ANALYSIS OF LEAD-SAFE WEATHERIZATION PRACTICES AND THE PRESENCE OF LEAD IN WEATHERIZED HOMES

FINAL REPORT

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
CAGI	Community Action of Greater Indianapolis
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GM	Geometric Mean
GSD	Geometric Standard Deviation
HEPA	High Efficiency Particulate Air
HHS	U.S. Department of Health and Human Services
HUD	U.S. Department of Housing and Urban Development
IN	Indiana
IRB	Institutional Review Board
LBP	Lead-Based Paint
MD	Maryland
$\mu g/dL$	Micrograms per Deciliter
$\mu g/ft^2$	Micrograms per Square Foot
mg/cm^2	Milligrams per Square Centimeter
NA	Not Applicable
NAS	National Academy of Science
NCHH	National Center for Healthy Housing
NLLAP	National Lead Laboratory Accreditation Program
ORNL	Oak Ridge National Laboratory
QAP	Quality Assurance Plan
QA/QC	Quality Assurance/Quality Control
RI	Rhode Island
Sq ft	Square Foot
UT	University of Tennessee
WAP	Weatherization Assistance Program
XRF	X-Ray Fluorescence

ANALYSIS OF LEAD-SAFE WEATHERIZATION PRACTICES AND THE PRESENCE OF LEAD IN WEATHERIZED HOMES

REPORT (RESPONSE TO PEER REVIEW)

ES. EXECUTIVE SUMMARY

ES.1 Overview of Study Design

The National Center for Healthy Housing (NCHH), with funding from the U.S. Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL) and support from Battelle, partnered with state weatherization programs in Rhode Island (RI) and Maryland (MD) and with local agencies in Indianapolis, Indiana (IN) to conduct a study of the effect of weatherization activities on levels of lead in settled dust in homes.

The study was divided into two smaller studies:

1. A study of dust-lead *creation* during four paint-disturbing activities (cutting holes in knee walls and ceilings to gain access to attics, repairing windows, replacing windows, and planing thresholds/installing weatherstripping on doors); and
2. A study of dust-lead *dispersion* during two activities (blower door tests and dense-packing of walls).

The Oak Ridge Institutional Review Board (IRB) determined that this project did not require formal IRB approval. To be eligible for the study, dwellings had to be built before 1950, have one or more target weatherization activities planned, one or more painted windows and/or doors, and no children with elevated blood lead levels (above 15 micrograms per deciliter (µg/dL)) residing in the dwelling. Before studying any target activity, paint on components to be disturbed and studied was tested for lead using a portable x-ray fluorescence (XRF) instrument. Only houses which had lead-based paint at 1.0 milligram per square centimeter (mg/cm^2) or greater on one or more study-specified surfaces were eligible.

To the extent possible, weatherization activities were conducted as they routinely would have been in the absence of the research study, and residents were not required to vacate homes during weatherization work or study data collection. For the dust-lead creation study, dust wipe samples were collected on floors at four stages: before worksite preparation (Stage 1), after the work but before removal of containment[1] (Stage 2), after removal of containment (Stage 3), and after final cleanup (Stage 4). For two of the four dust creation activities (window repair and window replacement), dust samples from window sills and troughs were also collected before and after the activities were completed. For the dust dispersion study, dust wipe samples were taken from specified surfaces (e.g., floors and sills) before the dust dispersion activity and, after the activity was completed, from sheeting placed over each sample location. All samples were analyzed for total lead by a laboratory participating in the U.S. Environmental Protection Agency's (EPA) National Lead Laboratory Accreditation Program (NLLAP).

A total of 58 dwellings were successfully enrolled. All enrolled dwellings had at least one tested component with lead-based paint (i.e., lead loading greater than or equal to 1 mg/cm^2). Window components were the largest subset containing lead-based paint.

[1] Containment is plastic sheeting placed horizontally on floors. Plastic sheeting containment is also placed vertically around work locations when areas potentially containing lead-based paint will be disturbed.

The dust lead loadings set by EPA for abatement clearance with single-surface settled dust wipe samples at 40 Code of Federal Regulations (CFR) 745.227(e)(8)(viii) (EPA 2006) were considered to be the relevant comparison values for sample results in this report. These comparison values were 40 micrograms per square foot (µg/ft^2) for floors, 250 µg/ft^2 for window sills, and 400 µg/ft^2 for window troughs. Compliance with EPA clearance standards is not technically required in weatherization work. Standards are presented in this report for comparison purposes only.

ES.2 Dust Creation Results

ES.2.1 Dust Creation Floor Results

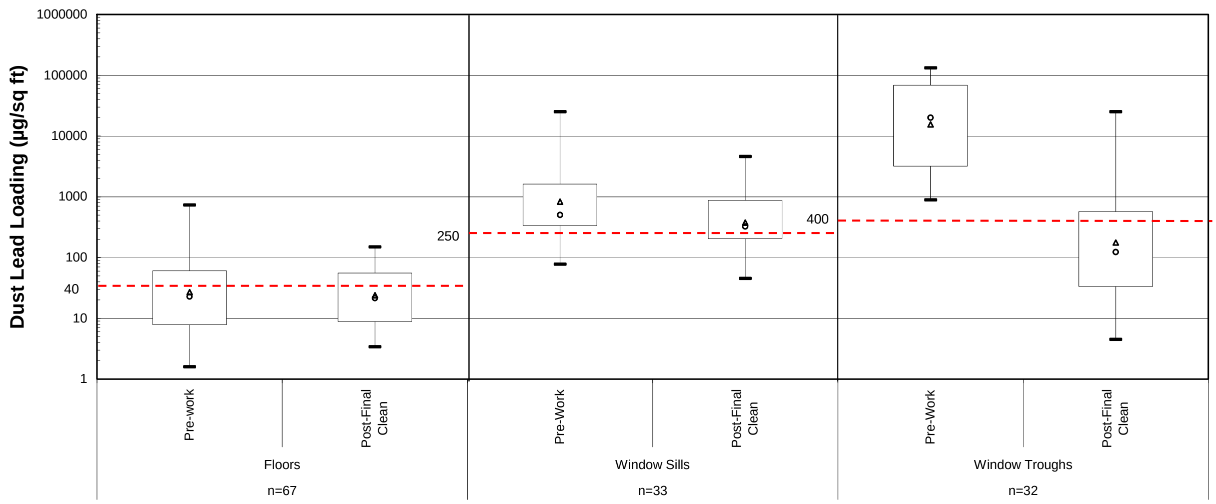
As shown in Table ES-1 and Figure ES-1, floor dust lead loadings that were measured before work began (Stage 1) and after final cleaning was finished (Stage 4) were similar to each other, and were lower than those measured on sheeting at Stages 2 and 3. The highest floor lead loadings were found on sheeting after the work was done but before workers cleaned up the area (Stage 2), due to the amount of lead dust deposited on top of the containment by the work. Geometric mean (GM) floor dust lead loadings measured after final cleaning was done were not significantly different from those measured before work began. Data analysis showed that the higher the dust lead loadings remaining on floors after containment was removed but before cleanup is performed, the higher the post-final cleaning floor dust lead loadings.

Table ES-1: GM (GSD)[a] Dust Lead Loadings (µg/ft^2) Associated with Dust Creation Activities

	Floors (sample size 67)	Window Sills (sample size 33)	Window Troughs (sample size 32)
Stage 1: Pre-Work	27 (6)	828 (5)	15,556 (5)
Stage 2: After work, on sheeting	142 (15)		
Stage 3: After work, on floor after sheeting removed	42 (6)		
Stage 4: After final cleaning	24 (4)	375 (4)	177 (14)

[a]GM=geometric mean. GSD=geometric standard deviation. As is commonly observed for environmental samples, lead dust wipe results tended to be log-normally distributed; therefore, GMs were calculated as the primary measures of central tendency (see Appendix B).

Figure ES-1
Pre-Work and Post-Final Cleaning Dust Lead Loadings for Dust Creation Activities, by Surface Type



Top whisker=95th percentile; bottom whisker=5th percentile; top of box=75th percentile; bottom of box=25th percentile; circle=median; triangle=geometric mean. Dashed lines=comparison values (40 µg/sq ft for floors, 250 µg/sq ft for window sills; 400 µg/sq ft for window troughs).

As shown in Table ES-2, one-third of pre-work floor sample results were above 40 µg/ft^2, and there was only a small increase (1%) in the percent of samples exceeding 40 µg/ft^2 from pre-work to post-final cleaning. Of the floor sample results exceeding 40 µg/ft^2 before work, almost half still exceeded the floor standard after final cleaning was done. Although there was only a small increase in the percent of samples exceeding 40 µg/ft^2 from pre-work to post-final cleaning, of the post-final cleaning samples that exceeded 40 µg/ft^2, dust lead loadings for 70% of the floor samples actually increased from pre-work to post-final cleaning. Furthermore, of the pre-work floor sample results that were less than 40 µg/ft^2, almost one-third exceeded 40 µg/ft^2 after final cleaning was done.

Table ES-2: Number (%) of Samples with Dust Lead Loadings Exceeding Comparison Values[a] at Each Work Stage for Dust Creation Activities

	Floors (sample size 67)	**Window Sills (sample size 33)**	**Window Troughs (sample size 32)**
Stage 1: Pre-Work	22 (33%)	28 (85%)	32 (100%)
Stage 2: After work, on sheeting	47 (70%)		
Stage 3: After work, on floor after sheeting removed	37 (55%)		
Stage 4: After final cleaning	23 (34%)	20 (61%)	11 (34%)
Of *pre-work* samples *exceeding* comparison, #(%) *exceeding* comparison, post-final cleaning	10/22 (45%)	17/28 (61%)	11/32 (34%)
Of *post-clean* samples *exceeding* comparison, # (%) samples w/increase, pre-work to post-clean	16/23 (70%)	8/20 (40%)	2/11 (18%)
Of *pre-work* samples *less than* comparison, # (%) *exceeding* comparison, post-final cleaning	13/45 (29%)	3/5 (60%)	NA[b]

[a]Comparison values for floors, sills, and troughs are 40 µg/ft^2, 250 µg/ft^2, and 400 µg/ft^2, respectively. Compliance with EPA clearance standards is not technically required in weatherization work. Standards are presented for comparison purposes.
[b]NA=Not applicable. No values are presented because all pre-work samples exceeded comparison values.

ES.2.2 Dust Creation Window Results

As shown in Table ES-1 and Figure ES-1, GM sill and trough dust lead loadings measured after workers finished cleaning work areas were less than those measured before work began. As shown in Table ES-2, before work began, 85% of sill results and 100% of trough results exceeded their respective comparison values of 250 and 400 $\mu g/ft^2$. There was a substantial decrease in the percent of samples exceeding sill and trough comparison values from pre-work to post-final cleaning. Despite these decreases, however, of the pre-work sill and trough samples that had results exceeding their respective standards, 61% and 34%, respectively, still exceeded standards after final cleaning was done. Of the post-final cleaning sample results that exceeded their respective comparison values, 40% and 18% of sill and trough sample results, respectively, showed an increase from pre-work to post-final cleaning. Of the pre-work sill sample results that were less than 250 $\mu g/ft^2$, 60% exceeded 250 $\mu g/ft^2$ after final cleaning.

ES.3 Dust Dispersion Results

As shown in Table ES-3, for blower door floors and sills, the percentage of sample results that were above comparison values before work began was similar to the percentage of sample results that were above comparison values after work was finished. For blower door testing, lead loadings on both floors and sills significantly increased from before work to after work.[2] For dense-packing of walls, the percentage of samples that exceeded comparison values did not significantly change from before to after work, although floor dust lead loadings significantly increased from before to after work.

Table ES-3: Summary of Dust Dispersion Study Results

	Blower Door (sample size 22)				**Dense-packing Walls (sample size 23)**	
	Floor		**Sill**		**Floor**	
	GM[a] (GSD) Dust Lead Loading ($\mu g/ft^2$)	**# (%) of Samples Exceeding Comparison Values[a]**	**GM[a] (GSD) Dust Lead Loading ($\mu g/ft^2$)**	**# (%) of Samples Exceeding Comparison Values**	**GM[a] (GSD) Dust Lead Loading ($\mu g/ft^2$)**	**# (%) of Samples Exceeding Comparison Values**
Pre-Work[b]	10 (4)	4 (18%)	142 (4)	9 (41%)	16 (5)	10 (43%)
Post-Work (sheeting)[b]	3 (3)	0 (0%)	8 (5)	1 (5%)	6 (4)	2 (9%)
Post-Work Sum[c]	14 (3)	5 (23%)	159 (4)	9 (41%)	26 (4)	11 (48%)
Of *pre-work* samples *exceeding* comparison, #(%) *exceeding* comparison, post-final cleaning		5 (100%)		9 (100%)		11 (100%)

[a]GM=geometric mean. GSD=geometric standard deviation. As commonly observed for environmental samples, lead dust wipe results tended to be log-normally distributed; therefore, GMs were calculated as the primary measures of central tendency (see Appendix B).
[b]Pre-work samples were collected directly from the listed surface. Post-work samples were collected from the sheeting directly over the location that was sampled before work.
[c]Post-work sum GM(GSD) values were calculated by first summing, for each set of samples, the pre-work result with the post-work result, then calculating the GMs of the sum values.

[2] For dust dispersion activities, "after-work" values were calculated by adding together the pre-work sample result and the post-work sheeting result for the sheeting placed over the floor or sill location.

ES.4 Conclusions

The results of this study indicate that levels of leaded dust created by typical weatherization work in older housing with lead-based paint are likely to be well above EPA clearance levels, and therefore pose a substantial risk to children. Study findings affirm the need for areas to be cleaned after containment is removed.

GM floor dust lead loadings measured after final cleaning was done were not significantly different from those measured before work began, while geometric mean window sill and trough dust lead loadings were significantly lower after work was done. When viewed through these measures of central tendency, these data indicate that the current work practices examined in this study have either a positive or generally little impact on potential lead dust exposures. However, despite the decreases observed between pre-work and post-final cleaning, of the samples that exceeded comparison values after final cleaning, dust lead loadings for 70%, 40%, and 18% of floor, sill, and trough samples, respectively, showed an increase in dust lead loadings from pre-work to post-final cleaning. Of the pre-work samples that were *less than* comparison values, post-final cleaning dust lead loadings for 29% and 60% of floor and sill samples, respectively, exceeded comparison values after final cleaning. Analysis of the study data indicated that the higher the dust lead loadings remaining on floors after containment is removed but before cleanup is performed, the higher the post-final cleaning floor dust lead loadings. This finding, in conjunction with the finding that substantial amounts of lead dust are created during the work activity itself, suggests that contractors need to exercise care when removing containment and need to more thoroughly clean dust creation areas after containment is removed.

Other activities were observed during the weatherization work and field data collection, including movement of residents, their pets, and movement of workers through sample areas. These influences may have impacted results, but it was not possible to quantify the impact, if any, of these activities on study results because field investigators reported on these other activities for only a few of the study dwellings.

The dust dispersion findings are similar to an earlier Cavallo study which suggested that dust dispersion activities such as blower door tests can increase dust lead loadings, but the change is not large enough to trigger EPA action levels (Cavallo 2000). When EPA action levels were exceeded, the dust lead loadings were generally of concern prior to the test. The dust dispersion results for floors suggest that in an older home with deteriorated lead-based paint, workers must use caution when performing dust dispersion activities. For example, alternative engineering controls could be used such as positive pressure for blower door testing.

1.0 INTRODUCTION

1.1 Background/Project Description

The purpose of this study was to provide reliable empirical data on settled dust lead levels before, during, and after weatherization work in order to assist the U.S. Department of Energy (DOE) in assessing the effectiveness of current policy in protecting occupants and workers from lead exposure during and after selected weatherization activities.

Based on national surveys of the prevalence of lead-based paint in housing, it is expected that many of the older dwellings treated under DOE's Weatherization Assistance Program (WAP) have lead-based paint and high levels of lead in dust (Jacobs et al. 2002). Weatherization activities that disturb painted surfaces may generate lead dust which, if not controlled and cleaned up, may cause lead exposure in occupants and workers (U.S. Environmental Protection Agency (EPA) 2000). Other activities that do not disturb lead-based paint, such as blower door tests or dense-packing of walls[3], may dislodge, and disperse into the living area, contaminated dust that was lodged in cavities of the house. The health effects of lead exposure, especially on young children, are well documented and include reduced IQ, learning difficulties, and behavioral problems (National Academy of Science (NAS) 1993, Needleman 2004, U.S. Department of Health and Human Services (HHS) 2005a).

DOE policy requires that WAP grantees train workers to use lead-safe weatherization practices where it is likely that lead-based paint will be disturbed. However, this policy was developed with very little specific data on the extent to which certain weatherization activities actually generate or disperse significant amounts of lead dust or disperse it. While there have been previous studies of dust lead generated by various residential renovation activities (e.g., EPA 2000), studies focusing specifically on the effect of weatherization activities on dust lead are limited. The National Center for Healthy Housing (NCHH), with funding from DOE's Oak Ridge National Laboratory (ORNL) and support from Battelle, partnered with state weatherization programs in Rhode Island (RI) and Maryland (MD) and with local agencies in Indianapolis, Indiana (IN) to conduct a study of the effect of weatherization activities on levels of lead in settled dust in homes. The weatherization programs identified seven local agencies that routinely work in pre-1950 homes with lead-based paint and conduct the type of weatherization activities of most interest to the study. The study focused on homes built before 1950 because the prevalence of lead-based paint is much higher in such structures than in newer dwellings (Jacobs et al. 2002). As demonstrated in lead hazard control programs in RI, MD, and IN, these regions have a clear problem with lead-based paint hazards in pre-1950 housing. The study was divided into two smaller studies:

1. A study of dust-lead *creation* centered around four paint-disturbing activities: Cutting holes in walls/ceilings, window repair, window replacement, and door weatherstripping; and

[3] In a blower door test, a specially designed variable speed fan is inserted into a doorway opening that has been sealed with a nylon cover to prevent air leakage. With all windows and other doors shut, the fan is activated, and workers monitor airflow and air pressure through the home, looking for leakages particularly around windows, doors, and attics. Contractors conduct dense-packing by drilling holes in outer walls then inserting a hose into the holes through which cellulose insulation is "blown" into the wall cavity.

2. A study of dust-lead *dispersion* during two activities: Blower door testing and dense-packing of walls.

1.2 Study Objectives

1.2.1 Dust-Lead Creation Objectives

Specific objectives for this part of the study were to answer the following questions:

1. How much preexisting lead, measured in dust lead loadings of micrograms per square foot ($\mu g/ft^2$), is present on floors, window sills, and window troughs where lead dust/debris generated by weatherization activities is expected to accumulate?
2. How much lead, measured in dust lead loadings of $\mu g/ft^2$, is generated on floors by discrete weatherization activities in homes that have paint with lead at 1.0 milligram per square centimeter (mg/cm^2) or greater?
3. How much lead, measured in dust lead loadings of $\mu g/ft^2$, remains on floors in areas impacted by weatherization activities after weatherization work has been completed and all protective materials have been removed, but before final cleanup?
4. How much lead, measured in dust lead loadings of $\mu g/ft^2$, is present on floors, window sills, and window troughs in areas impacted by weatherization activities after weatherization work has been completed and after final cleanup?

In the original study design, there were two additional objectives designed to investigate sample variability in dust creation locations before the activity was performed and after final cleanup of the area was completed; however, these two objectives could not be met due to unavoidable sampling constraints within the study dwellings. These constraints are discussed in detail in Section 2.5.1 of this report. The study also explored the variables that influence the dust-lead loadings of interest, such as building age and type, characteristics of the surfaces treated and sampled, and certain details of the weatherization task and cleanup.

1.2.2 Dust-Lead Dispersion Objectives

Specific objectives for this part of the study were to answer the following questions:

1. How much preexisting lead, measured in dust lead loadings of $\mu g/ft^2$, is present on floors and window sills that might be impacted by dust dispersion activities?
2. How much lead, measured in $\mu g/ft^2$, is dispersed on floors and window sills by blower door testing?
3. How much lead, measured in $\mu g/ft^2$, is dispersed on floors (e.g., below electrical outlets) during the dense-packing of walls?

In the original study design, there was a fourth objective to study the amount of lead dispersed on interior floors (e.g., directly adjacent to supply air vents) during ductwork repair. This objective could not be met, however, because ductwork repair was not performed in any of the dwellings enrolled in the study.

The dust lead loadings set by EPA for abatement clearance with single-surface settled dust wipe samples at 40 Code of Federal Regulation (CFR) 745.227(e)(8)(viii) were considered to be the relevant comparison values for sample results in this report (EPA 2001a). These comparison values were 40 $\mu g/ft^2$ for floors, 250 $\mu g/ft^2$ for window sills, and 400 $\mu g/ft^2$ for window troughs.

2.0 STUDY DESIGN AND SAMPLE COLLECTION PROCEDURES

All study tasks were performed in accordance with written study protocols and the Quality Assurance Plan (QAP) approved by ORNL (NCHH 2004; Battelle 2004).

2.1 Study Team

The two state agencies that were early participants in the study, the MD Weatherization Assistance Program and the RI Energy Office, worked with NCHH on the study design and helped to identify tasks that should be selected as target activities. Later in the study, NCHH contacted Community Action of Greater Indianapolis (CAGI) to invite them to participate in the study. The following seven local weatherization agencies were selected to participate in the study:

- MD: Baltimore City Department of Housing and Community Development, Frederick County, and Allegany County;
- RI: Blackstone Valley Community Action Project, Pawtucket; East Bay Heating Assistance, Riverside (formerly Self-Help); and Providence Community Action Project, Providence; and
- IN: Community Action of Greater Indianapolis.

Local agencies were responsible for providing candidate housing that had a standard energy audit[4] and met enrollment criteria (see Section 2.3). The study did not dictate a training program for teaching lead-safe work practices to weatherization contractors; however, local agencies verbally reported that their contractors and employees had received lead-safe work practices training, including instruction in cleanup after completion of work.

Certified risk assessors served as the field investigators for the study and were responsible for collecting environmental samples. NCHH hired risk assessor subcontractors in MD and RI, while in IN, CAGI partnered with the Marion County Health Department, which provided risk assessors to perform data collection services. Risk assessors were currently certified by the EPA-approved state certification program for lead hazard risk assessors in each state.

NCHH provided training in the research study protocols to local agency energy auditors and risk assessors, including training in the sampling plan, sample collection methods, chain of custody, completion of data collection forms, and submission of data. Weatherization contractors were included in part of the training to educate them on the proper way to coordinate their activities with the work of the risk assessor, but NCHH did not train the weatherization contractors in lead-safe work practices.

[4] An energy audit identifies energy problems within a home and identifies measures to be taken to correct those problems and make the home more energy-efficient.

2.2 Overview of Study Design

Data collection protocols, a QAP, and data collection forms were developed for this project prior to any enrollment or data collection. Investigators recorded answers directly on the study forms. Additional information or comments were made in the comment section of the appropriate form so that clarification could be obtained if needed at a later time. Samples of the data collection forms are included in Appendix A.

The study was divided into two smaller studies:

1. A study of dust-lead *creation* during four paint-disturbing activities; and
2. A study of dust-lead *dispersion* during two activities (see Table 1).

The target activities for each of the two studies are summarized in Table 1. Wall/ceiling repair (a dust creation activity conducted in only one study dwelling) and ductwork repair (a dust dispersion activity not conducted in any study dwellings) were included in the original study design but were dropped because these activities were conducted in too few study dwellings.

Table 1: Target Weatherization Activities for Dust-Lead Creation and Dust-Lead Dispersion Studies

Target Activities for Dust-Lead Creation	Target Activities for Dust-Lead Dispersion
• Cutting holes in knee walls to gain access to attics	• Blower door tests
• Repairing windows	• Dense-packing of walls
• Replacing windows	
• Planing thresholds/installing weatherstripping on doors	

Before studying any target activity, paint on components to be disturbed and studied was tested for lead using a portable x-ray fluorescence (XRF) instrument. Only houses which had lead-based paint at 1.0 mg/cm^2 or greater on one or more protocol-specified surfaces were included in the study. For the dust-lead creation study, dust wipe samples were collected on floors at four stages:

1. Before worksite preparation;
2. After the work but before removal of containment;
3. After removal of containment; and
4. After final cleanup.

Details on these four stages are given in Section 2.5.1. For two of the four dust creation activities (window repair and window replacement), dust samples from window sills and troughs were also collected before and after the activities were completed. For the blower door component of the dust dispersion study, dust wipe samples were taken from floors and sills of two rooms before the dust dispersion activity. After these samples were collected but before the blower door test began, plastic sheeting was placed over the floor sample location, and plastic wrap over the sill sample location. After the blower door test was completed, samples were collected from these sheeting materials. The sheeting was used to distinguish the pre-existing dust on the surface from the dust that was potentially dispersed by the work activities. For the dense-packing component of the dust dispersion study, dust wipe samples were taken from the floor of one to two rooms before the dense-packing began, then from sheeting after the activity was complete. If multiple activities were planned in a single dwelling (e.g., dense-packing of walls and dust creation activities), separate rooms were sampled for each activity, if feasible.

To the extent possible, weatherization activities were conducted as they routinely would have been in the absence of the research study. Residents were not required to vacate homes during weatherization work or study data collection. DOE regulations currently do not require an occupant protection plan unless the weatherization is done in coordination with federally assisted housing rehabilitation or lead hazard control work.

Information about the characteristics of each home (e.g., year built, type of structure, size), and each task (e.g., task type, component type, paint condition, dimensions of paint area disturbed, room type, containment, number of workers, and cleanup practices) were collected using the data collection forms designed for this study (Appendix A).

2.3 Recruitment and Enrollment Process

The Oak Ridge Site-Wide Institutional Review Board (IRB) determined that this project did not require formal IRB review because it did not meet the definition of research according to 45 CFR 46.102(f) (HHS 2005b) because it did not involve collecting data about human subjects through intervention or interaction with individuals or obtaining identifiable private information. Residents and rental property owners were advised of the research activities and signed a written agreement prior to participating in the study. NCHH provided written reports of paint lead and dust lead measurements to study participants and the owner of the dwellings.

For a dwelling to be enrolled in the study, it had to meet the following eligibility requirements:

- Pre-1950;
- One or more target weatherization activities planned;
- One or more windows and/or doors in the dwelling were painted; and
- No children with elevated blood lead levels (defined as a confirmed blood test result above 15 micrograms per deciliter (μg/dL)) residing in the dwelling. No blood lead testing was performed as part of this study. The written agreement included a question asking if a child with an elevated blood lead level lived in the dwelling.

2.4 Lead-Based Paint Testing Procedures

During the weatherization visit but before weatherization work began in target activity locations, the investigator used portable XRF analyzers to test selected painted surfaces to determine if lead was present at concentrations greater than or equal to 1.0 mg/cm^2 on one or more of nine designated mandatory surfaces or target activity locations. Designated surfaces included:

- Windows in the living room and kitchen. For every window tested, four components were tested (if accessible): exterior window sash, window jamb, interior window sill, and window trough; and
- One door leading to the exterior of the home and opening inwards. Exterior doors that open outwards were not included in this study.

Other surfaces that were tested included other rooms where target activities were planned (e.g., walls and/or ceilings to be cut for access to attics).

The condition (intact, fair, poor) of each tested painted surface was documented using the paint condition scale provided in the U.S. Department of Housing and Urban Development's (HUD) Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing (HUD 1995). Calibration and operation of instruments and interpretation of XRF readings followed manufacturer's instructions, relevant sections of Chapter 7 of the HUD Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing, and the EPA/HUD Performance Characteristics Sheet guidance for the specific XRF instrument used.

2.5 Dust Lead Sampling Protocols

Dust wipe sampling followed the American Society for Testing and Materials (ASTM) Standard E1728-03, Standard Practice for Collection of Settled Dust Samples Using Wipe Sampling Methods for Subsequent Lead Determination (ASTM 2003).

2.5.1 Dust Creation Activity Sampling Procedures

Dust wipe samples were collected at four stages near locations where the paint was disturbed during a target dust creation activity:

- Stage 1: From the floor before worksite preparation (before sheeting was set down), as close as possible to the work location,[5] but not directly in front of or beneath the work location. In some cases (e.g., when cutting holes in closets), the only choice for the Stage 1 sample location was directly behind the work location due to the small size of the work area.

- Stage 2: On top of the plastic sheeting immediately over the Stage 1 floor sample location, after the target activity was completed but before the sheeting was removed or cleaned.

- Stage 3: From the floor, near but not overlapping the Stage 1 sample location,[6] after the plastic sheeting was removed but before the floor was cleaned;

- Stage 4: From the floor, adjacent to but not overlapping either the Stage 1 or Stage 3 sample locations, after final cleaning.

In the original study design, floor samples at the various stages were to be taken along a specified sampling grid, so that in each house and for each dust creation activity, samples would be collected from approximately the same distance from the work surface location. The collection of samples at a fixed distance was considered important because previous studies have shown that dust lead settling varies by distance from the activity (EPA 2000, NCHH 2000).

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[5] The selection of a spot not directly in front of the work location was based on evidence from a recent study that dust lead settling was higher to the side of work rather than directly in front of the work site (NCHH 2000). This resulted from the worker blocking the heaviest amount of paint debris from falling directly behind the surface area being disturbed.

[6] It was necessary to avoid sampling the same location more than once, because dust wipe sampling itself removes dust lead.

However, investigators were not able to implement this grid design due to constraints of sampling within private homes. Investigators reported that they could not use the grid system because furniture blocked grid locations, work locations were in small areas (e.g., hall closets), or other obstacles prevented the grid from being used. In a subset of dwellings, additional samples were to be taken at specified grid locations at Stages 2 and 4, to aid in evaluating sample variability; however, due to the same space constraints, investigators were unable to collect these extra samples.

For two of the target dust creation activities, window repair and window replacement, the investigator collected one window sill dust sample and one window trough dust sample at both Stages 1 and 4. The sill and trough selected for sampling were each divided into two equal areas (left and right), with the left side being sampled at Stage 1 and the right side at Stage 4.

Investigators waited one hour prior to collecting wipe samples at Stages 2 and 4. This waiting period is to allow for fine particle fall-out, as recommended by HUD (HUD 1995). Any additional work done by the contractors and other possible activities that could influence sample results (e.g., resident or pet activity on or near sample locations) during this one-hour waiting period were documented.

2.5.2 Dust Dispersion Activity Sampling Procedures

2.5.2.1 Blower Door Tests. To measure change in dust lead loadings potentially caused by performing a blower door test, investigators collected dust wipe samples before the initial blower door test was conducted and within 1 hour after the initial blower door test was completed and before any other potentially dust-causing or dust-disturbing work was done in the rooms being tested (if feasible). The investigator collected blower door test samples from each of two rooms. Samples were collected from a window and from the floor directly beneath the window because windows are typically a main source of building envelope leakage and because the pressure from the blower test draws most strongly through small openings, such as the cracks or other gaps around windows. Also, elevated dust lead levels on sills are of concern because they are a federally defined hazard. A small study by the City of Milwaukee, the Wisconsin Energy Bureau, and DOE's Partnership of Affordable Housing found that dust lead levels on both floors and window sills can increase following blower door testing, although not above the federal dust lead standards at the time (Cavallo 2000).

Before the blower door test began, a wipe sample was collected from the floor beneath the window by centering the floor template immediately below the centerpoint of the window, with one edge of the template flush against the wall (i.e., 6 inches of the template floor wipe area extending on either side of the centerpoint of the window). If an unmovable obstruction (e.g., a built-in kitchen counter) was in the way, investigators collected the sample from the floor as close to the window as possible.

The investigator collected a pre-test window sill sample from the full length and width of the sill. After the pre-test floor and window samples were collected but before the blower door test began, the investigator taped sheeting over the floor sample location directly beneath the window and over the length of the sill. In the original study design, the window sill was to be divided into two equal areas (left and right), with the pre-blower door test sample to be collected from the left half of the sill, and the post-test sample to be collected from the right half. However, early in the data collection period, several dwellings were found to have high pre-test dust lead loadings, making it difficult to discern the blower door test's potential contribution to the settled dust lead loadings on sills after the test. Therefore, the original study design was modified to sample the entire sill before the test, and to collect the post-test sample from sheeting placed over the entire sill. One hour after the blower door test, the investigator collected a wipe sample from the floor sheeting and the sill sheeting in the locations that were sampled before the blower door test.

2.5.2.2 Dense-Packing of Walls. To measure the change in dust lead loadings that may be caused by the dispersion of leaded dust from inside wall cavities to indoor locations following dense-packing of walls, investigators collected dust wipe samples before dense-packing began and within 1 hour after the dense-packing of a wall was completed in the room being sampled. If feasible, this room was different from rooms where other dust dispersion activities were being studied. In 10 of the 18 study dwellings that had both a blower door test and dense-packing of walls, investigators collected dust samples in the same room.

Before the dense-packing began, the investigator collected a wipe sample from the floor directly beneath one electrical socket in one room by centering the floor template immediately below the centerpoint of the socket, with one edge of the template flush against the wall (i.e., 6 inches of the template floor wipe area extending on either side of the centerpoint of the socket). If there were no sockets located along an outside wall, investigators collected the sample from beneath a gap in the molding/baseboards (3 homes). After the pre-work floor sample was collected but before the dense-packing began, the investigator placed sheeting over the floor sample location directly beneath the socket/baseboard gap. One hour after the dense packing was finished along the wall being studied, the investigator collected a wipe sample from the sheeting.

2.5.3 Re-Cleaning Sampling Procedures

After final cleaning of dust creation activity locations (e.g., at Stage 4), if dust lead loading results were above comparison values (40 $\mu g/ft^2$ for floors, 250 $\mu g/ft^2$ for window sills, 400 $\mu g/ft^2$ for window troughs), the weatherization contractor returned to the dwelling to re-clean all areas where the type of dust creation activity was done in the dwelling. The investigator was present during the re-cleaning and collected post-cleaning samples from the area(s) that had high post-final cleaning results at the initial visit. If samples collected on floor or window surfaces after dust dispersion activities (e.g., blower door tests) had dust lead loading results that exceeded comparison values, the weatherization contractor cleaned the dust dispersion sampling location(s) that yielded the high results, after which the investigator collected post-cleaning samples from the area(s) that had high post-work sample results at the initial visit. Because weatherization programs are not designed to be lead hazard reduction programs and are not required to meet post-work EPA clearance levels, only one re-cleaning was performed in each dwelling. If the second dust testing showed that dust lead levels were above the comparison values, the owner and occupant were notified that a dust lead hazard remained after the work was done.

2.6 Laboratory Analysis Procedures

NCHH established a chain-of-custody procedure with all investigators and the analytical laboratory to be sure that samples were properly recorded, shipped and handled. Laboratory analysis of dust-wipe samples for lead was required to meet the standards of the National Lead Laboratory Accreditation Program (NLLAP). Laboratory analyses were conducted by the Hematology and Environmental Laboratories at the University of Cincinnati, an NLLAP-accredited laboratory. The samples were analyzed using flame atomic absorption using specific protocols found within EPA method SW-846 (EPA 2004) or equivalent. Instrument readings were reported to reduce statistical analysis problems with values below standard reporting limits.

2.7 Quality Assurance and Quality Control (QA/QC)

A formal QAP was prepared for this project, which addressed quality assurance/quality control (QA/QC) measures associated with sample collection, sample handling, analytical methods, field blanks, sheeting blank samples, QC spike samples, etc. (Battelle 2004).

2.7.1 QC Spiked Dust Wipe Sample Results

The purpose of the spike samples was to ensure that the laboratory was consistently able to accurately determine quantities of lead in samples over the course of the study. QA spike samples (spiked with a known quantity of standard lead reference material) were submitted at a rate of one per every other dwelling unit. The laboratory was unable to distinguish spike samples from ordinary field samples. Twenty-eight spike samples were analyzed, with dust lead loadings ranging from 21 to 324 $\mu g/ft^2$. In accordance with standard laboratory practice, all spike sample results were required to be within 20% of the known value. All spike sample results fell within this range of acceptability, 27 of the 28 spike sample results (96%) were within 10% of the known value, and 19 of the 28 results (67%) were within 5% of the known value.

2.7.2 Field Blank Dust Wipe Sample Results

Analysis of field blank samples determines if the sample media are contaminated and if the field staff are using appropriate sampling and decontamination techniques. A field blank is a clean wipe that is treated in the same way as field samples except that it is not wiped across a sample surface prior to insertion into a sample collection tube. Field blank wipes were submitted at a rate of one per dwelling unit. Four of the 62 field blank samples collected had results that were greater than or equal to 5 µg/sample. No pattern was evident in these findings, which appeared to be intermittently distributed across time, region, and investigators; therefore, no sample results were excluded based on field blank results, and no blank correction was performed.

2.7.3 Sheeting Blank Dust Wipe Sample Results

To determine that the plastic sheeting used during weatherization and sampling was not contaminated prior to use, investigators collected “sheeting blank” samples at a rate of one per every other dwelling unit. A sheeting blank is a clean wipe that is used on a piece of containment sheeting just after the sheeting is put into place. Seven of the 35 sheeting blank results were greater than or equal to 5 $\mu g/ft^2$. When questioned about these samples, field investigators reported that the sheeting blank sample collection protocol, which called for sheeting blank samples to be collected immediately after sheeting was put into place, was difficult to follow: Contractors and residents often walked across sheeting as it was being put into place and immediately after it was laid, or contractors began work before the sheeting blank sample could be collected. Because proper protocol could not be followed, these results could not be construed as true blank values. No sample results were adjusted based on sheeting blank results.

2.7.4 Audits of Field Data Collection Activities

On seven different occasions, NCHH observed investigators performing field data collection at study dwellings. Investigators were critiqued for their adherence to the data collection protocols, choice of sample locations, dust wipe sampling technique, and their observations of other activities occurring during data collection. Investigators generally performed to expectations, with NCHH personnel providing onsite guidance and written recommendations to improve sampling and data collection. Site visits were generally conducted early in the data collection period, to ensure that problems were identified and corrected before most dwellings in a particular region were sampled.

3.0 DATA PROCESSING AND STATISTICAL ANALYSIS PROCEDURES

3.1 Data Audit and Data Completeness Checks

Investigators checked each form for accuracy and completeness, and then sent all checked data collection forms to NCHH. NCHH reviewed each form for protocol compliance and completeness and worked with investigators to resolve any potential problems identified on the data collection forms. Data entry was done at NCHH with a data entry system in Microsoft Access© that was designed to perform basic range and logic checks. After data entry, forms were printed and visually compared to the handwritten form.

3.2 Statistical Analyses

All reports and statistical analyses were conducted using SAS/STAT® software version 9.1 (SAS Institute 2002-2003). Appendix B contains detailed definitions of statistical terms and statistical analyses used in this study.

A significant association was defined as a p-value below 0.05 and "marginal significance" as a p-value of at least 0.05 but less than 0.10 (see Appendix B).

For each of the dust creation activities, descriptive statistics were calculated on dust lead loadings within each of the four sampling stages, and on changes in dust lead loadings between stages. For the dust dispersion activities, descriptive statistics were calculated on dust lead loadings at the two sampling times and on changes in dust lead loadings between these times. As is commonly observed for environmental samples, lead dust wipe results tended to be log-normally distributed; therefore, geometric means (GMs) were calculated as the primary measures of central tendency (see Appendix B).

For both dust creation and dust dispersion activities, the percent of loadings above comparison values (40, 250, and 400 $\mu g/ft^2$ for floors, sills, and troughs, respectively) at the different times were also presented.

Analysis of variance (ANOVA) was conducted to determine if the state-wide arithmetic means of the unit mean paint lead loadings were the same for Indiana, Maryland and Rhode Island. Fisher's exact test was used to test that the percent of units with any components having non-intact lead-based paint (LBP) were the same for Indiana, Rhode Island and Maryland.

Paired student t-tests with log-transformed dust lead loadings were conducted to determine if there was a change in GM dust lead loadings between two times. McNemar's test, a measure of agreement between paired dichotomous variables, was employed to test that the percent of dust lead loadings above comparison values (40, 250, and 400 $\mu g/ft^2$ for floors, sills, and troughs, respectively) were different at two times (McNemar 1947).

Although several of the dust creation and dust dispersion research objectives (see Section 1.2) are descriptive in nature, statistical modeling analyses were performed in order to identify those variables that were significantly associated with dust lead loading measures at specific stages of dust sampling.

Statistical modeling was conducted to:

(1) Identify which housing characteristics and conditions influenced pre-work dust lead loadings;
(2) Identify which housing characteristics and conditions influenced dust lead loadings after final clean-up of dust creation activities and determine if dust lead loadings differed for different dust creation activities; and
(3) Identify which housing characteristics and conditions influenced dust lead loadings after final clean-up of dust dispersion activities and determine if dust lead loadings differed for different dust dispersion activities.

Analysis of covariance was used to model dust lead loading measures, after taking logarithmic transformations. This modeling was conducted using the SAS procedure MIXED using restricted maximum likelihood methods as described in Littell (2006). The models accounted for multiple work areas sampled in the same house. The dust lead loading measures and the sets of possible predictor variables considered in the modeling analyses were as follows:

(1) <u>Pre-work dust lead loading on (a) floors, (b) sills, and (c) troughs</u>. Possible predictor variables included: State (MD, RI, or IN); owner-occupied vs. rental; house age (pre-1930 vs. post-1930); housing type (single family detached versus all other types); condition of the wiped surface (carpeted cleanable, painted difficult to clean, bare smooth and cleanable, etc.); number of interior deteriorations (out of 2: Walls/ceilings/doors/trim or floor); number exterior deteriorations (out of 5: roofs/gutters/downspouts; walls and siding; windows and doors; porches and steps; and foundations); average paint lead loading of all XRF-tested components in the room;[7] and the average paint condition rating of all XRF-tested components in the room.[8]
(2) <u>Dust lead loading after final cleanup from dust creation activities on (a) floors, (b) sills, and (c) troughs</u>. Possible predictor variables included: Pre-work dust lead loading; dust lead loading at Stages 2 and 3; state; owner-occupied vs. rental; house age; housing type; dust creation activity; condition of the wiped surface; number of interior deteriorations; number exterior deteriorations; and average paint lead loading and average paint condition on disturbed surfaces.[9]
(3) <u>Dust lead loading, after performing dust dispersion activities, on (a) floors and (b) sills</u>. Possible predictor variables included: Pre-work dust lead loading; state; owner-occupied vs. rental; house age; housing type; dust dispersion activity; condition of the wiped surface; number of interior deteriorations; number exterior deteriorations; and average paint lead loading and average paint condition on disturbed surfaces.

Using the same SAS procedure described above, the following five variables were included in the models of dust lead loading after dust dispersion activities, but insufficient data prevented them from consideration within analyses of data associated with dust creation activities: (1) duration of activity; (2) indicator of whether the area was high efficiency particulate air (HEPA)-

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[7] Paint lead loadings above 9.9 mg/cm^2 were set at 9.9 mg/cm^2. Paint lead loadings below 0.1 mg/cm^2 were set at 0.1 mg/cm^2.
[8] 1=intact, 2=fair, and 3=poor. Values of "not painted" or "not present" were set at 1=intact.
[9] Surfaces disturbed for each activity were: cut holes=walls/ceilings; window repair=windows; window replacement=windows; weatherstripping doors=doors; blower door tests=windows; dense-packing walls=walls.

vacuumed after work was done; (3) indicator of whether the area was wet-cleaned after work was done; (4) indicator of whether other indoor weatherization tasks were performed during the target activity or during the one-hour waiting period; and (5) whether any non-weatherization activities occurred during the target activity or during the one-hour waiting period.

Within the analysis of covariance procedure, a backward stepwise procedure was used to remove non-significant variables from the model, followed by additional forward steps to allow addition and/or removal of variables. Appendix C summarizes those variables that were removed from specific models before beginning the model creation process because they had insufficient variability to provide reasonable estimates. Results of the statistical modeling analyses are given in Section 7.0.

Statistical modeling was also conducted to identify housing characteristics that predict pre-work/high post-final cleaning floor results. Logistic regression modeling with nesting to account for inclusion of multiple rooms from the same unit was employed. The possible predictors considered were the following: state; owner-occupied vs. rental; house age; housing type; dust creation activity; condition of the wiped surface; number of interior deteriorations; number exterior deteriorations; and average paint lead loading and average paint condition on disturbed surfaces. A backward stepwise procedure was used to remove non-significant variables from the model, followed by additional forward steps to allow addition and/or removal of variables.

4.0 ENROLLMENT RESULTS

Participating local agencies provided 77 dwellings that had an energy audit and met the enrollment criteria. Of these dwellings, 11 were excluded from the study because no lead paint with concentrations at or above 1.0 mg/cm^2 was found in the dwelling, and eight others were excluded because no target activities were planned in the unit or work was to be done in areas too small to sample. The remaining 58 dwellings were successfully enrolled in the study, and dust samples were collected from these dwellings. Table 2 lists the number of dwellings that were enrolled and studied in each state and presents a tally of the dust creation and dust dispersion activities that were studied.

Table 2: Number of Enrolled Units Associated with Each Target Activity

	# Units from Maryland	# Units from Rhode Island	# Units from Indianapolis	Total # Units
Total Number of Units	14	25	19	58
Dust Creation Activities:				
Cut holes in walls/ceilings	9	1	3	13
Window repair	4	3	0	7
Window replacement	1	19 (26 activities)[a]	0	20 (27 activities)
Weatherstripping door	9	15	0	24
Dust Dispersion Activities:				
Blower door test	2	1	19	22
Dense-pack walls	1 (1 activity)	2 (3 activities)[b]	17 (19 activities)[b]	20 (23 activities)

[a]Two window replacement activities (in separate rooms) were sampled in 7 of the 19 RI dwellings, yielding a total of 26 window replacement activities sampled in 19 dwellings.

[b]Two dense-packing activities (i.e., along 2 different walls) were sampled in 1 of the 2 RI dwellings and in 2 of the 17 IN dwellings, yielding a total of 23 dense-packing activities sampled in 20 dwellings.

4.1 Baseline Housing Characteristics and Condition

Study dwellings generally fell into one of three building type categories: single detached buildings (55%); 2-4 unit buildings (24%); and single attached dwellings (17%). Only 3% of dwellings were located in multi-unit buildings having more than 4 units. Building type varied by region. The majority of IN dwellings (89%) were single detached, most MD dwellings (64%) were single attached, and most RI dwellings were split between single detached (40%) and 2-4 unit buildings (52%). All study dwellings were built before 1950, 78% were constructed before 1930, and 24% were built before 1910. RI dwellings were almost all pre-1930 (88%), while 78% of MD dwellings were pre-1930 and 63% of IN dwellings were pre-1930. Seventy-nine percent (79%) of study dwellings were owner-occupied. MD and IN dwellings were almost all owner-occupied (93% and 95%, respectively), while RI dwellings were split between owner-occupied (60%) and rental (40%).

As shown in the last column of Table 3, 38% of dwellings showed one or more signs of exterior deterioration, and 33% of dwellings showed one or more signs of interior deterioration. Interior deterioration of walls, ceilings, doors, and trim was more prevalent (observed in 29% of all study dwellings) than any individual type of exterior deterioration.

Table 3: Summary of the Prevalence of Exterior and Interior Deterioration Across Enrolled Dwellings

Types of Deterioration	#(%) of Units			
	MD	RI	IN	All Units
Total Number of Units	14	25	19	58
Exterior Building Deterioration:				
• Roofs, gutters, downspouts – missing, broken, holes, cracks	4 (29%)	3 (12%)	3 (16%)	10 (17%)
• Walls and siding – large cracks or holes, boards or shingles broken or missing	3 (21%)	5 (20%)	2 (11%)	10 (17%)
• Windows and doors – ≥ two windows or doors broken, missing, boarded up	1 (7%)	3 (12%)	4 (21%)	8 (14%)
• Porch or steps – major elements broken, missing, out of plumb	2 (14%)	4 (16%)	0 (0%)	6 (10%)
• Foundation – major visible cracks, missing materials, unsound	2 (14%)	1 (4%)	2 (11%)	5 (9%)
• One or more exterior deteriorations	6 (43%)	10 (40%)	6 (32%)	22 (38%)
Interior Dwelling Deterioration:				
• Walls, ceilings, doors, trim - cracks, need for repair, replace or major repainting	4 (29%)	8 (32%)	5 (26%)	17 (29%)
• Floors – loose, missing or cracked, finish worn, deteriorated carpeting	3 (21%)	5 (20%)	1 (5%)	9 (16%)
• One or more interior deteriorations	5 (36%)	9 (36%)	5 (26%)	19 (33%)

4.2 XRF Testing Results

According to the regulatory definition of lead-based paint, paint contains lead if a test with an x-ray fluorescence (XRF) machine shows that the paint contains 1 milligram or more of lead per square centimeter of surface area (mg/cm^2) (EPA 2001b). As shown in Table 4, all 58 enrolled study dwellings had at least one tested component with lead-based paint (i.e., greater than or equal to 1.0 mg/cm^2), while within a given dwelling, an average of 50% of tested components had lead-based paint, yielding an overall average paint loading of 3.5 mg/cm^2. None of the dwellings had lead-based paint on any tested ceiling or wall components.[10] Looking only at window components, an average of 95% of dwellings had at least one window component that tested positive for lead. Within a given dwelling, an average of 53% of tested window components had lead-based paint, with an overall average of 3.7 mg/cm^2, while the average paint lead loading for tested door components was 2.4 mg/cm^2. For door components, an average of 48% of dwellings had at least one door component that tested positive for lead-based paint, and within a given dwelling, an average of 39% of tested door components contained lead paint.

In general, dwellings in IN had lower paint lead loadings than dwellings in either MD or RI. An ANOVA was conducted to test the hypothesis that the means of the unit mean paint lead loading were the same for Indiana, Rhode Island and Maryland. The test concluded that means were not the same for the three sites ($p<0.001$). The means for Indiana and Maryland, Indiana and Rhode Island, and Maryland and Rhode Island were significantly different ($p<0.001$,$p<0.001$, and $p=0.024$, respectively. However, a Fisher's exact test showed that the percent of dwellings having any components with non-intact lead-based paint not significantly different for IN, RI, and MD ($p=0.327$).

[10] As evidenced by the maximum paint lead loading of 0.8 mg/cm^2, paint on at least one wall component contained lead, but at a level below 1 mg/cm^2.

Table 4: Summary of XRF Testing Results in Enrolled Dwellings, by Component Type[c]

	MD					RI[c]				IN[c]				ALL				
	Ceil.	**Wall**	**Door**	**Win.**	**All**	**Wall**	**Door**	**Win**	**All**	**Wall**	**Door**	**Win.**	**All**	**Ceil.**	**Wall**	**Door**	**Win.**	**All**
Number of dwellings w/XRF results for given component type	8	2	14	14	14	1	25	25	25	19	17	19	19	8	22	56	58	58
Minimum paint lead loading[a] (mg/cm^2)	0.1	0.2	0.1	0.1	0.6	0.8	0.1	0.1	0.4	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.2
Mean paint lead loading[a] (mg/cm^2)	0.1	0.3	4.7	6.0	5.3	0.8	2.1	4.1	3.9	0.2	1.0	1.6	1.4	0.1	0.2	2.4	3.7	3.5
Maximum paint lead loading[a] (mg/cm^2)	0.1	0.3	9.9	9.9	9.5	0.8	9.9	7.4	7.0	0.5	5.2	4.3	3.5	0.1	0.8	9.9	9.9	9.5
Percentage of units with any LBP at or above 1 mg/cm^2 on given component[b]	0%	0%	71%	93%	100%	0%	40%	96%	100%	0%	41%	95%	100%	0%	0%	48%	95%	100%
Within given unit, average percentage of components with LBP at or above 1 mg/cm^2:	0%	0%	60%	76%	69%	0%	32%	57%	55%	0%	32%	32%	30%	0%	0%	39%	53%	50%
Percentage of units w/any non-intact LBP at or above 1 mg/cm^2 on given component	0%	0%	36%	79%	86%	0%	32%	80%	80%	0%	24%	58%	63%	0%	0%	30%	72%	76%

[a]Paint lead loading results were calculated by first calculating the average loading within the dwelling, then calculating the given statistic (e.g., minimum, mean, maximum) across all units.
[b]Lead-based paint (LBP) is defined as paint having a loading value greater than or equal to 1.0 mg/cm^2.
[c]No ceiling components were tested in RI and IN.

5.0 DUST CREATION ACTIVITY RESULTS

In this section, sample results are presented for the four stages of dust sample collection as described in Section 2.5.1. Table 5 presents GM dust lead loadings associated with specific target dust creation activities at each stage, by component type. Table 6 presents the number and percent of dust creation samples that had dust lead loadings exceeding comparison values at each work stage, by component type. Figure 1 presents box plots illustrating the distribution of data for each tested surface at pre-work and post-final cleaning. Table 7 summarizes the changes in GM dust lead loadings and exceedances across stages for dust creation activities.

5.1 Dust Creation Activity Results for Floors

5.1.1 Stage 1 (Pre-Work) Floor Results

As shown in Table 5, the pre-work GM dust lead loading in the rooms where dust creation activities later took place was 27 µg/ft^2. The pre-work GM dust lead loadings for the cut holes, window replacement, and door weatherstripping activities (33, 24, and 22 µg/ft^2, respectively) were lower than the pre-work floor GM for the window repair activity (64 µg/ft^2). As shown in Table 6, one-third (33%) of pre-work floor sample results exceeded 40 µg/ft^2, varying from 29% for window repair to 45% for cut holes in walls/ceilings. The majority of pre-work bare floor surfaces (92%) were judged to be smooth and cleanable by the risk assessor.

5.1.2 Stage 2 Floor Sheeting Results

After the work was done but before contractors removed the horizontal containment (i.e., plastic sheeting from the floor), the GM loading on the sheeting was 142 µg/ft^2 when all dust creation activities were considered together (Table 5). For three of the four dust creation activities (cut holes, window repair, and window replacement), the Stage 2 GM was the highest of all the stages, due to the amount of lead dust deposited on the horizontal containment by the weatherization work activities. For door weatherstripping, the Stage 2 GM was almost the same as the pre-work value.

The percentage of dwellings that had Stage 2 sheeting results exceeding 40 µg/ft^2 was higher than pre-work floor results, varying from 48% (for door weatherstripping) to 92% (for window replacement) (Table 6).

5.1.3 Stage 3 Floor Results

After the sheeting was removed but before contractors did a final cleaning of the work area, GM dust lead loadings ranged from 31 µg/ft^2 to 108 µg/ft^2 for the four dust creation activities, with an overall GM of 42 µg/ft^2 when all dust creation activities were considered together (Table 5). Stage 3 GM dust lead loadings on floors were similar to pre-work values for the cut holes dust creation activity, but higher than the pre-work GM values for the window repair, window replacement, and door weatherstripping activities. Overall, there was a significant increase (56%) in the GM floor dust lead loadings from pre-work to Stage 3 (paired student t-test; p=0.020), primarily due to the significant increase in loadings for the window replacement activity (paired student t-test; p=0.031), which showed a 121% increase in GMs between Stages 1 and 3 (Table 7).

Table 5: GM (GSD) Dust Lead Loadings (µg/ft^2) Associated with Specific Target Dust Creation Activities, by Component Type

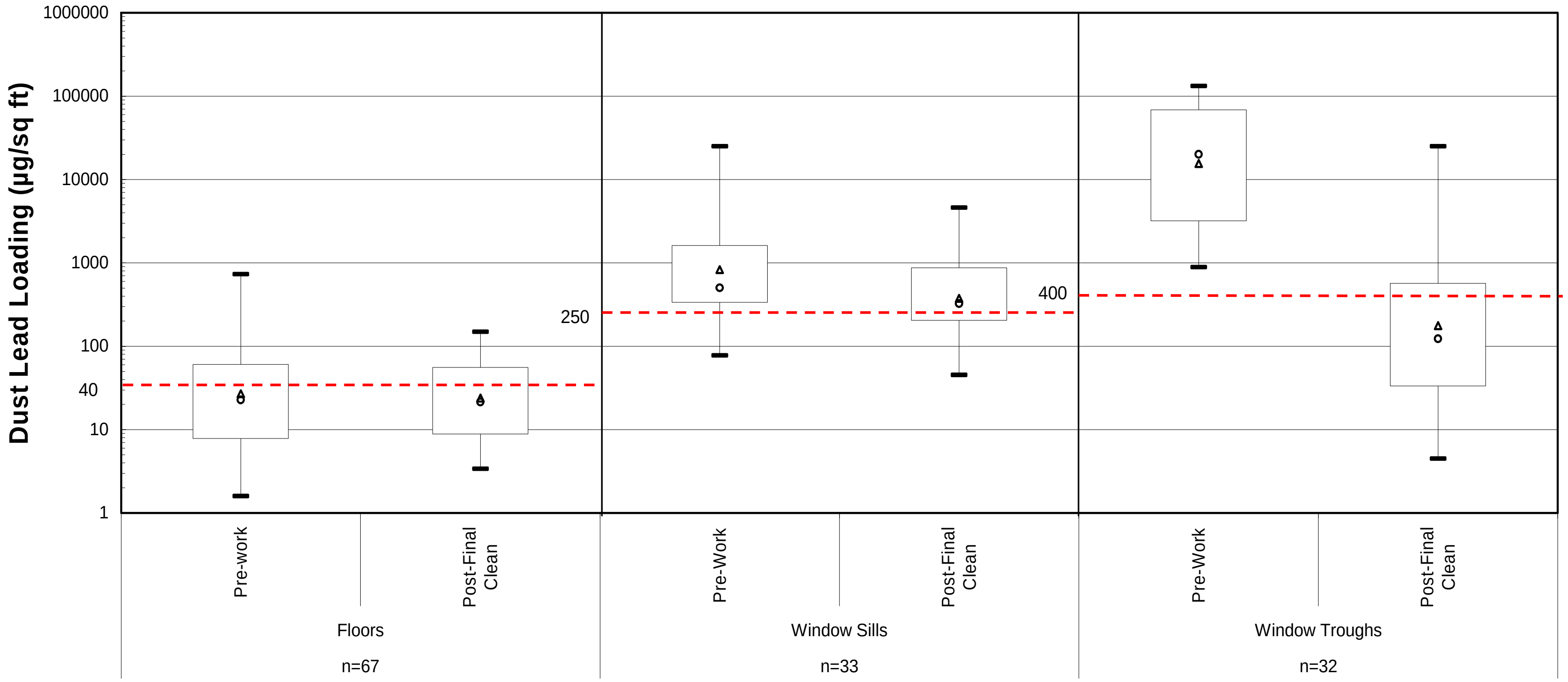
	Cut Holes Walls/Ceilings	Window Repair			Window Replacement			Weather-strip Doors	All Dust Creation Activities		
	Floors	Floors	Sills	Troughs	Floors	Sills	Troughs	Floors	Floors	Sills	Troughs
Sample Size (n)	11	7	6	5	26	27	27	23	67	33	32
Stage 1 (pre-work)	33 (12)	64 (7)	3,422 (6)	11,324 (4)	24 (5)	604 (4)	16,498 (6)	22 (4)	27 (6)	828 (5)	15,556 (5)
Stage 2 (after work, on sheeting)	223 (10)	100 (15)			736 (7)			20 (10)	142 (15)		
Stage 3 (after work, on floor after sheeting removed)	31 (7)	108 (4)			53 (5)			29 (6)	42 (6)		
Stage 4 (after final cleaning)	15 (6)	42 (6)	1,156 (7)	10,487 (3)	27 (4)	292 (3)	83 (8)	22 (3)	24 (4)	375 (4)	177 (14)

Table 6: Number (%) of Samples With Dust Lead Loadings Exceeding Comparison Values[a] at Each Work Stage for Dust Creation Activities, by Component Type

	Cut Holes Walls/ Ceilings	Window Repair			Window Replacement			Weather-strip Doors	All Dust Creation Activities		
	Floors	Floors	Sills	Troughs	Floors	Sills	Troughs	Floors	Floors	Sills	Troughs
1. Sample Size (n)	11	7	6	5	26	27	27	23	67	33	32
2. Number (%) of Pre-Work Samples w/Bare[a] Smooth and Cleanable Surfaces	7/8 (88%)	5/7 (71%)	4/6 (67%)	2/5 (40%)	19/19 (100%)	25/27 (93%)	10/26 (38%)	17/18 (94%)	48/52 (92%)	29/33 (88%)	12/31 (39%)
3. Comparison Values[b]	40	40	250	400	40	250	400	40	40	250	400
4. Stage 1 (pre-work)	5 (45%)	2 (29%)	6 (100%)	5 (100%)	8 (31%)	22 (81%)	27 (100%)	7 (30%)	22 (33%)	28 (85%)	32 (100%)
5. Stage 2 (after work, on sheeting)	8 (73%)	4 (57%)			24 (92%)			11 (48%)	47 (70%)		
6. Stage 3 (after work, on floor after sheeting removed)	6 (55%)	6 (86%)			15 (58%)			10 (43%)	37 (55%)		
7. Stage 4 (after final cleaning)	2 (18%)	4 (57%)	4 (67%)	5 (100%)	11 (42%)	16 (59%)	6 (22%)	6 (26%)	23 (34%)	20 (61%)	11 (34%)
8. Of *pre-work* samples *exceeding* comparison, #(%) *exceeding* comparison, post-final cleaning	2/5 (40%)	2/2 (100%)	4/6 (67%)	5/5 (100%)	4/8 (50%)	13/22 (59%)	6/27 (22%)	2/7 (29%)	10/22 (45%)	17/28 (61%)	11/32 (34%)
9. Of *post-clean* samples *exceeding* comparison, # (%) samples w/increase, pre-work to post-clean	0/2 (0%)	2/4 (50%)	1/4 (25%)	2/5 (40%)	9/11 (82%)	7/16 (44%)	0/6 (0%)	5/6 (83%)	16/23 (70%)	8/20 (40%)	2/11 (18%)
10. Of *post-clean* samples *exceeding* comparison, # (%) w/increase of at least 10 (floors) or 100 µg/ft² (sills/ troughs), pre-work to post-clean	0/2 (0%)	2/4 (50%)	1/4 (25%)	2/5 (40%)	8/11 (73%)	6/16 (38%)	0/6 (0%)	5/6 (83%)	15/23 (65%)	7/20 (35%)	2/11 (18%)
11. Of *pre-work* samples *less than* comparison, # (%) *exceeding* comparison, post-final cleaning	0/6 (0%)	2/5 (40%)	NA[b]	NA[b]	7/18 (39%)	3/5 (60%)	NA[c]	4/16 (25%)	13/45 (29%)	3/5 (60%)	NA[b]

[a]By definition, carpets are not "smooth;" therefore, 15 carpeted floors were not included in the calculation of smooth and cleanable surface condition. All 15 of these carpeted floors were judged to be cleanable before work began.
[b]Comparison values for floors, sills, and troughs are 40 µg/ft², 250 µg/ft², and 400 µg/ft², respectively. Compliance with EPA clearance standards is not technically required in weatherization work. Standards are shown for comparison purposes.
[c]NA=Not applicable; no values are presented because all pre-work sample results exceeded comparison values.

Figure 1
Pre-Work and Post-Final Cleaning Dust Lead Loadings for Dust Creation Activities, by Surface Type



Top whisker=95th percentile; bottom whisker=5th percentile; top of box=75th percentile; bottom of box=25th percentile; circle=median; triangle=geometric mean. Dashed lines=comparison values (40 µg/sq ft for floors, 250 µg/sq ft for window sills; 400 µg/sq ft for window troughs).

Table 7: Summary of Changes in GM Dust Lead Loading and Exceedances for Dust Creation Activities

	% Change in GM from Pre-Work to Stage 3 (p-value)[a]	**Change in percentage of samples that exceed comparison values[b] from pre-work to Stage 3 (p-value)[c]**	**% Change in GM from Pre-Work to Stage 4-Post-Final Cleaning[a]**	**Change in percentage of samples that exceed comparison values[b] from pre-work to post-final cleaning (p-value)[c]**
Cut holes walls/ceilings:				
• Floors (n=11)	6% decrease (p=0.807)	10% increase (p=0.564)	55% decrease (p=0.092)	27% decrease (p=0.083)
Window Repair:				
• Floors (n=7)	69% increase (p=0.408)	57% increase (p=0.046)	34% decrease (p=0.583)	28% increase (p=0.157)
• Sills (n=6)			66% decrease (p=0.085)	33% decrease[d]
• Troughs (n=5)			7% decrease (p=0.796)	0% change
Window Replacement:				
• Floors (n=26)	121% increase (p=0.031)	27% increase (p=0.020)	13% increase (p=0.780)	11% increase (p=0.366)
• Sills (n=27)			52% decrease (p=0.015)	22% decrease (p=0.083)
• Troughs (n=27)			99% decrease ($p<0.001$)	78% decrease[d]
Weatherstripping doors:				
• Floors (n=23)	32% increase (p=0.362)	13% increase (p=0.257)	0% (p=0.981)	4% decrease (p=0.739)
All Dust Creation Activities:				
• Floors (n=67)	56% increase (p=0.020)	22% increase (p=0.002)	11% decrease (p=0.507)	1% increase (p=0.804)
• Sills (n=33)			55% decrease (p=0.003)	24% decrease (p=0.033)
• Troughs (n=32)			99% decrease ($p<0.001$)	66% decrease[d]

[a]Based on paired t-tests of log-transformed dust lead loadings.
[b]Comparison values were 40, 250, and 400 $\mu g/ft^2$ for floors, sills, and troughs, respectively.
[c]Based on McNemar's test.
[d]McNemar's test cannot be calculated when the percent exceedances at either stage is 100% or 0%.

As shown in Table 6, the percentage of dwellings that had Stage 3 floor results exceeding 40 µg/ft^2 varied from 43% (door weatherstripping) to 86% (window repair) and in general significantly increased from pre-work to Stage 3 (overall increase 22%, p=0.002). This increase in the percent of floor samples exceeding comparison values was significant for the window repair and window replacement activities (McNemar's test; p=0.046 and 0.020, respectively), but was not significant for either the cut holes or the door weatherstripping activity.

5.1.4 Stage 4 (Post-Final Cleaning) Floor Results

Investigators reported that contractors generally cleaned work locations by vacuuming the work location, either with a HEPA vacuum or an industrial vacuum cleaner equipped with a non-HEPA filter. After vacuuming, contractors generally wet-wiped work surfaces. Vacuuming was not repeated after wet-wiping. As shown in Table 5, at Stage 4 (i.e., after the weatherization work was done and the contractors had completed their final cleaning of the work location), the overall GM floor dust lead loading was 24 µg/ft^2, close to the pre-work GM loading of 27 µg/ft^2. Post final cleaning GM floor dust lead loadings for the individual activities ranged from 15 µg/ft^2 for the cut holes activity to 42 µg/ft^2 for the window repair activity. For each of the four dust creation activities, GM dust lead loadings were generally less than or unchanged from pre-work GMs. As shown in Table 7, the percent change in floor GM loadings from pre-work to post-final cleaning was marginally significant only for the cut holes activity (paired t-test; p=0.092), which showed a 55% decrease in GMs between the two stages. Considering all dust creation activities together, GM floor dust lead loadings showed no significant change from pre-work to post-final cleaning (paired t-test; p=0.507).

The percentage of dwellings that had post-final cleaning floor results that exceeded 40 µg/ft^2 varied from 18% (cut holes) to 57% (window repair), 34% for all dust creation activities considered together (Table 6). The change in the percent of samples exceeding the floor comparison value from Stage 1 to Stage 4 was marginally significant only for the cut holes activity, which showed a 27% decrease (McNemar's test; p=0.083) (Table 7). Considering all dust creation activities together, there was only a 1% increase in the percent of samples exceeding the floor comparison value from pre-work to post-final cleaning (McNemar's test; not significant, p=0.841). Of the pre-work floor samples that had results exceeding 40 µg/ft^2 before work, almost half (45%) still exceeded the floor standard after final cleaning was completed (Table 6, row 7).

Although the overall increase in the percent of samples exceeding 40 µg/ft^2 from pre-work to post-final cleaning was not significant, it should be noted that of the samples that exceeded 40 µg/ft^2 after final cleaning, dust lead loadings for 70% of the floor samples increased from pre-work to post-final cleaning (Table 6, row 9). This percentage did not substantially change (65%) when screening out sample results that increased by less than 10 µg/ft^2 for floors (table 6, row 10).

As shown in Table 6, row 11, of the pre-work floor sample results that were *less than* 40 µg/ft^2, almost one-third (13 out of 45, or 29%) exceeded 40 µg/ft^2 after final cleaning. Comparing data in rows 9 and 11, of the 16 floor sample results that had both post-final cleaning results above 40 µg/ft^2 *and* an increase from pre-work to post-final cleaning, results for 13 were less than 40 µg/ft^2 before work began but greater than 40 µg/ft^2 after final cleaning. Because these 13 activities (performed in 12 dwellings) may be of particular concern, they were examined more closely to identify any discernible trends in region, type of weatherization activity performed, building type, building age, ownership, and other non-weatherization activities occurring in the vicinity of the target activity. Overall, RI had 43% (25/58) of the total units that were enrolled in the study, but had 92% (11/12) of the units that had low pre-work/high post-final cleaning floor results. Window replacement, conducted almost solely in RI, accounted for 38% (27/71) of the dust creation activities that were studied but accounted for 54% (7/13) of the low pre-work/high post-final cleaning results. Building type, building age, and ownership trends in the dwellings that had low pre-work/high post-final cleaning results tended to match those found in RI overall. The percentage of dwellings with low pre-work/high post-final cleaning results were split between single family (42%) and 2-4 unit buildings (50%) (versus a 55%/24% split overall), 92% of buildings were pre-1930 (versus 78% overall), and 58% (7/12) of the low pre-work/ high post-final cleaning dwellings were owner-occupied (versus 79% overall). As will be discussed in detail below in Section 5.3, non-weatherization activities (e.g., resident or pet movement in study areas) occurred for 21% of all activities studied (15/71); however, non-weatherization activities occurred during data collection or during one-hour waiting periods for 31% (4/13) of the low pre-work/high post-final cleaning activities.

Logistic regression modeling (with nesting to account for inclusion of multiple rooms from the same dwelling) was conducted to identify housing characteristics that predict the increases in floor dust lead loadings for these 13 activities. State was found to be the only significant predictor of increases in floor dust lead loading from below comparison values pre-work and above comparison values post-final cleaning ($p=0.018$), with 26% of dust creation activities in RI resulting in an increase from pre-work to post-final cleaning, while only 5% increased for IN and MD combined.[11] If an effect for state was not included in the model, then owner/rental was the only variable at least marginally significant ($p=0.056$), with 11% of the owner-occupied units resulting in an increase from pre-work to post-final cleaning while 35% of the rentals increased. However, since almost all the rental properties were located in RI, it is not possible to determine if the risk factor for increases is being in RI or being a rental property.

5.2 Dust Creation Activity Results for Windows

As shown in Table 5, for the window repair and the window replacement dust creation activities combined, pre-work GMs for sills and troughs were 828 and 15,556 $\mu g/ft^2$, respectively. Eighty-five percent of pre-work sill results and 100% of pre-work trough results exceeded the comparison values of 250 and 400 $\mu g/ft^2$ (Table 6). When both window dust creation activities were considered together, the post-final cleaning GMs for sills and troughs were 375 and 177 $\mu g/ft^2$, respectively. For both activities, the GM for both sills and troughs decreased from pre-work to post-final cleaning, with significant reductions for window repair sills (paired t-test; $p=0.085$, marginal), window replacement sills (paired t-test; $p=0.015$) and window replacement troughs (paired t-test; $p<0.001$) (Table 7). As shown in Table 7, considering both window dust creation activities together, significant reductions for both sills (55% decrease, $p=0.003$) and troughs (99% decrease, $p<0.001$) were observed from pre-work to post-final clean.

Overall, after final cleaning of the work locations, almost two-thirds (61%) of sill results and one third (34%) of trough results exceeded their respective comparison values (Table 6). As sown in Figure 1, 88% of sills and 39% of troughs were judged by the risk assessor to be smooth and cleanable before work began. The percentage of units that had sill post-final cleaning results that exceeded 250 $\mu g/ft^2$ was 67% for window repair and 59% for window replacement. The

[11] Because Indiana had no increases, it had to be combined with Maryland for modeling purposes.

percentage of units that had trough post-final cleaning results that exceeded 400 µg/ft^2 was 100% for window repair and 22% for window replacement. Considering both window weatherization activities together, there was a significant 24% decrease in the percent of samples exceeding the sill comparison value from pre-work to post-final cleaning (McNemar's test; p=0.033) (Table 7). Window troughs showed a 66% decrease in the percent of samples exceeding the trough comparison value from pre-work to post-final cleaning.[12] However, of the pre-work sill and trough samples that had results exceeding their respective standards before work, 61% and 34%, respectively, still exceeded standards after final cleaning was completed (Table 6, row 7).

While the percent of samples exceeding the sill and trough comparison values significantly decreased from pre-work to post-final cleaning, of the samples that exceeded their respective comparison values after final cleaning, 40% and 18% of sill and trough samples, respectively, actually showed an increase from pre-work to post-final cleaning (Table 6, row 9). These percentages did not substantially change when screening out sample results that increased by less than 100 µg/ft^2 for sills or troughs (Table 6, row 10). As shown in Table 6, row 11, of the pre-work sill sample results that were *less than* 250 µg/ft^2, 60% (3 out of 5) exceeded 250 µg/ft^2 after final cleaning.

5.3 Other Activities that May Have Influenced Dust Creation Activity Results

Overall, a total of 71 dust creation activities were performed in 42 dwellings. On early data collection forms, inspectors were provided a space on Form 3 to list comments concerning other non-weatherization activities occurring in the target dust creation activity areas. A completed early Form 3 was available for 63 activities in 35 dwellings. Based on comments provided on early Form 3's, non-weatherization activities were reported for 11 activities of the 63 activities (i.e., in 11 of the 35 dwellings). Later in the study, Form 7 was introduced, which allowed inspectors to more formally document these other non-weatherization activities, as well as other weatherization activities and cleaning practices that may have influenced dust creation results. A completed Form 7 was available for eight dust creation activities in seven dwellings. Based on Form 7 information, non-weatherization activities such as resident movement and pet movement in target activity areas occurred for 4 of the 8 dust creation activities (in 4 of the 7 dwellings) either during target activity work or during the 1-hour waiting period after cleaning was finished. Looking at Form 7 and early Form 3 information together, non-weatherization activities occurred in dust creation target areas for a total of 15 of the 71 dust creation activities (21%), or 15 of 42 dwellings (36%).

The remaining information about activities (e.g., cleaning practices and other indoor and outdoor non-target weatherization activities) that may have influenced dust creation activity results is available only from the eight Form 7's completed later in the study. Field investigators reported that for 7 of the 8 activities (88%), contractors used horizontal containment in the dust creation target activity location, but vertical containment was used for only 1 activity (13%). Work locations for 6 dust creation activities (75%) were vacuumed after work was completed, and 5 of the 8 locations (63%) were wet-wiped; however, investigators reported that a shop-vacuum with a regular filter instead of a HEPA filter was often used. HEPA vacuuming was not repeated after wet wiping for any of the eight dust creation activities having a Form 7. No other indoor weatherization tasks were performed in the target activity location during the target activity;

[12] McNemar's test of significance could not be calculated for the window troughs because 100% of the pre-work samples exceeded the trough standard.

however, other indoor weatherization tasks were performed for 2 of the 8 activities (25%) during the 1-hour waiting period. Outdoor weatherization tasks near the target activity location occurred for 2 of the 8 activities (25%).

6.0 DUST DISPERSION ACTIVITY RESULTS

Table 8 presents GM dust lead loadings, by surface type and dust dispersion activity, in study dwellings before and after dust dispersion activities. The pre-work samples were collected directly from the floor or sill surface, while the post-work samples were collected from sheeting that was placed over the surface after the pre-work sample was collected but before the dust dispersion activity began. Table 9 presents the number and percent of pre- and post-work samples whose dust lead loading results exceeded comparison values for dust dispersion activities. Table 10 summarizes the changes in GM dust lead loading and in exceedances from pre-work to post-work for the two dust dispersion activities. In these three tables, two types of post-work data are presented: (1) post-work results for the sheeting placed over the floor or sill surface, and (2) the sum of the pre-work floor or sill surface result and the post-work sheeting result for the same surface, referred to as the “post-work sum.” These sums were calculated based on the assumption that the dust dispersion activity could have added lead contamination to the amount of lead initially present on the given surface. This sum may overestimate the amount of lead contributed by the dust dispersion activity, because lead dust could also be expected to be *removed* from the surface by the action of the dust dispersion activity due to re-entrainment, i.e., leaded dust present on the surface may move off the surface by the action of the activity.

Table 8: GM (GSD) Dust Lead Loadings (µg/ft^2) for Target Dust Dispersion Activities, by Component Type

	Blower Door (n=22)		Dense-packing Walls (n=23)
	Floor	**Sill**	**Floor**
Pre-Work[a]	10 (4)	142 (4)	16 (5)
Post-Work (sheeting)[a]	3 (3)	8 (5)	6 (4)
Post-Work Sum[b]	14 (3)	159 (4)	26 (4)

[a]Pre-work samples were collected directly from the listed surface (i.e., floor or sill). The post-work sample was collected from the sheeting directly over the location that was sampled before work.
[b]Post-work sum GM (GSD) values were calculated by first summing, for each set of samples, the pre-work result with the post-work result, then calculating the GMs of the sum values.

Table 9: Number (%) of Samples With Dust Lead Loadings Exceeding Comparison Values[a] at Each Work Stage for Dust Dispersion Activities, by Component Type

	Blower Door (n=22)		Dense-packing Walls (n=23)
	Floor	**Sill**	**Floor**
Pre-Work	4 (18%)	9 (41%)	10 (43%)
Post-Work (from sheeting)	0 (0%)	1 (5%)	2 (9%)
Post-Work Sum[b]	5 (23%)	9 (41%)	11 (48%)
Of post-work sum samples exceeding comparison, # (%) samples w/increase, pre-work to post-work	5 (100%)	9 (100%)	11 (100%)
Of post-work sum samples exceeding comparison # (%) samples w/increase of at least 10 µg/ft^2 (floors) or 100 µg/ft^2 (sills), pre-work to post-clean	2 (40%)	1 (11%)	11 (100%)

[a]Comparison values for floors, sills, and troughs are 40 µg/ft^2, 250 µg/ft^2, and 400 µg/ft^2, respectively. Compliance with EPA clearance standards is not technically required in weatherization work. Standards are shown for comparison purposes.
[b]Post-work sum values were calculated by summing, for each set of samples, the pre-work result from the specified surface with the post-work result from sheeting that had been placed over the specified surface.

Table 10: Summary of Changes in GM Dust Lead Loading and Exceedances for Dust Dispersion Activities

	Blower Door (n=22)		Dense-packing Walls (n=23)
	Floor	**Sill**	**Floor**
% Change in GM from Pre- to Post-Work (p-value)[a]	40% increase (p=0.001)	12% increase (p=0.001)	63% increase (p=0.002)
Change in percentage of samples that exceed comparison values[b] from pre- to post-work sum (p-value)[c]	5% increase (p=0.317)	0% increase[d]	5% increase (p=0.317)

[a]Based on paired t-tests of log-transformed dust lead loadings.
[b]Comparison values were 40, 250, and 400 µg/ft^2 for floors, sills, and troughs, respectively.
[c]Based on McNemar's test.
[d]McNemar's test cannot be calculated when the percent exceedances at either stage are either 100% or 0%.

6.1 Blower Door Testing

Pre-work and post-work sum[13] GM dust lead loadings on floors were 10 and 14 µg/ft^2, respectively, 142 and 159 µg/ft^2 on sills (Table 8). For floors, while all of the post-work sheeting results were below 40 µg/ft^2, 4 (18%) of the 22 pre-work samples and 5 (23%) of the 22 post-work sum values exceeded 40 µg/ft^2 (Table 9). For sills, while only one (5%) of the 22 post-work sheeting results exceeded 250 µg/ft^2, 9 (41%) of the 22 pre-work and post-work sum values exceeded 250 µg/ft^2.

As shown in Table 10, the GM for both floors and sills significantly increased from pre-work to post-work sum, with a 40% increase in GMs for floors (paired t-test; p=0.001) and a 12% increase in GMs for sills (paired t-test; p=0.001). However, the percentage of samples that exceeded comparison values did not significantly change from pre-work to post-work sum (McNemar's test).

[13] For dust dispersion activities, the pre-work and post-work sum values were calculated for each sample by adding the pre-work floor or sill loading and the post-work loading result for the sheeting placed over the floor or sill location.

6.2 Dense-packing Walls

Pre-work and post-work sum GM dust lead loadings on floors were 16 and 26 $\mu g/ft^2$, respectively (Table 8). Ten (43%) of the 23 pre-work dense-packing samples exceeded 40 $\mu g/ft^2$, and 11 (48%) of the 23 post-work sum results exceeded 40 $\mu g/ft^2$.

As shown in Table 10, the GM for floors significantly increased from pre-work to post-work sum, with a 63% increase (paired t-test; $p=0.002$). However, the percentage of samples that exceeded comparison values did not significantly change from pre-work to post-work sum (McNemar's test, $p=0.317$).

6.3 Other Activities that May Have Influenced Dust Dispersion Activity Results

Information on other activities that may have influenced the dust dispersion results was collected for 41 dust dispersion activities in 24 dwellings. Locations for five of the 41 activities (12%) were vacuumed after work was completed, not to clean the dust dispersion area itself but to clean from some other activity occurring in close proximity to the dust dispersion sample location. Locations of two dust dispersion activities (5%) were wet-wiped and one location (2%) was vacuumed again after wet-wiping; however, investigators reported that a shop-vacuum with a regular filter instead of a HEPA filter was used. These results are not surprising because dust dispersion sample locations were not the sites of weatherization work and thus were not areas that weatherization contractors would routinely clean. Other outdoor weatherization tasks were performed in the target activity location during the target activity itself for 4 of the 41 activities (10%) and during the one-hour waiting period for 16 activities (39%). This outdoor activity was usually dense-packing of walls that occurred during the one-hour waiting period for the post-work blower door samples. Other indoor weatherization tasks (unspecified) were performed in the target activity area during 2 of the 41 activities (5%). Non-weatherization activities such as resident movement and pet movement in target activity areas occurred during the target activity work for 19 of the 41 activities (46%) and during the one-hour waiting period for 29 of the 41 activities (71%).

7.0 MODELING RESULTS

As discussed in Section 3.2, analysis of covariance was used to identify a set of variables that were significantly associated with the following dust lead loading measures (after log-transformation): (1) pre-work dust lead loading on floors, sills, and troughs; (2) dust lead loading on floors, sills, and troughs after final cleanup for dust creation activities; and (3) dust lead loading on floors and sills after dust dispersion activities. Table 11 presents those variables that were statistically significant in these models.

Table 11: Statistically Significant Predictor Variables in the Analysis of Covariance Models

Model and Effect	Estimate	Standard Error	P-value
Pre-Work Floor Dust Lead Loading (n=131):			
• Intercept	3.3097	0.2908	<.0001
• Single family detached (versus not)	-0.9631	0.3822	0.0139
Pre-Work Sill Dust Lead Loading (n=71):			
• Intercept	6.3903	0.3038	<.0001
• State=IN	-2.0009	0.4082	<.0001
• State=MD[a]	0.02249	0.8528	0.9791
• State=RI[a]	0	.	.
Pre-Work Trough Dust Lead Loading (n=26):			
• Intercept	10.2467	0.3934	<.0001
• Bare or Painted- Smooth and Cleanable (versus Painted- Not Smooth and Cleanable)	-1.3387	0.4514	0.0313
Dust Creation Activity, Post-Final Cleaning Floor Dust Lead Loading(n=62):			
• Intercept	1.5816	0.3375	<.0001
• Log floor dust lead loading at Stage 3	0.4331	0.08349	<.0001
Dust Creation Activity, Post-Final Cleaning Sill Dust Lead Loading (n=27):			
• No variables were significant			
Dust Creation Activity, Post-Final Cleaning Trough Dust Lead Loading (n=20):			
• Intercept[a]	0.1909	0.6120	0.7594
• Average Paint Condition[b] on components disturbed by activity[c]	2.4681	0.06565	<.0001
Dust Dispersion, Post-Work Sum Floor Dust Lead Loading (n=59)[d]:			
• Intercept	1.8834	0.3620	<.0001
• Blower Door Test (versus Dense-Pack Walls)	-1.1339	0.3159	0.0089
• Building Constructed pre-1930 (versus post)	1.5516	0.3589	0.0035
• Number of deteriorated interior systems (0, 1 or 2)	0.8268	0.3019	0.0290
• Average Paint Lead Loading on components disturbed by activity [b]	0.1973	0.07916	0.0414
Dust Dispersion, Post-Work Sum Window Sill Dust lead Loading (n=44):			
• No variables were significant			

[a]Variable was not found to be significant but was presented for comparison with other similar variables in the table.
[b]The paint condition of each component was coded 1=intact, 2=fair, and 3=poor. Values of "not painted" or "not present" were set at 1=intact. The unit average on disturbed components, ranging from 1=intact to 3=poor, was used in the model.
[c]Surfaces disturbed for each activity were: cut holes=walls/ceilings; window repair=windows; window replacement=windows; weatherstrip doors=doors.
[d]Post-Work Sum=Pre-work floor or sill dust lead loading added to post-work sheeting dust lead loading.

7.1 Pre-Work Model Outcomes

No pattern of variables significantly influencing pre-work dust lead loadings could be discerned from the models to predict pre-work dust lead loadings. In the pre-work dust lead models, only three variables were found to be significant predictors: (1) housing type (significant only for pre-work floor dust lead loadings, with single family detached housing having lower pre-work floor dust lead loadings than other types of dwellings); (2) state (significant only for pre-work sill dust lead loadings, with IN having lower pre-work sill dust lead loadings than either RI or MD); and (3) pre-work surface condition (significant only for pre-work trough dust lead loadings, with smooth and cleanable bare surfaces or painted troughs having lower dust lead loadings than not smooth and cleanable painted troughs).

7.2 Post-Final Cleaning Model Outcomes for Dust Creation

Model outputs for the floors after final cleaning of dust creation work areas indicated that Stage 3 (after weatherization work was done and containment was removed, but before final cleaning) dust lead loadings were significant predictors of floor dust lead loadings after contractors had completed final cleaning of dust creation work areas, with floors that had higher Stage 3 dust lead loadings having higher dust lead loadings after final cleaning. There were no significant predictors of post-final clean sill dust lead loadings. Initial paint condition was a significant predictor of trough dust lead loadings, with worse paint condition yielding higher post-final cleaning dust lead loadings. These modeling results, especially those on floors, suggest that contractors need to exercise care when removing containment and need to more thoroughly clean dust creation areas after containment is removed.

7.3 Post-Work Model Outcomes for Dust Dispersion

There were no significant predictors of post-work sum sill dust lead loadings for dust dispersion activities. Four variables were found to be significant predictors of the post-work sum floor dust lead loadings for dust dispersion activities:

- The type of dust dispersion activity, with blower door tests yielding lower floor dust lead loadings than dense-packing of walls;
- Housing age, with homes constructed before 1930 having higher post-work sum floor dust lead loadings than post-1930 homes;
- Number of baseline interior deteriorations, with higher post-work sum floor dust lead loadings when there were more interior deteriorations; and
- Average paint lead loading on components disturbed by the activity, with higher post-work sum floor dust lead loadings when there were higher average paint lead loadings.

The dust dispersion modeling results suggest that more leaded dust may be dispersed in older homes that have deteriorated lead-based paint.

8.0 RE-CLEANING RESULTS

As previously shown in Table 6, several dust creation activity samples had dust lead loadings exceeding comparison values after final cleanup (Stage 4). As discussed in Section 2.5.3, these dwellings were to be re-visited, re-cleaned, and re-sampled. Of the 27 dwellings that had at least one post-final cleaning sample that exceeded comparison values at the initial visit, 18 dwellings

(67%) were re-visited for a re-cleaning. A summary of re-cleaning results is provided in Table 12. Overall, 7%, 30%, and 29% of floor, window sill, and window trough samples had dust lead loadings that exceeded their respective comparison values after re-cleaning was completed. These percentages are lower than the percentages of samples exceeding comparison values after Stage 4 (final cleaning – see Table 6). All of the floors and 90% of the sills that were re-tested were judged to be cleanable surfaces, while only 14% of re-tested troughs were cleanable. Based on information provided by the field investigators for 11 of the dwellings that were re-cleaned, 60% of dwellings were vacuumed; 100% were wet-wiped, and 18% were re-vacuumed after wet-wiping. As with the initial visit, investigators reported that a shop-vacuum with a regular filter was sometimes used instead of a HEPA filter.

9.0 CONCLUSIONS

The results of this study indicate that levels of leaded dust created by typical weatherization work in older housing with lead-based paint are likely to be well above EPA clearance levels, and therefore pose substantial risk to children.

9.1 Dust Creation Activities

Study results indicate that leaded dust is prevalent in older homes that contain lead-based paint (greater than 1.0 mg/cm^2), particularly on window sills and window troughs, which had 85% and 100% of pre-work window sill and window trough results exceeding comparison values of 250 and 400 $\mu g/ft^2$, respectively. Almost one-third of pre-work floor samples exceeded 40 $\mu g/ft^2$. GM sheeting dust lead loadings were higher at Stage 2 (142 $\mu g/ft^2$ on floor sheeting for all dust creation activities together) than at any other stage (27, 42, and 24 $\mu g/ft^2$ for pre-work, Stage 3, and post-final cleaning stages, respectively). This confirms the benefit of placing appropriate containment in all work areas, particularly for window-related activities, which showed the highest Stage 2 floor sheeting dust lead loadings. After the sheeting was removed but before the contractors cleaned the work area (Stage 3), floor dust lead loadings were lower than those found on the sheeting itself, but were still significantly increased above the pre-work levels, affirming the need for areas to be cleaned after containment is removed. After contractors completed their cleanup of work areas, there was a significant decrease in both GM dust lead loadings and in the percent of samples exceeding comparison values from pre-work levels on window sills and window troughs; however, there was no significant change in floor dust lead loadings between pre-work and post-final cleaning.

GM floor dust lead loadings measured after final cleaning was done were not significantly different from those measured before work began, while geometric mean window sill and trough dust lead loadings were significantly lower after work was done. When viewed through these measures of central tendency, these data indicate that the current work practices examined in this study have either a positive or generally little impact on potential lead dust exposures. However, despite the decreases observed between pre-work and post-final cleaning, of the samples that exceeded comparison values after final cleaning, dust lead loadings for 70%, 40%, and 18% of floor, sill, and trough samples, respectively, showed an increase in dust lead loadings from pre-work to post-final cleaning. These percentages did not substantially change when

Table 12: Number (%) of Samples With Dust Lead Loadings Exceeding Comparison Values at Re-cleaning Visit for Dust Creation Activities, by Component Type

	Cut Holes Walls/Ceilings	Window Repair			Window Replacement			Weatherstrip Doors	All Dust Creation Activities		
	Floor (n=4)[a]	Floor (n=2)	Sill (n=2)	Trough (n=3)	Floor (n=6)	Sill (n=8)	Trough (n=4)	Floor (n=3)	Floor (n=15)	Sill (n=10)	Trough (n=7)
# (%) exceeding comparison values	0 (0%)	1 (50%)	1 (50%)	2 (67%)	0 (0%)	2 (25%)	0 (0%)	0 (0%)	1 (7%)	3 (30%)	2 (29%)
#(%) cleanable surfaces	4 (100%)	2 (100%)	1 (50%)	1 (33%)	6 (100%)	8 (100%)	0 (0%)	3 (100%)	15 (100%)	9 (90%)	1 (14%)

[a]Sample size of 4 is greater than the sample size of 2 shown in Table 6 (Stage 4) because Table 6 values were matched across all stages, but re-cleans are not matched against any other stage. Because some dwellings did not have samples at each stage, sample sizes in Table 6 may be smaller than those in Table 12.

screening out sample results that increased by less than 10 $\mu g/ft^2$ for floors and by less than 100 $\mu g/ft^2$ for sills and troughs. While we could not account for spatial variability or sampling error in the study dataset, the noted increases were larger than would be expected from sample variability, as evidenced by the fact that the percentages of sample results exceeding comparison values did not substantially change when screening out sample results that increased by less than 10 $\mu g/ft^2$ for floors and by less than 100 $\mu g/ft^2$ for sills and troughs.

In conclusion, a substantial amount of leaded dust is generated during various weatherization work activities such as cutting holes, window repair, and window replacement. In particular, a large amount of leaded dust was generated on floor sheeting by the cut holes weatherization activity, even though little leaded paint was found in cut hole wall and ceiling work locations by XRF testing. By contrast, relatively little dust was generated by the door weatherstripping work activity; however, this was not surprising given the fact that this activity primarily consisted of placing weatherstripping along the sides of the door, not in planing or sanding either doors or thresholds.

If dust generated by the dust creation activities fall on containment and if the area is cleaned up after work is completed, significant reductions in leaded dust levels can be achieved; however, cleaning may not be sufficient to reduce loadings to pre-work levels or to below clearance levels. Although there was no significant change in the GM floor dust lead loadings and a significant decrease in GM sill and trough dust lead loadings from pre-work to post-final cleaning, a moderate number and percent of dwellings had dust lead loadings on these surfaces that exceeded comparison values after final cleaning, some in dwellings with pre-work dust lead loadings that were below comparison values. While overall trends may generally indicate that weatherization work is not having a substantial impact on dust lead loading in homes, individual activities may have an adverse impact that must be taken into consideration.

Modeling results indicated that the higher the dust lead loadings remaining on floors after containment is removed but before cleanup is performed, the higher the post-final cleaning floor dust lead loadings. This finding, in conjunction with the finding that substantial amounts of lead dust are created during the work activity (i.e., at Stage 2), suggests that contractors need to exercise care when removing containment and need to more thoroughly clean dust creation areas after containment is removed. At the beginning of this study, the study hypotheses assumed that the training weatherization contractors received on the proper methods to conduct paint-disturbing weatherization work in older homes would protect children and others in those homes from increased dust lead loadings. The observations taken by the study team show that current training alone is not adequate to assure safe work practices and compliance with the training methodology. Because systematic observations of compliance with lead-safe work practices were not part of the original study design, it is not possible to determine conclusively whether dust lead loadings, especially on floors, would have decreased if work practices were changed. It is possible that even if cleaning that complied with lead-safe work practices training, weatherization workers need to apply more intensive cleaning methods. Dust-wipe testing following weatherization work would serve as an important means of ensuring adequate cleaning and occupant safety.

As discussed in Section 5.3, other activities were observed during the weatherization work and field data collection, including movement of residents, their pets, and movement of workers through sample areas. These influences may have impacted results, but it was not possible to quantify this impact. Future studies should more quantitatively document or isolate such activities in order to more fully characterize their potential influence on outcomes.

9.2 Dust Dispersion Activities

Pre-work dust dispersion data indicate that leaded dust was prevalent on window sills but not as common on floors in blower door dust dispersion locations. Over 40% of pre-work sill samples exceeded the comparison value of 250 $\mu g/ft^2$. Post-work sheeting results indicated that little leaded dust was generated by either blower door testing or dense-packing of walls; however, the increase in GM dust lead loadings from pre-work to post-work (i.e., the sum of pre-work surface and post-work sheeting results) was significant for both types of activities on both floors and sills. The percentage of sample results that exceed comparison values did not significantly change from pre-work to post-work sum. The findings are similar to the earlier Cavallo study which suggested that dust dispersion activities such as blower door tests can increase dust lead loadings, but the change is not large enough to trigger EPA action levels (Cavallo 2000). When EPA action levels were exceeded, the dust lead loadings were generally of concern prior to the test.

The dust dispersion modeling results for floors suggest that in an older home with deteriorated lead-based paint, workers must use caution when performing dust dispersion activities. For example, alternative engineering controls could be used such as positive pressure for blower door testing.

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Appendix A: Data Collection Forms

A set of data collection forms were developed before field sample collection began and were modified as needed during the data collection period. Most forms received their final modification before data collection formally began in December 2004. Therefore, with the exception of Form 7, the majority of data were collected on the final versions of all forms.

Form 1, Baseline Condition (Figures A-1 and A-2): Both pages of this form remained unchanged over the data collection period.

Form 2, Lead Paint XRF Testing (Figures A-3 through A-6): The original page 1 of this form (Figure A-3) did not identify mandatory XRF sampling locations; therefore a modified versions indicated required locations with an asterisk (Figure A-4). Page 1 was modified again in January 2005 (Figure A-5) to allow more rows to record XRF results for multiple door components. Page 2 of this form was unchanged over the data collection period (Figure A-6).

Form 3, Dust Creation Study Lead Dust Wipe Sampling on Floors (Figures A-7 through A-11): Although the title changed, Page 1 of this form (Figure A-7) was unchanged over the data collection period. The original design of page 2 (Figure A-8) was modified to allow the risk assessor to answer questions 1 through 7 for both target activities (Figure A-9). Once we realized that all floor samples could not be collected along the protocol-specified floor grid, we added a third page to provide a blank sample location map for each target activity so that risk assessors could show the actual sample locations when grid sampling was not feasible (Figure A-10). The first rule was to sample according to the grid whenever feasible; therefore, the “ideal” grid layout was provided on Figure A-10. The second rule was that if alternative sampling locations had to be used, the risk assessor could not overlap and re-sample locations that were sampled during an earlier step, and the risk assessor must document the distance of the sample location from the work location. The modified Form 3 allowed the risk assessor to delineate these measurements. Finally, pages 2 and 3 were consolidated in July 2005 when Questions 1 through 7 that appeared on the original Form 3 page 2 were moved to a new form, Form 7 (see Figure A-14), and the grids and QC table were placed onto a single Form 3 page 2 (Figure A-11).

Form 4, Dust Creation Study Lead Dust Wipe Sampling on Windows (Figures A-12 through A-13): The original form (Figure A-12) required that surface condition be judged only for pre-work samples; however, this form was later modified (Figure A-13) to include a surface condition column for post-final cleaning samples, to account for the fact that window repair and window replacement activities may have changed the surface condition of sills and/or troughs.

Form 5, Dust Dispersion Study Lead Dust Wipe Sampling (Figures A-14 through A-16): The original form (Figure A-14) assumed that blower door samples would always be collected from the living room and kitchen; however, these two rooms could not always be feasibly sampled, so the form was modified to leave room function blank (Figure A-15). The first table on the original form was also modified for the risk assessor to record the length and width of sill sample areas. The form was modified again (Figure A-16) to allow the risk assessor to record results for a second set of post-work wipe samples and the component location within the room.

Form 6, De-Enrollment (Figure A-17): This form was unchanged over the data collection period.

Form 7 (Figure A-18): This form did not exist at the beginning of the project but was added after the study team decided it needed to gather more information about the types of activities performed by workers and residents during and after the various sample collection stages.

Form 1 - Baseline Condition

Page 1 of 2

DOE LEAD-SAFE WEATHERIZATION DRAFT 08/25 /04

Building ID	Dwelling ID

Address	St. No	Street Name	Apt No.	City	State	Zip Code
Residence						

1. Type of Building: ☐
   1=Single detached
   2=Single attached
   3=2-4 units
   4=More than 4 units
   5=Other ____________

2. Exterior Building Materials: ☐
   1=Brick
   2=Stucco
   3=Wooden Clapboard/Shingles
   4=Asbestos Shingles
   5=Asphalt Shingles
   6=Aluminum Siding
   7=Vinyl Siding
   8=Other

3. Year of Construction: ☐
   1=Pre-1910
   2=1910-1919
   3=1920-1929
   4=1930-1939
   5=1940-1949

4. Tenure: ☐
   1=Rental
   2=Owner Occupied
   3=Other, specify ____________

For Q 5-11, Code: Y=Yes, N=No, D=Does Not Apply

Exterior of Dwelling Unit

5. Roofs, gutters, downspouts: ☐
   Roof missing parts or weathering surfaces or has extensive holes or cracks. Gutters or downspouts broken or missing.

6. Walls and Siding: ☐
   Large cracks or holes, missing or broken components requiring repairs or substantial painting.

7. Windows and doors: ☐
   Two or more windows or doors broken, missing, or boarded up.

8. Porch or steps: ☐
   Major elements broken or missing.

9. Foundation: ☐
   Major cracks or missing material.

Interior of Dwelling Unit

10. Walls, ceilings, doors and trim: ☐
    Extensive cracks in plaster; requires major painting; missing trim; doors need repair or replacement.

11. Floors: ☐
    Loose, missing or cracked floor surfaces, surface is worn; deteriorated carpeting.

12. Main Heating Source (check one) ☐
    1=Radiant Heat (hot water/steam)
    2=Radiant Heat (electric)
    3=Forced hot air with ducts
    4=Hot air without duct
    5=Other (specify): ____________

Inspector/Auditor (print name):	Initials:	Date (mm/dd/yy)
Risk Assessor (print name):	Initials:	Date (mm/dd/yy)

Figure A-1: Form 1 page 1 (unchanged over the course of data collection).

Form 1 - Baseline Condition

Page 2 of 2

DOE LEAD-SAFE WEATHERIZATION

DRAFT 06/09/04

Building ID	Dwelling ID

Address	St. No	Street Name	Apt No.	City	State	Zip Code
Residence						

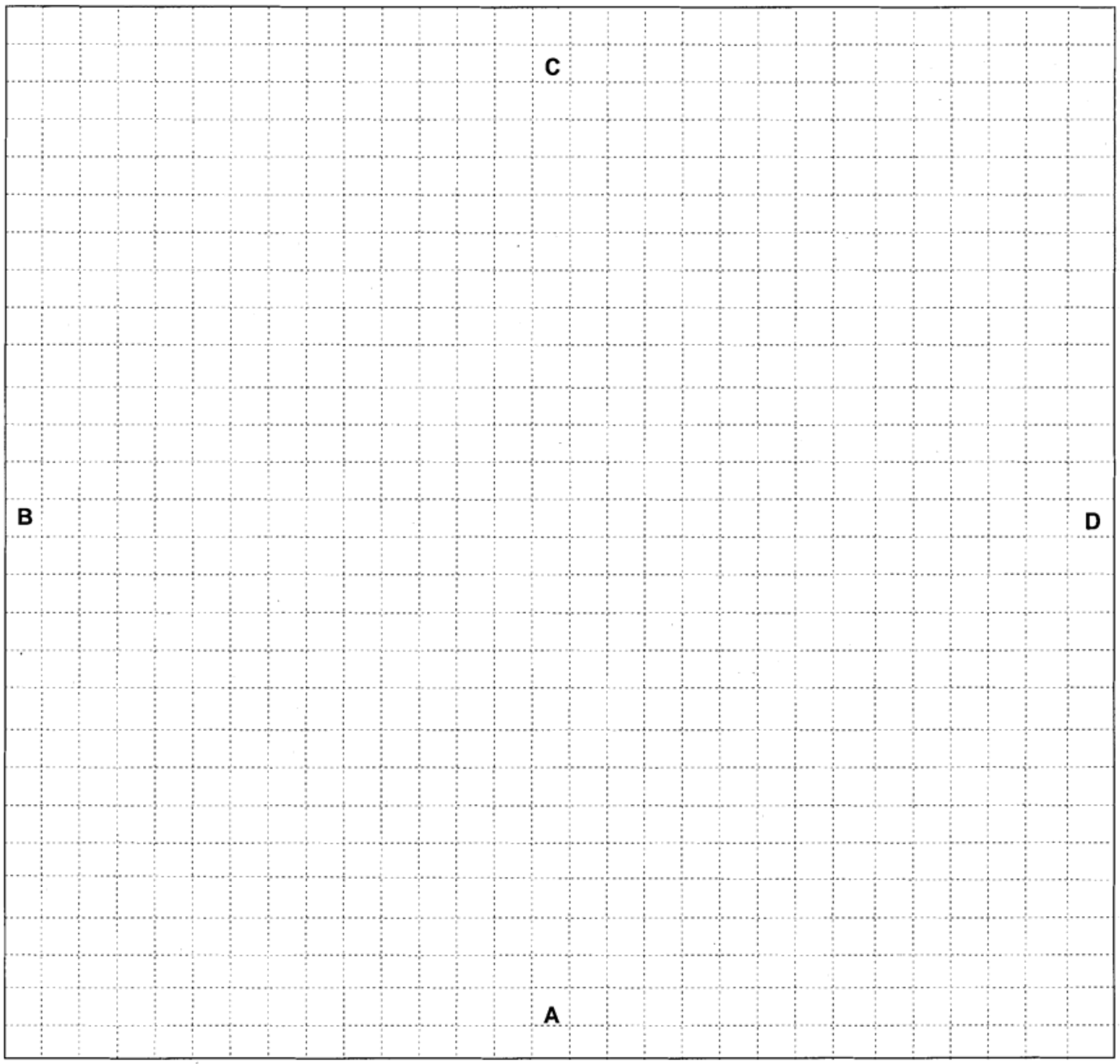


Figure A-2: Form 1 page 2 (unchanged over the course of data collection).

Form 2 - Lead Paint XRF Testing
Page 1 of 2

DOE LEAD-SAFE
WEATHERIZATION
DRAFT 06/09/04

Building ID	Dwelling ID

Address	St. No	Street Name	Apt No.	City	State	Zip Code
Residence						

Room Function	Component	Location	Condition	XRF Result (mg/cm2)
Living Room	Exterior Window Sash			
Living Room	Window Jamb			
Living Room	Interior Window Sill			
Living Room	Window Trough			
Kitchen	Exterior Window Sash			
Kitchen	Window Jamb			
Kitchen	Interior Window Sill			
Kitchen	Window Trough			
Rm: ________	Exterior Window Sash			
Rm: ________	Window Jamb			
Rm: ________	Interior Window Sill			
Rm: ________	Window Trough			
Rm: ________	Exterior Door (must open into house)			
Rm: ________	Knee Wall A, B, C, D			
Rm: ________	Knee Wall A, B, C, D			

Condition: 1=Intact; 2=Fair; 3=Poor; 4=Not painted; 5=Not Present
Location: Code A1, A2, A3, B1, B2, etc. Use wall codes (A, B, C or D) and number windows and doors from left to right

Risk Assessor (print name):	Initials:	Date (mm/dd/yy)

Figure A-3: Form 2 page 1 as it appeared in the original research plan.

Form 2 - Lead Paint XRF Testing
Page 1 of 2

DOE LEAD-SAFE WEATHERIZATION DRAFT 10/21/04

ilding ID	Dwelling ID

Address	St. No	Street Name	Apt No.	City	State	Zip Code
Residence						

Room Function	Component	Location	Condition	XRF Result (mg/cm2)
Living Room	Exterior Window Sash*			
Living Room	Window Jamb*			
Living Room	Interior Window Sill*			
Living Room	Window Trough*			
Kitchen	Exterior Window Sash*			
Kitchen	Window Jamb*			
Kitchen	Interior Window Sill*			
Kitchen	Window Trough*			
Rm: ________	Exterior Window Sash			
Rm: ________	Window Jamb			
Rm: ________	Interior Window Sill			
Rm: ________	Window Trough			
Rm: ________	Exterior Door (must open into house)*			
Rm: ________	Knee Wall A, B, C, D			
Rm: ________	Knee Wall A, B, C, D			

ondition: 1=Intact; 2=Fair; 3=Poor; 4=Not painted; 5=Not Present
cation: Code A1, A2, A3, B1, B2, etc. Use wall codes (A, B, C or D) and number windows and doors from left right

* Required in every unit.

Risk Assessor (print name):	Initials:	Date (mm/dd/yy)

Figure A-4: Form 2 page 1 as modified in October 2004.

Form 2 - Lead Paint XRF Testing
Page 1 of 2

DOE LEAD-SAFE
WEATHERIZATION
DRAFT 01/11/05

Building ID	Dwelling ID

Address	St. No	Street Name	Apt No.	City	State	Zip Code
Residence						

Room Function	Component	Location	Condition	XRF Result (mg/cm2)
Living Room	Exterior Window Sash*			
Living Room	Window Jamb*			
Living Room	Interior Window Sill*			
Living Room	Window Trough*			
Kitchen	Exterior Window Sash*			
Kitchen	Window Jamb*			
Kitchen	Interior Window Sill*			
Kitchen	Window Trough*			
Rm: ________	Exterior Window Sash			
Rm: ________	Window Jamb			
Rm: ________	Interior Window Sill			
Rm: ________	Window Trough			
Rm: ________	Exterior Door (must open into house)*			
Rm: ________	Exterior Door - Interior Door Jamb			
Rm: ________	Exterior Door - Exterior Door Jamb			
Rm: ________	Exterior Door - Threshold			
Rm: ________	Knee Wall A, B, C, D			
Rm: ________	Knee Wall A, B, C, D			

Condition: 1=Intact; 2=Fair; 3=Poor; 4=Not painted; 5=Not Present
Location: Code A1, A2, A3, B1, B2, etc. Use wall codes (A, B, C or D) and number windows and doors from left to right

* Required in every unit.

Risk Assessor (print name):	Initials:	Date (mm/dd/yy)

Figure A-5: Form 2 page 1, modified in January 2005.

Form 2 - Lead Paint XRF Testing
Page 2 of 2

DOE LEAD-SAFE
WEATHERIZATION
DRAFT 06/09/04

Building ID	Dwelling ID

Address	St. No	Street Name	Apt No.	City	State	Zip Code
Residence						

Room Function	Component	Location	Condition	XRF Result (mg/cm2)
Rm: ________	Other Wall A, B, C, D			
Rm: ________	Other Wall A, B, C, D			
Rm: ________	Ceiling			
Rm: ________	Ceiling			
Rm: ________	Exterior Window Sash			
Rm: ________	Window Jamb			
Rm: ________	Interior Window Sill			
Rm: ________	Window Trough			

Condition: 1=Intact; 2=Fair; 3=Poor; 4=Not painted; 5=Not Present
Location: Code A1, A2, A3, B1, B2, etc. Use wall codes (A, B, C or D) and numbers windows and doors from left to right

1. Type of XRF instrument ☐
   1=Niton
   2=RMD

2a. Time of initial calibration ☐ 2b. Passed ☐ Y=Yes, N=No

3a. Time of final calibration ☐ 3b. Passed ☐ Y=Yes, N=No

4. If no, action taken: ______________________________

5. XRF Testing performed at: ☐ Energy Audit ☐ Weatherization Visit

Comments:

____
____
____
____

Figure A-6: Form 2 page 2 (unchanged over the course of data collection).

FORM 3: Dust Creation Study Lead Dust Wipe Sampling on Floors (page 1 of 3) or (1 of 2 on MODIFIED)

Status:
I=Initial
R=Reclean

DOE LEAD-SAFE WEATHERIZATION STUDY

Draft 12/22/04

Building ID	Dwelling ID

Address	St. No.	Street Name	Apt No.	City	State	Zip
Residence						

Target Activity	Component location	Dimension disturbed	Room fxn	Surf cond	Stage 1: Floor before work		Stage 2: Sheet After work done		Stage 3: Floor before clean		Stage 4: Floor after final clean	
					Sample #	loading	Sample #	loading	Sample #	loading	Sample #	loading
cut hole knee wall window repair* window replace* plane door wall/ceiling repair												
cut hole knee wall window repair* window replace* plane door wall/ceiling repair												

Extra Stage 2 and Stage 4 Samples (collect at 20% of dwellings)

Target Activity	Stage 2: Sheet After work done						Stage 4: Floor after final clean					
	1 ft LEFT		3 ft LEFT		5 ft LEFT		1 ft CTR		3 ft CTR		5 ft CTR	
	ID	loading	ID	loading	ID	loading	ID	loading	ID	loading	ID	loading
cut hole knee wall window repair* window replace* plane door wall/ceiling repair												

Room Fxn: record room function as recorded on Forms 1 and 2.
Surface Condition: 1=bare, smooth and cleanable, 2=bare, not smooth and cleanable, 3=painted, smooth and cleanable, 4=painted, difficult to clean, 5=carpet, cleanable, 6=carpet, not cleanable.
Note: Record a "Z" in the room function cell if target activity was not studied at this dwelling. Leave remaining cells in that row blank. If samples are collected during a re-clean, fill in only the "floor: after final cleaning" section.
Dimension Disturbed: Dimension of paint area disturbed by target activity. Include units (sq inches, sq feet, linear feet, etc.)
Component Location=Using the sketch code A1, A2, B1, B2, etc. Use wall codes and number windows and doors from left to right.
* For window repair and replacement, also complete Form 4.

Date submitted to lab (mm/dd/yy):

Risk Assessor (print name)	Initials	Date (mm/dd/yy)

Data Entry Info

Batch	Initials	Date of Entry

Figure A-7: Form 3 page 1 (unchanged (other than title) over the course of data collection).

FORM 3: Dust Creation Study Lead Dust Wipe Sampling on Floors (page 2 of 2)

DOE LEAD-SAFE WEATHERIZATION STUDY

Draft 07/09/04

Status: I=Initial R=Reclean ☐

Building ID	Dwelling ID

Address Residence	St. No.	Street Name	Apt No.	City	State	Zip

QA/QC	Control Code#	True Value	Sample ID	Lab (µg/sample)
Spike Sample				
Field Blank				
Sheeting Blank				

Questions:

1.Were minimum-required containment procedures implemented:
☐ Yes ☐ No (describe deviations and impact on sample locations): ____________________

2.How long did containment remain in place before removal? _____ minutes

3.Was HEPA vacuum used after containment removed? ☐ Yes ☐ No

4.Were wet-cleaning techniques used for final cleaning after HEPA vacuum was done? ☐ Yes ☐ No

5 After final cleaning, were any other weatherization tasks performed in target activity location? ☐ Yes ☐ No

If yes, describe: ____________________

6.List each dust-lead creation activity and the duration of the activity

Activity: ______________ Minutes _____

Activity: ______________ Minutes _____

6b.Number of workers involved in activity_________

7a. Was a dropped ceiling present in any of the rooms sampled? ☐ Yes ☐ No

7b. If yes, locations: ____________________

Comments

Date submitted to lab (mm/dd/yy): ☐

Risk Assessor (print name)	Initials	Date (mm/dd/yy)

Data Entry Info

Batch	Initials	Date of Entry

Figure A-8: Form 3 pg 2 as it appeared in the original research plan.

FORM 3: Dust Creation Study Lead Dust Wipe Sampling on Floors (page 2 of 3)

DOE LEAD-SAFE WEATHERIZATION STUDY

Draft 12/22/04

Status:
I=Initial
R=Reclean

Building ID	Dwelling ID
000	000

Address	St. No.	Street Name	Apt No.	City	State	Zip
Residence						

QA/QC	Control Code#	True Value	Sample ID	Lab (µg/sample)
Spike Sample				
Field Blank				
Sheeting Blank				

Questions

1.List each dust-lead creation activity and the duration of the activity

Activity 1: Minutes:

Activity 2: Minutes:

2.Were minimum-required containment procedures implemented:
(describe deviations and impact on sample locations):

Activity 1 Yes No Missing

Activity 2 Yes No Missin

2.How long did containment remain in place before removal?

Activity 1 Minutes

Activity 2 Minutes

3.Was HEPA vacuum used after containment removed?

Activity 1 Yes No Missing

Activity 2 Yes No Missing

4.Were wet-cleaning techniques used for final cleaning after HEPA vacuum was done?

Activity 1 Yes No Missing

Activity 2 Yes No Missing

5 After final cleaning, were any other weatherization tasks performed in target activity location? Please describe:

Activity 1 Yes No Missing

Activity 2 Yes No Missing

6.Number of workers involved in activity

Activity 1

Activity 2

7a. Was a dropped ceiling present in any of the rooms sampled? Yes No Missing

7b. If yes, locations:

Comments

Figure A-9: Form 3 page 2, modified in December 2004.

Building ID	Dwelling ID
#Name?	#Name?

FORM 3: Dust Creation Study Lead Dust Wipe Sampling on Floors (page 3 of 3)

Status: I=Initial R=Replace

DOE LEAD-SAFE WEATHERIZATION STUDY
Draft 12/22/04

Address	St. No.	Street Name	Apt No.	City	State	Zip
Residence	#Name?	#Name?	#Name?	#Name?	#Name?	#Name?

Ideal Sampling Grid - DO NOT MARK ON THIS GRID, MARK BELOW!

Work Surface

	3	2	1	X	1	2	3
				2_E	4_E		
1							
2		1,2		2_E	4_E	4	3
3							
4				2_E	4_E		
5							

Target Activity 1

- cut hole knee wall
- window repair*
- window replace*
- plane door
- wall/ceiling repair

Template Used

- 9" x 9"
- 12" x 12"
- Other (specify)

For each dust sample, enter the sample # in the square of the grid sampled.

Work Surface

	3	2	1	X	1	2	3
1							
2							
3							
4							
5							

Target Activity 2

- cut hole knee wall
- window repair*
- window replace*
- plane door
- wall/ceiling repair

Template Used

- 9" x 9"
- 12" x 12"
- Other (specify)

For each dust sample, enter the sample # in the square of the grid sampled.

Work Surface

	3	2	1	X	1	2	3
1							
2							
3							
4							
5							

Comments

Figure A-10: Form 3 page 2, modified in December 2004.

Building ID	Dwelling ID

FORM 3: Dust Creation Study Lead Dust Wipe Sampling on Floors (pg 2 of 2) MODIFIED

Status: I=Initial R=Reclean

DOE LEAD-SAFE WEATHERIZATION STUDY

Draft 7/26/05

Address	St. No.	Street Name	Apt No.	City	State	Zip
Residence						

Ideal Sampling Grid - DO NOT MARK ON THIS GRID, MARK BELOW!

Work Surface

	3	2	1	X	1	2	3
			2E	4E			
1							
2	1,2		2E	4E	4	3	
3							
4			2E	4E			
5							

QA/QC	Control Code#	True Value	Sample ID	Lab (µg/sample)
Spike Sample				
Field Blank				
Sheeting Blank				

Target Activity 1

- cut hole knee wall
- window repair*
- window replace*
- plane door
- wall/ceiling repair

Template Used

- 9" x 9"
- 12" x 12"
- Other (specify)

For each dust sample, enter the sample # in the square of the grid sampled.

Work Surface

	3	2	1	X	1	2	3
1							
2							
3							
4							
5							

Target Activity 2

- cut hole knee wall
- window repair*
- window replace*
- plane door
- wall/ceiling repair

Template Used

- 9" x 9"
- 12" x 12"
- Other (specify)

For each dust sample, enter the sample # in the square of the grid sampled.

Work Surface

	3	2	1	X	1	2	3
1							
2							
3							
4							
5							

Comments

Figure A-11: Form 3 pg 2, modified in July 2005.

FORM 4: Dust Creation Study Lead Dust Wipe Sampling on Windows

DOE LEAD-SAFE WEATHERIZATION STUDY

Draft 07/09/04

Building ID	Dwelling ID

Status: I=Initial R=Reclean

Address	St. No.	Street Name	Apt No.	City	State	Zip
Residence						

Target Activity	Room Fxn	Comp Loc	Wind Surf	Before Work						After Final Clean				
				Surf Cond	Length (ft)	Width (ft)	Area (ft^2)	Sample #	Load ($\mu g/ft^2$)	Length (ft)	Width (ft)	Area (ft^2)	Sample #	Load ($\mu g/ft^2$)
Window Repair / Window Replace			Sill											
			Trough											
Window Repair / Window Replace			Sill											
			Trough											

Note: Form 3 must also be completed for these two target activities.

Surface Condition: 1=bare, smooth and cleanable, 2=bare, not smooth and cleanable, 3=painted, smooth and cleanable, 4=painted, difficult to clean.
Component Location: Using the sketch code A1, A2, B1, B2, etc. Use wall codes and number windows and doors from left to right.

Date Submitted to Lab:	

Risk Assessor (print name):	Initials	Date (mm/dd/yy)

Figure A-12: Form 4 as it appeared in the original research plan.

FORM 4: Dust Creation Study Lead Dust Wipe Sampling on Windows MODIFIED

DOE LEAD-SAFE WEATHERIZATION STUDY

Draft 08/01/05

Building ID	Dwelling ID

Status:
I=Initial
R=Reclean

Address	St. No.	Street Name	Apt No.	City	State	Zip
Residence						

Target Activity	Room Fxn	Comp Loc	Wind Surf	Before Work						After Final Clean					
				Surf Cond	Length (inches)	Width (inches)	Area (SQ FT)	Sample #	Load ($\mu g/ft^2$)	Surf Cond	Length (inches)	Width (inches)	Area (SQ FT)	Sample #	Load ($\mu g/ft^2$)
☐ Window Repair ☐ Window Replace			Sill												
			Trough												
☐ Window Repair ☐ Window Replace			Sill												
			Trough												

Note: Form 3 must also be completed for these two target activities.

Surface Condition: 1=bare, smooth and cleanable, 2=bare, not smooth and cleanable, 3=painted, smooth and cleanable, 4=painted, difficult to clean.
Component Location: Using the sketch code A1, A2, B1, B2, etc. Use wall codes and number windows and doors from left to right.

Comments:

Date Submitted to Lab:	

Risk Assessor (print name).	Initials	Date (mm/dd/yy)

Data Entry Info

Batch	Initials	Date of Entry

Figure A-13: Form 4, modified in August 2005.

FORM 5 : Dust Dispersion Study Lead Dust Wipe Sampling

DOE LEAD-SAFE WEATHERIZATION STUDY

Draft 07/09/04

Building ID	Dwelling ID

Address	St. No.	Street Name	Apt No.	City	State	Zip Code
Residence						

Target Activity	Room Fxn	Surface Type	Surface Cond	Before Work		After Work	
				Sample #	Loading ($\mu g/ft^2$)	Sample #	Loading ($\mu g/ft^2$)
Blower Door Test	LR	Floor					
Blower Door Test	LR	Sill					
Blower Door Test	K	Floor					
Blower Door Test	K	Sill					
Dense-Pack Walls		Floor/Sheeting					
Dense-Pack Walls		Floor/Sheeting					
Ductwork Repair		Floor/Sheeting					
Ductwork Repair		Floor/Sheeting					

Room Fxn: record room function as recorded on Forms 1 and 2.
Surface Condition: 1=bare, smooth and cleanable, 2=bare, not smooth and cleanable, 3=painted, smooth and cleanable, 4=painted, difficult to clean, 5=carpet, cleanable, 6=carpet, not cleanable, 7=sheeting.
Note: Record a "Z" in the room function cell if target activity was not studied at this dwelling. Leave remaining cells in that row blank.

	Control Code#	True Value	Sample ID	Lab (μg/sample)
Spike Sample				
Field Blank				
Sheeting Blank				

* Before work sheeting samples are to be collected from the second and seventh dwelllings sampled.

For dense-packing of walls, was baseboard sealed before dense-packing work began? YES ☐ NO ☐

Comments:

Date Submitted to Lab:	

Risk Assessor (print name)	Initials	Date (mm/dd/yy)

Figure A-14: Form 5 as it appeared in the original research plan.

FORM 5 : Dust Dispersion Study Lead
Dust Wipe Sampling

DOE LEAD-SAFE
WEATHERIZATION STUDY

Draft 12/14/04

FORM NOT APPLICABLE FOR THIS UNIT ☐

Building ID	Dwelling ID
000	000

Address	St. No.	Street Name	Apt No.	City	State	Zip Code
Residence						

Target Activity	Room Fxn	Surface Type	Surf. Cond	Before Work				After Work			
				Sample #	Length (inches)	Width (inches)	Loading ($\mu g/ft^2$)	Sample #	Length (inches)	Width (inches)	Loading ($\mu g/ft^2$)
Blower Door Test		Floor									
Blower Door Test		Sill									
Blower Door Test		Floor									
Blower Door Test		Sill									
Dense-Pack Walls		Floor/Sheeting									
Dense-Pack Walls		Floor/Sheeting									
Ductwork Repair		Floor/Sheeting									
Ductwork Repair		Floor/Sheeting									

Room Fxn: record room function as recorded on Forms 1 and 2. Surface Condition: 1=bare, smooth and cleanable, 2=bare, not smooth and cleanable, 3=painted, smooth and cleanable, 4=painted, difficult to clean, 5=carpet, cleanable, 6=carpet, not cleanable, 7=sheeting. Note: Record a "Z" in the room function cell if target activity was not studied at this dwelling. Leave remaining cells in that row blank.

	Control Code#	True Value	Sample ID	Lab (μg/sample)
Spike Sample				
Field Blank				
Sheeting Blank				

* Before work sheeting samples are to be collected from the second and seventh dwelllings sampled.

For dense-packing of walls, was baseboard sealed before dense-packing work began?

☐ Yes ☐ No

Comments:

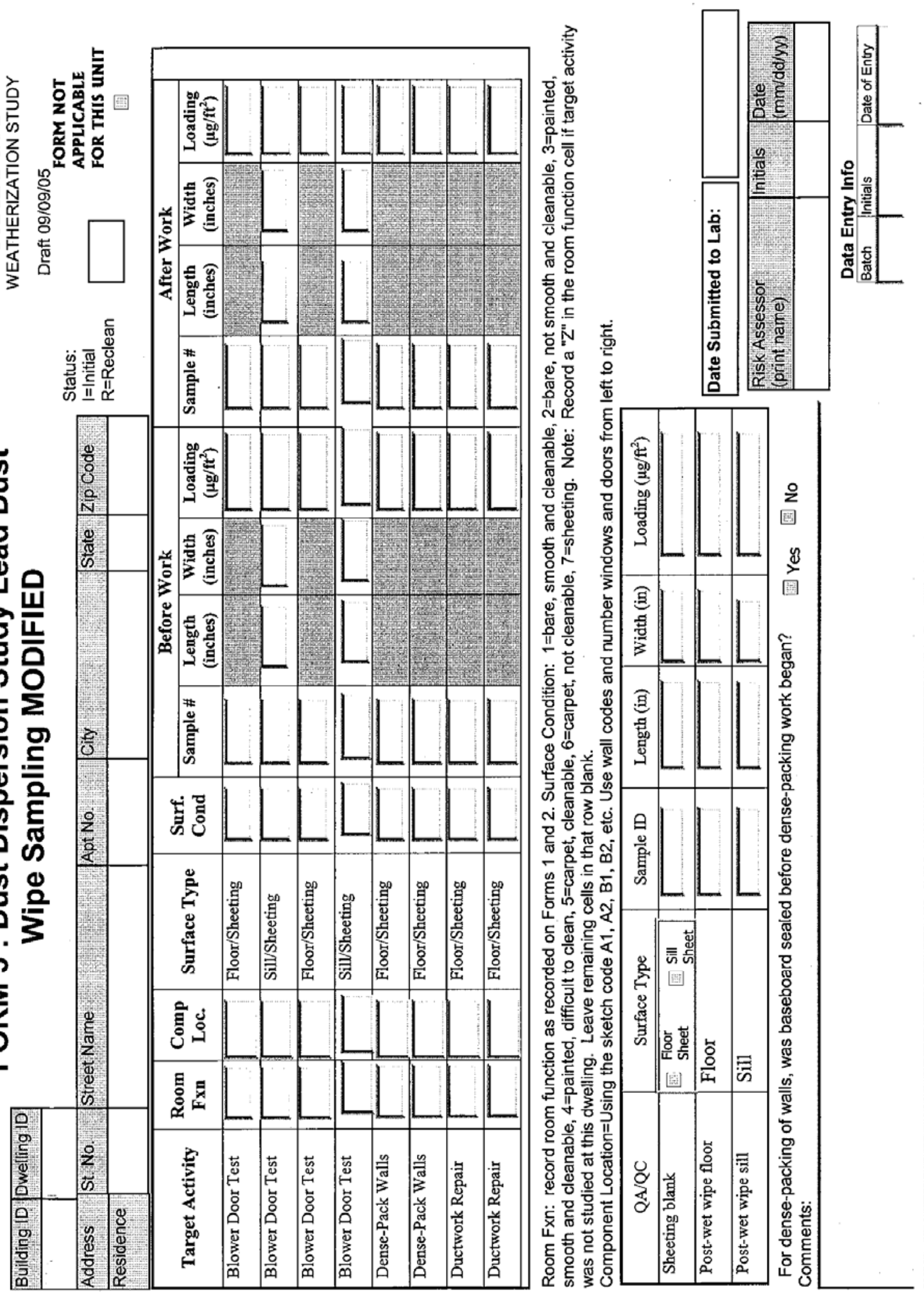
Date Submitted to Lab:	

Risk Assessor (print name)	Initials	Date (mm/dd/yy)

Data Entry Info

Batch	Initials	Date of Entry

Figure A-15: Form 5, modified in December 2004.



FORM 5 : Dust Dispersion Study Lead Dust Wipe Sampling MODIFIED

DOE LEAD-SAFE
WEATHERIZATION STUDY

Draft 09/09/05

FORM NOT APPLICABLE FOR THIS UNIT

Status:
I=Initial
R=Reclean

Building ID	Dwelling ID

Address	St. No.	Street Name	Apt No.	City	State	Zip Code
Residence						

Target Activity	Room Fxn	Comp Loc.	Surface Type	Surf. Cond	Before Work				After Work			
					Sample #	Length (inches)	Width (inches)	Loading (µg/ft²)	Sample #	Length (inches)	Width (inches)	Loading (µg/ft²)
Blower Door Test			Floor/Sheeting									
Blower Door Test			Sill/Sheeting									
Blower Door Test			Floor/Sheeting									
Blower Door Test			Sill/Sheeting									
Dense-Pack Walls			Floor/Sheeting									
Dense-Pack Walls			Floor/Sheeting									
Ductwork Repair			Floor/Sheeting									
Ductwork Repair			Floor/Sheeting									

Room Fxn: record room function as recorded on Forms 1 and 2. Surface Condition: 1=bare, smooth and cleanable, 2=bare, not smooth and cleanable, 3=painted, smooth and cleanable, 4=painted, difficult to clean, 5=carpet, cleanable, 6=carpet, not cleanable, 7=sheeting. Note: Record a "Z" in the room function cell if target activity was not studied at this dwelling. Leave remaining cells in that row blank.
Component Location=Using the sketch code A1, A2, B1, B2, etc. Use wall codes and number windows and doors from left to right.

QA/QC	Surface Type	Sample ID	Length (in)	Width (in)	Loading (µg/ft²)
Sheeting blank	Floor Sheet / Sill Sheet				
Post-wet wipe floor	Floor				
Post-wet wipe sill	Sill				

Date Submitted to Lab:

Risk Assessor (print name)	Initials	Date (mm/dd/yy)

For dense-packing of walls, was baseboard sealed before dense-packing work began? Yes No
Comments:

Data Entry Info

Batch	Initials	Date of Entry

Figure A-16: Form 5, modified in September 2005.

FORM 6: De-Enrollment

DOE LEAD-SAFE WEATHERIZATION STUDY

Draft 06/09/04

Building ID	Dwelling ID

Address	St. No.	Street Name	Apt No.	City	State	Zip
Residence						

De-enrollment Date:

Reason (check all that are appropriate)

- ☐ Owner declined to participate
- ☐ Resident declined to partcipate in study
- ☐ No lead present at levels greater than or equal to 1.0mg/cm2
- ☐ No dust-creation target activities were planned
- ☐ Risk Assessor not informed about weatherization work date
- ☐ Target activity goal reached before dwelling was weatherized (e.g., Home will have window repair only but we've already sampled 50 window repairs)
- ☐ Other- Specify

Risk Assessor (print name)	Initials	Date (mm/dd/yy)

Data Entry Info

Batch	Initials	Date of Entry

Figure A-17: Form 6 (unchanged over the course of data collection).

Building ID	Dwelling ID

FORM 7: Observation of Containment/Cleaning Practices

Status: I=Initial R=Reclean

DOE LEAD-SAFE WEATHERIZATION STUDY

Draft 9/09/05

Address	St. No.	Street Name	Apt No.	City	State	Zip
Residence						

1. Number of Target Activities covered by Form 7 ____ Page ____ of ____

*2a Target Activity:

- ☐ Cut hole knee wall
- ☐ Window repair
- ☐ Window replace
- ☐ Plane door
- ☐ Wall/ceiling repair
- ☐ Blower door
- ☐ Densepack walls
- ☐ Ductwork repair

2b. Duration of Activity: ____ Minutes

2c. Number of workers involved in activity: ____

Question	Yes/No/NA	Description/Comments
3. Was horizontal containment used in target activity location?	☐ Yes ☐ No ☐ NA	
4. Was vertical containment used in target activity location?	☐ Yes ☐ No ☐ NA	
5. How long did containment remain in place before removal?	☐ Yes ☐ No ☐ NA	
6. Was containment folded inwards during removal?	☐ Yes ☐ No ☐ NA	
7. *Was target activity location HEPA-vacuumed after work was completed?	☐ Yes ☐ No ☐ NA	
8. *Was target activity location wet-cleaned after work was completed?	☐ Yes ☐ No ☐ NA	
9. *Was HEPA-vacuuming of target activity location repeated after wet-cleaning?	☐ Yes ☐ No ☐ NA	
10. Was a final cleaning of all work locations performed after all weatherization work was completed in the home?	☐ Yes ☐ No ☐ NA	
11. Were other indoor weatherization tasks performed in the target activity location:		
• During the target activity work period?	☐ Yes ☐ No ☐ NA	
• During the one-hour waiting period?	☐ Yes ☐ No ☐ NA	
12. Were outdoor weatherization tasks performed in the target activity location:		
• During the target activity work period?	☐ Yes ☐ No ☐ NA	
• During the one-hour waiting period?	☐ Yes ☐ No ☐ NA	
13. *Did any ***non-weatherization*** activities (e.g., movement of residents, pets, etc.) occur in the target activity location:		
• During the target activity work period?	☐ Yes ☐ No ☐ NA	
• During the one-hour waiting period?	☐ Yes ☐ No ☐ NA	
14. Was there a dropped ceiling present in the room(s) sampled?	☐ Yes ☐ No ☐ NA	
15. Other Comments/Observations	☐ Yes ☐ No ☐ NA	

*For re-clean activities, fill in only those cells noted with asterisk.

Risk Assessor (print name)	Initials	Date (mm/dd/yy)

Data Entry Info

Batch	Initials	Date of Entry

Figure A-18: Form 7, introduced into data collection in September 2005.

Appendix B: Definitions of Statistical Terms and Types of Statistical Analyses Used in Report

1. Measures of Central Tendency: Arithmetic Means, Medians, and Geometric Means

An arithmetic mean is a measure of central tendency obtained by dividing the sum of a set of quantities (i.e., "N" numbers) by the number of quantities (N) in the set. It is also called an average and is the most widely used measure of central tendency.

The median describes the middle location of a set of quantities. That is, half the quantities are above the median and half are below.

The geometric mean (GM) is another measure of central tendency and is the Nth root of the product of N quantities. Unlike the arithmetic mean, the GM is often used to evaluate data that covers a wide range of values, perhaps an order of magnitude or more. It is used in situations where an arithmetic mean would be biased by very high or very low values. For example, consider 100 measurements, 99 of which have a value of 1 and the 100^{th} has a value of 1,000. Then the arithmetic mean is 10.99, the median is 1 and the GM is 1.07. The observation of 1,000 pulls the mean upward, away from the vast majority of the observations, while the GM is only minimally affected.

Dust lead loadings tend to follow a log-normal distribution, i.e., most results are low, but there tends to be a small but not insignificant percentage of values that are much higher than the other values. For log-normally distributed data, the arithmetic mean or average is higher than the GM because the arithmetic mean is "pulled" upward by the few high values. The GM provides a better measure of central tendency for log-normally distributed data. The GM is close to the median but has statistically more favorable distribution properties for hypothesis testing than the median.

2. Determination of Significance

The significance level, called the "p-value," is the probability that the observed difference between variables could have been observed by chance. A p-value below 0.05 is considered significant because it is highly unlikely that the observed difference was observed by chance alone. A p-value of 0.05 or more but less than 0.10 is considered marginally significant. A p-value of 0.10 or higher is not considered to be significant.

3. Analysis of Variance (ANOVA)

ANOVA was conducted to determine if the state-wide arithmetic means of the unit mean paint lead loadings were the same for Indiana, Maryland and Rhode Island. ANOVA is used to compare two or more arithmetic means from independent samples. The SAS procedure GLM was used to conduct this test.

4. Fisher's Exact Test

Fisher's exact test was used to test that the percent of units with any components having non-intact lead-based paint were the same for Indiana, Rhode Island and Maryland. Fisher's exact test is used to test that the percent of "yes" responses is the same for the three independent samples (i.e., states). The SAS procedure FREQ was used to conduct this test.

5. Paired Student T-Test

Paired student t-tests with log-transformed dust lead loadings were conducted to determine if there was a change in GM dust lead loadings between two times. This test is used when a dust sample is collected at the exact same location at two sampling times. This type of analysis is called "paired" because the statistic is based on the differences between the pairs of observations. The other underlying assumption for this test is that the dust lead measurements are log-normally distributed. The SAS procedure UNIVARIATE was used to conduct this test.

6. McNemar's Test

McNemar's test, a measure of agreement between paired dichotomous variables, was employed to test that the percent of dust lead loadings above comparison values (40, 250, and 400 $\mu g/ft^2$ for floors, sills, and troughs, respectively) were different at two times (McNemar 1947). Like the paired student t-test, this analysis is for "paired" measurements. However unlike the paired student t-test it is not based on the differences between pairs of observations. McNemar's test is based on the number of cases where measurements from the two sampling times agree (i.e., at both times a specific location is above the comparison value, or at both times a specific location is below the comparison value) and disagree (i.e., at one time a specific location is above comparison value but it is below at the other time). The SAS procedure FREQ was used to conduct this test.

7. Analysis of Covariance

Statistical modeling with was conducted with analysis of covariance to:

1) Identify which housing characteristics and conditions influenced pre-work dust lead loadings;
2) Identify which housing characteristics and conditions influenced dust lead loadings after final clean-up of dust creation activities and determine if dust lead loadings differed for different dust creation activities; and
3) Identify which housing characteristics and conditions influenced dust lead loadings after final clean-up of dust dispersion activities and determine if dust lead loadings differed for different dust dispersion activities.

This procedure was used to determine the set of housing characteristics and conditions that best predicts dust lead loadings. The result is an equation that predicts dust lead loadings based on the observed levels of the predictors (i.e., housing characteristics and conditions). The primary advantage of this type of analysis is that the effects of many predictors can be simultaneously examined.

Appendix C: Summary of Variables that were Removed from Statistical Models due to Insufficient Variability[a]

Model	Effect
Pre-Work Trough Dust Lead Loading	State
Pre-Work Trough Dust Lead Loading	Building Constructed pre-1930 (versus post)
Dust Creation Activity, Post-Final Cleaning Sill Dust Lead Loading	State
Dust Creation Activity, Post-Final Cleaning Sill Dust Lead Loading	Building Constructed pre-1930 (versus post)
Dust Creation Activity, Post-Final Cleaning Sill Dust Lead Loading	Condition of wiped surface
Dust Creation Activity, Post-Final Cleaning Trough Dust Lead Loading	State
Dust Creation Activity, Post-Final Cleaning Trough Dust Lead Loading	Building Constructed pre-1930 (versus post)
Dust Dispersion, Post-Work Sum Floor Dust Lead Loading	Rental (versus owner occupied)
Dust Dispersion, Post-Work Sum Floor Dust Lead Loading	Was area HEPA-vacuumed after work was done
Dust Dispersion, Post-Work Sum Floor Dust Lead Loading	Was area wet-cleaned after work
Dust Dispersion, Post-Work Sum Sill Dust Lead Loading	State
Dust Dispersion, Post-Work Sum Sill Dust Lead Loading	Was area HEPA-vacuumed after work was done
Dust Dispersion, Post-Work Sum Sill Dust Lead Loading	Was area wet-cleaned after work

[a]Insufficient variability means, for the model listed in Column 1, all dwellings had the same values, or all but one or two units had the same values, for the variable listed in Column 2.