JANUARY 23, 2007

DRAFT FINAL REPORT
ON
CHARACTERIZATION OF DUST LEAD LEVELS AFTER RENOVATION, REPAIR, AND PAINTING ACTIVITIES

Prepared By

BATTELLE
505 King Avenue
Columbus, Ohio 43201

EPA Contract No. EP-W-04-021

Prepared For

Sineta Wooten, Project Officer
John Schwemberger, Work Assignment Manager
Samuel Brown, Deputy Work Assignment Manager

Program Assessment and Outreach Branch
National Program Chemicals Division
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue NW (7404T)
Washington, D.C. 20460

Acknowledgements

Many people contributed to the completion of this study. At EPA, Mr. John Schwemberger served as the EPA Work Assignment Manager assisted by Mr. Samuel Brown. At Battelle, Mr. Tim Pivetz served as the project manager supported by a large team of people. In alphabetical order, those who contributed significantly include Mr. Wesley Baxter, Ms. Rona Boehm, Mr. Peter Bujnak, Dr. Cynthia Cooper, Mr. Steven Gomori, Mr. Brad Goodwin, Mr. Pernell Horton, Ms. Nicole-Iroz Elardo, Mr. Darrell Joseph, Ms. Michelle Lobdell, Ms. Kathya Mahadevan, Mr. Ian MacGregor, Mr. Mark Misita, Ms. Susan Morriss, Ms. Jyothi Nagaraja, Mr. Henry Pham, Ms. Cyndi Reese, Mr. Adam Ridenbaugh, Dr. Jessica Sanford, Dr. Ketra Schmitt, Ms. Elizabeth Slone, Mr. Warren Strauss, Mr. Joseph Tabor, Ms. Rena Thomas, Ms. Stephanie Weber, Mr. Zachary Willenberg, and Ms. Jennifer Zewatsky.

The study team expresses sincere thanks to the many property owners who made their houses available for renovation work under this study, as well as to Columbus Public Schools who provided access to one of their vacant buildings. The study team also thanks the many subcontractors who supported the study including police officers in Columbus and Pittsburgh, renovation firms and the renovation workers who implemented the study protocols, abatement cleaning firms, environmental testing firms who provided XRF testing and clearance testing services, the analytical laboratory, and staff at Healthy Housing Solutions, Inc. who supported the search for potential units. The study also thanks those staff at the Ohio Department of Health, Columbus Health Department, Pennsylvania Department of Health, and Allegheny County Health Department who provided guidance and assistance along the way.

Thanks also to other staff and subcontractors who provided support to the study but are not named above. The study could not have been completed without the full effort of everyone on the team.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Glossary of Terms
for the
Field Study to Characterize Dust Lead Levels After Renovation, Repair, and Painting

Baseline Cleaning – a series of steps to remove dust that are representative of standard cleaning practices used by RRP contractors without a final EPA rule for Renovation, Repair, and Painting. These include sweeping and vacuuming with a non-HEPA vacuum.

Baseline Practices – the set of protection and clean-up practices (no use of protective plastic during work and use of baseline cleaning following work) representing typical work practices utilized for a renovation job without a final EPA rule for Renovation, Repair, and Painting.

Child-Occupied Facility (COF) – a building, or portion of a vacant building, constructed before 1978 that could be used by children under six years old, such as a daycare center or early year kindergarten at a school, and that could conceivably meet the formal definition of a Child-Occupied Facility in 40 CFR part 745.223.

Experiment – full implementation of a single phase of one job, including all work, cleaning, and environmental sampling.

Housing Unit – a structure or portion of a structure that is typically occupied by one or more persons as living quarters.

Job – a specific renovation, repair, or painting activity that is of interest for the risk assessment and economic cost-benefit analysis, such as installing a new window.

Lead-based paint – paint or other coating with lead content at or above 1.0 mg/cm^2 or at or above 0.5% by weight (5,000 µg/g).

Level or Intensity-level – one of three job categories (low, medium, or high), determined based on pre-study expectations of the amount of dust expected to be generated by each activity; because analysis of post-work lead levels indicated that these pre-assigned levels were not entirely consistent with actual dust generated, the primary analyses presented in the report summarize the renovation activities by individual job.

Observation Room – an interior room adjacent to the Tool Room but not the Work Room that represents other areas of a house impacted by interior RRP work.

Phase – one of four iterations of a job specified by the use or non-use of containment and a particular cleaning method (Phase I=plastic sheeting with specialized cleaning, Phase II=plastic sheeting with baseline cleaning, Phase III=no plastic sheeting with specialized cleaning, and Phase IV=no plastic sheeting with baseline cleaning), each implemented under comparable conditions so the effect of containment and cleaning method can each be assessed.

Replicate – a repetition of a specific job, including all four phases or iterations associated with the job (e.g., a second set of window replacements).

RRP – an acronym that stands for Renovation, Repair, and Painting.

Rule Practices – the set of protection and clean-up methods (use protective plastic during work, specialized cleaning following work, and cleaning verification) representing work practices under EPA's Proposed Rule for Renovation, Repair, and Painting.

Sites - housing units or COFs where one or more study experiments were conducted.

Specialized (Rule) Cleaning – cleaning required by the EPA Proposed Rule for Renovation, Repair, and Painting; comprised of HEPA vacuuming and wet-mopping with two-bucket method.

Stage (of Sampling) – the four different points of time within an experiment at which environmental samples were collected (after completion of the RRP job, after completion of cleaning, after completion of the last wet cloth in the cleaning verification, and after completion of the last dry cloth in the cleaning verification).

Study Location – a city or other geographic area participating in the study through identification, recruitment, and participation of housing units and COFs.

Tool Room – an interior room immediately adjacent to the work room where workers might place equipment and materials needed for a job.

Work Area – the location within the work room or on the exterior perimeter where the actual RRP work was performed. Note that the interior work area could cross the boundaries of the work room, e.g. if a window was being replaced from the inside, the work area might have included portions of the exterior.

Work Room – the room in the housing unit or COF where the RRP work was to be performed.

1. Introduction

1.1. Background and Purpose of Study

Many residences built prior to 1978 contain lead-based paint that, if disturbed, is likely to create lead hazards for residents of the home. Data from the National Survey of Lead and Allergens in Housing indicate that lead-based paint was used in 24% of the housing constructed between 1960 and 1978, in 69% of housing constructed between 1940 and 1959, and in 87% of housing constructed prior to 1940.[1] Actions that involve the disturbance or removal of lead-based paint, including many renovation and repair activities, can result in high localized concentrations of lead dust in the air and on exposed surfaces within the home, as well as in surrounding soils.[2]

In support of the Federal government's goal of eliminating childhood lead poisoning by 2010, EPA proposed a rule establishing requirements to protect residents of pre-1978 housing units from lead hazards due to Renovation, Repair, and Painting (RRP) activities. The proposed rule, issued under the authority of §402(c)(3) of the Toxic Substances Control Act (TSCA), was published in the Federal Register on January 10, 2006.[3]

In an effort to support a thorough risk assessment and cost-benefit analysis of the proposed rule, a field study was designed and conducted to characterize dust lead levels during various stages of RRP activities. Results of that field study are presented in this report.

1.2. Proposed Rule Summary

EPA's proposed rule establishes training, certification, and accreditation requirements, as well as work practice standards, for contractors performing RRP work in housing built prior to 1978. Specifically, the proposal would establish requirements for training renovators and dust sampling technicians; certifying renovators, dust sampling technicians, and renovation firms; and accrediting providers of renovation and dust sampling technician training. The proposal would also require renovation professionals to follow certain lead-safe work practice standards. EPA developed these requirements, in part, based on conclusions drawn from a previous renovation and remodeling field study that identified relationships between certain renovation activities and elevated blood-lead levels.[4] The requirements address EPA's concern that RRP work conducted by untrained and uncertified contractors may create new lead hazards, increasing the risk of lead exposure to the residents of homes containing lead-based paint.

EPA has proposed a phased approach for implementation of this rule. Initially, the rule would apply only to RRP work performed in target housing built before 1960 – both rental and owner-occupied – where a child with an elevated blood-lead level resides, unless, with respect to owner-occupied target housing, the renovation professional obtains a signed statement from the

[1] U.S. Department of Housing and Urban Development (HUD). 2002. National Survey of Lead and Allergens in Housing, Volume I: Analysis of Lead Hazards, Final Report, Revision 7.1.
[2] U.S. EPA. 2006. Air Quality Criteria for Lead (Second External Review Draft), Volume I of II. EPA/600/R-5/144aB.
[3] U.S. EPA. 40 CFR 745, Lead; Renovation, Repair, and Painting Program; Proposed Rule. Federal Register (71 FR 1588, January 10, 2006).
[4] U.S. EPA. 1999. Lead Exposure Associated with Renovation and Remodeling Activities: Phase III, Wisconsin Childhood Blood-Lead Study. EPA 747-R-99-002.

owner-occupant indicating that the renovation will occur in the owner's residence and that no child under age 6 resides there. By the end of the phase-in period, the applicability of the rule would be expanded to include all rental and owner-occupied target housing built between 1960 and 1977 and occupied by a child under age six. "Target housing" is defined in §401 of TSCA as "any housing constructed before 1978, except housing for the elderly or persons with disabilities (unless any child under age 6 resides or is expected to reside in such housing) or any 0-bedroom dwelling." EPA is also proposing to authorize interested states, U.S. Territories, and Indian Tribes to administer and enforce all elements of the new renovation provisions.

1.3. Study Objectives

The study was designed to compare environmental lead levels at appropriate stages after various types of RRP activities were conducted on the interior and exterior of residential housing units and child-occupied facilities (COFs). All jobs disturbed more than 2 square feet of lead based paint, which is the de minimus amount of disturbed area, to which the proposed rule applies. Of particular interest was the impact of using specific work practices that renovation contractors would be required to follow under the proposed rule (e.g., the use of plastic containment in the work area and a multi-step cleaning protocol). The RRP activities conducted represented the range of activities permitted under the proposed rule, including work practices that are restricted or prohibited under 40 CFR part 745.227(e)(6). These restricted or prohibited work practices included:

- Open-flame burning or torching of lead-based paint;
- Machine sanding or grinding or abrasive blasting or sandblasting of lead-based paint without a High Efficiency Particulate Air (HEPA) exhaust control;
- Dry scraping of more than 2 square feet of interior lead-based paint in any one room and dry scraping totaling more than 20 square feet on exterior surfaces; and
- Operating a heat gun on lead-based paint at temperatures above 1100 degrees Fahrenheit.

The study design was tailored to generate data that would permit evaluation of the following six study objectives:

Objective 1: What is the effect of low-, medium-, and high-level RRP work on post-work, post-cleaning, and post-verification dust-lead levels (interior and exterior)?

Objective 2: Are there significant differences in lead levels at the post-cleaning and/or post-verification phases from the use of heavy-duty polyethylene plastic sheeting during the work activity? Is there an interaction between level of RRP work and the use of plastic?

Objective 3: Are there significant differences in post-cleaning and/or post-verification lead levels between surfaces cleaned with the proposed rule cleaning method and surfaces cleaned with baseline cleaning methods? Is there an interaction between level of RRP work and cleaning method used?

Objective 4: Are there differences in the amount of lead dust migration from the Work Room to adjacent rooms between different levels of RRP work, use and non-use of plastic, and use and non-use of proposed rule cleaning methods?

<u>Objective 5</u>: Does the use of plastic ground coverings during exterior work reduce the amount of dust lead falling onto the ground?

<u>Objective 6</u>: Are there significant differences in the lead levels remaining after the two steps of the cleaning verification process, i.e., the wet cloth step and the dry cloth step?

<u>Objective X</u>: Are there significant differences between post-job lead levels between jobs conducted using proposed rule practices (use of plastic, specialized cleaning, and cleaning verification) and those conducted using baseline practices (no plastic and baseline cleaning)?

2. Summary of Conclusions and Peer Reviews

2.1. Conclusions Summary

Interior

Application of the package of plastic protective sheeting, HEPA vacuuming and wet mopping, and cleaning verification practices in EPA's proposed rule did result in lower lead levels at the end of a job than were achieved using baseline practices (no plastic protective sheeting and cleaning with broom and a shop-vacuum vacuum). Descriptive analyses in this report display the lower geometric mean levels achieved consistently across jobs on work room floors and sills. Statistical modeling presented in the report confirms a statistically significant difference between proposed rule and baseline practices for work room floors and sills.

Exterior

The use of plastic as a ground covering during exterior jobs captured large amounts of leaded dust. Analyses in the report compare the amount of lead on top of the rule plastic to the amount under the rule plastic, both with and without samples of bulk debris. For most job types, there is a substantial difference between the amount of lead captured by the rule plastic and the amount under the rule plastic. One notable special case is Torching. Without the bulk debris samples, the amount of lead under the plastic for Torching exceeded the amount on top. For all 8 job types, the ratio of the amount of lead on top of the rule plastic to the amount underneath was statistically significant when bulk debris samples were included. This changed to 6 out of the 8 job types when bulk debris samples were excluded. In addition, for some job types, substantial amounts of lead were measured in collection trays just outside the rule plastic.

The study also examined the specific components of the rule package in comparison to baseline practices. Results for the specific components of the rule package are summarized in Sections 9.2, 9.3, and 9.4.

2.2. Peer Review of the Study Design

The design and quality assurance project plan of this study were peer reviewed. The peer review was conducted from May 24, 2006 to June 11, 2006. Experts in fields related to the study reviewed the design and quality assurance plan independently and provided written comments to EPA. The major comments of the reviewers as a group are summarized below.

Overall, most reviewers commented favorably on the study design. In response to a charge question asking for recommendations for alternative approaches, most reviewers indicated the design as proposed was satisfactory. Nevertheless, a number of reviewers recommended that more samples be collected. In response, more dust samples were added in the Work Room, more exterior soil samples were included for both interior and exterior renovation jobs, and background samples for exterior dust collection tray sampling were added.

Some reviewers suggested adding more intensive jobs to the study, and some reviewers questioned whether the less intensive jobs in the study would result in a sufficient amount of lead dust. In response, more intensive jobs, such as power sanding without a HEPA attachment and open flame burning, were added to the study. Less intensive jobs remained in the study, however, because the goal of the study was to examine the range of activities expected to be covered by the EPA rule. Approximate square footage of lead-based paint disturbed by each job was measured in each experiment, and all jobs in the study disturbed more than the de minimus 2 square feet in the proposed Renovation, Repair, and Painting rule.

A number of reviewers commented that the impact of "real world" renovation conditions, such as the presence of furniture, occupants, pets, pre-existing lead dust, and so on, would not be captured by the study. For health and safety reasons, the study was conducted in vacant housing units and other vacant units. The study results may underestimate the levels of dust that would result from a renovation job due to the absence of these "real world" factors, but the study will achieve its goal of providing comparative data on the difference in lead dust levels when lead-based paint is disturbed under proposed rule versus baseline work practices.

A reviewer questioned the use of the phrase "normal cleaning" in the design documentation to describe dry broom sweeping and shop vacuuming. Dry broom sweeping and shop vacuuming were included in the study for comparative purposes as the cleaning that would likely be done if there were no EPA rule for Renovation, Repair, and Painting. The phrase "normal cleaning" was changed to "baseline cleaning."

Some reviewers recommended the use of ASTM standards. ASTM standards were adopted for dust and soil sampling. An ASTM standard for paint chip collection was included in the design at the time of the peer review.

EPA has established an electronic record of the peer review of the study design. This record includes the comments from the reviewers and EPA's responses to those comments. The peer review record for the review of the study design can be found in the public docket for the final rule.

2.3. Human Subjects Review

The study was assessed by EPA as to whether it met the definition of a Human Subjects study as defined by 40 CFR Part 26 – Protection of Human Subjects. EPA made the determination that the study was not a Human Subjects study because; (1) the only human subjects monitoring in the study, via the collection of personal air monitoring samples and the collection of blood samples from the RRP workers, was conducted solely to ensure compliance with all OSHA requirements in 29 CFR Part 1926.62 – Lead Exposure in Construction, and (2) the ensuing personal air monitoring data and blood lead data were not to be analyzed or generalized as part of the study analysis. The personal air monitoring data and blood lead data were reported to appropriate parties as required by 29 CFR Part 1926.62.

Representatives of the Battelle Institutional Review Board (IRB) reviewed the study design and data collection plans early in the design stage and again once the study protocols were fully established. From both reviews, they determined that the study did not meet the regulatory definition of "human subjects research" according to the definitions at 45 CFR 102 (f)(2) (Common Rule) and 40 CFR 26.102 (f)(2) (EPA specific regulation). As such, the study was not subject to the Human Subjects Protections regulations.

Personal exposure monitoring was performed in accordance with health and safety requirements and was not used for *purposes of research*, but rather to determine the amount of airborne lead dust, if any, to which workers might be exposed and to confirm that the appropriate personal protective equipment (PPE) was used for the RRP workers. Thus, the IRB's opinion was that the personal exposure monitoring was not related to the research objectives and, therefore, did not invoke human subjects protections, but, rather, was a personnel protection activity. In addition, the IRB did not determine the RPP field study to be an "intentional exposure" study in accordance with the provisions of 40 CFR Part 26.1102(1), "*Research involving intentional exposure of a human subject means a study of a substance in which the exposure to the substance experienced by a human subject participating in the study would not have occurred but for the human subject's participation in the study.*".

3. Study Design

3.1. Site Selection Process and Requirements

As noted previously, the project was conducted to characterize the dust lead levels after various types and intensity of renovation, repair, or painting jobs in vacant housing units and vacant child-occupied facilities with lead-based paint (LBP). Both interior and exterior jobs were considered when evaluating sites for selection.

Potential sites were evaluated for the 60 interior experiments (48 at housing units and 12 at COFs) and 15 exterior experiments (12 at housing units and 3 at COFs) for a total of 75 experiments. Since multiple experiments could be performed at a single site, 75 individual sites were not required. To allow for multiple experiments at a site, however, there needed to be lead-based paint in sufficient quantities on the desired building components, ability to conduct the experiments in the available timeframe, and ability to avoid cross-contamination through cleaning and verification between experiments conducted at the same site.

The following characteristics summarize the requirements of potential sites for inclusion in the study:

- Built before 1978;
- Cleanable before work began, in between, and at the completion of all study activities;
- Vacant and accessible during the study data collection period and available to schedule work according to the study's needs;
- Presence of lead based paint at the required levels (defined as dried paint film that has a lead content at or exceeding 1.0 mg/cm^2 or 0.5 percent by weight) and of sufficient size [2 square feet (ft^2) or more] within a single room or on specific desired components of the prospective site;
- Ability of potential interior sites to meet the desired three room study layout by containing three sequentially adjacent rooms to allow sampling in a Work Room, a Tool Room, and an Observation Room; and
- Adequate space at potential exterior sites in the yard or around the exterior of the building to allow desired sample collection and containment of dust and debris.

Additional characteristics were also desirable but not required in potential sites, including:

- Availability of electricity;
- Selection of a cross section of building ages (e.g., 2 pre-1920, 2 built between 1920 and 1950, and 2 built between 1950-1978) was ideal, but this desire was balanced by other study considerations; and
- Sites within close proximity to each other so as to maximize site coordination efforts.

3.2. Sampling Methods

For interior work, the study-impacted areas of participating housing units or COFs was defined as a set of three rooms – one undergoing the RRP activity, an adjacent room for tool storage, and an observation room adjacent to the tool storage room. In addition, post-experiment samples were obtained from a hallway running between these areas and the entrance of the unit used for conducting and exiting the job.

Paint Chip Samples – Following initial identification of lead-based paint using an X-ray fluorescence instrument, paint chip samples were collected from prospective components for laboratory analysis in order to obtain an accurate measurement of the lead in the paint that was potentially going to be disturbed by the RRP work. The method used to collect paint samples was the cold-scraping method described in ASTM E1729, "Standard Practice for Field Collection of Dried Paint Samples for Subsequent Lead Determination." The size of the samples obtained was approximately two square inches and included all paint down to the substrate, minimizing the amount of substrate material in the sample. Lead-based paint is defined by EPA as paint or other surface coatings that contain lead greater than or equal to 0.5 percent by weight or greater than or equal to 1.0 mg/cm^2.

Interior Dust Wipe Samples – The interior sampling protocol involved collecting four floor dust wipe samples and one window sill dust wipe sample from the Work Room and two floor dust wipe samples and one window sill dust wipe sample from the other two study rooms (Tool and Observation rooms) at each stage of the experiment – post-work, post-cleaning, and post-cleaning verification. In addition, if a floor verification zone in the Work Room failed two wet cloth verifications, an additional post-wet cloth verification sample was collected for that floor zone before proceeding with the dry verification process. All dust wipes were collected in accordance with ASTM 1728, "Standard Practice for Collection of Settled Dust Samples Using Wipe Sampling Methods for Subsequent Lead Determination."

The locations of the floor and window sill dust wipe samples in all three study rooms were randomly selected prior to the experiment and specified in experiment-specific sampling plans. This ensured that the locations of the samples were not biased by the field technician, and that no two samples were collected from the same area. The randomized sample selection in each room was stratified as necessary, to ensure samples were obtained from different sections of a room. If window sills were badly damaged, inadequately sized, or missing, a dust collection tray was placed in the study room, and all window sill samples were collected from the tray. Dust collection trays also replaced actual window sills when sills could not be cleaned below 250 $\mu g/ft^2$. For the window replacement experiments, a dust collection tray was placed on the horizontal surface directly below the outside of the window and sampled after the work was completed.

Exterior Dust Wipe Samples – For exterior work, nine dust collection trays were set up prior to the RRP work – three on top of the Rule plastic coverings, three in corresponding positions underneath the Rule plastic coverings, and three near the Rule plastic and on top of the protection plastic. Dust wipe samples were taken from each tray following completion of the work. Background lead levels in the air at exterior job sites were measured by setting out a dust collection tray for a number of hours and subsequently taking a dust wipe of the tray.

Bulk Debris Samples – Where necessary, field technicians were instructed to collect excess debris that could not be collected with a dust wipe from each sampling location during the post-work sampling stage. The debris was collected by glove-covered hands and tools such as chisels that could scoop up material and placed in a plastic bag or centrifuge tube for further processing and laboratory analysis. For jobs that generated such large amounts of dust that it could not all be picked up using a dust wipe (such as the door planing job), technicians also used glove-covered hands to collect and place the excessive dust in a plastic bag.

Ambient Air Samples – Air samples were collected as part of this study following NIOSH Method 7082. For interior work, air samplers were placed in all three study rooms on tripods approximately five feet off the ground, so as to approximate levels of dust lead available to be inhaled.

Soil Samples – Soil samples were collected according to ASTM E1727-05, "Standard Practice for Field Collection of Soil Samples for Subsequent Lead Determination," before and after both interior and exterior work. The soil samples served to measure potential track-in contamination during work (interior) and background lead contamination of the property (exterior), as well as potential contamination of the property by study activities.

3.3. Laboratory Analysis Methods

Paint Chip Samples – Laboratory sample preparation was performed according to EPA Method 3050B, and the subsequent atomic absorption analysis of the determination of lead followed EPA Method 7420. The analysis provided measurements of lead concentrations in µg/g, with a minimum detection limit of 20 µg total lead per sample.

Dust Wipe Samples – All interior and exterior dust wipe samples were prepared according to EPA Method 3050B and analyzed for lead content using EPA Method 7420 (atomic absorption). The analysis provided measurements of lead concentrations in $\mu g/ft^2$, with a minimum detection limit of 10 µg total lead per sample, which was requested to provide more specificity at lower levels of lead.

Bulk Debris Samples –Battelle technicians recorded the total mass of each bulk debris sample. Subsequently, any non-paint chip/dust debris was removed (screws, nails, pieces of wood, etc.), the samples were homogenized (paint, dust, and other material crushed and mixed with a clean mortar and pestle), and two subsamples of at least 1 g each were obtained. Each was labeled appropriately and sent to the laboratory for analysis as paint chip samples. The laboratory reported percentage of lead by mass in each of the two subsamples. The mean lead mass percent was calculated; this mean multiplied by the total bulk mass gives the total lead in the bulk sample. The total lead mass in the bulk sample is added to the total lead mass measured in the associated dust wipe sample to obtain total mass per square foot ($\mu g/ft^2$) in the sampled area.

Ambient Air Samples – Air filter samples were analyzed using NIOSH Method 7082 (flame atomic absorption spectrophotometry). The analysis provided measurements of lead concentrations in $\mu g/m^3$, with a minimum detection limit of 2 µg total lead per filter.

Soil Samples – EPA Method 3050B was used to prepare the soil samples for analysis. EPA Method 7420 (atomic absorption) was used to analyze the samples for lead. The analysis of soil lead concentrations was reported in µg/g, with a minimum detection limit of 20 µg total lead per sample.

3.4. Field Sampling Protocols

3.4.1. Interior Jobs

Prior to the start of an experiment, paint chip samples were collected from building components that would potentially be disturbed during RRP activities to evaluate the lead concentrations in the paint. In addition, three composite soil samples were collected, where applicable, from bare soil nearest to (1) the entryway to the building used by the workers, (2) the walkway from the entryway to the street, and (3) a window closest to the work area. If the unit was used for multiple interior experiments, the post-experiment soil samples of the previous experiment were used as the pre-experiment soil samples for the next interior experiment, where appropriate.

All areas of the unit not being used in the study were barricaded using plastic coverings. All air vents in floors, walls, and ceilings in any of the areas impacted by the study were also covered with plastic. A thorough cleaning was conducted by a lead abatement firm with experience cleaning after lead abatement activities in accordance with the U.S. Department of Housing and Urban Development (HUD) Guidelines on abatement cleaning and clearance. An independent licensed clearance technician then collected five dust wipes (4 floor, 1 sill) from the Work Room and three dust wipes (2 floor and 1 sill) each from the Tool and Observation Rooms, plus up to three additional samples in hallways or other areas impacted by the study. If the lead loading on the clearance wipes was no greater than 40 $\mu g/ft^2$ on floors and 250 $\mu g/ft^2$ on window sills, the unit was declared clean. If one or more samples failed to meet these clearance standards, then the room in which that sample was collected was re-cleaned and re-sampled.

Deviations from this plan did occur in order to maintain progress. There were some cases where one or more samples in a room were measured above 40 $\mu g/ft^2$, but because the room average was below 40, the decision was made to proceed with work. There were a few cases where the room average was above 40 $\mu g/ft^2$, but work occurred because of schedule constraints. When floors in Tool and Observations were unable to achieve clearance, they were covered with clean plastic, which provided a clean surface with which to start the experiment. When window sills were in poor condition and/or could not be cleaned below 250 $\mu g/ft^2$, clean dust collection trays were used in place of the actual window sill in almost all cases.

If the interior protection/clean-up (P/CU) phase to be implemented involved containment, plastic coverings were set up in the Work Room by the RRP contractor according to the proposed rule. This included closing and sealing all doors into the Work Room; covering all doors within the work area that had to be used while the job was being performed with plastic sheeting in a manner that allowed workers to pass through, while confining dust and debris to the work area;

covering the entire floor surface with taped-down plastic sheeting in the Work Room; and taping plastic to the outside of the window frame, if a window was being replaced as part of the job, so that no debris could fall to the ground outside the window.

An area just outside of the Work Room (either in the hallway or the Tool Room) was identified to serve as the primary decontamination area where workers removed all dust and debris from their person, their equipment, and the exterior of any waste containers using a HEPA vacuum. The floor of the primary decontamination area was securely covered with plastic.

A secondary decontamination area was set up just inside or outside of the main entrance to the unit. This area was used to remove and dispose of the Tyvek suits and booties worn for worker protection while inside the unit. Respirators were also removed in the secondary decontamination area. Personnel also cleaned off any debris remaining on equipment, clothing, or the exterior of waste containers prior to leaving the study site. A tack pad was set up to remove any remaining dust from street shoes before leaving the property.

The hired RRP contractors conducted their job as they normally would, within the specifications of the study. Following job completion, study personnel waited for one hour before collecting post-work dust wipe and air samples. In instances where significant debris covered the pre-designated sampling location, the debris was collected in a plastic bag prior to wiping the area with a dust wipe. The bulk samples were sent separately to the lab for analysis.

Once post-work environmental samples were collected, the RRP contractor misted and picked up the plastic sheeting covering the floor, if present. The sheeting isolating the Work Room from the other areas of the unit remained in place until all cleaning activities were completed.
RRP contractors were instructed to follow one of two cleaning methods – a baseline cleaning or the proposed rule cleaning. For a baseline cleaning effort, the RRP contractor swept the entire Work Room with a broom and dustpan to collect large amounts of debris. Subsequently, the RRP contractor vacuumed the work area with a Shop Vac-type vacuum. For the rule cleaning, the RRP contractor followed the guidelines detailed in the proposed rule to clean the entire Work Room. Large pieces of debris were collected and disposed of prior to cleaning. All walls were vacuumed with a HEPA vacuum starting from the ceiling and working down to the floor. The remaining surfaces and objects in the work area, including floors and any fixtures, were then vacuumed with a HEPA vacuum. The floors were then thoroughly mopped using a 2-bucket mopping method. If containment was used in the experiment, [after completion of all appropriate cleaning activities], the plastic covering the door separating the Work Room from the other areas of the unit was taken down. This was performed by first misting and, then removing the plastic carefully folding it up, and placing it in a heavy duty garbage bag.

After the cleaning was complete, all study personnel waited for one hour before collecting post-cleaning dust wipe and air samples. Once all post-cleaning samples were collected, the RRP contractor began the cleaning verification process described in detail in the proposed rule. For both the window sills and floor zones, each area was wiped with a wet cleaning verification cloth and compared to the verification card provided as guidance for determining the cleanliness of the cloth. If that cloth failed, then the component was re-cleaned following the proposed rule cleaning method (i.e., using a HEPA vacuum and wet mop) and wiped again with a new wet cloth. Any re-cleanings were done with the proposed rule cleaning method in order to get more information regarding the cleaning cloth performance under proposed rule methods.

If the second wet cloth failed verification, then the component was re-cleaned and allowed to dry. The component was then wiped with a dry verification cloth, which was compared to the verification card provided. If the first dry cloth failed, then the component was wiped with a second dry verification cloth. The process was repeated for a maximum of four dry verification cloths. All windowsills were verified as clean before moving on to the floor verification. The floor was separated into zones approximately 40 ft^2 in area for the verification process. In the cases where a window sill or floor zone failed two wet verification tests, a post-wet verification sample was collected from that zone before proceeding with re-cleaning the component and dry cloth verification. The collection of post-verification dust wipe and air samples took place immediately following the cleaning verification.

After collection of the cleaning verification samples from the three study rooms, up to three additional 1 ft^2 floor dust wipe samples from a hallway connecting the study rooms to the unit's entrance were collected. In addition, three composite soil samples were collected in locations near those taken during pre-experiment sampling.

Following completion of an experiment, the areas of the unit impacted by the study were re-cleaned. If the unit was to be used in a subsequent experiment, the plastic sheeting protecting the parts of a housing unit not impacted by the study were left in place. A licensed clearance technician then collected five dust wipes (4 floor, 1 sill) from the Work Room and three dust wipes (2 floor and 1 sill) from the Tool and Observation Rooms, plus up to three additional samples in hallways or other areas impacted by the study. If the lead in the clearance wipes met the study's clearance standards, the unit was declared clean. If not, then each room that failed was re-cleaned and re-sampled.

If all interior work at the unit was complete, the plastic sheeting protecting the parts of the housing unit not impacted by the study was taken down, and the entire unit underwent an abatement style cleaning. A certified inspector/risk assessor or clearance technician then collected samples from one floor, one window sill, and one window trough, where accessible, from four rooms in the unit, in accordance with state procedures for clearance testing after lead abatement. If one or more samples were measured with dust lead levels over the clearance level, the area from which that sample was taken underwent re-cleaning. Following re-cleaning, another clearance sample was obtained and re-analyzed. Clearance levels were achieved in all study housing units, with the exception of some window troughs. Some window troughs did not get below 400 $\mu g/ft^2$, but these were either unimpacted by study activities or were in a deteriorated condition pointed out to the property owner. Final clearance results were provided to all property owners.

3.4.2. Exterior Jobs

Prior to the start of an experiment, paint chip samples were collected from building components that were potentially going to be disturbed during RRP activities to evaluate the lead concentrations in the paint. In addition, three composite soil samples were collected, where applicable, from bare soil (1) near the foundation of the housing unit/COF and within the area to be covered by the Rule plastic, (2) at the back edge (farthest from the housing unit/COF) of the Rule plastic, and (3) at the back edge (farthest from the housing unit/COF) of the containment plastic. If the unit was used in multiple exterior experiments, the post-experiment soil samples from the previous experiment were used as the pre-experiment soil samples for the next interior experiment, where appropriate. One or more dust collection trays were set out prior to work commencing to evaluate the background level of dust lead in the air at a housing unit.

The approximate size and location of the "Rule containment" was estimated in advance by the study team in order to identify pre-work soil sample locations. The exact size and location of the "Rule containment' was determined by the site supervisor in consultation with the RRP contractor, taking into account any physical constraints such as property lines, fences, nearby houses and the placement of the vertical containment structure. Before exterior work began, the RRP contractor set up "protection containment," which included a large area of plastic covering the ground and vertical containment spanning the entire distance between ground level and the maximum height of the component undergoing RRP work.

The Rule containment was set up subsequently by the RRP contractor in accordance with the proposed rule. This included lying securely taped- or weighed-down plastic on top of the containment plastic extending out from the edge of the building a reasonable distance to collect falling paint debris. All doors and windows within 20 feet of and below the work area were closed. Dust collection pans were placed by study technicians under, on top of, and near the Rule plastic covering.

A decontamination area was set up immediately outside of the work area, where all study personnel removed and disposed of their protective suits and booties, and removed all dust and debris from tools and supplies.

The hired RRP contractors conducted their job as they normally would, within the specifications of the study. Following an up to one-hour wait after job completion, field technicians obtained dust-wipe samples from the dust collection pans on top of the Rule plastic sheeting. Subsequently, the RRP contractor misted and folded the plastic sheeting inward to trap dust and debris inside. The dust wipe samples from the pans under the Rule plastic were sampled after the plastic was removed. The trays placed near the rule plastic were also sampled at this time. Technicians collected three composite soil samples, consisting of three sub-samples each, in locations similar to those used for the pre-experiment soil sampling. Once all study-related activities were complete, the RRP contractor removed the vertical containment.

3.5. Participating Contractors (RRP Workers, Cleaning, Clearance Technicians)

Study implementation required the participation of multiple contractors in both Columbus, Ohio, and Pittsburgh, Pennsylvania. In Columbus, the study utilized two licensed firms to conduct initial cleanings, recleanings, and final cleanings of the Columbus housing units and child-occupied facility. All XRF inspections and dust lead clearance tests were performed by ATC Associates, Inc. (ATC), also licensed by the state of Ohio to conduct these activities. Three separate contractors provided the renovation work support for the field operations at the Columbus housing units and school. All had at least one person who had received training in the EPA/HUD course in Lead Safety for Remodeling, Repair, and Painting. In some cases, property owners worked with study personnel to identify preferred contractors who would conduct the renovation work on their properties.

In Pittsburgh, the study utilized services of one abatement cleaning firm, one certified environmental firm to conduct XRF inspections and dust lead clearance tests, and one renovation contractor. The renovation workers in Pittsburgh received training in the EPA/HUD course in Lead Safety for Remodeling, Repair, and Painting prior to starting work.

All participating renovation workers underwent study-specific training that reviewed the study health and safety plan, reviewed study protocols, and introduced and demonstrated the cleaning verification process. In addition, the study arranged for respirator training and fit testing for those renovation workers who were not equipped with the necessary respirator protection.

Site security during working hours was provided by special-duty police officers in Pittsburgh and off-duty police officers in Columbus.

3.6. Environmental Safety and Health Plan

The health and safety requirements for the study were applicable to all RRP workers and study personnel. A Health and Safety Plan was drafted to specify the precautions required to comply with the OSHA Lead in Construction standard (29 CFR 1926.62); to prevent study personnel from injuring themselves, their families, or neighbors; and to protect the study property and surrounding properties. During study activities, standard safe work practices were followed to avoid falls, burns, lacerations, and other injuries.

All RRP contractors were trained in accordance with the Lead in Construction standard, as well as the HAZCOM standard (29 CFR 1910.1200) with regard to lead. In addition, at least one member of the RRP work crew present on site was required to have Lead Safe Renovation training. Half- or full-face respirators were worn during all work activities in accordance with the observed personal exposure results for each type of study-related activity performed. To ensure that workers had adequate respiratory protection prior to job-specific data being available, the study conservatively assigned respirator types to each job at the beginning of the study so that for many jobs a higher degree of protection was utilized beyond what might typically be used. For the experiments where paint was removed by open-flame torching, the RRP workers and study personnel wore supplied air respirators for increased protection against lead inhalation.

A blood lead surveillance program was implemented to monitor the pre- and post- study blood lead content of all RRP workers and study personnel.

For both interior and exterior work, personal air samples were collected to ensure compliance with OSHA requirements; however, the results are not analyzed as part of the study. Personal air sampling results were monitored closely to ensure that respirators used for each job were adequate to provide sufficient protection. All personal air monitoring and blood lead results were provided to the workers.

Great effort was taken to limit the potential for lead contamination outside of the study area. Workers and study personnel were required to wear hooded protective clothing made of Tyvek, or another appropriate material, while performing study activities. Upon exiting the work area, all protective clothing and equipment were cleaned with a HEPA vacuum, and, in some cases, a wet cloth. Protective booties were worn to protect against contamination of the study areas from the outside, as well as to protect the property from contamination due to the work-generated dust. Before exiting the property, the protective clothing was vacuumed, again, and discarded. A tack pad was used to remove any residual dust from the bottoms of shoes. Workers and study personnel were required to wash exposed skin with soap and water immediately after exiting the property. All waste generated during study activities was removed from the properties and transported to a municipal or construction landfill to be disposed of as household waste.

4. Field Work Summary

4.1. Overview of Site Selection/Screening Process

The study team developed a list of potential locations and contacts for identifying prospective housing units and COFs to enroll in the study. Initially, the study sought to identify locations in or around Columbus, Ohio because of their proximity to Battelle and because Columbus is home to a large scale effort by various housing agencies, neighborhood associations, non-profit agencies, and private developers to rehabilitate older, low-income housing. The study team thought such organizations would likely have vacant housing and would be open to collaborating on the study to have work done that is beneficial to their ongoing efforts in housing renovation and remodeling activities. Leads identified through various sources in other cities were explored including Milwaukee, Detroit, Los Angeles, Birmingham, Philadelphia, Chicago, Baltimore, Arlington (VA), and Washington, DC.

The site selection process involved contacting organizations thought to have information on ongoing RRP activities. During the initial contact, study representatives explained the study to the contact, offered to provide them with a Fact Sheet summarizing the study, and asked whether they knew of RRP activities planned for housing in their area or of housing fitting the study requirements that would be a good candidate for participation in the study. If they were interested in supporting the study, detailed discussions about potential candidate housing units were held. If phone conversations concerning potential sites seemed to satisfy all the necessary study requirements and the owner was amenable to working within the study requirements for available experiments and study schedule, then a site visit was scheduled to inspect the property.

Permission to inspect and test units or buildings was obtained from site owners or managers prior to any inspection or testing taking place. The permission included an agreement as to whether and how the results of the inspection and testing would be transmitted to the site owner or manager. The required study form was used to obtain formal permission of the property owner to conduct the XRF inspection and visual assessment of a property. Each prospective housing unit or COF underwent a visual inspection to ensure that it met the study requirements beyond the presence of LBP – three sequential rooms, vacant, cleanable, etc. If the visual inspection confirmed that a prospective housing unit met the study requirements, a full lead screening inspection was scheduled with a portable XRF device to measure lead content of various painted components in the house – walls, window sills, trim, doors, etc. Inspectors obtained a large number of XRF measurements throughout a house, which were recorded by the field operations coordinator for the area, or their representative, on the appropriate data collection forms. As the study progressed and experiments were assigned to prospective units to begin work, subsequent site inspections were targeted to the components for experiments that still needed to be assigned.

Following review of the XRF measurements at a prospective housing unit, study planners determined whether there were one or more rooms that could serve as the Work Room for an interior job or whether there was more than one exterior side of the house that could serve as the work area for an exterior job. Permission to collect paint chip samples was obtained from the property owner using the proper form. Paint samples were then collected from components in prospective rooms and exterior sides for laboratory analysis, as necessary. Based on confirmation of sufficient levels of lead based paint in the prospective housing site components, matching experiments were assigned and the housing owners were informed of their inclusion in the study and of the intended schedule of renovation activities to be performed at their housing unit.

In Columbus, Ohio and Pittsburgh, Pennsylvania, the study was able to conduct experiments in vacant housing owned by local non-profit agencies that own older housing needing renovation. Additionally, private citizens in Columbus who owned vacant housing containing lead-based paint also made their homes available to the study. A suitable COF was identified through the Columbus Public Schools system. A vacant school that contained sufficient amounts of lead-based paint was utilized for all COF experiments. Therefore, the study was able to use housing units in both Columbus and Pittsburgh and a COF in Columbus to provide some measure of geographic diversity while still being able to allow economy of site coordination efforts.

A total of 35 housing units were sufficient candidates to warrant a visual inspection of the properties. Of these 35 units, 27 properties were in good enough condition and satisfied the study requirements to warrant having an XRF screening performed. Based on the XRF measurements, the subsequent paint chip sampling, and a matching of the units to the study experiments, the study ultimately identified 15 housing units that met the selection criteria for use in the characterization of environmental lead levels associated with low, medium, and high levels of interior and exterior RRP activity. Table 4-1 summarizes the distribution of housing units among the two cities and interior/exterior experiments. As mentioned above, in addition to the housing units, one school was utilized to conduct 12 interior and 3 exterior experiments.

Table 4-1. Housing Unit Distribution by City.

	Columbus	Pittsburgh
Interior Only	3	4
Exterior Only	3	1
Interior/Exterior	1	3
TOTAL	**7**	**8**

4.2. Number and Type of Experiments Completed

The study conducted 12 interior jobs at housing units and 3 interior jobs at a COF and, similarly, 12 exterior jobs at housing units and 3 exterior jobs at a COF. Table 4-2 identifies each of the interior and exterior jobs performed at housing units across three work intensity levels specified prior to work taking place, while Table 4-3 lists the interior and exterior work performed at the COF. In parentheses at the end of each job description is the number of times each job was conducted. For interior jobs, each replicate of a job was to be done four times under each phase of plastic protection and cleaning method. Thus, interior housing unit jobs actually were conducted eight times to achieve the two full job replicates. As noted in Section 1.3, practices restricted by 40 CFR 745.227(e)(6) were included among the jobs conducted as part of the study. These are noted with roman numerals within the table corresponding to the four prohibited activities specified in 40 CFR 745.227(e)(6).

Table 4-2. Interior RRP Jobs Across Three Levels of RRP Work.

Type	Low Level Work	Medium Level Work	High Level Work
HOUSING UNITS	Make up to three cut-outs, each of a 2 foot or more section of wall with LBP disturbing approximately 6 ft^2 of LBP. (2) Replace window from inside unit, disturbing at least 2 ft^2 of LBP. (2)	Scrape deteriorating LBP from interior walls, scraping 50-75 ft^2 of painted surfaces [iii]. (2) Plane 20-40 ft^2 of LBP from an interior door [ii]. (2)	Remove paint from 75-100 ft^2 of lead-based painted components by using a heat gun over 1100° Fahrenheit held at one inch or the distance specified from paint [iv]. (2) Gut out a kitchen, disturbing 100 ft^2 or more of LBP. (2)
COF	Make three cut-outs, each of a 2 foot or more section of wall with LBP disturbing approximately 6 ft^2 of lead-based paint. (1)	Remove paint from 50 ft^2 of lead-based painted components by using a heat gun **UNDER** 1100° Fahrenheit held at one inch or the distance specified from paint [iv]. (1)	Remove paint from 75 ft^2 of lead-based painted components by using a heat gun **OVER** 1100° Fahrenheit held at one inch or the distance specified from paint [iv]. (1)

Table 4-3. Exterior RRP Jobs Across Three Levels of RRP Work.

Type	Low Level Work	Medium Level Work	High Level Work
HOUSING UNITS	Replace an exterior door and doorway, disturbing 25-50 ft^2 of lead-based paint. (2) Replace fascia boards, soffits, and other exterior trim on one side of the structure, disturbing approximately 50 ft^2 of lead-based paint. (2)	Remove lead-based paint from exterior components by dry scraping, disturbing approximately 100 ft^2 of lead-based paint [iii]. (4)	Remove paint by power sanding or grinding at least 100 ft^2 of lead-based paint on exterior wood components on one side of the structure [ii]. (2) Remove lead-based paint by torching or open-flame burning on at least 100 ft^2 of lead-based paint from wood porch ceilings [i]. (2)
COF	Remove approximately 50 ft^2 of LBP from an exterior component using a needle gun. (1)	Remove paint from 50-75 ft^2 of lead-based painted components by using a heat gun **UNDER** 1100° Fahrenheit held at one inch or the distance specified from paint. (1)	Remove paint from 75-100 ft^2 of lead-based painted components by using a heat gun **OVER** 1100° Fahrenheit held at one inch or the distance specified from paint [iv]. (1)

4.3. Protection and Cleaning Routines

Interior Jobs – For each interior job, the study evaluated four work area protection/clean-up (P/CU) routines or phases – the four combinations of (1) use of plastic coverings/no use of plastic coverings and (2) baseline cleaning after work completion/cleaning per the proposed rule after work completion. Thus, the four P/CU routines were:

- Phase I - Use of plastic coverings and rule cleaning after work completion;
- Phase II - Use of plastic coverings and baseline cleaning after work completion;
- Phase III - No plastic coverings and rule cleaning after work completion; and
- Phase IV - No plastic coverings and baseline cleaning after work completion.

Within each job, the study attempted to characterize the amount and spread of dust under each of the four P/CU routines. The preferred method for achieving this was to split the job into four phases of equal activity to be performed in one room – the 1 Unit/1 Room Approach – and conduct the experiment independently four times so that each experiment corresponded to one of the four P/CU routines. In the instances where the job was unable to be replicated four times in the same room, the next alternative was to conduct the work across two rooms – applying two of the four P/CU routines in one room and the other two routines in another room. For jobs that could not be replicated in one or two rooms, such as the kitchen gutting job, the study used a 4 Room approach where each P/CU routine was conducted in a different room. These rooms could be in the same unit or different units. The approaches requiring multiple rooms or units to complete a full job produced data for which comparability depends on the degree to which similar room layouts with lead-based paint on the same components could be found. Table 4-4 lists the jobs performed with the approach used to complete that job.

Table 4-4. Interior Jobs and Associated Approaches for Conducting Experiment.

Activity Level	Job	Job #	Columbus	Pittsburgh
Low	Cut outs	1		2 Units, 2 Rooms
		2	2 Units, 2 Rooms	
	Replace window from inside house	1		2 Units, 2 Rooms
		2	1 Unit, 3 Rooms	
Medium	Scrape deteriorating lead-based paint from a flat interior component	1	1 Unit, 1 Room	
		2		1 Unit, 1 Room
	Scrape or plane 20-40 ft^2 of lead-based paint from an interior door	1	2 Units, 3 Rooms	
		2	2 Units, 2 Rooms	
High	Remove paint from 75-100 ft^2 of lead-based painted components in a room by using a heat gun at or over 1100 degrees Fahrenheit	1		1 Unit, 1 Room
		2	1 Unit, 4 Rooms	
	Gut out a kitchen	1		4 Units, 4 Rooms
		2	2 Units, 2 Rooms	2 Units, 2 Rooms

The window replacement job in Columbus was conducted in one housing unit, but the windows were spread across three rooms with one room having two windows replaced. The other job that required three rooms, one door planing job, used two doors from a room in one house and two doors from another house, but the doors in the second house were in different rooms.

At the school, the three jobs were conducted in two separate classrooms, with six experiments conducted in each classroom. All four Cut-out experiments were conducted in one room, while the four low heat gun jobs were conducted in the second classroom. The high heat gun job was split between the two classrooms with two experiments conducted in each room. These assignments were made based on wall space available to have paint removed.

Exterior Jobs – For exterior jobs, the primary protection technique under evaluation was the use of plastic ground covering. To investigate this, plastic coverings were set up under an exterior job, as required by the proposed rule, with dust collection trays under, on top of, and near the plastic coverings. After completion of the exterior work, dust wipe samples were obtained from the dust collection trays. Thus, the exterior work and associated sampling were performed in one phase. Table 4-5 shows the distribution of the exterior jobs across city and the number of housing units required. The three exterior jobs at the COF were all conducted at the school in Columbus.

Table 4-5. Exterior Jobs Conducted in Each City.

Activity Level	Job (# Jobs)	Columbus	Pittsburgh
Low	Replace exterior door (2)		2 Units
	Replace soffit, fascia and trim (2)	1 Unit	1 Unit
Medium	Scrape deteriorating lead-based paint from a flat exterior component (4)	3 Units	
High	Remove paint from 100 ft^2 of lead-based painted components by power sanding (2)	1 Unit	
	Remove paint from 100 ft^2 of lead-based painted components by open flame burning (2)		2 Units

4.4. Environmental Samples Collected

Dust wipe and air samples were collected during each stage of the interior experiments. In addition, dust clearance samples were gathered following the pre-experiment (initial clearance) and post-experiment (final clearance) cleanings for interior jobs to ensure (1) that each phase of work began in a clean environment and (2) that housing units and buildings did not contain any residual lead hazards when work was completed. Table 4-6 summarizes the total number of environmental samples that were collected, including those collected for clearance purposes. The quality control samples included in the table include field spike and field blank samples inserted into the sample stream for quality assurance purposes.

Table 4-6. Total Number of Environmental Samples Collected

Experiment Type	Sample Type	Housing Units (12)	COF (3)	TOTAL
		# of Samples	# of Samples	
Interior	Dust Lead Clearance Wipe	806	132	**938**
	Dust Wipe	1,699	469	**2,168**
	Air	576	146	**722**
	Bulk	120	37	**157**
	Soil	170	0	**170**
	Paint Chip	187	22	**209**
Exterior	Dust Wipe	137	28	**165**
	Air	13	4	**17**
	Bulk	24	11	**35**
	Soil	72	0	**72**
	Paint Chip	29	4	**33**
Quality Control	Wipe QC	201	51	**252**
	Air QC	96	25	**121**
TOTAL		**4,130**	**929**	**5,059**

4.5. Protocol/Sampling Issues and Resolutions

Throughout the duration of field work, various circumstances impacted the performance of study protocols. Such circumstances generally resulted in minor adaptations to field activities or sampling procedures. Any adaptations were planned by field personnel, in consultation with study organizers whenever possible, to preserve the validity of each experiment. Summarized below are various protocol variations and sampling issues noted by field personnel over the course of the field study.

Protocol Variations

Obstructed floor samples – All sampling plans were prepared prior to sampling without access to detailed photographs of the study rooms. As a result, sampling plans sometimes included floor samples in areas occupied by air vents and other obstructions. When this occurred, field technicians moved the affected floor sample to an adjacent location not already used or designated for sampling.

Reduced wait times – The study design called for field personnel to wait for one hour following completion of the RRP work and cleaning stages before collecting dust wipe and air samples from the study rooms. Some RRP jobs took significantly longer than anticipated to complete, pushing the first one-hour wait period well into the afternoon. On several such occasions, site supervisors opted to reduce the post-cleaning wait time in an effort to finish the experiment before dark or before site security personnel left for the day (typically at 5:00 pm). When this occurred, wait times were reduced by as short a duration as possible to allow a settling time of 30 to 40 minutes. During exterior work, one hour post-work wait times also were planned to allow dust to settle before sampling. In a few cases, anticipated bad weather or increasing winds led site supervisors to shorten wait times in order to collect samples before weather conditions might lead to loss of samples.

Extreme weather conditions (during interior experiments) – In general, field personnel used a front porch or other non-study area of a housing unit to set up a staging area for all study-related equipment and supplies. Several experiments were conducted in Columbus on extremely cold or rainy days at housing units with no available interior space, aside from the study rooms, to set up a staging area. To protect study equipment and personnel from the elements, field technicians used a portion of the housing unit's Observation Room to hold study equipment. In these cases, which are noted in the experiment-level reports (see Appendix A), technicians first ensured that adequate space was available in the Observation Room to serve as a staging area and satisfy sampling requirements for that room. All equipment and cleaning supplies were protected under plastic whenever necessary to prevent contamination from RRP work and other study-related activities. Floor samples were moved, when necessary, to the open area nearest the planned sampling location to avoid sampling from areas partially or fully covered by study equipment.

Vacuuming protocol (Baseline cleaning) – Early in the study, field personnel in Pittsburgh were confused as to whether contractors should be using the Shop-Vac to vacuum the Work Room walls during baseline cleaning. In some experiments the walls had been vacuumed, and in others they had not. Field personnel consulted with study organizers in Columbus and determined that the walls should not be vacuumed during baseline cleaning, since the baseline scenario was intended to represent a less intensive cleaning effort than Rule cleaning. For all subsequent experiments, contractors were directed to vacuum the walls only during Rule cleaning.

Mopping protocol (Rule cleaning) – The application of the two bucket mopping method differed across the RRP contractors. Some contractors preferred to mop the entire Work Room with soapy water first, then remove the soapy bucket from the room and mop the entire floor again with the rinse water. Other contractors used both buckets simultaneously – mopping several square feet with soapy water and then going over the same area with rinse water. Since both approaches are consistent with the text in the proposed rule and as RRP contractors were expected to perform the job as they would under normal conditions, both approaches were represented in the study.

Sampling Issues

Use of sampling trays in place of window sills – During many experiments, sampling trays were used in place of actual window sills. This was done for a number of reasons including poor condition of a sill, inability to clean a sill so it would pass clearance, or insufficient sill surface area for repeated sampling. On a small number of occasions in Pittsburgh, sampling trays were not put into position before RRP work began, when they were supposed to be used. In these instances, field technicians taped off a rectangular section of floor in an area where no floor samples were supposed to be taken and sampled directly from the floor instead of the tray. On several other occasions when sampling trays should have been used in place of the unit's original window sills, field technicians inadvertently sampled from the sills instead of sampling trays. All such instances are noted in the experiment-level reports (see Appendix A).

Soil sample locations – Soil samples were intended to be taken from the same general locations before and after each experiment to facilitate a comparative analysis of soil-lead levels. In practice, field technicians occasionally took post-work samples from areas that were not sampled prior to work. A variety of field personnel was used in Columbus, and the same individuals did not always work at the same housing units. As a result, the individuals collecting the samples were occasionally uncertain about the location of pre-work samples and/or the most appropriate location of post-work samples.

Use of Plastic to cover tool and observation floors – The design of the study called for sampling to occur on actual floor surfaces, which had been cleaned prior to a renovation job occurring. Because of floors that were in poor condition and proved difficult to clean to a level at which they would pass clearance testing, during some experiments plastic sheeting was used to cover tool and observation room floors in order to provide a clean surface at the beginning of the experiment. No work room floors were ever covered because of the desire to have a realistic surface that had to be cleaned following work.

Cleaning Verification - Some RRP contractors appeared more likely than others to consider discolored wet verification cloths to be "clean," attributing discolorations to factors other than residual paint dust (with no apparent basis for such conclusions). The impact of this on the study is that there may have been fewer cleaning verifications than there should have been, and potentially higher post-verification lead levels than would have been achieved if re-cleaning was performed and additional verification cloths used.

Field personnel also observed that the use of Simple Green detergent could contribute to discoloration of the verification cloths, as on multiple occasions verification cloths used on zones that were re-cleaned with Simple Green appeared progressively more soiled after each re-cleaning. Field personnel eventually concluded that the cleaning solution itself was causing the grayish discoloration. Subsequent analysis of floor samples taken from these zones confirmed that the discoloration was not caused by lead-based paint particulates.

4.6. Adherence to Environmental Safety and Health Protocols

As described in Section 3, a site-specific health and safety plan was prepared for each housing unit and COF used for field work. The field work crews in Columbus and Pittsburgh kept copies of these plans on-site at all times. Each plan contained detailed health and safety protocols to be followed by contractors and field technicians. The site supervisor at each job site was responsible for ensuring that all crew members adhered to these guidelines, which could be grouped into the general categories described below.

Study unit containment (to prevent lead contamination of non-study areas) – Contractors were directed to seal off non-study areas of each housing unit/COF with plastic sheeting and tape prior to beginning work. If cuts, holes, or gaps were observed in the containment at any time, contractors or field technicians quickly took action to re-tape or otherwise re-seal the plastic so that non-study areas would continue to be protected from lead dust and other potential hazards.

Personal safety during all stages of field work and sampling – On each day of field work, prior to beginning the RRP activity, the site supervisor held a safety meeting to communicate potential hazards associated with the job (e.g., lead exposure, physical hazards) and remind the crew members about the personal protective equipment that would be required for the day's work. During work, contractors were routinely reminded to inform the site supervisor if they needed a break. Field crews had access to a fire extinguisher, first-aid kid, and emergency air horn at all times during the study.

Respiratory protection and monitoring – All crew members were required to wear NIOSH/MSHA-approved respirators when inside the work areas. The type of respirator initially required for each job was based on the OSHA requirements and an assessment of the air monitoring data available for the jobs in the study. Half-mask, air-purifying respirators were required for activities expected to generate relatively small amounts of leaded dust. Full-mask, air-purifying respirators or half-mask, supplied-air respirators were required for activities expected to generate significant dust or lead vapors. Air sampling for personal exposure to lead was performed during each of the three stages of the study – renovation work, post-work cleaning, and cleaning verification. Personal air sampling results were reviewed after each job and used to modify respirator requirements for subsequent jobs. For example, personal air samples collected during the cleaning verification stage were consistently below the analyzing laboratory's detection limits; therefore, contractors and field technicians in Pittsburgh and Columbus were not required to wear respiratory protection during the cleaning verification stage after the first two weeks of field work.

Hygiene – Site-specific health and safety plans called for handwashing facilities to include hot water, soap, and towels. Contractors in Columbus in Pittsburgh were responsible for providing these facilities, which typically consisted of two handheld pressure sprayers (one filled with soapy water, one with clear water) and a bucket to collect used water. Workers in the COF had access to a sink with running water and often elected to use hand soap at the sink instead of the pressure sprayers. Because much of the field work was conducted in cold weather, it was not always possible to use hot water for the handwashing stations set up at the housing units. Contractors had no way of heating the water or maintaining its temperature in the field. On days when outdoor temperatures were below freezing, some crew members elected to use baby wipes to clean their hands and faces in lieu of the cold water in the pressure sprayers.

Medical Surveillance – Medical surveillance was conducted on all field personnel and renovation workers. Each worker's blood lead level was measured before field work began and was or will be measured again following completion of work on the study.

4.7. Recordkeeping

Detailed records were kept of all field data collection activities. The information recorded by site supervisors and field technicians on data collection forms included:

- Clearance sampling locations and chain of custody records;
- Site wind speed and direction data for each day of exterior work;
- Precipitation activity during exterior work;
- P/CU phase of each experiment;
- Description of RRP work and duration of all RRP activities, including setting up plastic coverings, conducting cleaning, and conducting cleaning verification;
- Unit ID, location of study rooms or exterior work area, and specific location of samples obtained;
- Surface type and size of dust wipe samples;
- Air sampling locations and air flow rates for each sampler;
- Soil sample locations and associated sample IDs
- Location of the decontamination area where booties and other protective gear were removed upon exiting the work area;
- Paint lead levels on components undergoing work activity;
- Regular sample and QC sample identification information;
- Chain-of-custody records; and
- Signatures and initials of sample collectors.

When data collectors made or discovered errors on their data collection forms, they crossed out the incorrect information, inserted the correct information, and added their initials and the date next to the change.

In addition to written records, site supervisors obtained digital photographs and video recordings of various activities during the study across a subset of the housing units and experiments performed. Activities photographed or recorded include:

- initial inspection of the properties,
- RRP contractors conducting the work,
- plastic coverings being set up as containment,
- post-work cleaning,
- collection of environmental samples, and
- cleaning verification.

All digital photographs and video recordings were downloaded to computers for electronic storage.

Laboratory results were returned from the laboratory in electronic spreadsheet and Portable Document Format (PDF) files. All laboratory results were entered into a Microsoft (MS) Access 2003 database and exported into MS Excel 2003 and SAS v9.1 for statistical analyses. Data collection forms were archived for use in verifying the results entered in the database and in checking the electronic files received from the laboratory. These forms are not included in this final report in order to maintain the privacy of individual property owners.

5. Statistical Analysis Plan

5.1. Data Organization

A MS Access database was developed to manage the various types of data generated by the study. Throughout the study, paint chip, initial and final soil, initial and final dust clearance, dust wipe, air and bulk samples were collected, with respective collection information recorded on data collection forms (see Section 4). In addition to the environmental samples, property information, room designations and XRF results were recorded. The information recorded on the forms was entered by a data entry specialist or other professional into a customized interface that mirrored the look of the actual forms so that the information could be entered exactly as it was seen on the individual forms, thus reducing the potential for data entry errors. Laboratory analysis results were submitted electronically by the laboratory in MS Excel format. After review, they were directly uploaded into the database. The two sources of information could be linked by the unique sample ID. The information from the data collection sheets provided supplemental information to the lab results, including the collection date, location of the sample, and any issues encountered when collecting the sample.

5.2. Descriptive Analyses

The descriptive analysis section presents summary results for each type of data collected in the order listed below:

- Housing unit/experiment summary data,
- Paint lead levels,
- Pre-work clearance levels,
- Bulk debris samples,
- Interior dust samples,
- Interior air samples,
- Exterior dust samples with and without bulk debris samples included,
- Soil samples,
- Activity duration data, and
- Cleaning verification information.

For the environmental sample data, exploratory descriptive analyses were generated to summarize sampling results summarized by a variety of covariates of interest. The study was performed in multiple housing units in two different cities by four different renovation contractors, providing multiple sources of variance; thus, results are summarized by Unit, City, and Contractor. Results are also presented with respect to the type of job performed and the expected intensity level of the work. Jobs are further aggregated into those that did and did not use restricted practices. For interior experiments, the effect of the P/CU phase used during the experiment is investigated. The P/CU analysis is further broken down into the use or non-use of plastic coverings and whether the RRP contractors followed the rule cleaning or baseline cleaning guidelines. Additionally, floor and sill wipe results are summarized by work room floor type and condition.

For the various categorical variables investigated, detailed descriptive analyses in Appendices B-E contain box plots and summary tables, which illustrate and summarize the distribution of the data across the various factors. A box plot displays the median (represented by the center horizontal line), the 25^{th} percentile (represented by the bottom of the box), and the 75^{th} percentile (represented by the top of the box). The vertical lines, or whiskers, are drawn from the box to the most extreme point within 1.5 * interquartile range. (An interquartile range is the distance between the 25^{th} and the 75^{th} percentiles.) Any value more extreme than this, is identified individually with stars. The data are plotted using a log-base 10 scale. The summary statistics provided in the tables are sample size, arithmetic average, geometric average, minimum, 25^{th} percentile, median, 75^{th} percentile, maximum, and, for interior wipe data, the percentage of measurements exceeding the federal clearance standard.

Continuous variables investigated in the exploratory analyses include the paint lead concentration and size of the disturbed area for both interior and exterior work; pre- and post-work soil lead concentrations for both interior and exterior work; and floor dust lead loadings at clearance and average post-work work room floor lead level for interior work. For these variables, scatter plots of dust lead loadings are presented to illustrate the distribution of the data as a function of the various characteristics. Fitted linear regression lines are included on those scatter plots with associated r-square values to provide information on the correlation between the data and the characteristic of interest.

The detailed descriptive analyses (Appendices B-E) also present analysis of the distribution of the various types of data before and after transformation.

Due to laboratory limitations, some environmental samples were reported as having levels below the detection limit, which was 10 µg for dust wipes and 2 µg for air samples. In order to include these values in summary analyses, the lead level for all sample types was set to one half of the reporting limit of the laboratory.

The dust wipes in the descriptive analyses are presented as both wipe only and wipe plus bulk results. The wipe only results represent the amount of lead dust remaining on the floor after RRP work was performed and larger pieces of debris and excessive amounts of dust were picked up; a probable scenario for real-world RRP work. The inclusion of bulk samples provides a value of the total lead in the dust and debris, and thus total lead contamination, resulting from the work.

5.3. Statistical Models

Effectiveness of the proposed cleaning and interior plastic and exterior plastic protocols was analyzed using general linear models with mixed (fixed and random) effects. The response ($\log_e$-concentrations) was modeled to be linearly related to combinations of categorical and continuous covariates. The lead concentrations were $\log_e$-transformed prior to modeling so that residuals were approximately normally-distributed. Key fixed effects included indicators for rule- or baseline cleaning and use of containment plastic on interior jobs. On exterior jobs, the key fixed effects included tray position on, under or near a sheet of plastic.

A random effect was included for experiment number (grouped by Work-room number nested within housing unit) in order to model covariance among the multiple sub-samples to correctly assess significance and confidence limits. That is, floor-wipes within an experiment are treated as sub-samples (exchangeable repeated measures) on the experimental unit. Dustpan loadings in each exterior experiment are also treated as sub-samples on the experimental unit.

Besides key fixed effects, other covariates (both categorical and continuous) were analyzed to assess the extent that different factors explain differences in $\log_e$ lead concentrations in the samples. More detailed descriptions follow. Detailed model results across all objectives is available in Appendices I through N.

The first objective is assessed using only Work-room wipes at the Post-work (PW) stages. The effects of plastic and cleaning (the second and third objectives) on reduction of $\log_e$ lead levels subsequent to cleaning are assessed using Work-room wipes from Post-cleaning (PC) and Post-verification (PV) stages. The effects of plastic and cleaning on migration (the fourth objective) are assessed on wipes from Post-cleaning (PC) and Post-verification (PV) stages from the Observation and Tool rooms. Objective 5 addresses exterior plastic and involves only the exterior dust pan $\log_e$ loadings.

6. Descriptive Analyses

6.1. Housing Unit/Experiment Summary Information

Table 6-1 summarizes the 15 housing units and one COF utilized to complete the 75 experiments. The four apartments (H31-H33, H35) were located in two attached buildings and the two duplex units (H16-H17) were both halves of the same building. Thus, 12 separate buildings were used for the study, with most of the buildings built between approximately 1900 and 1925. The only exception was the COF school building, which was built in 1967.

Table 6-1. Housing Unit Information

Unit ID	City	Year Built	Building Type	Approximate Interior Square Footage
H01	Columbus, Ohio	1918	Single Family	Exterior Only
H02	Columbus, Ohio	OLD* (Pre-1920)	Single Family	Exterior Only
H03	Columbus, Ohio	OLD* (Pre-1920)	Single Family	1,500
H08	Columbus, Ohio	1910	Single Family	1,744
H09	Columbus, Ohio	OLD* (Pre-1920)	Single Family	2,404
H10	Pittsburgh, Pennsylvania	1920	Single Family	2,508
H13	Pittsburgh, Pennsylvania	1900	Single Family	Exterior Only
H16	Pittsburgh, Pennsylvania	1925	Duplex	1,472
H17	Pittsburgh, Pennsylvania	1925	Duplex	1,472
H19	Columbus, Ohio	1920	Garage	Exterior Only
H31	Pittsburgh, Pennsylvania	1925	Apartment	550
H32	Pittsburgh, Pennsylvania	1925	Apartment	550
H33	Pittsburgh, Pennsylvania	1925	Apartment	550
H35	Columbus, Ohio	1900	Single Family	1,538
H36	Pittsburgh, Pennsylvania	1925	Apartment	550
C01	Columbus, Ohio	1967	School	Not available

* Only information on Year Built from tax assessor records is "OLD." Nearby properties indicate that these houses were likely built between 1900 and 1920.

Tables 6-2 and 6-3 summarize various characteristics of the interior and exterior experiments, respectively. For the interior experiments, Table 6-2 contains the average paint lead, amount of surface disturbed and type of surface disturbed. Average paint lead ranged from 0.8 to 13.0 percent by weight across the 60 interior experiments. For the work room, floor type and condition and size are presented. The size of the tool and observation rooms is also included, as well as the distance from the observation room to the work room. This was calculated as the distance from the observation room entrance to the work room entrance. In some cases, these distances are relatively small, such as four and five feet. In those cases, the work room was a second floor bedroom and the observation room was another second floor bedroom. The hallway separating the bedrooms served as the tool room.

Table 6-2. Interior Experiment Summary Table

Job-Related Information							Work Room				Tool Room		Observation Room		
Exp. #	Unit ID	Job	Phase	Avg. Paint Lead (% by wt.)	Disturbed Paint (ft^2)	Substrate Behind Paint	Room #	Floor Type	Floor Condition	Size (ft^2)	Room #	Size (ft^2)	Room #	Size (ft^2)	Distance to Work Room (ft)
5	H03	Dry Scrape	I	1.6	90	Plaster	201	Wood	Poor	160	205	70	203	100	15
6	H03	Dry Scrape	II	2.7	90	Plaster	201	Wood	Poor	160	205	70	203	100	15
7	H03	Dry Scrape	IV	1.7	70	Plaster	201	Wood	Poor	160	205	70	203	100	15
8	H03	Dry Scrape	III	1.7	110	Plaster	201	Wood	Poor	160	205	70	203	100	15
9	H09	Window Repl.	III	7.3	9	Wood	201	Wood	Poor	180	204	100	203	200	5
10	H09	Window Repl.	IV	3.3	9	Wood	201	Wood	Poor	180	204	100	203	200	5
11	H09	Window Repl.	II	10.1	18	Wood	203	Wood	Poor	200	204	100	201	180	5
12	H09	Window Repl.	I	7.2	11	Wood	206	Wood	Poor	150	204	100	203	200	15
13	H09	Heat Gun	II	8.1	53	Wood/Stone	201	Wood	Poor	180	204	100	203	200	5
14	H09	Heat Gun	III	2.0	75	Wood	202	Wood	Poor	140	204	100	203	200	5
15	H09	Heat Gun	IV	10.2	75	Wood/Stone	203	Wood	Poor	200	204	100	206	150	15
16	H09	Heat Gun	I	4.0	75	Wood	206	Wood	Poor	150	204	100	203	200	15
22	H16	Cut-outs	IV	3.6	13	Plaster	103	Vinyl Tile	Good	190	102	215	101	230	14
23	H16	Cut-outs	I	3.6	14	Plaster	103	Vinyl Tile	Good	190	102	215	101	230	14
24	H17	Cut-outs	III	5.0	40	Plaster	103	Vinyl Tile	Good	190	102	215	101	230	14
25	H16	Cut-outs	II	3.6	14	Plaster	103	Vinyl Tile	Good	190	102	215	101	230	14
26	H17	Dry Scrape	III	2.1	60	Plaster	103	Vinyl Tile	Good	190	102	215	101	230	14
27	H17	Dry Scrape	IV	2.5	64	Plaster	103	Vinyl Tile	Good	190	102	215	101	230	14
28	H17	Dry Scrape	I	2.5	65	Plaster	103	Vinyl Tile	Good	190	102	215	101	230	14
29	H17	Dry Scrape	II	2.6	72	Plaster	103	Vinyl Tile	Good	190	102	215	101	230	14
30	H10	Heat Gun	IV	10	65	Wood	201	Wood	Poor	150	206	50	202	105	4
31	H10	Heat Gun	II	5.1	65	Wood	201	Wood	Poor	150	206	50	202	105	4
32	H10	Heat Gun	III	8.5	69	Wood	201	Wood	Poor	150	206	50	202	105	4
33	H10	Heat Gun	I	3.5	60	Wood	201	Wood	Poor	150	206	50	202	105	4
41	H16	Window Repl.	I	0.9	10	Wood	101	Wood	Poor	230	102	215	103	190	14
42	H16	Window Repl.	II	1.9	10	Wood	101	Wood	Poor	230	102	215	103	190	14
43	H17	Window Repl.	IV	1.9	10	Wood	101	Wood	Fair	230	102	215	103	190	14
44	H17	Window Repl.	III	4.1	10	Wood	101	Wood	Fair	230	102	215	103	190	14
45	H08	Cut-outs	IV	1.8	6	Plaster	103	Vinyl Tile	Poor	180	102	220	101	200	15
46	H08	Cut-outs	III	1.8	7	Plaster	103	Vinyl Tile	Poor	180	102	220	101	200	15
47	H08	Door Plane	IV	3.9	40	Wood	103	Vinyl Tile	Poor	180	102	220	101	200	15
48	H08	Door Plane	I	7.8	40	Wood	103	Vinyl Tile	Poor	180	102	220	101	200	15
49	H31	Kitchen Gut	II	1.7	55	Plaster	101	Vinyl Tile	Fair	80	106	80	102	110	10
50	H32	Kitchen Gut	IV	2.3	40	Plaster	101	Vinyl Tile	Fair	80	106	80	102	110	10

Table 6-2. (continued) Interior Experiment Summary Table

Job-Related Information							Work Room				Tool Room		Observation Room		
Exp. #	Unit ID	Job	Phase	Avg. Paint Lead (% by wt.)	Disturbed Paint (ft^2)	Substrate Behind Paint	Room #	Floor Type	Floor Condition	Size (ft^2)	Room #	Size (ft^2)	Room #	Size (ft^2)	Distance to Work Room (ft)
51	H33	Kitchen Gut	I	3.5	66	Plaster	101	Vinyl Tile	Fair	80	106	80	102	110	10
52	C01	Cut-outs	III	9.5	6	Plaster	102	Tile	Good	120	112	560	120	50	25
53	C01	Cut-outs	II	7.4	6	Plaster	102	Tile	Good	120	112	560	120	50	20
54	C01	Cut-outs	IV	7.4	6	Plaster	102	Tile	Good	120	112	560	120	50	15
55	C01	Cut-outs	I	7.4	6	Plaster	102	Tile	Good	120	112	560	120	50	15
56	C01	Low Heat Gun	II	2.2	50	Plaster	105	Tile	Good	190	115	550	125	120	20
57	C01	Low Heat Gun	IV	2.4	50	Plaster	105	Tile	Good	190	115	550	125	120	15
58	C01	Low Heat Gun	III	2.8	50	Plaster	105	Tile	Good	145	115	600	125	120	15
59	C01	Low Heat Gun	I	13.0	50	Plaster	105	Tile	Good	240	115	500	125	120	25
60	C01	Heat Gun	II	2.9	75	Plaster	105	Tile	Good	160	115	580	125	120	25
61	C01	Heat Gun	III	2.2	75	Plaster	105	Tile	Good	160	115	580	125	120	25
62	C01	Heat Gun	IV	2.2	73	Plaster	102	Tile	Good	160	112	520	120	50	25
63	C01	Heat Gun	I	2.6	75	Plaster	102	Tile	Good	160	112	520	120	50	25
67	H16	Kitchen Gut	I	1.2	40	Plaster	103	Vinyl Tile	Good	190	102	215	101	230	14
68	H17	Kitchen Gut	III	2.5	34	Plaster	103	Vinyl Tile	Good	190	102	215	101	230	14
69	H08	Kitchen Gut	IV	5.2	69	Plaster	103	Vinyl Tile	Poor	180	102	220	101	200	15
70	H35	Kitchen Gut	II	0.8	61	Plaster	101	Tile	Fair	115	110	50	104	180	10
71	H35	Cut-outs	II	0.8	6	Plaster	101	Tile	Fair	115	110	50	104	180	10
72	H35	Cut-outs	I	1.0	7	Plaster	101	Tile	Fair	115	110	50	104	180	10
73	H35	Door Plane	II	1.2	31	Wood	101	Tile	Fair	115	110	50	104	180	10
74	H35	Door Plane	III	3.2	26	Wood	101	Tile	Fair	115	110	50	104	180	10
76	H36	Kitchen Gut	III	1.6	60	Plaster	101	Vinyl Tile	Fair	80	106	80	102	110	10
77	H08	Door Plane	II	1.7	26	Wood	103	Vinyl Tile	Poor	180	102	220	101	200	15
78	H08	Door Plane	IV	2.0	25	Wood	103	Vinyl Tile	Poor	180	102	220	101	200	15
79	H09	Door Plane	I	2.1	32	Wood	202	Wood	Poor	140	204	100	203	200	5
80	H09	Door Plane	III	5.9	40	Wood	201	Wood	Poor	180	204	100	203	200	5

Table 6-3. Exterior Experiment Summary Table

Exp. #	Job	Unit ID	Work Location	Painted Material	Average Paint Lead (% by wt.)	Disturbed Paint (ft^2)	Length of Rule Plastic from Work Location (ft)	Width of Rule Plastic (ft)	Length of Containment Plastic Beyond Rule Plastic (ft)
1	Dry Scrape	H01	North Wall	Wood	13.5	90	7	12	10
2	Power Sanding	H01	North Wall	Wood	11.7	100	12	35	5
3	Power Sanding	H01	North Wall	Wood	13.1	100	12	25	5
4	Trim Replacement	H02	Rear Porch	Wood	15.3	40	5	20	2
21	Dry Scrape	H09	North Wall	Wood	1.3	150	12	25	6
34	Replace Exterior Door	H16	South Wall	Wood	10.5	25	4	8	4
35	Replace Exterior Door	H17	North Wall	Wood	11.2	25	4	8	4
36	Trim Replacement	H10	Front Porch	Wood	16.8	60	13	24	4
37	Torching	H10	Porch Ceiling	Wood	2.7	98	13	20	4
38	Torching	H13	Porch Ceiling	Wood	11.4	80	10	15	4
40	Dry Scrape	H19	North Wall	Wood	15.7	250	6	20	6
64	Low Heat Gun	C01	Door Trim in Courtyard	Wood	31.5	75	5	10	3
65	Needle Gun	C01	Railing in Courtyard	Metal	5.3	30	5	30	Varied*
66	High Heat Gun	C01	Awning in Courtyard	Metal	18.3	30	8	12	8
75	Dry Scrape	H09	North Wall	Wood	1.3	100	6	25	10

* The containment plastic did not extend an identical amount in all directions around the railing. The railing was bordered on one side by a staircase and a vertical wall, which limited the size of the rule and containment plastic on that side.

6.2. Paint Lead Levels

Once the presence of lead-based paint was established based on XRF measurements, paint chips were obtained from each building component that would be disturbed by the renovation work. In all cases, the laboratory reported lead levels in the paint chips consistent with the definition of LBP. In general, higher levels of lead were found on exterior surfaces with average paint lead levels ranging from 1 percent to 32 percent by weight across the 15 exterior experiments with an overall average of approximately 12 percent. Across the 60 interior experiments, overall average paint lead levels ranged from 1 to 13 percent with an average of approximately 4 percent.

The lead content of the paint in a particular experiment could affect the resulting dust lead levels. To investigate this within Appendix G, Section G2 contains detailed summaries of the average paint lead levels by intensity level, city, job, use of plastic and cleaning method, and other experimental characteristics. The bullets below summarize some findings of interest from those analyses:

- Average paint lead levels were similar across the three intensity levels for both interior and exterior work. Average interior levels were 3 or 4 percent across the three levels for interior work and 11 to 13 percent across the three levels for exterior work (see Figure/Table G2.1a).
- Average paint lead levels differed a bit across jobs (see Figure/Table G2.3a). Average paint lead levels ranged from 2 to 5 percent across different interior jobs with dry scraping and kitchen gut/cabinet replacement having the lowest average levels. Average paint lead levels ranged from 5 to 32 percent across different exterior jobs with the needle gun, torching, and dry scraping being the only jobs averaging less than 10 percent. The low heat gun job on an exterior door and doorway at the school was the job with a paint lead average of 32 percent lead, much higher than the next highest single job average of 18 percent.
- Average paint lead level did not differ based on plastic use, cleaning method, or phase (see Figures/Tables G2.5a-2.7a).
- There appeared to be only a slight association between paint lead levels and average post-work floor lead loadings in the work room (see Figure G2.11).
- Paint lead levels and post-work soil lead levels after interior work appeared to have some association with an r-square of 0.11 (see Figure G2.14).

In addition to the average paint lead level, the amount of paint disturbed during the work was another factor that might influence the lead levels resulting from the job. Following work, field technicians recorded the approximate number of square feet that were disturbed by each job. Area disturbed ranged from 25 to 250 ft^2 across exterior jobs and 6 to 110 ft^2 across interior jobs. Appendix G, Section G3 explores the association of square footage disturbed with the various other study characteristics of interest. Findings of interest are listed below:

- Low level interior and exterior jobs disturbed significantly less area than the medium and high intensity jobs, which is consistent with the study design (see Figure/Table G3.1a)

- Of the interior jobs, the cut outs and window replacement jobs disturbed the least amount of paint (see Figure/Table G3.2a).
- Average area disturbed did not differ much based on plastic use, cleaning method, or phase (see Figures/Tables G3.5a-2.7a).
- For interior restricted jobs, average area disturbed was 61 ft^2 compared to 26 ft^2 for non-restricted jobs (see Figure/Table G3.8a).
- As seen in Figure 6-1 below, average area disturbed did appear to be associated with average post-work floor lead levels in the work room with an r-square of 0.28 (see also Figure G3.11). Average area disturbed may be associated with job intensity, since the disturbed area increased as the (initial) job intensity increased.

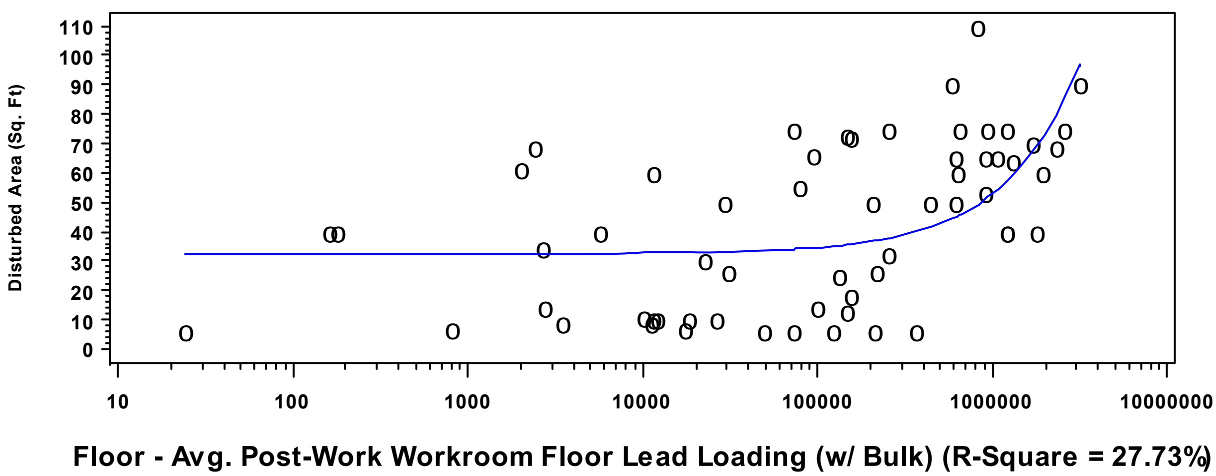

Figure 6-1. Scatter Plot of Area Disturbed Versus Average Post-work Work Room Floor Lead Loading

6.3. Pre-work Clearance Levels

The goal at the beginning of each experiment was to obtain values of <10 µg/ft^2 for all pre-work floor clearance samples and <62.5 µg/ft^2 for all pre-work window sill clearance samples. Because of study implementation issues such as some floors and sills that were difficult to clean and in poor condition, the pre-work clearance standards were changed to target an average of <40 µg/ft^2 for floors and < 250 µg/ft^2 for sills, the current EPA clearance levels for lead in dust. For most experiments these targets were achieved; however, there were a few cases where they were not.

As seen in Table 6-4, which presents the average clearance levels for all experiments, there were three experiments that started with average work room floor lead levels above 40 µg/ft^2, ranging from 44 to 151 µg/ft^2. Tool room and observation room floor lead levels started above 40 µg/ft^2 once in each room type. Additionally, exit hallways started above 40 µg/ft^2 four times. There were also a handful of cases where a window sill was used for sampling after failing to get below clearance levels. For most experiments, dust collection trays replaced window sills when they were in poor condition or could not pass clearance.

Pre-work clearance levels did not appear to be associated with other endpoints. Within Appendix G, pre-work clearance levels are compared to average post-work lead levels and little or no correlation is evident with an r-square of 0.03 (see Figure G1.12). Figures C3.2a-c within Appendix C explore the correlation between pre-work clearance levels and post-work, post-cleaning, and post-verification floor lead levels. No correlation was apparent in any of the three rooms at any of the three sampling stages. Figures D3.2a-c within Appendix D present these analyses for sill lead levels with similar results.

Table 6-4. Summary of Pre-Work Clearance Information

			Final Pre-work Floor Lead Levels								Final Pre-work Sill Lead Levels **					
			Work Room		Tool Room		Observ. Room		Hallway		Work Room		Tool Room		Observ. Room	
Exp. #	Job	Phase	Avg. (μg/ft^2)	# of Cleans^	Avg. (μg/ft^2)	# of Cleans	Avg. (μg/ft^2)	# of Cleans	Avg. (μg/ft^2)	# of Cleans	Avg. (μg/ft^2)	# of Cleans	Avg. (μg/ft^2)	# of Cleans	Avg. (μg/ft^2)	# of Cleans
5	Dry Scrape	I	28.4	1	29.8	1	25.7	1	<10	1	323.1[T]	1	n/a		1,980[T]	1
6	Dry Scrape	II	27.4	2	15.3	1	22.1	1	<10	1	-	-	-	-	-	-
7	Dry Scrape	IV	35.0	1	32.3	1	17.8	1	<10	1	-	-	-	-	-	-
8	Dry Scrape	III	7.1	2	8.3	1	< 10	1	<10	1	-	-	-	-	-	-
9	Window Repl.	III	30.0	2	10.5	1	19.6	1	20.6	1	120.8	2	< 10	1	58.5	2
10	Window Repl.	IV	< 10	1	55.8*	1	44.7*	1	8.4	1	30.9	1	756.9[T]	1	44	1
11	Window Repl.	II	6.8	3	< 10	1	< 10	2	4.1	1	46.3	1	7,737.4[T]	1	228.8	1
12	Window Repl.	I	43.9	2	< 10	1	< 10	1	<10	1	346.9[T]	2	172.0[T]	1	404.7[T]	1
13	Heat Gun	II	10.4	1	< 10	1	8.7	1	57.6	1	18.3[T]	1	481.3[T]	1	80.5[T]	1
14	Heat Gun	III	< 10	2	28.2	1	32.5	1	9.9	1	1684.4[T]	1	1096.6[T]	1	74.7[T]	1
15	Heat Gun	IV	< 10	1	< 10	1	< 10	1	45.7	1	89.7[T]	1	453.3[T]	1	552.3[T]	1
16	Heat Gun	I	< 10	1	< 10	1	< 10	1	6.0	1	374.3[T]	1	1,828.1[T]	1	7.3[T]	1
22	Cut-outs	IV	< 10	1	< 10	1	< 10	1	-	-	61.1	1	960.6[T]	1	35.8	1
23	Cut-outs	I	< 10	1	< 10	1	< 10	1	-	-	<15.9	1	73.3	1	<20.0	1
24	Cut-outs	III	< 10	2	12.7	1	21.4	1	-	-	<76.9	1	88.3	1	94	1
25	Cut-outs	II	< 10	1	< 10	1	< 10	1	-	-	<15.9	1	63.2	1	<20.0	1
26	Dry Scrape	III	< 10	1	< 10	1	8.7	1	-	-	< 20	1	143.7	1	24.4	1
27	Dry Scrape	IV	< 10	1	< 10	1	< 10	1	-	-	25.9	1	78.8	1	19.7	1
28	Dry Scrape	I	< 10	1	< 10	1	< 10	1	-	-	< 20	1	18.9	1	29.4	1
29	Dry Scrape	II	< 10	1	< 10	1	< 10	1	-	-	< 20	1	< 20	1	16.5	1
30	Heat Gun	IV	11.0	2	< 10	2	< 10	2	29.3	2	-	-	-	-	-	-
31	Heat Gun	II	17.8	2	< 10	2	< 10	2	<10	2	-	-	-	-	-	-
32	Heat Gun	III	18.3	1	< 10	1	< 10	1	12.0	1	-	-	-	-	-	-
33	Heat Gun	I	< 10	1	< 10	1	< 10	1	10.0	1	-	-	-	-	-	-
41	Window Repl.	I	< 10	1	< 10	1	< 10	1	-	-	< 16.1	1	45.4	1	< 16.1	1
42	Window Repl.	II	< 10	1	< 10	1	< 10	1	-	-	< 16.1	1	< 16.1	1	13	1
43	Window Repl.	IV	< 10	1	< 10	1	< 10	1	-	-	20.2	1	65.3	1	< 16.1	1
44	Window Repl.	III	< 10	1	< 10	1	< 10	1	-	-	18.3	1	< 16.1	1	< 16.1	1
45	Cut-outs	IV	95.0	2	20.7	2	18.8	2	-	-	1,217.50	2	29.6	1	< 20.8	1
46	Cut-outs	III	19.0	2	39.3*	1	146.1*	1	-	-	336.8[T]	2	45.0[T]	1	< 20.8[T]	1
47	Door Plane	IV	< 10	1	< 10	1	< 10	1	-	-	107.1	1	<10.9	1	<1.8	1

Table 6-4. (continued) Summary of Pre-Work Clearance Information

			Final Pre-work Floor Lead Levels								Final Pre-work Sill Lead Levels **					
			Work Room		Tool Room		Observ. Room		Hallway		Work Room		Tool Room		Observ. Room	
Exp. #	Job	Phase	Avg. (µg/ft^2)	# of Cleans^	Avg. (µg/ft^2)	# of Cleans	Avg. (µg/ft^2)	# of Cleans	Avg. (µg/ft^2)	# of Cleans	Avg. (µg/ft^2)	# of Cleans	Avg. (µg/ft^2)	# of Cleans	Avg. (µg/ft^2)	# of Cleans
48	Door Plane	I	150.7	1	708.7*	1	250.3*	1	-	-	516.8	1	599.7	1	55.7	1
49	Kitchen Gut	II	< 10	1	< 10	1	< 10	1	-	-	<30.3	1	-	-	<13.3	1
50	Kitchen Gut	IV	< 10	1	< 10	1	< 10	1	-	-	<30.3	1	-	-	< 10	1
51	Kitchen Gut	I	< 10	1	< 10	1	< 10	1	-	-	<30.3	1	-	-	154.2	1
52	Cut-outs	III	< 10	1	< 10	1	19.3	1	< 10	1	-	-	-	-	-	-
53	Cut-outs	II	< 10	1	< 10	1	< 10	1	8.9	1	-	-	-	-	-	-
54	Cut-outs	IV	< 10	1	< 10	1	< 10	1	< 10	1	-	-	-	-	-	-
55	Cut-outs	I	6.8	1	< 10	1	< 10	1	< 10	1	-	-	-	-	-	-
56	Low Heat Gun	II	7.9	1	10.8	1	< 10	1	< 10	1	-	-	-	-	-	-
57	Low Heat Gun	IV	6.8	1	8.6	1	8.6	1	12.3	1	-	-	-	-	-	-
58	Low Heat Gun	III	18.4	1	12.5	1	9.1	1	< 10	1	-	-	-	-	-	-
59	Low Heat Gun	I	9.4	1	14.4	1	< 10	1	< 10	1	-	-	-	-	-	-
60	Heat Gun	II	14.1	1	82.0	1	< 10	1	< 10	1	-	-	-	-	-	-
61	Heat Gun	III	12.5	1	11.2	1	< 10	1	< 10	1	-	-	-	-	-	-
62	Heat Gun	IV	< 10	1	< 10	1	< 10	1	< 10	1	-	-	-	-	-	-
63	Heat Gun	I	< 10	1	< 10	1	< 10	1	< 10	1	-	-	-	-	-	-
67	Kitchen Gut	I	< 10	1	< 10	1	< 10	1	-	-	< 16.1	1	131.3	1	< 16.1	1
68	Kitchen Gut	III	< 10	1	< 10	1	<10	1	-	-	152.1	1	19.2	1	66.1	1
69	Kitchen Gut	IV	< 10	1	< 10	1	<10	1	-	-	264.8	1	55.1	1	< 15.4	1
70	Kitchen Gut	II	8.4	1	< 10	1	<10	1	69.2	1	< 30.3	1	-	-	27.4	1
71	Cut-outs	II	< 10	1	8.0	1	< 10	1	141.1	1	22.4	1	-	-	28.9	1
72	Cut-outs	I	< 10	1	< 10	1	< 10	1	17.2	1	< 18.5	1	-	-	< 13.2	1
73	Door Plane	II	< 10	1	< 10	1	< 10	1	<10	1	<18.9	1	-	-	13.4	1
74	Door Plane	III	< 10	1	< 10	1	< 10	1	<10	1	<14.5	1	-	-	23.2	1
76	Kitchen Gut	III	< 10	1	< 10	1	< 10	1	-	-	<30.3	1	-	-	404.6^{T}	1
77	Door Plane	II	7.5	1	< 10	1	< 10	1	-	-	3,304.9^{T}	1	25.4	1	25.1	1
78	Door Plane	IV	18.0	1	< 10	1	< 10	1	-	-	1,161.1^{T}	1	90.5	1	10.4	1
79	Door Plane	I	< 10	1	< 10	1	48.9	1	8.2	1	1,691.9^{T}	1	1,078.8^{T}	1	104.7	1
80	Door Plane	III	9.6	1	< 10	1	38.6	1	37.0	1	417.9^{T}	1	7.8	1	7.4	1

* Clean plastic was put over the floor prior to the start of work

** Where the window sill clearance sample is missing (-), or has a 'T' (^{T}), a dust collection tray was used instead of the window sill

^ # of Cleans represents the number of times that a unit was cleaned prior to an experiment. If one or more rooms did not pass clearance, re-cleaning and additional clearance testing was required.

6.4. Bulk Debris Samples

Many of the intensive renovation jobs generated large amounts of debris and dust. When larger pieces of debris and/or excessive dust were present, technicians collected it in a sample bag or container prior to collecting the dust wipe. For interior work, all these samples were taken in the work room during the post-work stage. For exterior work, all bulk samples were taken on top of the rule plastic. In later analyses, the bulk sample results are largely excluded from interior data analyses based on the concept that renovators would typically pick up larger debris and excessive dust. Table 6-5 contains a summary of the bulk debris samples collected on each interior job. Each bulk sample was collected from a specific sampling area, and the average lead in the wipes that correspond to those sampling areas is presented, as well. For the exterior analyses, descriptive analyses of the exterior dust results are presented both with and without the bulk debris samples. Table 6-6 contains summary data by job for the exterior jobs. Similar to the interior experiments, the average lead in the wipes represents the trays from which the bulk samples were collected.

Table 6-5. Interior Bulk Samples by Job Type

Interior Job	# of Bulk Samples	Average Lead in Corresponding Wipes (µg/ft^2)	Average Lead in Bulk Sample (µg/ft^2)	Average Total Lead in Sample Area (µg/ft^2)
Cut-outs	17	1,809.9	255,734.2	257,544.1
Window Replacement	8	10,771.1	84,976.4	95,747.5
Dry Scrape	19	7,659.4	1,946,557.5	1,954,216.9
Door Plane	19	59,802.2	1,685,459.9	1,745,262.0
Low Heat Gun	8	20,509.9	630,303.9	650,813.8
Kitchen Gut	9	3,362.7	74,610.1	77,972.8
Heat Gun	34	32,780.4	1,558,268.2	1,591,048.6
TOTAL	**114**	**23,750.7**	**1,164,304.1**	**1,188,054.8**

Table 6-6. Exterior Bulk Samples by Job Type

Exterior Job	# Bulk Samples	Average Lead in Corresponding Wipes (µg/ft^2)	Average Lead in Bulk Sample (µg/ft^2)	Average Total Lead in Sample Area (µg/ft^2)
Replace Exterior Door	1	5,285.9	212,025.0	217,310.9
Trim Replacement	3	58,423.5	2,087,562.2	2,145,985.6
Needle Gun	2	21,466.4	613,410.1	634,876.4
Dry Scrape	5	58,974.6	5,479,144.3	5,538,118.9
Low Heat Gun	4	65,883.5	34,193,430.5	34,259,314.0
Power Sanding	2	46,608.0	6,431,385.6	6,477,993.6
High Heat Gun	3	17,383.9	490,164.1	507,548.0
Torching	5	25,297.3	6,827,905.1	6,853,202.4
TOTAL	**25**	**42,150.0**	**8,813,750.6**	**8,855,900.6**

6.5. Interior Dust Samples

The exploratory analyses of the interior dust samples include data for both the housing units and COF combined. The bulk debris samples, which all were in the work room at the post-work stage, are not included in these analyses.

6.5.1. Interior Floor Samples

Appendix C contains numerous box plots, summary tables, and scatter plots of the interior floor dust lead loadings across the three study room. The bullets below list highlights of those analyses separately for the Work room and the Tool/Observation rooms.

Work Room

- Figure and Table C2.1a summarize the work room data by intensity level. The geometric means (GM) and medians for the medium intensity job are higher than the high intensity jobs at all three sampling stages. The low intensity jobs do have lower GMs and median floor lead levels compared to the other two intensity levels.
- Floor lead levels are similar between the work in Columbus and Pittsburgh, as seen in Figures and Tables C2.2a to C2.2c.
- The door planing and heat gun jobs >1100 degrees Fahrenheit jobs generated the highest amounts of post-work lead dust in the work room, as seen in Table C2.3.a and Figure 6-2 below.

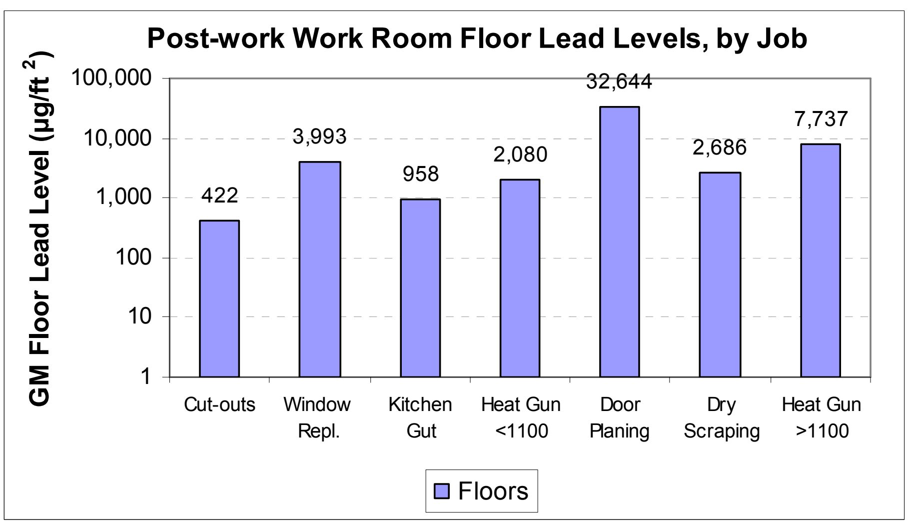

Figure 6-2. Post-work Floor Lead Levels in the Work Room, by Job

- There are differences in work room floor lead levels across the three contractors that performed interior work with post-cleaning GMs ranging from 27 $\mu g/ft^2$ to 90 $\mu g/ft^2$ and post-verification GMs ranging 18 $\mu g/ft^2$ to 53 $\mu g/ft^2$. (Figure/Table C2.4a)
- When plastic protective sheeting was used as required in the proposed EPA rule, GM post-cleaning floor lead levels in the work room are 41 $\mu g/ft^2$ compared to 62 $\mu g/ft^2$ when

plastic was not used. Figure 6-3 compares work room post-cleaning floor lead levels by use of plastic and by job. Use of plastic did not lead to lower post-cleaning floor lead levels in the Work Room for all jobs.

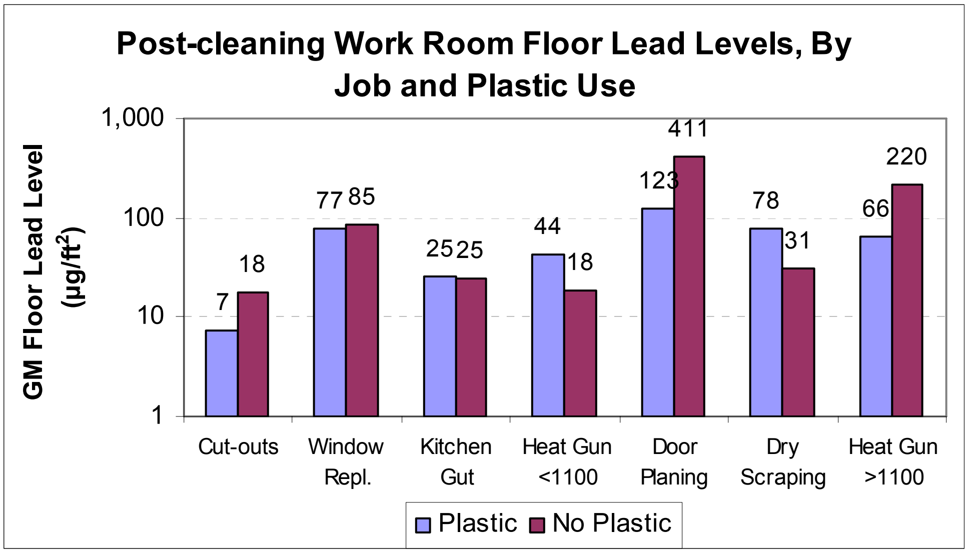

Figure 6-3. Post-Cleaning Work Room Floor Lead Levels, By Job And Plastic Use

- When rule cleaning was performed following work, post-cleaning GM and median floor lead levels in the work room were lower (see Figure/Table C2.7a). Across all jobs, the GM post-cleaning lead level was 34 µg/ft^2 with rule cleaning and 75 µg/ft^2 with baseline cleaning. There is variability in this difference by job, as seen in Figure 6-4, but except for the door planing job, rule cleaning consistently achieved lower post-cleaning levels.

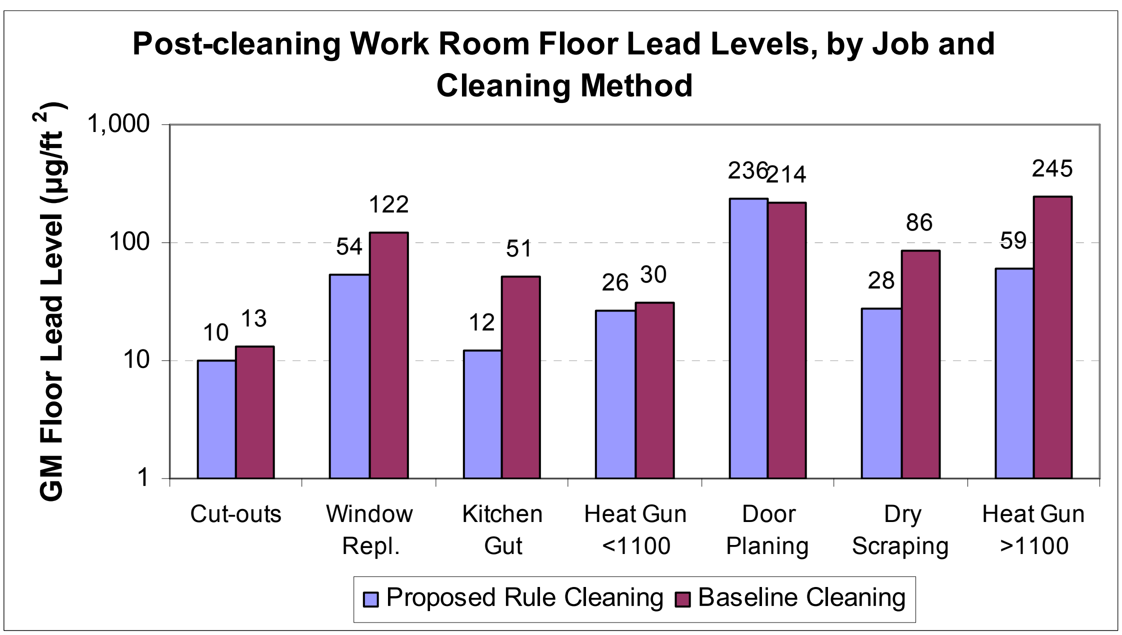

Figure 6-4. Post-Cleaning Work Room Floor Lead Levels, By Job And Cleaning Method

- Table C2.8a reports that the phases using rule cleaning (I and III) led to lower GM floor lead levels in the work room following post-work cleaning, with Phase IV (no plastic and baseline cleaning) having a GM nearly twice that of the nearest phase – 105 µg/ft^2 compared to 54 µg/ft^2 for baseline cleaning with plastic. When analyzing how the four phases compare, it is appropriate to use post-cleaning data for the baseline cleaning phases and post-verification data for the rule cleaning phases, since under the proposed rule the rule cleaning would be followed by the cleaning verification process. These data are referred to as "post-job" levels throughout this and subsequent analyses. Figure 6-5 compares those data for each job, illustrating the consistently lower levels achieved by the proposed rule practices compared to the baseline practices. Regarding the phases that combined rule and baseline practices, in five of seven jobs no plastic/rule cleaning achieved noticeably lower GM floor lead levels than plastic/baseline cleaning, indicating that rule cleaning may be more important than the use of plastic sheeting for lowering lead levels on floors in the Work Room. Large differences are evident for a few jobs such as heat gun over 1100 degrees with GM post-job floor lead levels of 36 µg/ft^2 using proposed rule methods and 445 µg/ft^2 using baseline methods.

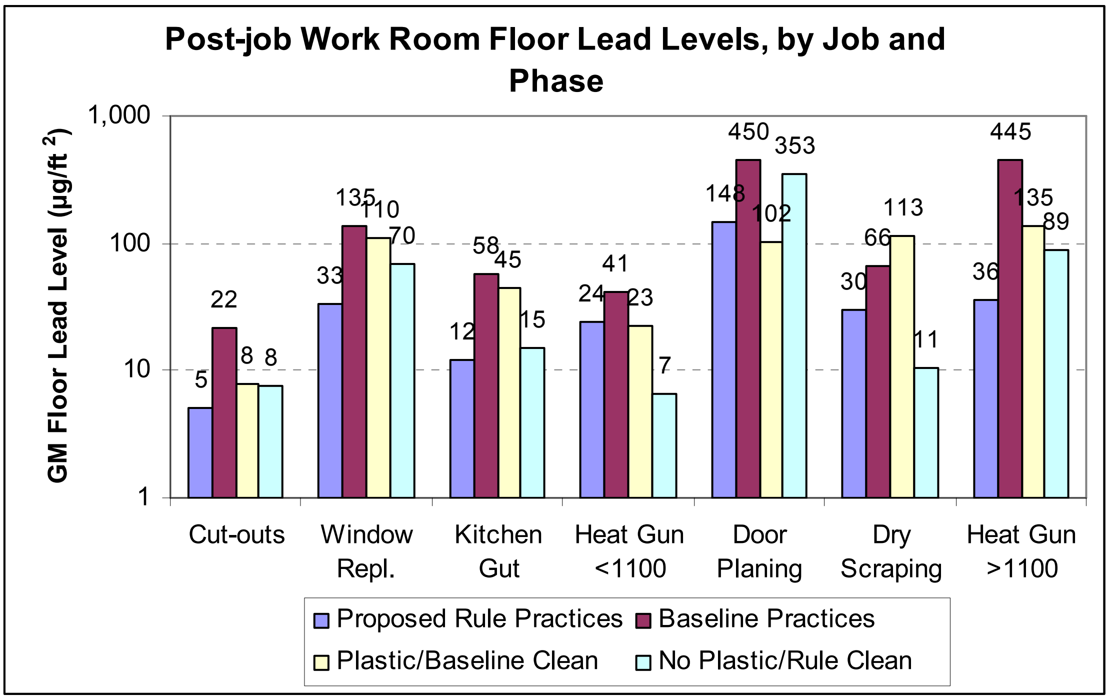

Figure 6-5. Post-Job Work Room Floor Lead Levels, By Job And Phase

- When grouping jobs together by whether a restricted practice was used, the non-restricted practice jobs achieved significantly lower GM and median work room floor lead levels at each of the post-work, post-cleaning, and post-verification phases (see Figure/Table C2.9a).

- Higher lead levels were measured on wood floors compared to tile floors (see Figure/Table C2.10a); however, because the post-work levels are measurably higher on wood floors, this may be correlated with the types of jobs done on wood floors and the paint lead level and square footage disturbed in those rooms.

- Similarly, floor in poor condition also had higher floor lead levels across the three sampling stages; however, because post-work levels are measurably higher, the differences at the subsequent two stages may be caused by higher intensity work (see Figure/Table C2.11a).
- There is some correlation between the average paint lead concentration of the components worked on and the work room floor lead levels measured at the three main sampling stages (see Figure C3.1a). R-square values range from 0.10 to 0.15 across the post-work to post-verification stages. Work room floor lead levels also appear to be correlated with average post-work work room floor lead levels (including bulk debris samples) with r-square values of 0.24 at post-cleaning and 0.16 at post-verification (see Figure C3.6a).
- Work room floor lead levels do not appear to be correlated with pre-work clearance levels, initial and final soil lead levels, and area disturbed.

Tool/Observation Rooms

- Similar to the Work room, the Medium intensity jobs led to a higher GM floor lead level in both the Tool and Observation rooms at all three sampling stages – post-work, post-cleaning, and post-verification (see Figure/Table C2.1b-c).
- Tool and Observation room floor lead levels vary by job performed, with the jobs leading to higher work room levels (Door planing and high heat gun) also having higher levels in the non-work rooms (see Figure/Table C2.3b-c).
- Lower GM floor lead levels were achieved with plastic than without plastic across the three sampling stages (see Figures/Tables C2.6b-c). On the other hand, the levels measured in the non-work rooms did not vary much based on cleaning method used (see Figures/Tables C2.7b-c). Thus, for Tool and Observation rooms, use of plastic sheeting for the Work Room as required by the Proposed Rule appears to be more important than the cleaning method used in the Work Room.
- Comparing proposed rule practices to baseline practices in the Tool room, post-job (post-cleaning for baseline cleaning phases and post-verification for rule cleaning phases) GM floor lead levels are 36 $\mu g/ft^2$ using proposed rule practices and 66 $\mu g/ft^2$ using baseline practices (see Table C2.8b). In the Observation room, post-job floor lead levels are 20 $\mu g/ft^2$ using proposed rule practices and 34 $\mu g/ft^2$ using baseline practices (see Table C2.8c).
- Figures 6-6 and 6-7 plot the post-job (post-cleaning for baseline cleaning phases and post-verification for rule cleaning phases) floor lead levels for Phase I and Phase IV by job. The differences in the non-work rooms become more pronounced in the higher intensity jobs. Further evidence of this is seen when comparing restricted practice jobs to non-restricted practice jobs (see Figure/Table C2.9b-c). The restricted practice jobs have higher GM floor lead levels across the three sampling stages in both non-work rooms, although the difference is larger in the Tool room.

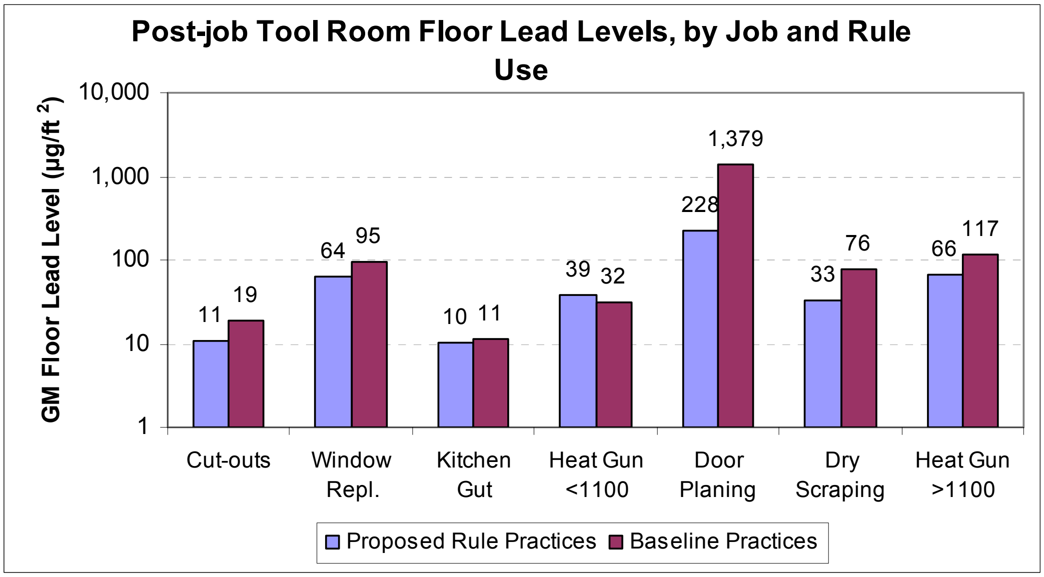

Figure 6-6. Post-Job Tool Room Floor Lead Levels, By Job And Phase

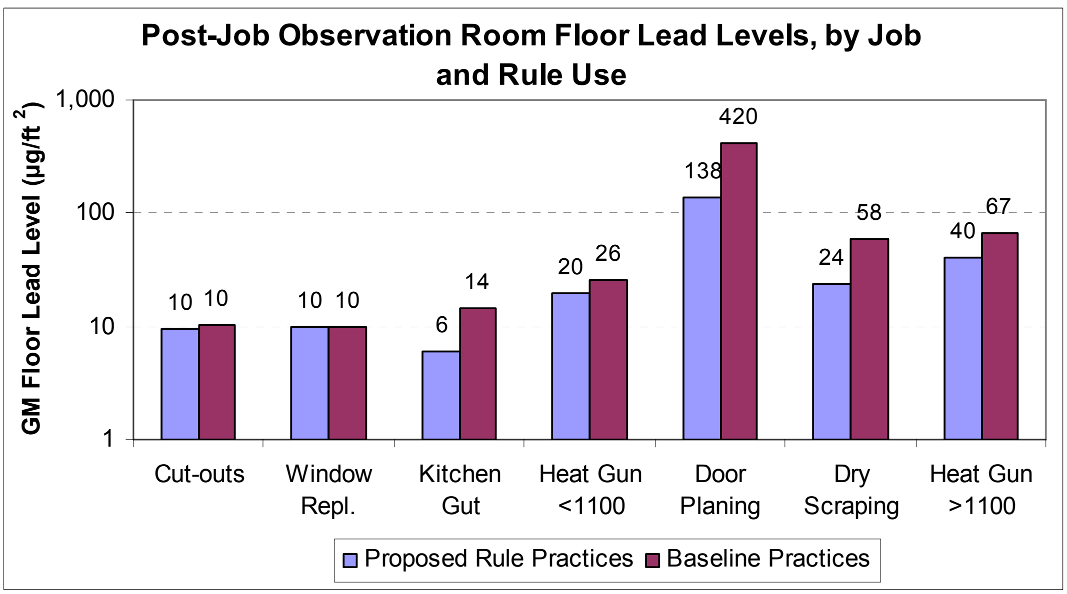

Figure 6-7. Post-Job Observation Room Floor Lead Levels, By Job And Phase

- Tool and Observation room floor lead levels are not correlated with most of the continuous covariates considered (soil lead levels, paint lead levels, square footage); however they do appear to be correlated with post-work work room floor lead levels, i.e., the more lead dust stirred up by the work, the more lead dust escapes to nearby rooms (see Figures C3.6b-c).

6.5.2. <u>Interior Sill Samples</u>

Appendix D contains an identical set of exploratory analyses to that generated for the floor dust data. As seen in Table D1.1, a higher percentage of non-detect measurements was obtained for the window sill data. For example, over 70 percent of Observation Room samples were below the detection limit at the post-cleaning and post-observation stages. Note that the sample sizes for most of the window sill samples were less than 1 square foot. With less surface area to work with on actual window sills and dust collection trays serving as window sills, the size of some sill samples is around 0.25-0.35 ft^2. With a reporting limit of 10 µg of lead and a sample size of .2 ft^2, the reported measurement would be <50 µg/ft^2. As noted earlier, half the detection limit was used for analysis purposes. Thus, a <50 µg/ft^2 sample was reported as 25 µg/ft^2 for the following analyses.

The bullets below contain selected results of interest from the detailed Appendix D analyses.

- The window sill data are much closer to a normal distribution following the log transformation (see Figures D1.1a-D1.3b). The large number of non-detects still skews the distribution, but use of the log-transformed data should be acceptable.
- The post-work sill samples in the Work room do not have a consistent relationship across sampling stages when analyzed by intensity level. At post-work, medium intensity jobs yielded higher sill levels; however at post-cleaning, the high level jobs yielded higher GM sill lead levels (see Figure/Table D2.1a).
- Jobs in Pittsburgh appear to have yielded higher sill lead levels across the three study rooms and all sampling stages than jobs in Columbus (see Figures/Tables D2.2a-D2.2c).
- The door planing job generated higher lead dust on window sills as measured at each sampling stage in all three study rooms (Figure/Tables D2.3a-D2.3c). Generally, the high heat gun job and window replacement job also led to somewhat higher levels than the other jobs.
- Contractor C2's jobs led to lower sill lead levels at all sampling stages across the three rooms (see Figure/Tables D2.4a-D2.4c). This may be correlated with the job types conducted by each contractor.
- The sill lead levels are highly variable across housing units. Unit H10 yielded much higher post-cleaning and post-verification sill lead levels in the work room with GMs of 4,067 µg/ft^2 and 1,367 µg/ft^2 at the two stages, respectively (see Figure/Tables D2.5a-D2.5c). The next highest GM at both stages in the Work room belonged to H08 at 367 µg/ft^2 and 196 µg/ft^2, respectively.
- Use of plastic is associated with lower post-cleaning and post-verification GM and median sill lead levels across all three rooms (see Figure/Tables D2.6a-D2.6c). Sill lead levels in the Tool room are also lower when plastic was used with a post-cleaning GM of 67 µg/ft^2 with plastic and 124 µg/ft^2 without plastic. When focused on post-cleaning levels by job in the Work room, five of seven jobs yielded similar or lower sill lead levels when plastic was used, as illustrated in Figure 6-8.

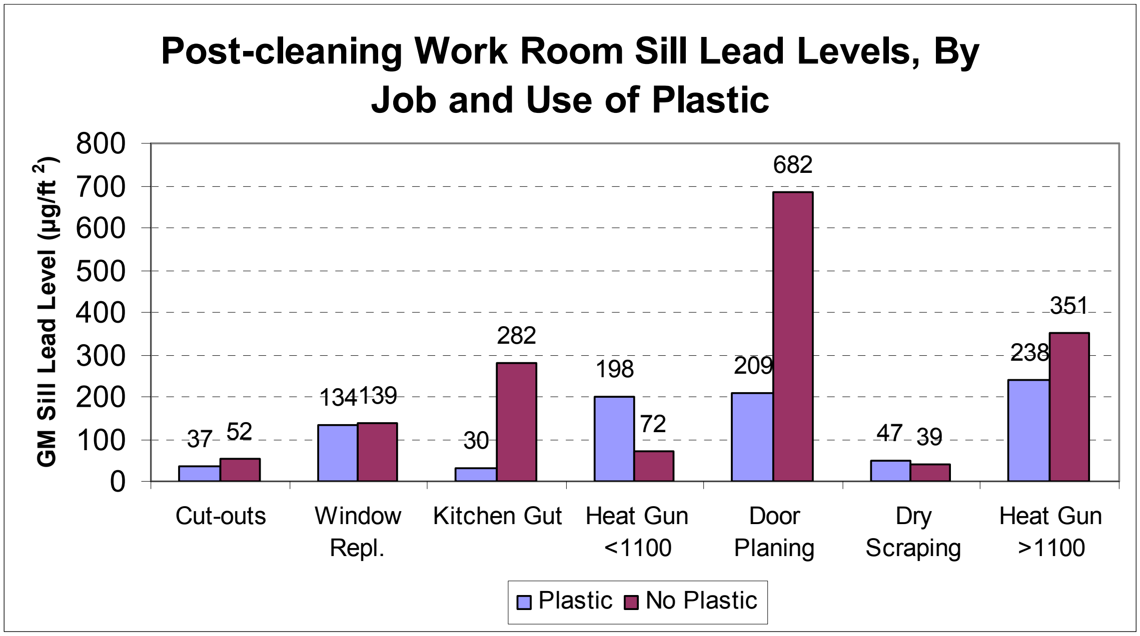

Figure 6-8. Post-Cleaning Work Room Sill Lead Levels, By Job And Plastic Use

- Use of rule cleaning appears to be associated with lower post-cleaning and post-verification sill lead levels in the Work room (see Figure/Tables D2.7a). Figure 6-9 displays Work room sill lead levels by job and cleaning method. Similarly, lower sill lead levels were found in the Tool room at all three sampling stages with GMs of 74, 81, and 54 $\mu g/ft^2$ across the three stages using rule cleaning and 117, 103, and 125 $\mu g/ft^2$ using baseline cleaning (see Figure/Tables D2.7b). Not much difference is observed in the Observation room by cleaning method (see Figure/Tables D2.7c).

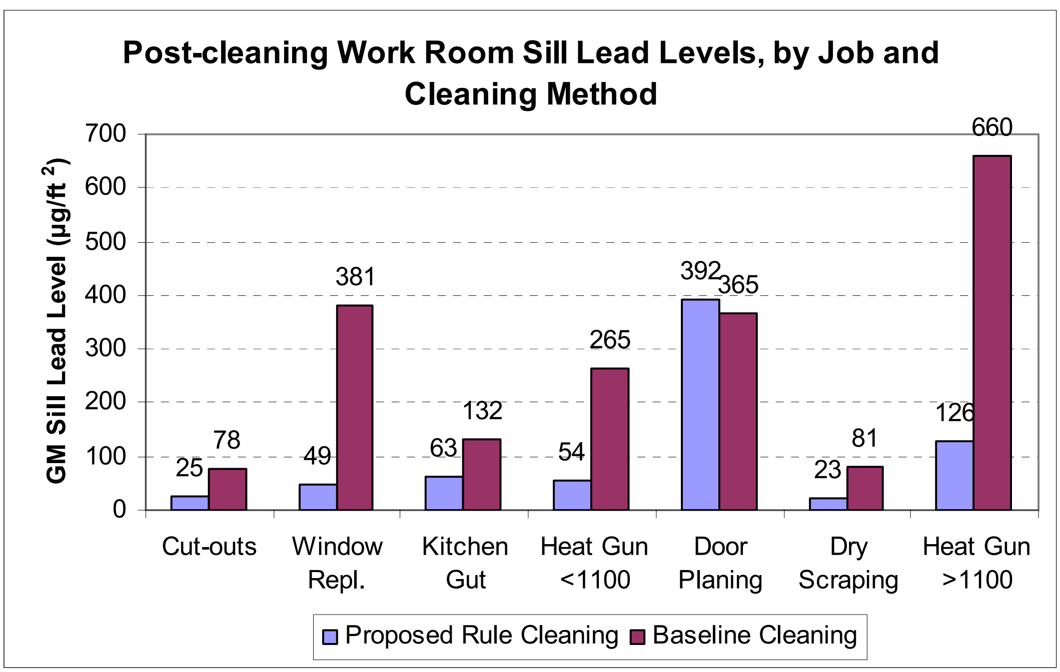

Figure 6-9. Post-Cleaning Work Room Sill Lead Levels, By Job And Cleaning Method

Analyzing the work room sill lead levels by phase, the largest post-cleaning and post-verification differences are between Phases I and IV, with the proposed rule practices having the lowest GM and the baseline practices having the highest GM (see Figure/Tables D2.8a). Figure 6-10 presents the work room data from these two phases by job, using post-verification levels for Phase I and post-cleaning levels for Phase IV. Figure 6-11 presents the work room data for all four phases using post-verification levels for Phases I and III and post-cleaning levels for Phases II and IV. The largest differences are usually between the Proposed Rule Practices and the Baseline practices; however, in the dry scraping and high heat gun jobs, the plastic/baseline cleaning routine yielded higher GM sill lead levels than no plastic/baseline cleaning. [Note that there was only one Heat Gun < 1100°F experiment that used no plastic/rule cleaning and the corresponding post-verification window sill sample in the Work Room was not received by the laboratory, which explains the missing bar in Figure 6-11.]

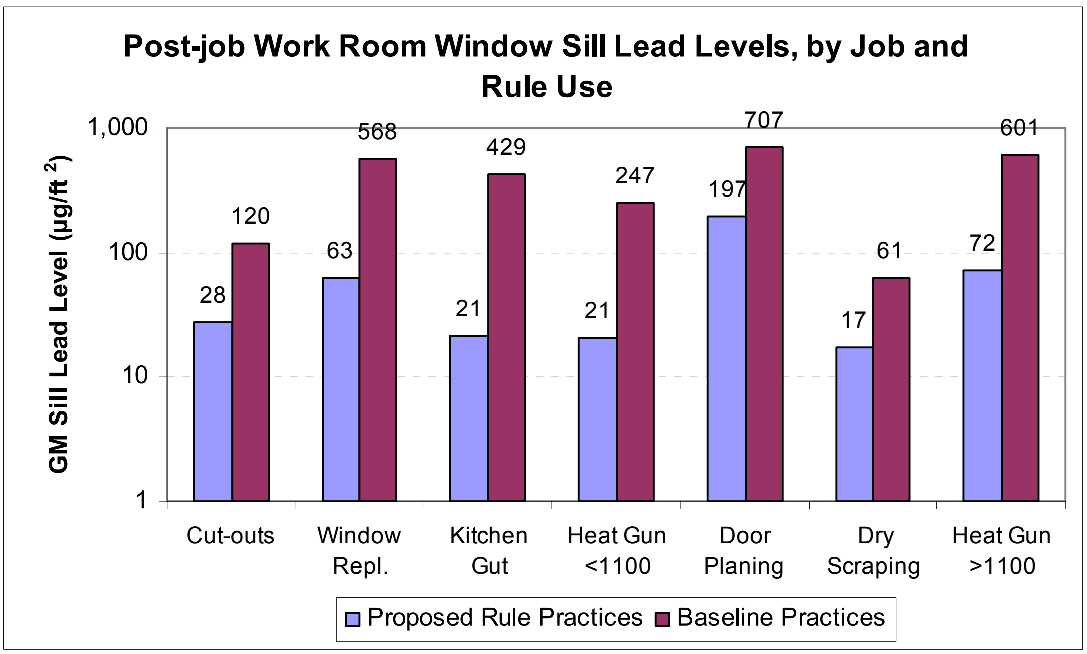

Figure 6-10. Post-Job Work Room Sill Lead Levels, By Job And Rule Use

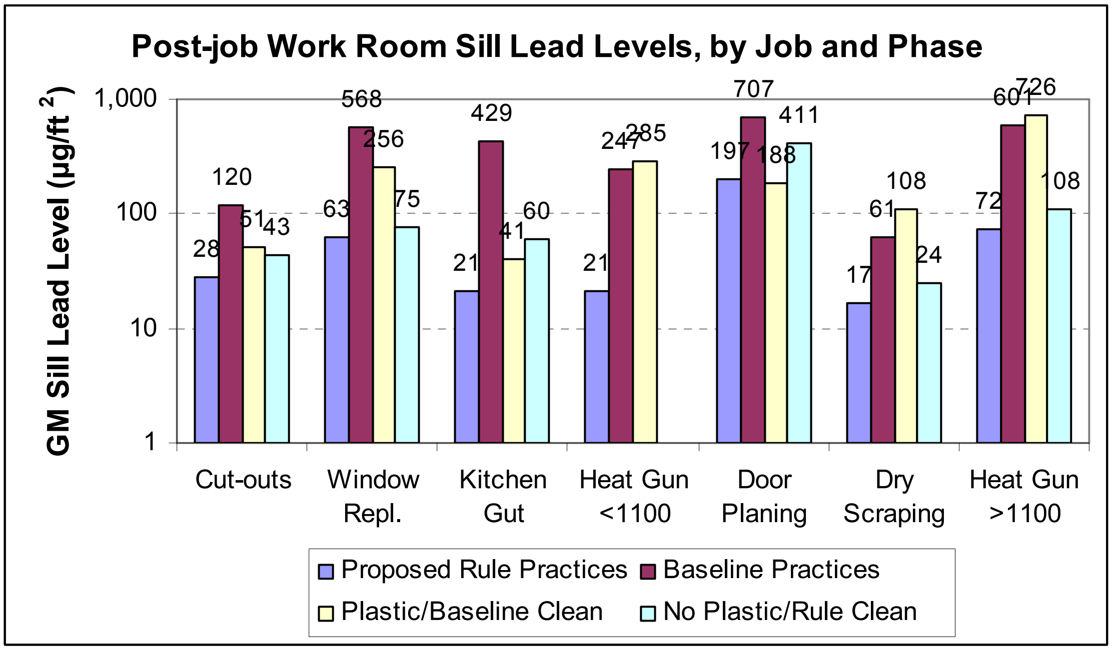

Figure 6-11. Post-Job Work Room Sill Lead Levels, By Job And Phase

- GM Tool room sill lead levels are also lower across the three sampling stages under the Proposed Rule Practices (Phase I) compared to the Baseline Practices (Phase IV) – 57 µg/ft^2 vs. 127 µg/ft^2 at post-work, 55 µg/ft^2 vs. 131 µg/ft^2 at post-cleaning, and 41 µg/ft^2 vs. 150 µg/ft^2 at post-verification. Figure 6-12 displays the post-work Tool room lead levels by job for these two phases.

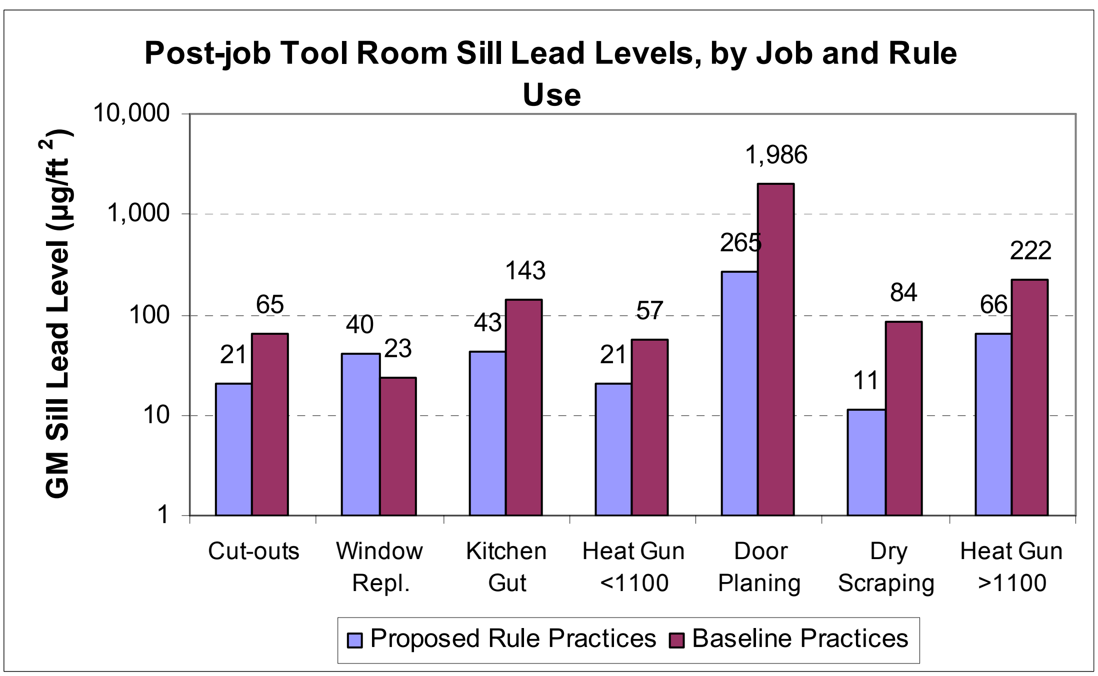

Figure 6-12. Post-Job Tool Room Sill Lead Levels, By Job And Rule Use

- There is not as much difference between GM Observation room sill lead levels under the Proposed Rule Practices (Phase I) compared to the Baseline Practices (Phase IV) – 53 µg/ft^2 vs. 58 µg/ft^2 at post-work, 35 µg/ft^2 vs. 52 µg/ft^2 at post-cleaning, and 35 µg/ft^2 vs. 49 µg/ft^2 at post-verification (see Figure/Table D2.8c). Figure 6-13 displays the post-job Observation room lead levels by job for these two phases. There are mostly minor differences in the non-restricted practice jobs, whereas the Proposed Rule Practices appear to have led to lower post-job lead levels from the restricted practice jobs.

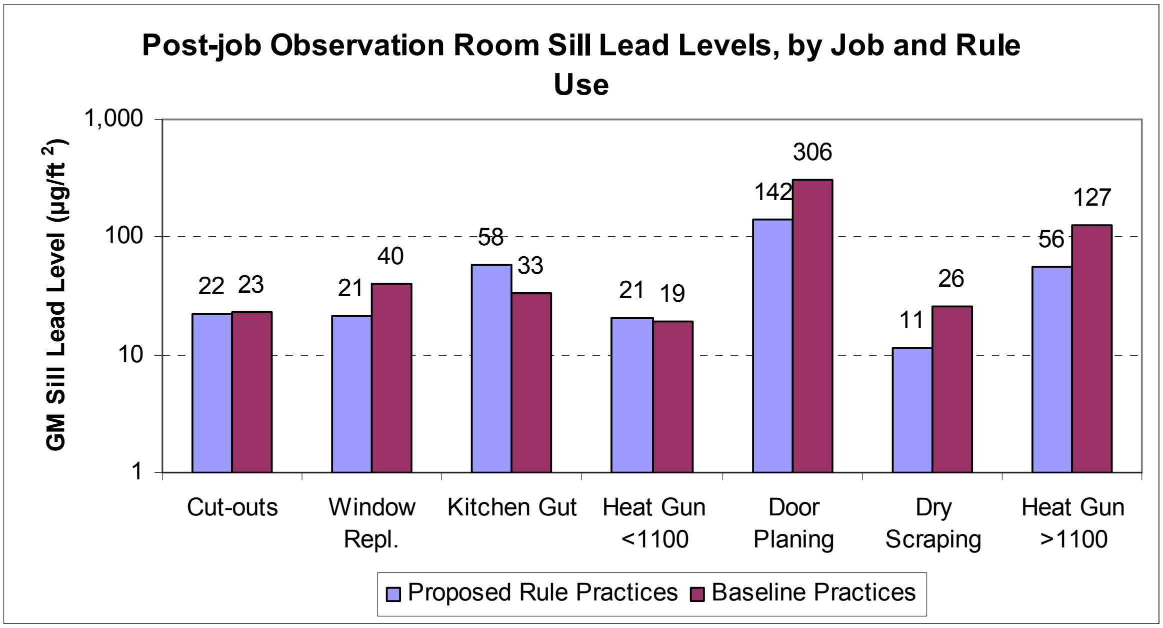

Figure 6-13. Post-Job Observation Room Sill Lead Levels, By Job And Rule Use

- Use of restricted practices is associated with higher GM sill lead levels in each of the three study rooms. Note that the use of restricted practices yielded higher post-work sill lead levels, which translated to higher post-cleaning and post-verification levels, as well (see Figure/Tables D2.9a-D2.9c).

6.5.3. Hallway/Exit Samples

The study design specified collection of three samples at the end of each experiment along the path from the work room to the entrance used by workers. These samples provide data on both the track-in of lead dust from the outside and tracking of lead dust from the work room through the house as workers enter and exit. The location of the samples was not pre-specified in sampling plans. Technicians were instructed to obtain one sample near the entrance of the house, one from an area closer to the work room, and one in between. In houses where work was done on the second floor, the hallway samples were generally taken from the bottom of the steps, near the entrance, and in between these two areas. The samples were taken following the collection of all post-verification samples in the three main study rooms. At this point, the workers would have removed most if not all of their job-related equipment, and remaining traffic through the house mainly involved removal of study-related equipment.

Appendix H contains a set of exploratory analyses similar to those generated for the other data types. As with the other dust wipe data, the data were log-transformed to get closer to a normal distribution. The bullets below present some key results seen in Appendix H.

- Higher lead levels are seen in exit samples taken after medium intensity jobs with a GM of 507 $\mu g/ft^2$ for medium intensity jobs compared to 212 $\mu g/ft^2$ for high intensity and 73 $\mu g/ft^2$ for low intensity (see Figure/Table H2.1a).
- The GM exit sample lead level for Door Planing jobs was 500 $\mu g/ft^2$, much higher than all other jobs (see Figure/Table H2.3a). GMs of the other six jobs range from 21 to 83 $\mu g/ft^2$, with the high heat gun job having the next highest level below the door planning job.
- As seen in Figure/Table H2.6a, there is little difference in GM lead levels between jobs that used plastic in the Work room during the work (67 $\mu g/ft^2$) and those that did not (69 $\mu g/ft^2$).
- The difference in GM lead levels is relatively small between jobs using rule cleaning (59 $\mu g/ft^2$) compared to jobs using baseline cleaning (78 $\mu g/ft^2$).
- The baseline practices (no plastic/baseline cleaning) yielded higher GM exit levels of 88 $\mu g/ft^2$ compared to a range of 55 $\mu g/ft^2$ to 69 $\mu g/ft^2$ for the other three P/CU routines (see Figure/Table H2.8a).
- Higher hallway lead levels were measured following restricted practice jobs compared to non-restricted jobs with GM of 136 $\mu g/ft^2$ versus 34 $\mu g/ft^2$ (see Figure/Table H2.9a).
- When the work room floors were in poor condition, hallway lead levels were higher than when work room floors were in good condition with GMs of 143 $\mu g/ft^2$ for poor condition floors and 18 $\mu g/ft^2$ for floors in good condition (see Figure/Table H2.11a).
- Hallway/exit lead levels were not associated with pre-work or post-work soil lead levels (see Figures H3.4 and H3.5).
- Hallway/exit lead levels do appear to be correlated with average post-work work room floor lead levels with an r-square value of 0.11 (see Figure H3.7).

6.5.4. Exterior Post-Work Tray Samples During Window Replacements

For the experiments where a window was replaced from the interior of a housing unit, one dust collection tray was placed for sampling on top of plastic sheeting on the exterior of the unit, directly below the window. This sampling was done to evaluate potential exterior contamination when performing a window replacement from the inside of the house. Prior to conducting the window replacements, the RRP workers covered the window with plastic from the outside to prevent falling debris from contaminating the ground below. After the replacement was finished, the RRP workers carefully removed the exterior plastic sheeting. The dust collection tray was sampled immediately after the work was completed and the plastic removed. The results of those exterior dust collection tray samples are shown in Table 6-7. The results are not consistent, even when considering variability due to contractor, housing unit, and tray location. For experiments 11 and 42, a significant amount of debris was observed falling from a pocket at the bottom of the external plastic sheeting when the RRP workers were removing it. The debris fell onto the ground covering and into the dust collection tray. For some of the other experiments, small paint chips were present in the tray when sampled, but no significant debris was observed falling out of the protective plastic.

Table 6-7. Exterior Dust Wipe Samples During Window Replacement

Experiment	Concentration ($\mu g/ft^2$)	Location
9	291.2	Porch roof under second story window
10	232	Porch roof under second story window
11	31,715.1	Ground under second story window
12	11.6	Ground under second story window
41	17.0	Porch floor under first story window
42	20,590.9	Porch floor under first story window
43	43.6	Porch floor under first story window
44	338.2	Porch floor under first story window

6.6. Interior Air Samples

Indoor air samplers collected samples during each work stage (work, cleaning, and cleaning verification) in each of the three study rooms. The work and cleaning stages included a one-hour wait time following completion of activity to allow settling of airborne dust. The air monitors operated from the beginning of the activity until the end of the one-hour wait time. Field technicians recorded information on flow rate at the beginning and end of the sampling period in order to calculate a mean flow rate. In a few cases, multiple air filters were needed during a single sampling stage because of a filter getting clogged with dust. In these cases, the concentrations obtained for the two samples were averaged and that value used in subsequent analyses.

Appendix F contains detailed exploratory analyses of the indoor air filter samples. Laboratory analysis of the air filter samples had a 2 µg detection limit. With many of the filters not running for long, e.g. during the cleaning verification stage that sometimes only lasted 10-15 minutes, this made it more challenging to measure enough lead to be over the detection limit. Additionally, with only small amounts of air monitored, laboratory measurements are relatively variable. Reported levels range anywhere from <2.7 to <20 to <666 $\mu g/m^3$. Table 6-8 (also Table F1.1) presents the number and percentage of samples that contained lead below the detection limit. Appendix F presents analyses using the half the reporting limit for each sample that was below the detection limit; thus, the three example values listed above are included as 1.35, 10, and 333 $\mu g/m^3$ in the analyses.

Table 6-8. Number (and Percentage) of Interior Air Dust Lead Concentration Measurements (µg/m^3) Below Detection Limit Measurements by Room and Stage

Stage	Room		
	Work	Tool	Observation
Post-Work	29 (48.3%)	43 (71.7%)	45 (75.0%)
Post-Cleaning	50 (82.0%)	53 (88.3%)	54 (90.0%)
Post-Verification	59 (98.3%)	59 (98.3%)	58 (96.7%)

Below are a few findings from the air lead analyses. Since the Tool and Observation rooms have at most 28% reported values in any given stage, no results from those analyses are presented. Similarly, because the post-cleaning and post-verification data in the Work room have no more than 18 percent reported measurements, no results from those analyses are discussed. Because the post-work stage in the work room is the only set of data with more than half of its values actually being reported measurements, only those data are discussed.

- Air lead concentrations in the work room during Medium intensity jobs were higher than the High and Low intensity jobs.
- The finding regarding intensity level is driven largely by the door planing job, which has a GM air lead concentration far greater than any other job – 300 µg/m^3 compared to the next highest job, heat gun above 1100 degrees, with 13 µg/m^3 (see Figure/Table F2.3a).
- The GM work room air lead level when plastic was used is higher than when plastic was not used - 12 µg/m^3 compared to 8 µg/m^3 (see Figure/Table F2.6a).
- The GM work room air lead level was higher during restricted practice jobs than other jobs, which is not surprising since the door planing is defined as a restricted practice job (see Figure/Table F2.9a). Figure 6-14 plots air lead concentrations for each job.

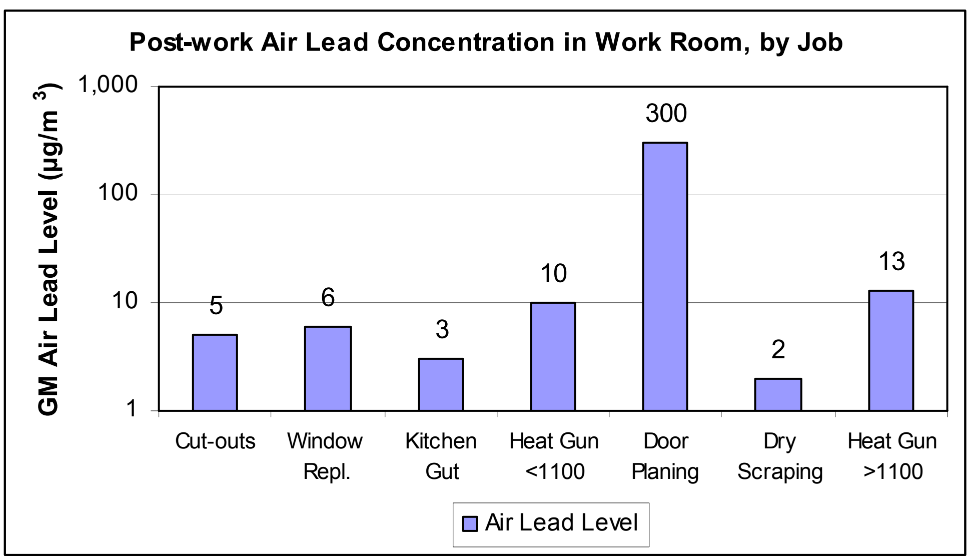

Figure 6-14. Post-work Air Lead Concentration in the Work Room, by Job

6.7. Exterior Dust Samples

The exterior study design specified collection of three types of dust collection tray samples – on the Rule plastic, under-the-Rule plastic, and near-the-Rule plastic. Three samples were obtained from each location during each experiment. The size of the Rule plastic varied from job to job. The proposed rule does not identify specific areas of ground to be covered during exterior work, so the size of the rule plastic was determined for each experiment within the constraints of the dimensions of the property being worked on and the need to collect samples near the Rule plastic as well. For this study, vertical containment and additional ground plastic were set up as a precaution to capture dust and debris that might not be captured on the Rule plastic. Table 6-9 contains distances from the work location for all on and near Rule plastic samples, as well as associated results. The under Rule plastic samples were obtained from similar locations to those used for the on Rule plastic samples.

Table 6-9. Distance of Exterior Trays from Work.

				On top of Rule Plastic		Near Rule Plastic	
Exp. #	Job Type	Unit ID	Sample #	Loading* (µg/ft^2)	Dist. From Work (ft)	Loading* (µg/ft^2)	Dist. From Work (ft)**
1	Dry Scrape	H01	1	12,516,130.5	1	4,178.0	8
			2	50,819.0	5	953.0	12
			3	8,556.0	7	929.0	17
2	Power Sanding	H01	1	4,666,775.9	1	58,718.0	15
			2	341,492.0	5	85,985.0	14
			3	106,383.0	11	65,719.0	12
3	Power Sanding	H01	1	8,289,211.2	3	18,002.0	14
			2	234,877.0	8	9,865.0	17
			3	129,738.0	12	16,905.0	15
4	Trim Replacement	H02	1	4,109.0	2	61,388.0	5
			2	1,652,382.1	1	27,082.0	6
			3	115,207.0	2	54,851.0	5
21	Dry Scrape	H09	1	1,463,973.8	1	274.0	13
			2	2,357.0	7	172.0	18
			3	417.0	11	574.0	15
34	Replace Exterior Door	H16	1	217,310.9	1	31,708.0	6
			2	79,163.0	3	84,290.0	6
			3	14,441.0	3	1,129.0	6
35	Replace Exterior Door	H17	1	30,060.0	1	3,793.0	5
			2	43,976.0	1	30,426.0	5.5
			3	151,734.0	1	17,590.0	5.5
36	Trim Replacement	H10	1	161,018.0	3	19,278.0	7
			2	2,991,198.3	2	133,690.0	7
			3	1,794,376.6	2	217,900.0	7
37	Torching	H10	1	1,134,828.9	4.5	150.0	15
			2	956.0	12	198.0	15
			3	349,643.9	10	151.0	15
38	Torching	H13	1	29,401,680.1	2	658.0	16.5
			2	1,560,303.3	10.5	1,836.0	16.5
			3	1,819,556.0	9	1,093.0	16.5

Table 6-9. (continued) Distance of Exterior Trays from Work.

				On top of Rule Plastic		Near Rule Plastic	
Exp. #	**Job Type**	**Unit ID**	**Sample #**	**Loading* (μg/ft²)**	**Dist. From Work (ft)**	**Loading* (μg/ft²)**	**Dist. From Work (ft)****
40	Dry Scrape	H19	1	14,348.0	6	7,596.0	11
			2	11,480,352.4	2	12,169.0	9
			3	268,359.2	4	16,597.0	10
64	Low Heat Gun	C01	1	130,674,044.8	1	2,692,069.2	7
			2	1,133,090.0	5	27,650.0	8
			3	2,538,052.1	3	16,884.0	7
65	Needle Gun	C01	1	381,586.2	3	21,158.0	6
			2	22,004.0	1	8,768.0	6
			3	888,166.7	2	1,380.0	12
66	High Heat Gun	C01	1	196,759.9	7	14,689.0	11
			2	494,822.3	5	331.0	16
			3	831,062.0	3	363.0	13
75	Dry Scrape	H09	1	1,961,778.8	1	1,205.0	8
			2	14,345.0	4	190.0	15
			3	1,845.0	7	488.0	12

* Where applicable, the loading represents the sum of the dust wipe plus the bulk sample.
** Distance from work represents the perpendicular distance from the work wall/area to the collection tray

Appendix B contains detailed exploratory analyses of the exterior tray samples by location summarized by intensity level, city, job, contractor, and housing unit. The bulk debris samples are included in these analyses. Appendix E contains the same analyses, but excludes the bulk debris samples. Figures B1.1a-1.3b and Figures E1.1a-1.3b display histograms of the raw and log-transformed data collected for each location – on, under, and near Rule plastic. The log-transformation does lead to a data more closely approximating normality. The following bullets describe selected findings observed from Appendices B and E:

- The GM and median lead levels measured on the Rule plastic across all jobs is much higher than the other two locations with GM of 241,977 μg/ft^2 and median 268,359 μg/ft^2, compared to GM of 479 μg/ft^2 and median of 322 μg/ft^2 under-the-Rule plastic and GM of 5,771 μg/ft^2 and median of 9,865 μg/ft^2 near-the-Rule plastic. Excluding the bulk debris samples reduced the top of Rule plastic GM to 21,292 μg/ft^2 and median to 22,004 μg/ft^2. No bulk debris samples were collected near or under rule plastic.
- The high intensity jobs resulted in higher GM lead levels on and under-the-Rule plastic, when the bulk samples are included, but the high and low level jobs have similar GMs when bulk samples are excluded. The low level jobs yielded higher levels near-the-Rule plastic (see Figure/Tables B2.1a-c). A possible explanation for this is that the Rule plastic covered less area in the low-level jobs (trim/soffit and door replacements and needle gun) because of space constraints.
- The low heat gun job yielded the bulk samples with the most amount of lead, which gave this job a much higher GM on the Rule plastic than all other jobs. With bulk samples excluded, the power sanding job yielded a much higher GM on the Rule plastic. Figures 6-15 and 6-16 present the on and under Rule plastic samples both with and without the bulk debris samples, respectively, by each job. All jobs yielded much higher

lead levels on the plastic than under the plastic regardless of whether the bulk samples are included, except the torch burning job. The torching job has a GM on the Rule plastic of 562,462 µg/ft^2 with the bulk samples included and only 5,447 µg/ft^2 with the bulk samples excluded. The GM of the under Rule plastic samples for the torching jobs is 8,565 µg/ft^2.

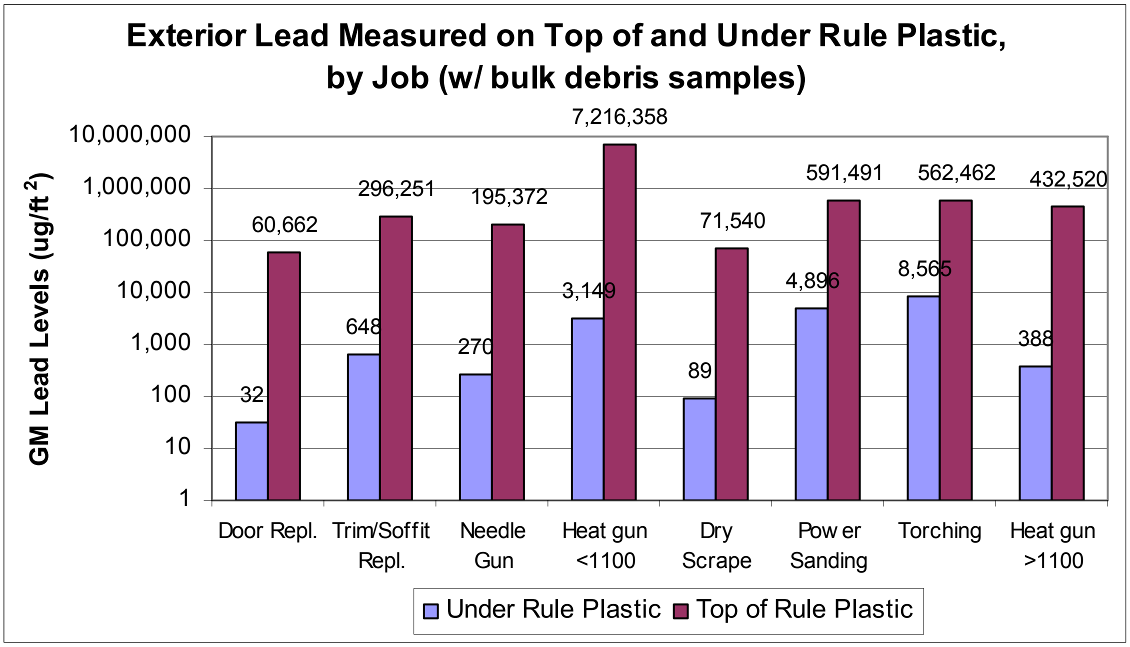

Figure 6-15. Exterior Dust Lead Levels On and Under Rule Plastic, by Job (w/ Bulk Samples)

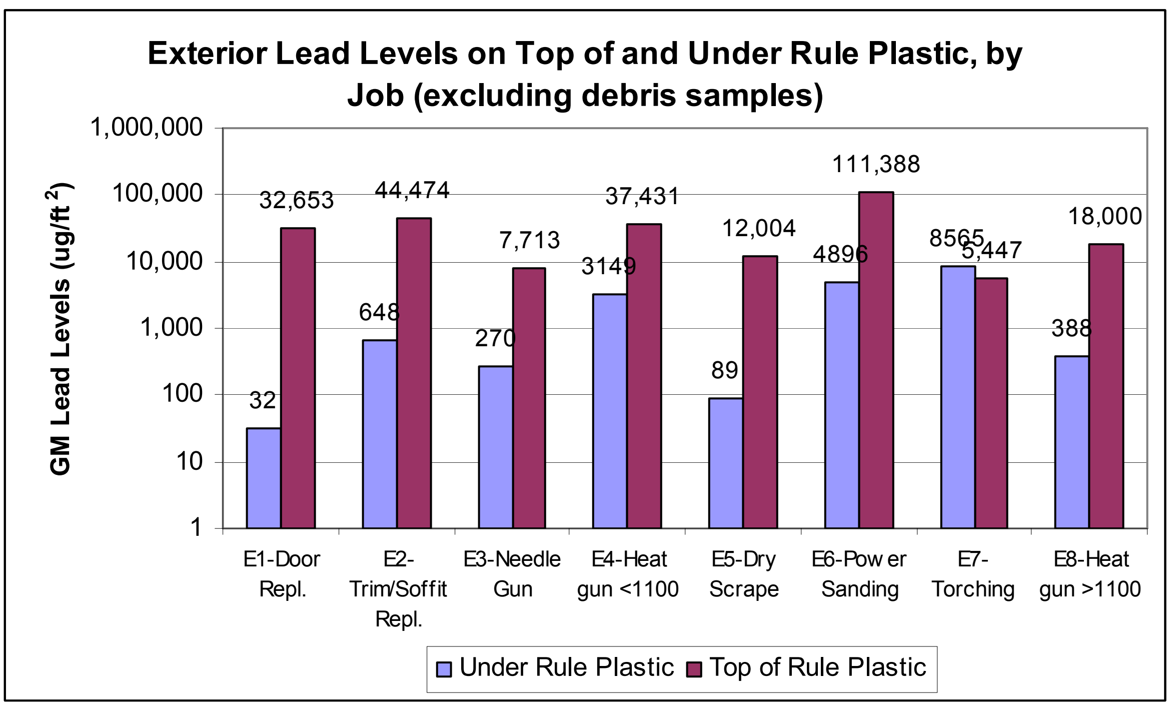

Figure 6-16. Exterior Dust Lead Levels On and Under Rule Plastic, by Job (excl. bulk samples)

- There does appear to be an association between paint lead levels and lead levels measured on and near-the-Rule plastic with r-square values of 0.16 and 0.17, respectively (see Figure B3.1). No association between paint lead level and under Rule plastic samples was found.
- No association is observed between initial soil lead levels and lead measured in any of the three exterior tray locations (see Figure B3.2). While no association is observed between post-work soil lead levels and lead measured on or under Rule plastic, there does appear to be some correlation between post-work soil levels and lead levels measured in trays near-the-Rule plastic (see Figure B3.3).
- There does not appear to be an association between amount of area disturbed by the RRP work and lead measured at any of the three locations (see Figure B3.4).

Prior to performing exterior experiments, one or more dust collection trays were set out in the area of the rule plastic to measure the background concentration of lead at the property. The number of samples collected for each job type and associated lead levels are presented in Table 6-10. In the instances where more than one experiment was performed at the same unit (e.g. the trim replacement and torching at H10), the results of the background tray(s) are included for both experiments.

Table 6-10. Average Background Dust Loading for Exterior Experiments, by Job Type

Exterior Job	# Samples	Average Background Lead Level (µg/ft^2)
Trim Replacement	6	13.9
Door Replacement	6	< 9.6
Dry Scrape	5	16.4
Power Sanding	2	51.2
Torching	6	32.8

6.8. Soil Samples

6.8.1. Soil Sampling for Interior Jobs

For interior experiments, soil samples were collected before work began and again after work was completed at three sampling locations: near the main entrance to the unit used during the experiment, near the path traveled by the workers and study personnel from their vehicles to the unit, and from the ground immediately below a window that led into the Work Room. See Table 6-11 for the all soil lead measurements for each interior experiment. The soil samples were collected to evaluate the possible contamination of the soil by study activities, as well as to get an idea of the potential track-in from the outside. There was no soil or dirt at any of the sampling locations for H31, H32, H33, H36 and C01, thus no soil samples were collected for experiments performed at those units.

Table 6-11. Pre- and Post-Work Soil Sample Results (μg/g) by Interior Experiment

	05 - H03		06 - H03		07 - H03		08 - H03		09 - H09		10 - H09	
	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work
Near Entrance	903	1,635	1,635	737	737	856	856	709	679	391	391	408
Near Path	96	125	125	129	129	86	86	74	401	273	273	317
Under Window	141	385	385	288	288	44	44	105	705	700	700	2,077

	11 - H09		12 - H09		13 - H09		14 - H09		15 - H09		16 - H09	
	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work
Near Entrance	5,551	2,245	3,460	2,508	5,006	2,074	4,540	3,348	3,026	5,352	2,508	8,044
Near Path	276	229	343	291	241	289	367	288	323	230	291	268
Under Window	10,361	11,226	1,746	2,117	2,411	2,845	10,097	8,643	5,672	15,150	2,117	2,442

	22 - H16		23 - H16		24 - H17		25 - H16		26 - H17		27 - H17	
	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work
Near Entrance	1,213	910	910	485	752	677	485	575	616	571	571	685
Near Path	408	429	429	286	334	204	286	274	213	272	272	287
Under Window	1,136	1,410	1,410	1,772	622	564	1,772	2,355	644	911	911	613

	28 - H17		29 - H17		30 - H10		31 - H10		32 - H10		33 - H10	
	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work
Near Entrance	685	286	286	1,105	1,230	929	2,258	1,033	1,033	957	957	886
Near Path	287	652	652	329	773	940	700	426	426	877	877	544
Under Window	613	541	541	879	n/a	1,441	n/a	4,031	4,031	1,505	1,505	1,154

	41 - H16		42 - H16		43 - H17		44 - H17		45 - H08		46 - H08	
	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work
Near Entrance	8,120	8,167	8,167	2,921	529	622	622	1,138	359	308	308	940
Near Path	457	399	399	473	278	203	203	542	133	146	146	121
Under Window	n/a	386	386	444	n/a	521	521	346	367	336	336	519

	47 - H08		48 - H08		67 - H16		68 - H17		69 - H08		70 - H35	
	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work
Near Entrance	450	390	390	359	575	1,178	677	616	940	347	496	383
Near Path	218	170	170	133	274	344	204	213	121	118	411	355
Under Window	482	204	204	367	2,355	3,650	564	644	519	416	752	478

	71 - H35		72 - H35		73 - H35		74 - H35		77 - H08		78 - H08	
	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work
Near Entrance	471	413	413	772	383	476	476	471	347	395	395	311
Near Path	481	500	500	502	355	337	337	481	118	175	175	139
Under Window	554	567	567	1,260	478	426	426	554	416	n/a	n/a	478

	79 - H09		80 - H09	
	Pre-Work	Post-Work	Pre-Work	Post-Work
Near Entrance	684	1,659	1,659	3,098
Near Path	35	49	49	308
Under Window	11,121	16,547	n/a	1,387

If work was performed in the same unit within the same Work Room, the post-work soil samples from the previous experiment were used as the pre-work soil samples for the next experiment. For two experiments performed at H09 and one experiment each at H16 and H17, the Work Room changed from experiment to experiment and pre-soil samples were not collected to correspond to the correct Work Room window. At H10, exterior experiments were performed alternately with interior experiments, resulting in two experiments where there were no pre-work soil samples collected under the Work Room window, and the post-work sample of the previous experiment could not be used due to possible contamination by the exterior experiment.

The samples collected near the main entrance and under the Work Room window were typically higher than the near path samples, due to their proximity to the foundation of the house. Large variations in the lead content of the soil were observed when samples were collected within the same general area. When examining an increase from pre-work soil lead to post-work soil lead, the variability became evident as subsequent samples collected in the same location were consistent with the lower, pre-work samples. An example of this for samples collected near the front porch of H09 is given in Figure 6-17. In cases where post-work samples were collected in the same general area but different locations than the pre-work samples, it is difficult to discern the change due to natural variability and change due to study activities.

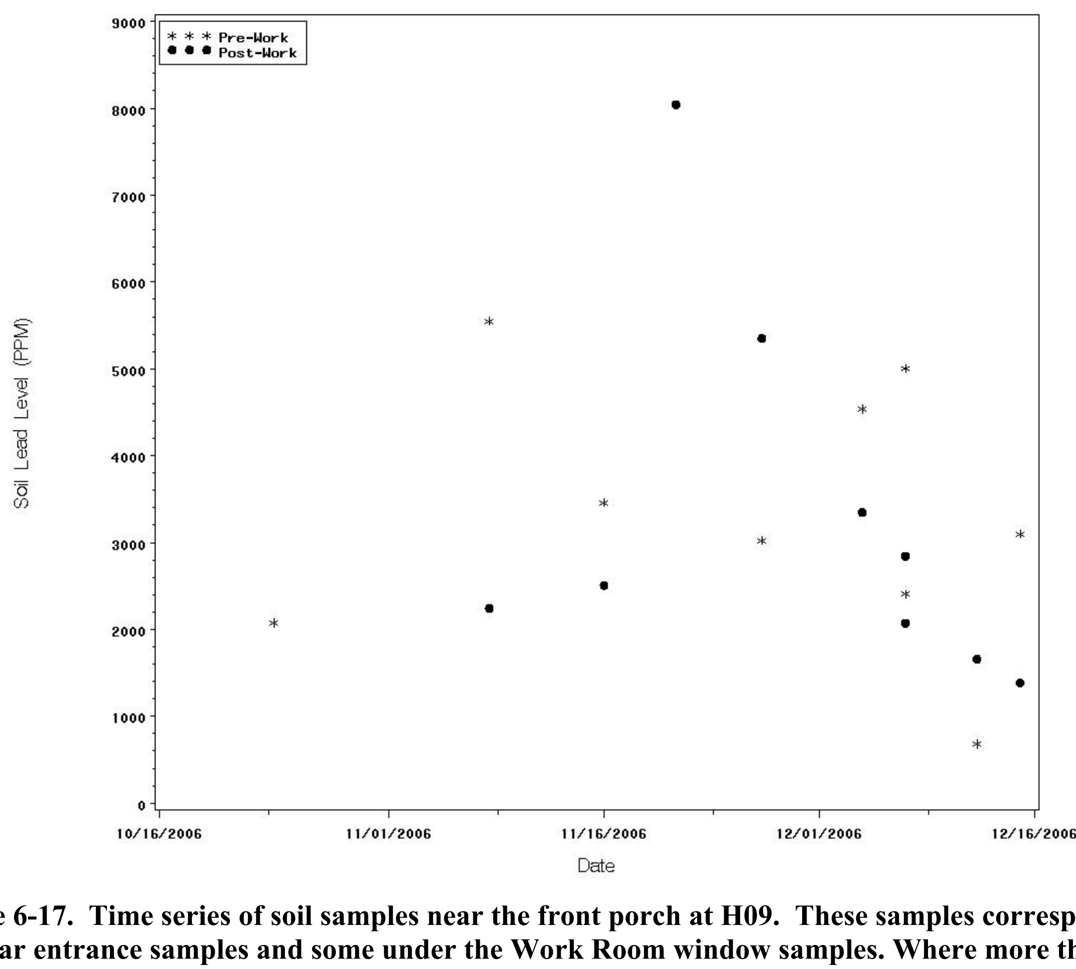

Figure 6-17. Time series of soil samples near the front porch at H09. These samples correspond to the near entrance samples and some under the Work Room window samples. Where more than one sample is collected on the same day, the plot shows whether the sample was pre-work or post-work.

Table 6-12 lists the number of collected samples and average post-work to pre-work soil lead level ratio. Instances where the two samples were collected from inconsistent locations are not included in this table. The job type, job intensity, and sample location do not appear to play a significant role in determining the change in soil lead level. This table also depicts the effect of variability as some locations across the study experienced an overall decrease in soil lead levels.

Table 6-12. Average Post-work/Pre-work Ratios for Interior Work Soil Samples, by Job Type

	Near Main Entrance		Near Path		Under Work Room Window	
Interior Job	**#**	**Ratio**	**#**	**Ratio**	**#**	**Ratio**
Cut-outs	8	1.25	8	0.91	8	1.30
Window Replacement	8	0.89	8	1.12	6	1.35
Dry Scrape	8	1.33	8	1.12	8	1.33
Door Plane	8	1.28	8	1.74	5	1.18
Kitchen Gut	4	1.02	4	1.03	4	1.03
Heat Gun	8	1.15	8	1.02	6	1.17

Figures C3.3a-c and C3.4a-c within Appendix C plot pre-work and post-work soil lead levels, respectively, against floor dust lead loadings in the work, tool, and observation rooms. Little if any association is evidenced from these plots between soil lead levels and interior floor lead levels. The highest r-square value (.06) is seen in Figure C3.4a showing slight association between post-work soil lead level and post-cleaning floor lead levels in the work room. Identical analyses are presented in Figures D3.3a-c and D3.4a-c for sill lead levels and no correlation between sill lead levels and soil lead levels is indicated.

There is some evidence of correlation between paint lead levels in the work room and soil lead levels. Within Appendix G, Figures G2.13 and G2.14 plot pre-work and post-work soil lead levels, respectively, by average paint lead levels. The association between pre-work soil lead and average paint lead yielded an r-square of .08 while the association between post-work soil lead and average paint lead yielded an r-square of 0.11.

6.8.2. Soil Sampling for Exterior Jobs

Similar to the interior experiments, soil samples were collected for all exterior experiments at three distinct locations: near the foundation of the house, near the back edge of the rule containment plastic, and near the back edge of the plastic used for property containment purposes. See Table 6-13 for the actual soil lead levels for each exterior experiment. These soil samples were collected to evaluate the possible contamination of the soil resulting from study activities. The samples collected near the foundation of the house were generally higher than the other locations, as the deteriorating paint from house components are more likely to collect there. For H02, H16 and H17, there were no soil samples collected near the foundation due to a concrete sidewalk resting against the house.

Table 6-13. Pre- and Post-Work Soil Sample Results (µg/g) for Exterior Experiments

	01 - H01		02 – H01		03 – H01		04 - H02		21 – H09	
	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work
Near Foundation	2,347	2,880	2,733	16,540	4,590	1,782	n/a	n/a	657	373
Near Edge of Rule Plastic	371	853	111	279	422	480	218	253	352	1,882
Near Edge of Containment Plastic	299	480	178	97	258	336	194	147	550	467

	34 – H16		35 – H17		36 – H10		37 – H10		38 – H13	
	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work	Pre-Work	Post-Work
Near Foundation	n/a	n/a	n/a	n/a	1,075	1,230	181	2,258	1,123	1,529
Near Edge of Rule Plastic	2,953	8,120	562	529	944	773	548	700	543	678
Near Edge of Containment Plastic	438	457	294	278	316	358	213	335	439	416

	40 - H19		75 – H09	
	Pre-Work	Post-Work	Pre-Work	Post-Work
Near Foundation	3,164	4,522	373	382
Near Edge of Rule Plastic	306	371	1,882	1,592
Near Edge of Containment Plastic	146	226	467	434

Variability in the soil lead levels also played a role in the change in pre-work to post-work soil samples for exterior experiments. Samples were sometimes not collected at the same location, making it more difficult to determine the study effect. The number of collected samples and average post-work to pre-work exterior soil lead level ratio for each sampling location, by job, are contained in Table 6-14. Note that the exterior experiments were only performed two or four times, so the averages include a small number (1-2) of values. The largest change is observed near the foundation, while the medium and high level jobs appear to have a larger change in soil lead than the low intensity jobs.

Table 6-14. Ratio of Post-work to Pre-work Soil Lead Level in Exterior Soil Samples, by Job Type

	Near Foundation	Near Edge of Rule Plastic	Near Edge of Containment Plastic
Trim Replacement	1.144	.990	.945
Door Replacement	n/a	1.846	.994
Dry Scrape	2.124	4.852	2.466
Power Sanding	3.220	1.825	.924
Torching	6.918	1.263	1.260

6.9. Length of Activity Data

Field technicians recorded the length of time required to perform various activities throughout each experiment including pre-work set up, renovation work, post-work cleaning, and cleaning verification. The tables included below present summary data on cleaning and cleaning verification activities.

6.9.1. Duration of Post-work Cleaning

The summary data on post-work cleaning times does indicate a small difference in the length of time required to conduct Rule and baseline cleaning – an average of 45 minutes for rule cleaning and 36 minutes for baseline cleaning. Table 6-15 indicates that there is not a difference in cleaning time based on the use of plastic. Some differences are evident across jobs, with higher dust producing jobs (door planing, heat gun) resulting in higher clean-up times, as seen in Table 6-16. Table 6-17 reports that one contractor took approximately 8 minutes longer on average to conduct post-work cleaning than the other two.

Table 6-15. Summary of Post-work Cleaning Times, by Phase (in Minutes)

P/CU Phase	# Obs.	Avg.	Std. Dev.	Min	Max
Phase I - Plastic/Rule cleaning	15	44.7	18.0	20.0	80.0
Phase II - Plastic/Baseline cleaning	14	35.6	12.3	18.0	60.0
Phase III - No Plastic/Rule cleaning	15	45.3	12.9	30.0	70.0
Phase IV - No Plastic/Baseline cleaning	15	36.1	12.3	19.0	60.0
Total	59	40.5	14.5	18.0	80.0

Table 6-16. Summary of Post-work Cleaning Times, by Job (in Minutes)

Job	# Obs.	Avg.	Std. Dev.	Min	Max
Cut-outs	12	38.8	12.7	18.0	62.0
Door Plane	7	45.3	20.1	25.0	80.0
Dry Scrape	8	40.1	19.9	20.0	80.0
High Heat Gun	12	44.9	12.6	29.0	70.0
Kitchen Gut	8	35.9	11.1	22.0	55.0
Low Heat Gun	4	42.5	12.6	30.0	60.0
Window Replacement	8	36.4	14.1	19.0	65.0
Total	59	40.5	14.5	18.0	80.0

Table 6-17. Summary of Post-work Cleaning Times, by Contractor (in Minutes)

Job	# Obs.	Avg.	Std. Dev.	Min	Max
Contractor 2	20	45.9	13.8	25.0	80.0
Contractor 3	17	38.1	16.5	18.0	80.0
Contractor 4	22	37.5	12.6	20.0	65.0
Total	59	40.5	14.5	18.0	80.0

6.9.2. Duration of Cleaning Verification

The length of the cleaning verification process was measured from its start to when the last floor verification zone was declared clean. This included time spent recleaning zones if any failed and performing both the wet cloth verification and dry cloth verification, if any were necessary. Across all experiments, the cleaning verification process averaged 21 minutes with a range from 5 minutes to 135 minutes. As seen in Table 6-18, the average cleaning verification length was longer when baseline cleaning was used following work as opposed to Rule cleaning. Summarizing the cleaning verification durations by job, as reported in Table 6-19, the jobs taking longest on average to pass cleaning verification were the kitchen gut (35.5. minutes) and cut out (24.5 minutes) jobs, which were relatively low intensity in terms of dust production. On average, Contractor 3 took longer to conduct the cleaning verifications, as seen in Table 6-20.

Table 6-18. Duration of Cleaning Verification Stages, by Phase (in Minutes)

Phase	# Obs.	Avg.	Std. Dev.	Min	Max
Phase I - Plastic/Rule cleaning	15	12.9	5.3	7.0	25.0
Phase II - Plastic/Baseline cleaning	14	21.8	33.4	5.0	135.0
Phase III - No Plastic/Rule cleaning	15	15.5	10.6	6.0	45.0
Phase IV - No Plastic/Baseline cleaning	15	35.0	28.0	10.0	95.0
Total	59	21.3	23.4	5.0	135.0

Table 6-19. Duration of Cleaning Verification Stages, by Job (in Minutes)

Job	# Obs.	Avg.	Std. Dev.	Min	Max
Cut-outs	12	24.5	24.4	5.0	95.0
Door Plane	7	21.0	20.8	6.0	60.0
Dry Scrape	8	22.9	29.4	8.0	95.0
Heat Gun	12	11.1	4.9	5.0	25.0
Kitchen Gut	8	35.5	41.4	10.0	135.0
Low Heat Gun	4	16.3	7.5	10.0	25.0
Window Replacement	8	18.8	12.5	10.0	45.0
Total	59	21.3	23.4	5.0	135.0

Table 6-20. Duration of Cleaning Verification Stages, by Job (in Minutes)

Job	# Obs.	Avg.	Std. Dev.	Min	Max
Contractor 2	20	18.7	19.5	5.0	95.0
Contractor 3	17	31.2	35.7	6.0	135.0
Contractor 4	22	16.0	9.2	8.0	40.0
Total	59	21.3	23.4	5.0	135.0

6.9.3. Duration of Pre-work Set Up

Before work could begin prior to a job, renovation workers had to prepare for the work by unloading tools and equipment, setting up generators, setting up plastic containment if it was necessary, etc. Table 6-21 reports that experiments that required plastic containment took more time on average to prepare for. There was little difference by contractor, as seen in Table 6-22, or by type of building as seen in Table 6-23.

Table 6-21. Duration of Interior Pre-work Set Up, by Phase (in Minutes)

Phase	# Obs.	Avg.	Std. Dev.	Min	Max
Phase I - Plastic/Rule cleaning	15	96.2	27.3	60.0	140.0
Phase II - Plastic/Baseline cleaning	14	96.6	24.8	65.0	140.0
Phase III - No Plastic/Rule cleaning	15	75.6	25.1	30.0	135.0
Phase IV - No Plastic/Baseline cleaning	15	64.3	13.6	45.0	95.0
Total	59	83.0	26.6	30.0	140.0

Table 6-22. Duration of Interior Pre-work Set Up, by Contractor (in Minutes)

Contractor	# Obs.	Avg.	Std. Dev.	Min	Max
C2	20	87.0	27.3	45.0	140.0
C3	17	81.6	24.9	40.0	135.0
C4	22	80.3	28.0	30.0	135.0

Table 6-23. Duration of Interior Pre-work Set Up, by Building Type (in Minutes)

Unit Type	# Obs.	Avg.	Std. Dev.	Min	Max
Housing Unit	47	83.8	27.4	30.0	140.0
COF	12	79.6	24.1	45.0	120.0

The pre-work set up times for exterior work encompassed a significant amount of study-required set up including vertical containment set up and laying out containment plastic on the ground. Thus, the exterior pre-work set up times are not indicative of set up required by the proposed rule, which would primarily be laying out the rule plastic, and are not presented.

6.9.4. Duration of Interior RRP Work

The length of time that it took to conduct each job for the study varied significantly. A summary of interior work duration times is reported in Table 6-24. The heat gun jobs took the longest averaging three hours for the heat gun <1100 degrees job and about three and half hours for the heat gun >1100 degrees job. On the other hand, the jobs averaging the shortest amount of time were the cut outs and kitchen gut jobs. There is high variability among the cut out jobs as some experiments only involved the cutting of the holes in the wall, but not any electrical or plumbing work, while others included actual installation of wiring, outlets, or lights.

Table 6-24. Duration of Interior Work, by Job (in Minutes)

Job	# Obs.	Avg.	Std. Dev.	Min	Max
Cut-outs	12	49.8	48.7	7.0	170.0
Window Replacement	8	90.9	46.6	45.0	188.0
Dry Scrape	8	95.4	44.0	65.0	201.0
Door Plane	7	60.4	31.0	30.0	125.0
Heat Gun < 1100 degrees	4	180.0	24.8	145.0	200.0
Kitchen Gut	8	50.0	23.5	25.0	90.0
Heat Gun > 1100 degrees	12	214.8	44.4	145.0	300.0
Total	59	105.2	75.7	7.0	300.0

A summary of exterior work duration times is reported in Table 6-25. The paint removal jobs conducted at the COF took the longest, while the door replacement and dry scraping jobs took less time on average than the others.

Table 6-25. Duration of Exterior Work, by Job (in Minutes)

Job	# Obs.	Avg.	Std. Dev.	Min	Max
Replace Exterior Door	2	47.5	10.6	40.0	55.0
Trim Replacement	2	115.0	134.4	20.0	210.0
Needle Gun	1	239.0	n/a	239.0	239.0
Dry Scrape	4	70.0	63.5	35.0	165.0
Heat Gun <1100 degrees	1	245.0	n/a	245.0	245.0
Power Sanding	2	112.5	10.6	105.0	120.0
Heat Gun > 1100 degrees	1	305.0	n/a	305.0	305.0
Torching	2	152.5	31.8	130.0	175.0
Total	15	128.3	91.5	20.0	305.0

6.10. Cleaning Verification Data

The analyses contained in this section explore the impact of the cleaning verification process on lead levels remaining in the Work room at the completion of an RRP job. The analyses explore the association of different factors with post-verification floor and sill lead levels, including phase, job type, contractor, floor type and condition. Of interest were the relation of post-verification levels to EPA clearance standards.

6.10.1. Verification Of Floor Zones

As detailed in Section 3, each interior experiment contained a cleaning verification stage, where the RRP workers performed cleaning verification in accordance with the proposed rule. In an effort to keep the cleaning verification process as close as possible to what the RRP workers would do if the rule was enacted, they were given training on how to do the cleaning verification, and minimal guidance was provided by study personnel during the execution. The decision to pass or fail a verification cloth was left solely up to the RRP workers, although the study field supervisors were instructed to overrule any clearly unwarranted determinations. Information on the cleaning verification for all interior experiments is seen in Table 6-34. All average values presented in this section refer to the Work Room only.

Floor Cleaning Verification by Phase

Figure 6-18 displays the post-verification (PV) floor lead levels for all interior experiments by Phase. Note that the sample results below the detection limit of the laboratory are set to 5 $\mu g/ft^2$, one half of the detection limit, for plotting and analysis purposes.

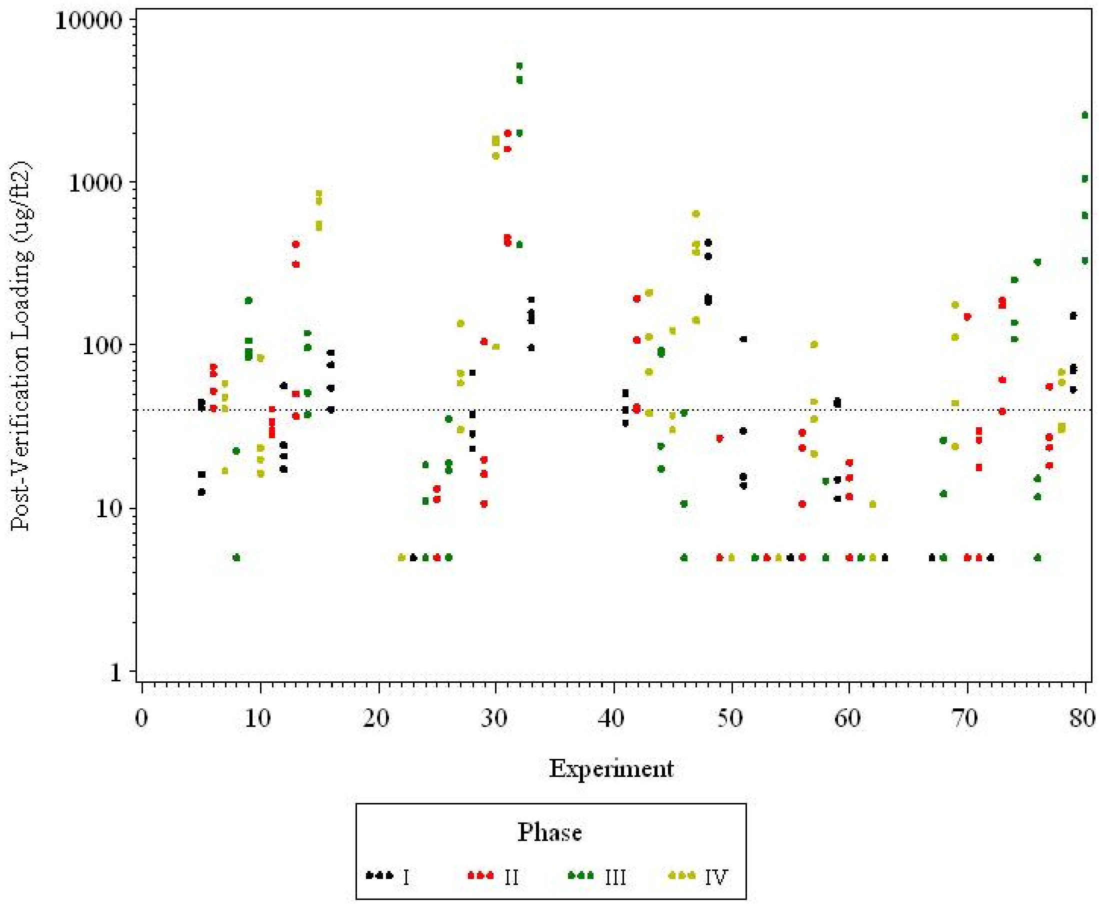

Figure 6-18. Post-verification Floor Lead Loadings by Phase. The reference line is set at the EPA clearance standard of 40 µg/ft^2 for floor surfaces.

When considering the percentage of floor zones that failed cleaning verification on the first wet verification cloth, Table 6-26 reports that 48.6% of floor zones that were tested after Phase IV (no plastic and baseline cleaning) failed. The two phases which involved no use of plastic had the highest average post-verification floor lead levels (313.5 and 192.7 µg/ft^2). When plastic was used and the rule cleaning method performed, the average post-verification floor lead level was the closest to the EPA clearance standard of 40 µg/ft^2. One problem that arose during the study was that after the use of insufficiently diluted Simple Green solution during the rule cleaning and all cleanings after the first wet verification failure, the verification cloths had a gray color to them, making them visibly darker than the verification card. This led to the failure of some floor zones, although the post-cleaning (PC) and post-verification (PV) floor lead levels were below clearance standards. This was especially true for the experiments performed at C01-the school.

Table 6-26. Floor Verification Information by Phase

Phase	Avg. PC Floor Lead Level (µg/ft²)	% 1st Wet Cloth Failure	% 2nd Wet Cloth Failure	Avg. PV Floor Lead Level (µg/ft²)
I – Plastic/Rule Cleaning	69.0	9.4%	0.0%	55.1
II – Plastic/Baseline Cleaning	172.8	10.9%	4.7%	121.2
III – No plastic/Rule Cleaning	305.9	4.5%	0.0%	313.5
IV – No plastic/Baseline Cleaning	476.8	48.6%	2.9%	192.7

As seen in Table 6-27, the average percent change (PV versus PC) in floor lead level for Phase III is positive due to an unusual value for experiment 76 where the average post-cleaning floor lead level was less than 10 µg/ft² and the average post-verification lead level was 89.6 µg/ft². If this experiment is excluded, the overall average percent change in floor lead level across all experiments between the post-cleaning and post-verification stages results in a decrease of 29.1%. A greater decrease in the floor lead levels is observed when one or more of the floor zones failed and were re-cleaned at least once. For phases involving baseline cleaning, this meant that the floor was cleaned according to the rule method following the first failure and any subsequent failures, as called for by the design. This shift in cleaning methods for cleaning verification should be considered in interpreting the data from the cleaning verification portion of the experiments.

Table 6-27. Post-cleaning and Post-verification Floor Lead Levels for Experiments with Zero and ≥1 Verification Failures by Phase

	Phase							
	I		II		III		IV	
# of Verification Failures	0	≥1	0	≥1	0*	≥1	0	≥1
Average PC Floor Lead Level (µg/ft²)	79.1	41.3	204.1	47.6	369.442	75.4	752.8	235.3
Average PV Floor Lead Level (µg/ft²)	69.0	17.0	145.7	23.0	374.192	61.6	328.2	74.2
Avg. % Change per Experiment	-18.6%	-27.2%	-19.5%	-50.7%	-17.4%	-41.5%	-35.1%	-60.2%
Overall Avg. Change	-12.7%	-58.9%	-28.6%	-51.6%	3.2%	-18.3%	-56.4%	-68.4%

* excludes one experiment with <10 at post-cleaning and 89.6 at post-verification

Floor Cleaning Verification by Job

Figure 6-19 and Table 6-28 display the post-verification floor lead levels for all interior experiments by job type. The jobs with the highest average floor lead level after cleaning verification were the door planing and the high heat gun jobs. The door plane job resulted in a significant amount of fine dust distributed around the entire Work Room, while the other jobs resulted in larger paint chips and pieces of debris. This could be the cause of the high post-verification lead levels, as the fine dust was difficult to clean, especially when the floor surface was not in good condition. The fine dust was also more difficult to see on the verification cloths than any dark, soot-like residue.

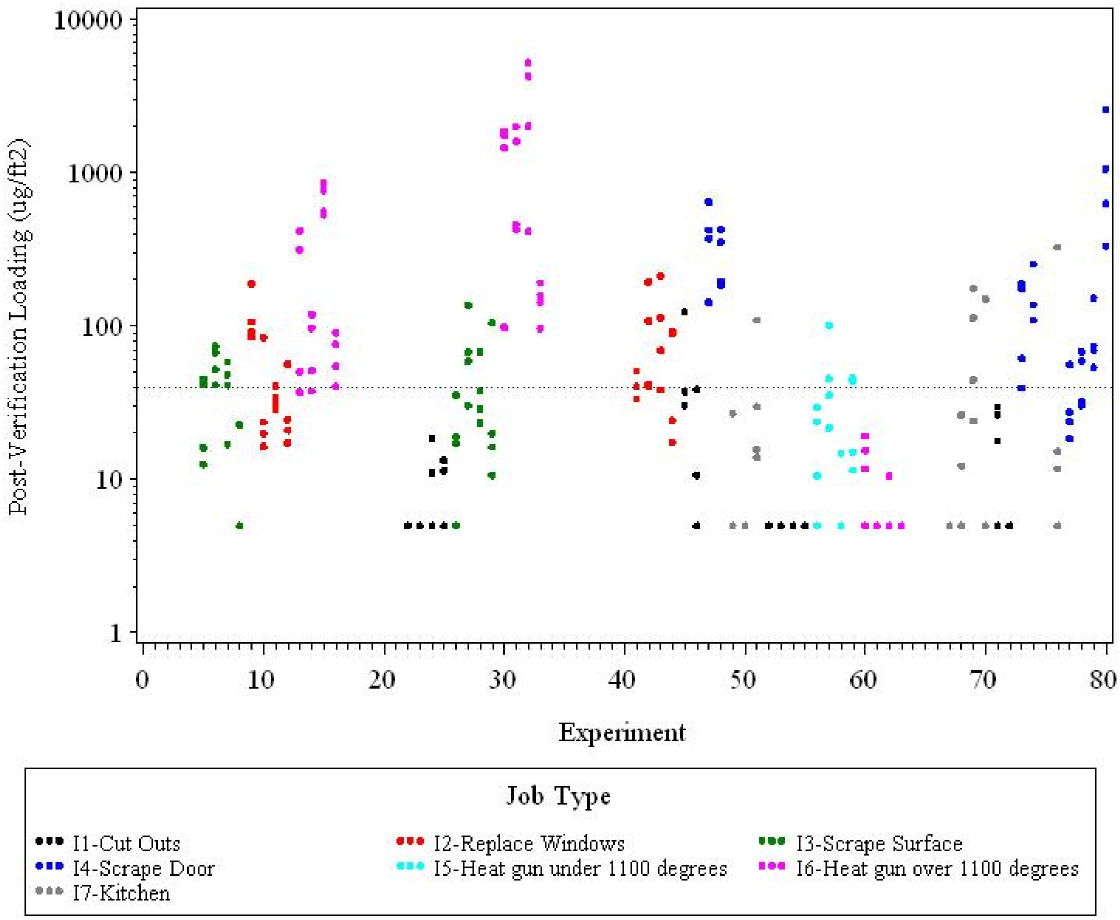

Figure 6-19. Post-verification Floor Lead Loadings by Job Type. The reference line is set at the EPA clearance standard of 40 µg/ft^2 for floor surfaces.

Table 6-28. Floor Verification Information by Job Type

Job Type	Average PC Floor Lead Level (µg/ft^2)	% 1st Wet Cloth Failure	% 2nd Wet Cloth Failure	Average PV Floor Lead Level (µg/ft^2)
Cut-outs	19.2	33.3%	2.1%	12.1
Window Replacement	109.1	11.9%	0.0%	65.0
Dry Scrape	81.3	15.0%	0.0%	38.6
Door Plane	431.7	28.6%	2.9%	284.0
Heat Gun <1100 degrees	50.4	20.0%	0.0%	26.2
Kitchen Gut	45.2	20.0%	10.0%	37.0
Heat Gun >1100 degrees	799.8	6.1%	0.0%	549.4

Floor Cleaning Verification by Contractor

Across the study, the cleaning verification was performed variably by the RRP workers. Some of the observed differences included the amount of force applied to the verification cloth, the speed of wiping the verification zones, the cleaning performed if a particular zone or zones failed verification, and the determination of whether a zone passed or failed. Table 6-29 reports that RRP workers in Pittsburgh were less likely to fail a floor zone, and had an average PV floor lead level of more than double that of Columbus contractors.

Table 6-29. Floor Verification Information by Contractor

City	Contractor	# of Exp.	Avg. PC Floor Lead Level (µg/ft^2)	% 1st Wet Cloth Failure	% 2nd Wet Cloth Failure	Avg. PV Floor Lead Level (µg/ft^2)
Columbus	C2	20	175.5	28.6%	6.5%	65.9
	C3	18	220.0	22.4%	0.0%	147.7
Pittsburgh	C4	22	365.6	8.8%	0.0%	291.1

Floor Cleaning Verification by Floor Type and Condition

Tables 6-30 and 6-31 report the floor verification summary data by floor type and floor condition, respectively. Table 6-30 reports that the first verification cloths taken on floors were more likely to fail on vinyl tile and tile floors even though the post-cleaning levels on average are lower on the tile floors as opposed to the wood floors. The vinyl and tile floors were located in residential kitchens and in the classrooms at the COF. Table 6-31 reports that the floors in poor condition had significantly higher post-verification floor lead levels. Note that nearly all of the wood floors (20 of 22 experiments) were in poor condition.

Table 6-30. Floor Verification Information by Floor Type

Floor Type	# of Exp	Avg. PC Floor Lead Level (µg/ft^2)	% 1st Wet Cloth Failure	% 2nd Wet Cloth Failure	Avg. PV Floor Lead Level (µg/ft^2)
Wood	22	543.5	10.6%	0.0%	384.5
Vinyl	21	123.8	23.7%	2.1%	61.4
Tile	17	47.7	25.4%	4.8%	28.8

Table 6-31. Floor Verification Information by Floor Condition

Floor Type	# of Exp	Avg. PC Floor Lead Level (µg/ft^2)	% 1st Wet Cloth Failure	% 2nd Wet Cloth Failure	Avg. PV Floor Lead Level (µg/ft^2)
Good	22	35.8	19.4%	0.0%	16.8
Fair	11	76.5	15.4%	7.7%	58.8
Poor	27	508.9	15.4%	1.6%	341.5

Table 6-32 provides information regarding how the interaction between job type and floor type and condition impacts cloth failures and post-verification floor lead levels. Certain jobs occurred only in rooms with certain floor types and conditions, which highlights some differences between and within jobs. While door planing resulted in relatively high post-verification floor lead levels as seen in Table 6-28, the two jobs that occurred on wood floors in poor condition performed significantly worse with a post-verification average of 619 µg/ft^2 than the other six jobs that occurred in rooms with vinyl or tile floors. Within the cut out and kitchen jobs, although relatively low post-verification lead levels were found across all jobs, higher levels were found for the jobs performed in rooms with poor floor condition.

Table 6-32. Floor Verification Information by Job Type, Floor Type, and Floor Condition

Job Type	Floor Type/ Condition	# of Exp	Avg. PC Floor Lead Level (µg/ft^2)	% 1st Wet Cloth Failure	% 2nd Wet Cloth Failure	Avg. PV Floor Lead Level (µg/ft^2)
Cut-Outs	Tile-Good	4	10.5	50.0%	0.0%	5.0
	Vinyl-Good	4	16.4	30.0%	0.0%	7.2
	Tile-Fair	2	11.6	0.0%	0.0%	12.4
	Vinyl-Poor	2	49.9	40.0%	10.0%	36.1
Window Replacement	Wood-Fair	2	96.4	0.0%	0.0%	82.2
	Wood-Poor	6	113.4	16.7%	0.0%	59.2
Dry Scrape	Vinyl-Good	4	92.3	0.0%	0.0%	42.6
	Wood-Poor	4	70.2	30.0%	0.0%	34.6
Door Plane	Tile-Fair	2	196.6	0.0%	0.0%	134.5
	Vinyl-Poor	4	443.8	50.0%	5.0%	191.2
	Wood-Poor	2	642.4	0.0%	0.0%	619.2
Heat Gun <1100 degrees	Tile-Good	4	50.4	20.0%	0.0%	26.2
Kitchen Gut	Vinyl-Good	2	14.8	0.0%	0.0%	8.6
	Tile-Fair	1	71.5	100.0%	100.0%	41.4
	Vinyl-Fair	4	40.2	25.0%	0.0%	36.9
	Vinyl-Poor	1	99.7	0.0%	0.0%	89.6
Heat Gun >1100 degrees	Tile-Good	4	19.8	18.8%	0.0%	7.3
	Wood-Poor	8	1,189.8	0.0%	0.0%	820.4

Impact of Dry Cloth Verification

Table 6-33 shows the corresponding average post-cleaning, post-wet verification and post-verification floor lead levels for each of the five floor zones that failed the second wet verification cloth. For each experiment, the number of dry verification cloths used is also listed. Each of these three experiments occurred with a tile floor using the kitchen as the work room.

Table 6-33. Floor Zones That Failed Second Wet Cloth Verification

Exp # - Job	Floor Zone	PC Floor Lead Level (µg/ft^2)	WV Floor Lead Level (µg/ft^2)	# of Dry Cloths	PV Floor Lead Level (µg/ft^2)
45 – Cut outs	2	91.5	61.5	2	37.3
47 – Door planing	2	1,292.1	550.8	1	643.6
70 – Kitchen gut	1	n/a	150.7	1	77.9
	2	46.2	< 10	2	< 10
	3	147.1	< 10	1	n/a

Comparison of Post-cleaning and Post-verification Lead Levels

Figure 6-20 plots the number of experiments in various categories of floor lead levels at the post-cleaning and post-verification stages. With floors, over 50 percent of the experiments ended with average post-verification levels less than 40 µg/ft^2. The number of experiments with average levels over 100 µg/ft^2 dropped from 20 at the post-cleaning stage to 13 at post-verification.

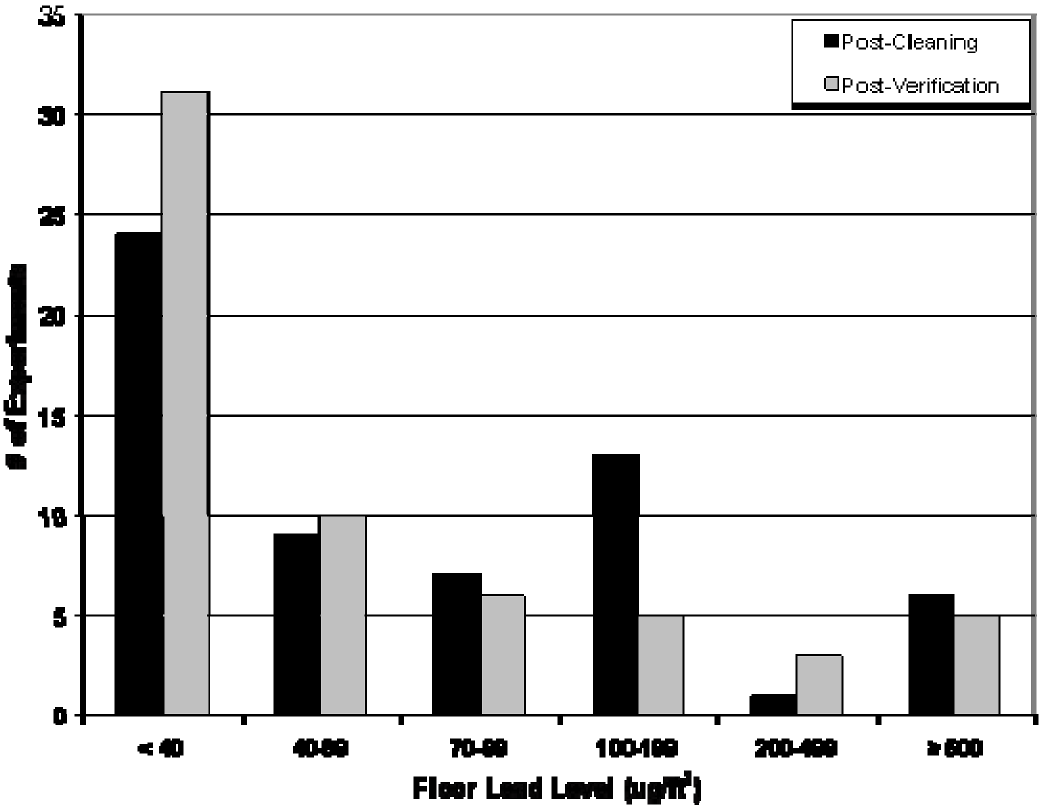

Figure 6-20. Number of Experiments by Post-cleaning and Post-verification Floor Lead Loadings

Table 6-34. Verification Information for Interior Experiments

Exp. #	Unit ID	Job	Phase	Floor Type	Floor Cond.	Cont.	# of Floor Zones	Avg. PC Floor Lead Level (µg/ft^2)	# Failed 1st Wet Cloths	# Failed 2nd Wet Cloths	Post-Wet Verif. (µg/ft^2)	# Failed Dry Cloths	Avg. PV Floor Lead Level (µg/ft^2)	# PV Samples >40 µg/ft^2	Verif. Time (min)*
23	H16	Cut-outs	I	Vinyl	Good	C4	5	6.6	1	0	-	0	< 10	0	19
55	C01	Cut-outs	I	Tile	Good	C2	3	< 10	1	0	-	0	< 10	0	15
72	H35	Cut-outs	I	Tile	Fair	C3	3	14.8	0	0	-	0	< 10	0	7
25	H16	Cut-outs	II	Vinyl	Good	C4	5	11	0	0	-	0	8.7	0	15
53	C01	Cut-outs	II	Tile	Good	C2	3	7.8	0	0	-	0	< 10	0	5
71	H35	Cut-outs	II	Tile	Fair	C3	3	8.5	0	0	-	0	19.8	0	12
24	H17	Cut-outs	III	Vinyl	Good	C4	5	31.1	0	0	-	0	9.9	0	15
46	H08	Cut-outs	III	Vinyl	Poor	C3	5	15.9	0	0	-	0	14.9	0	15
52	C01	Cut-outs	III	Tile	Good	C2	3	17.8	2	0	-	0	< 10	0	20
22	H16	Cut-outs	IV	Vinyl	Good	C4	5	16.7	5	0	-	0	< 10	0	70
45	H08	Cut-outs	IV	Vinyl	Poor	C3	5	84	4	1	61.5	1	57.2	1	95
54	C01	Cut-outs	IV	Tile	Good	C2	3	11.3	3	0	-	0	< 10	0	35
48	H08	Door Plane	I	Vinyl	Poor	C3	5	180.9	0	0	-	0	290.4	4	8
79	H09	Door Plane	I	Wood	Poor	C3	4	139.1	0	0	-	0	87.4	4	10
73	H35	Door Plane	II	Tile	Fair	C3	3	233.9	0	0	-	0	116.3	3	7
77	H08	Door Plane	II	Vinyl	Poor	C3	5	50.7	0	0	-	0	31.4	1	8
74	H35	Door Plane	III	Tile	Fair	C3	3	159.4	0	0	-	0	152.6	4	6
80	H09	Door Plane	III	Wood	Poor	C3	5	1,145.80	0	0	-	0	1,150.90	4	10
47	H08	Door Plane	IV	Vinyl	Poor	C3	5	1,372.70	5	1	550.8	0	395.5	4	55*
78	H08	Door Plane	IV	Vinyl	Poor	C3	5	171	5	0	-	0	47.6	2	40
5	H03	Dry Scrape	I	Wood	Poor	C2	5	31.6	1	0	-	0	28.9	2	20
28	H17	Dry Scrape	I	Vinyl	Good	C4	5	104.4	0	0	-	0	39.5	1	8
6	H03	Dry Scrape	II	Wood	Poor	C2	5	180.5	0	0	-	0	58.7	4	15
29	H17	Dry Scrape	II	Vinyl	Good	C4	5	156.1	0	0	-	0	38.1	1	10
8	H03	Dry Scrape	III	Wood	Poor	C2	5	12.9	0	0	-	0	9.4	0	15
26	H17	Dry Scrape	III	Vinyl	Good	C4	5	23.2	0	0	-	0	19.3	0	10
7	H03	Dry Scrape	IV	Wood	Poor	C2	5	55.9	5	0	-	0	41.2	3	35
27	H17	Dry Scrape	IV	Vinyl	Good	C4	5	85.5	0	0	-	0	73.6	3	10
16	H09	Heat Gun>1100	I	Wood	Poor	C2	3	54	0	0	-	0	65.5	4	10
33	H10	Heat Gun>1100	I	Wood	Poor	C4	4	191.8	0	0	-	0	147.5	4	10

Table 6-34. (continued) Verification Information for Interior Experiments

Exp. #	Unit ID	Job	Phase	Floor Type	Floor Cond.	Cont.	# of Floor Zones	Avg. PC Floor Lead Level (µg/ft^2)	# Failed 1st Wet Cloths	# Failed 2nd Wet Cloths	Post-Wet Verif. (µg/ft^2)	# Failed Dry Cloths	Avg. PV Floor Lead Level (µg/ft^2)	# PV Samples >40 µg/ft^2	Verif. Time (min)*
63	C01	Heat Gun>1100	I	Tile	Good	C2	4	< 10	0	0	-	0	< 10	0	10
13	H09	Heat Gun>1100	II	Wood	Poor	C2	5	97.2	0	0	-	0	205.3	3	10
31	H10	Heat Gun>1100	II	Wood	Poor	C4	4	1,393.00	0	0	-	0	1,122.90	4	10
60	C01	Heat Gun>1100	II	Tile	Good	C2	4	30.2	0	0	-	0	12.9	0	5
14	H09	Heat Gun>1100	III	Wood	Poor	C2	4	84.9	0	0	-	0	76.4	3	8
32	H10	Heat Gun>1100	III	Wood	Poor	C4	4	2,876.60	0	0	-	0	2,976.10	4	10
61	C01	Heat Gun>1100	III	Tile	Good	C2	4	11.3	0	0	-	0	< 10	0	10
15	H09	Heat Gun>1100	IV	Wood	Poor	C2	5	2,669.60	0	0	-	0	678.9	4	10
30	H10	Heat Gun>1100	IV	Wood	Poor	C4	4	2,151.00	0	0	-	0	1,290.70	4	30
62	C01	Heat Gun>1100	IV	Tile	Good	C2	4	32.7	3	0	-	0	6.4	0	25
51	H33	Kitchen Gut	I	Vinyl	Fair	C4	3	45.4	0	0	-	0	42.3	2	10
67	H16	Kitchen Gut	I	Vinyl	Good	C4	5	< 10	0	0	-	0	< 10	0	10
49	H31	Kitchen Gut	II	Vinyl	Fair	C4	3	45.8	3	0	-	0	10.5	0	35
68	H17	Kitchen Gut	III	Vinyl	Good	C4	5	24.6	0	0	-	0	12.2	0	34
76	H36	Kitchen Gut	III	Vinyl	Fair	C4	3	< 10	0	0	-	0	89.6	11	15
50	H32	Kitchen Gut	IV	Vinyl	Fair	C4	3	64.7	0	0	-	0	< 10	0	25
70	H35	Kitchen Gut	II	Tile	Fair	C3	3	71.5	3	3	150.7 <10 <10	1	41.4	1	135
69	H08	Kitchen Gut	IV	Vinyl	Poor	C3	5	99.7	0	0	-	0	89.6	3	20
59	C01	Low Heat Gun	I	Tile	Good	C2	6	122.2	3	0	-	0	29.1	2	25
56	C01	Low Heat Gun	II	Tile	Good	C2	5	25.6	1	0	-	0	17.2	0	15
58	C01	Low Heat Gun	III	Tile	Good	C2	4	9.5	0	0	-	0	7.5	0	10
57	C01	Low Heat Gun	IV	Tile	Good	C2	5	44.2	0	0	-	0	51	2	10
12	H09	Window Repl.	I	Wood	Poor	C3	3	60.5	0	0	-	0	29.9	1	10
41	H16	Window Repl.	I	Wood	Poor	C4	6	69	0	0	-	0	41.4	3	15
11	H09	Window Repl.	II	Wood	Poor	C3	5	96.9	0	0	-	0	33.5	1	15
42	H16	Window Repl.	II	Wood	Poor	C4	6	183.4	0	0	-	0	96.2	4	10
9	H09	Window Repl.	III	Wood	Poor	C3	5	133	1	0	-	0	118.2	4	45
44	H17	Window Repl.	III	Wood	Fair	C4	6	38.1	0	0	-	0	56.1	2	10
10	H09	Window Repl.	IV	Wood	Poor	C3	5	137.8	4	0	-	0	36	1	30
43	H17	Window Repl.	IV	Wood	Fair	C4	6	154.7	0	0	-	0	108.3	3	15

* Verification time includes window sill and floor verification, re-cleaning, and wait times.

6.10.2. Verification of Window Sills

Along with the floor zones, each window sill in the Work Room was subject to cleaning verification. As stated previously, all window sills had to pass clearance before the RRP workers moved on to the cleaning verification of the floor. Overall, only three window sills failed the first wet cloth verification, despite the fact that nineteen window sills had post-cleaning lead levels of greater than 250 µg/ft^2. Tables 6-35, 6-36, and 6-37 list the post-cleaning and post-verification average sill lead levels by phase, job intensity level, and contractor respectively. Table 6-39 reports window sill cleaning verification information across all experiments.

Table 6-35. Window Sill Verification Information by Phase

Phase	PC Sill Lead Level (µg/ft^2)	PV Sill Lead Level (µg/ft^2)	# 1st Wet Cloth Failures
I – Plastic/Rule Cleaning	151.8	198.7	1
II – Plastic/Baseline Cleaning	761.6	119.6	0
III – No plastic/Rule Cleaning	1439.0	490.5	1
IV – No plastic/Baseline Cleaning	601.4	467.4	1

Table 6-36. Window Sill Verification Information by Intensity Level

Intensity Level	PC Sill Lead Level (µg/ft^2)	PV Sill Lead Level (µg/ft^2)	# 1st Wet Cloth Failures
Low	159.9	155.7	2
Medium	366.1	451.9	1
High	1689.3	347.6	0

Table 6-37. Window Sill Verification Information by Contractor

City	Contractor	# of Exp	Avg. PC Sill Lead Level (µg/ft^2)	% 1st Wet Cloth Failure	% 2nd Wet Cloth Failure	Avg. PV Sill Lead Level (µg/ft^2)
Columbus	C2	20	142.0	0.0%	0.0%	39.3
	C3	18	469.2	7.7%	0.0%	526.8
Pittsburgh	C4	22	1,500.9	3.1%	0.0%	381.1

No window sills failed a second wet cloth verification. For two of the three window sills that failed the first wet verification cloth, there are no corresponding post-cleaning or post-verification samples. This is because the sampling protocol called for one window sill sample at each sampling stage for interior experiments, while the cleaning verification protocol requires the testing of all window sills within the Work Room. For the one window sill that does correspond to the window used in the three-stage sampling, the post-cleaning lead level was 44.5 µg/ft^2 and the post-verification level was 20 µg/ft^2.

Comparison of Post-cleaning and Post-verification Lead Levels

Figure 6-21 plots the number of experiments in various categories of sill lead levels at the post-cleaning and post-verification stages. The number of experiments with sill lead levels below the clearance standard of 250 µg/ft^2 increased from 41 to 48 between post-cleaning and post-verification. Table 6-38 presents the percent change in window sill lead levels from post-cleaning to post-verification by phase and whether a cloth failure was identified. It is worth noting that lead levels from 24 experiments were below the detection limit at post-cleaning and 34 experiments are post-verification, with 21 being below the detection limit at both stages (9 from Phase I).

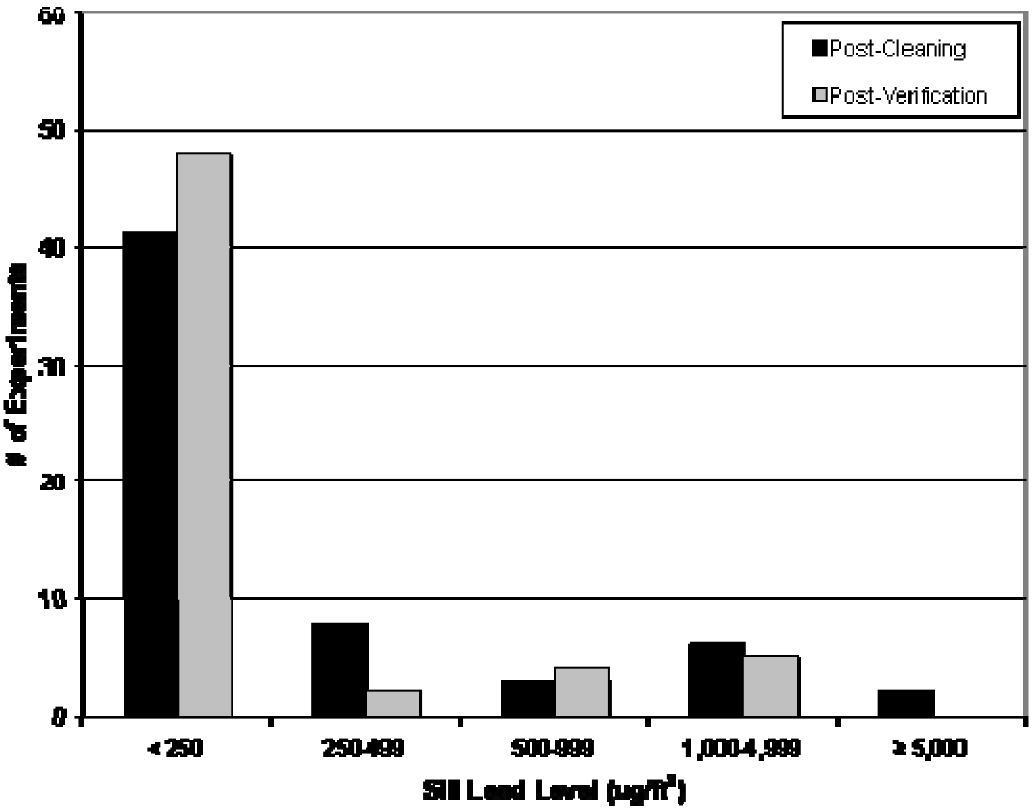

Figure 6-21. Number of Experiments by Post-cleaning and Post-verification Sill Lead Loadings

Table 6-38. Post-cleaning and Post-verification Sill Lead Levels for Experiments with Zero and ≥1 Verification Failures by Phase.

	Phase							
	I		II		III		IV	
# of Verification Failures	**0**	**≥1**	**0**	**≥1**	**0**	**≥1**	**0**	**≥1**
Average PC Sill Lead Level (µg/ft²)	156.5	85.8	761.6	n/a	1,538.6	44.5	614.9	411.5
Average PV Sill Lead Level (µg/ft²)	208.8	57.5	118.8	n/a	526.7	20.0	438.4	873.3
Avg. % Change per Experiment	1.7%	-33.0%	-52.5%	n/a	106.1%*	-55.1%	-44.2%	112.2%
Overall Avg. Change	33.4%	-33.0%	-84.4%	n/a	-65.8%	-55.1%	-28.7%	112.2%

* with exclusion of 2 experiments that changed from below detection limit to 166 and 282 µg/ft², average percent change would be -14.2%

Table 6-39. Window Sill Verification Information for Interior Experiments

Exp. #	Unit ID	Job	Phase	Sill Type	Cont.	# of Sills	PC Sill Lead Level (µg/ft^2)	# Failed 1st Wet Cloths	PV Sill Lead Level (µg/ft^2)	# PV Samples >250 µg/ft^2
23	H16	Cut-outs	I	SILL	C4	2	< 40	0	< 40	0
55	C01	Cut-outs	I	TRAY	C2	1	< 41.6	0	< 41.6	0
72	H35	Cut-outs	I	SILL	C3	2	< 100	0	< 100	0
25	H16	Cut-outs	II	SILL	C4	2	< 52.6	0	< 52.6	0
53	C01	Cut-outs	II	TRAY	C2	1	48.7	0	< 45.5	0
71	H35	Cut-outs	II	SILL	C3	2	101.1	0	< 62.5	0
24	H17	Cut-outs	III	SILL	C4	2	< 50	0	166.4	0
46	H08	Cut-outs	III	TRAY	C3	1	< 41.6	0	< 41.6	0
52	C01	Cut-outs	III	TRAY	C2	1	< 45.5	0	< 45.5	0
22	H16	Cut-outs	IV	SILL	C4	2	198.2	0	< 40	0
45	H08	Cut-outs	IV	SILL	C3	1	416.9	0	276.6	1
54	C01	Cut-outs	IV	TRAY	C2	1	< 41.6	0	< 41.6	0
48	H08	Door Plane	I	SILL	C3	1	521.3	0	1,707.90	1
79	H09	Door Plane	I	TRAY	C3	1	104.2	0	< 45.5	0
73	H35	Door Plane	II	SILL	C3	3	127.1	0	115.7	0
77	H08	Door Plane	II	TRAY	C3	1	278.6	0	61.7	0
74	H35	Door Plane	III	SILL	C3	2	170.4	0	< 100	0
80	H09	Door Plane	III	TRAY	C3	1	2,546.10	0	3,378.20	1
47	H08	Door Plane	IV	SILL	C3	1	1,798.70	0	2,625.30	1
78	H08	Door Plane	IV	TRAY	C3	1	277.9	0	96.5	0
5	H03	Dry Scrape	I	TRAY	C2	1	< 10	0	< 10	0
28	H17	Dry Scrape	I	SILL	C4	2	85.8	1*	57.5	0
6	H03	Dry Scrape	II	TRAY	C2	1	< 50	0	< 25	0
29	H17	Dry Scrape	II	SILL	C4	2	467	0	115	0
8	H03	Dry Scrape	III	TRAY	C2	1	< 45.5	0	< 45.5	0
26	H17	Dry Scrape	III	SILL	C4	2	< 52.6	0	< 52.6	0
7	H03	Dry Scrape	IV	TRAY	C2	1	< 50	0	< 50	0
27	H17	Dry Scrape	IV	SILL	C4	2	150.8	0	< 52.6	0
16	H09	Heat Gun	I	TRAY	C2	1	< 41.6	0	< 41.6	0
33	H10	Heat Gun	I	TRAY	C4	1	1005.3	0	790.2	1
63	C01	Heat Gun	I	TRAY	C2	1	< 45.5	0	< 45.5	0
13	H09	Heat Gun	II	TRAY	C2	1	253.7	0	81.4	0
31	H10	Heat Gun	II	TRAY	C4	1	8,838.80	0	927.2	1
60	C01	Heat Gun	II	TRAY	C2	1	170.4	0	< 45.5	0
14	H09	Heat Gun	III	TRAY	C2	1	< 45.5	0	< 45.5	0
32	H10	Heat Gun	III	TRAY	C4	1	18,132.80	0	2,669.60	1
61	C01	Heat Gun	III	TRAY	C2	1	< 41.6	0	< 41.6	0
15	H09	Heat Gun	IV	TRAY	C2	1	1,352.40	0	182.7	0
30	H10	Heat Gun	IV	TRAY	C4	1	1,697.60	0	1,784.50	1

Table 6-39. (continued) Window Sill Verification Information for Interior Experiments

Exp. #	Unit ID	Job	Phase	Sill Type	Cont.	# of Sills	PC Sill Lead Level (µg/ft^2)	# Failed 1st Wet Cloths	PV Sill Lead Level (µg/ft^2)	# PV Samples >250 µg/ft^2
62	C01	Heat Gun	IV	TRAY	C2	1	94.4	0	< 45.5	0
51	H33	Kitchen Gut	I	SILL	C4	1	< 45.5	0	< 45.5	0
67	H16	Kitchen Gut	I	SILL	C4	2	< 40	0	< 40	0
49	H31	Kitchen Gut	II	SILL	C4	1	< 100	0	< 100	0
70	H35	Kitchen Gut	II	SILL	C3	2	< 66.6	0	< 66.6	0
68	H17	Kitchen Gut	III	SILL	C4	2	396.5	0	< 52.6	0
76	H36	Kitchen Gut	III	SILL	C4	1	86.2	0	138.3	0
50	H32	Kitchen Gut	IV	SILL	C4	1	130.3	0	< 41.6	0
69	H08	Kitchen Gut	IV	SILL	C3	1	1,414.20	0	73.5	0
59	C01	Low Heat Gun	I	TRAY	C2	1	137.7	0	< 41.6	0
56	C01	Low Heat Gun	II	TRAY	C2	1	285.1	0	133.1	0
58	C01	Low Heat Gun	III	TRAY	C2	1	< 41.6	0	n/a	1
57	C01	Low Heat Gun	IV	TRAY	C2	1	246.8	0	70.4	0
12	H09	Window Repl.	I	TRAY	C3	1	< 45.5	0	< 45.5	0
41	H16	Window Repl.	I	SILL	C4	1	218.1	0	176	0
11	H09	Window Repl.	II	SILL	C3	1	106.9	0	< 45.5	0
42	H16	Window Repl.	II	SILL	C4	1	611.9	0	126.2	0
9	H09	Window Repl.	III	SILL	C3	2	44.5	1	< 40	0
44	H17	Window Repl.	III	SILL	C4	1	< 52.6	0	281.5	1
10	H09	Window Repl.	IV	SILL	C3	2	411.5	1*	873.3	1
43	H17	Window Repl.	IV	SILL	C4	1	784.9	0	892.5	1

* The failed verification cloth does not correspond to the sill from which the samples were collected.

7. Statistical Modeling Results

The following sections provide the results of statistical models applied to floor and window sill dust-lead results from the RRP Field Study. The results are organized by Stage (Post Work, Post Cleaning, and Post Verification) and Room (Work, Tool, and Observation) – with separate statistical models being specified within each Stage-by-Room combination to address the multiple inferential objectives mentioned earlier in Section 1. Section 7.1 corresponds to all results obtained in the Post Work Stage of field data collection, with subsections 7.1.1 – 7.1.3 corresponding to results in the Work Room, Tool Room and Observation Room, respectively. Similarly, Section 7.2 and 7.3 (and their associated sub-sections) correspond to the Post Cleaning and Post Verification Stages. Section 7.4 corresponds to a cross-stage analysis that compares full rule implementation (use of plastic sheeting and RRP rule cleaning in the Post-verification Stage) to baseline activities or no rule implementation (no use of plastic sheeting and baseline cleaning in the Post-cleaning Stage).

The results summarized in the following sections provide an overview of the statistical modeling results for floor and window sill dust-lead loadings from interior RRP jobs for two subsets of study data: (1) data limited to residential units only, and (2) Combined data for all interior RRP jobs (both residential and COFs). All analyses that were conducted on the second subset of data include a term in the model that adjusts for differences between residential units and COFs. Thus, a COF variable appears in all models of the Combined data.

The rationale for presenting the analysis results for each Stage-by-Room combination is that the series of statistical models that are fit to a subset of data (e.g. post-cleaning floor dust-lead loadings in the Observation room) are directly comparable using a likelihood ratio test statistic. Differences in reported likelihood fit statistics (-2 Log-Likelihood) between two models applied to the same dataset can be assessed by comparing to the Chi-Squared (χ^2) distribution with degrees of freedom matching the difference in the number of fixed effects included in the two models. Generally, the lower likelihood ratio statistic indicates the better fitting model. Within each subset of data, a potential best model is identified based on evaluation of the likelihood ratio along with the number of variables included and the significance of additional variables.

A mixed models analysis of variance approach including both fixed and random effects was used to fit the statistical models presented in this section and test the various study hypotheses, using Proc Mixed in SAS®. Each of the models explained dust-lead loadings on floors or window sills as a function of one or more fixed effects variables (intensity-level, job-type, use of plastic sheeting, post-work cleaning method, average paint-lead loading on disrupted component(s), square feet of lead-based paint disturbed, etc.) – with some models investigating interactions between some of these fixed effect variables to address specific analysis objectives.

Adjustments were made in the model to account for the data not being independent. There is anticipated positive correlation between the multiple samples of each type taken within the same room during the same experiment, within the same room across experiments, and within the same housing unit across experiments. To account for this, the models applied to floor dust-lead loadings included random effect terms that adjusted for anticipated positive correlation among multiple results observed from within the same unit, among multiple results observed from within the same room (within a unit), and among multiple results observed from within the same RRP experiment. The models applied to window sill dust-lead loadings included a random effect for the anticipated positive correlation among multiple results observed from within the same room within a unit (a random effect for experiment was unnecessary because there was only one window sill sample obtained from each Stage-by-Room combination within an experiment).

Because the statistical models assume the data are normally distributed and because the dust lead loading data were non-normal (as indicated by various figures in Appendices B-E), all floor and sill data underwent log-transformation to more closely approximate normality, which generally is done with environmental lead data. Although most sets of transformed data still differ significantly enough from normality to be identified as non-normal by the test statistic presented in the appendices, the statistical models utilized are robust enough to account for this level of non-normality. Plots of residuals from each set of data are presented within the section to illustrate the suitability of the models used.

In the sections that follow, we provide summary tables for the models fit for each Stage-by-Room combination of data. The summary tables provide an overview of the p-value associated with each explanatory factor and the likelihood fit statistic for model fit to that particular subset of data. The p-values for categorical variables are based on an F-test for the combined effect across multiple levels. Statistical significance is generally attributed to p-values less than 0.05. P-values between .05 and about .10 are referred to as borderline significant.

Additional detail on the specific parameter estimates and standard errors from each model can be found in Appendices I through N. Residential floor and sill results are in Appendices I and J; COF floor results are in Appendix K; combined interior results are in Appendices L and M; and detailed exterior model results are in Appendix N. Residual plots for the best fitting models are contained in Appendix O. In a few places in this section, we compare the specific parameter estimates for a variable of interest and calculate the model-predicted difference in geometric mean levels based on those estimates. This is done using the formula $100*(1-e^{x})$, with "x" being the difference in parameter estimates.

7.1. Post-Work Dust Lead Levels

The following three subsections provide an overview of statistical modeling results for floor and window sill dust lead loading results in the post work stage of the field study, in the Work room (subsection 7.1.1), Tool room (subsection 7.1.2), and Observation room (subsection 7.1.3).

7.1.1. Post-Work Work Room Dust Lead Levels

Table 7-1 provides an overview of results from statistical models developed to describe post-work floor and window sill dust-lead loadings in the Work room across the two subsets of data described earlier (residential units only and all units combined). The results are repeated using the wipe-only dust-lead results, as well as the results that also integrated the bulk samples.

Objective 1-Model 1 assesses the total effect of Intensity-Level (High, Medium, and Low) on floor and window sill dust lead loadings, which was shown to be statistically significant in all models. Objective 1-Model 2 assesses the total effect of Job-Type (a 6-level variable in the residential unit dataset, and a 7-level variable in the all units combined dataset), which explained additional variability in floor and window sill dust-lead loadings as anticipated. Job-type is nested within intensity level by design.

In addition to the models assessing the total effect of intensity level and job type, Objective 1-Models 3 and 4 investigate whether these two variables are still statistically significant predictors of floor and window sill dust lead loadings after adjusting for the paint-lead loading on the surface being disturbed and a measure of the square feet of lead-based paint disturbed during the RRP activity. The summary of results provided in Table 7-1 demonstrate that both Intensity-Level and Job-Type are statistically significant predictors of post-work floor and window sill dust-lead loadings in the work room after adjusting for the effects of paint-lead loading and square footage disturbed, and the addition of these two variables does not always improve the predictive ability of these models. This suggests that these two additional terms may compete for explanatory power with intensity-level and job-type. A comparison of the wipe-only dust-lead loadings with the measures that integrate the bulk samples did not yield any meaningful differences in interpretation of the data.

The highlighted rows in Table 7-1 indicate the models that appear to fit the data best. Objective 1-Model 2, which accounted only for job type and COF, performs best for the residential floor data and both sets of window sill data. Within the combined floor data, the inclusion of area disturbed and average paint lead level improved the model fit slightly with average paint lead significantly impacting the floor lead levels. Section O1 of Appendix O contains the residual plots from these four best fitting models. The floor model residuals appear to be approximately normally distributed. The residuals from the sill models appear to contain some skewness.

Table 7-1: Post-work Work Room Modeling Results

Model	Variables Included in Model	Floors				Sills			
		All Residential		Combined		All Residential		Combined	
		p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
Objective 1: Model 1	COF	.	756.3	0.20	945.5	.	214.8	0.28	263.8
	Intensity level	<.01		<.01		<.01		<.01	
Objective 1: Model 2	COF	.	726.7	0.05	921.3	.	192.5	0.35	231.3
	Job type	<.01		<.01		<.01		<.01	
Objective 1: Model 3	COF	.	755.5	0.05	943.2	.	215.2	0.16	269.4
	Square feet disturbed	0.34		0.76		0.35		0.95	
	Avg. paint lead	<.01		<.01		<.01		0.10	
	Intensity level	<.01		<.01		<.01		<.01	
Objective 1: Model 4	COF	.	731.7	0.03	915.4	.	197.2	0.34	236.1
	Square feet disturbed	0.58		0.82		0.33		0.21	
	Avg. paint lead	0.04		<.01		0.35		0.19	
	Job type	<.01		<.01		<.01		<.01	
Objective 1: Model 1, with bulk	COF	.	954.5	0.67	1222.9	.	228.4	0.28	278.4
	Intensity level	<.01		<.01		<.01		<.01	
Objective 1: Model 2, with bulk	COF	.	931.0	0.29	1195.3	.	205.9	0.34	247.1
	Job type	<.01		<.01		<.01		<.01	
Objective 1: Model 3, with bulk	COF	.	952.1	0.20	1222.3	.	228.1	0.15	283.1
	Square feet disturbed	0.57		0.20		0.34		0.89	
	Avg. paint lead	<.01		<.01		<.01		0.07	
	Intensity level	<.01		<.01		<.01		0.01	
Objective 1: Model 4, with bulk	COF	.	934.7	0.18	1193.7	.	209.8	0.33	251.1
	Square feet disturbed	0.55		0.94		0.32		0.22	
	Avg. paint lead	0.03		<.01		0.33		0.16	
	Job type	<.01		<.01		<.01		<.01	

7.1.2. Post-work Tool Room Dust Lead Levels

Table 7-2 provides an overview of results from statistical models developed to describe post-work floor and window sill dust-lead loadings in the Tool room across the two subsets of data described earlier (residential units only and all units combined). The results are provided for the wipe samples only (as there were no bulk samples found in the Tool room).

Objective 1-Model 5 assesses the total effect of Intensity-Level on floor and window sill dust lead loadings, which was shown to be statistically significant in all models. Model 6 assesses the total effect of Job-Type, which explained additional variability in floor and window sill dust-lead loadings as anticipated. In addition to the models assessing the total effect of intensity level and job type, Objective 1-Models 7 and 8 investigate whether these two variables are still statistically significant predictors of floor and window sill dust lead loadings after adjusting for the paint-lead loading on the surface being disturbed and a measure of the square feet of lead-based paint disturbed during the RRP activity.

The summary of results provided in Table 7-2 demonstrate that both Intensity-Level and Job-Type are statistically significant predictors of post-work floor and window sill dust-lead loadings in the Tool room after adjusting for the effects of paint-lead loading and square footage disturbed. The addition of these two variables does not always improve the predictive ability of these models, which suggests that these two additional terms may compete for explanatory power with intensity-level and job-type.

Models were also developed to assess whether the use of plastic sheeting reduced post-work dust-lead loadings observed in the Tool room. Objective 1–Models 9 and 10 provide the results of these analyses. Although the use of plastic sheeting did not always result in statistically significant reductions in post-work dust lead loadings in the Tool room – inspection of the parameter estimates of these models (found in Appendices I through M) reveals that the effect of using plastic sheeting results in lower estimated post-work dust lead loadings for the Tool Room across all models. The effects of Job-Type and Intensity-Level were found to be statistically significant, after adjusting for the use of plastic sheeting in all models applied to dust lead loadings in the Tool room at the post-work stage.

Objective 1–Model 6, which accounts for job type and the differences between residential units and the COF, is highlighted in Table 7-2 as the best fitting model for all four data sets. Although the log-likelihoods are slightly lower for Objective 1–Model 10, that model also included an additional variable, which did not lead to much gain in the likelihood statistic and was not significant. Although use of plastic was not statistically significant, the detailed results of this model in Table L2 report that combined floor lead levels are 0.32 units lower on the log scale when plastic was used, which equates to geometric means predicted to be 27% lower when plastic was used than when it was not used. Section O2 of Appendix O contains the residual plots from these best fitting models, which all indicate reasonable normal distributions.

Table 7-2: Post-Work Tool Room Modeling Results

		Floors				Sills			
		All Residential		Combined		All Residential		Combined	
Model	Variables Included in Model	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
Objective 1: Model 5	COF	.	328.1	0.36	436.3	.	176.4	0.32	212.0
	Intensity level	<.01		<.01		0.03		0.01	
Objective 1: Model 6	COF	.	306.5	0.31	413.4	.	164.0	0.21	198.2
	Job type	<.01		<.01		0.02		0.02	
Objective 1: Model 7	COF	.	334.6	0.21	441.9	.	172.0	0.07	211.1
	Square feet disturbed	0.78		0.78		0.09		0.18	
	Avg. paint lead	0.06		0.02		<.01		<.01	
	Intensity level	<.01		<.01		<.01		0.01	
Objective 1: Model 8	COF	.	311.7	0.25	417.2	.	164.9	0.12	199.6
	Square feet disturbed	0.07		0.32		0.50		0.72	
	Avg. paint lead	0.49		0.01		<.01		<.01	
	Job type	<.01		<.01		0.04		0.03	
Objective 1: Model 9	COF	.	326.0	0.36	435.2	.	175.2	0.32	212.0
	Plastic	0.12		0.19		0.32		0.60	
	Intensity level	<.01		<.01		0.02		0.01	
Objective 1: Model 10	COF	.	305.0	0.31	412.7	.	163.1	0.22	198.3
	Plastic	0.16		0.20		0.37		0.66	
	Job type	<.01		<.01		0.02		0.02	

7.1.3. Post-Work Observation Room Dust Lead Levels

Table 7-3 provides an overview of results from statistical models developed to describe post-work floor and window sill dust-lead loadings in the Observation room across both residential units only and all units combined. The results are provided for the wipe samples only as there were no bulk samples found in the Observation room.

As in the other two rooms, both intensity level and job type are statistically significant when assessed by themselves – in Objective 1-Model 11, and Objective 1-Model 12, respectively. Again Job Type performs better than intensity level in explaining more variability in the floor and window sill dust-lead loadings as anticipated, achieving lower log-likelihood ratios. Objective 1-Models 13 and 14 investigate whether intensity level and job type were still statistically significant predictors of floor and window sill dust lead loadings after adjusting for the paint-lead loading on the surface being disturbed and area disturbed during the RRP activity. The summary of results provided in Table 7-3 demonstrate that both Intensity-Level and Job-Type are statistically significant predictors of post-work floor and window sill dust-lead loadings in the work room after adjusting for the effects of paint-lead loading and square footage disturbed. The addition of these two variables improved the predictive ability for floors, but not for window sills. Furthermore, average paint-lead loading on components disrupted by the RRP activity was a statistically significant predictor of dust-lead levels found in the Observation room in the post-work stage in most of the models.

Models were also developed to assess whether the use of plastic sheeting reduced dust-lead loadings found in the Observation room in the post work stage. Objective 1–Models 15 and 16 provide the results of theses analyses. The use of plastic sheeting resulted in statistically significant reductions in post-work floor lead loadings in the Observation room for residential units only. This effect was only borderline significant in the combined data (p-value=.10), which included the COFs.

The detailed results in Table L3 of Appendix L report floor lead levels from the combined model 0.46 units less when plastic was used, which equates to a predicted GM 36.9% lower than when plastic was not used. The use of plastic sheeting did not significantly lower window sill dust lead loadings in the Observation room at the post-work stage. The effects of Job-Type and Intensity-Level were found to be statistically significant, after adjusting for the use of plastic sheeting in all models applied to dust lead loadings in the observation room at the post-work stage.

The best-fitting models differed across data sets for the post-work Observation room data. As highlighted in Table 7-3, the model adjusting for plastic use in addition to job type performed best for residential floors, while in the combined data the model adjusting for paint lead level and area disturbed performed better. For window sills, the model adjusting only for job type performed best. Section O3 of Appendix O contains the residual plots from these best fitting models, which indicate reasonable normal distributions for floors and some skewness for sills. If additional analyses are performed, these can be investigated further to determine impact of outliers in the window sill data.

Table 7-3: Post-Work Observation Room Modeling Results

Model	Variables Included in Model	Floors: All Residential p-value	Floors: All Residential -2 Log Likelihood	Floors: Combined p-value	Floors: Combined -2 Log Likelihood	Sills: All Residential p-value	Sills: All Residential -2 Log Likelihood	Sills: Combined p-value	Sills: Combined -2 Log Likelihood
Objective 1: Model 11	COF	.	304.3	0.78	368.6	.	161.7	0.23	191.3
	Intensity level	<.01		<.01		0.02		0.01	
Objective 1: Model 12	COF	.	285.8	0.85	350.1	.	151.9	0.35	179.0
	Job type	<.01		<.01		0.04		0.02	
Objective 1: Model 13	COF	.	300.6	0.24	362.9	.	165.3	0.09	197.5
	Square feet disturbed	0.53		0.58		0.24		0.64	
	Avg. paint lead	<.01		<.01		<.01		0.02	
	Intensity level	<.01		<.01		0.03		0.03	
Objective 1: Model 14	COF	.	285.3	0.54	344.5	.	158.1	0.23	184.5
	Square feet disturbed	0.18		0.50		0.97		0.79	
	Avg. paint lead	<.01		<.01		0.09		0.03	
	Job type	<.01		<.01		0.09		0.03	
Objective 1: Model 15	COF	.	298.8	0.78	366.1	.	161.9	0.24	191.9
	Plastic	0.02		0.09		0.83		0.79	
	Intensity level	<.01		<.01		0.02		0.02	
Objective 1: Model 16	COF	.	280.4	0.86	348.1	.	152.1	0.35	179.6
	Plastic	0.02		0.10		0.80		0.81	
	Job type	<.01		<.01		0.04		0.03	

7.2. Post Cleaning Stage - Dust Lead Levels

The following three subsections provide an overview of statistical modeling results for floor and window sill dust lead loadings in the post-cleaning stage of the field study, in the Work room (subsection 7.2.1), Tool room (subsection 7.2.2), and Observation room (subsection 7.2.3).

7.2.1. <u>Post-Cleaning Work Room Dust Lead Levels</u>

Table 7-4 provides an overview of results from statistical models developed to describe post-cleaning floor and window sill dust lead loadings in the work room for residential units only and all units combined. The results are provided for the wipe samples only (as there were no bulk samples after the post-work stage). Below are some highlights of some of the models run for these data.

- Objective 1-Models 17 and 18 assess the total effects of Intensity-Level and Job-Type, respectively, on floor and window sill dust lead loadings in the Work room during the post-cleaning stage. Intensity-Level and Job-Type were shown to be statistically significant in all models.
- Objective 1-Models 19 and 20 investigate whether intensity level and job type are still statistically significant predictors of floor and window sill dust lead loadings after adjusting for the paint lead loading on the surface being disturbed and a measure of the square feet of lead-based paint disturbed during the RRP activity. The results in Table 7-4 demonstrate that both Intensity-Level and Job-Type remain statistically significant predictors of post-cleaning floor dust lead loadings in the Work room after adjusting for

the effects of paint lead loading and square footage disturbed. While average paint lead loading was found to be a significant predictor of post-cleaning floor dust lead loadings in the Work room – Models 19 and 20 did not improve the prediction over Models 17 and 18, as evidenced by a comparison of the log-likelihoods. Models 19 and 20 applied to the window sill dust lead loadings demonstrate that the addition of these two variables (average paint-lead loading and square footage disturbed) competes with intensity-level and job-type for predictive power, without improving the model fit.

- Objective 2–Model 1 assesses the total effect of using plastic sheeting on post-cleaning dust lead levels in the work room, which was not a statistically significant predictor (on its own) in any of the models applied to floor and window sill dust lead levels. Inspection of the parameter estimates from these models in Appendices I through M, however, demonstrates that use of plastic sheeting was consistently associated with lower predicted post-cleaning dust lead levels in the Work room.
- Objective 2–Models 2 through 5 assess whether the use of plastic is significant after adjusting for intensity-level or job-type, and whether there is any significant interaction between the use of plastic and either intensity-level or job-type when predicting floor and window sill dust lead loadings following cleaning in the work room. These results follow the same general trend as observed in Objective 2–Model 1, in which the use of plastic sheeting was not statistically significant, but inspection of the parameter estimates is suggestive of a modest protective effect.
- Objective 3–Model 1 assesses the total effect of using RRP rule cleaning on post-cleaning dust-lead levels in the Work room, which was highly statistically significant in lowering dust lead loadings in all of the models.
- Objective 3–Models 2 through 5 assess whether the use of RRP rule cleaning is significant after adjusting for intensity-level or job-type, and whether there is any significant interaction between the use of RRP rule cleaning and either intensity-level or job-type when predicting floor and window sill dust lead loadings following cleaning in the Work room. The use of RRP rule cleaning was highly significant in all models, even after adjusting for intensity-level or job-type. The addition of the interaction term between RRP rule cleaning and either intensity-level or job-type did not significantly improve the prediction of the model – suggesting that the effectiveness of RRP rule cleaning does not change as a function of intensity level or job type.
- The remaining models fit to the post-cleaning stage in the Work room investigate the simultaneous effects of using plastic sheeting and RRP rule cleaning by adding both of these terms and their interaction to the model. Objective 1 – Models 21 and 22 explore the interactive effects of plastic sheeting and RRP rule cleaning on dust lead loadings after adjusting for the effects of intensity-level (21) and job-type (22). Objective Y – Models 1 and 2 build further on these models by also adjusting for average paint lead loading, which was found to be a significant predictor in previously described models.

The results suggest that Model 22, which explains floor dust lead loading as a function of job-type, plastic sheeting, RRP rule cleaning, and the interaction between plastic sheeting and RRP rule cleaning, provides the best fit for the floor data. In this model, post-cleaning work room floor dust lead loadings were lowest in the experiments that combined both proposed rule cleaning and the use of plastic sheeting, next lowest for experiments that just the proposed RRP rule cleaning but not plastic, followed by experiments that only employed the use of plastic.

Each of these three combinations resulted in significantly lower floor dust lead loadings than found in experiments that had baseline cleaning and no use of plastic, as seen in the detailed parameter estimates found in Table I4 of Appendix I and Table L4 of Appendix L.

For window sills, the results suggest that Objective 3–Model 5 provides the best fit by adjusting for job type, cleaning method, and their interaction. It makes sense that use of plastic would have less impact on window sills, as the plastic did not cover the sills as it did floors. Table J4 of Appendix J and Table M4 of Appendix M contain the detailed parameter estimates for this model. Looking at some of the models that explores the differences between phases, such as Objective Y-Model 2, the results indicate that the window sill dust lead loadings were only found to be significantly lower for the experiments that employed proposed rule cleaning and use of plastic on its own did not yield statistically significant lower window sill dust lead loadings.

Section O4 of Appendix O contains the residual plots from some of the best-fitting models, which indicate reasonably normal distributions for floors and some skewness for sills. If additional analyses are performed, these can be investigated further to determine potential causes of normality in these residuals.

Table 7-4: Post-Cleaning Work Room Modeling Results

		Floors				Sills			
		All Residential		Combined		All Residential		Combined	
Model	Variables Included in Model	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
Objective 1: Model 17	COF	.	529.6	0.16	646.6	.	173.6	0.45	208.5
	Intensity level	<.01		<.01		0.14		0.07	
Objective 1: Model 18	COF	.	513.4	<.01	634.4	.	164.1	0.21	197.8
	Job type	<.01		<.01		0.14		0.15	
Objective 1: Model 19	COF	.	529.2	0.02	646.5	.	178.8	0.33	216.1
	Square feet disturbed	0.60		0.90		0.18		0.32	
	Avg. paint lead	<.01		<.01		0.05		0.16	
	Intensity level	<.01		<.01		0.10		0.08	
Objective 1: Model 20	COF	.	516.8	<.01	630.5	.	171.2	0.15	205.7
	Square feet disturbed	0.89		0.65		0.54		0.55	
	Avg. paint lead	<.01		<.01		0.26		0.21	
	Job type	<.01		<.01		0.25		0.17	
Objective 1: Model 21	COF	.	510.2	0.01	623.0	.	162.8	0.29	195.6
	Avg. paint lead	<.01		<.01		0.09		0.06	
	Clean*Plastic	<.01		<.01		0.02		<.01	
	Intensity level	<.01		<.01		0.11		0.03	
Objective 1: Model 22	COF	.	499.0	<.01	607.4	.	153.4	0.15	184.1
	Avg. paint lead	<.01		<.01		0.29		0.10	
	Clean*Plastic	<.01		<.01		0.02		<.01	
	Job type	<.01		<.01		0.12		0.05	
Objective 2: Model 1	COF	.	542.7	0.19	661.6	.	176.8	0.43	213.8
	Plastic	0.38		0.37		0.22		0.48	
Objective 2: Model 2	COF	.	527.2	0.17	644.9	.	171.4	0.44	208.0
	Intensity level	<.01		<.01		0.10		0.06	
	Plastic	0.08		0.11		0.15		0.37	
Objective 2: Model 3	COF	.	521.6	0.18	639.2	.	165.3	0.45	202.9
	Intensity level	<.01		<.01		0.08		0.05	

Table 7-4: (continued) Post-Cleaning Work Room Modeling Results

Model	Variables Included in Model	Floors				Sills			
		All Residential		Combined		All Residential		Combined	
		p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
	Plastic	0.03		0.05		0.15		0.37	
	Intensity level*Plastic	0.15		0.10		0.25		0.28	
Objective 2: Model 4	COF	.	511.7	0.01	633.4	.	162.1	0.21	197.5
	Job type	<.01		<.01		0.12		0.15	
	Plastic	0.14		0.18		0.17		0.41	
Objective 2: Model 5	COF	.	495.2	0.01	614.8	.	147.1	0.23	179.5
	Job type	<.01		<.01		0.14		0.16	
	Plastic	0.15		0.52		0.16		0.44	
	Job type*Plastic	0.10		0.13		0.56		0.46	
Objective 3: Model 1	COF	.	538.1	0.21	656.1	.	171.8	0.41	203.5
	Clean	0.02		<.01		0.01		<.01	
Objective 3: Model 2	COF	.	523.5	0.20	639.5	.	167.0	0.42	197.5
	Intensity level	<.01		<.01		0.12		0.04	
	Clean	<.01		<.01		0.01		<.01	
Objective 3: Model 3	COF	.	521.2	0.21	636.6	.	161.6	0.42	194.3
	Intensity level	<.01		<.01		0.14		0.05	
	Clean	<.01		<.01		0.01		<.01	
	Intensity level*Clean	0.76		0.41		0.27		0.54	
Objective 3: Model 4	COF	.	506.1	<.01	627.0	.	156.1	0.19	185.2
	Job type	<.01		<.01		0.07		0.05	
	Clean	<.01		<.01		<.01		<.01	
Objective 3: Model 5	COF	.	494.9	<.01	614.0	.	140.9	0.19	169.5
	Job type	<.01		<.01		0.08		0.08	
	Clean	<.01		<.01		<.01		<.01	
	Job type*Clean	0.57		0.58		0.36		0.47	
Objective Y: Model 1	COF	.	509.9	0.11	621.8	.	155.4	0.72	186.3
	Intensity level	0.74		0.75		0.49		0.61	
	Avg. PostWork Work Floor Lead	<.01		<.01		<.01		<.01	
	Clean*Plastic	0.01		<.01		0.03		<.01	
Objective Y: Model 2	COF	.	500.4	0.02	615.6	.	148.4	0.37	177.4
	Job type	0.08		0.64		0.55		0.57	
	Avg. PostWork Work Floor Lead	0.04		<.01		0.03		<.01	
	Clean*Plastic	0.01		<.01		0.02		<.01	

7.2.2. Post-Cleaning Tool Room Dust Lead Levels

Table 7-5 provides an overview of results from statistical models developed to describe post-cleaning floor and window sill dust-lead loadings in the Tool room across residential units only and all units combined. The results provided are for wipe samples only as there were no bulk samples found in the Tool room. The bullets below summarize the various models tested.

- Objective 1-Models 23 and 24 assess the total effects of Intensity-Level and Job-Type, respectively, on floor and window sill dust lead loadings in the Tool room during the post-cleaning stage. Intensity-Level and Job-Type were shown to be statistically significant in all models.

- Regarding Objective 1-Models 25 and 26, the results provided in Table 7-5 demonstrate that both Intensity-Level and Job-Type remain statistically significant predictors of post cleaning floor dust-lead loadings in the Tool room after adjusting for the effects of paint lead loading and square footage disturbed. While average paint-lead loading was found to be a significant predictor of post-cleaning floor and window sill dust lead loadings in the Tool room for most of the models – Models 25 and 26 did not improve the prediction over Models 23 and 24, as evidenced by a comparison of the log-likelihoods.
- Objective 2–Model 6 assesses the total effect of using plastic sheeting on post-cleaning dust lead levels in the tool room, which was not a statistically significant predictor (on its own) in any of the models applied to floor and window sill dust lead levels. Inspection of the parameter estimates from these models in Appendices I through M, however, demonstrates that use of plastic sheeting is consistently associated with lower predicted post-cleaning dust-lead levels in the Tool room.
- Objective 2–Models 7 through 10 assess whether the use of plastic is significant after adjusting for intensity-level or job-type, and whether there is any significant interaction between the use of plastic and either intensity-level or job-type when predicting floor and window sill dust lead loadings following cleaning in the Work room. The results of these analyses suggest that there may be a significant interaction between the use of plastic and job-type when explaining both floor and window sill dust-lead loadings in the tool room following cleaning – and that these models provided the best fit of the data compared to any of the remaining models described below.
- Objective 3–Model 6 assesses the total effect of using the proposed Rule cleaning on post-cleaning dust lead levels in the Tool room, and Objective 3–Models 7 through 10 assess this effect after adjusting for intensity and job-type and their interaction with cleaning method. As anticipated, the method of cleaning applied in the Work room did not influence floor or window sill dust lead levels in the Tool room.
- The remaining models fit to the post-cleaning stage in the Tool room investigate the simultaneous effects of using plastic sheeting and proposed rule cleaning by adding both of these terms and their interaction to the model. These models did not improve upon the models that simply adjusted for the interaction between use of plastic and job-type.

As noted above, Objective2-Model 10 provided the best fit for all four data sets – residential floors and sills and combined floors and sills. Although use of plastic is not found to be significant by this model, there are significant or borderline significant interactions between job type and use of plastic for the floor data. Section O5 in Appendix O contains residual plots for these models, which all are reasonably normally distributed.

Table 7-5: Post-Cleaning Tool Room Modeling Results

Model	Variables Included in Model	Floors: All Residential p-value	Floors: All Residential -2 Log Likelihood	Floors: Combined p-value	Floors: Combined -2 Log Likelihood	Sills: All Residential p-value	Sills: All Residential -2 Log Likelihood	Sills: Combined p-value	Sills: Combined -2 Log Likelihood
Objective 1: Model 23	COF	.	315.6	0.40	411.6	.	171.4	0.25	204.9
	Intensity level	<.01		<.01		0.05		0.04	
Objective 1: Model 24	COF	.	297.9	0.39	392.8	.	157.9	0.24	189.8
	Job type	<.01		<.01		0.02		0.02	
Objective 1: Model 25	COF	.	319.0	0.08	415.4	.	168.7	0.05	205.8
	Square feet disturbed	0.91		0.97		0.06		0.10	
	Avg. paint lead	<.01		<.01		<.01		<.01	
	Intensity level	<.01		<.01		<.01		0.01	
Objective 1: Model 26	COF	.	300.2	0.26	392.2	.	160.8	0.15	194.0
	Square feet disturbed	0.08		0.20		0.97		0.83	
	Avg. paint lead	0.11		<.01		0.02		0.02	
	Job type	<.01		<.01		0.03		0.03	
Objective 1: Model 27	COF	.	309.2	0.21	405.9	.	161.0	0.08	197.5
	Avg. paint lead	0.01		<.01		<.01		<.01	
	Clean*Plastic	0.54		0.52		0.36		0.31	
	Intensity level	<.01		<.01		0.02		0.01	
Objective 1: Model 28	COF	.	294.3	0.27	385.5	.	151.1	0.12	184.3
	Avg. paint lead	0.05		<.01		0.02		0.01	
	Clean*Plastic	0.53		0.40		0.44		0.32	
	Job type	<.01		<.01		0.03		0.02	
Objective 2: Model 6	COF	.	328.0	0.41	424.5	.	176.4	0.23	210.3
	Plastic	0.34		0.42		0.20		0.20	
Objective 2: Model 7	COF	.	312.5	0.40	410.3	.	168.7	0.24	202.7
	Intensity level	<.01		<.01		0.03		0.02	
	Plastic	0.07		0.18		0.11		0.12	
Objective 2: Model 8	COF	.	305.6	0.41	404.3	.	160.7	0.25	198.2
	Intensity level	<.01		<.01		0.04		0.03	
	Plastic	0.16		0.29		0.24		0.18	
	Intensity level*Plastic	0.14		0.15		0.10		0.36	
Objective 2: Model 9	COF	.	295.5	0.39	391.9	.	155.5	0.24	187.9
	Job type	<.01		<.01		0.01		0.02	
	Plastic	0.10		0.20		0.12		0.13	
Objective 2: Model 10	COF	.	277.4	0.42	370.5	.	137.8	0.27	168.7
	Job type	<.01		<.01		0.01		0.02	
	Plastic	0.30		0.52		0.40		0.44	
	Job type*Plastic	0.06		0.04		0.16		0.21	
Objective 3: Model 6	COF	.	329.0	0.42	425.2	.	178.1	0.25	212.0
	Clean	0.96		0.77		0.77		0.97	
Objective 3: Model 7	COF	.	315.8	0.41	412.1	.	171.2	0.25	205.3
	Intensity level	<.01		<.01		0.05		0.04	
	Clean	0.91		0.72		0.61		0.90	
Objective 3: Model 8	COF	.	311.7	0.41	408.2	.	168.0	0.26	202.9
	Intensity level	<.01		<.01		0.07		0.05	
	Clean	0.83		0.73		0.68		0.91	
	Intensity level*Clean	0.57		0.43		0.97		0.98	

Table 7-5: (continued) Post-Cleaning Tool Room Modeling Results

Model	Variables Included in Model	Floors				Sills			
		All Residential		Combined		All Residential		Combined	
		p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
Objective 3: Model 9	COF	.	298.1	0.41	392.9	.	158.0	0.24	190.2
	Job type	<.01		<.01		0.02		0.02	
	Clean	0.81		0.40		0.89		0.79	
Objective 3: Model 10	COF	.	285.6	0.41	379.3	.	146.5	0.24	176.7
	Job type	<.01		<.01		0.03		0.03	
	Clean	0.97		0.70		0.97		0.68	
	Job type*Clean	0.62		0.69		0.92		0.85	
Objective Y: Model 3	COF	.	308.5	0.51	402.0	.	165.0	0.43	197.5
	Intensity level	0.25		0.12		0.80		0.92	
	Avg. PostWork Work Floor Lead	<.01		<.01		0.01		<.01	
	Plastic	0.23		0.22		0.19		0.12	
Objective Y: Model 4	COF	.	296.9	0.48	391.2	.	155.5	0.36	186.1
	Job type	0.04		0.06		0.39		0.43	
	Avg. PostWork Work Floor Lead	0.62		0.08		0.21		0.05	
	Plastic	0.14		0.24		0.18		0.14	

7.2.3. Post-Cleaning Observation Room Dust Lead Levels

Table 7-6 provides an overview of statistical modeling results post-cleaning floor and window sill dust-lead loadings in the Observation room across the residential units only and all units combined data sets. The results are provided for wipe samples only as there were no bulk samples found in the Observation room. The bullets below summarize findings from the various models.

- Objective 1-Models 29 and 30 assess the total effects of Intensity-Level and Job-Type, respectively, on floor and window sill dust lead loadings in the work room during the post-cleaning stage. Intensity-Level and Job-Type were shown to be statistically significant in all models.
- Objective 1-Models 31 and 32 investigate whether intensity level and job type are still statistically significant predictors of floor and window sill dust lead loadings after adjusting for the paint lead loading on the surface being disturbed and a measure of the square feet of lead-based paint disturbed during the RRP activity. The summary of results provided in Table 7-6 demonstrates that both Intensity-Level and Job-Type remain statistically significant predictors of post-cleaning floor dust-lead loadings in the Observation room after adjusting for the effects of paint lead loading and square footage disturbed. While average paint-lead loading was found to be a significant predictor of post-cleaning floor and window sill dust lead loadings in the Observation room in all of the models – these more complex models did not always improve the prediction over Models 29 and 30, suggesting that these terms may compete with intensity-level and job-type for explanatory power.
- Objective 2–Model 11 assesses the total effect of using plastic sheeting on post-cleaning dust-lead levels in the observation room, which a statistically significant predictor for

floors in residential units (p-value = 0.03) and nearly significant for all units (p-value = 0.06). The total effect of plastic on lowering window sill dust lead levels in the Observation room was borderline significant (p-value of 0.10 in residential units and 0.12 in all units combined).

- Objective 2–Models 12 through 15 assess whether the use of plastic was significant after adjusting for intensity-level or job-type, and whether there was any significant interaction between the use of plastic and either intensity-level or job-type when predicting floor and window sill dust lead loadings following cleaning in the work room. Although the F-test associated with the interaction term was not statistically significant across any of these models, Objective 2 – Model 15 provided the best fit of the data across floors and window sills within both subsets of data explored.
- Objective 3–Model 11 assesses the total effect of using the proposed Rule cleaning method on post-cleaning dust-lead levels in the Observation room, and Objective 3–Models 12 through 15 assess this effect after adjusting for intensity and job-type and their interaction with cleaning method. As in the Tool room, the method of cleaning applied in the Work room did not influence floor or window sill dust lead levels in the Observation room.
- The remaining models fit to the post-cleaning stage in the Observation room investigate the simultaneous effects of using plastic sheeting and RRP rule cleaning by adding both of these terms and their interaction to the model. These models did not significantly improve upon the models that simply adjusted for the interaction between use of plastic and job-type.

As noted above, Objective2-Model 15 provided the best fit for all four data sets – residential floors and sills and combined floors and sills. Although use of plastic is not found to be significant by this model, there are significant or borderline significant interactions between job type and use of plastic for the floor data. Section O6 in Appendix O contains residual plots for these models, which all are reasonably normally distributed.

Table 7-6: Post-Cleaning Observation Room Modeling Results

		Floors				Sills			
		All Residential		Combined		All Residential		Combined	
Model	Variables Included in Model	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
Objective 1: Model 29	COF	.	298.7	0.61	363.3	.	154.6	0.22	179.5
	Intensity level	<.01		<.01		0.08		0.07	
Objective 1: Model 30	COF	.	281.6	0.50	349.0	.	137.5	0.33	157.1
	Job type	<.01		<.01		<.01		<.01	
Objective 1: Model 31	COF	.	294.3	0.26	356.8	.	154.2	0.07	185.1
	Square feet disturbed	0.28		0.23		0.19		0.43	
	Avg. paint lead	<.01		<.01		<.01		0.01	
	Intensity level	<.01		<.01		0.04		0.09	
Objective 1: Model 32	COF	.	283.6	0.36	344.6	.	138.5	0.28	160.0
	Square feet disturbed	0.79		0.80		0.15		0.03	
	Avg. paint lead	<.01		<.01		0.04		0.09	
	Job type	<.01		<.01		<.01		<.01	
Objective 1: Model 33	COF	.	277.9	0.24	343.1	.	145.0	0.09	175.5
	Avg. paint lead	<.01		<.01		<.01		0.02	

Table 7-6: (continued) Post-Cleaning Observation Room Modeling Results

Model	Variables Included in Model	Floors				Sills			
		All Residential		Combined		All Residential		Combined	
		p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
	Clean*Plastic	0.01		0.03		0.26		0.25	
	Intensity level	<.01		<.01		0.03		0.04	
Objective 1: Model 34	COF	.	265.7	0.37	330.4	.	130.9	0.25	155.8
	Avg. paint lead	<.01		<.01		0.02		0.05	
	Clean*Plastic	<.01		0.03		0.26		0.22	
	Job type	<.01		<.01		<.01		<.01	
Objective 2: Model 11	COF	.	311.1	0.69	376.7	.	156.8	0.19	182.2
	Plastic	0.03		0.06		0.10		0.12	
Objective 2: Model 12	COF	.	288.9	0.59	358.1	.	150.5	0.22	176.7
	Intensity level	<.01		<.01		0.02		0.03	
	Plastic	<.01		0.02		0.03		0.06	
Objective 2: Model 13	COF	.	286.3	0.60	355.1	.	147.2	0.22	174.1
	Intensity level	<.01		<.01		0.05		0.05	
	Plastic	<.01		0.03		0.07		0.09	
	Intensity level*Plastic	0.75		0.63		0.61		0.55	
Objective 2: Model 14	COF	.	270.8	0.72	343.4	.	133.4	0.34	154.0
	Job type	<.01		<.01		<.01		<.01	
	Plastic	<.01		0.01		0.03		0.04	
Objective 2: Model 15	COF	.	259.7	0.74	326.6	.	120.9	0.35	139.4
	Job type	<.01		<.01		<.01		<.01	
	Plastic	<.01		0.06		0.14		0.20	
	Job type*Plastic	0.62		0.27		0.36		0.22	
Objective 3: Model 11	COF	.	316.1	0.72	380.2	.	159.3	0.21	184.4
	Clean	0.75		0.81		0.60		0.60	
Objective 3: Model 12	COF	.	298.5	0.62	363.6	.	154.7	0.22	180.1
	Intensity level	<.01		<.01		0.08		0.07	
	Clean	0.49		0.61		0.54		0.55	
Objective 3: Model 13	COF	.	294.2	0.62	360.7	.	151.6	0.22	178.1
	Intensity level	<.01		<.01		0.11		0.09	
	Clean	0.50		0.61		0.49		0.51	
	Intensity level*Clean	0.44		0.66		0.66		0.69	
Objective 3: Model 14	COF	.	281.9	0.50	349.6	.	138.3	0.33	158.3
	Job type	<.01		<.01		<.01		<.01	
	Clean	0.66		0.84		0.92		0.95	
Objective 3: Model 15	COF	.	269.3	0.51	335.9	.	127.8	0.30	147.9
	Job type	<.01		<.01		0.02		<.01	
	Clean	0.63		0.76		0.77		0.85	
	Job type*Clean	0.55		0.71		0.65		0.68	
Objective Y: Model 5	COF	.	284.4	0.92	351.4	.	148.5	0.36	173.1
	Intensity level	0.02		0.04		0.81		0.84	
	Avg. PostWork Work Floor Lead	<.01		<.01		0.03		0.01	
	Plastic	<.01		0.01		0.08		0.06	
Objective Y: Model 6	COF	.	272.4	0.99	340.2	.	134.6	0.44	155.1
	Job type	<.01		0.02		0.04		0.01	
	Avg. PostWork Work Floor Lead	0.51		0.02		0.32		0.23	
	Plastic	<.01		0.01		0.05		0.04	

7.3. Post-Verification Stage Dust Lead Levels

The following three subsections provide an overview of statistical modeling results for floor and window sill dust lead loading results in the post-verification stage of the field study, in the Work room (subsection 7.3.1), Tool room (subsection 7.3.2), and Observation room (subsection 7.3.3).

7.3.1. Post-Verification Work Room Dust Lead Levels

Table 7-7 provides an overview of results from statistical models developed to describe post-verification floor and window sill dust lead loadings in the work room across the two subsets of data described earlier (residential units only and all units combined). Detailed floor and sill modeling results are contained in Appendices I through M. It is important to keep in mind when considering the Work room data at the post-verification stage that zones of the work room that failed a cleaning verification step underwent recleaning using the proposed Rule cleaning method, regardless of which cleaning method was used at the post-cleaning stage. The bullets below summarize the various models run to explore the post-verification Work room data.

- Objective 1-Models 35 and 36 indicate that Intensity-Level and Job-Type were shown to be statistically significant predictors of post-verification floor dust lead loadings – but not significant predictors of window sill dust-lead loadings.
- Objective 1-Models 37 and 38 demonstrate that intensity-level and job-type are still statistically significant predictors of floor dust lead loadings after adjusting for the paint-lead loading on the surface being disturbed and a measure of the square feet of lead-based paint disturbed during the RRP activity. Average paint-lead loading was found to be a significant predictor of post-verification floor dust lead loadings in the Work room. None of the variables in Models 37 and 38 appeared significantly predictive of window sill dust-lead loadings in the Work room following verification.
- The remaining models fit to the post-verification dust lead loadings in the Work room were largely unremarkable – with the remaining variables (use of plastic, cleaning method, etc.) failing to explain a major portion of variability in post-verification dust lead results. This result suggests that the verification step acts as an equalizer – removing the factors that previously explained elevated dust lead levels in earlier phases of the experiment.
- The fact that intensity-level, job-type, and average paint lead loading are still predictive of post-verification floor dust-lead levels may be a concern. On the other hand, over half of all experiments ended with the average post-verification floor lead levels below 40 $\mu g/ft^2$ indicating that the various cleaning techniques utilized were able to return floor levels to a clean condition in the majority of experiments.

Objective 3-Model 20 provided the best fit for three of the four data sets – residential floors and residential and combined sills. This model adjusted for cleaning method, job type, and their interaction. This model performed well for the combined floor data set as well, but Objective 1-Model 40, which adjusted for phase (Clean*Plastic) and average paint lead, may have performed slightly better. Cleaning method was no longer significant at the post-verification stage. Section O7 in Appendix O contains residual plots for these models. The residuals from the floor models are normally distributed, although there does appear to be an outlier on the upper end of the distribution. The sill models appear to contain some skewness in the residuals.

Table 7-7: Post-Verification Work Room Modeling Results

		Floors				Sills			
		All Residential		Combined		All Residential		Combined	
Model	Variables Included in Model	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
Objective 1: Model 35	COF	.	542.0	0.16	640.6	.	167.9	0.33	194.3
	Intensity level	<.01		<.01		0.27		0.10	
Objective 1: Model 36	COF	.	520.1	<.01	627.8	.	155.6	0.12	180.5
	Job type	<.01		<.01		0.08		0.06	
Objective 1: Model 37	COF	.	536.3	0.02	639.8	.	174.5	0.30	204.3
	Square feet disturbed	0.92		0.53		0.94		0.70	
	Avg. paint lead	<.01		<.01		0.09		0.50	
	Intensity level	<.01		<.01		0.28		0.13	
Objective 1: Model 38	COF	.	522.4	<.01	623.8	.	161.5	0.17	187.8
	Square feet disturbed	0.81		0.91		0.12		0.09	
	Avg. paint lead	<.01		<.01		0.69		0.90	
	Job type	<.01		<.01		0.08		0.03	
Objective 1: Model 39	COF	.	526.9	0.02	629.3	.	164.4	0.27	195.1
	Avg. paint lead	<.01		<.01		0.09		0.40	
	Clean*Plastic	0.27		0.10		0.48		0.44	
	Intensity level	<.01		<.01		0.24		0.14	
Objective 1: Model 40	COF	.	514.3	<.01	614.3	.	153.5	0.12	181.1
	Avg. paint lead	<.01		<.01		0.40		0.59	
	Clean*Plastic	0.42		0.17		0.37		0.35	
	Job type	<.01		<.01		0.13		0.07	
Objective 2: Model 16	COF	.	556.5	0.19	658.9	.	170.0	0.30	198.0
	Plastic	0.40		0.51		0.29		0.34	
Objective 2: Model 17	COF	.	539.9	0.17	639.9	.	166.5	0.33	193.4
	Intensity level	<.01		<.01		0.22		0.08	
	Plastic	0.09		0.18		0.22		0.23	
Objective 2: Model 18	COF	.	535.4	0.17	637.4	.	163.1	0.33	191.1
	Intensity level	<.01		<.01		0.22		0.09	
	Plastic	0.06		0.16		0.22		0.24	
	Intensity level*Plastic	0.24		0.47		0.89		0.93	
Objective 2: Model 19	COF	.	518.0	<.01	627.5	.	154.3	0.12	179.8
	Job type	<.01		<.01		0.07		0.06	
	Plastic	0.08		0.26		0.22		0.26	
Objective 2: Model 20	COF	.	508.2	<.01	617.0	.	142.2	0.12	166.8
	Job type	<.01		<.01		0.10		0.08	
	Plastic	0.10		0.39		0.27		0.33	
	Job type*Plastic	0.69		0.89		0.86		0.92	
Objective 3: Model 16	COF	.	556.6	0.21	658.2	.	170.8	0.30	198.2
	Clean	0.42		0.26		0.56		0.38	
Objective 3: Model 17	COF	.	542.1	0.19	640.2	.	167.8	0.32	194.2
	Intensity level	<.01		<.01		0.28		0.11	
	Clean	0.41		0.20		0.58		0.41	

Table 7-7: (continued) Post-Verification Work Room Modeling Results

Model	Variables Included in Model	Floors				Sills			
		All Residential		Combined		All Residential		Combined	
		p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
Objective 3: Model 18	COF	.	540.2	0.20	639.2	.	164.3	0.32	191.8
	Intensity level	<.01		<.01		0.33		0.13	
	Clean	0.41		0.20		0.62		0.45	
	Intensity level*Clean	0.92		0.92		0.73		0.81	
Objective 3: Model 19	COF	.	520.2	<.01	627.5	.	155.0	0.12	179.7
	Job type	<.01		<.01		0.07		0.05	
	Clean	0.39		0.25		0.39		0.24	
Objective 3: Model 20	COF	.	505.6	<.01	612.7	.	142.8	0.13	165.5
	Job type	<.01		<.01		0.10		0.09	
	Clean	0.49		0.39		0.45		0.18	
	Job type*Clean	0.11		0.27		0.76		0.68	
Objective X: Model 7	COF	.	534.9	0.31	632.9	.	156.5	0.48	185.3
	Intensity level	0.90		0.59		0.39		0.45	
	Avg. PostWork Work Floor Lead	<.01		<.01		<.01		<.01	
	Clean*Plastic	0.67		0.35		0.64		0.47	
Objective X: Model 8	COF	.	517.6	<.01	623.9	.	148.8	0.21	175.4
	Job type	<.01		0.01		0.42		0.43	
	Avg. PostWork Work Floor Lead	0.17		<.01		0.04		0.04	
	Clean*Plastic	0.42		0.48		0.54		0.41	

7.3.2. Post-Verification Tool Room Dust Lead Levels

Table 7-8 provides an overview of results from models developed to describe post-verification floor and window sill dust lead loadings in the Tool room. The bullets below summarize the various models run.

- Objective 1-Models 41 and 42 assess the total effects of Intensity-Level and Job-Type, respectively, on floor and window sill dust lead loadings in the Tool room during the post-verification stage. Job-Type was shown to still be a statistically significant predictor of post-verification floor dust lead loadings – but not a significant predictor of window sill dust lead loadings. Intensity-level was not a significant predictor of post-verification floor or window sill post-verification dust lead levels in the Tool room.
- In the remaining models fit to the data, average paint lead loading appeared to be predictive of window sill dust lead levels – and models that accounted for the combined effects of job type and cleaning method appeared to be most predictive of window sill dust-lead loadings. Similarly, average paint lead levels appeared only marginally predictive of floor dust-lead loadings, and models that accounted for the combined effects of job-type and use of plastic provided the best fit for the post-verification floor dust lead models for the Tool room.

Objective 2-Model 25, which adjusted for job type, plastic, and their interaction, appeared to be the best-fitting model for the floor lead data. Use of plastic was significant in residential units, but not significant when including the COF data in the analysis. Note that the COF variable was significant indicating differences between the residential units and the school. In the school, the classroom being worked on was separated into both the Work room and Tool room whereas in houses the Tool room was an adjacent room usually accessed through a doorway. This difference may impact the Tool room results. Interestingly, Objective3-Model 25 fits the sill data best and found a borderline significance for cleaning method in the combined data set. Section O8 in Appendix O contains residual plots for these models. As with most of the other analyses, the residuals from the floor models appear normally distributed while the residuals from the sill models are somewhat skewed.

Table 7-8: Post-Verification Tool Room Modeling Results

		Floors				Sills			
		All Residential		Combined		All Residential		Combined	
Model	Variables Included in Model	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
Objective 1: Model 41	COF	.	351.2	0.42	452.6	.	181.6	0.29	217.2
	Intensity level	0.08		0.03		0.25		0.13	
Objective 1: Model 42	COF	.	334.5	0.06	436.8	.	172.7	0.43	206.4
	Job type	<.01		<.01		0.28		0.23	
Objective 1: Model 43	COF	.	357.7	0.14	461.2	.	179.8	0.09	222.2
	Square feet disturbed	0.96		0.90		0.19		0.33	
	Avg. paint lead	0.09		0.10		<.01		0.02	
	Intensity level	0.10		0.06		0.08		0.12	
Objective 1: Model 44	COF	.	342.5	0.04	444.5	.	173.0	0.32	212.5
	Square feet disturbed	0.67		0.98		0.89		0.64	
	Avg. paint lead	0.74		0.16		<.01		0.08	
	Job type	0.02		0.02		0.28		0.32	
Objective 1: Model 45	COF	.	342.7	0.13	447.3	.	170.2	0.04	209.9
	Avg. paint lead	0.14		0.10		<.01		<.01	
	Clean*Plastic	0.08		0.09		0.41		0.13	
	Intensity level	0.03		0.02		0.17		0.14	
Objective 1: Model 46	COF	.	328.0	0.03	431.7	.	162.4	0.19	200.3
	Avg. paint lead	0.79		0.15		<.01		0.02	
	Clean*Plastic	0.07		0.10		0.40		0.13	
	Job type	<.01		<.01		0.25		0.28	
Objective 2: Model 21	COF	.	354.7	0.37	457.8	.	185.1	0.25	221.3
	Plastic	0.12		0.16		0.65		0.49	
Objective 2: Model 22	COF	.	347.4	0.39	450.0	.	181.0	0.28	216.7
	Intensity level	0.04		0.02		0.24		0.12	
	Plastic	0.06		0.09		0.56		0.41	
Objective 2: Model 23	COF	.	341.9	0.40	445.7	.	176.4	0.28	213.4
	Intensity level	0.04		0.02		0.29		0.15	
	Plastic	0.06		0.10		0.66		0.47	
	Intensity level*Plastic	0.41		0.46		0.71		0.88	
Objective 2: Model 24	COF	.	330.3	0.05	434.2	.	172.1	0.43	206.0
	Job type	<.01		<.01		0.28		0.23	
	Plastic	0.04		0.09		0.60		0.45	
Objective 2: Model 25	COF	.	313.3	0.05	417.3	.	158.0	0.42	191.0
	Job type	<.01		<.01		0.38		0.34	
	Plastic	0.03		0.16		0.81		0.70	
	Job type*Plastic	0.29		0.59		0.89		0.95	

Table 7-8: (continued) Post-Verification Tool Room Modeling Results

Model	Variables Included in Model	Floors: All Residential p-value	Floors: All Residential -2 Log Likelihood	Floors: Combined p-value	Floors: Combined -2 Log Likelihood	Sills: All Residential p-value	Sills: All Residential -2 Log Likelihood	Sills: Combined p-value	Sills: Combined -2 Log Likelihood
Objective 3: Model 21	COF	.	355.6	0.39	458.7	.	184.2	0.22	219.2
	Clean	0.20		0.29		0.26		0.10	
Objective 3: Model 22	COF	.	349.2	0.41	451.7	.	180.4	0.25	215.1
	Intensity level	0.08		0.03		0.29		0.15	
	Clean	0.16		0.27		0.31		0.13	
Objective 3: Model 23	COF	.	344.4	0.42	447.1	.	176.5	0.26	211.7
	Intensity level	0.07		0.03		0.31		0.15	
	Clean	0.18		0.31		0.30		0.14	
	Intensity level*Clean	0.55		0.38		0.88		0.74	
Objective 3: Model 24	COF	.	332.6	0.06	435.9	.	171.1	0.38	203.6
	Job type	<.01		0.01		0.27		0.19	
	Clean	0.17		0.28		0.24		0.09	
Objective 3: Model 25	COF	.	318.2	0.06	420.3	.	155.9	0.41	185.6
	Job type	<.01		0.02		0.24		0.16	
	Clean	0.18		0.38		0.27		0.06	
	Job type*Clean	0.66		0.71		0.62		0.45	
Objective Y: Model 9	COF	.	346.6	0.45	448.7	.	180.9	0.35	217.4
	Intensity level	0.57		0.27		0.94		0.62	
	Avg. PostWork Work Floor Lead	0.03		0.04		0.12		0.21	
	Plastic	0.11		0.10		0.64		0.42	
Objective Y: Model 10	COF	.	331.5	0.07	435.0	.	173.1	0.46	207.4
	Job type	0.05		0.10		0.74		0.58	
	Avg. PostWork Work Floor Lead	0.82		0.31		0.75		0.80	
	Plastic	0.05		0.09		0.64		0.45	

7.3.3. Post-Verification Observation Room Dust Lead Levels

Table 7-9 provides the results from the statistical models developed to describe post-verification floor and window sill dust-lead loadings in the Observation room. Objective 1-Models 47 and 48 assess the total effects of Intensity-Level and Job-Type, respectively, on post-verification floor and window sill dust lead loadings. Both were shown to still be statistically significant predictors of post-verification floor and window sill dust lead loadings in the Observation room. In the remaining models fit to the post-verification Observation room data, average paint lead loading appeared to be predictive of both floor and window sill dust-lead levels, and models that accounted for the combined effects of job type and use of plastic provided the best fit.

Objective 2-Model 30 is highlighted in Table 7-9 as providing the best fit for each of the four data sets; however, the results for these data are not as clear. Use of plastic is found to be borderline significant in the residential data but not is significant in the combined data. When the job type by plastic use interaction is not included, the effect of plastic use is significant for the residential data and for window sills in the combined data. The residual plots in Section O9 of Appendix O appear approximately normal for floors and window sills.

Table 7-9: Post-Verification Observation Room Modeling Results

Model	Variables Included in Model	Floors: All Residential p-value	Floors: All Residential -2 Log Likelihood	Floors: Combined p-value	Floors: Combined -2 Log Likelihood	Sills: All Residential p-value	Sills: All Residential -2 Log Likelihood	Sills: Combined p-value	Sills: Combined -2 Log Likelihood
Objective 1: Model 47	COF	.	273.0	0.84	346.8	.	151.4	0.25	176.2
	Intensity level	<.01		<.01		0.07		0.05	
Objective 1: Model 48	COF	.	249.1	0.80	325.7	.	138.6	0.35	159.7
	Job type	<.01		<.01		0.02		<.01	
Objective 1: Model 49	COF	.	267.1	0.38	348.5	.	145.9	0.03	179.2
	Square feet disturbed	0.82		0.56		0.10		0.25	
	Avg. paint lead	<.01		<.01		<.01		<.01	
	Intensity level	<.01		<.01		0.02		0.05	
Objective 1: Model 50	COF	.	244.6	0.48	323.0	.	135.2	0.24	161.8
	Square feet disturbed	0.03		0.10		0.46		0.10	
	Avg. paint lead	<.01		<.01		<.01		0.01	
	Job type	<.01		<.01		<.01		<.01	
Objective 1: Model 51	COF	.	253.9	0.37	339.0	.	134.6	0.08	168.4
	Avg. paint lead	<.01		<.01		<.01		<.01	
	Clean*Plastic	0.08		0.31		0.06		0.12	
	Intensity level	<.01		<.01		<.01		0.02	
Objective 1: Model 52	COF	.	235.5	0.48	317.4	.	123.8	0.18	153.8
	Avg. paint lead	<.01		<.01		<.01		<.01	
	Clean*Plastic	0.04		0.39		0.10		0.14	
	Job type	<.01		<.01		<.01		<.01	
Objective 2: Model 26	COF	.	292.2	0.87	366.5	.	152.8	0.21	178.8
	Plastic	0.26		0.59		0.05		0.08	
Objective 2: Model 27	COF	.	268.8	0.83	346.4	.	145.8	0.24	172.8
	Intensity level	<.01		<.01		0.01		0.02	
	Plastic	0.03		0.29		0.01		0.04	
Objective 2: Model 28	COF	.	266.4	0.83	344.4	.	141.4	0.24	169.1
	Intensity level	<.01		<.01		0.03		0.03	
	Plastic	0.05		0.32		0.04		0.07	
	Intensity level*Plastic	0.95		0.99		0.32		0.32	
Objective 2: Model 29	COF	.	244.7	0.80	325.6	.	133.4	0.37	156.2
	Job type	<.01		<.01		<.01		<.01	
	Plastic	0.03		0.32		0.02		0.03	
Objective 2: Model 30	COF	.	230.8	0.83	306.3	.	118.9	0.38	140.3
	Job type	<.01		<.01		<.01		<.01	
	Plastic	0.06		0.85		0.08		0.13	
	Job type*Plastic	0.17		0.07		0.21		0.18	
Objective 3: Model 26	COF	.	293.0	0.88	366.7	.	155.6	0.24	180.6
	Clean	0.44		0.65		0.30		0.25	
Objective 3: Model 27	COF	.	272.5	0.84	347.3	.	150.4	0.26	175.5
	Intensity level	<.01		<.01		0.06		0.04	
	Clean	0.33		0.58		0.22		0.19	
Objective 3: Model 28	COF	.	269.8	0.83	344.4	.	147.9	0.25	173.8
	Intensity level	<.01		<.01		0.08		0.06	
	Clean	0.37		0.60		0.22		0.19	
	Intensity level*Clean	0.86		0.59		0.85		0.81	

Table 7-9: (continued) Post-Verification Observation Room Modeling Results

Model	Variables Included in Model	Floors				Sills			
		All Residential		Combined		All Residential		Combined	
		p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
Objective 3: Model 29	COF	.	248.9	0.79	326.6	.	138.5	0.36	159.9
	Job type	<.01		<.01		0.02		<.01	
	Clean	0.33		0.84		0.40		0.33	
Objective 3: Model 30	COF	.	239.3	0.77	313.6	.	126.9	0.35	147.6
	Job type	<.01		<.01		0.05		0.02	
	Clean	0.32		0.92		0.33		0.26	
	Job type*Clean	0.82		0.63		0.55		0.51	
Objective 4: Model Y	COF	.	266.3	0.96	342.3	.	143.9	0.39	168.9
	Intensity level	<.01		0.02		0.93		0.97	
	Avg. PostWork Work Floor Lead	0.02		<.01		0.02		<.01	
	Plastic	0.08		0.34		0.05		0.05	
Objective 4: Model Y	COF	.	246.8	0.88	326.3	.	133.8	0.50	156.5
	Job type	<.01		<.01		0.19		0.16	
	Avg. PostWork Work Floor Lead	0.79		0.20		0.19		0.11	
	Plastic	0.03		0.34		0.04		0.04	

7.4. Comparison of Rule Practices and Baseline Practices - Post-Job Dust Lead Levels

The following three subsections provide an overview of statistical modeling results for floor and window sill dust lead loadings in a cross-stage analysis comparing full rule implementation (use of plastic sheeting and proposed Rule cleaning at the Post-Verification Stage) to no rule implementation (no use of plastic sheeting and baseline cleaning at the Post-Cleaning Stage).

7.4.1. Post-Job Work Room Dust Lead Levels

Table 7-10 provides an overview of results from the various statistical models applied across stages within the Work room - comparing full rule implementation to no rule implementation. Model 1 assesses the total effect of rule implementation, which was shown to be highly significant in both floors and window sills in the two subsets of data explored. Models 2 through 5 assess the effect of full rule implementation in the Work room, after adjusting for intensity-level or job type and their interaction with full rule implementation. In each of these adjusted models, full rule implementation was associated with significantly lower dust-lead loadings in the Work room. Model 5 appears to fit the data best for each of the four data sets. The residual plots from the floor models appear reasonable, while the residual plots from the sill models appear to be heavy-tailed.

Table 7-10: Post-Job Work Room, Rule vs. Non-Rule Modeling Results

Model	Variables Included in Model	Floors: All Residential p-value	Floors: All Residential -2 Log Likelihood	Floors: Combined p-value	Floors: Combined -2 Log Likelihood	Sills: All Residential p-value	Sills: All Residential -2 Log Likelihood	Sills: Combined p-value	Sills: Combined -2 Log Likelihood
Objective X: Model 1	COF	.	245.1	0.22	293.4	.	78.1	0.31	92.8
	Rule	0.01		<.01		0.02		<.01	
Objective X: Model 2	COF	.	238.8	0.12	285.5	.	76.4	0.33	91.3
	Rule	<.01		<.01		0.03		<.01	
	Intensity level	0.06		0.01		0.93		0.77	
Objective X: Model 3	COF	.	234.3	0.11	280.9	.	71.4	0.33	87.8
	Rule	<.01		<.01		0.04		<.01	
	Intensity level	0.17		0.02		0.69		0.61	
	Rule*Intensity level	0.49		0.23		0.58		0.74	
Objective X: Model 4	COF	.	215.9	<.01	268.0	.	64.7	0.19	76.7
	Rule	<.01		<.01		0.02		<.01	
	Job type	<.01		<.01		0.35		0.34	
Objective X: Model 5	COF	.	202.7	<.01	253.2	.	49.6	0.33	59.4
	Rule	<.01		<.01		0.10		0.02	
	Job type	<.01		<.01		0.61		0.52	
	Rule*Job type	0.35		0.68		0.66		0.60	

7.4.2. Post-Job Tool Room Dust Lead Levels

The model results from comparing full rule implementation to no rule implementation within the Tool room are presented in Table 7-11. Model 6 assesses the total effect of rule implementation, which was not a statistically significant predictor of dust lead loadings in the Tool room. Models 7 through 10 assess the effect of full rule implementation in the Work room, after adjusting for intensity-level or job type and their interaction with full rule implementation. These models suggest that full rule implementation was associated with a marginally significant decrease in window sill dust lead levels, after adjusting for the effects of job-type (Model 9). Model 10 appears to provide the best fit, although by adding the rule use by job type interaction the effect of the rule was no longer significant. Section O11 presents the residual plots for Model 10, which appear to be normally distributed except for the residential sill data.

Table 7-11: Post-Job Tool Room, Rule vs. Non-Rule Modeling Results

Model	Variables Included in Model	Floors: All Residential p-value	Floors: All Residential -2 Log Likelihood	Floors: Combined p-value	Floors: Combined -2 Log Likelihood	Sills: All Residential p-value	Sills: All Residential -2 Log Likelihood	Sills: Combined p-value	Sills: Combined -2 Log Likelihood
Objective X: Model 6	COF	.	180.4	0.47	233.2	.	91.0	0.45	107.6
	Rule	0.46		0.46		0.24		0.13	
Objective X: Model 7	COF	.	171.5	0.33	224.8	.	83.4	0.40	102.1
	Rule	0.22		0.23		0.18		0.10	
	Intensity level	<.01		<.01		0.14		0.20	
Objective X: Model 8	COF	.	165.9	0.37	220.3	.	76.7	0.40	96.7
	Rule	0.35		0.31		0.23		0.13	
	Intensity level	0.05		0.03		0.12		0.17	
	Rule*Intensity level	0.78		0.84		0.45		0.59	

Table 7-11: (continued) Post-Job Tool Room, Rule vs. Non-Rule Modeling Results

Model	Variables Included in Model	Floors				Sills			
		All Residential		Combined		All Residential		Combined	
		p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
Objective X: Model 9	COF	.	144.2	0.23	205.1	.	69.2	0.54	85.8
	Rule	0.08		0.23		0.09		0.06	
	Job type	<.01		<.01		0.07		0.16	
Objective X: Model 10	COF	.	131.3	0.22	186.5	.	52.2	0.46	66.6
	Rule	0.17		0.36		0.19		0.14	
	Job type	<.01		0.10		0.30		0.36	
	Rule*Job type	0.97		0.99		0.80		0.91	

7.4.3. Post-Job Observation Room Dust Lead Levels

Table 7-12 contains the model results from comparing full rule implementation to no rule implementation across stages within the Observation room. Model 11 assesses the total effect of rule implementation, which was not a statistically significant predictor of dust lead loadings. Models 12 through 15 assess the effect of full rule implementation, after adjusting for intensity-level or job-type and their interaction with full rule implementation. The effect of full rule implementation was not a significant predictor of dust-lead loadings in any of these adjusted models within the Observation room.

Model 15 seems to provide the best fit to the data, but the variable added for the interaction between rule use and job type is not significant at all. The residuals plots for Model 15 contained in Section O12 of Appendix O are approximately normal except for the residential floor data.

Table 7-12: Post-Job Observation Room, Rule vs. Non-Rule Modeling Results

Model	Variables Included in Model	Floors				Sills			
		All Residential		Combined		All Residential		Combined	
		p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood	p-value	-2 Log Likelihood
Objective X: Model 11	COF	.	167.4	0.68	201.2	.	78.3	0.33	91.7
	Rule	0.43		0.66		0.43		0.56	
Objective X: Model 12	COF	.	154.4	0.49	191.5	.	74.0	0.29	88.0
	Rule	0.23		0.40		0.38		0.50	
	Intensity level	<.01		0.01		0.32		0.27	
Objective X: Model 13	COF	.	149.2	0.50	186.9	.	69.6	0.31	84.4
	Rule	0.23		0.41		0.43		0.54	
	Intensity level	0.02		0.03		0.44		0.38	
	Rule*Intensity level	0.77		0.79		0.90		0.85	
Objective X: Model 14	COF	.	135.1	0.49	174.9	.	58.9	0.34	70.7
	Rule	0.10		0.26		0.23		0.32	
	Job type	<.01		<.01		0.06		0.07	
Objective X: Model 15	COF	.	122.5	0.55	157.9	.	44.9	0.35	56.0
	Rule	0.14		0.35		0.35		0.47	
	Job type	<.01		0.12		0.33		0.32	
	Rule*Job type	0.96		1.00		0.80		0.93	

7.5. Exterior Dust Lead Levels

The main comparisons of interest for the exterior experiments are (1) the levels of lead measured on top of the Rule plastic compared to levels measured under the Rule plastic, and (2) the levels of lead measured on top of the Rule plastic compared to levels measured near the Rule plastic. The first comparison focuses on the effectiveness of the Rule plastic at preventing dust from spreading to the ground underneath it, while the second focuses on whether the Rule plastic was adequate to prevent contamination of the ground a bit further away from the work area. Appendix N contains the detailed model results for the mixed models run on both sets of exterior data. Table 7-13 presents the ratios of the model-predicted lead levels measured at each of the three locations: near (N) Rule plastic vs. on (O) Rule plastic; near (N) Rule plastic vs. Under (U) Rule plastic; and on (O) Rule plastic vs. Under (U) Rule plastic. Bulk debris samples are included in Table 7-13; however, the same statistics are presented in Table 7-14 without the bulk debris samples.

Table 7-13. Comparison Exterior Dust Pan Levels Within Each Job with Bulk Debris Samples Included (Model Based Estimate Differences and Ratios)

Job Type	Location 1	Location 2	Estimate (Log. Scale)	StdErr of Estimate (Log. Scale)	Ratio	95% Confidence Interval on the Ratio	
						Lower	Upper
Door Replacement	Near	On	-1.50	1.19	0.2	0.0	2.4
	Near	Under	6.03	1.19	417.0	39.6	4,386.7
	On	Under	7.53	1.19	1,869.9	177.7	19,672.5
Trim/Soffit Replacement	Near	On	-1.58	1.19	0.2	0.0	2.2
	Near	Under	4.54	1.19	94.0	8.9	989.3
	On	Under	6.13	1.19	457.1	43.5	4,809.4
Needle Gun	Near	On	-3.43	1.68	0.0	0.0	0.9
	Near	Under	3.16	1.68	23.6	0.8	657.0
	On	Under	6.59	1.68	724.9	26.0	20,213.6
Heat gun under 1100 degrees	Near	On	-4.20	1.68	0.0	0.0	0.4
	Near	Under	3.53	1.68	34.3	1.2	955.5
	On	Under	7.74	1.68	2,291.3	82.2	63,895.1
Dry Scrape	Near	On	-4.03	0.84	0.0	0.0	0.1
	Near	Under	2.65	0.84	14.2	2.7	75.0
	On	Under	6.69	0.84	802.0	151.9	4,235.4
Power Sanding	Near	On	-2.93	1.19	0.1	0.0	0.6
	Near	Under	1.86	1.19	6.5	0.6	67.9
	On	Under	4.79	1.19	120.8	11.5	1,271.1
Torching	Near	On	-7.19	1.19	0.0	0.0	0.0
	Near	Under	-3.00	1.19	0.1	0.0	0.5
	On	Under	4.18	1.19	65.7	6.2	690.9
Heat gun over 1100 degrees	Near	On	-5.88	1.68	0.0	0.0	0.1
	Near	Under	1.14	1.68	3.1	0.1	86.8
	On	Under	7.02	1.68	1,113.8	39.9	31,058.6

The Estimate column within tables 7-13 and 7-14 provides the predicted difference from the model for Location 1 – Location 2. Thus, the predicted difference of On-Under for the door replacement job (including bulk debris samples) is 6.9 units on the log scale. This translated to a ratio of 1,870:1 with a lower bound on a 95% confidence interval of 178:1. For the O:U comparison, a ratio greater than one indicates significantly higher levels on the plastic than under, which was expected. For the N:O comparison, a ratio less than one indicates that the lead levels measured near the Rule plastic are lower than those on the Rule plastic.

Table 7-14. Comparison Exterior Dust Pan Levels Within Each Job Excluding Bulk Debris Samples (Model Based Estimate Differences and Ratios)

Job Type	Location 1	Location 2	Estimate (Log. Scale)	StdErr of Estimate (Log. Scale)	Ratio	95% Confidence Interval on the Ratio	
						Lower	Upper
Door Replacement	Near	On	-0.88	0.92	0.41	0.07	2.58
	Near	Under	6.03	0.92	416.95	66.92	2598.06
	On	Under	6.91	0.92	1006.52	161.53	6271.66
Trim Soffit Replacement	Near	On	0.32	0.92	1.37	0.22	8.54
	Near	Under	4.54	0.92	94.03	15.09	585.93
	On	Under	4.23	0.92	68.63	11.01	427.62
Needle Gun	Near	On	-0.19	1.30	0.82	0.06	10.94
	Near	Under	3.16	1.30	23.56	1.77	313.20
	On	Under	3.35	1.30	28.62	2.15	380.44
Heat gun under 1100 degrees	Near	On	0.01	1.30	1.01	0.08	13.48
	Near	Under	2.49	1.30	12.05	0.91	160.24
	On	Under	2.48	1.30	11.88	0.89	158.01
Dry Scrape	Near	On	-2.25	0.65	0.11	0.03	0.38
	Near	Under	2.65	0.65	14.21	3.90	51.80
	On	Under	4.90	0.65	134.58	36.91	490.70
Power Sanding	Near	On	-1.26	0.92	0.28	0.05	1.77
	Near	Under	1.86	0.92	6.46	1.04	40.22
	On	Under	3.12	0.92	22.75	3.65	141.77
Torching	Near	On	-2.55	0.92	0.08	0.01	0.49
	Near	Under	-3.00	0.92	0.05	0.01	0.31
	On	Under	-0.45	0.92	0.64	0.10	3.96
Heat gun over 1100 degrees	Near	On	-2.70	1.30	0.07	0.01	0.89
	Near	Under	1.14	1.30	3.11	0.23	41.37
	On	Under	3.84	1.30	46.35	3.49	616.23

The results in Table 7-13, which include the bulk debris samples, report that O:U ratios range from 66:1 to 2,291:1 with the power sanding the torch burning jobs having the lowest lower confidence interval bounds at 12:1 and 6:1, respectively. Generally, this indicates that only a small percentage of the lead levels that landed on top of the Rule plastic were measured underneath the plastic. Note that the 95% confidence bounds are very wide because of the relatively small number of samples available for each job. The N:O ratios are less than 0.2:1 across all jobs, although the upper confidence bound on the door replacement and trim/soffit replacement jobs exceeded 1:1.

Because the impact of excluding the bulk debris samples was to significantly lower the amounts of lead measured on top of the Rule plastic, the results in Table 7-14 differ somewhat from those in Table 7-13. The estimated O:U ratio of the torch burning job is below 1:1, as over 99 percent of the on Rule plastic samples were comprised of the bulk debris. The O:U ratios for the other jobs declined, but the lowest predicted ratio other than the torch burning was 12:1 for the heat gun job below 1100 degrees. Similarly, the lower 95% confidence bounds decreased with the torch burning and heat gun <1100 degrees below 1:1. The N:O ratios increased with the decline in the lead levels on the Rule plastic causing two jobs exceed 1:1 – the trim/soffit replacement and the heat gun under 1100 degrees. The upper confidence bounds on five jobs exceeds 1:1 with the exclusion of the bulk debris samples.

Note that the lead levels measured near the Rule plastic are somewhat impacted by the amount of Rule plastic that could be used for a job given the property constraints. Both door replacement jobs only had seven or eight feet of space between the door being worked on and a fence, which limited the size of the Rule plastic that could be used. Similarly, one of the trim/soffit replacement jobs had about the same distance between the porch being worked on and a neighboring fence. For that job especially, which occurred on components about 10 feet off the ground, in a real-world situation more rule plastic would be used than was used in the experiment.

8. Quality Assurance and Quality Control Results

8.1. Field Audit Results

8.1.1. Site Selection Audit

The Battelle Quality Assurance officer conducted audits of the X-ray fluorescence (XRF) measurement procedure and the methodology for collection of paint chip samples on September 11, 2006, and October 24, 2006, respectively. Both audits were performed by observing actual work done in the field. The procedures as performed by the study technicians, including Battelle staff and subcontractors, followed those outlined in the Site Selection QAPP. Only minor suggestions, usually concerning documentation, were offered to the field staff, who immediately implemented the corrective actions as appropriate.

8.1.2. Field Implementation

The Battelle Quality Assurance officer conducted three on-site field audits of renovation work and related environmental sampling. The first audit was of an exterior paint removal job in Columbus on October 19, 2006. Observed was the construction of the containment structure, use of personal protective equipment (PPE), manual paint removal, and sampling by collection of dust and paint chips accumulated on the dust collection trays, followed by subsequent take down of the containment structure. The procedures as performed by the field crew, including Battelle staff and subcontractors, followed those outlined in the Full Study QAPP. Personnel for the on-site RRP contractor were reminded that they must use the appropriate PPE, and they complied immediately; however, no major deficiencies were identified.

An on-site audit of an interior window removal job (Phase III) in Columbus was performed on October 20, 2006. The Battelle auditor observed, among other tasks, removal and replacement of the window, personal and area air sampling, rule cleaning using HEPA vacuums followed by wet mopping, and cleaning verification. Specifically inspected was the method of dust wipe collection in the work, tool, and observation rooms. It was confirmed that the study technicians were following ASTM guidelines to properly collect wipe samples by using a proper "S" pattern and using as much of the wipe surface area as possible in order to maximize dust collection efficiency. The procedures as performed by the field crew, including Battelle staff and subcontractors, followed those outlined in the Full Study QAPP.

A third on-site audit was conducted in Pittsburgh during an interior kitchen gutting (Phase II) on November 6, 2006. Essentially the same activities were observed as for the on-site field audit in Columbus on October 19, 2006, for the window removal job. Specifically inspected was the method of dust wipe collection in the work, tool, and observation rooms. It was confirmed that the study technicians were following ASTM guidelines to properly collect wipe samples. In general, the procedures as performed by the field crew, including Battelle staff and subcontractors, followed those outlined in the Full Study QAPP.

During all three field audits, no major deficiencies were identified; only minor suggestions, usually concerning documentation, were offered to the field staff, who immediately implemented corrective actions as appropriate.

8.1.3. EPA Site Visits

EPA staff made four separate visits to observe the field work in the study, and provided written and oral reports to the Principal Investigator on their observations. The Principal Investigator reviewed the observations in these reports and responded promptly to any concerns.

8.2. Laboratory Audit Results

The Battelle Quality Assurance officer conducted an on-site, day-long inspection of the analytical laboratory, Schneider Laboratories, Incorporated (SLI), in Richmond, VA, on November 13, 2006. Reviewed were: all pertinent documentation, the lab's organization and project staff responsibilities, elements of Quality Assurance and Quality Control, the staff training program, lab safety, document control, as well as a general review of the lab facilities, equipment, and software. In addition, a thorough review was performed of the procedures employed to prepare and analyze samples. During the course of the audit, no significant issues were identified that required follow-up by the Battelle Quality Assurance officer. A formal audit report was prepared and forwarded to Schneider staff and to project leaders.

8.3. QC Sample Results, Issues, and Resolutions

In general, the results of the analysis of the quality control (QC) samples revealed not only that field staff were handling samples appropriately, but also that the results from the contract analytical laboratory, Schneider Laboratories, Inc., (SLI) were accurate and reproducible.

A number of different external QC samples were prepared. Blank wipes were prepared by field technicians who donned clean gloves, opened the wipe packet, and placed the unused wipe into a clean, prelabeled sample vial. Blank air cassettes were flow checked by passing a nominal amount of air through them (no more than approximately 6 L), then were capped and labeled. Spiked wipes and air cassettes were prepared by the Department of Environmental Services (DES) at the University of Cincinnati using National Institutes of Standards and Technology (NIST) Standard Reference Materials. The spikes were then inserted into the sample stream as blind performance evaluation samples to verify the integrity of the analytical results provided by SLI.

Table 8-1 contains the results from analyzing the external quality control samples.
As seen in Table 8-1, for both the spiked wipes and air cassette blanks, more than 95% of the external QC samples came back within the desired tolerance. Approximately 91% of the blank wipes showed values less than the laboratory's reporting limit (10 μg lead), and over 95% of the blank wipes had lead amounts less than 20 μg.

Table 8-1. Summary of External QC Results

Media	QC Type	Total Number	Acceptable Tolerance	Percent Within Tolerance	Number Out Of Tolerance	Percent Out Of Tolerance
Wipe	Spike	117	Bias < 20%	95.7	5	4.3
Wipe	Blank	113	Amount < RL[†]	91.2	10	8.8
Air	Spike	46	Bias < 20%	82.6	8	17.4
Air	Blank	66	Amount < RL	97.0	2	3.0
[†]RL = reporting limit; for wipes, 10 μg lead; for air cassettes, 2 μg lead						

A total of eight of the spiked air cassettes were recovered beyond the acceptable bias range of 20%; of these, four consecutively numbered samples (as labeled by UC DES) showed lead levels less than the reporting limit of 2 μg. DES was contacted and the most likely explanation was an error by the preparation laboratory - that blank cassettes were inadvertently mistaken for spiked cassettes. Excluding these four samples, 90% (42 of 46) of the external QC air cassettes demonstrated acceptable recoveries.

In all cases in which the laboratory measured external QC samples outside the acceptable tolerance ranges, it was requested that samples be reanalyzed in order to confirm the original results. In all cases, the initial results were confirmed upon repeat analysis.

An analysis of laboratory's internal quality control data is shown in Table 8-2. These results indicate that the laboratory's internal QC procedures were adequate and, except for the matrix spike, met the study's QC requirements.

Table 8-2. Schneider Laboratories Quality Control Data

Schneider Laboratories QC Type	Number of Samples	QC Tolerance	# Out of Tolerance	% Out of Tolerance
Reagent Blank	908	< RL[a]	0	0
Wipe Blank	248	< RL	0	0
Soil Blank	61	< RL	0	0
Paint Blank	72	< RL	0	0
Air Filter Blank	74	< RL	0	0
Paint Control Sample	74	Bias < 20%	0	0
Wipe Control Sample	248	Bias < 20%	0	0
Soil Control Sample	61	Bias < 20%	0	0
Air Filter Control Sample	148	Bias < 20%	0	0
Calibration Verification	904	Bias < 15%	0	0
Duplicates	133	RPD[b] < 25%	6	4.5%
Replicates	454	RPD[b] < 25%	0	0

[a]RL = Reporting Limit ; for most analyses, RL = 10 μg; for air, RL = 2 μg
[b]Relative percent deviation: $RPD = |x_1-x_2|/[(x_1+x_2)/2]*100\%$

Duplicate and replicate tolerances were calculated as relative percent deviation (RPD). A replicate analysis is one in which the sample extract is analyzed twice and is a measure of the repeatability of a measurement (instrument reproducibility). This is substantially different from a duplicate analysis in which a given sample is homogenized and split into two subsamples. Duplicate samples could only be prepared for matrices that could be subsampled, i.e., only for paint chip and soil samples. Results from duplicate analyses provide a measure of the reproducibility of the sample handling and extraction procedures, superimposed onto any instrumental variability. Approximately 13% of the replicate analyses showed lead concentrations below the applicable reporting limit. In all cases, both sample and replicate values were below the applicable reporting limit; as such, all were within tolerance.

Matrix spikes are prepared in a manner similar to a duplicate sample, with the exception that one of the subsamples was subsequently spiked with 200 µg of lead. In most cases, a sample to be prepared for duplicate analysis was also used for the matrix spike; thus a total of three subsamples were collected: one for the primary sample, one for the duplicate, and one for the matrix spike. The spike amount of 200 µg of lead, however, was generally only a small fraction of the total lead concentration in the samples. Thus, small variations in the amount of lead in the samples, due primarily to the heterogeneity of paint and soil samples, resulted in matrix spike recoveries generally outside of the specified tolerance. For example, one particular paint chip sample extract was found to contain 124,206 µg of lead and its duplicate sample showed 139,579 µg lead (RPD = 11.7 %). The matrix spike should have had 124,406 µg of lead, but instead 130,495 µg was found, which calculates to a spike recovery of (130,495 – 124,206 µg)/200 µg * 100% = 3,144%. Given the relatively low spike amount, the ordinary variation between duplicate subsamples resulted in poor spike recoveries.

8.4. Data Audit Process and Results

Battelle's Quality Assurance officer traced approximately 2% of the data (169 field and QC samples) acquired during the field study and subsequent laboratory analyses from the initial acquisition, through data reduction and statistical analysis to ensure the integrity of the results. All calculations performed on these data were verified as correct. Comments that stemmed from the data audit are listed below.

- The need for recording actual batch IDs for environmental samples in the database was identified, in order to allow linking of QC results to samples in a given batch. If necessary, environmental data associated with out-of-tolerance QC samples could be flagged as potentially suspect.
- Field blank and field spike samples were included in the database table containing all the environmental data. It seemed appropriate to move those data to the table containing QA/QC samples.

8.5. Software Reviews

EPA prepared test data sets of interior and exterior data that were processed using the descriptive and statistical summary programs used to summarize the study data. EPA reviewed the output resulting from the analysis of the test data sets and determined that the analytical programs performed as expected.

9.0 Conclusions

9.1. Results for the Proposed Rule Package versus the Baseline Package

Interior

Application of the package of plastic protective sheeting, HEPA vacuuming and wet mopping, and cleaning verification practices in EPA's proposed rule did result in lower lead levels at the end of a job than were achieved using baseline practices (no plastic protective sheeting and cleaning with broom and a shop-vacuum vacuum). Descriptive analyses in Section 6 of this report display the lower geometric mean levels achieved consistently across jobs on work room floors and sills (see Figures 9-1 and 9-2). Statistical modeling presented in Section 7 confirms a statistically significant difference between proposed rule and baseline practices for work room floors. The associated hypothesis test had a p-value <.01 from models that compared proposed rule practices to baseline practices adjusting for job type and the interaction between job type and use of rule practices for housing units only and for all units combined. The difference between the proposed rule practices and baseline practices was significant (p-value=<.01) for window sills in the Work room, using the combined housing unit and COF data and adjusting for job type and COF. This comparison was also significant using only the residential data (p-value =.02) and adjusting for job type.

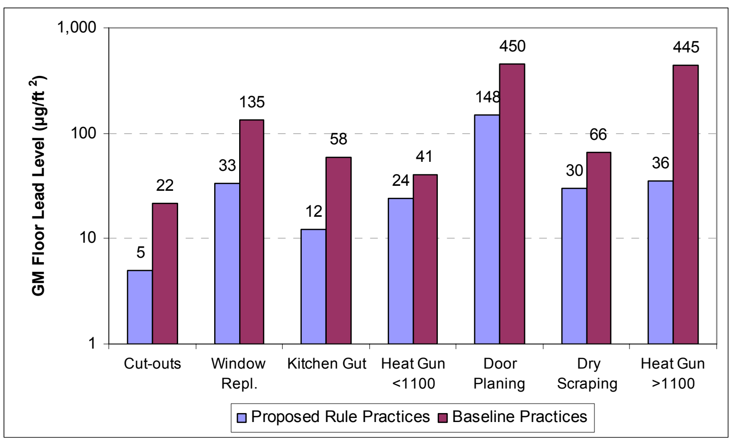

Figure 9-1. Post-Job Work Room Floor Lead Levels, By Job And Rule Use

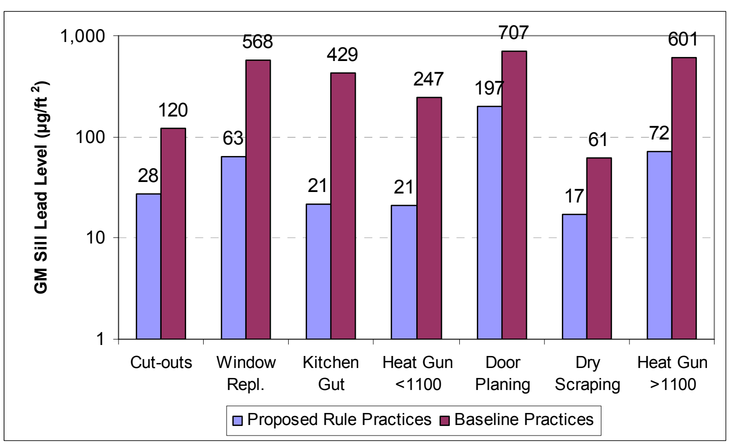

Figure 9-2. Post-Job Work Room Sill Lead Levels, By Job And Rule Use

For the Tool and Observation room floors, differences between the rule package and baseline package were smaller, not consistent across all jobs, and not statistically significant. Figures 6-6 and 6-7 display smaller and non-uniform differences between use of proposed rule practices and baseline practices in the two non-work rooms for floors, with the rule package being lower than the baseline package in five of seven jobs in each room. For some jobs, Tool and Observation room geometric mean floor lead levels at the end of a job were above the EPA standard, even when the rule package was followed. Application of the same statistical model applied to the Work room achieved a non-significant p-value of .17 in the Tool room and .14 in the Observation room for the difference between rule and baseline practices when looking just at housing units. These p-values were even higher with the combined housing unit and COF data. Figures 6-12 and 6-13 display post-job geometric mean lead levels on window sills in the Tool and Observation Rooms, respectively. The differences between rule and baseline practices were non-uniform. Rule practices had lower levels than baseline practices in five of the seven job types for the Tool room, and for four of the seven job types in the Observation room. In the Tool room, the difference between proposed rule practices and baseline practices was borderline significant for window sills (p-value=.06 combined, p-value=.09 housing units only) adjusting for job type and COF. In the Observation room, the difference between proposed rule practices and baseline practices was not significant for window sills (p-value=.32 combined, p-value=.23 housing units only) in models accounting for job type and COF in the combined model and job type in the housing units only model. Tool and Observation room geometric mean sill lead levels were below the EPA standard for all job types except door planing.

While the rule package resulted in lower lead levels than the baseline package in the work room, the final lead levels measured under the rule package were not always lower than the EPA standards. Table 9-1 and Table 9-2, for floors and sills respectively, show the arithmetic mean post-job lead levels and average number of samples above the EPA standard by job type and study phase. The post-job results displayed include post-verification results for phases with rule cleaning and post-cleaning results for phases with baseline cleaning. The arithmetic average post-job floor lead level over all samples collected in the work room for Phase I (plastic and rule cleaning) is less than 40 $\mu g/ft^2$ for all job types except Door Planing and Heat Gun >1100 Degrees. The average number of samples above or equal to 40 $\mu g/ft^2$ was two or less out of four in five of the seven job types. The arithmetic average post-job window sill lead level over all samples collected in the work room for Phase I is less than 250 $\mu g/ft^2$ for all job types except Door Planing and Heat Gun >1100 Degrees, with the latter job just beyond that clearance standard at 278 $\mu g/ft^2$. Consistent with this result is that no post-job sill samples above 250 $\mu g/ft^2$ were collected in Phase I except in the Door Planing and High Heat Gun jobs.

Table 9-1. Post-job* Average Floor Lead Levels and Failed Samples by Job Type

Job Type	Phase	# of Exp.	Post-Job* Average Lead Level ($\mu g/ft^2$)	Post-Job* Average # of Samples > 40 ($\mu g/ft^2$)
Cut-outs	I (plastic/rule)	3	5.0	0.0
	II (plastic/baseline)	3	9.1	0.0
	III (no plastic/rule)	3	9.9	0.0
	IV (no plastic/baseline)	3	37.3	1.3
Window Replacement	I (plastic/rule)	2	35.7	2.0
	II (plastic/baseline)	2	140.2	4.0
	III (no plastic/rule)	2	87.2	3.0
	IV (no plastic/baseline)	2	146.2	4.0
Dry Scrape	I (plastic/rule)	2	34.2	1.5
	II (plastic/baseline)	2	168.3	3.5
	III (no plastic/rule)	2	14.4	0.0
	IV (no plastic/baseline)	2	70.7	3.5
Door Plane	I (plastic/rule)	2	188.9	4.0
	II (plastic/baseline)	2	142.3	3.5
	III (no plastic/rule)	2	651.8	4.0
	IV (no plastic/baseline)	2	771.9	4.0
Heat Gun<1100 Degrees	I (plastic/rule)	1	29.1	2.0
	II (plastic/baseline)	1	25.6	1.0
	III (no plastic/rule)	1	7.5	0.0
	IV (no plastic/baseline)	1	44.2	2.0
Kitchen Gut	I (plastic/rule)	2	23.7	1.0
	II (plastic/baseline)	2	58.6	2.5
	III (no plastic/rule)	2	50.9	0.5
	IV (no plastic/baseline)	2	82.2	3.0
Heat Gun>1100 Degrees	I (plastic/rule)	3	72.7	2.7
	II (plastic/baseline)	3	506.8	3.0
	III (no plastic/rule)	3	1,019.2	2.3
	IV (no plastic/baseline)	3	1,617.8	3.0

* Post-job refers to the post-verification values for phases that involve the rule cleaning method (I and III) and the post-cleaning values for phases that involve the baseline cleaning method (II and IV).

Table 9-2. Post-job* Window Sill Average Lead Levels and Failed Samples by Job Type.

Job Type	Phase	# of Exp.	Post-Job* Average Lead Level (µg/ft^2)	Post-Job* Average # of Samples > 250 (µg/ft^2)
Cut-outs	I (plastic/rule)	3	30.3	0.0
	II (plastic/baseline)	3	58.7	0.0
	III (no plastic/rule)	3	70.0	0.0
	IV (no plastic/baseline)	3	212.0	0.3
Window Replacement	I (plastic/rule)	2	99.4	0.0
	II (plastic/baseline)	2	359.4	0.5
	III (no plastic/rule)	2	150.8	0.5
	IV (no plastic/baseline)	2	598.2	1.0
Dry Scrape	I (plastic/rule)	2	31.3	0.0
	II (plastic/baseline)	2	246.0	0.5
	III (no plastic/rule)	2	24.5	0.0
	IV (no plastic/baseline)	2	87.9	0.0
Door Plane	I (plastic/rule)	2	865.3	0.5
	II (plastic/baseline)	2	202.9	0.5
	III (no plastic/rule)	2	1,714.1	0.5
	IV (no plastic/baseline)	2	1,038.3	1.0
Heat Gun <1100 Degrees	I (plastic/rule)	1	20.8	0.0
	II (plastic/baseline)	1	285.1	1.0
	III (no plastic/rule)	1	n/a	1.0
	IV (no plastic/baseline)	1	246.8	0.0
Kitchen Gut	I (plastic/rule)	2	21.4	0.0
	II (plastic/baseline)	2	41.7	0.0
	III (no plastic/rule)	2	82.3	0.0
	IV (no plastic/baseline)	2	772.3	0.5
Heat Gun >1100 Degrees	I (plastic/rule)	3	277.9	0.3
	II (plastic/baseline)	3	3,087.6	0.7
	III (no plastic/rule)	3	904.4	0.3
	IV (no plastic/baseline)	3	1,048.1	0.7

* Post-job refers to the post-verification values for phases that involve the rule cleaning method (I and III) and the post-cleaning values for phases that involve the baseline cleaning method (II and IV).

Exterior

The use of plastic as a ground covering during exterior jobs captured large amounts of leaded dust. Figure 6-14 and Figure 6-15 compare the amount of lead on top of the rule plastic to the amount under the rule plastic, with Figure 6-14 including bulk debris samples and Figure 6-15 excluding the bulk debris samples. For most job types, there is a substantial difference between the amount of lead captured by the rule plastic and the amount under the rule plastic. One notable special case is Torching. Without the bulk debris samples, the amount of lead under the plastic for Torching exceeded the amount on top. For all 8 job types, the ratio of the amount of lead on top of the rule plastic to the amount underneath was statistically significant when bulk debris samples were included. This changed to 6 out of the 8 job types when bulk debris samples were excluded.

For some job types, substantial amounts of lead were measured in collection trays just outside the rule plastic. The job types for which substantial amounts of lead were measured just outside the rule plastic were trim/soffit replacement, power sanding, and door replacement.

9.2. Results for Use of Plastic Protective Sheeting on Floors and Doorways versus Non-Use of Plastic Protective Sheeting

Figure 6-3 indicates that use of plastic did not consistently result in lower geometric mean work room floor lead levels across job types at the post-cleaning phase. The use of plastic sheeting, however, did lower geometric means for door planing and high heat gun jobs as measured at the post-cleaning phase. Similar results are found with window sills, as seen in Figure 6-8. Modeling and hypothesis testing of the effect of plastic on lead levels on floors in the Work room was not statistically significant at either the post-cleaning (p-value = .15) or post-verification stages (p-value = .10) for housing units when adjusted for job and interactions with job type. For window sills, statistical modeling and hypothesis testing also showed that the use of plastic was not statistically significant at either the post-cleaning for housing units. Using the combined housing unit and COF data, similar results were obtained.

Conclusions about protective plastic are different when considering other parts of a house or building. Figure/Table C2.6b and C2.6c reported consistently lower geometric mean floor lead levels in the Tool and Observation rooms, respectively, with the use of plastic across all three sampling stages – although the differences were relatively small. For example, Tool room floor geometric mean lead levels were 41, 43, and 39 $\mu g/ft^2$ across post-work, post-cleaning, and post-verification stages with plastic compared to 57, 61, and 79 $\mu g/ft^2$ without plastic; Observation room geometric mean levels were 18, 17, and 22 $\mu g/ft^2$ with plastic compared to 30, 38, and 31 $\mu g/ft^2$ without plastic.

When modeling the Tool room floor levels, use of plastic was not significant at the post-work stage (p-value=.20, combined data) adjusting for job type and was not significant at the post-cleaning stage (p-value=.52, combined data) adjusting for job type and interactions with job type. At the post-verification stage, use of plastic was borderline significant using the combined data (p-value=.09, adjusted for job type) and significant (p-value=.03, adjusted for job type and post-work lead levels) using only the housing unit data.

Findings for the Observation room floor levels differ somewhat depending on whether COF data are included in the analysis. For residential units only, modeling Observation room levels resulted in significantly lower levels when using plastic at all three stages with p-values of .02 at post-work (adjusted for job type) and <.01 at post-cleaning and post-verification (adjusted for job type and interactions with job type). When analyzing the combined data, the model predicts lower levels using plastic but the difference is borderline significant (p-value =.10) at the post-work stage; significant at the post-cleaning stage (p-value=.01) when adjusted for job type and average post-work work room floor lead; and not significant at post-verification (p-value=.34) using that same model.

The statistical modeling did not find that the use of plastic significantly impacted sill lead levels in the Tool room at any of the three sampling stages. There is evidence, however, when analyzing the residential data of use of plastic leading to lower sill lead levels in the Observation room at post-cleaning (p-value =.03) and post-verification (p-value =.02) when adjusting for job type or post-work work room floor lead levels.

9.3. Results for Rule Cleaning with HEPA Vacuum and Wet Mopping with Cleaning Solution versus Baseline Cleaning

The data do provide evidence that the proposed rule cleaning method of HEPA vacuuming followed by wet mopping with a cleaning solution yielded lower lead levels than the baseline cleaning method. Analyzing differences in cleaning method is focused on the Work room, as little impact of cleaning method was observed in either of the two non-work rooms. Table C2.7a reports GM post-cleaning floor lead across all jobs of 34 $\mu g/ft^2$ for the Rule cleaning and 75 $\mu g/ft^2$ for the baseline cleaning. Figure 6-4, which plots post-cleaning GM floor lead levels by job and cleaning method, reports lower levels across all job types except door planing. Figure 6-9 shows similar results for window sills. The statistical models verify these trends, reporting significantly lower post-cleaning floor lead levels after rule cleaning (p-value <.01). No significant difference is found between cleaning methods for floors at the post-verification stage. It should be noted that any cleaning verification failures after baseline cleaning led to recleanings by rule cleaning method in this study. Significantly lower work room window sill lead levels are also found at the post-cleaning (p-value<.01) stages following rule cleaning. Similar to floor lead levels, however, no significant difference based on cleaning method is found at the post-verification stage.

9.4. Results for Cleaning Verification

The cleaning verification process as stated in the proposed rule resulted in decreases in lead levels, but under the conditions of the study was not always accurate in identifying the presence of levels above EPA standards for floors and sills. Factors such as floor condition, contractor performance, job type, and dust particle characteristics impacted the cleaning verification process in the study. All interior experiments did result in final passed cleaning cloths for all floor zones and for all window sills, but nearly half of the experiments ended with average Work room floor lead levels above 40 $\mu g/ft^2$ on floors. Lead levels for the cases above the floor standard were distributed as follows: 10 between 40 and 69, 6 between 70 and 99, 5 between 100 and 199, 3 between 200 and 499, and 5 greater than 500. The eight highest levels were associated with high heat gun or door planing jobs and floors in poor condition. Of the 29 experiments where final lead levels were above 40 $\mu g/ft^2$ on floors, 20 were on floors in poor condition. Excluding the door planing and high heat gun jobs, which had higher post-job lead levels than the others and which appeared to generate fine particle size dust and, in the case of the door planing, a white dust that was hard to detect on a white cloth, post-job averages when the proposed rule cleaning was used were below clearance levels. For window sills, approximately 20 percent of the experiments ended with lead levels above 250 $\mu g/ft^2$. Almost all of the high levels, well above the standard, were associated with door plane and high temperature heat gun jobs. The study did not yield much evidence to evaluate differences in lead levels after the wet and dry cleaning verification steps because the dry cleaning verification was only required in three experiments.

Table 9-3 summarizes the arithmetic average post-verification lead levels and number of samples > 40 µg/ft^2 for rule cleaning phases and post-cleaning lead levels and number of samples > 40 µg/ft^2 for baseline cleaning phases. Note that for Phases II and IV, which included baseline cleaning, any recleanings required were done by rule cleaning methods. Within the no plastic/rule cleaning phase, experiment 32 achieved an average post-verification floor lead level of 2,976 µg/ft^2. If that experiment were excluded, the average post-verification floor lead level for phase III would become 123.4 µg/ft^2. Factors such as contractor, floor condition, and floor type impacted the performance of the cleaning verification process. One contractor obtained higher post-verification lead levels than the others due in part to this contractor being more willing to pass a verification cloth.

Table 9-3. Post-job Floor Lead Levels and Number of Samples Failing Clearance

	RULE CLEANING - Post Verification		BASELINE CLEANING - Post Cleaning	
Phase	**I - Plastic**	**III - No plastic**	**II - Plastic**	**IV - No plastic**
Average Lead Level (µg/ft^2)	55.1	313.5*	172.8	305.9
Average # of Dust Wipes > 40 µg/ft^2	1.8	1.4	2.5	2.9

* Excluding Experiment 32, which had a very high post-verification floor level, the average lead level is 123.4 µg/ft^2

The door planing and high heat gun jobs resulted in the highest post-job lead levels. Table 9-4 summarizes post-job floor lead levels with these two jobs excluded. Significantly lower levels than those presented in Table 9-3 were achieved with these two jobs excluded. Without the two jobs, the post-verification averages for the rule cleaning phases are below clearance, while the baseline cleaning post-cleaning averages are between 75 and 80 µg/ft^2. For comparison, Table 9-5 presents the summary data for only these two jobs, which generated a lot of fine dust. The distribution across the four P/CU phases is different for these two jobs, with the combination of use of plastic and baseline cleaning associated with lower post-job levels than no plastic and baseline cleaning. Again, one very high post-verification value (2,976.1) from a Phase III heat gun job impacts that average significantly. With that sample excluded, the post-verification average for phase III for door planes and heat guns becomes 346.2 µg/ft^2.

Table 9-4. Post-job Floor Lead Levels and Number of Samples Failing Clearance (excluding Door Planing and High Heat Gun)

	RULE CLEANING - Post Verification		BASELINE CLEANING - Post Cleaning	
Phase	**I - Plastic**	**III - No plastic**	**II – Plastic**	**IV - No plastic**
Average Lead Level (µg/ft^2)	23.1	34.2	78.7	75.5
Average # of Dust Wipes > 40 µg/ft^2	1.1	0.6	2.1	2.7

Table 9-5. Post-job Floor Lead Levels and Number of Samples Failing Clearance (Door Planing and High Heat Gun Jobs Only)

	RULE CLEANING - Post Verification		BASELINE CLEANING - Post Cleaning	
Phase	I - Plastic	III - No plastic	II – Plastic	IV - No plastic
Average Lead Level ($\mu g/ft^2$)	119.2	872.2	361.0	1,279.4
Average # of Dust Wipes > 40 $\mu g/ft^2$	3.2	3.0	3.2	3.4

Similar to the post-job floor levels and number of samples above the clearance standard, Table 9-6 summarizes the average post-verification lead levels and number of samples > 250 $\mu g/ft^2$ for rule cleaning phases and post-cleaning lead levels and number of samples > 250 $\mu g/ft^2$ for baseline cleaning phases. Overall, the two phases involving rule cleaning resulted in lower post-job window sill lead levels than the two phases involving baseline cleaning.

Table 9-6. Post-job Window Sill Lead Levels and Number of Samples Failing Clearance

	RULE CLEANING - Post Verification		BASELINE CLEANING - Post Cleaning	
Phase	I - Plastic	III - No plastic	II - Plastic	IV - No plastic
Average Lead Level ($\mu g/ft^2$)	198.7	490.5	761.6	601.4
Average # of Dust Wipes > 250 $\mu g/ft^2$	0.1	0.4	0.3	0.5

Due to the configuration of the study rooms and above clearance pre-work lead levels, dust collection trays were substituted for window sills in the Work Room for half (30) of the interior experiments. Tables 9-7 and 9-8 show the comparison of post-job lead levels and number of failures by cleaning method for sampled window sills and dust collection trays, respectively. The average lead level across the phases appears to be lower when sills were sampled, however, 16 out of 20 door plane and heat gun experiments, noted above as having the most dust generated, were completed with dust collection trays serving as window sills.

Table 9-7. Post-job Window Sill Lead Levels and Number of Samples Failing Clearance for Sampled Window Sills

	RULE CLEANING - Post Verification		BASELINE CLEANING - Post Cleaning	
Phase	I - Plastic	III - No plastic	II - Plastic	IV - No plastic
Average Lead Level ($\mu g/ft^2$)	293.4	101.3	190.5	663.2
Average # of Dust Wipes > 250 $\mu g/ft^2$	0.1	0.3	0.1	0.6

Table 9-8. Post-job Window Sill Lead Levels and Number of Samples Failing Clearance for Sampled Dust Collection Trays.

	RULE CLEANING - Post Verification		BASELINE CLEANING - Post Cleaning	
Phase	**I - Plastic**	**III - No plastic**	**II - Plastic**	**IV - No plastic**
Average Lead Level (µg/ft^2)	115.7	879.7	1,414.3	530.7
Average # of Dust Wipes > 250 µg/ft^2	0.1	0.6	0.4	0.4