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An Evaluation of One-Time Professional Cleaning in Homes with Lead-Based Paint Hazards

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A key challenge in reducing the burden of lead poisoning is to identify cost-effective interventions that minimize lead-based paint hazards. One-time professional cleaning of lead-contaminated dust and debris was conducted in 37 housing units with deteriorated lead-based paint and dust lead hazards. These study units are a subset of a larger cohort of the nearly 3500 housing units enrolled in the Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program. Dust lead loading measurements were taken prior to cleaning, immediately after cleaning (i.e., clearance), and six months, one, two, and three years post-intervention. The cleaning intervention significantly reduced dust lead loadings on floors, windowsills, and window troughs immediately following the work. However, these reductions did not persist at six months and one year post-intervention. Six months and one year post-intervention dust lead loadings are not significantly different from the pre-intervention loadings on either bare floors or windowsills. Although window trough lead loadings declined over 50 percent from pre-intervention to one year post-intervention, the loadings rebounded markedly from the geometric mean at clearance of 101 μg/ft^2 to 5500 μg/ft^2 at 6 months and 5790 μg/ft^2 at one-year post-intervention. These results demonstrate that a single professional cleaning of dust and debris without addressing potential sources of lead dust (such as deteriorated lead-based paint) or repeating the cleaning are unlikely to result in significant and sustained reductions in dust lead loadings. More extensive interventions that address deteriorated lead-based paint, although more expensive, are likely to provide longer term reductions in dust lead loadings. Cleaning strategies, however, may be useful in emergency situations to reduce lead dust hazards when paint repair and other lead hazard control activities cannot be done immediately.

Keywords Lead Paint, Lead Hazard, Lead Dust, Lead Hazard Control, Dust Removal

The Centers for Disease Control and Prevention (CDC) estimates that 890,000 children below the age of 6 in the United States (4.4%) have a blood lead level of 10 μg/dL or higher.[1,2] Lead poisoning disproportionately affects children living in older housing, low-income families, and large metropolitan areas, and non-Hispanic black children.[3] The most common sources of environmental lead exposures for U.S. children are from lead-based paint and lead in dust and soil.[4–6]

A key challenge in reducing the burden of lead poisoning is to identify cost-effective interventions that minimize lead-based paint hazards (such as deteriorated lead-based paint and lead dust hazards). In 1993, the U.S. Department of Housing and Urban Development (HUD) began funding grants to state and local governments to control lead-based paint hazards in low-income, privately owned housing (HUD Lead-Based Paint Hazard Control Grant Program). A comprehensive Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program (the evaluation) undertaken in the initial years of the grant program concluded that, collectively, these treatments reduce floor and window dust lead loadings.[7] Grantees used a variety of treatments, ranging from full abatement to low-cost cleaning strategies, but the most common strategy entailed replacing windows and repairing deteriorated lead-based paint.

This article presents results from an analysis of dust lead data from a subset of the grantee units in which low-cost one-time professional cleaning interventions were undertaken. Many lead programs and property owners rely on such low-cost techniques, particularly when limited resources are available. Previous research demonstrates that providing occupants with cleaning supplies and education is not sufficient to alter dust lead loadings or reduce children's blood lead levels.[8] In contrast, other studies indicate that ongoing professional cleaning services reduce both dust lead loadings and children's blood lead levels.[9] Others have shown that professional cleaning of lead dust and debris in units with lead hazards where repairs are needed but not pursued produce immediate reductions in dust lead loadings but that the lead loadings rebound over time.[10] The units followed in this study represent a similar cleaning alternative—one-time use of professional cleaning staff.

METHODS

This study evaluated one-time, professional, low-cost cleaning interventions to reduce lead dust and debris. The interventions were conducted from 1994 to 1996 in dwelling units included in the Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program. The purpose of the evaluation is to measure the relative cost and effectiveness of the various methods used by state and local government grantees to reduce lead-based paint hazards in housing. Data used in this analysis were collected following the evaluation protocols and quality control and quality assurance procedures.[11] The interventions in the evaluation ranged from full abatement of all lead hazards to strategies where only cleaning was conducted.[12]

A subset of 37 units from the evaluation where the primary intervention was removal of lead-contaminated dust and debris through cleaning and where cleaning costs on a per unit basis did not exceed \$2000 constituted the study population. Study units were also required to have no work implemented beyond cleaning ("clean only") and have reported dust lead measurements on floors and windowsills, or window troughs at pre-intervention and 12 months, and 36 months post-intervention. Study units were in Milwaukee, Wisconsin (n = 25 units; 68%), Minneapolis, Minnesota (n = 10 units; 27%), and St. Paul, Minnesota (n = 2 units; 5%).

In Minnesota, the cleaning protocol entailed a two-step vacuuming and wet washing of most accessible surfaces (e.g., windowsills and troughs, window sashes, baseboards, door tops, window frames, floors, wainscoting, radiators) and was conducted by trained workers. A Nilfisk GS-90 (Nilfisk-Advance, Inc., Malvern, PA) High Efficiency Particulate Air (HEPA) vacuum was used. Workers cleaned horizontal surfaces with a trisodium phosphate (TSP) liquid solution. Workers used disposable paper towels on all horizontal surfaces except floors, where a mop was used for the wet cleaning. Mini-blinds were replaced with lead-free shades.

The cleaning protocol in Milwaukee focused on windows. Two trained workers conducted the cleaning by placing containment beneath the windows, raising the double-hung window, and removing all surface paint chips and dust using a Nilfisk GS-90 HEPA vacuum. Workers then scraped off the loose paint on the exterior portion of the window sash, jamb track, and window well. This debris was again HEPA vacuumed. The windowsill, well, and jamb tracks were washed using a solution of TSP followed by clean water. Floor areas beneath and around the containment for the window work were also cleaned using a HEPA vacuum and followed by wet washing. Workers used disposable rags during the wet washing. Cleaning extended to the entire floor area in the room if pre-intervention dust lead testing documented that the floor lead loading exceeded the dust lead hazard standard in effect at the time the work was performed (200 $\mu g/ft^2$).

All units were required to pass the clearance thresholds established for HUD grantees[13] (floors 200 $\mu g/ft^2$; windowsills 500 $\mu g/ft^2$; and window troughs 800 $\mu g/ft^2$) or state clearance standards in effect at the time work was conducted, if more stringent. The "clean-only" practices were undertaken in the early years of the lead grant program and were curtailed when HUD determined the treatments did not satisfy all of the grant program requirements. Minneapolis, St. Paul, and Milwaukee have not used "clean-only" treatments since August 1997.

Pre-intervention dust lead and paint lead sampling was conducted from 1994 to 1996. Individuals certified and trained in dust sampling techniques collected the dust lead measurements. Dust lead loadings were sampled using a single-surface wipe protocol and collected from floors, windowsills, and window troughs.[11] Samples were collected on floors in the principal play room, kitchen, bedroom, entryway, and second bedroom (if available). Samples were also collected on at least one windowsill and one window trough in each unit. The inspector assessed the condition of each surface wiped for dust on a three-point scale, with 1 = good, 2 = fair, and 3 = poor.[11]

Dust lead was sampled pre-intervention, immediate post-intervention (i.e., clearance), 6 months post-intervention, and 1, 2, and 3 years post-intervention in the 37 units. Individuals certified as lead inspectors measured paint lead loading (mg/cm^2) using an X-ray Fluorescence Analyzer (Microlead I, Warrington; or XK-3, Princeton Gamma-Tech, Inc.) on all interior and exterior paint component systems prior to the intervention. Lead inspectors also rated paint condition of each component with paint lead testing on a three-point scale: poor, fair, good,[11] where:

- Good: Less than 0.5 ft^2 of deteriorated paint on interior large surfaces, or less than 1 percent of the total surface area of interior small building components.
- Fair: Between 0.5 to 2 ft^2 of deteriorated paint on large surfaces, or 1–10 percent of the total surface area of small building components.
- Poor: More than 2 ft^2 of deteriorated paint on large surfaces, or more then 10 percent of total surface area of small building components.

Grantees submitted double-blind quality control dust lead samples to laboratories on a regular basis.[7] The Wisconsin State Laboratory prepared the quality control samples by applying set quantities of NIST Standard Lead Paint Dust (Standard 1578) to a wipe. The evaluation QA/QC procedures required laboratories to report results from spiked samples within 80 percent to 120 percent of the actual lead levels. Samples were submitted to labs recognized by EPA as participating in the Environmental Lead Proficiency Analytic Testing Program and either being recognized under the National Lead Laboratory Accreditation Program or moving toward recognition. Lead was measured by flame atomic absorption, graphite furnace atomic absorption, or inductively coupled plasma-atomic emission spectrometry.

The method detection limits of the laboratories varied from 1 to 25 μg/sample. Because dust lead loadings on floors were often reported by laboratories to be below these detection limits, the evaluators were concerned that they would not be able to reliably calculate re-accumulation rates (one of the most important measures of intervention outcome) and compare floor dust lead loadings over time. To address these concerns, the evaluators asked laboratories to supply the actual machine values for samples with lead content below the reporting limits. When machine values could not be obtained, dust lead values were imputed according to the methods delineated in Succop et al.[14]

Statistical Methods

Hypothesis tests of the equality of geometric mean paint lead levels in "study" and a larger cohort of non-study evaluation units were implemented with t-tests on log-transformed values. For dust lead loadings, we used paired t-tests based on the log-transformed average dust lead level in each dwelling at two data collection phases and the hypothesis of equality of the geometric mean dust lead levels at the two phases was tested. A nested model was used with log-transformed individual samples to test the hypothesis that geometric mean dust lead loading at clearance depends on the condition of the wiped surface.

RESULTS

The majority of study units were in buildings with two or more units (70%). The living area for the individual dwellings ranged from 600 ft^2 to 1776 ft^2 with a mean of 1018 ft^2. All units were built before 1950. Forty-nine percent were constructed prior to 1910; 19 percent were constructed between 1910 and 1929; and 32 percent were built between 1930 and 1949. Inspectors reported that all units had some interior lead-based paint in fair or poor condition before interventions occurred.

The paint lead levels documented in the study units were consistently high; geometric mean paint lead levels were at least 1 mg/cm^2 on all surfaces (Table I). Paint lead levels were higher in study units than the levels observed in the larger cohort of non-study evaluation units. These differences were statistically significant for exterior components ($p = 0.003$) and other interior components ($p = 0.005$). Baseline conditions of painted components were consistent between the study units and the larger cohort of non-study evaluation units. Geometric mean paint lead levels reported were based on the unit arithmetic mean levels for all tested surfaces of a given component.

Nested models were used to examine the hypothesis that geometric mean dust lead loading at the first clearance test depends on the condition of the wiped surface. Surface condition on window troughs at the first clearance dust lead sampling was a significant predictor of geometric mean trough lead loadings ($p < 0.01$). The geometric mean trough dust loading levels for good, fair, and poor wiped surfaces are 31 μg/ft^2, 125 μg/ft^2, and 931 μg/ft^2, respectively. Surface condition was not a significant predictor of clearance dust lead loadings on bare floors, carpeted floors, or windowsills ($p = 0.06$, $p = 0.83$, and $p = 0.28$, respectively).

TABLE I
Paint lead loading (mg/cm^2) and paint lead condition[A] in "study" and non-study evaluation units

	Study units (n = 37)		Non-study evaluation (n = 3444)	
Component class	GM paint lead loading	Mean paint condition	GM paint lead loading	Mean paint condition
Exterior	7.6	2.0	3.8	2.1
Window	7.1	1.8	4.9	1.9
Door/trim	2.7	1.4	2.3	1.5
Other interior	1.7	1.4	1.0	1.5

[A]Condition was rated on a 3-point scale where 1 = poor condition, 2 = fair condition, 3 = good condition.

The effectiveness of the intervention in lowering and then maintaining lowered dust lead levels is examined in Tables II, III, and IV. Two perspectives are employed; observed dust lead levels and the presence of dust lead hazards. Some units failed the initial clearance test, and as a result these units were re-cleaned and a second clearance test conducted.

The clearance results reported and used to calculated average dust lead loadings are those of the final clearance test. Trends in dust lead loadings and in percentages of dwelling units having dust lead hazards are presented separately for floors (Table II), windowsills (Table III), and window troughs (Table IV) across all study phases.

Because federal regulations and standards used to identify dust lead hazards have changed over the course of the study, the tables present the percentage of dwelling units having dust lead hazards as defined at the start of the study in 1993 and in 2001. Dust lead loading hazard standards dropped from the 1993 interim HUD standards[13] to the current federal standards[15,16] as follows:

- Floors: 200 μg/ft^2 to 40 μg/ft^2
- Window sills: 500 μg/ft^2 to 250 μg/ft^2
- Window troughs (wells): 800 μg/ft^2 to no standard

At the time the grants were awarded, HUD required grantees to employ the HUD interim guideline hazard identification levels that are different than the current dust lead hazard identification levels. According to the interim guidance a hazard existed if any individual wipe sample exceeded the hazard level, while currently a hazard exists if the average of the samples on a surface type exceeds the hazard level.

TABLE II
Lead dust on floors of "study units": geometric mean dust lead loading and percent of units exceeding current (40 μg/ft^2) and past (200 μg/ft^2) federal dust lead hazard standards

Phase	Dwelling units (n)	Geometric mean (μg/ft^2) (95% CI)	Percent of dwelling units exceeding federal standards	
			40 μg/ft^2	200 μg/ft^2
Baseline	37	14 (9,21)	11	3
Clearance	35	9 (7,21)	3	0
6 Months	37	10 (6,17)	11	5
1 Year	37	10 (7,15)	5	0
2 Years	35	18 (11,28)	17	6
3 Years	37	11 (8,16)	14	0

Pre-Intervention to Clearance

There was a significant difference in geometric mean dust lead loadings on bare floors, windowsills, and window troughs between pre-intervention and final clearance (floors, $p = 0.01$; windowsills, $p < 0.01$; window troughs, $p < 0.01$). The geometric mean dropped on bare floors from 14 μg/ft^2 to 9 μg/ft^2, windowsills from 360 μg/ft^2 to 73 μg/ft^2, and window troughs from 12,800 μg/ft^2 to 101 μg/ft^2.

Clearance to 6 Months and 1 Year Post-Intervention

Dust lead loadings at 6 months and 1 year post-intervention were significantly different from clearance loadings for both windowsills (6 months and 1 year, $p < 0.01$) and window troughs (6 months and 1 year, $p < 0.01$). Windowsill geometric mean dust lead loadings increased from 73 μg/ft^2 at clearance to 308 μg/ft^2 at 6 months and 263 μg/ft^2 at 1 year post-intervention. Geometric mean dust lead loadings on troughs increased from 101 μg/ft^2 at clearance to 5500 μg/ft^2 at 6 months and 5790 μg/ft^2 at 1 year post-intervention. On bare floors there was no significant difference in dust lead loadings at clearance and those at 6 months ($p = 0.53$) or between clearance and 1 year post-intervention ($p = 0.60$).

Pre-Intervention to 6 Months and 1 Year Post-Intervention

Dust lead loadings at 6 months and 1 year post-intervention were not significantly different from pre-intervention loadings on bare floors (6 months, $p = 0.29$; 1 year $p = 0.19$) and windowsills (6 months, $p = 0.57$; 1 year $p = 0.26$). At 6 months and 1 year post-intervention window trough dust lead loadings were significantly different than pre-intervention levels (both $p < 0.01$). Geometric mean trough dust lead loadings declined over 50 percent from pre-intervention levels of 12,800 μg/ft^2 to 5500 μg/ft^2 at 6 months and 5790 μg/ft^2 at 1 year post-intervention.

1, 2, and 3 Years Post-Intervention

Floor dust lead loadings remained stable from 1 year to 3 years post-intervention. We observed a decline in windowsill and trough lead loadings. On windowsills, dust lead loadings declined from 263 μg/ft^2 at one year to 199 μg/ft^2 at 2 years and to 180 μg/ft^2 at 3 years post-intervention. However, the difference from 1 year to 3 years was not significant ($p = 0.36$). There was a significant change for window trough dust lead loadings from 1 to 3 years post-intervention ($p = 0.01$). The window trough geometric means declined from 5790 μg/ft^2 at

TABLE III
Lead dust on windowsills of "study units": geometric mean dust lead loading and percent of units exceeding current (250 μg/ft^2) and past (500 μg/ft^2) federal dust lead hazard standards

Phase	Dwelling units (n)	Geometric mean (μg/ft^2) (95% CI)	Percent of dwelling units exceeding federal standards	
			250 μg/ft^2	500 μg/ft^2
Baseline	37	360 (205,633)	43	38
Clearance	37	73 (50,117)	22	5
6 Months	37	308 (189,502)	59	32
1 Year	37	263 (156,444)	49	35
2 Years	35	199 (115,344)	49	23
3 Years	37	180 (95,343)	43	22

TABLE IV
Lead dust on window troughs of "study units": geometric mean dust lead loading and percent of units exceeding applicable federal dust lead hazard standards on window troughs

Phase	Dwelling units (n)	Geometric mean (μg/ft^2) (95% CI)	Percent of dwelling units exceeding federal standards 800 μg/ft^2
Baseline	36	12800 (6800;24,000)	97
Clearance	36	101 (55;184)	17
6 Months	36	5500 (1970;10,200)	92
1 Year	36	5790 (3000;11,200)	89
2 Years	34	2580 (1010;6580)	74
3 Years	36	1970 (690;5640)	69

one year to 2580 μg/ft^2 at 2 years and to 1970 μg/ft^2 at 3 years post-intervention.

DISCUSSION

Although the selection criteria for this study eliminated dwellings with additional non-lead work at the time of the one-time cleaning intervention, additional lead or non-lead work may have occurred at a later date in the course of the three years of follow-up. Although data collection at each phase included reporting of additional work by adult occupants, we found that the reporting of additional work did not influence dust lead loadings at post-intervention phases. It is possible that some work did occur on buildings or neighborhoods but was not reported by occupants, particularly new residents.

The results presented in this study come from two states and the majority of units are from one city. The results therefore may not be applicable to other locations. In addition, given the perceived low pre-intervention floor dust lead loadings found by the Milwaukee grantee it did not undertake general cleaning of floor dust. Most professional cleaning efforts include a general floor cleaning. It is unclear how the results would have differed if the Milwaukee protocol had included a general floor cleaning. There were not enough non-Milwaukee units to examine units where floor cleaning occurred versus units where comprehensive floor cleaning did not occur.

The study raises significant questions about the potential of one-time professional cleaning interventions to reduce significantly and maintain reductions in dust lead loadings in units with deferred maintenance, deteriorated lead-based paint, and high window paint lead levels. Since units in this type of condition represent the units likely to pose the greatest potential lead hazards to children, the results have widespread implications for lead poisoning prevention efforts.

The cleaning interventions produced an immediate reduction in dust lead loadings on all surfaces studied. However, these declines did not persist. The differences between clearance and 6 month dust lead loadings and between clearance and 1 year post-intervention loadings were statistically significant for both sills and troughs. At 6 months and 1 year post-intervention, the increases in dust lead loadings from clearance resulted in dust lead loadings for bare floors and sills that are not significantly different than pre-intervention loadings. It may be that the increase in dust lead loadings between clearance and 6 months is partially due to the continued presence of interior lead-based paint hazards (e.g., deteriorated lead-based paint) and partially due to exterior lead-contaminated dust that enters dwellings units through windows (blown in) until the window dust lead loadings reach an equilibrium with the ambient neighborhood dust lead levels.

For troughs, the one-year post-intervention loadings were significantly different and lower than pre-intervention loadings despite the increase in lead loadings after clearance. The absolute declines from pre-intervention to one year post-intervention were substantial. The geometric mean trough dust lead loadings declined by 55 percent from baseline to 1 year post-intervention. Despite this persistent decline in trough lead loadings over time, it is critical to note that the trough dust loadings rebounded substantially from clearance to 6 months and 1 year post-intervention. While there is no current federal standard for lead dust hazards on window troughs, this substantial increase may represent an increase in lead exposure.

The window trough and sill lead loadings declined from 1 to 3 years post-intervention even without the continued benefit of a professional cleaning. It is possible that other environmental factors outside the dwelling may have influenced window dust lead loadings. These results are consistent with results of other low-cost interventions that document declines in dust lead loadings even in units where no active controls were pursued.[10] In addition, window dust lead loadings in the comprehensive evaluation decreased from 1 to 3 years post-intervention.[7]

While others have been able to demonstrate a substantial decline in dust lead loadings and blood lead levels following ongoing professional cleaning interventions, these interventions occurred on a regular basis (i.e., 4 hours of professional cleaning repeated every 2 weeks) over 12 months, which may be difficult to replicate on a widespread basis in neighborhoods with significant lead hazards.[9] While such interventions appear to lower blood lead levels, it is unlikely that either occupants or landlords in economically and physically distressed housing will be able to afford such interventions or overcome the logistical hurdles associated with providing ongoing cleaning services. Environmental interventions that do not require ongoing interventions are generally easier to implement.

These data also should give pause to those who criticize parents and caregivers living in housing units with deteriorated lead-based paint, and overall deferred maintenance for not doing a better job of cleaning their homes. It may be that typical family cleaning practices are not effective in reducing dust lead loadings on certain surfaces in poor condition and maintaining these reductions over time. Even the professional cleaning crews employed in this study did not clean troughs in poor condition to acceptably low levels.

Lead programs and property owners should consider the results observed in this cleaning study and in the comprehensive evaluation when deciding whether to pursue one-time professional cleaning efforts versus interventions that also repair deteriorated lead-based paint and other lead hazards. Dwellings in the study and a larger cohort of evaluation units had high paint lead levels prior to intervention. Interventions in the evaluation ranged from cleaning to full abatement with a median cost of $5960,[17] while the median cost of cleaning study units was $218 (maximum of $1900). Substantial reductions in dust lead loading from baseline to immediate post-intervention were observed on all sampled surfaces in the study units and the larger cohort of evaluation units. In contrast with the units in this cleaning study, floor dust lead loadings in evaluation units remained below the immediate post-intervention level three years later. While window dust lead loadings in evaluation units exhibited some increases, they remained substantially below pre-intervention levels and below applicable standards.[7] These data and other studies suggest that interventions that repair deteriorated paint and treat windows to provide smooth and cleanable troughs are more effective in reducing dust lead loadings than one-time professional cleaning.[7,9,10]

CONCLUSIONS

Low-cost lead hazard control interventions that rely solely on one-time professional cleaning of lead-contaminated dust and debris conducted in units with deteriorated lead-based paint and deferred maintenance can substantially reduce dust lead loadings immediately following the work, but these reductions are not maintained at six months and 1 year post-intervention on windows. Conclusions concerning professional floor cleaning cannot be drawn based on this study because it was not performed in the majority of the study units. Cleaning strategies may be useful in emergency situations to reduce lead dust hazards when paint repair and other lead hazard control activities cannot be done immediately. While such cleaning can produce immediate reductions in dust lead, additional efforts to repair existing lead hazards and/or offer ongoing cleaning support appear to offer greater reductions in dust lead loading over time.

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