# FINAL REPORT

on

# ELECTROSTATIC CLOTH AND WET CLOTHS FIELD STUDY IN RESIDENTIAL HOUSING

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## EXECUTIVE SUMMARY

An innovative approach to lead clearance testing was developed and tested for use after renovation and remodeling projects. This new approach to clearance testing is intended to serve as an alternative to the wipe sampling clearance method currently recommended after renovation and remodeling projects. It is hoped that the new approach will provide a viable alternative method for lead clearance testing that is faster and less expensive than the current method. The new method was tested on floors and window sills[1] at 31 urban residential sites in two large urban cities where lead hazard reduction work had recently been conducted.

The new lead clearance protocol was tested with dry electrostatic and wet detergent-based disposable cleaning cloths (DCCs). Although DCCs were developed for light household cleaning, they were used here as sampling tools in the new clearance protocol. The DCC products employed for this study were all commercially available products purchased at local retail stores.

The new clearance protocol utilizes a DCC to sample an entire floor or window sill, and a visual assessment of the used DCC follows. If the DCC looks dirty or discolored (compared to a reference standard), resampling with a fresh DCC is required. When the DCC remains nearly white after use, the surface is judged clean enough to pass clearance. The visual assessment has been named the 'white glove' test and the new clearance testing method is called the disposable cleaning cloth/white glove (DCC/WG) clearance protocol. With the DCC/WG clearance protocol, an entire floor or window sill is sampled rather than sampling a small area. Therefore, the judgment about the used DCC passing or failing White glove reflects the status of the entire floor or window sill surface.

The central question asked by this field study is whether sampling with DCCs and passing the white glove test is indicative that the floor or window sill would pass standard clearance testing with wipes. Side-by-side pairs of wipe samples were collected before and after each DCC/WG clearance protocol and analyzed for lead content to evaluate the efficacy of the new clearance method. Of particular interest was an assessment of whether the average lead loading from the two ASTM wipe samples fell below 40 $\mu g/ft^2$ for floors and below 250 $\mu g/ft^2$ for window sills.

The results of this field study indicate that the DCC/WG clearance protocol offers a promising alternative for clearance testing of smooth and cleanable surfaces in residential renovation and remodeling projects. The data demonstrate that when white glove is achieved, the new protocol affords a quick, low-cost, and reasonably accurate method for concluding that lead clearance standards have been met for floors and window sills.

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[1]Window troughs are part of lead abatement clearance testing but were not included in this study because EPA does not intend to regulate them in renovation and remodeling situations.

## 1.0 OBJECTIVE

The objective of the current field study in residential housing is to determine to what extent, and under what conditions within renovation and remodeling (R&R) work, an electrostatic cloth/wet cloth clearance protocol used along with a white glove visual test can obtain comparable results to current dust-lead clearance protocols based on results of wipe sampling. The approach of the white glove test is that the electrostatic or wet cloth must be essentially free of visible dust after sampling in order to pass clearance. In this way, the new white glove protocol might function as a simple, quick and inexpensive approach for clearance testing.

## 2.0 BACKGROUND

This report primarily presents the results from limited field testing with a potential new clearance protocol that EPA is calling the disposable cleaning cloth/white glove (DCC/WG) clearance protocol. However, this report also presents the results of other pilot studies EPA conducted leading up to the current field study. These prior results are summarized later in Section 2, as well as the appendices of this report. Section 2.1 discusses EPA's purpose in performing this field study, while Section 2.2 provides background on current clearance testing and defines the alternative DCC/WG clearance protocol. Section 2.3 summarizes the earlier pilot results from studies of white glove clearance testing using various disposable cleaning cloth protocols. Sections 3 through 7 provide the detailed results from the current DCC/WG field testing study. Section 3 presents the study design, while Sections 4 and 5 describe the field sampling and laboratory analysis protocols. Section 6 presents the study results, as well as the interpretation of the data relative to the study objectives. Section 7 provides discussion and conclusions based on the study results. Section 8 summarizes the key inputs from a peer review panel that evaluated the study. Section 9 addresses Quality Assurance. The Appendices A through E present supporting material in the form of quality assurance project plans and previous pilot study reports. Appendix F contains the wipe sample data for the field study. Appendix G is a picture gallery of the floors sampled during the study.

### 2.1 EPA Purpose

EPA currently is developing technical guidance to help prevent potential lead poisoning of household residents resulting from residential renovation and remodeling (R&R) activities. Evidence exists that R&R work activities may release hazardous levels of leaded dust and debris into residential environments. In one study, R&R activities such as demolition, window replacement and surface preparation were found to release leaded dust onto horizontal surfaces at levels as high as 40,000 $\mu g/ft^2$ or more (see EPA's report on Lead Exposure Associated with Renovation and Remodeling Activities: Environmental Field Sampling Study, Volume I: Technical Report, EPA 747-R-96-007, May, 1997). Effective cleanup and cleaning verification following any such R&R activity is essential for protection of household occupants, especially young children, who are often most highly exposed and most vulnerable to the adverse health effects of lead.

Cleanup methods commonly used by R&R professionals (e.g., broom sweeping and vacuum cleanup) can sometimes be ineffective in reducing lead dust loadings to safe levels. In limited testing, EPA concluded that residual lead levels after R&R activities followed by broom or vacuum cleanup could often be well over 100 $\mu g/ft^2$ on floors (see EPA report 747-R-96-007, May, 1997). A fast, inexpensive and reliable method for assessing post-R&R cleanup is an important component of EPA's formulation of R&R guidance. To be effective, a clearance protocol needs to meet several criteria, including:

- provide quick feedback,
- be relatively inexpensive and easy to conduct,
- possess good predictive accuracy concerning surface lead loadings, and
- be compliant with EPA regulations.

It is envisioned that some R&R work and cleanup will be conducted by homeowners themselves and various contractors (e.g., painters, carpenters) who do not necessarily fall within the jurisdiction of existing EPA, HUD or other federal regulations. These individuals may also have limited training and familiarity with existing best practices for lead hazard reduction and lead poisoning prevention. Therefore, it is important that EPA's R&R regulations, guidance and associated protocols and methods are intuitive, relatively easy to implement, and at the same time accurate and effective for their intended purposes. The R&R clearance protocol is one of these important elements of EPA's R&R program.

## 2.2 History and Motivation for Development of White Glove Clearance Test with Disposable Cleaning Cloths

The clearance testing method currently used in abatement or lead hazard control settings relies on ASTM dust wipe sampling. The objective of clearance testing is to verify that cleanup has reduced lead to safe levels below the applicable EPA standards (see 66 FR 1206, January 5, 2001). Clearance testing requires that a dust collection technician take single wipe samples from the floor, window sill, and window trough in areas where lead hazard control work and cleanup activities have been performed.

Dust wipe samples using wipes that meet the ASTM criteria are sent to an accredited laboratory recognized by EPA/NLLAP for analysis. If the lead measured in any of the wipes indicates a lead loading greater than or equal to EPA's clearance standards (i.e., 40 $\mu g/ft^2$ on floors, 250 $\mu g/ft^2$ on sills, and 400 $\mu g/ft^2$ in troughs), the cleanup is declared to have failed and the cleanup and clearance sampling process is repeated until acceptable wipe measurements are reached for all sampled surfaces.

Because of the large number of R&R projects performed in the country, there are potential cost and scheduling concerns associated with the idea of applying standard abatement or lead hazard control clearance testing in a residential R&R environment. As such, EPA decided to investigate whether a white glove protocol performed with disposable cleaning cloths might be useful for conducting clearance testing in an R&R setting.

### 2.2.1 Description of the Protocol

EPA has developed an alternative method for lead clearance testing to verify the efficacy of cleanup after R&R projects. This clearance method does not require wipe sampling to determine if lead loadings after cleanup are acceptable. Instead, the new clearance sampling method uses disposable cleaning cloths (DCCs) as clearance testing tools. These commercial products are available as dry electrostatic cloths (e.g., Swiffer®, Grab-it™) or as wet mopping pads that function with the aid of a detergent (e.g., Swiffer®WetJet®, Clorox®Ready Mop®). Dry and wet DCC products come in different sizes and shapes, but all involve mopping with a dust collection device. Both dry electrostatic and wet DCCs were evaluated in the current field study.

The proposed DCC/WG clearance protocol is relatively simple to conduct and intuitively easy to understand. It involves thoroughly (and uniformly) mopping the entire floor or window sill with a DCC. Next the used DCC is visually inspected. If the cloth retains its pre-use, near-white appearance, the floor or window sill is judged to pass clearance and no additional treatment or sampling is necessary. (A comparison photograph is provided which shows the greatest amount of soiling which should be tolerated to still conclude a near-white appearance in the visual assessment.) If the DCC visually appears more soiled than the comparison photograph, mopping of the entire floor (or window sill ) is repeated with a new cloth. After this mopping, the visual test is repeated using the replacement cloth. This sequence of mopping and visually assessing the used cloths is repeated until a cloth retains its near-white appearance after being used to mop the surface.

Figure 1 is a flow chart diagram describing the DCC/white glove clearance protocol. It illustrates the sequence of steps taken to test each floor or window surface. In addition to the central instructions regarding the mopping and comparison to visual standards described above, the figure provides other important steps for acknowledging the limitations of when the protocol may be used. These issues are discussed further below.

### 2.2.2 Potential Issues with the Protocol

In the new clearance testing protocol, DCCs fulfill two functions: (1) they provide an easy way to immediately assess the lead clearance status of floors and window sills, and (2) they continue removing dust/lead that remains after the primary cleanup. Even when cleanup has failed to remove some dust (and potentially lead), the DCC protocol has the potential to finish the cleaning job. However, it must be emphasized that the DCC clearance protocol is not intended to replace or supplement the primary cleanup of the site. The DCC/white glove protocol is being evaluated as a tool for identifying when cleanup has been effective. Clearly, the DCC does continue to remove residual lead dust that cleanup may have missed, but this is viewed as a bonus and not a core function of the protocol.

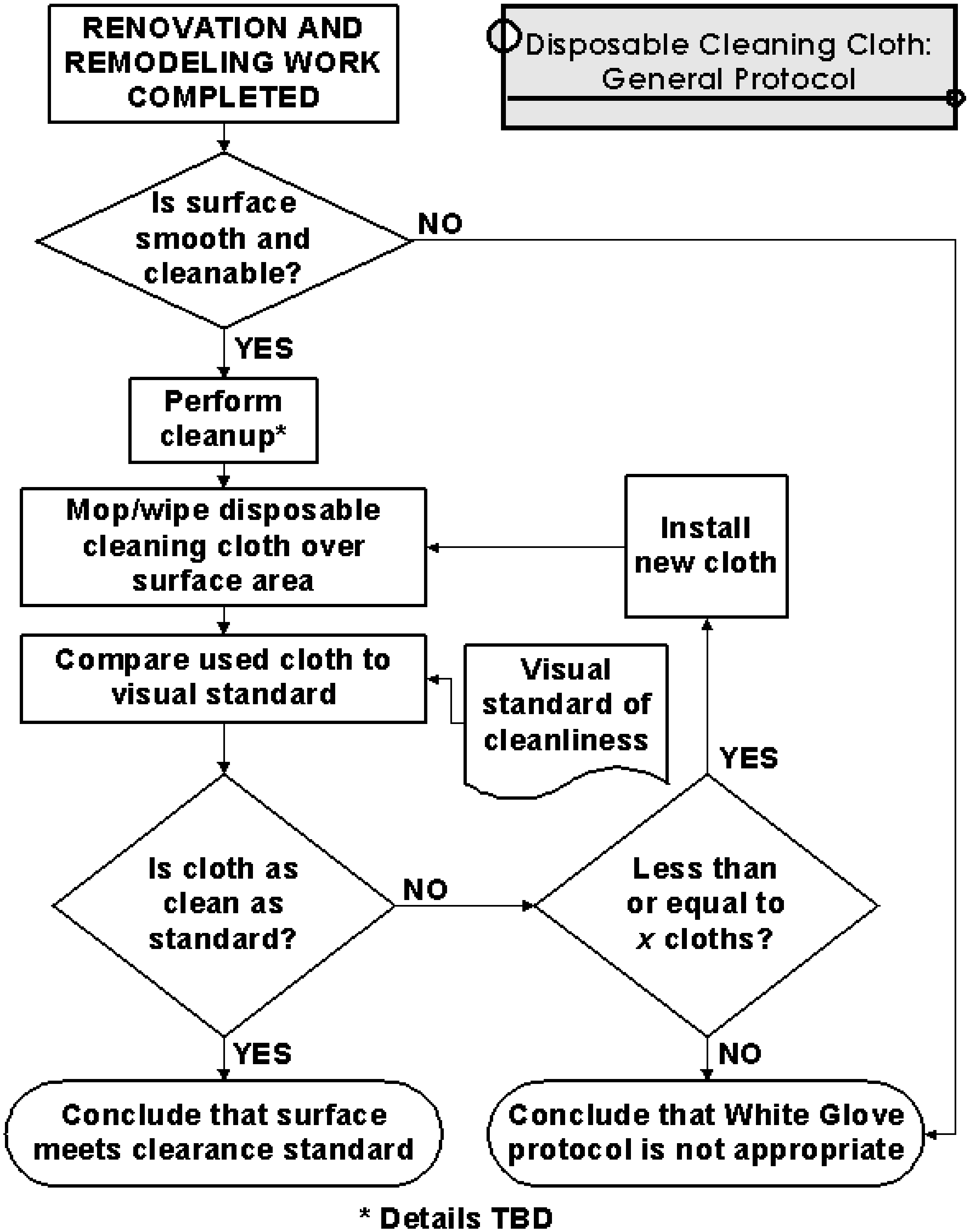



**Figure 1. White Glove Clearance Testing Protocol in an R&R Environment**

The implicit assumption with the white-glove test is that a near-white DCC (dry or wet) will prove to be a reliable predictor of successful clearance. In other words, it is assumed that a used DCC with no visible dust will accurately indicate that lead loadings fall below the clearance standard. Hazardous lead loadings on floors may not produce visible dust residues, but it is hypothesized that a wet or dry DCC, when mopped over an entire floor, will capture, accumulate, and amplify the visual appearance of low levels of lead dust. In this way, lead dust that may have been invisible on floors may become visually evident on the white cloth.

Experience has shown that some floor or window surfaces accumulate a dried layer of strongly adhering dirt/grime that only an intensive cleaning or scrubbing can remove. It must be emphasized that in EPA's evaluation of the DCC/WG protocol, sampling with the DCC was never intended to be used on these challenging surfaces. This is why, after completion of R&R work, the first question that must be addressed concerns the condition of the floor or window sill surface to be tested. Specifically, is the surface smooth and cleanable? A surface that has numerous cracks and crevices or a surface missing much of its finish will invariably be unsuitable for DCC clearance testing as it would not be considered smooth and cleanable. This kind of surface would require refinishing, replacement, or some other appropriate remedial work.

## 2.3 Summary of Prior Work Completed to Date

EPA has been conducting technical studies related to the development of a white glove test for the past five years (beginning in 2001). A central question of concern is how effective disposable cleaning cloths are for sampling. That is, how well do these cloths pick up leaded dust? Early in this work, EPA considered two primary ways of evaluating this question. First, EPA evaluated how much leaded dust a DCC could be expected to pick up (i.e., collect) from the total amount of dust available on a horizontal surface (i.e., floors or window sills) in a controlled laboratory setting. Second, EPA evaluated how likely it is that a DCC will pick up any residual leaded dust that might be left on a horizontal surface after R&R cleanup, so that the surface could subsequently be expected to pass lead clearance testing. While these were two central questions, EPA also considered related issues such as chemical analysis protocols for analyzing DCCs for lead content, and the ability of sampling technicians to visually and accurately determine when DCCs are free of leaded dust when a white glove condition has been reached.

Leading up to the current field study, EPA conducted four other studies that each examined different aspects of the questions listed above. The reports from these four studies, which are provided in Appendices B through E, cover the following topics, respectively:

- Chemical analysis protocol for analyzing DCCs for lead content
- Collection efficiency of ASTM dust wipes and DCCs in a controlled room setting, and accuracy of visual assessments for judging the amount of leaded dust on a DCC.
- Efficacy of DCCs for collecting leaded dust in a real-world setting and reducing residual dust-lead to levels below clearance standards

- Efficacy of different dry and wet DCC white glove protocols for reducing a variety of leaded dust loadings to levels below clearance standards.

In the progression of these pilot studies, questions related to the DCCs were first investigated in controlled laboratory conditions, and then in limited real-world testing outside of the laboratory. The first two studies focused on the ability of an individual DCC to collect a known amount of leaded dust from a smooth surface under relatively ideal conditions. Those favorable conditions included reasonably low lead loadings and sampling from linoleum floors that were in good condition. The third and fourth pilot studies then presented increasing challenges to the evolving DCC/WG protocol. In the third study, sampling was conducted in real buildings that represented residential R&R settings in some ways, but also differed from those R&R settings in other ways. And, in the fourth pilot study, the DCC/WG protocol was challenged with higher lead loadings back under controlled laboratory conditions.

In total, these preliminary studies indicated that a white glove DCC protocol had the potential to serve a useful role in the R&R program. However, the protocol had not yet been tested in the field, in real-world residential housing by dust sampling technicians. Therefore, the current field study also was conducted to help fill this information gap. Results from the four preliminary studies are briefly summarized in the following Sections 2.3.1 through 2.3.4, while the design and results from the current field study are discussed in Sections 3 through 7.

### 2.3.1 Round Robin Study

As noted above, one question of central importance for the evaluation of the white glove protocol was that concerning the amount of available leaded dust on a horizontal surface that DCCs could be expected to collect. One direct way to evaluate this question (and the approach taken in the First Controlled Room Study - see Section 2.3.2 and Appendix C) is to “spike” (i.e., apply in a controlled fashion) a known amount of leaded dust onto a clean horizontal surface, and then pick the dust back up with a DCC and determine how much dust is collected. However, in order to determine how much leaded dust the DCC collected, a chemical analysis protocol was needed to determine the lead content of a DCC. Such a laboratory protocol was the focus of the Round Robin Study.

Early in 2001, EPA funded the development of a laboratory protocol for digesting and chemically analyzing DCCs for lead content. The protocol was developed by the University of Cincinnati and Battelle. Subsequently, Battelle conducted the Round Robin Study to assess the accuracy of the new protocol. The primary objective of this study was to confirm with a high degree of confidence that the recovery rates associated with the DCC chemical analysis protocol are within the 80-120% recovery range. An additional objective of the study was to examine possible nuisance factors affecting the lead recovery. Factors considered were the cloth brand or manufacturer, the amount of lead spiked on the cloth, the laboratory type, and the analytical method of lead detection.

For the final study design, four laboratories (two commercial, NLLAP-accredited labs and two research-oriented labs) analyzed three replicates at each of four lead spike levels (blank, low, medium, and high) on each of three different cloth brands (Proctor and Gamble®'s Swiffer™, Vileda® Exstatic™, and Pledge® Grab-It™). Each of the four laboratories was to digest and analyze 36 spiked DCCs. All the labs agreed to digest the cloths according to the protocol set forth by Battelle. All four labs were to conduct Flame-AA analysis of the resulting digestates. In addition, the two research laboratories were to conduct ICP-MS analysis on aliquots of the same digestates. The results from the Exstatic™ DCCs were excluded from the data analysis due to complications experienced by the laboratories when digesting these cloths. All other data were included in the final results.

The study data were analyzed with a statistical model to assess the probability that a lead recovery between 80-120% can be achieved with different DCCs, laboratories, lead levels, and analytical instruments. In most cases, the digestion and analysis protocol was found to be feasible, and in some cases the protocol worked very well (i.e., there was a high probability that the recovery would be between 80-120%). However, in the case of one type of cloth (i.e., the Exstatic™) digestion was a serious problem, and in other cases certain types of cloths, laboratories, and/or analytical instrumentation do not appear to assure lead recovery in the 80-120% range with high probability. Overall, the research laboratories were able to perform the protocol with greater success than the randomly selected NLLAP laboratories; the Grab-It™ cloths yielded recoveries in the 80-120% range with higher probability; and the ICP-MS analytical instrumentation yielded recoveries in the 80-120% range for a broader (especially lower) range of lead levels. The commercial labs, Swiffer cloths, and Flame-AA analysis were generally associated with lower probabilities of achieving the targeted 80-120% recovery.

### 2.3.2 First Controlled Room Study

Knowing from the Round Robin Study that it is feasible to digest and chemically analyze some DCCs for lead content, EPA was next able to perform a study to directly assess the amount of leaded dust that DCCs might be expected to pick up from a horizontal surface. This assessment was performed in the First Controlled Room Study. The primary objectives of this study were to gauge the efficiency of disposable cloths when the dust was collected in a manner similar to standard clearance testing, and to assess the feasibility of utilizing a visual assessment to determine the amount of dust present on a DCC. Also, an additional objective of this study was to gauge the sampling efficiency of standard wipes. Earlier work by EPA (see Laboratory Evaluation of Dust and Dust Lead Recoveries for Samplers and Vacuum Cleaners, Volume I: Objectives, Methods, and Results, EPA 747-R-94-004A, March, 1995) suggested that the sampling efficiency of wipes is about 60-65%.

The basic approach of this study was to apply (i.e., "spike") a known amount of leaded dust onto a horizontal surface and then determine how much of the dust a DCC might be expected to pick up. The study design consisted of two replicates at each of two lead loading levels (40 $\mu g/ft^2$ and 100 $\mu g/ft^2$) using two wipe methods (standard ASTM wipes and one brand of ECC) from four sampling regions (1 $ft^2$ and 4 $ft^2$ for ASTM wipes; and 1 $ft^2$, 4 $ft^2$, 24 $ft^2$, and

48 $ft^2$ for ECCs). ASTM wipe primary samples were taken from each 1 $ft^2$ section of the sampling regions, and two primary ECCs were taken, one right after the other, from each sampling region. In addition, following the primary samples, secondary ASTM wipe samples were collected to assess the amount of any residual dust that might have been left after primary sampling. All cloths were digested and analyzed by Battelle's laboratory using ICP-MS.

The results from the sampling study indicated that the efficiency of the DCCs was not statistically different from the efficiency of the ASTM wipes, which currently are used in regulations that establish hazard and clearance levels. The efficiency for both was found to be 65-70%. Thus, the DCCs worked as well as the current standard wipes to collect settled dust in a controlled room setting. Analysis of the lead collection efficiencies of the DCCs over the four sampling region sizes (from 1 $ft^2$ to 48 $ft^2$) at the two lead loadings (40 $\mu g/ft^2$ and 100 $\mu g/ft^2$) revealed a small decline in efficiency as the dust lead levels increased. However, this decline was not statistically significant.

The basic study approach for the visual assessment was to develop photographic standards depicting different amounts of leaded dust, and then to ask several sampling technicians to compare the appearance of different real DCC samples with the photographic standards. A total of 444 visual assessments of the amount of dust present on 45 ECCs were performed by 10 Battelle staff. The amounts of dust on the cloths varied from about 0 mg to 500 mg. For each ECC, each staff member visually examined the amount of dust present and categorized the amount according to a set of 11 photographic standards (except for one technician who did not evaluate six blank cloths that he had helped prepare). The true amount of dust on each ECC also was measured via chemical analysis of the ECCs (along with numerical back-calculations using the known lead concentration of the standard reference material dust) after the visual assessments had been completed. Out of the 444 visual assessments, 212 assessments correctly selected the amount of dust (i.e., the correct photographic standard). In addition, 119 other visual assessments missed the correct amount of dust by just one photographic standard (approximately 50 mg of dust) on the high or low side. In total, 331 of the 444 visual assessments (i.e., 75%) judged the correct amount of dust on each DCC to within one photographic standard, or within about 50 mg of dust.

Results from the First Controlled Room Study indicated that DCCs can pick up leaded dust from horizontal surfaces with the same collection efficiency (approximately 65-70%) as standard ASTM dust wipes. Furthermore, DCCs can achieve this same collection efficiency for larger surfaces. In addition, visual assessment of DCCs appears to be a feasible tool for determining the amount of dust on a DCC, and hence, for determining when DCC sampling has reached a white glove status (i.e., no significant dust present on the DCC). It should be noted that the First Controlled Room Study only included testing of dry electrostatic cloths; no wet disposable cleaning cloths were tested.

### 2.3.3 Pilot Field Study in Vacant Buildings

Results from the Round Robin Study and First Controlled Room Study indicated the potential feasibility of utilizing DCCs to collect residual dust from horizontal surfaces. However, both of these studies were conducted in controlled laboratory settings. Therefore, it was important for EPA to begin to assess how well a white glove DCC protocol might perform in real-world conditions. As a first step in this assessment, EPA conducted the Pilot Field Study in Vacant Buildings. By necessity, this study changed the focus of the DCC evaluation to account for uncontrolled, real-world conditions as opposed to the controlled, laboratory conditions of the first two studies. In particular, a direct assessment of the amount of available dust that is collected by a DCC can not be made in real-world conditions because the pre-existing amount of leaded dust on the sampling surface is unknown. Also, pre-existing dust accumulates naturally over time, rather than being spiked in a known amount by researchers. Therefore, the efficacy of the DCC sampling protocol was evaluated by its ability to leave a horizontal surface suitably free of leaded dust so that the surface would pass lead clearance testing.

To make this assessment, EPA required a large number of available horizontal surfaces in a real-world setting where some amount of leaded dust was present. While investigating several alternative locations at which to conduct this type of field work, EPA became aware of two large vacant buildings likely to contain leaded dust. One building was the Seneca Hotel in Columbus, Ohio, and the other was the Armstrong Vocational School in Washington, D.C. Both are older, established structures likely to contain leaded dust, and both were vacant with plans for renovation, so they were readily accessible for sampling teams.

The general study approach was to select a variety of horizontal surfaces, sample a portion of each surface to determine the initial dust lead loading, apply the DCC protocol until a white glove condition was achieved, and then sample a portion of the surface to determine the residual dust-lead level and whether the surface would pass clearance testing. Because both the Seneca Hotel and Armstrong School are relatively large structures, a variety of floor and window sill surfaces constructed of different building materials were available for sampling. The experimental design at the Seneca Hotel included 65 sampling locations consisting of eight different uncarpeted, hard-floor surface types; 52 low-pile, carpeted sampling locations; and 101 wooden window sill sampling locations. Sampling at the Armstrong School included 101 sampling locations consisting of three different uncarpeted, hard-floor surface types. All sampling in both the Seneca Hotel and Armstrong School was conducted with dry electrostatic cloths; no wet disposable cleaning cloths were tested in these buildings.

The Seneca Hotel contained several flooring and window types that might reasonably be found in residential housing. However, the Seneca had been empty for several months and was in a relatively poor state of disrepair when testing was performed. This meant that the initial, pre-testing lead levels were often high. Also, the existing dust was often quite thick and caked. Often the floors and window sills were heavily cracked, or boards and joints were separated. Additionally, there were a large number of rooms in the Seneca Hotel where low-pile carpeting had been laid down to cover flooring that was in poor condition.

Because of these and other limitations, the Seneca Hotel results must be interpreted with caution. However, there were several relevant and interesting findings. Perhaps the most significant was that in a large number of cases (35 of 37 cases) where the DCC/WG protocol was applied to uncarpeted hard-floor areas that had pre-testing lead levels between 40 $\mu g/ft^2$ (i.e., the clearance standard) and 100 $\mu g/ft^2$, the lead level measured after the DCC/WG protocol was below 40 $\mu g/ft^2$ (i.e., low enough to pass clearance testing). Although there is limited information about lead levels in an R&R setting where clearance testing has failed (see Section 6.3.2), the current study suggests that when the pre-protocol lead levels are between 40 $\mu g/ft^2$ and 100 $\mu g/ft^2$, the lead levels after performing the DCC/WG protocol would be below the clearance standard.

The Seneca Hotel results also were analyzed from the perspective of false negative and false positive decision-making errors. In this context, a false-negative decision error was defined as a situation where the DCC/WG protocol achieved a white glove condition (indicating that the surface would probably pass clearance testing), but the post-protocol ASTM wipe sampling indicated that the lead level was still above 40 $\mu g/ft^2$ (i.e., that the surface would <u>not</u> pass clearance testing). Considering potential decision errors in the other direction, a false-positive decision error was defined as a situation where the DCC/WG protocol failed to achieve a white glove condition after eight to ten moppings (indicating that the surface would probably fail clearance testing), but the post-protocol ASTM wipe sampling indicated that the lead level was actually below 40 $\mu g/ft^2$ (i.e., the surface <u>would</u> pass clearance testing). When examining all of the Seneca Hotel uncarpeted hard-floor results, a false-negative decision error rate of approximately 30% was indicated (31 of 93 cases) and a false-positive decision error rate of about 40% was found. These error rates include a range of pre-protocol lead levels (from less than 40 $\mu g/ft^2$ to well over 1000 $\mu g/ft^2$) and a range of floor materials (e.g., wood, linoleum and ceramic tile, marble and concrete).

The Seneca Hotel Study also provided an opportunity to collect similar DCC testing information from window sills. In total, 101 window sills were tested with 93 of the sills achieving a white glove condition. In a large number of cases (18 of 20 cases) where the DCC/WG protocol was applied to window sills that had pre-testing lead levels between 250 $\mu g/ft^2$ (i.e., the clearance standard) and 500 $\mu g/ft^2$, the lead level measured after the protocol was below 250 $\mu g/ft^2$ (i.e., low enough to pass clearance). Similar to the floor results discussed earlier, these are cases where the DCC/WG protocol took pre-existing lead levels as high as twice the clearance standard and pushed them after the protocol to levels below the clearance standard. In terms of false-negative and false-positive decision error rates for the Seneca Hotel window sills, the results indicated a false negative error rate of approximately 20% (16 out of 93 cases) and a false positive error rate of about 75% (6 out of 8 cases). Note that the high false positive rate is based on very limited information.

Pilot field testing of the DCC protocol also was conducted in the Armstrong Vocational School in Washington, D.C. However, in this case, although initial inspection of the property indicated that it was suitably representative of residential R&R conditions, the subsequent detailed sampling and field work indicated that it probably was not an accurate surrogate for these residential conditions. Although large floor surfaces with leaded dust were available, the dust was commonly much greasier and more heavily caked than one would expect in a residential setting after R&R work and the subsequent cleanup have been completed. In addition, the percentage of pre-testing lead levels between 100 $\mu g/ft^2$ and 1000 $\mu g/ft^2$ was much higher in the Armstrong School than in the Seneca Hotel.

Despite these limitations, the results from the Armstrong School have been included in Appendix D because they may provide information about the performance of the DCC/WG protocol under especially challenging conditions. In cases where the protocol was applied to uncarpeted hard-floor surfaces that had pre-testing lead levels between 40 $\mu g/ft^2$ and 100 $\mu g/ft^2$, post-protocol lead levels below 40 $\mu g/ft^2$ were achieved in a majority of cases (15 of 22 cases). In terms of false-negative and false-positive decision error rates for Armstrong School hard-floor surfaces, the results indicated a false-negative error rate of 67% (8 out of 12 cases), and a false positive error rate of 30% (55 out of 186 cases). In addition, because of the greasy and heavily soiled floor conditions, there were relatively few cases where a white glove condition could be achieved at all. Out of a total of 198 cases, the white glove condition after multiple DCC moppings was only achieved in 12 cases (i.e., less than 10% of the time).

### 2.3.4 Second Controlled Room Study

Building upon the laboratory and field experiences of the three earlier studies, EPA decided to conduct a Second Controlled Room Study that primarily investigated the ability of the DCC/WG protocol to handle elevated pre-testing dust lead loadings. Both the First Controlled Room Study and the Pilot Field Study in Vacant Buildings suggested that the protocol could achieve good success on hard-floor surfaces in cases where the pre-testing dust-lead levels are between 40 $\mu g/ft^2$ (i.e., the clearance standard) and 100 $\mu g/ft^2$. However, the Study in Vacant Buildings suggested that the protocol was less successful at handling cases where the pre-testing lead levels are above 100 $\mu g/ft^2$. But, these results were collected in vacant commercial buildings rather than residential R&R settings. Therefore, the decision was made to investigate the higher lead loadings back in a controlled room setting.

The study took place in a controlled room setting at Battelle in which each of three different 24 $ft^2$ floor surface areas, following initial cleaning, was "spiked" with a known amount of leaded dust (using two different standard reference materials; SRM #2584 = house dust with 1% lead, SRM #2589 = pulverized paint with 10% lead), subsequently mopped with disposable cleaning cloths, and then subjected to wipe sampling. The wipe samples were chemically digested and analyzed for lead content. The results of the laboratory analysis were used to estimate the amount of lead remaining on the floor following the protocol.

Under the base protocol, a series of dry electrostatic cloths was used within the sample area to collect the dust lead until a clean cloth was achieved after wiping the area (i.e., white glove). Determination of this white glove condition was done by visual comparison to a photographic standard. After white glove was achieved, four ASTM wipe samples were collected from randomly selected 1 $ft^2$ sections within the area, as well as from two random 1 $ft^2$ areas on the perimeter of the sample region. Four lead loadings (40, 200, 600, and 1,600 $\mu g/ft^2$ ) were examined for each of two different standard reference materials. Each combination of lead loading and standard reference material was examined for each of the three floor sample areas. Testing was completed over 10 days in October, 2003.

In every testing sequence of the Second Controlled Room Study, the DCC/WG protocol was continued until a white glove condition was achieved. Therefore, when interpreting the results the conclusions are necessarily limited to the protocol's ability to take pre-existing lead levels that are well above the clearance standard and push them to levels below the clearance standard. Along with this, an assessment can be made about the false-negative decision error rate. However, no assessment of the false-positive error rate was possible in this study because a white glove condition was achieved in every case. In addition, because some experience in the previous studies indicated that several iterations with the DCCs might be required in some cases to achieve the white glove condition, the Second Controlled Room Study also considered three potential variations of the protocol in hopes that they might achieve the white glove condition in fewer moppings.

The results with the base DCC/WG protocol indicated good success when the pre-testing lead levels were either 40 $\mu g/ft^2$ or 200 $\mu g/ft^2$. In these cases, 47 of 48 tests resulted in post-testing lead levels below 40 $\mu g/ft^2$, implying a false-negative error rate of about 2% (i.e., 1 out of 48 cases). At higher lead levels, the results showed higher false-negative rates. When the pre-testing lead level was 600 $\mu g/ft^2$, 15 of 24 tests resulted in post-testing lead levels below 40 $\mu g/ft^2$ – a false-negative error rate of about 40% (i.e., 9 of 24 cases). And, when the pre-testing lead level was 1600 $\mu g/ft^2$, only 4 of 24 tests resulted in a post-testing lead level below the clearance standard – indicating a false-negative error rate of more than 80% (i.e., 20 of 24 cases).

Supplemental testing with the three variations of the basic DCC/WG protocol was run at the highest lead level of 1600 $\mu g/ft^2$ to investigate whether improvements in the false-negative error rate could be achieved. The first protocol variation consisted of performing the base DCC/WG protocol, and then after a white glove decision had been made, performing additional moppings with two more dry DCCs. This first protocol variation led to some improvements with 17 of 24 cases resulting in post-testing lead levels below the clearance standard – a false-negative error rate of about 30% (i.e., 7 of 24 cases).

The second protocol variation included everything from the first protocol variation (i.e., perform the base protocol, then two more dry DCC moppings) plus one additional mopping with a wet ECC at the end. With this second protocol variation, all 12 tests that were performed resulted in post-testing lead levels below the clearance standard – that is, a 0% false-negative error rate.

The third protocol variation included a somewhat simplified approach from the first two. Namely, the basic DCC/WG protocol was performed until a white glove decision was made, and then one additional mopping was performed with a wet ECC at the end. This third protocol variation resulted in 11 of 12 cases where the post-testing lead level was below the clearance standard – indicating a false-negative error rate of about 10% (i.e., 1 out of 12).

In all cases, the concentration and form of lead in dust was not found to be a significant covariate in explaining results.

Overall, results from the Second Controlled Room Study indicated that reasonably good results can be expected (at least under controlled conditions) with the basic testing protocol that employs dry DCCs when the pre-testing lead levels are as high as 200 $\mu g/ft^2$. In addition, including a wet sampling cloth after the basic dry DCC protocol may provide a reasonable means of handling even higher pre-testing lead levels, with levels up to 1600 $\mu g/ft^2$ being investigated in this study.

## 3.0 STUDY DESIGN

Following the work detailed in Section 2.3, the present field study was performed with a primary objective of evaluating the real-world efficacy of a white glove clearance protocol using disposable cleaning cloths. In simple terms, if disposable cleaning cloths remain near-white after application to a surface, can we reliably conclude that lead loadings are at or below the clearance standard? If the effectiveness can be empirically validated, then this protocol might prove a legitimate option for clearance sampling in an R&R environment.

The study design and results sections in this report will refer to a Disposable Cleaning Cloth/White Glove clearance protocol. This will be abbreviated as DCC/WG clearance protocol. The DCC/WG clearance protocol is a general term that refers to the set of activities performed in determining whether or not a surface wiped with cleaning cloths achieves white glove, and hence meets clearance standards. This idea was presented and discussed in Section 2.2 and was depicted graphically in Figure 1. Several important points apply to the DCC/WG clearance protocol used in this field study:

- The protocol used in this evaluation is similar to what was done in previous studies but not identical. To understand the specific details of the protocol execution for this study, refer to Sections 3.2 and 3.3. See the appropriate appendices for references as to how the protocol was performed in previous studies.

- The studies previously done for this protocol used mostly dry electrostatic cleaning cloths (also called ECCs or ECs). However, it was discovered that the protocol might be most effective when employing cleaning cloths that included a liquid detergent rather than just ECCs. To reflect this broader population of potential cleaning cloths, the term "ECC" has been replaced with the more generic "DCC", for disposable cleaning cloth. The two types of clothes are distinguished by calling them a wet DCC or a dry DCC.

- To assess the impact of the critical question of protocol effectiveness as a function of the type of cleaning cloth used, a design was created that tested implementation of the same basic protocol but with different disposable cleaning cloth configurations, both dry and wet. Commonly referred to throughout the following report as "treatments", they include:

    - <u>Dry DCC/WG clearance protocol (Max 15 cloths) on floors</u> - Also known as the dry treatment or dry protocol, this version of the protocol used only dry (electrostatic) cloths attached to their appropriate manufacturers' mop heads. For time and cost reasons, if 15 cloths were used without reaching white glove, the protocol was stopped and the surface categorized as 'failed to reach white glove'.

- Dry+1 Wet DCC/WG clearance protocol (Max 15 dry DCCs) on floors - Also known as the dry+1 wet treatment, this refers to the protocol that is the same as the dry protocol except that one additional pass is made of the floor surface using a wet DCC after the dry treatment is complete.

- Wet DCC/WG clearance protocol (Max 15 Cloths) on floors - Also known as the wet treatment, this refers to the protocol using exclusively disposable wet cleaning cloths attached to their appropriate manufacturers' mop heads. The protocol was stopped if white glove could not be achieved in 15 cloths.

- Dry DCC/WG clearance protocol (Max 3 Cloths) on sills - Also known as the dry treatment or dry protocol, this version of the protocol used only dry (electrostatic) cloths. Wiping was done by hand for sills. The protocol was stopped if white glove could not be achieved in three cloths.

- Wet DCC/WG clearance protocol (Max 3 cloths) on sills - Also known as the wet treatment, this refers to the protocol using exclusively disposable wet cleaning cloths. Wiping was done by hand for sills. The protocol was stopped if white glove could not be achieved in three cloths.

Note: the small sample surfaces of sills did not permit the evaluation of the dry+1 wet treatment, as was done on floors.

The following sections describe the data quality objectives of the study (Section 3.1), compare the DCC/WG clearance protocol for general application to that used in this field study (Section 3.2), discuss the implemented study design (Section 3.3), and identify important departures from the Quality Assurance Project Plan (Section 3.4).

## 3.1 Study Data Quality Objectives

Four data quality objectives (DQOs) have been identified for this study. These represent specific and measurable ways to evaluate the general hypothesis of the study. There are three DQOs associated with a core assumption that the DCC/WG clearance protocol achieves a "passing" condition, and one DQO for cases where this does not happen (i.e., white glove is not achieved).

1. How does a DCC/WG clearance protocol "pass" result compare to a formal wipe clearance sample result?

   a. The primary data quality objective of this study was to estimate the probability (and corresponding 95 % lower confidence bound) that surfaces will achieve the wipe sampling clearance standards, given that the surfaces have passed the white glove condition. Separate estimates were obtained for hard floors and window sills and for each treatment applied to these two types of surfaces.

b. An additional primary data quality objective was to compare the lead loadings before and after application of DCC/WG clearance protocols from the Second Controlled Room study results (as referenced in Section 2.3.4) to the results from this study. If they are found to be similar, results from the two studies could complement each other and provide a stronger conclusion regarding efficacy of the protocol(s).

c. A secondary data quality objective was to evaluate whether and how certain covariates impact the results. Covariates of interest include the specific nature of the protocol (e.g., whether dry DCC, wet DCC, or both), the initial dust-lead level before application of the protocol, the surface area where the protocol was applied, the type of surface material (e.g., hardwood, linoleum, painted concrete, ceramic tile), and the condition of the surface (e.g., cleanliness, wear).

2. How does a DCC/WG clearance protocol "fail to achieve white glove" result compare to a formal wipe clearance sample result?

   a. Under certain conditions (e.g., caked on grease/grime or chipping paint), the protocol did not always achieve white glove within the maximum number of cloths permitted. For such cases encountered in this study, a separate estimate was made of the probability that a wipe sample would result in a pass even when the cleaning/clearance protocol fails to achieve a white glove condition. This particular estimate was designated as a secondary data quality objective.

## 3.2 DCC/WG Clearance Protocol as Implemented in the Field Study

Figure 2 depicts the data collection protocol employed in this field study overlaid on the envisioned implementation of a real-world protocol (as was illustrated in Figure 1). Those steps in Figure 1 that are not included in the field study data collection protocol are indicated by dashed connecting lines and the text boxes are cross-hatched with reverse color text (white on dark). The additional steps in Figure 2 that do not apply to a real-world application, but were needed to collect the data for this study, are shown as text boxes with gray (rather than white) backgrounds. The 15 cloth limit shown in the lower right diamond of the figure is also grayed to reflect the fact that this number was selected specifically for the field study. A different criteria may well apply to an implemented real-world protocol.

The implemented study, as shown in Figure 2, differed in some important ways from the envisioned application of the protocol in real-world settings (see Figure 1). These differences included:

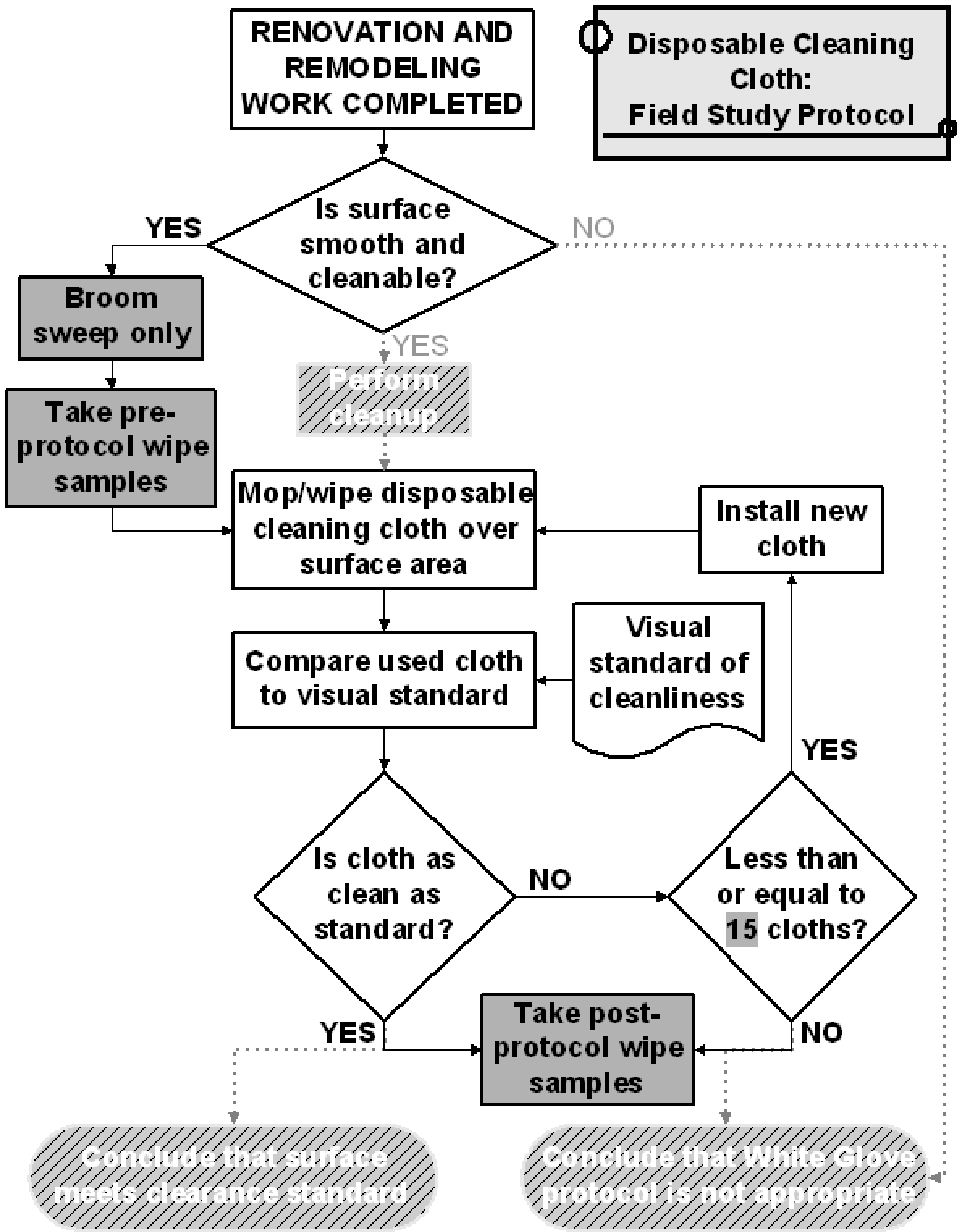



**Figure 2. White Glove Clearance Testing Protocol for Field Study in Residential Housing**

- For the field study, two floors were selected at each field site that best met the desired "smooth and cleanable" criteria that might apply to a real-world application of the protocol. However, conditions at some sites were so poor that two adequately smooth and cleanable surfaces were not available and the study had to settle with selecting floors that came closest to meeting the desired criteria. In part, this was necessitated by the supply of residential housing units where the study could be performed. However, it ultimately served the additional purpose of providing insight into what might eventually constitute a definition of a surface that is not "smooth and cleanable." For instance, specific exclusionary floor (or sill) conditions might include: large surface areas without finish, frequent and large cracks or crevices, protuberances (e.g., staples, splinters), and a layer of accumulated grime/dirt.

- A thorough site cleanup (that typically would be conducted after R&R but before clearance) was intentionally not included in the field testing protocol. Rather, a perfunctory broom sweeping was conducted before any data collection commenced. The objective of only broom sweeping was to increase the chances of having lead levels above the clearance standards before beginning the protocol. This permitted evaluation of two important concerns about the DCC/WG clearance protocol; (1) Would it ever achieve white glove when the surface lead levels exceed the clearance standard? and (2) Can it successfully identify (by passing the white glove criteria) that the lead loading was below the clearance standard when the DCCs are the vehicle through which the lead reduction occurred? To get the results of this evaluation, the DCCs were evaluated after a less intensive cleaning than might typically be done. In the real world, a dirty DCC would demonstrate that primary cleaning had been inadequate and this would trigger a complete recleaning effort for the entire room. For the field study, this was not the case. Regardless of how "dirty" the used cloth was, a fresh DCC was instituted, up to an operational limit of 15 DCCs for floors and 3 for sills. This extended use of DCCs would be impractical and inefficient in actual practice.

- To quantitatively assess the efficacy of the protocol, an objective measurement was needed for lead measurement before and after performance of the protocol. The experimental design specifies that ASTM wipe samples be collected both before and after DCC clearance testing. To minimize the inaccuracies introduced in measuring overall floor lead loading with a 1 $ft^2$ wipe sample, the experimental design provided for two spatially separated samples on each floor surface at each time point. These two measurements were averaged to determine the lead loading before and after application of the protocol. For sills, a single pre and post-protocol wipe sample were adequate because of the much smaller surface areas involved.

### 3.3 Implemented Field Study

The implemented field study in residential housing comprised three important components:

1. The locations - Locations were selected which might reasonably be expected to have leaded dust from some renovation and remodeling work but primarily from lead hazard control work . Additional information on the procedure for identification and qualification of potential study locations is provided in Section 4.1, Site Selection.

2. The people - The field study protocol was generally performed by two sampling technicians at each site. In Baltimore, the sampling technicians were employees of Leadtec Services, Inc. or Healthy Housing Solutions, Inc. In Milwaukee, the sampling technicians were staff of the Milwaukee Health Department. All technicians were certified in clearance wipe sampling. The majority were experienced lead risk assessors. Technicians followed the experimental protocol as defined in the Quality Assurance Project Plan (see Appendix A). On-site training was provided for all sampling technicians.

3. The protocol - A DCC/WG clearance protocol was performed on window sills and floors at the residences with dust wipe clearance sampling before and after to determine protocol efficacy.

A summarized and simplified version of the study protocol is as follows:

1. Identify two suitable rooms (designated Room A and Room B) within the housing unit. In each chosen room, there should be evidence that lead hazard control, lead abatement, or R&R-type work was completed, and that leaded dust might reasonably be expected on the floors and window sills.

2. In each selected room, identify, measure, and, using masking tape, partition the floor area into two approximately equal test areas. (The dry DCC and dry/wet DCC protocol was tested in one area; the wet DCC protocol was tested in the other half.)

3. Identify one window sill area in each room and partition this sill into two roughly equal areas using masking tape.

4. In Room A, for the window sill:
   a. Sweep any large debris from the sill.
   b. Collect an ASTM wipe sample on one half of the sill.
   c. Measure the associated dimensions of the sill to determine the area represented by the wipe sample.

d. Successively wipe dry DCCs over the other side of the sill until the used DCC appears as clean as the reference white glove visual standard or until a maximum number of DCCs (three) have been soiled.
e. Once achieving white glove (or the final limit cloth), perform a clearance wipe sample on this same side of the sill, once again measuring the associated dimensions of the sill.

5. In Room A, for the floor:
   a. Sweep any large debris from the floor.
   b. On one half of the floor
      i. Randomly designate two, 1 $ft^2$ locations, and perform a clearance wipe sample in each location.
      ii. Perform the dry DCC/WG clearance protocol until a DCC mopped over the entire floor surface is as clean as the appropriate visual standard for white glove or until 15 cloths have been soiled without reaching this standard.
      iii. Adjacent to the first two sampling locations, without overlapping any other sample locations, take a second set of clearance wipe samples.
      iv. Wipe the entire half floor surface with a single, wet DCC.
      v. Adjacent to the first and second sets of samples, without overlapping any other sample locations, take a final set of clearance wipe samples.
   c. On the other half of the floor
      i. Randomly designate two, 1 $ft^2$ locations, and perform a clearance wipe sample in each location.
      ii. Perform the wet DCC/WG clearance protocol until a DCC mopped over the entire floor surface is as clean as the appropriate visual standard for white glove or until 15 cloths have been soiled without reaching this standard.
      iii. Adjacent to the first two sampling locations, without overlapping any other sample locations, take a second set of clearance wipe samples.

6. In Room B, for the window sill
   a. Perform exactly the same protocol as for Room A, but use disposable wet cloths instead of dry.

7. In Room B, for the floor
   a. Perform exactly the same protocol as for Room A.

The critical sampling and cleaning cloth activities are illustrated in Figure 3. Floor sampling is shown in the top diagram and sill sampling below. Each process diagram shows a progressive view of the steps performed for each surface from initial wipe sampling, through cloth mopping, and finally to post-protocol wipe sampling. At each step, the legend box under each surface picture identifies the activity completed in that step. Activities previously completed are retained on the diagram but are relegated to the background by graying or dashed lines. In this way, the total protocol can be envisioned as a set of layers applied to a surface.

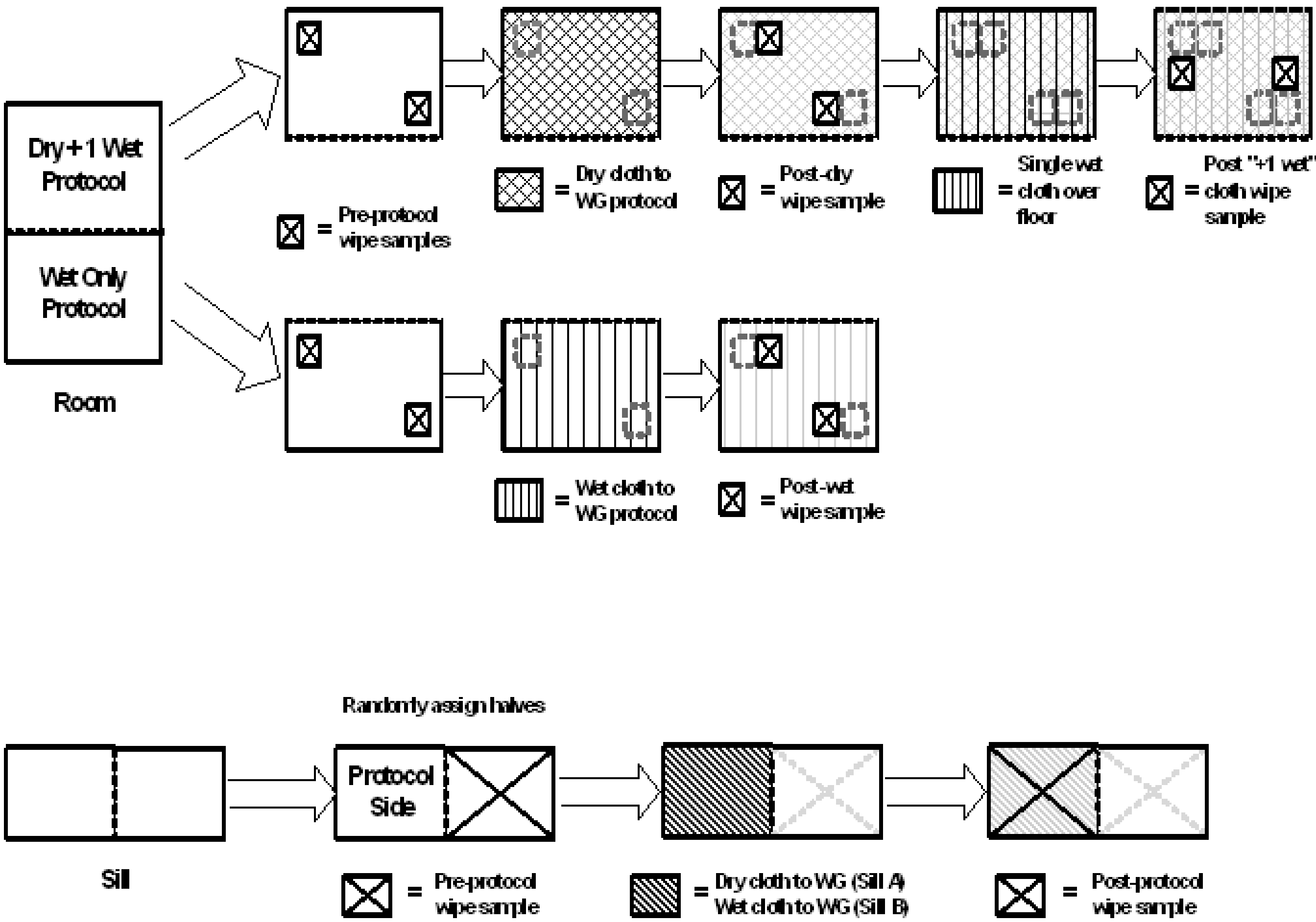



**Figure 3. Process Flow Diagram of Sampling for Residential Field Study**

From the diagrams in Figure 3, it can be seen that the protocols can be evaluated for effectiveness in the following manner:

For Floors

a. By comparing the mean of the two wipe samples taken after the dry protocol to the mean of the two wipe samples before the dry protocol began, we can evaluate the effectiveness of the Dry DCC/WG clearance protocol.
b. By comparing the mean of the two wipe samples after the dry protocol with one additional wet DCC, to the mean of the two wipe samples before dry protocol began,

we can evaluate the effectiveness of the Dry + 1 Wet DCC/WG clearance protocol.

c. By comparing the mean of the two wipe samples after the wet protocol to the mean of the two wipe samples before the wet protocol began, we can evaluate the effectiveness of the Wet DCC/WG clearance protocol.

For Sills

a. By comparing the value for the wipe sample taken after the dry protocol to the value of the wipe sample before the dry protocol began, we can evaluate the effectiveness of the Dry DCC/WG clearance protocol.
b. By comparing the value for the wipe sample taken after the wet protocol to the value of the wipe sample before the wet protocol began, we can evaluate the effectiveness of the Wet DCC/WG clearance protocol.

Note: No Dry + 1 Wet DCC/WG clearance protocol was evaluated for window sills because the surface areas were insufficient to include this third treatment.

More specific details regarding selection of sampling locations, instructions for performing the clearance wipe sampling, instructions for execution of the protocols (including the appropriate visual standards), and required documentation of activities is provided in the Quality Assurance Project Plan (see Appendix A).

### 3.4 QAPP Modifications

The following table details the deviations from the Quality Assurance Project Plan (see Appendix A). For completeness, every known deviation has been included. However, it should be noted that most of these deviations resulted from normal operational limitations that can be expected in a field study of this type. The number and nature of the deviations were not judged to threaten the accuracy or validity of the study results.

| Sampling Unit | Exception to QAPjP |
|---|---|
| Pilot (Unit 00) | For Floor A, the condition of the half of the floor designated for the wet treatment was deemed too poor to permit completion of the protocol. Hence, pre-protocol wipe samples were taken but the protocol was not completed, no post-protocol wipe samples were taken, and this half of the floor surface was eliminated from the study. |
| 01 | For Floor B, the sampling staff ran out of time to do the half of the floor surface slated to get the wet treatment, so this half of the floor surface was eliminated from the study. |

| Sampling Unit | Exception to QAPjP |
|---|---|
| 03 | The two “halves” of Floor B are actually two very small adjacent rooms in the unit. Additionally, in each of these spaces, the accumulation of significant dried “mounds” or “caked-on” debris required more than just a broom sweep before application of the protocol. In each case, debris was first scraped from the floor surface before the broom sweep. |
| 05 | The sill with the wet treatment was recorded as failing to reach white glove after two DCCs though this conclusion should not have been reached until three DCCs had failed the visual inspection for white glove. |
| 11 | The wipe samples from this site were found to be mislabeled during execution of the protocol. The measurements for this unit have been excluded from the study results. |
| 12 | The sill with the wet treatment reached white glove in six DCCs, though the treatment was supposed to be stopped and concluded as a white glove failure after three DCCs failing the visual standard for white glove. |
| 20 | The sill with the wet treatment failed to reach white glove in six DCCs, though the treatment was supposed to be stopped and concluded as a white glove failure after three DCCs had failed the visual standard for white glove. |
| 23 | The sill with the dry treatment failed to reach white glove in six DCCs, though the treatment was supposed to be stopped and concluded as a white glove failure after three DCCs had failed the visual standard for white glove. |
| 25 | The sill with the wet treatment failed to reach white glove in six DCCs, though the treatment was supposed to be stopped and concluded as a white glove failure after three DCCs had failed the visual standard for white glove. |
| 26 | The sill with the wet treatment failed to reach white glove in six DCCs, though the treatment was supposed to be stopped and concluded as a white glove failure after three DCCs had failed the visual standard for white glove. |
| 27 | The sill with the wet treatment reached white glove in six DCCs, though the treatment was supposed to be stopped and concluded as a white glove failure after three DCCs failing the visual standard for white glove. |

| Sampling Unit | Exception to QAPjP |
|---|---|
| 28 | No Floor A or Sill protocols were done in this unit. The Floor B protocol consisted of the Wet Only treatment on both halves of the floor; one with the mop manufacturer's cleaning solution and one with only water as a cleaning solution in the mop. Additionally, sampling where white glove could not be achieved was limited to five cloths instead of the 15 required in the QAPjP. |
| 29 | Floor A had the Dry+1Wet protocol applied to both halves of the floor. The one wet cloth used the mop manufacturer's cleaning solution on one half of the floor. The one wet cloth on the other side of the floor used only water as a cleaning solution in the mop. Floor B had the Wet Only protocol applied to both halves of the floor. The mop manufacturer's cleaning solution was used on one half of the floor and only water was used as a cleaning solution in the mop on the other half of the floor. The side of the floor with only water failed to reach white glove in 14 DCCs, though the protocol should have used 15 cloths before reaching that conclusion. |
| 30 | Floor A had the Dry+1Wet protocol applied to both halves of the floor. The one wet cloth used the mop manufacturer's cleaning solution on one half of the floor. The one wet cloth on the other side of the floor used only water as a cleaning solution in the mop. Floor B had the Wet Only protocol applied to both halves of the floor. The mop manufacturer's cleaning solution was used on one half of the floor and only water was used as a cleaning solution in the mop on the other half of the floor. |

# 4.0 FIELD DATA COLLECTION

Field data collection was performed in Baltimore and Milwaukee from July to December 2004. A total of 31 housing units are included in the study results, 11 in Baltimore and 20 in Milwaukee. The process for identifying and qualifying potential sample locations is explained in Section 4.1. The locations, dates, and sample conditions for each unit are provided in Section 4.2.

## 4.1 Site Selection

The objective of the study was to identify real-world residential housing that could provide an opportunity to assess the effectiveness of the protocol in determining if clearance had been met. The selection of these units was restricted by the following factors:

- Units were obtained from owners willing to volunteer their property for the study. Study team members in Baltimore worked through the City of Baltimore's Lead Program, as well as private owners, to identify units where the sampling team would be allowed to complete the protocol. In Milwaukee, the City Lead Program was the sampling team, though they still had to obtain permission from property owners to perform the study. Though not strictly a requirement, it turned out to be logistically easier to perform the protocol in uninhabited units. All sample units were uninhabited at the time of sampling.
- It was desired to include as many units as possible with expected, pre-protocol lead levels above the clearance standard for reasons explained in Section 3.2. In Baltimore, selection of units with expected lead hazards was done subjectively, which resulted in some units that were sampled having very low lead contamination levels. In Milwaukee, risk assessment sampling was used to identify and qualify units with floors over the clearance standard.
- Some surface conditions were known in advance of this study to be untenable with the proposed experimental protocol; therefore, these conditions were used to screen potential sample locations. To the extent possible, surfaces were required to be "smooth and cleanable." While this terminology could be interpreted in different ways, it was used in this study to exclude any surfaces that were in very poor condition (e.g., cracking, splintering) so that the protocol could not be reasonably implemented, because the DCCs would catch or tear apart on the surface imperfections. As discussed in Section 3.2, this still resulted in some testing for the field study of surfaces that would probably not meet "smooth and cleanable" standards applicable to a general use of the protocol. Additionally, only hard surfaces were considered (e.g., no carpeting). Other factors of floor condition were considered in this study and are discussed in more detail in Section 6.3.

## 4.2 Sampling Locations and Conditions

Tables 1 and 2 show detailed descriptions of the 31 units sampled. In addition to the location and date, each table shows the size of the surface area, the surface material, the surface condition, and what treatments were applied.

The floor areas in this evaluation ranged from 48 to 225 $ft^2$. Since two separate treatments were completed on each floor (combined dry and dry+1wet or wet only), the results reported for this study represent floor areas ranging from approximately 24 to 113 $ft^2$. The majority of floor surfaces sampled were wood (72 %). An additional 26% were linoleum or tile. In one location, concrete floors were sampled. Surface conditions varied from very good (newly installed or refinished wood floors with a polyurethane seal) to very poor (rough surfaces, unfinished surfaces, cracked). Appendix G contains a gallery of digital photographs of the floor surfaces sampled. In this appendix, Floor A for Unit 01 is an example of a floor in good condition. and Floor A for Unit 03 is an example of a floor in poor condition.

The protocol was applied to sill surfaces ranging from 0.4 to 2.4 $ft^2$. Two sill surfaces were identified as 'painted' without designation to their underlying surface material. Otherwise, all other sills were recorded to be wood. Sill surface conditions varied over the same range as floor conditions.

The Swiffer® and Swiffer® Wet® cloths were used for all dry DCC and wet DCC sampling, respectively, on window sills. For floors, the dry treatment was completed with the Swiffer® mop and corresponding dry, electrostatic cloths at all locations. The wet treatment (and the +1 wet cloth after the dry treatment) used two different systems; the Swiffer® WetJet® and the Clorox® ReadyMop®. These are commercially available mop handles with an attachment for a bottle of cleaning solution. Dry disposable cleaning pads are affixed to the rectangular mop head and a trigger on the mop sprays a stream of cleaning solution ahead of the mop head onto the floor. The spray function is battery-operated for the Swiffer® product and manual for the Clorox® product.

For Units 28-30, the treatments utilizing wet DCCs were modified slightly to obtain a comparison of the protocol effectiveness with the manufacturer's cleaning solution to performance with only water as the cleaning solution. The results of this analysis are shown in Section 6.2.3.4.

# Table 1. Field Study Floor Sampling

| | | | Floor A | | | | Floor B | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Unit** | **Location** | **Date** | *Area (ft²)* | *Material* | *Condition* | *Protocol (Product)* | *Area (ft²)* | *Material* | *Condition* | *Protocol (Product)* |
| 00 | Baltimore | 7/15/04 | 150 | W | 4 | Dry(S) + 1 Wet(SWC)[1] | 160 | T | 1 | Dry(S) + 1 Wet(SWC), Wet(SWC)[2] |
| 01 | Baltimore | 7/27/04 | 108 | W | 1 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 132 | W | 2 | Dry(S) + 1 Wet(SWJ)[3] |
| 02 | Baltimore | 8/12/04 | 135 | W | 1 | Dry(S) + 1 Wet(CRM), Wet(CRM) | 156 | W | 2 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 03 | Baltimore | 9/10/04 | 219 | W | 3 to 4 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 28 | W | 3 to 4 | Dry(S) + 1 Wet(CRM)[4] |
| | | | | | | | 20 | W | 3 to 4 | Wet(CRM) |
| 04 | Baltimore | 9/15/04 | 169 | W | 1 to 2 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 94 | W | 1 to 2 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 05 | Baltimore | 9/23/04 | 154 | W | 2 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 94 | W | 2 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 06 | Baltimore | 9/24/04 | 167 | L/V | 3 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 160 | W | 2 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 07 | Baltimore | 10/12/04 | 186 | L/V | 1 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 103 | L/V | 1 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 08 | Milwaukee | 9/21/04 | 110 | L/V | 1 | Dry(S) + 1 Wet(CRM), Wet(CRM) | 99 | W | 3 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 09 | Milwaukee | 9/22/04 | 56 | L/V | 4 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 99 | W | 3 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 10 | Milwaukee | 9/23/04 | 56 | W | 4 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 64 | L/V | 2 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 11 | Milwaukee | 9/23/04 | 72 | W | 2 | Dry(S) + 1 Wet(CRM), Wet(CRM) | 80 | L/V | 2 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 12 | Milwaukee | 9/22/04 | 99 | L/V | 2 | Dry(S) + 1 Wet(CRM), Wet(CRM) | 90 | W | 4 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 13 | Milwaukee | 9/28/04 | 80 | W | 3 | Dry(S) + 1 Wet(CRM), Wet(CRM) | 80 | L/V | 1 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 14 | Milwaukee | 9/29/04 | 64 | W | 3 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 64 | W | 3 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 15 | Milwaukee | 9/30/04 | 105 | W | 3 | Dry(S) + 1 Wet(CRM), Wet(CRM) | N/R | W | 2 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 16 | Milwaukee | 9/30/04 | 70 | W | 2 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 49 | W | 3 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 17 | Milwaukee | 10/1/04 | 72 | L/V | 2 | Dry(S) + 1 Wet(CRM), Wet(CRM) | 90 | W | N/R | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 18 | Milwaukee | 10/4/04 | 81 | L/V | 2 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 64 | L/V | 2 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 19 | Milwaukee | 10/5/04 | 64 | W | 3 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 64 | W | 4 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 20 | Milwaukee | 10/11/04 | 100 | W | 2 | Dry(S) + 1 Wet(CRM), Wet(CRM) | 100 | W | 3 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 21 | Milwaukee | 10/15/04 | 64 | W | 3 | Dry(S) + 1 Wet(CRM), Wet(CRM) | 88 | W | 3 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 22 | Milwaukee | 10/18/04 | 48 | L/V | 3 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 48 | T | 3 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 23 | Milwaukee | 10/20/04 | 80 | C | 2 | Dry(S) + 1 Wet(CRM), Wet(CRM) | 56 | L/V | 1 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 24 | Milwaukee[5] | 10/27/04 | 64 | W | 3 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 64 | W | N/R | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 25 | Milwaukee | 10/27/04 | 100 | W | 3 | Dry(S) + 1 Wet(CRM), Wet(CRM) | 100 | W | 3 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 26 | Milwaukee | 10/29/04 | 48 | W | 3 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) | 48 | W | 3 | Dry(S) + 1 Wet(CRM), Wet(CRM) |
| 27 | Milwaukee | 11/1/04 | 100 | W | 2 | Dry(S) + 1 Wet(CRM), Wet(CRM) | 100 | W | 2 | Dry(S) + 1 Wet(SWJ), Wet(SWJ) |
| 28 | Baltimore | 10/20/04 | | | | | 84 | W | 3 to 4 | Wet(SWJ), Wet(SWJ-$H_2O$) |
| 29 | Baltimore | 10/20/04 | 225 | W | 3 | Dry(S) + 1 Wet(CRM), Dry(S) + 1 Wet(CRM-$H_2O$) | 124 | W | 3 to 4 | Wet(CRM), Wet(CRM-$H_2O$) |
| 30 | Baltimore | 12/8/04 | 188 | W | 2 to 3 | Dry(S) + 1 Wet(SWJ), Dry(S) + 1 Wet(SWJ-$H_2O$) | 110 | W | 2 to 3 | Wet(SWJ), Wet(SWJ-$H_2O$) |

**KEY:**

Material: C = Concrete; L/V = Linoleum or Vinyl; T = Tile; W = Wood

Condition: 1 = Undamaged/New; 2 = Slight Damage/Wear; 3 = Partial Damage/Wear; 4 = Majority Damaged/Worn; 5 = Entire Area Damaged/Worn

N/R = Not reported

Protocol: Dry(S) = Swiffer Dry Cloth; Wet(CRM) = Clorox ReadyMop & Cleaning Solution; Wet(SWC) = Swiffer Wet Cloth; Wet(SWJ) = Swiffer Wet Jet & Swiffer Cleaning Solution; Wet(CRM-H2O) = Clorox ReadyMop & plain water; Wet (SWJ-H2O) = Swiffer Wet Jet & plain water

[1] Had to restrict protocol area because of catching/tearing of mop; did not perform wet-only protocol due to poor floor condition

[2] Performed wet protocol only on area surrounding samples

[3] Wet cloth protocol not performed due to lack of time

[4] Two treatments were performed in adjacent rooms rather than on two halves of one room

[5] Units 24 and 25 were the same residence

# Table 2. Field Study Sill Sampling

| | | | Sill A | | | | Sill B | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Unit** | **Location** | **Date** | *Area ($ft^2$)* | *Material* | *Condition* | *Protocol (Product)* | *Area ($ft^2$)* | *Material* | *Condition* | *Protocol (Product)* |
| P | Baltimore | 7/15/04 | 0.776 | N/R | 1 | Dry(S) | 0.668 | N/R | 1 | Wet(SWC |
| 1 | Baltimore | 7/27/04 | 1.172 | W | 1 | Dry(S) | 1.286 | W | 1 | Wet(SWC |
| 2 | Baltimore | 8/12/04 | 1.969 | W | 1 | Dry(S) | 1.657 | W | 1 | Wet(SWC |
| 3 | Baltimore | 9/10/04 | 0.742 | W | 2 | Dry(S) | 0.742 | W | 2 | Wet(SWC |
| 4 | Baltimore | 9/15/04 | 0.743 | W | 1 | Dry(S) | 0.406 | W | 1 to 2 | Wet(SWC |
| 5 | Baltimore | 9/23/04 | 0.515 | W | 2 | Dry(S) | 0.545 | W | 2 | Wet(SWC |
| 6 | Baltimore | 9/24/04 | 0.734 | W | 2 | Dry(S) | 0.563 | W | 2 | Wet(SWC |
| 7 | Baltimore | 10/12/04 | 0.571 | W | 1 | Dry(S) | 0.826 | W | 1 | Wet(SWC |
| 8 | Milwaukee | 9/21/04 | 0.534 | W | 1 | Dry(S) | 0.948 | W | 2 | Wet(SWC |
| 9 | Milwaukee | 9/22/04 | 0.937 | W | 3 | Dry(S) | 0.806 | W | 2 | Wet(SWC |
| 10 | Milwaukee | 9/23/04 | 0.542 | P | 2 | Dry(S) | 0.438 | W | 3 | Wet(SWC |
| 11 | Milwaukee | 9/23/04 | 0.750 | W | 3 | Dry(S) | 0.612 | W | 3 | Wet(SWC |
| 12 | Milwaukee | 9/22/04 | 0.438 | W | 4 | Dry(S) | 2.444 | W | 4 | Wet(SWC |
| 13 | Milwaukee | 9/28/04 | 0.584 | W | 1 | Dry(S) | 0.724 | W | 3 | Wet(SWC |
| 14 | Milwaukee | 9/29/04 | 0.562 | W | 1 | Dry(S) | 0.562 | W | 1 | Wet(SWC |
| 15 | Milwaukee | 9/30/04 | 0.778 | N/R | 2 | Dry(S) | 0.778 | W | 3 | Wet(SWC |
| 16 | Milwaukee | 9/30/04 | 0.500 | W | 2 | Dry(S) | 0.500 | W | 2 | Wet(SWC |
| 17 | Milwaukee | 10/1/04 | 0.700 | W | 2 | Dry(S) | 0.474 | W | 2 | Wet(SWC |
| 18 | Milwaukee | 10/4/04 | 1.432 | W | 3 | Dry(S) | 0.772 | W | 2 | Wet(SWC |
| 19 | Milwaukee | 10/6/04 | 0.826 | W | 3 | Dry(S) | 0.775 | W | 2 | Wet(SWC |
| 20 | Milwaukee | 10/11/04 | 0.438 | W | 3 | Dry(S) | 0.438 | W | 3 | Wet(SWC |
| 21 | Milwaukee | 10/15/04 | 0.584 | W | 2 | Dry(S) | 0.516 | W | 3 | Wet(SWC |
| 22 | Milwaukee | 10/18/04 | 0.590 | W | 2 | Dry(S) | 0.638 | W | 3 | Wet(SWC |
| 23 | Milwaukee | 10/20/04 | 1.218 | W | 3 | Dry(S) | 1.152 | W | 2 | Wet(SWC |
| 24 | Milwaukee | 10/27/04 | 1.504 | W | 2 | Dry(S) | 1.390 | W | 2 | Wet(SWC |
| 25 | Milwaukee | 10/27/04 | 1.302 | P | 2 | Dry(S) | 1.302 | W | 2 | Wet(SWC |
| 26 | Milwaukee | 10/29/04 | 0.618 | W | 3 | Dry(S) | 0.618 | W | 3 | Wet(SWC |
| 27 | Milwaukee | 11/1/04 | 0.688 | W | N/R | Dry(S) | 0.688 | W | 2 | Wet(SWC |
| 28 | Baltimore | 10/20/04 | | | | | | | | |
| 29 | Baltimore | 10/20/04 | 0.934 | W | 1 | Dry(S) | 0.891 | W | 1 to 2 | Wet(SWC |
| 30 | Baltimore | 12/8/04 | 0.772 | W | 1 | Dry(S) | 1.121 | W | 1 | Wet(SWC |

**KEY:**

Material: P = Painted (surface not specified)
W = Wood

Condition: 1 = Undamaged/New
2 = Slight Damage/Wear
3 = Partial Damage/Wear
4 = Majority Damaged/Worn
5 = Entire Area Damaged/Worn

N/R = Not reported

Protocol: Dry(S) = Swiffer Dry Cloth
Wet(SWC) = Swiffer Wet Cloth

## 5.0 LABORATORY ANALYSIS

All ASTM wipe sample preparation and analysis was conducted by Microbac Laboratories, Inc., Gascoyne Division, an NLLAP-accredited laboratory. Details of the applicable analytical methods are provided in Section 5.1. Descriptions of the laboratory QC results are provided in Section 5.2.

### 5.1 Review of Analytical Methods

Sample analysis was conducted using Flame Atomic Absorption Spectrophotometry in accordance with NIOSH method 7082. This method provided accurate measurement of lead content to a lower quantitation limit of 10 µg per wipe sample.

All digestates from samples were stored following analysis in the event that EPA should desire a re-analysis of the samples (e.g., with an analytical method providing a lower quantitation limit).

### 5.2 Laboratory QC Results

QC samples for this study included the following:

Field Blanks - Field sampling staff inserted a single blank wipe into an empty sample collection tube at the conclusion of sampling activities at each unit and returned that sample with the other wipe samples. This sample was analyzed by the laboratory with the expectation that the result would show no lead contamination.

Table 3 shows that all field blanks with the exception of one were below the quantitation limit. The one exception was for Unit 08 which showed a measurement of 15 µg. This sample was re-analyzed in the lab with a similar result (17 µg). Review of the sample log yielded no explanation for why the field blank might have had lead contamination. Consequently, the data for Unit 08 have been left in the final statistical analysis.

Spiked Samples - To provide a check on the analytical laboratory, Battelle laboratory staff prepared two spiked wipe samples for analysis with other sampling data in each unit. One wipe was spiked at 20 micrograms of lead and the second at 40 micrograms. Table 4 shows the Microbac laboratory analytical results for these spiked samples.

**Table 3. Field Blank Sample Results**

| Unit | Lead Result (µg/wipe) | Exceeds Quantitation Limit |
|---|---|---|
| 0 | <10 | No |
| 1 | <10 | No |
| 2 | <10 | No |
| 3 | < 10 | No |
| 4 | < 10 | No |
| 5 | < 10 | No |
| 6 | < 10 | No |
| 7 | < 10 | No |
| 8 | 15 | Yes |
| 9 | < 10 | No |
| 10 | < 10 | No |
| 11 | < 10 | No |
| 12 | < 10 | No |
| 13 | < 10 | No |
| 14 | < 10 | No |
| 15 | < 10 | No |
| 16 | < 10 | No |
| 17 | < 10 | No |
| 18 | < 10 | No |
| 19 | < 10 | No |
| 20 | < 10 | No |
| 21 | < 10 | No |
| 22 | < 10 | No |
| 23 | < 10 | No |
| 24 | < 10 | No |
| 25 | < 10 | No |
| 26 | < 10 | No |
| 27 | < 10 | No |
| 28 | < 10 | No |
| 29 | < 10 | No |
| 30 | < 10 | No |

**Table 4. Sampling Results from Battelle Laboratory Spike QC Samples**

| Unit | 20 µg Target Lead Spike Sample | | | | 40 µg Target Lead Spike Sample | | | |
|---|---|---|---|---|---|---|---|---|
| | Sample Mass (g) | True Lead Level (µg) | Measured Lead Level (µg) | Percent Recovery | Sample Mass (g) | True Lead Level (µg) | Measured Lead Level (µg) | Percent Recovery |
| 0 | 0.0020 | 19.52 | 17 | 87% | 0.0041 | 40.02 | 33 | 82% |
| 1 | 0.0022 | 21.47 | 18 | 84% | 0.0040 | 39.04 | 36 | 92% |
| 2 | 0.0019 | 18.55 | 17 | 92% | 0.0039 | 38.07 | 35 | 92% |
| 3 | 0.0022 | 21.47 | 19 | 88% | 0.0041 | 40.02 | 37 | 92% |
| 4 | 0.0021 | 20.50 | 16 | 78% | 0.0041 | 40.02 | 40 | 100% |
| 5 | 0.0019 | 18.55 | 16 | 86% | 0.0040 | 39.04 | 37 | 95% |
| 6 | 0.0020 | 19.52 | 16 | 82% | 0.0039 | 38.07 | 35 | 92% |
| 7 | 0.0023 | 22.45 | 21 | 94% | 0.0038 | 37.09 | 31 | 84% |
| 8 | 0.0023 | 22.45 | 16 | 71% | 0.0041 | 40.02 | 34 | 85% |
| 9 | 0.0020 | 19.52 | 19 | 97% | 0.0041 | 40.02 | 34 | 85% |
| 10 | 0.0020 | 19.52 | 18 | 92% | 0.0045 | 43.92 | 35 | 80% |
| 11 | 0.0019 | 18.55 | 18 | 97% | 0.0042 | 41.00 | 39 | 95% |
| 12 | 0.0020 | 19.52 | 16 | 82% | 0.0042 | 41.00 | 37 | 90% |
| 13 | 0.0021 | 20.50 | 21 | 102% | 0.0041 | 40.02 | 41 | 102% |
| 14 | 0.0021 | 20.50 | 18 | 88% | 0.0041 | 40.02 | 39 | 97% |
| 15 | 0.0021 | 20.50 | 17 | 83% | 0.0040 | 39.04 | 44 | 113% |
| 16 | 0.0020 | 19.52 | 24 | 123% | 0.0039 | 38.07 | 40 | 105% |
| 17 | 0.0022 | 21.47 | 20 | 93% | 0.0039 | 38.07 | 30 | 79% |
| 18 | 0.0023 | 22.45 | 16 | 71% | 0.0039 | 38.07 | 33 | 87% |
| 19 | 0.0024 | 23.43 | 26 | 111% | 0.0042 | 41.00 | 38 | 93% |
| 20 | 0.0020 | 19.52 | 16 | 82% | 0.0040 | 39.04 | 31 | 79% |
| 21 | 0.0020 | 19.52 | 16 | 82% | 0.0040 | 39.04 | 37 | 95% |
| 22 | 0.0021 | 20.50 | 22 | 107% | 0.0040 | 39.04 | 35 | 90% |
| 23 | 0.0022 | 21.47 | 17 | 79% | 0.0040 | 39.04 | 31 | 79% |
| 24 | 0.0020 | 19.52 | 16 | 82% | 0.0040 | 39.04 | 32 | 82% |
| 25 | 0.0020 | 19.52 | 20 | 102% | 0.0040 | 39.04 | 37 | 95% |
| 26 | 0.0024 | 23.43 | 22 | 94% | 0.0040 | 39.04 | 34 | 87% |
| 27 | 0.0020 | 19.52 | 22 | 113% | 0.0041 | 40.02 | 39 | 97% |
| 28 | 0.0022 | 21.47 | 17 | 79% | 0.0044 | 42.95 | 39 | 91% |
| 29 | 0.0022 | 21.47 | 20 | 93% | 0.0042 | 41.00 | 40 | 98% |
| 30 | 0.0022 | 21.47 | 19 | 88% | 0.0039 | 38.07 | 31 | 81% |

(gray shading) Outside of +/- 20% acceptance criteria

In 9 of the 62 samples (highlighted in gray), the measured recovery was outside the QAPjP requirement of +/- 20% of the target values. These samples exhibit greater variability than expected in the spiked sample recoveries. Additionally, the average measured recovery was 90.5 percent for the 20 microgram samples and 90.8 percent for the 40 microgram samples. This suggests also a potential bias in sample recoveries. However, the small amounts of SRM 2584 (nominal 1% lead[2] by weight) required to produce the 20 and 40 microgram samples (two and four milligrams, respectively) fall well below the minimum 100 mg sample size at which NIST

[2]NIST certified 9761 mg/kg with 95 percent prediction interval of ± 67 mg/kg for samples of at least 100 mg.

has specified a known uncertainty of the mass fraction of lead in the SRM. Therefore, it could well be that the failures and bias result from variation (about one percent) in the true mass fraction of lead used to spike the samples.

If the observed bias is reflective of the laboratory lead measurement (and not a bias in preparation of the spiked samples), it may indicate that the measured results from the wipe samples in the study are artificially low. To understand the impact of this possibility, the study results were adjusted under the assumption that laboratory measured lead levels were only 90 percent of the true lead levels. These recalculated results were not different for the primary data quality objective of assessing whether attaining white glove was reflective of meeting the clearance standard. The recalculated results did show minor changes for other study results.

Laboratory QC Samples - As part of its standard laboratory QC procedures, Microbac Laboratories performed QC samples including independent calibration verifications, independent calibration blanks, continuing calibration verifications and blanks, post-digest analytical spikes and duplicates, and sample wipe laboratory blanks. These were collected consistent with the requirements of Table 2-2 in Section 2.4 of the QAPjP (see Appendix A). They are summarized in Table 5 below.

Review of the QC data did not identify any deviations from the required frequency or acceptance limits for these samples.

**Table 5. Analytical Laboratory QC Sample Results**

| QC Result | Actual Frequency | Acceptance |
|---|---|---|
| Independent Calibration Verification (ICV) | Once per day | All ICVs within ± 10% of known value |
| Initial Calibration Blank (ICB) | Once per run | All results less than the lowest calibration standard (10 µg/wipe), usually non-detections |
| Continuing Calibration Verification (CCV) | At least once per 10 samples | All CCVs within ± 15% of known value |
| Continuing Calibration Blank | At least once per 10 samples | All results less than the lowest calibration standard (10 µg/wipe), usually non-detections |
| Post-Digest Analytical Spike | At least once per 20 samples | All within ± 20% of calculated value (most within ± 10% of calculated value) |
| Post-Digest Analytical Duplicate | At least once per 20 samples | All within ± 20% Relative Percent Difference (RPD) (most within ± 10% of calculated value) |
| Sample Wipe Laboratory Blank | At least once per 20 samples | All results less than the lowest calibration standard (10 µg/wipe), usually non-detections |

## 6.0 ANALYSIS RESULTS

This section provides graphical and tabular summaries of the data obtained from the field study as well as detailed discussion of findings with regard to each of the study data quality objectives (as introduced in Section 3.1). Section 6.1 provides reference graphs and tables of the field study data. Section 6.2 contains a detailed discussion of the results by quality objective.

### 6.1 Graphical and Tabular Summaries of Results

Five separate treatments were evaluated in the field study. These included:

– For Floors
Dry Cloth to White Glove (or a maximum limit of 15 DCCs) - Graph 1
Dry Cloth to White Glove (or a maximum limit of 15 DCCs) Followed by One Wet Cloth - Graph 2
Wet Cloth to White Glove (or a maximum limit of 15 DCCs) - Graph 3

– For Window Sills
Dry Cloth to White Glove (or a maximum limit of 3 DCCs) - Graph 4
Wet Cloth to White Glove (or a maximum limit of 3 DCCs) - Graph 5

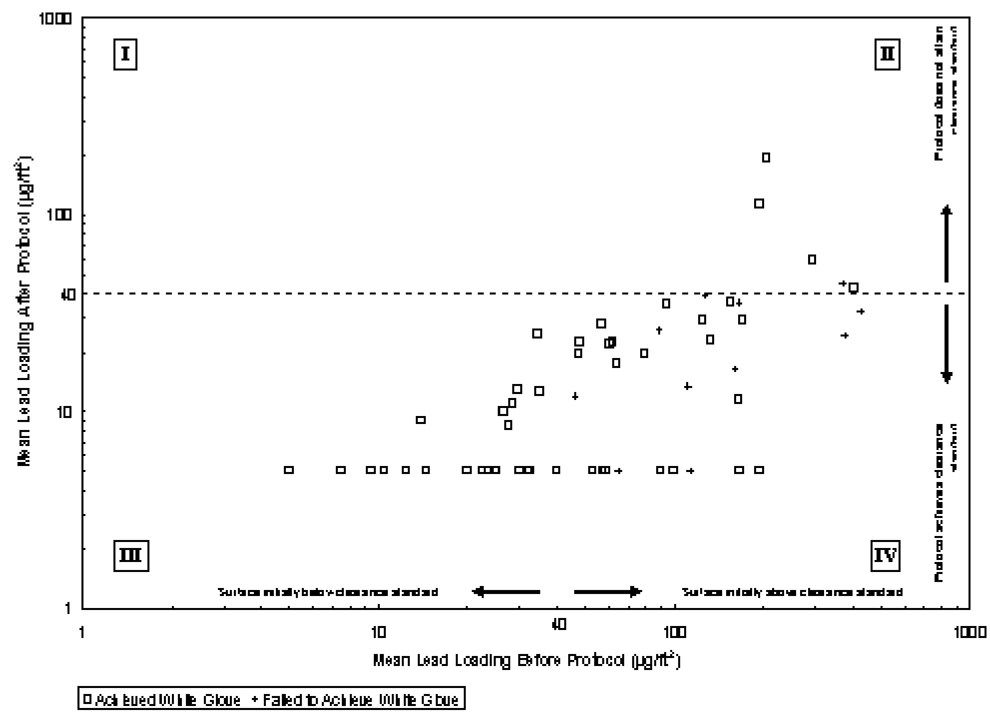
Each of the scatter plots for these five treatments display the relationship between the lead loading on each test floor or window surface before the protocol was begun and the lead loading after completion of the clearance protocol. Note that for each floor test surface, two wipe samples were collected before and after conducting each treatment protocol. (The before and after wipe samples were collected side by side to minimize spatial variability.) The measurement results used in each scatter plot graph are the arithmetic means of the paired wipe sample measurements. For the window sill surfaces, only a single pre-protocol and post-protocol wipe sample were taken due to sill size limitations. Both the horizontal and vertical axes are a logarithmic scale.

Each graph includes two types of points. The empty boxes represent the data points where the clearance protocol achieved white glove. The pluses are the data points where the protocol failed to achieve white glove. Measured lead loadings less than the laboratory's minimum quantitation limit of 10 $\mu g/ft^2$ are represented as one half this limit (i.e., 5 $\mu g/ft^2$).

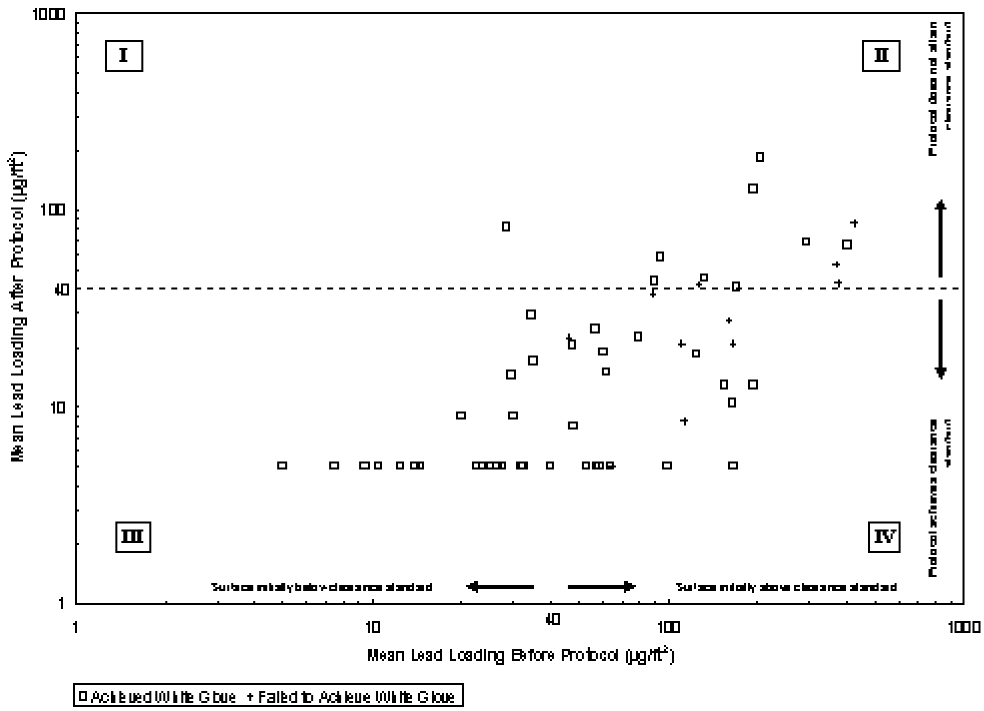
Finally, each graph shows dotted reference lines (both horizontally and vertically) at the clearance standard (40 micrograms for floors, 250 micrograms for sills). Using these lines, the graphs are separated into four quadrants with the following labels and definitions:

a. Points plotted in the upper left hand quadrant represent surfaces that were below the clearance standard before the DCC/WG protocol and ended up above the clearance standard afterward.
b. Points plotted in the upper right hand quadrant represent surfaces that were above the clearance standard before the DCC/WG protocol and remained above the clearance standard afterward.
c. Points plotted in the lower left hand quadrant represent surfaces that were below the clearance standard before the DCC/WG protocol and remained below the clearance standard afterward.
d. Points plotted in the lower right hand quadrant represent surfaces that were above the clearance standard before the DCC/WG protocol and fell below the clearance standard afterward.

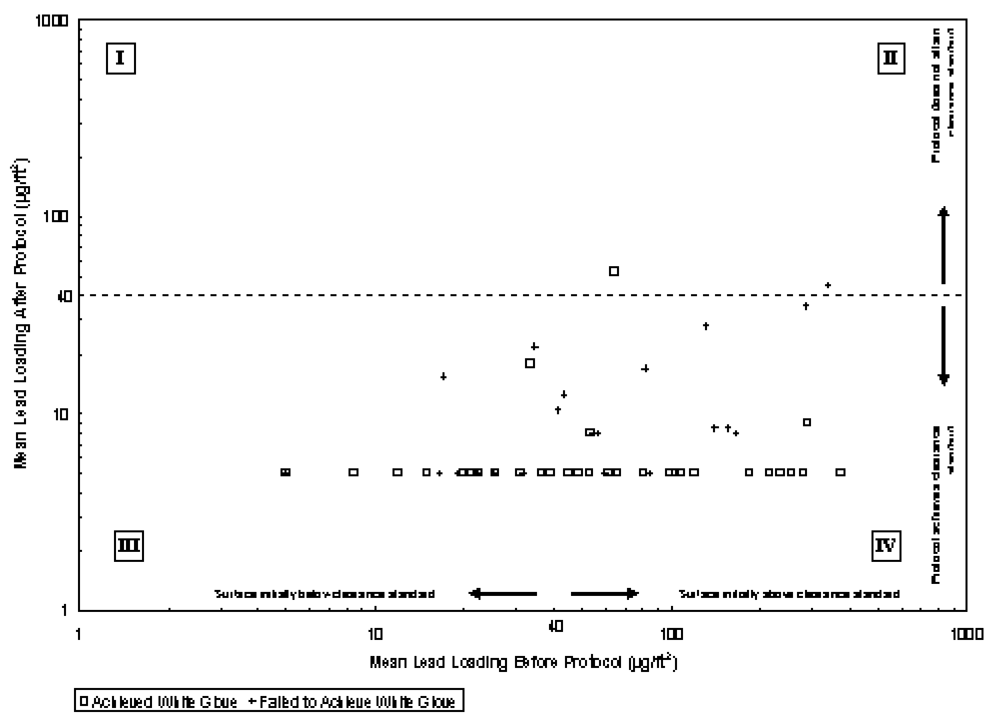
Graph 1 - Dry Cloth to White Glove (or Max 15 Cloths) on Floors



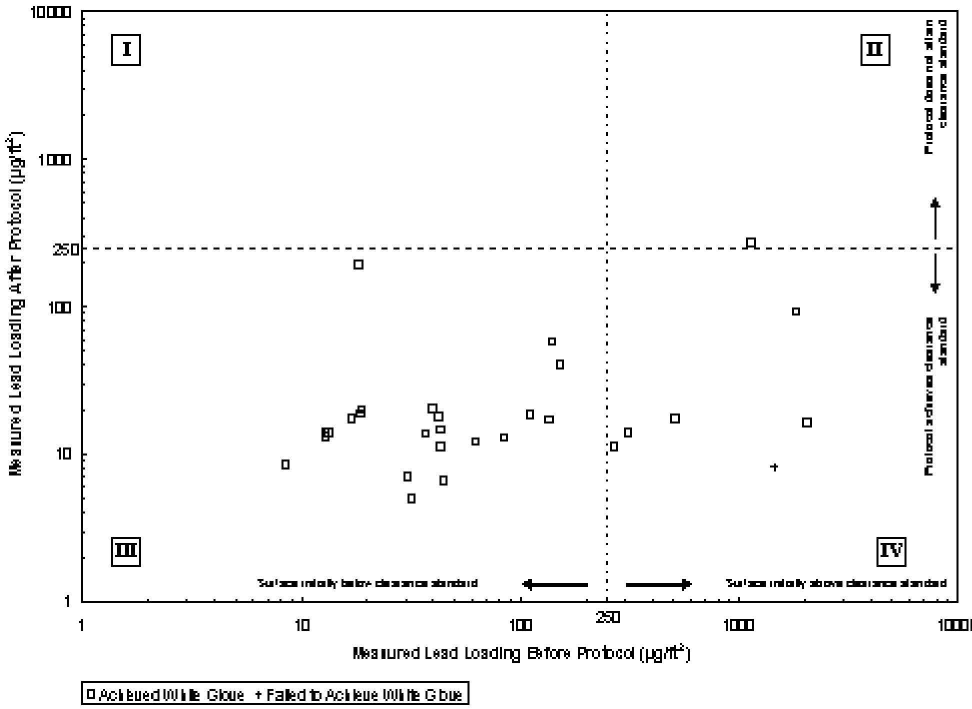
Graph 2 - Dry Cloth to White Glove (or Max 15 Cloths)
Followed by One Wet Cloth on Floors




Graph 3 - Wet Cloth to White Glove (or Max 15 Cloths) on Floors



Graph 4 - Dry Cloth to White Glove (or Max 3 Cloths) on Sills




Graph 5 - Wet Cloth to White Glove (or Max 3 Cloths) on Sills

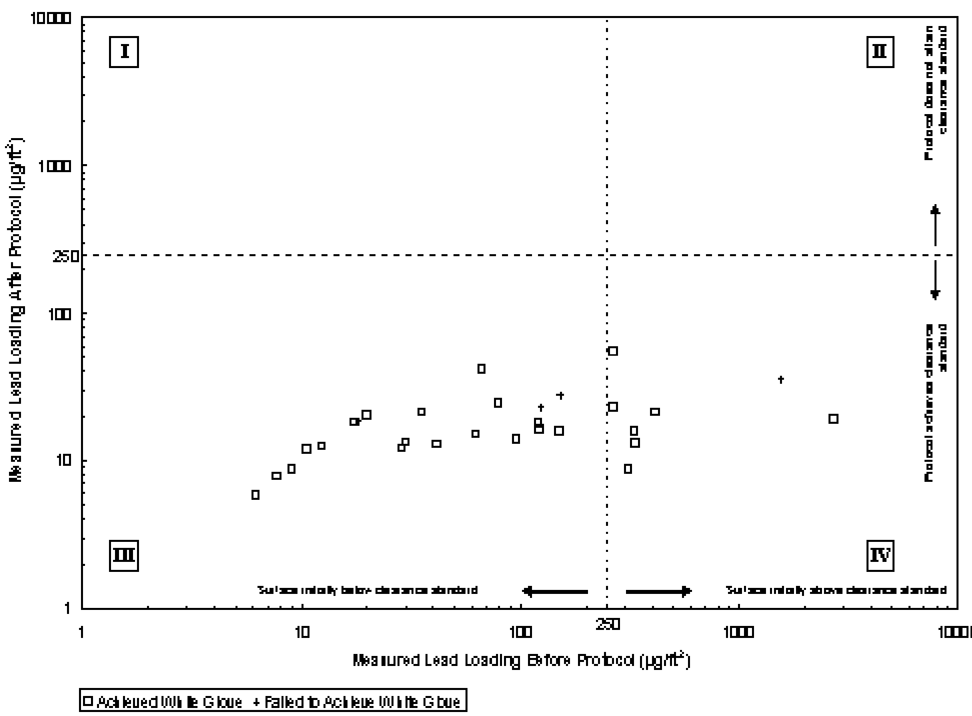


Table 6 provides counts of surfaces over or under the clearance standard after completing each of the five treatments. The counts are grouped by whether or not white glove was achieved and whether the surface was initially above or below the clearance standard before performance of the protocol. In this way, Table 6 essentially provides two cross tabulations (achieving white glove or not achieving white glove) of numbers of data points in each of the four quadrants of Graphs 1-5.

**Table 6. Counts of Surfaces Over or Under Clearance Standards by Treatment, Pre-Protocol Lead Loading, and White Glove Status**

| Floor<br>Dry Cloth to White Glove | | Surfaces Achieving White Glove<br>Mean Lead Loading Before Protocol | | Surfaces Not Achieving White Glove<br>Mean Lead Loading Before Protocol | |
|---|---|---|---|---|---|
| | | At or Below Clearance Standard | Above Clearance Standard | At or Below Clearance Standard | Above Clearance Standard |
| Mean Lead Loading After Protocol | Above Clearance Standard | 0 | 4 | 0 | 1 |
| | At or Below Clearance Standard | 23 | 20 | 0 | 10 |

| Floor<br>Dry Cloth to White Glove + 1 Wet Cloth | | Surfaces Achieving White Glove<br>Mean Lead Loading Before Protocol | | Surfaces Not Achieving White Glove<br>Mean Lead Loading Before Protocol | |
|---|---|---|---|---|---|
| | | At or Below Clearance Standard | Above Clearance Standard | At or Below Clearance Standard | Above Clearance Standard |
| Mean Lead Loading After Protocol | Above Clearance Standard | 1 | 8 | 0 | 4 |
| | At or Below Clearance Standard | 22 | 16 | 0 | 7 |

| Floor<br>Wet Cloth to White Glove | | Surfaces Achieving White Glove<br>Mean Lead Loading Before Protocol | | Surfaces Not Achieving White Glove<br>Mean Lead Loading Before Protocol | |
|---|---|---|---|---|---|
| | | At or Below Clearance Standard | Above Clearance Standard | At or Below Clearance Standard | Above Clearance Standard |
| Mean Lead Loading After Protocol | Above Clearance Standard | 0 | 1 | 0 | 1 |
| | At or Below Clearance Standard | 16 | 20 | 8 | 12 |

| Sill<br>Dry Cloth to White Glove | | Surfaces Achieving White Glove<br>Mean Lead Loading Before Protocol | | Surfaces Not Achieving White Glove<br>Mean Lead Loading Before Protocol | |
|---|---|---|---|---|---|
| | | At or Below Clearance Standard | Above Clearance Standard | At or Below Clearance Standard | Above Clearance Standard |
| Mean Lead Loading After Protocol | Above Clearance Standard | 0 | 1 | 0 | 0 |
| | At or Below Clearance Standard | 22 | 5 | 0 | 1 |

| Sill<br>Wet Cloth to White Glove | | Surfaces Achieving White Glove<br>Mean Lead Loading Before Protocol | | Surfaces Not Achieving White Glove<br>Mean Lead Loading Before Protocol | |
|---|---|---|---|---|---|
| | | At or Below Clearance Standard | Above Clearance Standard | At or Below Clearance Standard | Above Clearance Standard |
| Mean Lead Loading After Protocol | Above Clearance Standard | 0 | 0 | 0 | 0 |
| | At or Below Clearance Standard | 18 | 7 | 3 | 1 |

Table 7 presents an overall summary of the effectiveness of each treatment. For surfaces achieving white glove, the number of surfaces sampled and the number below the standard after performance of the protocol are shown. From these two quantities, the estimated protocol success rate is calculated as:

$$\text{Estimated Protocol Success Rate} = \frac{\text{Below Standard After Protocol}}{\text{Total Surfaces}} \bullet 100$$

This is an estimate of the probability that the lead level of the surface will be below the clearance standard given that the white glove condition was met. If the number of surfaces Below Standard After Protocol is designated as **s** and the number of Total Surfaces as **n**, an estimated lower 95% confidence bound on the protocol success rate is:

$$\text{The value of p such that} \sum_{i=s}^{n} \left( \frac{n!}{i!(n-i)!} \right) p^{i} (1-p)^{(n-i)} = 0.05$$

This **p** signifies the true population success rate below which it would be unusual (i.e., less than or equal to 5% chance) to observe as many or more successes as were observed in this study.

For surfaces that failed to achieve white glove, Table 7 shows the total number of surfaces, the number below the standard after the protocol, and the percentage that met the clearance standard (despite failing to achieve white glove).

**Table 7. Overall DCC/WG Clearance Protocol Success Rates by Treatment**

| | | | Surfaces Achieving White Glove | | | | Surfaces Not Achieving White Glove | | |
|---|---|---|---|---|---|---|---|---|---|
| Surface | Clearance Standard ($\mu g/ft^2$) | Treatment | Total Surfaces | Below Standard After Protocol | Estimated Protocol Success Rate | Lower 95% Confidence Bound | Total Surfaces | Below Standard After Protocol | Percentage at or Below Standard |
| Floor | 40 | Dry Cloth to White Glove | 47 | 43 | 91.5% | 81.6% | 11 | 10 | 90.9% |
| | | Dry Cloth to White Glove + 1 Wet Cloth | 47 | 38 | 80.9% | 69.0% | 11 | 7 | 63.6% |
| | | Wet Cloth to White Glove | 37 | 36 | 97.3% | 87.8% | 21 | 20 | 95.2% |
| Sill | 250 | Dry Cloth to White Glove | 28 | 27 | 96.4% | 84.1% | 1 | 1 | 100.0% |
| | | Wet Cloth to White Glove | 25 | 25 | 100.0% | 88.7% | 4 | 4 | 100.0% |

## 6.2 Results by Data Quality Objective

### 6.2.1 Data Quality Objective 1

The first data quality objective of this study was to estimate the probability (and corresponding one-sided 95% lower confidence bound) that surfaces will achieve the appropriate clearance standard (as determined by wipe sampling), given that the floor or window sill surfaces have passed the white glove test using the DCC/WG clearance protocol. Table 7 provides these estimates for each of the protocol variations examined on floors and sills.

In Table 7, each of the five treatments is listed in a separate row, identified by the surface type (floor or sill), corresponding clearance standard, and specific variation of the protocol tested (wet, dry, or a combination). Data Quality Objective 1 is concerned with the portion of the table for 'Surfaces Achieving White Glove.' Further discussion is provided for each of the five treatments in Sections 6.2.1.1 through 6.2.1.5.

**6.2.1.1 Data Quality Objective 1 - Dry Cloth to White Glove Treatment on Floors.** The first row of Table 7 shows that 47 floor surfaces out of a total of 58 treated floors achieved white glove with the dry cloth treatment. In 43 of these 47 cases, the post-treatment protocol mean wipe sample results were at 40 $\mu g/ft^2$ or less. This results in an estimated 91.5% success rate. The lower bound for a one-sided 95% confidence interval for this estimate is an 81.6% success rate. Hence, the results from this study provide strong evidence (i.e., 95% confidence) that the protocol would be effective in similar housing at least 81.6% of the time. The results for this treatment were shown in Graph 1.

Further examination of the dry protocol results is provided under Data Quality Objective 2 (Section 6.2.2).

**6.2.1.2 Data Quality Objective 1 - Dry Cloth to White Glove + 1 Wet Cloth Treatment on Floors.** For each of the 47 surfaces that achieved white glove with the dry cloth treatment, a single additional clearance wiping was performed with a wet cloth. Only 38 of these 47 surfaces (second row of Table 7) showed mean wipe sample results of 40 $\mu g/ft^2$ or less after the additional wet cloth. This corresponds to an estimated 80.9% success rate. The lower bound for a one-sided 95% confidence interval for this estimate is 69.0%. Hence, the results from this study provide strong evidence (i.e., 95% confidence) that the protocol would be effective in similar housing at least 69.0% of the time. The results for this treatment were shown in Graph 2.

The poorer estimated success rate for this treatment (80.9%) as compared to the dry cloth treatment alone (91.5%) was unexpected. Laboratory data collected on smooth vinyl tile floors had shown that a protocol that included a wet cloth mopping after reaching white glove with dry cloths was more effective at reducing lead levels than the dry cloth treatment alone. While the result from this study is not explained, one hypothesis is that the single wet cloth loosens and disburses significant lead from cracks or crevices that subsequently become available to a wipe sample collection but which would not have been accessible after a dry cloth treatment alone.

Also, it should be noted that though the dry cloth treatment alone has a higher estimated effectiveness than the combined dry and wet cloth treatment, the difference observed in this study is not statistically significant.

**6.2.1.3 Data Quality Objective 1 - Wet Cloth to White Glove Treatment on Floors.** The wet only DCC/WG clearance protocol performed best of the three DCC protocols tested on floors (third row of Table 7 and Graph 3). The wet cloth protocol passed clearance for 36 of 37 surfaces where white glove was achieved, corresponding to a 97.3% success rate. The lower bound for a one-sided 95% confidence interval for this estimate is 87.8%. Hence, the results from this study provide strong evidence (i.e., 95% confidence) that the protocol would be effective in similar housing at least 87.8% of the time. Although higher than the results for either the Dry or Dry+1 Wet treatments, the observed success rate for the wet protocol was not statistically significantly better than either of the other two.

Though not statistically significant, the order of observed effectiveness (dry+1 wet, dry only, wet only), if true, is still puzzling: Why would one wet cloth not improve on the dry result but multiple wet cloths would have the best observed performance? A possible explanation for the poorer performance of the dry+1 wet cloth treatment compared to the dry cloth only treatment was presented in 6.2.1.2 above. The logical extension to this hypothesis is that the additional leaded dust exposed by the wet cloth cannot be adequately removed with only one wet cloth. However, multiple wet cloths will eventually remove it and ultimately leave even less available leaded dust for a dust wipe sample than a protocol based on dry DCCs.

**6.2.1.4 Data Quality Objective 1 - Dry Cloth to White Glove Treatment on Sills.** The fourth row of Table 7 shows that 27 of 28 (96.4%) sills receiving the dry cloth to white glove treatment where white glove was achieved were found to be below the clearance standard of 250 $\mu g/ft^2$. This corresponds to a lower 95% confidence bound of 84.2% on the protocol success rate. One important factor with the sill results (as seen in Graph 4 and on Table 6) is that only a small number of sills that reached white glove with this treatment (six sills) were initially above the clearance standard before application of the treatment. Also, the surface of the single window sill that failed clearance was one of those initially above the clearance standard and that it was in especially poor condition with deterioration to the paint and underlying wood.

**6.2.1.5 Data Quality Objective 1 - Wet Cloth to White Glove Treatment on Sills.** The fifth row of Table 7 shows that 25 of 25 (100%) sills receiving the wet cloth to white glove treatment where white glove was achieved were found to be below the clearance standard of 250 $\mu g/ft^2$. This corresponds to a lower 95% confidence bound on the protocol success rate of at least 88.7%. As with the dry cloth protocol, only a small number of sills that reached white glove with this treatment (seven sills) were initially above the clearance standard before application of the treatment (as seen in Graph 5 and on Table 6).

### 6.2.2 Data Quality Objective 2

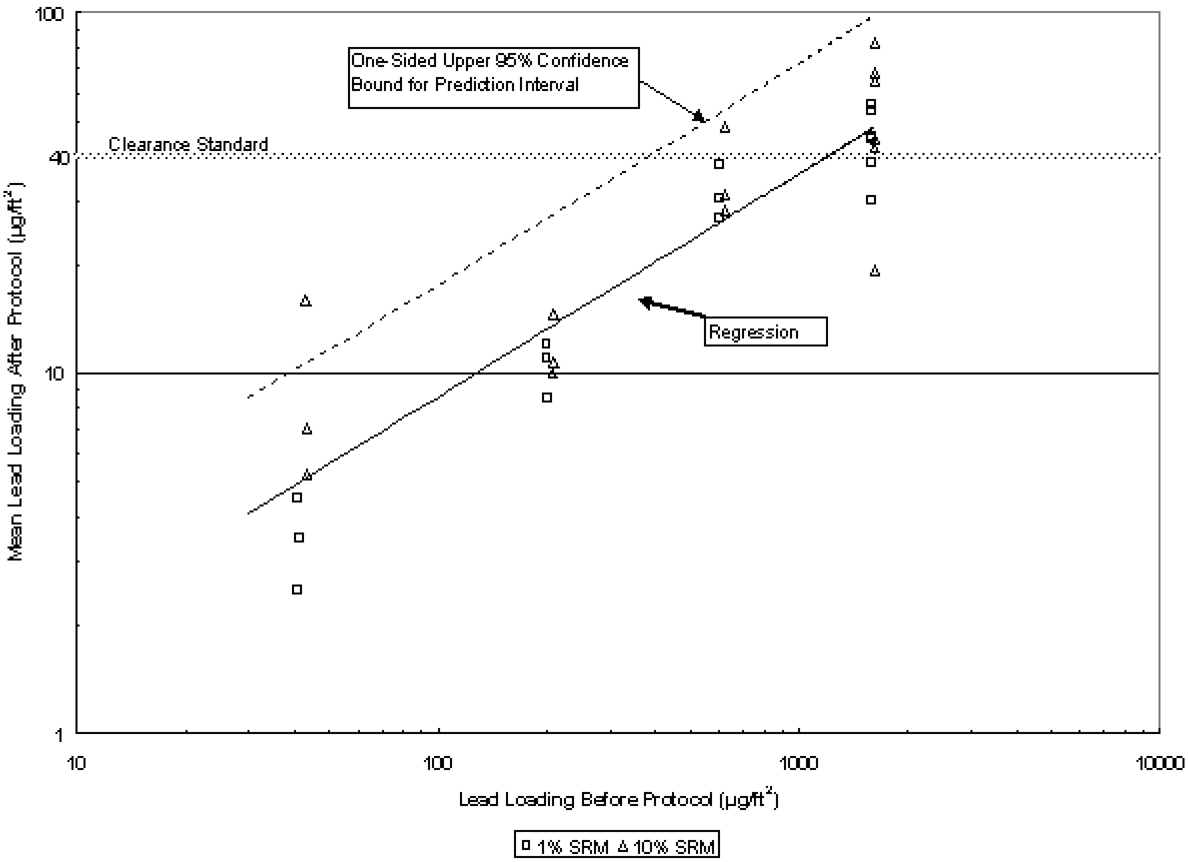
One objective of this field study was to compare the results obtained with those of the Second Controlled Room Study (see Appendix E). In the Second Controlled Room Study, the effectiveness of the DCC/WG clearance protocol was examined on a single floor surface and with predetermined lead contamination levels. The planned nature of this previous study is the source of the 'controlled room' name. It is titled the 'second' controlled room study because an earlier controlled room evaluation was performed (see Appendix C). For simplicity, future references in Section 6.2.2 to the Second Controlled Room Study will refer to it as the controlled room study.

The experimental design for the controlled room study involved spiking a vinyl tile floor (48 $ft^2$ test areas) with one of two lead-containing standard reference materials (SRM #2584 = house dust with 1% lead, SRM #2589 = pulverized paint with 10% lead). For each test area, carefully measured quantities of the SRM were uniformly dispersed over the entire 48 $ft^2$ area at one of four different lead loadings: 40 $\mu g/ft^2$, 200 $\mu g/ft^2$, 600 $\mu g/ft^2$, and 1600 $\mu g/ft^2$. Each of the two SRM/lead concentrations and four lead loading combinations was repeated three times for a total of 24 floor areas tested (2 x 4 x 3 = 24). A DCC/WG clearance protocol (similar to the dry cloth treatment used in the field study) was executed for each floor test area and was followed by collection of four clearance wipe samples from each floor test area. By comparing the wipe sample results collected after the protocol with the known (initial) lead spiking levels, the effectiveness of the treatment was evaluated for each lead loading/lead concentration combination.

**6.2.2.1 Comparison of Dry DCC/WG Treatment Between Controlled Room and Field Study.** The following sections separately outline the results for the dry DCC/WG treatment in the controlled room study (Section 6.2.2.1.1), the field study (Section 6.2.2.1.2), and then the comparison of the two results (Section 6.2.2.1.3).

*6.2.2.1.1 Dry Cloth to White Glove in Second Controlled Room Study.* Graph 6 displays the comparison of the means of post-protocol lead loadings to initial lead loadings for the dry DCC mopping protocol executed in the Second Controlled Room Study in late 2003. As described above, each floor surface was spiked with a carefully measured mass of lead (approximately 40, 200, 600, or 1,600 $\mu g/ft^2$) in one of two different concentrations (1% and 10% by weight).

Graph 6 - Dry Cleaning Cloth to White Glove on Floors - Second Controlled Room Study (2003)

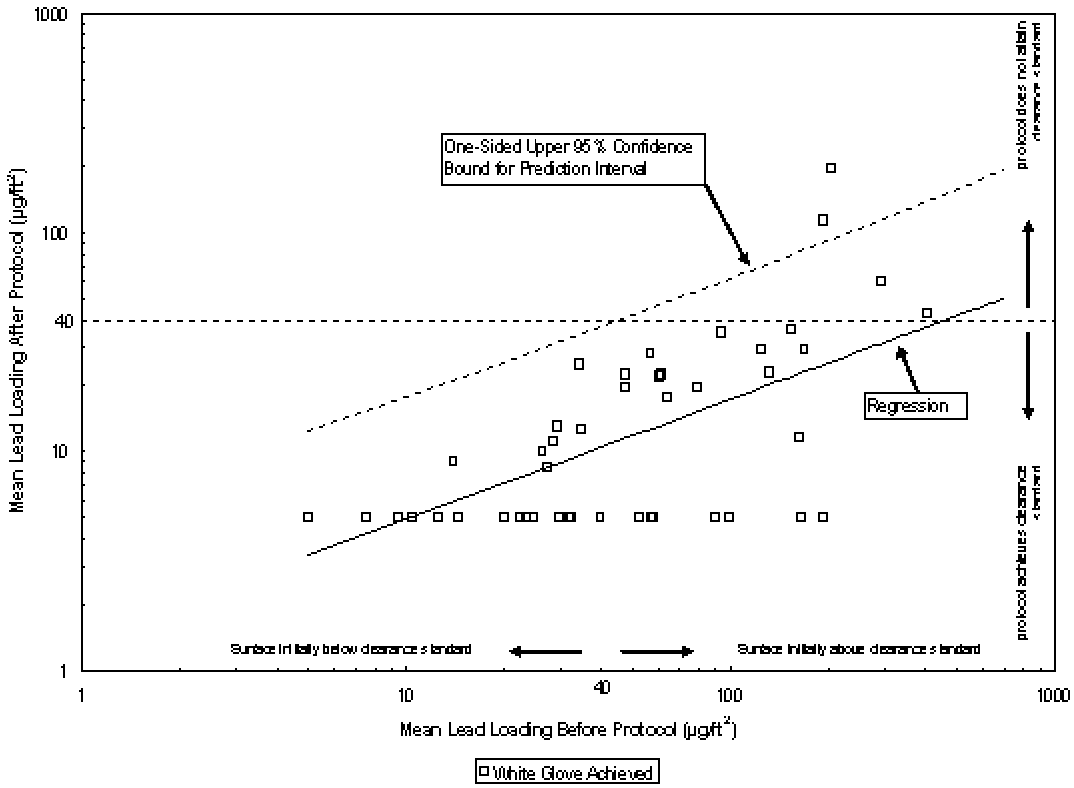



Graph 6 shows a linear regression model fit of the post-protocol lead levels versus the initial lead loading (after log-transforming both measures). The model shows a moderately strong linear relationship ($r^2 = 0.83$) between the dependent (post-protocol lead loading) and independent (initial lead loading) variables. Though depicted individually, there was not a statistically significant difference in relationship between the 1% and 10% SRM concentrations.

Graph 6 also shows an upper 95% confidence interval for a single predicted value. It is this upper prediction interval that is of particular interest, especially at the point where it intersects the horizontal reference line (40 µg/ft$^2$) for the clearance standard. The intersection point in Graph 6 falls at approximately 385 µg/ft$^2$. This mean that we are 95% confident that a floor with an initial (pre-treatment) lead loading of 385 µg/ft$^2$ or less would pass clearance based on the data from the controlled room study.

*6.2.2.1.2 Dry Cloth to White Glove in Field Study in Residential Housing.* Graph 7 displays the relationship of the means for post-protocol to initial lead loadings for the dry cloth DCC/WG protocol from the current field study in residential homes. These data are the same as plotted in Graph 2 except that the data points for the floor surfaces that did not achieve white glove are excluded because they are not relevant to this assessment of protocol success. The point where the upper 95% prediction interval for Graph 7 intersects the clearance standard line falls at approximately 45 $\mu g/ft^2$.

Graph 7 - Dry Cleaning Cloth to White Glove on Floors -
Field Study in Residential Housing (2004)




It should be noted that the linear regression model fit (and accompanying upper 95% prediction interval) have two important limitations as compared to the model for the controlled room study: (1) the assumption of equal variance about the regression fit line seems much less reasonable than it does for Graph 6, and (2) there are many censored values in this data set (also relates to the first limitation). Hence, while a regression line has been fit through the data, it should be interpreted cautiously.

*6.2.2.1.3 Comparison of Second Controlled Room Study and Field Study in Residential Housing - Dry Cloth to White Glove.* The intersection point for the upper 95% prediction interval with the 40 $\mu g/ft^2$ clearance standard reference line is lower in the field study (45 $\mu g/ft^2$) than in the controlled room study (385 $\mu g/ft^2$). The interpretation of this finding is that the controlled room study suggests the possibility of ultimately achieving a passing clearance level with the DCC/WG clearance protocols when starting from a much higher initial lead loading than what appears achievable based on the field study results.

Although the true reasons for the difference in the prediction intervals between the two studies are not known, some observations may clarify the situation. The research staff involved in both studies noted that the field study involved a more complex lead-contamination scenario than in the controlled room. The controlled room study involved 'spiking' with leaded dust 'sprinkled uniformly' onto the floor surfaces, which were then misted with water and left to dry. The objective of misting with water was to develop some adhesion between the floor surface and the lead dust. It is conjectured that a relatively high proportion of this recently deposited (and water misted) lead dust was easy to remove with a dry DCC.

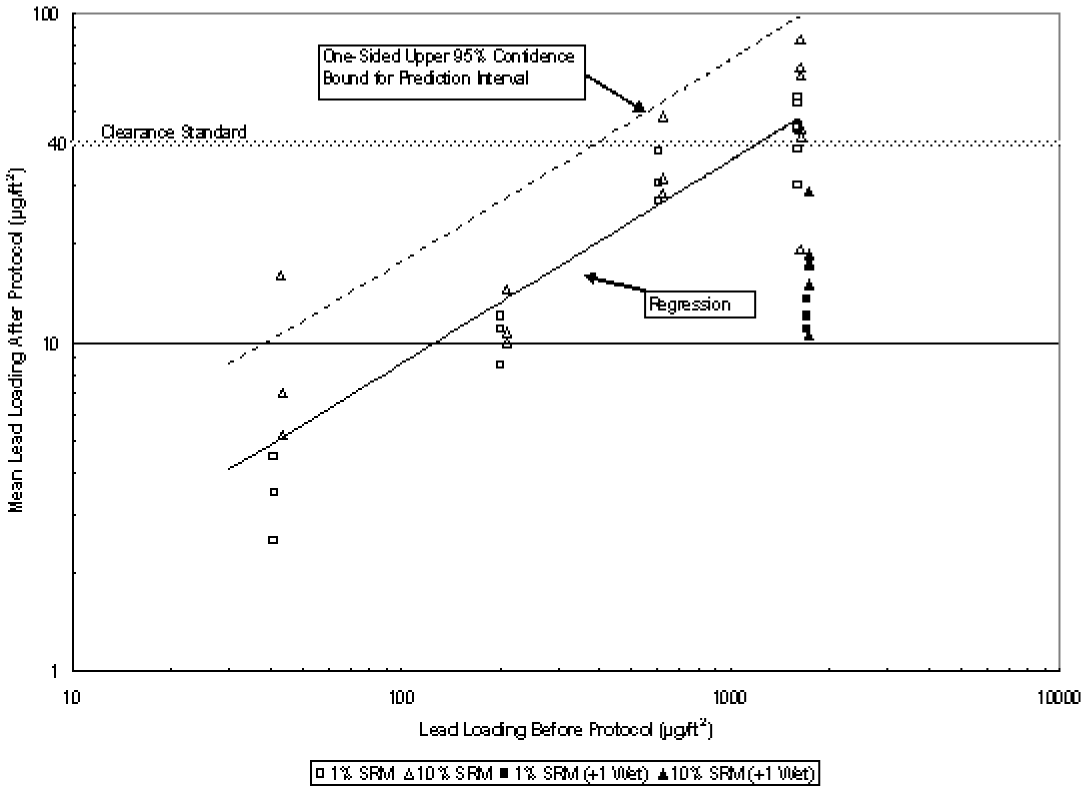
By comparison, in some of the real-world sites of the field study, lead dust adhered to floors far more strongly than in the controlled room. Leaded dust had probably been accumulating on floors over a long time and may have been mixed with sticky substances such as wax and grease. Under these condition, the result was a much stronger adhesion of lead to the floor surfaces. A floor with caked-on, dried grime presents special problems for the dry cloth treatment. The dry cloths reach a point where no additional free dirt or debris are collected (i.e., white glove is achieved) but the ground-in dirt or dried residue still retains lead that can be dissolved by moist clearance wipe sample cloths. Clear adhesion of lead-containing grime to surfaces can be a critical issue in real-world situations.

Another critical factor is the condition of the floors (and window sills). In the controlled room study, the vinyl tile floor was in excellent condition with no observable cracks or crevices. Many of the field study floors exhibited considerable damage and deterioration. Floors with exposed wood grain, disintegrating wood, or with frequent cracks and crevices are problematic for cleaning and sampling. They tend to capture and retain lead dust even after cleanup. So, the factors of floor condition, lead-dust contamination and the interaction of the two may account for the difference observed between the two studies in the apparent efficacy of the dry cloth treatment.

In the final analysis, Graph 6 and Graph 7 clearly show that dry cloth treatment performance was far better in the controlled room than for the field study. The controlled room study employed a clean vinyl floor that was in good condition. Lead-containing materials (SRM 2584 and 2589) were recently applied. The adhesion and entrapment of lead particles that inevitably occurs in the real-world sites was not a serious issue in the controlled room study. As such, the controlled room study may be viewed as a near-best-case scenario demonstrating how well the dry DCC/WG clearance protocol might be expected to perform under ideal conditions.

**6.2.2.2 Comparison of Dry+1 Wet DCC/WG Treatment Between Controlled Room and Field Study.** As in the current field study, the controlled room study also examined variations on the DCC/WG clearance protocol. The controlled room study included some trials with a single wet DCC after the dry DCC/WG treatment had been completed. This protocol variation was performed on nine floors for a lead loading level of 1600 µg/ft$^2$. Graph 8 is a duplicate of Graph 6 except that it includes these additional data points with a wet DCC. They are identified as the filled-in data points and are all at an initial lead loading of approximately 1600 µg/ft$^2$.

Graph 8 - Dry DCC/WG and Dry + 1 Wet DCC/WG Treatments on Floors - Second Controlled Room Study (2003)




From Graph 8 it can be seen that the inclusion of a single wet DCC after the dry DCC/WG clearance protocol produced a reduction in the mean lead loading compared to the comparable points with only the dry DCC/WG treatment. Floors starting at 1600 µg/ft$^2$ lead contamination and treated with the dry DCC/WG clearance protocol reached a mean post-treatment lead level of 49.1 µg/ft$^2$ (standard deviation=17.3). Adding one additional wet DCC mopping to floors contaminated at the same initial level resulted in a post-treatment level averaging 16.0 µg/ft$^2$ (standard deviation=5.6). (Note that the dry+1 wet treatment points are offset slightly to the right in Graph 8 so they can be clearly distinguished from the dry treatment only points. Both sets of points are at very nearly 1600 µg/ft$^2$ lead loading before performance of their respective DCC/WG clearance protocols.)

As was discussed in 6.2.1.2, the application of the dry cloth + 1 wet cloth DCC/WG clearance protocol in the field study did not produce a statistically significant improvement over the treatment with the dry DCC alone. The controlled room study did seem to show better protocol performance with the addition of a wet DCC. Within the context of the previous discussion, the apparent contradiction in the two study results may be explainable. For the controlled room study where (1) floor conditions were very good, (2) the application of the leaded material was recent, and (3) attempts to produce adhesion were minor, the addition of a single wet DCC was sufficient to significantly improve lead reduction relative to a dry DCC/WG treatment alone. In the field study with many floors in poor condition and firmly adhered leaded matter, a single wet DCC was not sufficient to improve lead reduction relative to the dry DCC/WG treatment alone. However, multiple wet DCCs in the field study could eventually break down and remove the more embedded leaded material.

### 6.2.3 Data Quality Objective 3

A number of covariate factors relating to the performance (success or failure) of the DCC/WG clearance protocols were examined. The primary focus of this analysis was the scenario of meeting the clearance standard when white glove is achieved. Covariates that were examined included the specific DCC/WG clearance protocol performed (Section 6.2.3.1), the pre-treatment lead contamination level (Section 6.2.3.2), and other covariates (Section 6.2.3.3). Additionally, this field study incorporated an evaluation of whether the specific cleaning solution used had an impact on the performance results (Section 6.2.3.4).

**6.2.3.1 Performance of DCC/WG Clearance Protocol by Treatment Type.** The results for each DCC/WG clearance protocol on floors and sills was discussed under Data Quality Objective 1 (Section 6.2.1).

- The observed performance of the wet treatment on floors (97.3%) was greater than that of the dry treatment (91.5%) which in turn was greater than that of the dry + 1 wet treatment (80.9%). However, the comparisons of each pair of treatments in this set using Fisher’s exact test shows that none of the differences are statistically significant when the joint confidence level for the three pairwise comparisons is 95%. Hence, there is not sufficient evidence to conclude that the true performance of any of the three DCC/WG treatments on floors are different from each other. However, it should be noted that the small sample sizes limit the likelihood of identifying a sample difference as statistically significant unless the true population difference is fairly large. This study showed approximate 80% power (probability of concluding a difference when one actually does exist) when one treatment’s performance was 95% and either of the comparison treatments was at least 30% poorer.

- The observed performance of the wet treatment on sills (100%) was greater than that of the dry treatment (96.4%). However, comparison of these two treatments with Fisher's exact test shows that the difference between them is not statistically significant with 95% confidence. The small sample size affects this comparison just as for the floor treatments. The statistical comparison of sill performance by treatment has approximate 80% power when one treatment's performance is 95% and the comparison treatment is at least 30% poorer.

**6.2.3.2 Performance of DCC/WG Clearance Protocol by Pre-treatment Contamination Level.** For the dry treatment results on floors (see Graph 1), there does appear to be a relationship between pre-protocol contamination levels and final lead loading achieved upon reaching white glove. This relationship is most apparent when initial lead loading levels exceed about 20 $\mu g/ft^2$. (Because of the heavy censoring effect of the method detection limit in this study, it is not possible to examine this relationship at lower initial lead loading levels.) Generally, floors initially contaminated at higher lead levels were observed to have higher final lead loadings after reaching white glove. However, there is considerable variability about this relationship. As discussed earlier, it is believed that the success or failure of the dry treatment at higher initial lead loadings lies in whether the lead content is contained in loose dust or whether the lead is somehow bound to the floor surface. If lead is contained only in loose dust, the dry treatment can achieve white glove and reduce lead loadings to levels equivalent to that of a floor with lower initial lead levels (though, of course, it may require more dry DCCs to do so). However, if the lead is tightly bound to the floor surface, the dry protocol can be susceptible to attaining white glove when no further leaded material can be picked up by this protocol even though there are higher remaining levels of lead that could be collected (as with a wet clearance wipe).

For the dry + 1 wet treatment results on floors (see Graph 2), the conclusions appear very similar to the dry treatment alone.

Unlike the treatments with the dry DCCs, the wet DCC/WG clearance protocol results on floors appear equally effective across the entire range of initial lead concentrations encountered for this field study (average of side-by-side measurements ranging from less than 10 $\mu g/ft^2$ to a maximum of 375 $\mu g/ft^2$). This can be seen in Graph 3. Of course, because of the heavy censoring effect of the quantitation limit, it is possible that some trend exists below 10 $\mu g/ft^2$. Regardless, the result is still clear that across a wide range of initial contamination levels, the wet treatment consistently and substantially reduced lead levels to well below the clearance standard.

For both the dry (see Graph 4) and wet (see Graph 5) treatment results on sills, there is no obviously visible relationship between measured lead level after the DCC/WG clearance protocol compared to before the protocol. For both treatments, the range of initial lead loadings on sills extended from less than 10 $\mu g/ft^2$ to more than 2,000 $\mu g/ft^2$. Therefore, it does not appear within this range of initial lead loadings that the pre-protocol contamination level had a significant effect on the lead loading attained after the protocol.

**6.2.3.3 Performance of DCC/WG Clearance Protocol as a Function of Other Covariates.** The primary statistical results from this study are presented for each treatment as the proportion of surfaces achieving white glove that were found to have residual lead contamination below the clearance standard. It would be desirable to ascertain whether the observed results can be associated with additional covariates encountered in the field study such as: (1) size of surface treated, (2) type of surface material, and (3) initial condition of the surface. The small sample size for this study and the form of the performance estimates (i.e., proportions) preclude a robust statistical evaluation of the effects of these covariates. However, Table 8 provides a summary of the characteristics of the surfaces that failed (i.e., reached white glove but were not below the clearance standard) and compares these to all surfaces tested in the field study.

**Table 8. Covariate Levels for DCC/WG Clearance Protocol Failures Compared to All Surfaces**

| DCC/WG Clearance Protocol Treatment | Met White Glove, Failed to Achieve Clearance Standard | | | | All Surfaces Tested | | | |
|---|---|---|---|---|---|---|---|---|
| | Count | Mean Area ($ft^2$) | Material Distribution [1] | Mean Condition Code [2] | Count | Mean Area ($ft^2$) | Material Distribution [1] | Mean Condition Code [2] |
| Floor Dry Cloth to White Glove | 4 | 59.0 | W=50%<br>L/V=25%<br>T=25% | 2.8 | 58 | 51.7 | W=72%<br>L/V=23%<br>T=3%<br>C=2% | 2.5 |
| Floor Dry Cloth to White Glove + 1 Wet Cloth | 9 | 44.4 | W=67%<br>L/V=22%<br>T=11% | 2.8 | 58 | 51.7 | W=72%<br>L/V=23%<br>T=3%<br>C=2% | 2.5 |
| Floor Wet Cloth to White Glove | 1 | 32.0 | W=100% | 3.0 | 58 | 47.4 | W=72%<br>L/V=23%<br>T=3%<br>C=2% | 2.5 |
| Sill Dry Cloth to White Glove | 1 | 0.4 | W=100% | 4.0 | 29 | 0.8 | W=92.6%<br>P=7.4% | 1.9 |

Note: Wet Cloth to White Glove on Sills is not included since no observations (1) met white glove and (2) failed to achieve clearance standard

[1] L/V = Linoleum/Vinyl, W=Wood, T=Tile, C=Concrete, P=Painted

[2] 1=Undamaged/New, 2=Slight Damage/Wear, 3=Partial Damage/Wear, 4=Majority Damaged/Worn

From the summary results in Table 8, the average treated surface areas, distribution of surface material types, and average initial surface condition codes are similar between the surfaces that failed to meet the clearance standard (after reaching white glove) and the entire sample of surfaces in the field study. One possible exception is the sill that did not meet clearance after reaching white glove. The surface condition code for this sill is poorer (at 4) than most other sills encountered in the study (average of 1.9).

Additional anecdotal observation of covariate results included:

- Wood floor surfaces that were not finished and sealed (e.g., with polyurethane) did not fair poorly in reduction of lead but they did present difficulties in achieving white glove.
- Floors with cracks, splintering, or protuberances (dried spackle, staples) made it operationally difficult to perform the protocol because the DCCs would tear on the imperfections. Interestingly, though, despite the fact that the protocol could not be recommended from an operational standpoint on these surfaces, the reduction of lead levels was often just as successful here as on smoother surfaces.

**6.2.3.4 Performance of Wet DCC/WG Clearance Protocol as a Function of Cleaning Fluid Used.** A question raised in the development of the study plan was whether the results observed for the wet treatment would be applicable only for the specific cleaning fluid used with the DCCs. This issue is important because it ultimately bears on how a final recommendation is made for which wet DCC products are acceptable. To examine this study question, two different mopping products were evaluated. Additionally, for a small number of floors, a change was made to the experimental protocol on floor surfaces to evaluate the effects of using plain tap water as the cleaning fluid rather than the mop manufacturer's own detergent. Table 9 shows the relevant results from this evaluation.

**Table 9. Comparison of Wet DCC/WG Clearance Protocol Performance with Two Commercially Available Cleaning Solutions and Water**

| Unit - Mop Used | First Half of Room | | | Second Half of Room | | |
|---|---|---|---|---|---|---|
| | Cleaning Solution | Lead Loading ($\mu g/ft^2$) | | Cleaning Solution | Lead Loading ($\mu g/ft^2$) | |
| | | Pre-Protocol | Post-Protocol | | Pre-Protocol | Post-Protocol |
| 28 - Swiffer® WetJet® | Swiffer | 42 | <10 | Water | 50 | <10 |
| | | 41 | 16 | | 63 | 11 |
| 29 - Clorox® ReadyMop® | Clorox | 47 | 16 | Water | 16 | 17 |
| | | 40 | 9 | | 18 | 14 |
| 30 - Swiffer® WetJet® | Swiffer | 81 | <10 | Water | 61 | <10 |
| | | 80 | <10 | | 62 | <10 |

The results obtained appear repeatable whether using the two commercial cleaning solutions or water. If true, this may imply that it is not actually the specific formula of the detergent that is important in achieving success with the wet DCC/WG clearance protocol but the fact that a liquid is used at all. However, the very small sample size of this evaluation precludes coming to a definitive conclusion on this issue and further study is recommended.

Note that due to the comparability of results for the different cleaning solutions (as well as water), results presented elsewhere for the wet DCC/WG clearance protocol in this study are made without distinction as to which cleaning solution was used.

### 6.2.4 Data Quality Objective 4

Data Quality Objective 4 was created to examine those cases where a DCC/WG clearance protocol was completed but white glove was not achieved. It was asserted that a beneficial concept of the white glove test would be that it recognized its own limits. That is, if the protocol failed to achieve white glove, it would be an indication that the clearance standard had not been met and that a more thorough cleaning or surface refinishing was necessary.

Table 7 (presented in Section 6.1) showed, by treatment, the proportion of surfaces that had measured lead levels below the clearance standard even though white glove was not achieved. The results are surprisingly similar to the performance of the treatments when white glove was achieved. With Fisher's exact test, none of the five treatments exhibited a statistically significant difference in performance between the surfaces that reached white glove and those that did not. Therefore, we cannot conclude that whether a treatment reached white glove in this field study impacted the final effectiveness of the treatment in reducing the surface lead loadings to below the clearance standard. However, it should be noted that the small sample sizes involved in these comparisons do not preclude the possibility that some true (and possibly large) differences do exist.

Table 10 provides summary statistics on the average and standard deviation of the number of DCCs required to reach white glove for each treatment as well as the corresponding average and variability in number of DCCs when white glove was not achieved.

**Table 10. Average Numbers of DCCs Used**

| Surface | Treatment | Surfaces Achieving White Glove | | | Surfaces Not Achieving White Glove | | |
|---|---|---|---|---|---|---|---|
| | | Total Surfaces | Average Number of DCCs Used | Standard Deviation of DCCs | Total Surfaces | Average Number of DCCs Used | Standard Deviation of DCCs |
| Floor | Dry Cloth to White Glove | 47 | 7.3 | 3.4 | 11 | 15.0 | 0.0 |
| | Wet Cloth to White Glove | 37 | 7.9 | 3.1 | 21 | 14.0 | 3.0 |
| Sill | Dry Cloth to White Glove | 28 | 2.2 | 0.5 | 1 | 6.0 | N/A |
| | Wet Cloth to White Glove | 25 | 2.4 | 1.1 | 4 | 5.0 | 2.0 |

Note: Limit to stop protocol was 15 DCCs for floors and 3 for sills; however, different limits were observed for some surfaces (see Section 3.4)

Those surfaces that did not meet white glove had on average about twice the number of DCC moppings used as surfaces where white glove was achieved. It is possible that the surfaces not meeting white glove achieved comparable performance to those that did meet white glove because they had so much more cleaning and whatever remaining soiling that led to the white glove failures was not highly related to recoverable lead content.

It is important to reiterate the point previously made about the number of DCCs used in this field evaluation compared to what would be used in a real-world application of the protocol. The very high numbers of DCCs used in this field study were the result of minimal initial cleaning of surfaces and this minimal cleaning was intentional to allow an evaluation of the DCC/WG clearance protocols in the worst case scenario (i.e., an inadequate cleanup after R&R). Effectively, some portion of the DCCs used in the field evaluation were principally serving as a cleaning tool and not as a clearance evaluation (though, of course, the two purposes cannot be strictly separated). In a real-world incorporation of these protocols, it is expected that a more efficient cleaning step would be mandated before application of the DCC/WG clearance protocol.

## 6.3 Additional Results and Discussion

When examining the results from this study across the different data quality objectives, some results and conclusions appear that are global rather than isolated to one DQO. This section presents each of these different issues.

### 6.3.1 Effect of Reaching White Glove on Efficacy of Treatment

From Table 7, it is noteworthy that only 37 out of 58 floors passed the white glove test for the wet treatment as compared to 47 out of 58 floors for the dry treatment. The experiences of those performing the protocol was that white glove could be reached more often for the dry treatment than the wet. After the dry treatment had removed any non-adhering dirt and dust, subsequent dry DCCs would appear white even if there was significant visible dirt and grime remaining on the surface. Though dry DCCs could not pick up this remaining dirt, the clearance wipe sample collection could. This effect would account for the lower observed success rate of the dry treatment in predicting clearance has been met. Conversely, the wet treatment sometimes could not reach white glove (i.e., wet DCCs continued to be discolored after mopping) even though visual inspection of the surface showed no remaining dirt or dust. A very interesting result of this study, as shown in Table 7, was that the effectiveness of the wet protocol on floors when white glove was achieved (36 of 37 = 97.3%) was almost identical to the effectiveness when white glove was not achieved (20 of 21 = 95.2%). This suggests that whatever material continued to discolor the wet DCCs (and result in white glove failures) may not have been a lead reservoir. These materials might include bits of the floor finish or even of the flooring itself.

### 6.3.2 Representativeness of Field Study Locations to R&R Population

The data collected from the field study are representative of a certain population of real-world housing units. To address the applicability of the proposed clearance testing protocol to the R&R population in general, it is necessary to determine to what extent the field study units reflect the R&R population at large. One indicator that the sample from this field study is "representative" would be if the lead levels encountered before application of the protocol are consistent with R&R experience. No source is known for true R&R experience but two studies provide some relevancy to this issue.

The EPA report "Analysis of Lead Dust Clearance Testing," EPA 747-R-01-005, December 2001, includes a summary of first site visit wipe sampling results across eight different sources, collected over the period from 1989 to 1999, in lead hazard control and abatement locations. For these sources, the median lead loadings ranged, on floors, from 5 to 48 $\mu g/ft^2$ and the $90^{th}$ percentiles from 68 to 418 $\mu g/ft^2$. On sills, the median ranged from 17 to 443 $\mu g/ft^2$ and the $90^{th}$ percentiles from 175 to 1624 $\mu g/ft^2$. For the present field study, the median level before applying the DCC/WG clearance protocol (counting only those surfaces which would ultimately achieve white glove) was 48 $\mu g/ft^2$ with a $90^{th}$ percentile of 202 $\mu g/ft^2$ on floors and 45 $\mu g/ft^2$ with a $90^{th}$ percentile of 401 $\mu g/ft^2$ on sills. The similar median and $90^{th}$ percentile values for all floors (including those where the DCC/WG clearance protocol did not achieve white glove) were 56 $\mu g/ft^2$ and 225 $\mu g/ft^2$, respectively. On sills, the median and $90^{th}$ percentile of all surfaces in the field study were 63 $\mu g/ft^2$ and 703 $\mu g/ft^2$, respectively. Hence, it would appear that the lead levels encountered in the field study are at least similar to those found in lead hazard control and abatement programs.

The report, “Lead Exposure Associated with Renovation and Remodeling Activities: Environmental Field Sampling Study, Volume I: Technical Report,” EPA 747-R-96-007, May 1997 provides information on lead levels encountered after performing some types of R&R work and subsequent cleanup. The evaluations in this study were simulated and are not necessarily representative of real-world R&R work. However, they do provide insight into the lead levels that might be encountered under certain types of work practices. Specifically, drilling followed by a broom or vacuum cleanup of floor areas resulted in mean post-cleanup lead levels of 130 and 147 $\mu g/ft^2$, respectively, at five to six feet from the activity. Abrasive sanding followed by the same two cleanup methods produced even higher average post-cleanup measurements; 865 and 357 $\mu g/ft^2$, respectively. These levels are higher, on average, than what was encountered in the field study. However, it should be noted that each estimate has a fairly large uncertainty associated with it and that the types of cleanup evaluated (broom and vacuum) are not expected to be adequate in conjunction with the DCC/WG clearance protocol.

In addition to the lead loading levels, the experience of the field study suggests that surface condition (both in terms of deterioration and cleanliness) is an important factor in determining the effectiveness of the DCC/WG clearance protocol. The general impression of the team conducting the study was that the selection of the units in this study resulted in a disproportionate number of residences with surfaces in poorer condition than they encounter in their normal lead hazard control and abatement work.

## 7.0 CONCLUSIONS

Several important conclusions are suggested by the analysis of the residential field study data.

**Wet Treatment of DCC/WG Clearance Protocol Very Successful**

In every case for sills and in all but one case for floors, when the wet treatment was used and white glove was attained, the average wipe sample results confirmed that the surface was below the clearance standard. On floors, the protocol was estimated to be 97.3% successful with lower 95% confidence bound of 87.8%. On sills, the protocol was estimated to be 100% successful with lower 95% confidence bound of 88.7%. Success is the positive predictive value of the protocol and is defined as the ratio of true positive results (protocol achieves white glove and clearance standard is met) to all results that achieved white glove. The relatively conservative lower confidence bounds for the results are a result of the small sample of units in the study.

While the number of units was small, the results comprise housing units in two different cities, using a number of different sampling personnel, and covering a range of floor sizes, types, and conditions. The sampled units were primarily lead hazard control and abatement sites so no definitive conclusion can be reached as to how representative they are of typical R&R locations.

**Dry Treatment of DCC/WG Clearance Protocol Not as Good as Wet**

The dry treatment results for floors and sills in the field study were not as good as the wet treatment results, but not different enough to be statistically significant.

The dry treatment in the field study was less effective at reducing floor lead levels than a similar treatment evaluated in the Second Controlled Room Study. It is believed that this may be due to the more complex nature of the lead contamination in the real-world environment (e.g., ground-in dirt and grime) than what was simulated in the controlled room experiment (e.g., sprinkled, misted, and dried lead-dust).

**Dry + 1 Wet Treatment of DCC/WG Clearance Protocol Less Effective Than Dry**

The hybrid treatment of the dry DCC/WG clearance protocol followed by one additional wet DCC (evaluated on floors only) was the poorest performing protocol on average, though it was not statistically significant in comparison to the other treatments. A version of this protocol had quite strong results in limited testing for the Second Controlled Room Study. Hence, it might still offer promise but would likely need to be re-evaluated and possibly re-defined (i.e., more than one wet DCC). The one drawback of this hybrid protocol will always be the need to have both dry and wet DCC equipment and supplies.

## "Smooth and Cleanable" Criteria Important Operationally

The selection of sampling surfaces based on "smooth and cleanable" criteria likely will be an important part of any guidance. Contrary to expectations, the floor surfaces sampled that did not strictly meet these requirements often displayed positive results in predicting clearance. However, the criteria are important to the practical execution of any protocol.

## No Other Covariate Results Were Definitively Linked to Treatment Performance

No significant effects were observed for the covariates of surface area, surface material type, and surface condition in bivariate analysis. Also, no significant effect was found for mop manufacturer and cleaning solution (manufacturer's solution versus plain water). More complex multivariate analyses were not possible based on the limited amount of data obtained. Lack of findings here should not necessarily be interpreted to mean that there are no covariate effects, just that none were obvious from the limited sample of data in this study.

## Failure to Reach White Glove Not a Good Indicator of Failing to Achieve Clearance Standard

Among the small sample of units where white glove could not be reached using one of the treatments, the post-treatment wipe samples showed in most cases that clearance had been achieved anyway. Epidemiologically, this can be interpreted as the tested protocol having a poor negative predictive value, where negative predictive value is the ratio of true negative results (failed to achieve white glove and lead level is above clearance standard) to all results that failed to reach white glove.

## 8.0 PEER REVIEW

EPA put the current study through a rigorous peer review process. This provided key stakeholders and experts in the field of lead hazard control and mitigation the opportunity to assess the importance of the study results and to provide critical feedback. This section of the report summarizes the results of the peer review. Section 8.1 provides background on the peer review. Section 8.2 identifies several of the key points uncovered in the peer review process and provides EPA responses. Additionally, many minor editorial issues were identified in the peer review process. These are not explicitly identified but they have been incorporated in the final report from this study.

### 8.1 Peer Review Background

A draft version of the current report was prepared in early August of 2005. EPA provided this draft in addition to a set of charge questions to a contractor that organized the peer review. EPA requested the peer review panel collectively include individuals with all the following qualifications:

- Employees of the Federal Government with experience in measuring exposure to lead dust in residential settings, preferably including experience in sampling and lead clearance testing. EPA requested that two reviewers be recruited for this category, but not from the same Federal agency.

- Employees of state, city, or local governments with experience in measuring exposure to lead dust in residential settings, preferably including experience in sampling and lead clearance testing. EPA requested that one or two individuals be selected from this category.

- At least one statistician who is familiar with residential lead dust contamination and is capable of evaluating variation and uncertainty in indoor air data. Ideally, this reviewer would have a M.S. or Ph.D. in Statistics.

- One individual from the private sector with professional experience in lead dust sampling, especially sampling in indoor environments.

- One chemist with knowledge and experience in lead sampling. In particular, extensive experience in analyzing wipe samples is important.

A panel of six individuals was selected that collectively met all the requirements above. Each reviewer received a copy of the draft report and a set of charge questions from EPA. These questions included four general and nine specific questions about the report and the prospect of implementing the technology examined in the report. Additionally, all reviewers were encouraged to provide any additional thoughts that would be useful to EPA. The reviewers were given approximately one month to complete their reviews.

## 8.2 Peer Review Results

Upon their receipt, EPA carefully reviewed the collective peer review responses. In some cases, EPA contacted the peer reviewer to obtain additional clarification. The general impression of the peer reviewers were positive to the report and to the prospects of using the DCC/WG protocol. However, some important questions were raised and criticisms leveled.

The issues listed below were selected as the most important due either to their prevalence (i.e., a comment appearing from multiple reviewers) or their potential impact to the implementation of the study results in EPA's R&R rulemaking process. In this latter category, comments made by the HUD lead program personnel were particularly important (whether or not their comments were shared by other peer reviewers). Following each key issue is a response from EPA.

1) Reviewers indicated that the overall sample size for the study was small.

EPA Response: A total of 58 separate floor surfaces and 29 window sills from 31 residential sites located in 2 cities (with documented lead-based paint hazards) were included in this field study. Every floor surface (58 floors) was divided into two areas that were treated by different DCC protocols. Two wipe samples were collected and analyzed both before and after DCC treatment for each treatment area. While this field study was not large, it was nevertheless a major research effort in which a substantial amount of empirical data was collected. This field study systematically explored the effectiveness of the DCC/WG testing protocol under a variety of challenging real world conditions.

In addition, the field study employed essentially the same DCC testing protocol that had already been thoroughly tested under controlled laboratory conditions. The lab results were consistent with the findings from the field study. EPA believes that both the quality and quantity of the data was sufficient to conclude that the DCC method is useful and reliable for the proposed use.

2) Reviewers indicated that sites and work activities were not (or may not have been) representative of R&R work.

EPA Response: The residential units used for this field study included both lead hazard reduction and R&R project sites. A wide, overlapping range of work activities are shared by both lead hazard reduction and R&R (e.g. sanding, scraping, cutting, drilling). At virtually every site where data was collected, some work had been done prior to data collection. EPA has no reason to believe the actual mix of work activities at each site and the particular sites employed in this study are in any way atypical of R&R work. To actually attempt to define what constitutes a representative mix of R&R work activities and then ensure that those activities were employed at these work sites would have presented an almost impossible logistical challenge for completion of this field study. EPA feels that it was better to view 'work activities' as a random effect for the purposes of this study design. That is, a random set of work activities that might reasonably be expected to occur as part of R&R work were believed to have been conducted at these sites, but there was no attempt to document or control for specific work activities.

3) Reviewers commented on the challenge of defining "Smooth and Cleanable" floors.

EPA Response: For the purpose of the field study, some floors were excluded. Based on experience in some of the first units tested, floor surfaces that were expected to tear or damage the disposable cleaning cloths (DCCs) were dropped. Floors that were excluded from testing typically had broken or splintering wood or the floor surface/finish was so rough that it would have caught on and torn the DCCs.
Surprisingly and unexpectedly, for those floors with rough or deteriorated surfaces that were tested before rough floors were dropped, they often did not pass the 'white glove' test, but most of them still had post-treatment lead levels below the Federal hazard standard.

4) Reviewers noted that the Unit 08 field blank did not yield the expected "zero" result but that the remaining protocol wipe samples were not eliminated from study consideration.

EPA Response: The QA procedure for an unusual result (either a failed quality sample or an outlier) is to examine the sample logs and other available information to identify if any explanation can be found for the anomalous record. If none is found, the unusual observation is identified in the results but the original data is not removed. This is the process that was employed for this case.

Additionally, EPA thinks it important to point out this result in context of the entire study. The purpose of the field blanks was to provide assurance that the multiple wipe samples taken in a lead contaminated field environment had minimal risk of being cross-contaminated. The fact that only 1 of 31 field blanks showed lead contamination above the method detection limit and this was at a relatively modest level actually provides assurance that the field data collection procedures minimized the potential for errors dues to cross-contamination.

5) Reviewers expressed concern about the large number of QAPP modifications.

EPA Response: The relatively large number of QAPP modifications (14) reflects the extreme care that was taken in documenting even minor changes in the planned study protocol. Since this field study was conducted at sites that displayed considerable variation in their physical characteristics, a number of adjustments to the data collection protocol were necessary. Even minor adjustments were carefully and thoroughly documented in the QAPP.

6) Review pointed out that the DCC/WG protocol may lead to extra, unnecessary cleaning.

EPA Response: EPA acknowledges that the DCC/WG protocol may sometimes result in extra cleaning of floors. In order to insure a high level of confidence that the floor lead level falls below the Federal hazard standard when white glove is achieved, extra cleaning may occur. The trade-off of employing a method that may require extra, unnecessary cleaning to save the time and expense associated with the use of wipe sampling appears worthwhile.

In addition, it must be noted that only a perfunctory broom sweep of each floor was performed prior to DCC treatment. This was done to increase the likelihood that a range of 'higher' lead loadings would be encountered during the field study. In actual practice, the DCC/WG protocol would be implemented after a thorough cleanup had been completed, so fewer DCC treatments would be likely to occur than were needed in the study. Hence, while additional cleaning may occur in an implemented version of the protocol, it is expected that its prevalence would be a lower proportion than was observed in this field study.

7) Review identified a possible bias from spike laboratory QA sample results.

EPA Response: The recovery (average bias) for the 20 µg samples is 90.5% and for the 40 µg samples is 90.8%. This observed bias may have been related to the preparation of the spike samples, either through the methodology employed in spiking sample wipes or as a result of bias inherent in the SRM material. In this case, the bias should have had no effect on the laboratory wipe sample analysis. However, under the assumption that the observed bias is a true laboratory measurement bias and that this bias is consistent throughout the study, the study results were recast assuming the true measured lead levels should have been a factor of 10/9 greater than observed. In this process, very little difference was found in the study results and no changes were found for the key data quality objective of protocol success rates. This observation has been added into the report.

8) Reviewers questioned the omission of window troughs.

EPA Response: Testing of window troughs is a component of Lead Abatement Clearance testing. Testing of troughs is not a part of the proposed post-cleanup testing for R&R. This has been identified as a footnote to the report in the Executive Summary section.

## 9.0 QUALITY ASSURANCE

This study featured a thorough and rigorous quality assurance process. This process was embodied in two key components of the study:

1) The Quality Assurance Project Plan (QAPP) - The QAPP is a formal document prepared in advance of the study, signed by all key personnel, and includes the detailed instructions on performing the field study procedures. It has been incorporated in its entirety into the current study report as Appendix A. Among its most important elements with regard to quality are:

- The key staff working on the study, their qualifications, and their roles.
- An objective for the study accompanied by a set of data quality objectives to assess this objective. These DQOs are included in Section 3.1 of this document and they form the basis of reporting the results of this study in Section 6.2.
- Specifications for procedures regarding sample handling and custody as well as study documentation and records.
- Detailed specification of the study design, the protocols to be completed, and the analytical methods to be employed. Each of these components have also been thoroughly documented in the final report with study design and protocols in section 3.1 through 3.4, and 4.1. The analytical methods are discussed in section 5.1.
- Quality control procedures including quality control samples as well as procedures for data review, validation, and verification. The results of the quality control samples are discussed in section 5.2.
- Procedures for data review, validation, and verification as well as the planned calculations of final study estimates. The results and discussion of same are provided in section 4.2 and throughout Section 6.

2) The Peer Review - An important final component to quality assurance for this study was subjecting the results to a review by professionals of several different disciplines with experience in the field of lead hazard control and removal. This peer review is documented in Section 8 of the report.