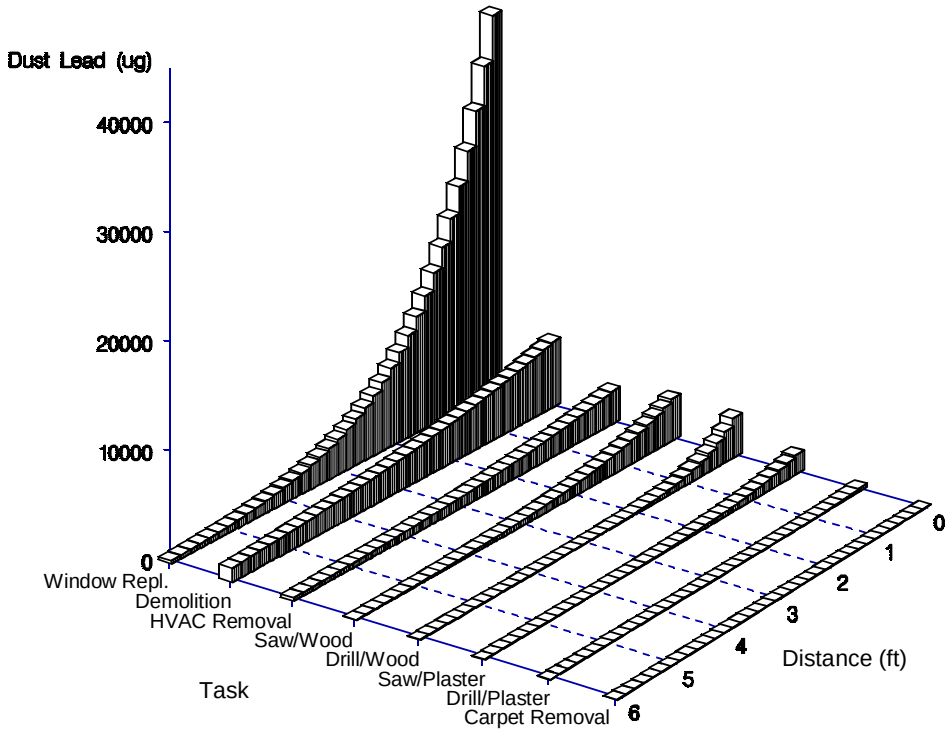
	Average Lead Loading ($\mu g/ft^2$) in Settled Dust (Measured Post-Activity, Before Cleanup)		
	Estimated Loading in a 6'x1' Region Extending from the Activity	Estimated Loading at 6 Feet from Activity	Standard Unit of Activity
Target Activity			
Carpet Removal	16.9	[1]	100 ft^2
Window Replacement	7,710.0	482	1 window
Paint Removal	42,900.0	15,500	no standard unit of activity
HVAC Work	1,290.0	414	1 room
Large Structure Removal (Interior Demolition)	3,250.0	1,530	1 room
Generic Activity			
Drilling into Wood	432.0	1.27	10 holes
Drilling into Plaster	34.5	0.04	10 holes
Sawing into Wood	999.0	105.00	1 linear ft
Sawing into Plaster	328.0	10.60	1 linear ft

[1] No samples were collected at six feet from the activity.

For each R&R activity in which a standard unit of activity was defined (i.e., all but paint removal), Figure 3 illustrates the relationship between distance extending from the area where the activity is performed and the amount of lead deposited. The amount of lead is estimated based on conducting the standard unit of activity.

Table 3 reveals that, with the exception of carpet removal and drilling into plaster, all monitored activities showed the potential to deposit considerable amounts of lead in the 6' x 1' region. Average lead loadings in this region ranged from 328 $\mu g/ft^2$ for sawing into plaster to over 40,000 $\mu g/ft^2$ for paint removal (dry sanding).

The estimates of settled dust lead loadings presented in Table 3 assume that the area was not cleaned up following the activity. To address the issue of how much lead is removed by cleanup, an additional data collection effort was designed to assess pre- and post-cleanup measurements of the lead deposited on a fresh linoleum surface after completing two generic R&R tasks (drilling into wood and dry abrasive sanding). Cleanup was conducted by one of two methods: broom sweeping and shop-vacuuming. These two methods were selected because results from the Blood-Lead Study indicate that they are used by the vast majority of R&R workers (see Section 5.1).



Note: Results are based on conducting a standard unit of activity (see Table 3).

Figure 3. Estimated Distribution of Dust Lead in a 6' x 1' Region Extending from the Activity Area for Various Activities

Table 4 presents results from the assessment of cleanup effectiveness. While the lead loading estimates in Table 3 assume no cleanup has taken place, the results in Table 4 also include the amount of lead that may be left in an occupant's environment after typical R&R activity and cleanup. Table 4 results of lead after cleanup may be considered "best-case" because:

1. These estimates represent the amount of lead remaining and the percent reduction achieved on new linoleum

2. The estimates represent cleanup of the entire area that was contaminated with lead.

The results of this assessment of the effectiveness of cleanup were:

1. Both methods resulted in a substantial reduction in the total amount of lead available to occupants. Before cleanup, the estimated total amount of lead in a 6' x 1' region ranged from 4,430 µg to 2,800,000 µg. After cleanup, the total amount of lead ranged from 232 µg to 48,100 µg, averaging a more than 95% reduction in lead.

Table 4. The Effect of Cleanup on Reducing Lead Loadings on New Linoleum Floors After Conduct of Two R&R Activities

R&R Activity	Methods of Cleanup	Time of Sample Collection	Average Lead Loading ($\mu g/ft^2$) Adjacent to the Activity	Average Lead Loading ($\mu g/ft^2$) at Six Feet Away from the Activity[1]
Drilling	Broom	After the Activity	26,700	65
		After the Cleanup	166	124
		% Reduction	99.4%	(90.8%)
Drilling	Shop-Vacuum	After the Activity	73,500	146
		After the Cleanup	360	123
		% Reduction	99.5%	15.8%
Abrasive Sanding	Broom	After the Activity	653,000	1380
		After the Cleanup	1070	828
		% Reduction	99.8%	40.0%
Abrasive Sanding	Shop-Vacuum	After the Activity	203,000	490
		After the Cleanup	808	303
		% Reduction	99.6%	38.2%

[1] Negative percentages are indicated with parentheses.

2. Although, on average, more than 95% of the lead disturbed by drilling or sanding was removed by standard broom or shop-vacuum cleanup, the average amount of lead left behind after cleanup still often remained above EPA's current guidance of 100 $\mu g/ft^2$ for floors.

3. The efficiency of cleanup, as measured by the percent reduction in lead, declines as distance from the activity increases.

5.0 RESULTS: EXPOSURE ASSOCIATED WITH SPECIFIC R&R WORKER GROUPS

As stated in Section 1.1, the information collected in the R&R study is to be used, primarily, to help determine which worker groups require training or certification because of the potential lead exposure associated with activities they perform. The exposure assessment strategy to meet this goal in the R&R study is illustrated in Figure 4.

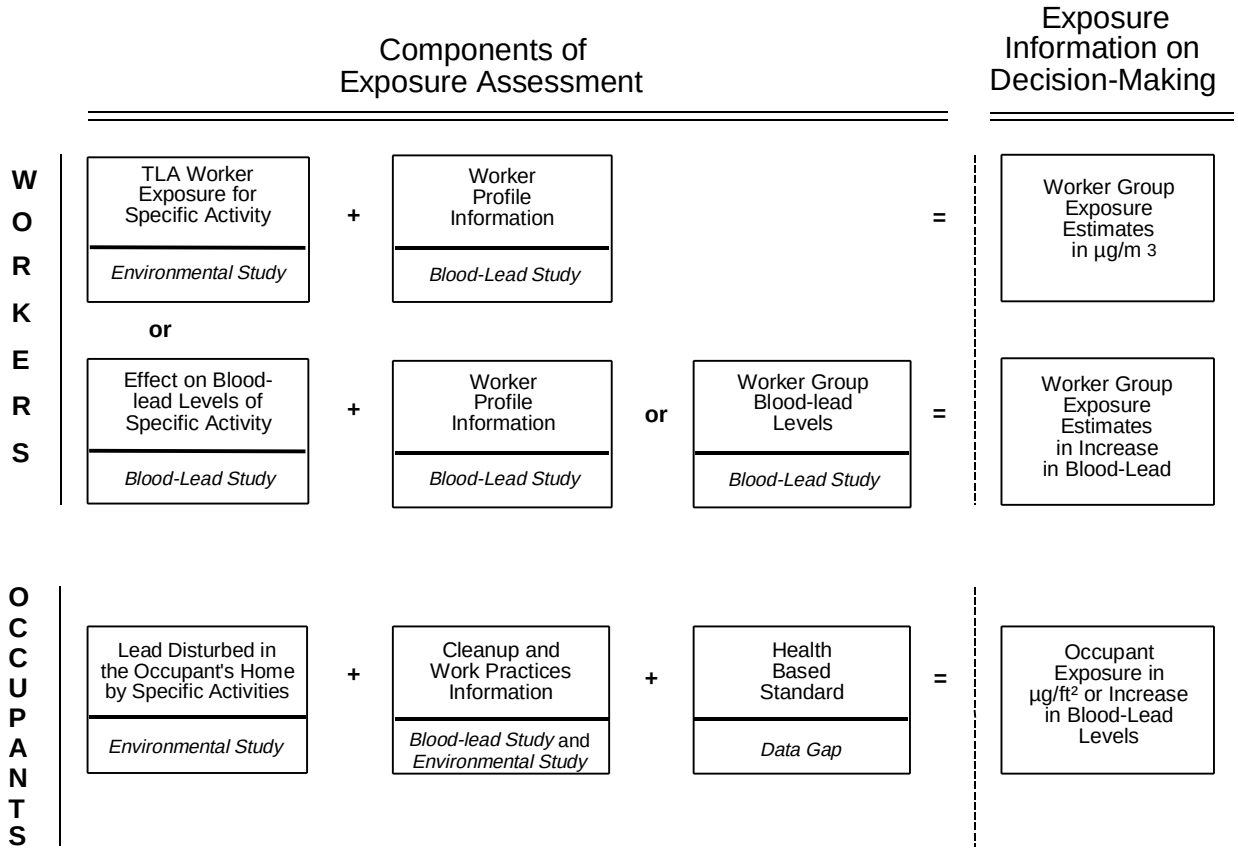


Figure 4. Exposure Assessment Strategies for R&R Workers and Building Occupants, Along with Sources of Information in the R&R Study

The strategy involves providing the components of exposure information that can be combined to make informed decisions concerning potential lead exposures to workers or occupants. For each component of information shown in the boxes on the left side of Figure 4, the source of information is listed in the bottom section of the box.

Note that certain components of information in Figure 4 are available to assess any worker group covered under the Title X legislation. For worker exposure, these components include average personal air exposure over the duration of performing activity as measured in the Environmental Study, and the increase in blood-lead concentration related to specific activities as measured in the Blood-Lead Study. For occupant exposure, these components include the lead distributed in a 6' x 1' gradient region related to specific activities. Other components of

information in Figure 4 are applicable only to the specific worker groups examined in the R&R study. Table 5 presents the number of workers in each worker group who were surveyed in the Blood-Lead Study. Information for groups other than carpenters, floor layers, and laborers is based on small sample sizes as indicated in Table 5.

Table 5. The Number of Workers Surveyed Within Each Worker Group in the Blood-Lead Study

Worker Group	Number of Workers Sampled
Union Carpenters	159
Non-Union Carpenters	105
Floor Layers	82
Laborers	56
Supervisors	57
Painters	34
Drywall Workers	64
Window Replacement Workers	14

5.1 SUMMARY OF WORKER PROFILE INFORMATION IN THE BLOOD-LEAD STUDY

Questionnaire information was collected from a total of 581 union carpenters and employees of independent contractors in the Blood-Lead Study. The questionnaire included data on how often each worker conducted specific target activities in homes of any age and in pre-1950 homes during the past 30 days. For each activity, workers indicated the number of days that activity was performed at some point in the day (not necessarily the entire day).

The workers surveyed in the Blood-Lead Study had spent an average of 17 days during the past month on general R&R, of which 11 were spent in pre-1950 homes. The most frequent activity performed was cleanup, which occurred on an average of 11 days during the month. Over all workers, large structure removal occurred on an average of 7 days during the month, paint removal on 6 days, window or door replacement on 4 days, carpet removal on 2 days, and HVAC work on 1 day.

Each worker was assigned to a worker group based on his or her job title and job activities. Table 6 presents, for each worker group, the average number of days a given target activity was conducted during the past 30 days, as well as, the average number of days that workers conducted the activity in pre-1950 dwellings. The information in Table 6 indicates that laborers, drywall workers, non-union carpenters, painters, and window and door replacement workers spent more than ten days per month performing the target activities in pre-1950 dwellings.

Table 6. Average Number of Days that Included Specific Activities for R&R Workers in the Blood-Lead Study

Worker Group		Number of Days Per Month That an Activity is Conducted By the Worker Group				
		Carpet Removal	HVAC Work	Large Structure Removal	Paint Removal	Window Replacement
Union Carpenters	All buildings	1	0	6	2	3
	Pre-1950 buildings	0	0	4	1	2
Non-union Carpenters	All buildings	2	2	9	7	6
	Pre-1950 buildings	1	1	7	6	4
Floor Layers	All buildings	6	1	1	8	1
	Pre-1950 buildings	2	0	0	2	0
Laborers	All buildings	5	4	10	9	7
	Pre-1950 buildings	4	4	7	8	6
Supervisors	All buildings	1	0	7	2	3
	Pre-1950 buildings	0	0	3	1	1
Painters	All buildings	3	1	6	14	5
	Pre-1950 buildings	3	1	4	11	4
Drywall Workers	All buildings	1	1	8	4	2
	Pre-1950 buildings	1	1	6	3	2
Window Replacement Workers	All buildings	2	2	11	7	14
	Pre-1950 buildings	2	2	10	6	11

Summary statistics on work practices over all workers are presented in the bar charts in Figure 5. These work practices include respirator usage, previous training on lead issues, methods of paint removal, and methods of cleanup. Each bar presents a percentage of workers in the given category.

Overall, 60% of the workers reported that they did not use a dust mask or respirator, 30% reported using a dust-mask, and 10% reported using a respirator. Among the eight worker groups, respirator use was most frequent for painters and laborers. Relatively few of the workers had received formal training on R&R in lead-contaminated environments (13%) or educational materials on lead exposures (33%). Of the 293 workers who had removed paint during the past 30 days, over 90% reported using dry methods (power or hand sanding, hand scraping) and only 17% reported using wet methods. Wet methods of paint removal were employed most often by drywall workers and laborers. Of the 482 workers who had performed cleanup during the past 30

days, 99% reported that they used a broom, and only 11% reported using a HEPA vacuum or wet mop. HEPA vacuum or wet mop methods were employed most often by window or door replacement workers, painters, and laborers.

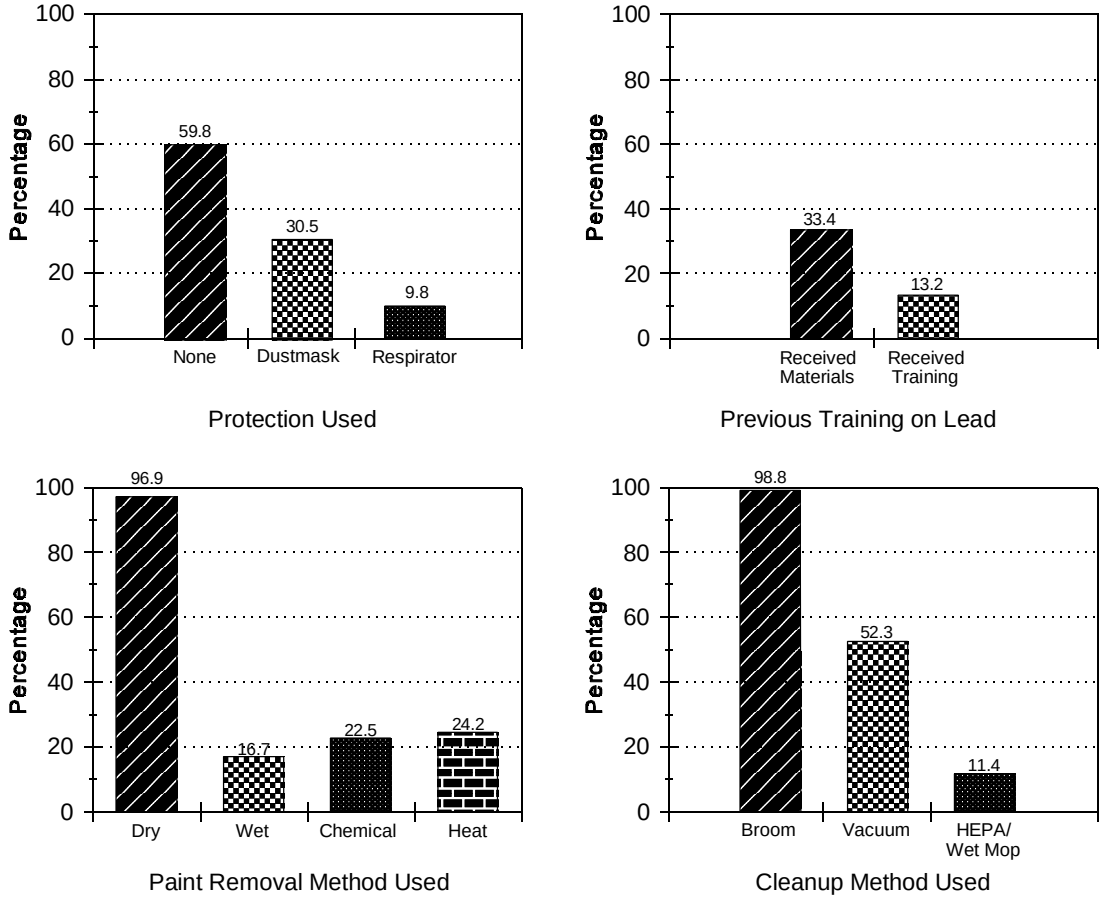


Figure 5. Trends in Work Practices as Reported by Workers in the Blood-Lead Study

5.2 WORKER EXPOSURE

Figure 6 displays a histogram of the blood-lead concentrations across 581 workers sampled in the Blood-Lead Study. These concentrations were generally low, ranging from (below the detection limit of) 1 to 55 µg/dL, with a geometric mean of 4.5 µg/dL. Less than 10% of the workers (52 of 581) had blood-lead concentrations greater than 10 µg/dL, less than 1.5% had blood-lead concentrations greater than 25 µg/dL, and only one had a blood-lead concentration greater than 40 µg/dL.

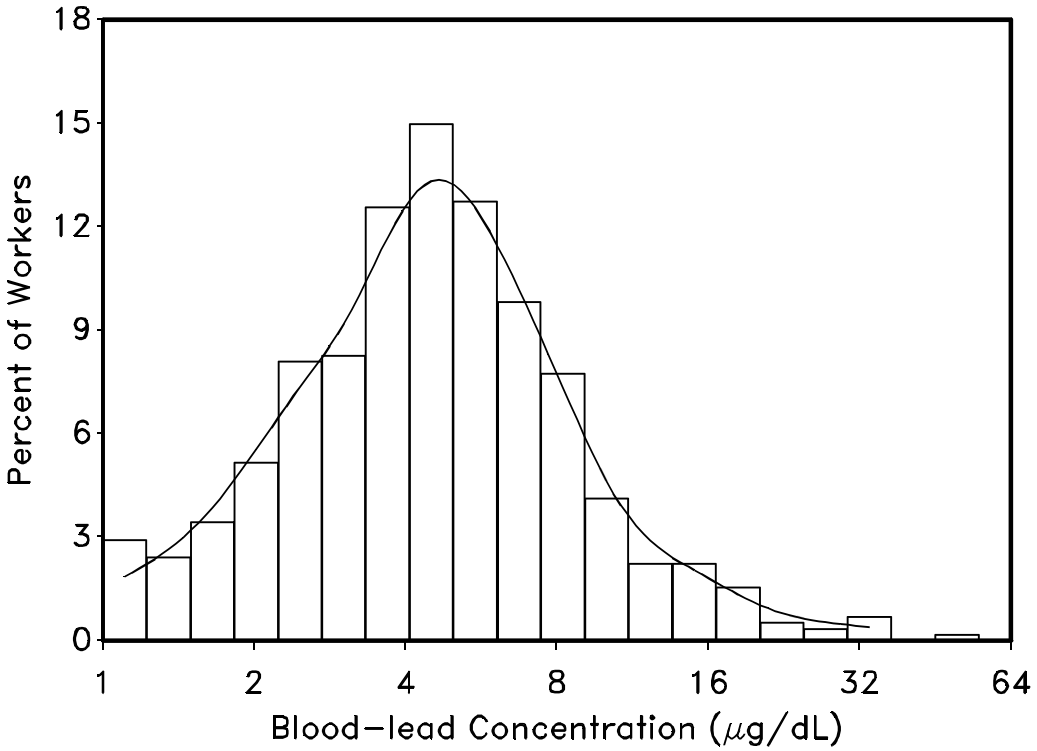


Figure 6. Histogram of Blood-Lead Concentration (Semi-logarithmic Scale) for Workers in the Blood-Lead Study

As discussed in Section 5.1, information regarding job title and primary activities was used to classify each worker into one of eight different worker groups: union carpenters, non-union carpenters, drywall workers, floor layers, laborers, painters, supervisors, and window replacement workers. A statistical model was developed to estimate geometric mean blood-lead concentrations and associated 95% confidence intervals for workers within each worker group. These estimated intervals were adjusted for the effects of the same potential confounding factors discussed in Section 4.1.2.1. The geometric mean blood-lead concentration and 95% confidence interval for each worker group are illustrated in Figure 7. Geometric mean blood-lead concentrations were low across all worker groups, with the lowest concentrations observed among floor layers (2.8 µg/dL) and the highest concentrations observed among drywall workers (6.1 µg/dL), painters (5.9 µg/dL), and window replacement workers (5.8 µg/dL).

Table 7 presents the information to be used in assessing worker exposures related to specific worker groups. The table provides, for each worker group, the number of workers monitored, geometric mean blood-lead concentration, 95% confidence interval on the geometric mean, percentage of workers who use a respirator, and percentage of workers who received some lead training. Examination of Table 7 leads to the conclusion that worker exposures, as measured by blood-lead concentrations, were low for all worker groups monitored on this study even though levels of training and respirator usage were low.

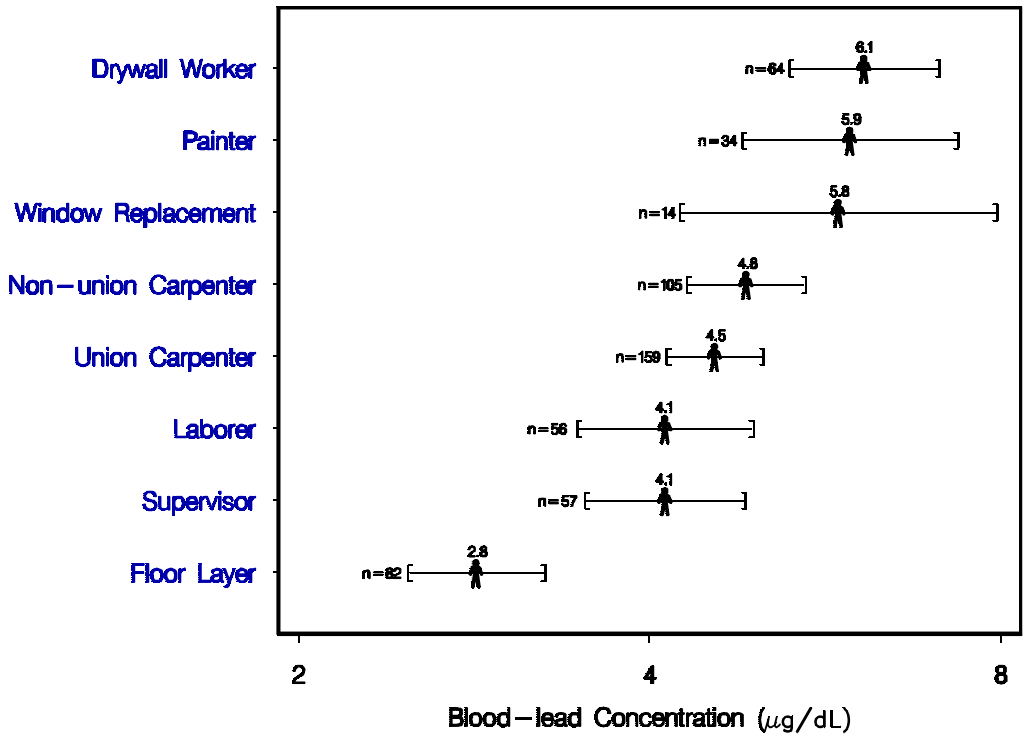


Figure 7. Geometric Mean of Blood-Lead Concentration (Adjusted for Potential Confounding Factors) and Associated 95% Confidence Intervals for Each Worker Group

Table 7. Information for an Assessment of Worker Exposures Associated with Different R&R Worker Groups

Worker Group	# Workers Monitored	MEASURES OF WORKER EXPOSURES			
		Geometric Mean Blood-Lead Conc. (μg/dL)	95% Confidence Interval on Geometric Mean	Percentage of Workers That Use a Respirator[1]	Percentage of Workers That Received Some Lead Training
Union Carpenters	159	4.5	(4.1, 5.0)	4	9
Non-Union Carpenters	105	4.8	(4.3, 5.4)	12	16
Floor Layers	82	2.8	(2.5, 3.2)	7	9
Laborers	56	4.1	(3.5, 4.9)	23	16
Supervisors	57	4.1	(3.5, 4.8)	5	23
Painters	34	5.9	(4.8, 7.3)	21	21
Drywall Workers	64	6.1	(5.3, 7.1)	2	6
Window Replacement Workers	14	5.8	(4.3, 7.9)	14	14

[1] Does not include wearing dust masks.

5.3 OCCUPANT EXPOSURE

Table 8 may be used to assess the potential lead exposure to occupants from work conducted by each of the eight worker groups. As discussed in Section 4.2, potential occupant exposures were addressed by measuring lead loadings in dust and debris that settled following completion of an R&R activity but prior to cleanup. Five target activities for which worker profile information was collected in the Blood-Lead Study are included in Table 8, along with the estimated average lead loading (per square foot) in a 6' x 1' region extending from the activity. The lead loading represents the effect of the standard unit of activity as presented in Table 3. For each worker group, the average number of days in a month that workers within the group participated in each activity is given, along with the estimated percentage of time that workers in each worker group use abatement type cleanup methods such as high efficiency particle air (HEPA) vacuuming or tri-sodium phosphate (TSP) washing.

Table 8. Information for an Assessment of Potential Occupant Exposures Associated with Different R&R Worker Groups

Worker Group	# Workers Monitored	R&R ACTIVITIES CONDUCTED BY THE WORKER GROUP					Percentage of Time that Workers Clean with HEPA Vacuum or TSP
		Carpet Removal	HVAC Work	Large Structure Removal	Paint Removal	Window Replacement	
		Estimated Average Lead Loading ($\mu g/ft^2$) in a 6' x 1' Region Extending From the Activity					
		16.9	1290	3250	42900	7710	
		Average Number of Days Per Month That the Activity is Conducted Per Worker					
Union Carpenters	159	1	0	6	2	3	0.1
Non-union Carpenters	105	2	2	9	7	6	2.4
Floor Layers	82	6	1	1	8	1	0.7
Laborers	56	5	4	10	9	7	11.0
Supervisors	57	1	0	7	2	3	0.1
Painters	34	3	1	6	14	5	7.5
Drywall Workers	64	1	1	8	4	2	3.3
Window Replacement Workers	14	2	2	11	7	14	8.5

In making conclusions about the relationship between worker group and potential occupant exposure, the average number of days in which an activity is performed by a worker group in pre-1950 homes can act as a weighting factor on the settled dust lead loading for the activity and, therefore, on potential occupant exposure. For a given worker group, as the average number of days increases, more weight should be given to the lead loading for the associated activity. However, other weighting factors need also be taken into account. These factors include:

- The extent to which lead loadings are reduced by post-activity cleanup including the use of abatement-type cleanup methods. Some of this information is provided in Table 4 and the last column of Table 8.

- The expected amount of activity to be conducted in an occupant's home. For instance, lead loadings in Table 8 for window replacement represent the effect of removing one window. Most R&R window replacement jobs would involve more than one window.

- The potential for lead dust and debris to become airborne and scatter over a wide area. Some activities (such as drilling) result in little lead distributed beyond a six foot radius while others (such as demolition) have significant potential to contaminate other areas of the house.

- The particle size and bioavailability of the lead disturbed as related to pathways of exposure (inhalation versus ingestion), effectiveness of cleanup, and an actual applied dose to occupants.

The uncertainty in all aspects of the occupant exposure information does not allow for calculation of an overall quantitative "exposure index" to be used in comparing worker groups. From the results of this study, only a general conclusion can be drawn that there is potential for significant amounts of lead to be disturbed by R&R activities that may become available for occupant exposures if appropriate cleanup and containment practices are not conducted.

6.0 REFERENCES

1. U.S. Environmental Protection Agency (EPA), December, 1995. "Lead Exposures Associated With Renovation and Remodeling Activities: Environmental Field Sampling Study." (Draft).

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3. 40 CFR Part 745, Requirements for Lead-Based Paint Activities.

4. U.S. EPA, April, 1994. "Reducing Lead Hazard When Remodeling Your Home."

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16. Abstract (Limit 200 words)

The U.S. Environmental Protection Agency, in response to the Residential Lead Based Paint Hazard Reduction Act of 1992 (Title X) conducted a study of lead exposure associated with renovation and remodeling (R&R) activities. The results of a literature review and two data collection efforts are reported. The first data collection effort, the Environmental Field Sampling Study (EFSS), collected 90 personal air samples and 556 settled dust samples to assess potential exposure to workers and occupants from selected R&R activities. The second effort, the Worker Characterization and Blood-Lead Study (WCBS), collected blood-lead measurements and questionnaire information from 585 R&R workers in two cities. The task length average exposures measured by personal air samples of R&R workers in the EFSS were often very high (greater than 50 $\mu g/m^3$). However, the blood-lead levels from R&R workers in the WCBS were quite low, with only 7 out of 581 workers above 25 $\mu g/dL$ and only one out of 581 above 40 $\mu g/dL$. The settled dust samples indicated that there is potential for significant amounts of lead to be disturbed by R&R activities, well over the current EPA guidance of 100 $\mu g/ft^2$ for floors.

17. Document Analysis

a. Descriptors
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