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Immediate and one-year post-intervention effectiveness of Maryland's lead law treatments

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Abstract

A 1994 Maryland law prescribes a lead-based paint risk reduction standard for pre-1950, privately owned rental housing. This standard, applied at each tenancy change, can be met by sampling to verify that dust lead loadings are within acceptable limits or by performing specific lead hazard reduction treatments, followed by an independent visual inspection without dust sampling. We evaluated the ability of visual inspection to predict treatment completion and dust lead loadings.

Fifty-two Baltimore housing units were enrolled and received the law-specified treatments. Before treatment, study risk assessors conducted visual assessments and dust lead wipe sampling in each unit. After treatment, Maryland-certified visual inspectors conducted the law's required visual inspection, followed by the study risk assessors, who performed a separate visual assessment and collected dust wipe samples. One year later, study risk assessors performed another visual assessment and dust wipe sampling ($n = 34$).

Dust lead loadings declined significantly immediately after prescribed lead treatments were implemented. Fifty-three percent, 20%, and 47% of units had at least one sample that exceeded 1995 EPA/HUD floor, window sill and window trough clearance guidance of 100, 500 and 800 $\mu g/ft^2$, respectively. Overall, 73% of units had one or more immediate post-intervention single surface sample results exceeding the 1995 clearance values that were in effect at the time of the study. One-year post-intervention loadings remained significantly below pre-intervention levels for floors but not window sills or troughs.

Visual assessments alone, without dust lead testing, did not ensure that prescribed treatments were completed or that dust lead loadings were below clearance values.

Keywords: Maryland Lead Law; Visual inspection; Dust lead loading; Clearance testing

1. Introduction

Children living in housing with deteriorated lead-based paint and lead in household dust and soil are at risk of having elevated blood lead levels (Centers for Disease Control, 1991; National Academy of Science (NAS), 1993). In Maryland, this problem is especially prevalent in Baltimore City, which contains a disproportionately high number of residences with children who have elevated blood lead levels compared with other areas of the state (Maryland Department of the Environment (Maryland Department of the Environment (MDE), 2001). In 1994, the Maryland legislature passed a law intended to prevent childhood lead poisoning resulting from deteriorating lead-based paint while also preserving the state's affordable rental housing stock. "The Lead Poisoning Prevention Program," codified in the Maryland Environmental Article as Section 6-801 et. seq. (EA 6–8) (Maryland, 1994), became fully effective on February 24, 1996.

EA 6–8 applies to all pre-1950, privately owned rental housing and, at a property owner's option, to any residential rental property constructed after 1949 but before 1978. An owner must register such properties with the MDE. The law contains an approach and schedule for reducing lead-based paint hazards at each change in

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occupancy (i.e., turnover), mandating that the owner meet a prescribed "risk reduction standard." This standard can be met in one of two ways: (1) by performing dust sampling to verify that dust lead loadings in the property are within acceptable limits, or (2) by performing 10 prescribed lead hazard reduction treatments:

- visually examine all exterior and interior painted surfaces;
- remove and repaint chipping, peeling or flaking paint on exterior and interior painted surfaces;
- repair 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 (e.g., a leaking roof);
- strip and repaint, replace or encapsulate all interior window sills with vinyl, metal or any other material;
- ensure that caps of vinyl, aluminum, or any other material are installed in all window wells in order to make them smooth and cleanable;
- except for a treated or replacement window that is free of lead-based paint on its friction surfaces, fix the top sash of all windows in place in order to eliminate friction caused by movement of the top sash;
- re-hang all doors as needed in order to prevent the rubbing together of a lead-painted surface with another surface;
- make all uncarpeted floors smooth and cleanable;
- ensure that all kitchen and bathroom floors are overlaid with a smooth, water-resistant covering (if one is not already in place); and
- HEPA-vacuum and wash the interior of the affected property with high phosphate detergent or its equivalent.

These 10 treatments must be followed by an independent visual inspection conducted by an MDE-certified inspector. At each turnover thereafter, the owner is required to have the housing unit visually inspected again to verify that the lead hazard reduction treatments are still in effect. Dust lead sampling after treatment, i.e., clearance testing, is not required under the second alternative.

The law also provides limited liability relief to rental property owners who meet the risk reduction standard. Under EA 6–8, children and their representatives cannot sue for traditional tort damages for lead poisoning if the rental property owner has met the risk reduction standard and certain housing unit registration requirements. The owner and/or the property insurer must make a "qualified offer" to any resident children and their legal representative when the child's blood lead level has exceeded 25 micrograms per deciliter of blood (μg/dl). (This limit has since been changed to 20 μg/dl.) The qualified offer is, in effect, a remedial compensation settlement of the child's potential lead poisoning claim, which is designed to pay for necessary out-of-pocket medical treatment and relocation costs for the child's family to move to "lead-safe" housing, up to a stated cap.

Through its system of registration, risk reduction standards, and visual inspections, EA 6–8 is intended to identify and treat homes before resident children become poisoned. However, the second alternative for meeting the law's risk reduction standard does not require clearance dust sampling upon completion of treatments. Few if any studies have evaluated the ability of visual inspections, in the absence of clearance testing, to verify that a home is safe from lead hazards, particularly those with excessive lead dust. A review of studies of lead hazard control states "…neither abatement nor interim control measures can be considered safe until the dwelling has been thoroughly cleaned and passed clearance testing" (Staes and Rinehart, 1995). Several studies have shown a strong correlation between dust lead loadings and children's blood lead levels, indicating that dust lead loading can be used as a surrogate measure of exposure (Lanphear et al., 1998a, b). The US Environmental Protection Agency (EPA) currently requires that pre-1978 federally assisted housing that has had lead-based paint or lead-based paint hazard abatement pass both visual inspection and dust sampling for clearance (EPA, 1996a). The US Department of Housing and Urban Development (HUD) currently requires clearance after either abatement or after interim control of lead-based paint hazards in pre-1978 housing that is receiving federal assistance or that is being sold by the federal government (HUD, 1999). Studies have shown that properties that are subject to these requirements sometimes have initial post-intervention dust lead loadings that are above clearance standards (Dixon et al., 2004).

This study was undertaken to determine the efficacy of the law's prescribed treatments and the independent visual inspection in units that underwent these treatments. Pre-intervention, immediate post-intervention, and one-year post-intervention dust lead sampling and visual assessment data tools were utilized to determine the extent to which dust lead loadings were reduced immediately following treatment, to evaluate whether the independent visual inspection adequately determined whether the treatments required by the risk reduction standard were carried out, and to determine the continued effectiveness of the prescribed treatments one year after the treatments were performed. Previous studies have shown that dust lead loadings can remain well below baseline levels six years after treatment of lead-based paint hazards (Galke et al., 2005; Wilson et al., 2006); however, this study tested the one-year effectiveness of the treatments prescribed by EA 6–8.

2. Methods

2.1. Enrollment

Enrollment of housing units into the study began in late 1996. To be enrolled in the study, a unit had to be located in Baltimore City, constructed prior to 1950, vacant at intervention and structurally sound as determined by the Baltimore City Health Department Lead Abatement Action Program's (LAAP) screening inspection. A structurally deficient unit could be enrolled at a later date if the owner corrected observed deficiencies. In order to qualify for the study, the property owner had to (1) substantiate that the unit was registered with MDE as required by EA 6–8, (2) provide evidence of fire insurance on the unit, (3) produce documentation of acceptable lead treatment specifications (according to EA 6–8's prescribed treatments) and costs prior to construction, (4) agree to rent the enrolled unit to low-income families for a period of at least five years, (5) keep rents affordable for low-income families, (6) agree to dust sampling and visual assessments of the unit as part of the study, and (7) sign a LAAP grant contract.

2.2. Visual assessment

Visual assessments were performed at pre-intervention, immediate post-intervention, and one-year post-intervention by a two-person team of risk assessors from the LAAP program. During pre-intervention visual assessments, general signs of deterioration inside and outside the building were noted using a standardized checklist originally developed for the National Evaluation of HUD's Lead-Based Paint Hazard Control Program (Galke et al., 2005).

As required by EA 6–8, MDE-certified lead paint visual inspectors, hired by the rental property owners, performed independent visual inspections in each unit upon completion of treatments. Just after this visual inspection was completed, the study risk assessor team performed a second separate visual assessment to determine if the 10 prescribed lead hazard reduction treatments had been fully completed. The study risk assessor team also conducted a final post-intervention visual assessment one year after the immediate post-intervention visual assessment.

During each assessment, the study risk assessor team visually assessed each room in the unit, as well as the building exterior. For the purposes of this article, an ''incomplete treatment'' was defined as an observation by the study risk assessor team that one or more of the 10 prescribed lead hazard reduction treatments had not been fully or properly completed. EA 6–8 does not specify a ''de minimis'' level above which a treatment is to be considered incomplete. Therefore, study protocols required that any observed deficient or missing treatment would be classified as incomplete. Each observed incomplete treatment was recorded, according to the room in which it was found, the magnitude of the deficiency, and its unit of measure (e.g., 10 square inches of visible paint chips or debris).

The study risk assessor team was permitted to use a variety of measurement units, depending on the type and location of the incomplete treatment. For example, non-intact paint tended to be measured in units of square inches or square feet on walls, in linear inches on trim, and as ''each'' when an entire component had non-intact paint. For this article, measurement units were converted to common measurement units when possible (e.g., square inches and square yards converted to square feet). For each type of treatment, data are presented for the unit of measure having the most data available.

2.3. Dust lead sampling

During the pre-intervention visual assessment visit, the study risk assessor team collected dust wipe samples from floors, window sills and window troughs (i.e., the surface where the window sash comes to rest on the window frame) in specific rooms. Moist towelettes were used to collect all dust wipe samples, according to HUD wipe sampling methods (HUD, 1995). These methods were also used to dust wipe the same surfaces, rooms and locations during the study risk assessor team's immediate post-intervention and one-year post-intervention visits. At pre-intervention, both composite and single surface dust wipe samples were collected. At immediate post-intervention, composite samples were collected in all units, and single surface samples were collected in a subset of units. At one-year post-intervention, only composite samples were collected. Single surface sampling was included to allow comparison of sample results with 1995 HUD/EPA clearance guidance values.

Using an 8-inch by 9-inch template, separate uncarpeted and carpeted floor composite dust samples were collected, consisting of sub-samples from at least two and up to four locations: entryway, child's playroom (or living room), kitchen and the smallest bedroom. All floor samples were collected just inside doorways leading into the room, slightly to the left of center. Window sill and window trough samples were collected as separate composite samples, each consisting of subsamples from at least two and up to four locations: child's playroom (living room), kitchen and the two smallest bedrooms. Window sub-samples were collected from the left half (looking out) of each window. Only one window per room was sampled, with the selected window being re-sampled during the post-intervention visits.

Using an 8-inch by 9-inch template, single surface floor samples were collected from each of five locations: entryway (slightly right of center), playroom (living room), kitchen and the two smallest bedrooms. Window sill single surface samples were collected from the kitchen and the smallest bedroom, while window trough single surface samples were collected from the playroom (living room) and the next smallest bedroom. Window single surface samples were collected from the right half (looking out) of each window.

2.4. Laboratory analysis

All dust wipe samples were analyzed by laboratories that participate in the EPA's National Lead Laboratory Accreditation Program (NLLAP) and are proficient in the Environmental Lead Proficiency Analytical Testing Program (ELPAT). All samples were first digested in acid and then analyzed for total lead by flame atomic absorption spectroscopy (EPA, 1996b). Each composite sample was handled and analyzed by extracting all subsamples simultaneously in a single container. Testing of composite wipe samples has not been part of either the NLLAP or ELPAT programs.

All samples underwent quality assurance/quality control (QA/QC) procedures delineated by the study protocols, including the analysis of field blank and QC spike samples at a specified frequency. The single surface reporting limit varied from 5 μg to 24 μg per sample, the composite reporting limit was 20 μg per sample.

2.5. Data management and data analysis

The study's risk assessor team recorded all data on standardized field forms. Field audits and data audits were routinely performed during the study. Before computer data entry, all data were audited for correctness, completeness and adherence to the study protocols. Data were then transmitted into and maintained in Jetform's FormFlow software program (JetForm, 1997–1998). Statistical analyses were performed using SAS/STAT® software, which also generated reports and tables (SAS Institute, 1989-1996). Sample results reported by the laboratory to be at or below the laboratory's reporting limits were replaced by a value calculated by dividing the laboratory reporting limit by the square root of 2 (Hornung and Reed, 1990). Eight of the 483 total composite samples were below reporting limits while 14 of 135 single surface immediate post-intervention clearance samples were below reporting limits. Immediate post-intervention dust lead loadings and one-year post-intervention dust lead loadings were each compared with pre-intervention dust lead loadings.

The median dust lead loading was used as the measure of central tendency because it did not necessitate distributional assumptions. For changes from pre-intervention to immediate post-intervention or to one-year post-intervention, the percent reduction in the dust lead loading was used. A Wilcoxon signed-rank test was used to test for a median percent reduction in dust lead loading and whether the median difference between single and composite sample results equaled zero.

Dust lead loading results for composite carpeted floors are not presented in this article because few samples were collected on carpets. However, single surface dust samples on carpets are included in the clearance exceedance calculations because the standards pertain to both carpeted and uncarpeted floors.

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Although EA 6–8 does not require clearance dust sampling in connection with the prescribed treatments, immediate post-intervention single surface samples were collected to determine whether dust lead loadings met clearance standards. Immediate post-intervention single surface dust lead loadings were compared with 1995 EPA/HUD clearance guidance values of 100, 500 and 800 μg/ft^2 for floors, window sills and window troughs, respectively (EPA, 1995). Results were also compared with 1995 Maryland clearance standards, which were equivalent to the 1995 EPA/HUD guidance values for sills and troughs but were higher for floors, at 200 μg/ft^2 (Maryland Register, 1995). In 2001, EPA set reduced clearance standards for floors, sills and troughs of 40, 250 and 400 μg/ft^2, respectively. However, in this study, comparisons were made only to the 1995 values since they were the only ones in effect during the study period.

Immediate post-intervention and one-year post-intervention visual assessment results were evaluated on a per-report basis (i.e., each individual report of an incomplete or missing treatment was summarized by type of treatment) and on a dwelling unit-wide basis (i.e., all reports of specific incomplete treatments within a single dwelling were first summed, then geometric means were calculated across all dwellings in which this type of incomplete treatment was reported).

3. Results

The immediate post-intervention dataset consisted of 52 units that underwent lead hazard reduction treatments and had both pre- and immediate post-intervention composite dust data. The one-year post-intervention dataset consisted of 34 of these units that also had one-year post-intervention composite dust data.

3.1. Building characteristics and pre-intervention conditions

Seventy-five percent of units were single-family row-houses, and 82% were constructed before 1930. At baseline, 69% of units had one or more signs of obvious interior deterioration (e.g., walls/ceilings/door/trim deterioration, loose/missing/cracked floors, obvious need of extensive repair of water damage due to heating/cooling/plumbing issues, interior damage due to a roof leak). Half of the units (50%) had one or more signs of obvious exterior deterioration (e.g., exterior windows or doors that were broken/boarded-up/missing, damaged/missing roof/gutters/downspouts, damaged chimneys, broken/missing porches/steps, foundation damage).

3.2. Pre- and immediate post-intervention results

Pre-intervention and immediate post-intervention composite dust lead loadings for the 52 units in the immediate post-intervention analysis dataset are summarized in Fig. 1 and Table 1. Study units experienced significant percent reductions in dust lead loadings on all surfaces immediately after treatment (Table 1) (each $p<0.001$).

Fifteen units had both composite and single surface dust sampling conducted at immediate post-intervention. For these units, the median difference between composite dust lead loading and the (dwelling average) single surface dust lead loadings for uncarpeted floors, window sills, or window troughs was not significantly different from zero even though single and composite samples may not have been collected in the same rooms ($p = 0.587$, $p = 0.208$ and $p = 0.107$, respectively).

Fifty-three percent, 20%, and 47% of the units had at least one single surface sample that exceeded 1995 HUD/EPA floor, window sill and window trough clearance guidance of 100, 500 and 800 μg/ft^2, respectively, at the immediate post-intervention sampling (Table 2). Overall, 73% of units had one or more immediate post-intervention single surface samples that exceeded these clearance guidance values.

Although each unit passed the independent visual inspection prescribed by EA 6-8, the study risk assessor team's immediate post-intervention visual assessments found one or more incomplete lead hazard reduction treatments in 88% of units (Table 3). The mean number of incomplete treatments per unit was 2.1 (95% CI = 1.8, 2.4). The three most common incomplete treatments reported during the visual assessment were (1) not all paint intact, with some chipping, flaking and peeling paint remaining; (2) one or more painted doors continuing to rub and/or bind; and (3) visible paint chips and/or debris remaining (Table 4).

The magnitude of these incomplete treatments varied over a wide range (Fig. 2). There were 60 reports of non-intact paint found in 29 dwellings, yielding a per-report geometric mean of 0.2 ft^2 and a dwelling unit geometric mean of 0.5 ft^2. Incomplete removal of visible chips and debris was reported 26 times in 17 dwellings, yielding a

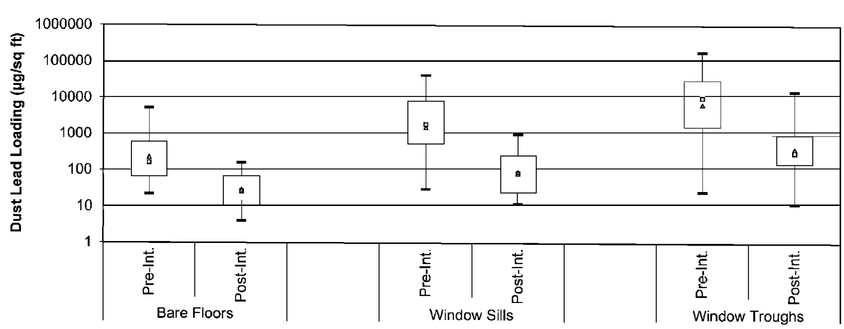

Fig. 1. Pre- and immediate post-intervention composite dust lead loadings by surface type: Legend: bottom whisker = 5th percentile; top whisker = 95th percentile; box = 25th and 75th percentiles; square = median; triangle = geometric mean.

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Table 1
Median composite dust lead loadings (μg/ft²) and median reductions in composite dust lead loadings from pre- to immediate post-intervention and from pre- to one-year post-intervention

Surface	Number of units	Median pre-intervention (μg/ft²)	Median immediate post-intervention (μg/ft²)	Median one-year post-intervention (μg/ft²)	Median within-dwelling reduction (μg/ft²)		Median percent reduction (%)	
					From pre- to immed. post	From pre- to one-year post	From pre- to immed. post	From pre- to one-year post
Immediate post-intervention dataset[a]								
Uncarpeted floor	49	160	26	NA	147 ($p<0.001$)	NA	85 ($p<0.001$)	NA
Window Sill	52	1854	83	NA	1686 ($p<0.001$)	NA	94 ($p<0.001$)	NA
Window trough	52	10178	310	NA	9708 ($p<0.001$)	NA	95 ($p<0.001$)	NA
One-year post-intervention dataset[b]								
Uncarpeted floor	33	110	21	20	NA	87 ($p<0.001$)	NA	84 ($p<0.001$)
Window sill	34	1644	75	430	NA	683 ($p = 0.002$)	NA	84 ($p = 0.204$)
Window trough	33	8320	281	1074	NA	($p = 0.009$)	NA	89 (p = 0.212)

NA = Not applicable. The immediate post-intervention dataset was used to examine differences only from pre- to immediate post-intervention, while the one-year post-intervention dataset was used to examine differences only from pre- to one-year post-intervention.

[a]The immediate post-intervention dataset consisted of those dwellings that had completed (1) pre-intervention dust lead sampling, (2) prescribed lead hazards reduction interventions, (3) immediate post-intervention visual assessment, and (4) immediate post-intervention dust lead sampling.

[b]The one-year post-intervention dataset consisted of those dwellings that met the four requirements of the immediate post-intervention dataset, plus they completed one-year post-intervention dust lead sampling and a one-year post-intervention visual assessment.

Table 2
Percentage of units with one or more immediate post-intervention single surface sample results above clearance guidance values

Surface type ($n = 15$)	Clearance guidance values[a] (μg/ft²)	Percent of units with at least 1 sample at or above guidance/standard
Floor	100	53
	200	33
Window sill	500	20
Window trough	800	47
Any surface	100,500,800	73
Any surface	200,500,800	60

[a]Guidance values of 100, 500, and 800 μg/ft² for floors, window sills, and window troughs, respectively, are levels that were recommended in 1995 for clearance testing after lead abatement or interim control activities (EPA, 1995). The standard of 200 μg/ft² for floors is a 1995 Maryland clearance standard (Maryland Register, 1995). EA 6-8 does not require clearance dust sampling in connection with the prescribed treatments.

per-report geometric mean of 6.8 ft² and a dwelling unit geometric mean of 6.4 ft². (The depth and lead concentration of chips/debris were not measured.) Doors continuing to rub were reported 33 times in 23 dwellings. In 74% of the units only 1 door rubbed, in 22% of the units 2-3 doors rubbed and in 4% of the units 4-5 doors rubbed.

Table 3
Number of incomplete treatments per unit at immediate post-intervention and one-year post-intervention

Number of incomplete lead hazard reduction treatments per unit	Immediate post-intervention	One-year post-intervention
	$n = 52$ ♯ units (% units)	$n = 34$ ♯ units (% units)
0	6 (12%)	0 (0%)
1	7 (13%)	8 (24%)
2	20 (38%)	11 (32%)
3	16 (31%)	10 (29%)
4	2 (4%)	3 (9%)
5	1 (2%)	2 (6%)
Total units with 1–5 incomplete treatments per unit	46 (88%)	34 (100%)

Of the six units for which the study team reported no incomplete treatments at immediate post-intervention, only one had immediate post-intervention single surface data available. The immediate post-intervention window sill and window trough dust lead loadings (195 and 792 μg/ft², respectively) were below 1995 EPA/HUD clearance guidance values of 500 and 800 μg/ft², respectively. However,

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Table 4
Number (percent) of units having incomplete lead hazard reduction treatments reported during immediate post-intervention and one-year post-intervention visual assessments

Type of incomplete treatment	Immediate post-intervention ($n = 52$)	One-year post-intervention ($n = 34$)
Not all paint intact (chipping, peeling or flaking paint remains)		
Number	39	32
Percent (95% CI)	75% (63%, 87%)	94% (86%, 100%)
Visible structural defect that could cause paint deterioration remains		
Number	1	1
Percent (95% CI)	2% (NA)	3% (NA)
If sills stripped/repainted or replaced, not all treatments in place		
Number	2	1
Percent (95% CI)	4% (0%, 38%)	3% (NA)
If sills encapsulated with vinyl, metal, etc., not all material is properly attached		
Number	0	0
Percent (95% CI)	0% (NA)	0% (NA)
If troughs capped with vinyl, metal, etc., not all material is properly attached		
Number	14	5
Percent (95% CI)	27% (14%, 40%)	15% (0%, 32%)
For windows, not all top sashes are fixed in place		
Number	0	0
Percent (95% CI)	0% (NA)	0% (NA)
For doors, painted surfaces continue to rub together		
Number	23	16
Percent (95% CI)	44% (30%, 59%)	47% (29%, 65%)
Some bare floors are not smooth and cleanable		
Number	2	5
Percent (95% CI)	4% (0%, 38%)	15% (0%, 32%)
Not all kitchen and bathroom floors are overlaid with smooth, water-resistant coverings		
Number	4	10
Percent (95% CI)	8% (0%, 19%)	29% (12%, 47%)
Visible paint chips or debris remains		
Number	23	12
Percent (95% CI)	44% (30%, 59%)	35% (17%, 53%)

the immediate post-intervention floor dust lead loading in this unit was 117 μg/ft^2, above the 1995 EPA/HUD clearance guidance value of 100 μg/ft^2 for floors.

3.3. One-year post-intervention results

One-year post-intervention visits were conducted an average of 55 weeks after the immediate post-intervention sampling visit, with a minimum of 48 weeks and a maximum of 74 weeks between the two visits. During the one-year post-intervention period, additional lead hazard reduction work was reportedly done in one of the units included in this paper, with the work done at a tenancy change, as prescribed by EA 6–8.

Pre-intervention and one-year post-intervention composite dust lead loadings for the 34 units in the one-year post-intervention analysis dataset are summarized in Table 1 and Fig. 3. Percent reductions from pre- to one-year post-intervention were significant for floors ($p < 0.001$) but not for sills or troughs ($p = 0.204$ and $p = 0.212$, respectively).

At one-year post-intervention, there were one or more incomplete lead hazard reduction treatments in all 34 units (Table 3). The mean number of incomplete treatments per unit was 2.4 (95% CI = 2.0, 2.8). The three most common incomplete treatments reported during the one-year post-intervention visual assessment were the same as those at immediate post-intervention: (1) not all paint intact, with some chipping, flaking and peeling paint remaining; (2) one or more painted doors that rub together and/or bind; and (3) visible paint chips and/or debris (Table 4). "Not all kitchen and bathroom floors are overlaid with smooth, water-resistant coverings" was also nearly as prevalent.

The magnitude of these one-year post-intervention incomplete treatments varied over a wide range (Fig. 4). There were 57 reports of non-intact paint found in 21 dwellings, yielding a per-report geometric mean of 0.2 ft^2 and a dwelling unit geometric mean of 0.7 ft^2. Painted door surfaces rubbing was reported 19 times in 16 dwellings. In all 16 dwellings, one door was reported to rub. Incomplete removal of visible chips and debris was reported 23 times in seven dwellings, yielding a per-report geometric mean of 0.4 ft^2 and a dwelling unit geometric mean of 0.7 ft^2. The depth and lead concentration of chips/debris were not measured.

4. Discussion

Study results suggest that the independent visual inspection alone was not able to accurately identify homes that had dust lead loadings exceeding clearance values. In another study in which both clearance testing and visual assessments were required (Galke et al., 2001), initial clearance exceedances were found in units that passed visual assessment. Of the 393 Baltimore City housing units that underwent lead hazard control activities as part of the Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program, 31% of units had one or more samples

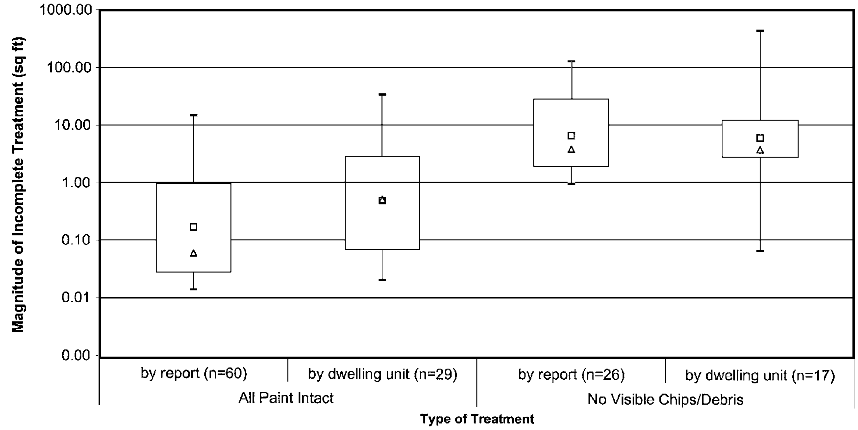

Fig. 2. Magnitude of two most commonly reported incomplete treatments at immediate post-intervention by report and by dwelling unit: Legend: bottom whisker = 5th percentile; top whisker = 95th percentile; box = 25th and 75th percentiles; square = median; triangle = geometric mean.

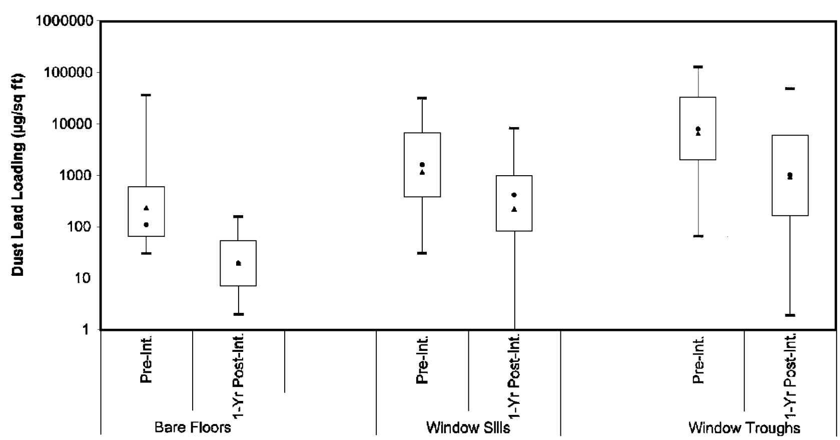

Fig. 3. Pre- and one-year post-intervention composite dust lead loading results by surface type: Legend: bottom whisker = 5th percentile; top whisker = 95th percentile; box = 25th and 75th percentiles; square = median; triangle = geometric mean.

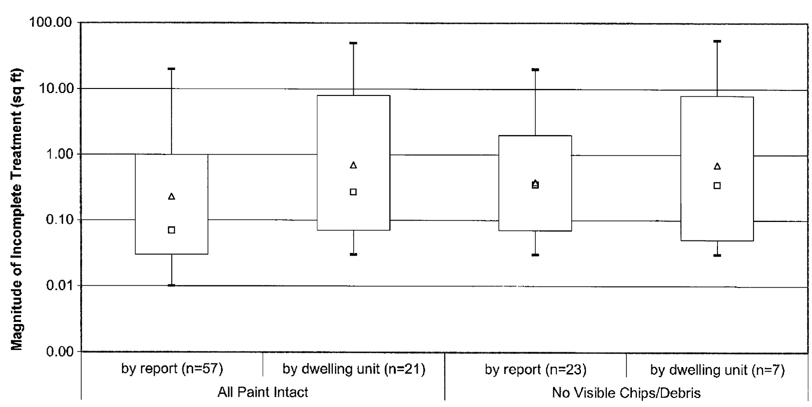

Fig. 4. Magnitude of two most commonly reported incomplete treatments at one-year post-intervention by report and by dwelling unit: Legend: bottom whisker = 5th percentile; top whisker = 95th percentile; box = 25th and 75th percentiles; square = median; triangle = geometric mean.

that exceeded the same clearance thresholds (National Center for Healthy Housing and University of Cincinnati Department of Environmental Health (NCHH and UC), 2004).

Since the study was implemented, HUD promulgated a new lead-based paint regulation governing virtually all pre-1978 housing receiving federal assistance as well as federally owned housing. The regulation includes new clearance standards applicable to such housing: 40 μg/ft^2 for floors, 250 μg/ft^2 for window sills, and 400 μg/ft^2 for window troughs. Seventy-three percent of study units had at least one floor sample result at or exceeding 40 μg/ft^2, 27% had at least one sill sample result at or exceeding 250 μg/ft^2, and 67% had at least one trough sample result at or exceeding 400 μg/ft^2. Lead hazard control contractors that worked on the study dwellings had experience cleaning to the 1995 standards. Results may have differed had the contractors been used to working under the 2001 regulations.

Recently, EPA has proposed a regulation that would cover many types of housing repairs and renovation that disturb paint. In the proposal, EPA has proposed to remove the requirement to conduct dust lead testing as part of clearance and to substitute a form of visual assessment known as the "white glove test." This test, which is a qualitative method to assess the cleanliness of a given surface, does not measure dust lead loading nor does it assess small particles not visible to the naked eye. Such small particles are known to be absorbed readily into the body and are therefore important to assess from a public health standpoint. The results of this study suggest that dust lead testing is an important part of the process to determine whether a given housing unit is safe for children.

Because EA 6–8 does not specify "de minimis" levels for incomplete treatments, in some instances the magnitude of reported incomplete treatments was small. For example, the federal Lead-Safe Housing Rule (24 CFR Part 35, subparts B-R; HUD, 1999) specifies that, although non-intact lead-based paint less than 2 ft^2 in any room is a hazard and must be treated, lead-safe work practices and clearance dust sampling are not required (although HUD recommends their use). The per-report geometric mean of 0.2 ft^2 of non-intact paint at immediate post-intervention is less than this federal "de minimis" amount. However, other types of incomplete treatments were relatively large and easily observed (e.g., a per-report geometric mean of 6.8 ft^2 of visible chips and debris at immediate post-intervention), indicating that the independent visual inspectors missed many treatment deficiencies. Such large omissions would clearly place children at risk. At one-year post-intervention, although several surfaces were in need of additional treatment, these deficiencies generally did not yield high one-year post-intervention dust lead loadings on the surfaces tested.

This study was initiated soon after the Maryland lead law first went into effect, during the early stages of the state's enforcement of the statutory requirements. Because only five or six independent inspectors conducted visual inspections for the group of enrolled units, the findings do not necessarily reflect on the performance of other Maryland-certified visual inspectors. The results indicate that some of these inspectors missed important items. Because two people were on the study team of risk assessors (instead of just one inspector), and because this team was specifically looking for items missed by the first inspector, they may have been more likely to identify small incomplete treatments.

No control group (i.e., a group of dwellings receiving no treatments) was established for this study, because all pre-1950 rental properties were covered by EA 6–8. Without a control group, the observed reductions in dust lead loadings cannot be solely attributed to EA 6–8's prescribed treatments. However, there is no reason to presume that these types of vacant, deteriorated dwellings would have received the same level of treatment in the absence of the law and in the absence of the federal funds that were used to pay for the treatments performed during this study. It is also unknown whether the level of work carried out in these dwellings would have been the same if the treatments had been privately funded.

5. Conclusions

Dust lead loadings declined significantly immediately after EA 6–8 prescribed lead hazard reduction treatments were implemented in the study units. One-year loadings remained below pre-intervention for floors but not for window sills or troughs.

However, many units had one or more immediate post-intervention dust lead loadings that would have exceeded 1995 Maryland clearance standards and 1995 EPA/HUD clearance guidance values, had such tests been required, suggesting that children living in such units would be at risk. In addition, the prescribed independent visual inspections conducted in these units immediately following treatment did not identify many incomplete treatments. Although many units had incomplete treatments and one or more immediate post-intervention dust lead loadings that would have exceeded clearance standards/guidance, and at least one unit with complete treatments exceeded the EPA/HUD clearance guidance, the reductions in dust lead loadings suggest that the statute's prescribed treatments helped reduce some, but not all, lead exposure risks.

EPA currently requires that pre-1978 federally assisted housing that has had lead-based paint or lead-based paint hazard abatement pass both visual inspection and dust sampling for clearance (EPA, 1996a). However, EA 6–8 applies to all non-federally assisted pre-1950 housing in Maryland. The results in this article do not support the omission of dust sampling.

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