AN EVALUATION OF THE EFFICACY OF THE LEAD HAZARD REDUCTION TREATMENTS PRESCRIBED IN MARYLAND ENVIRONMENTAL ARTICLE 6-8

EXECUTIVE SUMMARY

PREPARED BY:

THE NATIONAL CENTER FOR HEALTHY HOUSING
(formerly the National Center for Lead-Safe Housing)
10227 WINCOPIN CIRCLE, SUITE 205
COLUMBIA, MD 21044

JANUARY 24, 2002

Working with the U.S. Department of Housing and Urban Development's (HUD's) Office of Healthy Homes and Lead Hazard Control (OHHLHC), Baltimore City's Healthy Start Program and the Baltimore City Health Department's Lead Abatement Action Program (LAAP), the National Center for Lead-Safe Housing (the Center) designed this study to evaluate the efficacy of a prescribed set of "lead hazard reduction treatments" found in Maryland's lead law, Maryland Environmental Article 6-8 (EA 6-8) in reducing dust lead loadings.

In this study, pre- and immediate post-intervention dust sampling and visual assessment tools were utilized to determine the efficacy of the law's requirement that, upon completion of the prescribed treatments, only an independent visual inspection is needed to determine whether a treated rental housing unit visually "passes" or "fails" the prescribed standard.[1] One-year post-intervention dust sampling and visual assessment tools were then utilized to evaluate the continued effectiveness of treatments prescribed and performed under EA 6-8. The extent to which lead hazards were decreased immediately following treatment is discussed, primarily by comparing pre- with immediate post-intervention dust lead loadings on floors, window sills and window troughs in a set of rooms where young children were likely to play, eat or sleep. This report also documents the extent to which lead dust re-accumulated on various surfaces over a one-year period after completion of the treatments, primarily by comparing one-year post-intervention dust lead loadings on floors, window sills and window troughs with pre-intervention dust lead loadings. Limited data for a two-year post-intervention period are also discussed.

LAAP inspectors, who were trained and certified as lead-based paint risk assessors, recruited property owners or managers to enroll their rental housing units in this study. To be enrolled, a unit had to be located in Baltimore City, constructed prior to 1950, vacant at intervention and structurally sound as determined by a LAAP screening inspection. A structurally deficient unit could be accepted into the study at a later date if the owner corrected observed deficiencies. (Information on pre-program repairs was not collected as part of the study.) Enrolled units were assigned into two treatment categories: (1) units that underwent EA 6-8's prescribed treatments (referred to as "LHR units"); and (2) units that underwent these treatments plus window replacement (referred to as "LHR+W units"). The owner prepared work specifications for the lead hazard intervention, according to EA 6-8's prescribed treatment requirements. LAAP

---

[1] Ten "lead hazard reduction treatments" are prescribed by the standard:

- Visual review of all exterior and interior painted surfaces;
- Removal and repainting of chipping, peeling or flaking paint on exterior and interior painted surfaces;
- Repair of any structural defect that is causing paint to chip, peel or flake that the owner of the affected property has knowledge of or, with the exercise of reasonable care, should have knowledge of;
- Stripping and repainting, replacing or encapsulating all interior window sills with vinyl, metal or any other material;
- Ensuring that caps of vinyl, aluminum, or any other material are installed in all window wells in order to make the window wells smooth and cleanable;
- Except for a treated or replacement window that is free of lead-based paint on its friction surfaces, fixing the top sash of all windows in place in order to eliminate friction caused by movement of the top sash;
- Re-hanging all doors necessary in order to prevent the rubbing together of a lead-painted surface with another surface;
- Making all bare floors smooth and cleanable;
- Ensuring that all kitchen and bathroom floors are overlaid with a smooth, water-resistant covering; and
- HEPA-vacuuming and washing the interior of the affected property with high phosphate detergent or its equivalent.

inspectors then conducted a pre-intervention walk-through inspection, during which, in accordance with study protocols, they collected composite and single surface dust wipe samples from floors, window sills and window troughs in specific rooms, using HUD wipe sampling methods. During subsequent phases, in accordance with study protocols, LAAP inspectors visited units to collect composite and single surface samples from the same surfaces, rooms and locations that were sampled at pre-intervention.

All samples were analyzed for total lead by laboratories participating in EPA's National Lead Laboratory Accreditation Program (NLLAP) and proficient in the Environmental Lead Proficiency Analytical Testing Program (ELPAT). Study protocols included laboratory and field quality assurance/quality control procedures. Field audits and data audits were also routinely performed.

The Center was responsible for all data entry and processing. All study data were transmitted into and maintained in Jetform's FormFlow software program. Statistical analyses were performed using a SAS Institute program, which also generated reports and tables. A Crystal Reports software package was also used to generate certain reports.

A. Results Through Immediate Post-Intervention

A total of 177 units (91 LHR and 86 LHR+W) underwent complete pre-intervention baseline visual assessments. Pre-intervention composite dust samples were collected in 148 of the 177 units[2] and single surface dust samples were collected in 98 units. The EA 6-8 prescribed lead hazard reduction treatments were completed in 121 units (57 LHR and 64 LHR+W). A full immediate post-intervention study assessment was performed in these units, including a visual assessment by LAAP inspectors, collection of cost and concurrent work data and dust testing. Immediately after treatment, both the LHR and the LHR+W units experienced substantial reductions in dust lead loadings on all surfaces (see Table E-1 on page 4). Using either of the dust sampling methods, immediate post-intervention dust lead loadings on bare floors of LHR units were generally similar to those on bare floors of LHR+W units. However, as expected, immediate post-intervention dust results for window sills and troughs in LHR units were significantly higher than those in LHR+W units.

Despite the significant median decreases in dust lead loadings between pre- and immediate post-intervention, data in Table E-2 (on page 4) do show that some units experienced increases in dust lead loadings between these two phases. The percentage of LHR+W units that underwent an increase was generally lower than that of LHR units and was comparable to that of Baltimore HUD units.

[2] Twenty-nine (29) units were not included primarily because the owners' grant applications were not approved.

Table E-1: Median Percent and μg/ft^2 Reductions in Pre- to Immediate Post-Intervention Dust Lead Loadings for LHR, LHR+W and Baltimore Round One HUD Evaluation Units[b]

Surface Type and Sample Type	LHR Median % Reduction (& Median μg/ft^2 Reduction)	LHR+W Median% Reduction (& Median μg/ft^2 Reduction)	Balt. HUD Median% Reduction (& Median μg/ft^2 Reduction)
Bare Floors:			
Composite	85% (147 μg/ft^2)	89% (225 μg/ft^2)	NA[a]
Single Surface	70% (99 μg/ft^2)	88% (226 μg/ft^2)	95% (265 μg/ft^2)
Interior window sills:			
Composite	94% (1,686 μg/ft^2)	99% (2,596 μg/ft^2)	NA[a]
Single Surface	84% (497 μg/ft^2)	99% (2,511 μg/ft^2)	>99% (2,492 μg/ft^2)
Window Troughs:			
Composite	95% (9,708 μg/ft^2)	>99% (11,284 μg/ft^2)	NA[a]
Single Surface	94% (4,111 μg/ft^2)	99% (12,022 μg/ft^2)	99% (3,591 μg/ft^2)

[a]NA=not applicable. Composite dust samples were not taken in the Baltimore Round One HUD Evaluation units.
[b]Single surface dust data were compared to data obtained from Baltimore City housing units enrolled in Round I of the National Evaluation of HUD's OHHLHC's Lead Hazard Control Grant Program. These units underwent interventions similar to those of the LHR+W units, and more intensive than those of the LHR units.

Table E-2: Number and Percent of Units Having an Increase in Dust Lead Loadings from Pre- to Immediate Post-Intervention

Surface Type and Sample Type	LHR	LHR+W	Baltimore HUD Units
Bare Floors:			
Composite	6/49 (12%)	3/56 (5%)	NA
Single Surface	4/16 (25%)	4/63 (6%)	12/278 (4%)
Interior window sills:			
Composite	4/52 (8%)	2/62 (3%)	NA
Single Surface	2/16 (12%)	1/62 (2%)	2 (1%)
Window Troughs:			
Composite	3/52 (6%)	1/62 (2%)	NA
Single Surface	2/16 (10%)	1/62 (2%)	13 (5%)

Although EA 6-8 does not require clearance dust testing in connection with the prescribed treatments, post-intervention results were compared with clearance standards to assess the extent to which the treatments produced dust results sufficient for safe occupancy of the treated units and the extent to which the prescribed independent visual inspection provided a sufficient level of risk reduction. When applying these clearance standards to immediate post-intervention individual single surface dust results, an appreciable number of units had at least one floor, window sill or window trough dust lead result that exceeded the Maryland and HUD/EPA guidance/standards at the time of the study (see Table E-3 on page 5). Assigned treatment group was significantly associated with post-intervention window sill and trough results "passing" or "failing" their respective standards but was not significantly associated with bare floors "passing" or "failing" standards. Had clearance testing been required, 46 percent of the units had at least one sample that would have "failed" a floor clearance level of 100 µg/ft^2, nine percent had at least one sample that "failed" interior window sill clearance of 500 µg/ft^2 and 27 percent had at least one sample that "failed" window trough clearance of 800 µg/ft^2. These are higher "failure" rates than those observed for vacant Baltimore HUD units enrolled in the HUD National Evaluation (29 percent for floors, one percent for sills and six percent for troughs).[3] It is apparent that dust clearance testing is critical to ensure that treated dwellings are safe for re-occupancy.

Table E-3: Percentage of Units with Immediate Post-Intervention Single Surface Clearance "Failures"

	Percent of Units within Specified Category			
Surface Type:	**Floors**		**Interior Window Sills**	**Window Troughs**
Std/Guidance:	\$100 µg/ft^2	\$200 µg/ft^2	\$500 µg/ft^2	\$800 µg/ft^2
LHR Units	60%	35%	20%	50%
LHR+W Units	41%	25%	5%	19%
Total All Units	46%	28%	8%	27%

Although statistically significant dust lead loading reductions were found and each unit passed the independent visual inspection prescribed by EA 6-8, immediate post-intervention confirmatory visual assessments conducted by LAAP inspectors yielded a high percentage of units (93 percent) with visual "failures" of one or more of the prescribed lead hazard reduction treatments (see Table E-4 on page 6).[4] The three most common "failures" were: (1) not all paint intact, with some chipping, flaking and peeling paint remaining (75 percent of all units); (2) one or more painted doors continuing to rub together and/or bind (43 percent); and (3) visible paint chips and/or debris remaining (38 percent). The "failures" that LAAP inspectors recorded were easily observed, with a dwelling unit geometric mean of 1 ft^2 of non-intact paint reported in LHR and LHR+W units, and dwelling unit geometric means of 8 and 16 ft^2 of visible paint chips and debris in LHR and LHR+W units. It should be noted that the areal density (i.e., depth) and lead concentration of chips/debris were not measured. The owner corrected treatment "failures" noted during the immediate post-intervention sampling visit before tenants moved in. These corrections were "validated" by LAAP inspectors, who required owners and/or contractors to complete their work prior to payment.

These results indicate that lead hazard reduction treatments did not completely meet the EA 6-8 risk reduction standard and more strongly suggest that the independent visual inspections failed to identify all lead hazard reduction "failures." Because only five or six independent inspectors conducted inspections for these study units, this finding does not necessarily reflect on all other Maryland-certified inspectors.

[3] Clearance failure rates for the Baltimore HUD units are based on initial clearance testing conducted after treatment.

[4] For the purposes of this study, a treatment "failure" was defined as an observation by the LAAP inspector that one or more of the ten lead hazard reduction treatments prescribed in the statute had not been fully completed. Note that the Maryland statute did not specify a "de minimis" level above which the treatment was considered a failure; therefore, any observable deficient or missing treatment was classified as a "failure."

Table E-4: Number of Immediate Post-Intervention Visual Assessment "Failures" Per Unit[a]

Number of Immediate Post-Intervention Visual Assessment "Failures" Per Unit[b] 57 LHR units, 64 LHR+W units)	LHR # Units (% Units)	LHR+W # Units (% Units)	All Units # Units (% Units)
"0" lead hazard treatment "failures"	5 (9%)	4 (6%)	9 (7%)
"1" lead hazard treatment "failure"	6 (10%)	26 (41%)	32 (26%)
"2" lead hazard treatment "failures"	20 (35%)	21 (33%)	41 (34%)
"3" lead hazard treatment "failures"	22 (39%)	10 (16%)	32 (26%)
"4" lead hazard treatment "failures"	3 (5%)	3 (5%)	6 (5%)
"5" lead hazard treatment "failures"	1 (2%)	0 (0.0)	1 (0.8)

Source: Form 05

[a]For the purposes of this study, a treatment "failure" was defined as an observation by the LAAP inspector that one or more of the ten lead hazard reduction treatments prescribed in the statute had not been fully completed. "Failures" were counted on a per unit basis. Within each unit, failures were listed by room ID.

[b]The mean number of "failures" per unit (2.3 for LHR units; 1.7 for LHR+W units) was significantly associated with assigned treatment group (p=0.0044).

Various cost data were collected during this study, including LAAP-approved costs for the prescribed lead hazard reduction treatments, plus the additional window replacement costs for the LHR+W units. Owner-estimated turnover costs that would have been incurred even if the enrolled units had not been subject to the EA 6-8 treatments were also collected. However, these data were highly subjective and were excluded from the study. Finally, the type of contractor performing the work and information on concurrent work was also collected. The median cost for completing the prescribed treatments in LHR units and LHR+W units was $2,154 and $1,649, respectively. Costs in LHR units were likely higher because the expense of the prescribed window treatments was included, while window replacement costs in the LHR+W units were calculated separately. The median cost of treatment plus window replacement in the LHR+W units was $4,348, with an average of 9 to 10 windows being replaced per unit. Treatment costs were higher than expected for a typical Baltimore City dwelling and should not be considered average or representative of all Baltimore City rental unit costs.

For LHR units, the mean costs for for-profit contractors were slightly higher than those for property owners/employees, while the reverse was observed for LHR+W units. Concurrent work (e.g., roofing, plumbing, heating and electrical repairs and replacement of other fixtures and components) was performed in 17 of the 57 LHR units and in 27 of the 64 LHR+W units.

For each surface type, a backward elimination multiple regression model was run to identify factors that were significant predictors of immediate post-intervention dust lead loadings. No significant predictors were found for bare floors. However, pre-intervention sill dust lead loadings and the assigned treatment group were found to be significant predictors of immediate post-intervention sill results. For window troughs, pre-intervention trough dust lead loadings and the assigned treatment group were significant predictors of immediate post-intervention trough results.

Clearance "failures" on bare floors was not modeled since no relationship was found when attempting to predict dust lead loading at clearance. For sills and troughs, a logistic regression model was run to identify factors that are significant predictors of whether units would have clearance "failures" based on floor, sill and trough standards of 100 µg/ft^2, 500 µg/ft^2 and 800 µg/ft^2, respectively. For sills, the only variable found to significantly predict immediate post-intervention clearance "failures" was the percent of windows replaced out of the total number of windows in a unit. For troughs, the number of items of exterior building deterioration (yielding more clearance "failures") and the percent of windows replaced (yielding fewer clearance "failures") were found to be significant predictors of clearance "failure" at immediate post-intervention.

A logistic model was employed to identify factors that are significant predictors of immediate post-intervention visual assessment "failures." The only variable found to significantly influence visual assessment "failure" was the number of items of exterior building deterioration (increasing items yielding more visual assessment "failures").

B. Results Through One-Year Post-Intervention

A total of 73 units (36 LHR and 37 LHR+W) were sampled approximately one year after treatments were completed. LAAP inspectors also performed a full visual assessment at one year post-intervention, noting any "failures" that had occurred since their previous visit.

At one-year post-intervention, composite and single surface dust lead loadings on all surfaces remained well below pre-intervention levels (see Table E-5). Substantial median percent decreases and median µg/ft^2 decreases in dust lead loadings were observed for floors, sills and window troughs between pre- and one-year post-intervention. Dust lead loadings on window sills and troughs in LHR units were significantly higher than those in LHR+W units.

Table E-5: Median Percent (µg/ft^2) Reductions in Dust Lead Loadings for LHR, LHR+W and Baltimore Round One HUD Evaluation Units Between Pre-Intervention and One Year Post-Intervention

Surface Type and Sample Type	LHR Median % Reduction (& Median µg/ft^2 Reduction)Pre to 1 Year Post	LHR+W Median % Reduction (& Median µg/ft^2 Reduction) Pre to 1 Year Post	Balt. HUD Median Reduction (& Median µg/ft^2 Reduction) Pre to 1 Year Post
Bare Floors:			
Composite	82% (87 µg/ft^2)	94% (335 µg/ft^2)	NA[a]
Single Surface	NA[b]	96% (420 µg/ft^2)	84% (220 µg/ft^2)
Interior window sills:			
Composite	82% (713 µg/ft^2)	97% (2,803 µg/ft^2)	NA[a]
Single Surface	NA[b]	97% (1,875 µg/ft^2)	98% (2,617 µg/ft^2)
Window Troughs:			
Composite	89% (4,507 µg/ft^2)	98% (12,014 µg/ft^2)	NA[a]
Single Surface	NA[b]	99% (16,338 µg/ft^2)	86% (3,308 µg/ft^2)

[a]NA=not applicable. Composite dust samples were not taken in Baltimore Round I HUD Eval. units.
[b]NA=not applicable. Single surface samples were collected in only 2 LHR unit at one year post-intervention.

One-year post-intervention single surface results for LHR+W units were compared with clearance standards to assess the extent to which the treatments continued to produce dust results sufficient for safe occupancy of the treated units. Insufficient single surface data were available for LHR units. Less than 20 percent of units had at least one bare floor, sill, or trough result that exceeded HUD standards (see Table E-6). The percentages for floors and troughs in LHR+W units were significantly lower than those found for Baltimore Round I units in the HUD National Evaluation.

Table E-6: Percentage of Units with One-Year Post-Intervention Single Surface Clearance "Failures"

	Percent of Units within Specified Category			
Surface Type:	**Floors**		**Interior Window Sills**	**Window Troughs**
Std/Guidance:	\$100 µg/ft^2	\$200 µg/ft^2	\$500 µg/ft^2	\$800 µg/ft^2
LHR+W Units	14	11	17	14
Balt. HUD Units	57	NA	11	35

Although dust lead loadings remained less than pre-intervention levels and a large percentage of units had dust lead loadings less than HUD clearance standards at one year post-intervention, inspections conducted by LAAP inspectors one year after treatments were first implemented found that 96% of the 73 units had at least one visual assessment "failure" (see Table E-7 on page 9). The most common "failures" were the same as those identified at immediate post-intervention: not all paint intact (93%), doors continuing to rub (41%) and visible chips or debris (29%). It should be noted that, for the visible paint chips or debris, the areal density (i.e., depth) of the chips/debris and the lead concentration in those chips/debris was not measured. A geometric mean[5] of 1 ft^2 of paint was not intact, 1 ft^2 of paint chips or debris remained, and 4 ft^2 of flooring was not smooth and cleanable. While these types of problems were reportedly treated after immediate post-intervention dust samples were collected and visual assessments were performed, these results are not entirely surprising given that few units appeared to experience turnover or had further treatments during the one-year post-intervention period.

For each surface type, a multiple regression model with backward elimination[6] was run to identify factors that were significant predictors of one-year post-intervention dust lead loadings. The only significant predictor of bare floor dust lead loadings was the percent of rooms with visual assessment "failures" at one year post-intervention. Pre-intervention sill dust lead loadings and assigned treatment group were significant predictors of one-year post-intervention

[5] Note that these geometric mean values were calculated using only values reported for units that had the specified type of "failure" reported. Units that did not have the specified type of "failure" reported were not included in the calculations.

[6] In a multiple regression model with backward elimination, all possible predictors of the outcome are initially entered into the model. Then hypothesis tests are run to determine if any factors can be removed from the predictive equation when the other factors are retained. The least significant factor (i.e., the factor with the largetst observed significance level) is removed and the process is repeated to determine if more factors can be dropped. In a logistic model with backward elimination, the outcome of interest is a binary response variable (e.g., "pass/fail"). In a Poisson regression model with backward elimination, the outcome of interest is a count variable (e.g., number of failures). The same backward elimination procedure described above for regression modeling was followed for both the logistic and the Poisson models.

sill dust lead loadings. Assigned treatment group was the only significant predictor of one year post-intervention trough dust lead loadings.

Table E-7: Number of One-Year Post-Intervention Visual Assessment "Failures" Per Unit[a]

Number of Visual Assessment "Failures" Per Unit (36 LHR units, 37 LHR+W units)	LHR # Units (% Units)	LHR+W # Units (% Units)	All Units # Units (% Units)
"0" One-yr post-int visual assessment "failures"	0	3 (8%)	3 (4%)
"1" One-yr post-int visual assessment "failure"	8 (22%)	13 (35%)	21 (29%)
"2" One-yr post-int visual assessment "failures"	12 (33%)	9 (24%)	21 (29%)
"3" One-yr post-int visual assessment "failures"	11 (31%)	9 (24%)	20 (27%)
"4" One-yr post-int visual assessment "failures"	3 (8%)	3 (8%)	6 (8%)
"5" One-yr post-int visual assessment "failures"	2 (6%)	0	2 (3%)

Source: Form 05

[a]For the purposes of this study, a treatment "failure" was defined as an observation by the LAAP inspector that one or more of the ten lead hazard reduction treatments prescribed in the statute had not been fully completed. "Failure" was counted on a per unit basis. Within each unit, "failures" were listed by room ID.

For floors, sills and troughs, a logistic regression model with backward elimination[6] was run to identify factors that were significant predictors of whether units would have clearance "failures" at immediate post-intervention based on floor, sill and trough standards of 100 $\mu g/ft^2$, 500 $\mu g/ft^2$ and 800 $\mu g/ft^2$, respectively. For bare floors, the only significant predictor of one-year post-intervention composite results exceeding 100 $\mu g/ft^2$ was the year of construction. For sills, pre-intervention sill dust lead loadings and assigned treatment group were significant predictors of one-year post-intervention composite dust lead loadings exceeding 500 $\mu g/ft^2$. For troughs, the only significant predictor of one-year post-intervention composite dust lead loadings being above 800 $\mu g/ft^2$ was assigned treatment group.

Finally, a Poisson regression model with backward elimination[6] was employed to identify factors that are significant predictors of visual assessment "failures" at one-year post-intervention. Significant predictors were lead hazard reduction cost at Phase II, building type, whether work had been performed during the past year and the estimated market value of the dwelling.

C. Summary of Study Findings

The main findings of this study are that dust lead loadings declined substantially immediately after EA 6-8 prescribed lead hazard reduction treatments were implemented. However, many units would not have "passed" clearance dust tests immediately following treatment had such testing been required. In addition, the prescribed independent visual inspections conducted in these units immediately following treatment generally missed many treatment "failures." At one year post-intervention, dust lead loadings generally remained very low, with over 80 percent of units having floor, sill and trough dust lead loadings that were below clearance standards. However, almost every unit had at least one visual assessment failure one year after treatment.

Based on study findings, it is recommended that:

- Appropriate state agencies should increase oversight of independent visual inspectors to ensure that such inspectors are performing visual inspections in accordance with approved protocols and inspector training;
- Clearance dust testing should be added to the independent visual inspection as part of the lead hazard reduction treatment requirements of EA 6-8, either by regulation or by amendment to the statute;
- Rental property owners and their crews and independent contractors should perform a more intensive final cleaning upon completion of the prescribed treatments;
- More comprehensive window treatments may be needed to ensure that interior window sills and troughs do not continue to be an exposure source for lead; and
- Proper adjustment and re-hanging of doors to eliminate friction points should be an emphasis of the prescribed treatments.