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Project Summary

Field Demonstration of Lead Paint Abatement Technologies in Residential Housing

A study was conducted to demonstrate lead-based paint (LBP) removal from architectural wood components in unoccupied residential housing using four technologies: granulated carbon dioxide (CO_2) blasting, pelletized CO_2 blasting, encapsulant paint remover, and wet abrasive blasting with an engineered abrasive. The three former technologies were demonstrated on interior components, the latter on exterior components. An X-ray fluorescence (XRF) spectrum analyzer (K-shell) was used to quantify the change in lead levels on the substrate before and after paint removal. Inductively-coupled plasma atomic emission spectroscopy (ICP-AES) was used to quantify the change in lead levels of airborne particulate and settled dust wipe samples before and after paint removal. Aerodynamic particle size distributions of lead particulate were measured using a multistage personal cascade impactor.

The paint removal effectiveness of the encapsulant paint remover and wet abrasive blasting technologies were comparable with overall residual lead levels below the U.S. Housing and Urban Development (HUD) Guideline (1 mg/cm²); both technologies removed the paint to bare substrate with no apparent damage (minimal sanding prior to painting) to the underlying substrate. The estimated paint removal rate and abatement cost were 10.3 and 134 ft²/hour and $1.90 and $2.24/ft², respectively. The CO_2 technologies yielded residual paint levels of >5 mg/cm² and rendered the substrate nonuseable for its intended purpose. Although the airborne particulate and settled dust levels varied with LBP abatement technology, the encapsulant paint remover technology consistently showed the lowest levels.

This Project Summary was developed by EPA's National Risk Management Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Lead-Based Paint Poisoning Prevention Act of 1971, as amended by the Housing and Community Development Act of 1987, established 1.0 milligram of lead per square centimeter of surface area (mg/cm²) as the federal threshold requiring abatement of LBP on architectural components in public and Indian housing developments nationwide. The Residential Lead-Based Paint Hazard Reduction Act of 1992 (commonly referred to as "Title X") mandated the evaluation and reduction of LBP hazards in the nation's existing housing. Title X also established 0.5% lead by weight as an alternative to the 1.0 mg/cm² threshold.

Objectives

The overall objective of this study was to demonstrate LBP removal from architectural wood components in unoccupied residential housing using four technologies: (1) granulated carbon dioxide blasting, (2) pelletized carbon dioxide blasting, (3) encapsulant remover paint system, and (4) wet abrasive blasting with an "engineered abrasive."

Study Design

The study was conducted in unoccupied single-family and two-family residential housing units in the City of Buffalo, NY. Although the housing units were not randomly selected, they did include different housing components (e.g., baseboards, door and window moldings), paint thicknesses, and lead levels. Each technology was evaluated two or three times during a one-week period (depending on the logistical and technical problems experienced).

Technologies Evaluated

Granulated and Pelletized CO_2 Blasting—The granulated and pelletized CO_2 blasting technologies are manufactured by Alpheus Cleaning Technologies Corporation and by Cold-Jet Incorporated, respectively. Although the technologies are similar in principle, primary differences between them are the size, density, and application feed rate of the carbon dioxide blasting media. One other primary difference is that the Alpheus technology uses block dry ice, which is shaved to create a fine, crystalline blasting medium, whereas the Cold-Jet technology uses uniform pellets.

The mechanism responsible for removal of the paint coating is a combination of several operations. First is the mechanical abrasion caused by the movement of one solid material against another. The second is spalling of the material surface that is caused by the rapid expansion of the CO_2 during sublimation. The third is thermal fracturing where the significant thermal differential between the substrate and surface material causes these materials to expand and contract at different rates, resulting in fracturing of the coating.

Encapsulant Paint Remover Technology—The encapsulant paint remover is manufactured by Kwick Kleen Industrial Solvents, Inc. The spray-applied encapsulant paint remover is a two-part liquid system consisting of potassium hydroxide (13.2% by wt. in water) and a proprietary polymer (9% by wt. in water).

The solutions are sprayed with an applicator gun that employs an external mixing technique. The applicator gun facilitates a flat spray pattern for uniform coverage of the surface. The dwell or residence time of the solution is dependent upon the number of layers of paint, temperature, and other environmental conditions. In the present study, the dwell time was approximately 2 hours for the first application of the encapsulant paint remover, and 1 hour for each additional application. After the paint is absorbed into the remover matrix, the paint remover material is removed from the surface with a putty knife. The encapsulant paint remover is reapplied if visible paint remains on the surface. Following removal of the paint remover waste, a vacuum device equipped with a low-pressure/low-volume sprayer is used to rinse the surface with a trisodium phosphate solution. The surface is then sprayed with a "weak" acidic solution to neutralize wood substrate.

Wet Abrasive Blasting with Chemical Stabilizer Technology—This technology, Turbo® Wet Abrasive Blasting System, is manufactured by Keizer Technologies Americas, Inc. The system uses conventional blasting abrasives mixed with water (80% abrasive to 20% water) in a pressure vessel. The system combines an abrasive medium and water to create a slurry-mixture that is fed to a blast nozzle much like a conventional blasting system. In concept it both reduces the heat generated by friction and is a cohesive bond for the dust created by the blasting process. The paint coating is removed by the kinetic energy/mechanical abrasion of the blast media striking the surface.

A chemical stabilizer, Blastox®, is added at a 15 to 25% mixture to the abrasive/water media prior to blasting of the surface to create an "engineered abrasive." Blastox®, manufactured by TDJ Group, Inc., is a di- and tri-calcium silicate-based material similar in chemical composition to Type I cement. This calcium-silicate-based material and lead in the paint waste react to chemically stabilize the leachable lead as lead silicate with stabilization mechanisms similar to those of Portland cement. Chemical substitution reactions and physical encapsulation of the waste are the two stabilization mechanisms that reportedly render the lead nonleachable based on EPA's Toxicity Characteristic Leaching Procedure (TCLP).

Selection of Housing Units

A lead-based paint prescreening survey was conducted among a pool of residential housing units in Buffalo, NY. The housing units selected for this study met the following criteria:

1. Each housing unit had a minimum lead-in-paint level of 2.0 mg/cm² (arithmetic average of greater than 6.0 mg/cm²) on all components targeted for paint removal. This level exceeds the upper limit (1.3 mg/cm²) of the inconclusive range for the XRF instrument used during this study.
2. Housing units for selected interior lead paint removals had similar properties including: chronological age; architectural structure; average levels of lead in paint; and amounts (i.e., square feet) and types of building components targeted for paint removal.

Sampling and Analytical Methods

Thickness of Dry Paint Film

The measurement of dry film thickness of the paint was made in accordance with ASTM Method D 4138 - 88.

Lead in Paint Film

A SCITEC Corporation MAP-3 X-ray fluorescence (XRF) spectrum analyzer was used to determine the mass of lead per unit area of painted substrate reported as milligrams of lead per square centimeter of surface (mg/cm²). The typical linear operational range for the MAP-3 XRF is 0.2 to 10 mg lead/cm² for the K-shell x-ray.[1] The K-shell (or high-energy X-ray emission) was used for the measurements because it allows measurement of lead in the deeper layers of multilayered paint.[1] An evaluation of MAP-3 instruments, using a 15-second nominal reading time, showed that the K-shell measured lead levels with low bias on wood substrates, provided that substrate correction was used.[2] The XRF measurements were made using a single nominal reading time of 15 seconds. The inconclusive range of the MAP-3 XRF instrument is ≤0.9 to ≥1.3 mg/cm² (wood substrates).

The MAP-3 XRF instrument was calibrated and a fresh radioactive source (40 mCi Co^{57}) was installed within 1 month prior to use of the instrument. The manufacturer calibrated the instrument using standard reference natural paint films (SRM 2579) developed by NIST. Five concentration ranges were used 0.0001 to 3.53 mg lead/cm². Because most of the lead concentrations measured in the paint film before paint removal exceed the maximum calibration standard, the corresponding XRF measurements should be interpreted as approximate or minimum values.

Lead in Settled Dust

Wet wipe samples for settled lead-contaminated dust were collected in accordance with the sampling procedures specified in the HUD Guidelines[3]. The samples were prepared for analysis in accordance with EPA SW-846 Method 3050 and analyzed by ICP-AES in accordance with EPA SW-846 Method 6010.

Lead in Airborne Particulate

Personal Breathing Zone Samples—Personal breathing zone and work area air samples were collected during each technology demonstration. The samples were collected and prepared for analysis by ICP-AES in accordance with NIOSH Method 7300.

Lead Particulate Aerodynamic Particle Size Distribution—An 8-stage Marple Personal Cascade Impactor (Model 298) was used to determine the aerodynamic particle size distribution of the lead particulate generated during each technology demonstration. The samples were collected and prepared for analysis by ICP-

AES in accordance with NIOSH Method 7300.

Lead in Paint Chips

The paint chip samples were collected from the substrate before paint removal in accordance with the sampling procedures specified in the HUD Guidelines.[3] The samples were prepared for analysis in accordance with EPA SW-846 Method 3050 and analyzed by ICP-AES in accordance with EPA SW-846 Method 6010.

Lead in Soil

The samples were collected from the perimeter of the housing units both before and after the wet abrasive blasting technology in accordance with the sampling procedures specified in the HUD Guidelines[3]. The samples were prepared for analysis in accordance with EPA SW-846 Method 3050 and analyzed by ICP-AES in accordance with EPA SW-846 Method 6010.

Wet Abrasive Blasting Debris

Single samples of the wet abrasive blasting debris from the exterior lead abatement demonstration were collected to determine the leachable lead based on TCLP. The samples were extracted in accordance with EPA SW-846 Method 1311 and digested in accordance with EPA SW-846 Method 3015. The samples were then analyzed in accordance with EPA SW-846 Method 6010.

Statistical Methods

XRF Measurements and Lead in Settled Dust, Air, and Soil

The relative change in lead concentration on the sampled building components was measured by the ratio of the lead concentration before paint removal to the concentration after paint removal. This ratio was calculated for each pair of before and after measurements. These ratios were then compared by taking the natural logarithm and comparing the averages by standard analysis of variance (ANOVA) techniques.

XRF lead concentrations before and after paint removal were compared by using a 2-factor ANOVA with Site and Room, nested within Site, as the experimental factors. The relative decrease in lead concentration was tested by calculating a 95% confidence interval for the mean lead concentration before paint removal as a proportion of the lead concentration after removal.

Lead concentrations in settled dust before and after paint removal were compared by using a 3-factor ANOVA with Site, Room nested within Site, and Location (floor, wall) as the experimental factors. The relative increase in surface lead concentration was tested by calculating a 95% confidence interval for the mean lead concentration after paint removal as a proportion of the lead concentration before removal.

Airborne lead concentrations before and during paint removal were compared by using a 1-factor ANOVA with Site as the experimental factor. The relative increase in airborne lead concentration was tested by calculating a 95% confidence interval for the mean lead concentration during paint removal as a proportion of the airborne lead concentration before removal.

Lead concentrations in the soil before and after paint removal were compared by using a one-factor ANOVA with Site as the experimental factor. The relative increase in lead concentration was tested by calculating a 95% confidence interval for the mean lead concentration after paint removal as a proportion of the lead concentration before removal.

Results and Discussions

Encapsulant Paint Remover Technology

Effectiveness of Paint Removal (XRF Measurements)—Table1 presents descriptive statistics for the XRF measurements collected before and after paint removal at each site. The encapsulant paint remover system effectively removed the paint to bare substrate with no apparent damage, yielding a substrate that required little preparation before painting. The average paint removal rate was 10.3 ft^2/hr (range 8 to 13 ft^2/hr).

The ANOVA results show that the magnitude of the decrease in lead concentration on the sampled components varied significantly by site ($p=0.0122$). Sites 4 and 5 showed similar decreases, whereas the decrease at Site 3 was approximately 2 times higher than at Sites 4 and 5. This is due primarily to the higher concentrations of lead before paint removal at Site 3. Residual levels of lead contamination after removal were essentially the same at all three sites. The ANOVA results further showed that the variation between the rooms within each site was not statistically significant ($p=0.4496$).

8-hr TWA Exposure Concentrations—The 8-hr TWA exposure concentrations of lead measured on the technology operator and helper ranged from 0.16 to 4.1 µg/m^3. None of the calculated 8- hr TWA concentrations exceeded the OSHA Action Level of 30 µg/m^3.

Wet Abrasive Blasting Technology

Effectiveness of Paint Removal (XRF Measurements)—Table 2 presents descriptive statistics for the XRF measurements collected before and after paint removal at each site. The wet abrasive blasting paint remover technology effectively removed the paint to bare substrate with no apparent damage to the underlying substrate. Thus, a substrate was produced that required little preparation before painting (i.e., light sanding prior to painting. The average paint removal rate was 134 ft^2/hr (range 133 to 135 ft^2hr).

The ANOVA results show that the magnitude of the decrease in lead concentra-

Table 1. XRF Measurements (K-Shell) Collected Before and After Paint Removal Using Encapsulant Paint Remover

Site	Lead Concentration (mg/cm²)			
No.	N	Mean	Minimum	Maximum
Before Paint Removal				
3	64	14.7	7.2	26.9
4	64	9.6	4.2	16.6
5	32	9.2	6.1	18.9
Overall	160	11.3	4.2	26.9
After Paint Removal				
3	64	0.7	ND[a]	4.2
4	64	1.1	ND	9.5
5	32	0.8	ND	6.7
Overall	160	0.8	ND	9.5

[a] Denotes that the XRF reading was ≤ 0 after substrate correction.

Table 2. XRF Measurements Collected Before and After Paint Removal Using Wet Abrasive Blasting Technology

Site No.	N	Lead Concentration (mg/cm²) Mean	Minimum	Maximum
Before Paint Removal				
8	64	20.4	0.7	43.0
9	64	8.2	2.5	20.7
Overall	128	14.3	0.7	43.0
After Paint Removal				
8	64	0.8	ND[a]	3.0
9	64	1.0	ND	2.5
Overall	128	0.93	ND	3.0

[a] Denotes that the XRF reading was ≤ 0 after substrate correction.

tion on the wood siding varied significantly by site ($p=0.0062$). Specifically, the decrease in lead concentration after paint removal at Site 8 was approximately 3 times greater than at Site 9. This is due primarily to the higher lead concentrations before removal at Site 8. Residual levels of lead contamination after removal were essentially the same at both sites. The ANOVA results further showed that the variability between areas within each site was statistically significant ($p=0.0561$).

Figure 1 shows the differential particle size distribution based on the lead particulate aerodynamic measurement using the multistage cascade impactor. This graph provides the lead particle mass concentration ΔC_i) in each particle-size band versus the geometric mean diameter (GMD_i), where $GMD_i = \sqrt{D_i \times D_{i-1}}$. The lead particulate generated by the wet abrasive blasting paint removal technology covers a wide-size spectrum, where the larger particles account for the greatest mass of lead. The corresponding cumulative particle size distribution was determined by preparing a log-probability plot of the particle size cut-point (D_p) versus the cumulative percent of mass (mg/m³) less than the D_p. The distribution of sample weights appeared to approximate a lognormal distribution with a mass median diameter (MMD) of 15 µm. That is, 50% of the particle mass is borne by particles larger than 50 µm. The calculated geometric standard deviation (GSD) was 6.3.

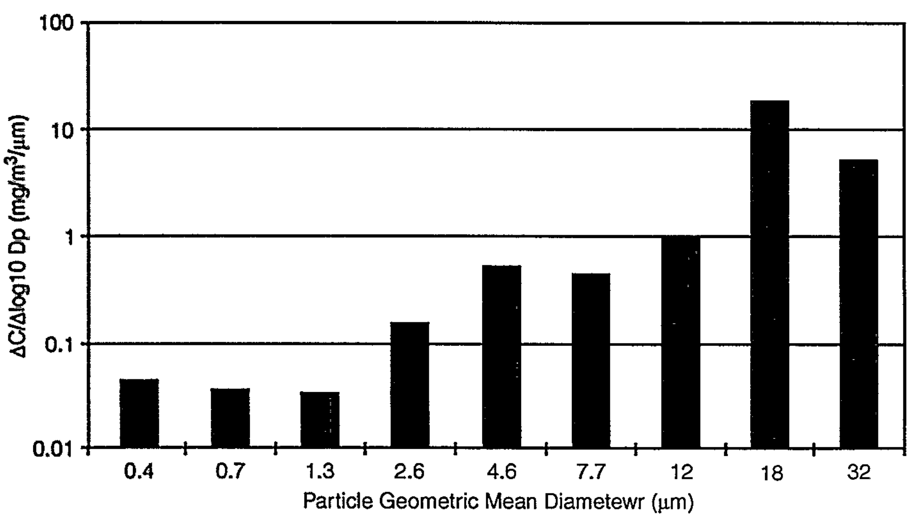

Figure 1. Differential particle size distribution for lead particulate generated during wet abrasive blasting.

The 8-hr TWA exposure concentrations of lead measured on the technology operator and helper ranged from 171 to 198 µg/m³. All of the calculated 8-hr TWA exposure concentrations exceed both the OSHA Action Level of 30 µg/m³ and Permissible Exposure Limit of 50 µg/m³, 8-hr TWA.

TCLP Analyses of Blastox® Debris—The samples of the Blastox® debris collected at Site 8 showed that the maximum concentration of lead (range 0.1 to 4.7 mg/L) for the Toxicity Characteristic by TCLP did not exceed the regulatory limit of 5.0 mg/L (40 CFR 261). The samples collected at Site 9 showed lead concentrations (26 to 33 mg/L) above 5.0 mg/L. The results at Site 9 are inconsistent with previous TCLP analysis of Blastox® debris from paint removal.[4]

Granulated and Pelletized CO_2 Blasting Technologies

Effectiveness of Paint Removal—Both the granulated and pelletized CO_2 blasting technologies sporadically removed the paint to base substrate, but they also caused significant abrasion of the wood substrate. That is, the underlying substrate was textured and gouged. This condition would render the abated substrate nonreusable as an architectural building component.

Cost Analysis

A cost analysis was performed based on the field data from the actual test demonstrations. Table 3 summarizes the total costs for application of these four technologies. The actual costs in terms of square feet was calculated by dividing the costs per site hour by the paint removal rate (i.e., the rate of paint removal in square feet abated per hour).

Conclusions

The following are the principal conclusions reached during this study.

- The encapsulant paint remover technology effectively removed lead-based paint from interior architectural wood components to bare substrate with no apparent damage, yielding a substrate that required little preparation prior to painting.
- The granulated and pelletized carbon dioxide blasting technologies were not effective in removal of the lead-based paint from interior architectural wood components without severe damage (abraded/gouged) to the underlying substrate.
- The wet abrasive blasting technology with an abrasive mixed with Blastox® (a di- and tri-calcium sili-

Table 3. Estimated Costs Based on Square Feet of Surface Abated

	Technology Type		
Cost Factor	Wet Abrasive Blasting with Chemical Stabilizer	Encapsulant Paint Remover	Granulated CO_2 Blasting
Equipment/Materials/ Waste Disposal	$160/site hour	$4.32/site hour[b]	$30/site hour
Labor	$140/site hour	$15/site hour	$30/site hour
Subtotal	$300/site hour	$19.32/site hour	$60/site hour
Strip Rate	134 ft²/hr[a]	10.3 ft²/hr[a,c]	140 ft²/hr[a,d]
Removal Cost	$2.24/ft²	$1.88/ft²	$0.43/ft²

[a] Based on total ft² stripped and total time observed.
[b] Based on chemical cost of $0.72/ft² painted surface abated; 2 applications of paint stripper.
[c] Does not include the dwell time for the chemical to react with the paint. The average dwell time was 2 hr per application.
[d] The strip rate was based on the total ft² tested/total time of test.

cate based material) effectively removed lead-based paint from exterior architectural wood components to bare substrate with no apparent damage, yielding a substrate that required little preparation prior to painting.

- The smallest increase in work area contamination of settled lead dust and airborne lead dust above baseline levels resulted from the encapsulant paint removal technology.
- The encapsulant paint remover technology did not result in personal exposures to airborne lead particulate above the OSHA Action Level (30 µg/m³). The airborne lead particulate exposures generated during granulated carbon dioxide blasting, pelletized carbon dioxide blasting, and wet abrasive blasting technologies exceeded the OSHA Action Level (12-, 13-, and 7-times, respectively) as well as the Permissible Exposure Limit (50 µg/m³).

Recommendations

- The encapsulant paint remover technology can remove lead-based paint from architectural wood components without damage (only requiring light sanding) to the underlying substrate, as well as requiring minimal worker protection and environmental containment. It is recommended that this technology be included in a future study to (1) further evaluate its efficacy on interior architectural components including more emphasis on decorative "historic" wood substrates, (2) confirm the adequacy of worker protection safeguards and environmental containments, and (3) obtain more definitive estimates of performance rates, hazardous waste generation, and overall usage costs of this technology.
- Both the granulated and pelletized carbon dioxide blasting technologies (as demonstrated in this study) do not appear to be viable technologies to remove lead-based paint from architectural wood components due to the resultant damage to the underlying substrate. However, these commercially available technologies offer outstanding environmental gains regarding hazardous waste minimization; i.e., these technologies do not generate secondary waste. Hence, it is recommended that these technologies be included in a future study to (1) evaluate their efficacy to remove lead-based paint from masonry surfaces of residential housing units, (2) determine the worker protection safeguards and environmental containment requirements, and (3) determine the performance rates and overall usage costs of these technologies.
- The wet abrasive blasting technology can remove lead-based paint from exterior architectural wood components without damage (only requiring light sanding) to the underlying substrate, as well as potentially offering outstanding environmental gains regarding hazardous waste minimization due to the addition of Blastox® to the abrasive blasting media. It is recommended that this technology be included in a future study to (1) evaluate its efficacy to remove lead-based paint from masonry surfaces of residential housing units, (2) further evaluate the worker protection safeguards and environmental containment requirements including an evaluation of lead particulate exposures during sanding of the abated substrate (e.g., wood), (3) further evaluate Blastox®-blasting debris as a hazardous waste based on the EPA TCLP, and (4) determine the performance rate and overall usage cost of this technology.

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The complete report, entitled "Field Demonstration of Lead Paint Abatement Technologies in Residential Housing," (Order No. PB98-172489; Cost: $36.00, subject to change) will be available only from:
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