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Evaluation of two lead-based paint removal and waste stabilization technology combinations on typical exterior surfaces

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Abstract

A study was conducted to demonstrate the effectiveness of a wet abrasive blasting technology to remove lead-based paint from exterior wood siding and brick substrates as well as to evaluate the effectiveness of two waste stabilization technologies to stabilize the resulting blast media (coal slag and mineral sand) paint debris thereby reducing the leachable lead content. The lead-based paint removal technology effectiveness was determined by the use of an X-ray fluorescence (XRF) spectrum analyzer (L- and K-shell). The effectiveness of the technologies to stabilize the debris was evaluated through the toxicity characteristic leaching procedure (TCLP). Wet abrasive blasting effectively removed the lead-based paint coating from both the wood and brick substrates to below the US Department of Housing and Urban Development Guideline (1 mg/cm²) with no minimal or no damage to the underlying substrates ($P < 0.0001$). The mean area air levels of lead-containing particulate generated during paint removal were significantly below the personal exposure limit (PEL) ($P < 0.0001$). However, the mean personal breathing zone lead levels were approximately three times higher than the PEL. Neither of the two stabilization technologies consistently stabilized the resultant paint debris to achieve a leachable lead content below the RCRA regulatory threshold of <5 mg/l. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Since 1994, the National Risk Management Research Laboratory (NRMRL) has evaluated a total of six lead-based paint abatement technologies for their removal efficiency as

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well as the relative costs to use each of them. During that time, EPA sponsored a program aimed at reducing lead-based paint emissions in the environment from demolition and renovation projects in commercial buildings. This research agenda was developed in reference to the Residential Lead-Based Paint Hazard Reduction Act of 1992 (commonly known as Title X) mandating the evaluation and reduction of lead-based paint hazards in the existing housing in the US.

NRMRL, in cooperation with the US Army Corps of Engineers, Construction Engineering Research Laboratory (CERL), initiated a lead paint abatement program to evaluate the most promising lead-based paint waste stabilization technologies that were nearly or commercially ready. This research project was conducted to further examine two wet abrasive blasting-based technologies that showed promise in an EPA funded study in 1996. One of the main goals of this study was to evaluate the technologies on larger exterior substrate surface areas to formulate more accurate conclusions on the efficacy of the technologies studied previously.

2. Technology descriptions

The two technologies evaluated in this study were both inorganic stabilizer processes that are capable of rendering the lead-based paint waste non-hazardous once it is removed from the substrate surface and reacts with the key ingredients of each system. Both technologies required the use of the Torbo wet abrasive blasting system to remove the paint from the substrate surface. The two inorganic-based stabilization technologies, as well as the wet abrasive blasting technology used in conjunction with them, are described below.

2.1. Torbo wet abrasive blasting system

The Torbo wet abrasive blasting system is manufactured by Keizer Technologies of America, Inc. in Euless, Texas. The system utilizes conventional blasting abrasives mixed with water (80% abrasive to 20% water) in a pressure vessel. The system combines the abrasive media and water to create a slurry-mixture that is fed to a blast nozzle much like a conventional blasting system. In theory, each particle of the abrasive is encased in a thin layer of water. It utilizes this coating to both reduce the heat generated by friction and form a cohesive bond for the dust created by the blasting process that reduces the particulate emissions. During this study, mineral slag was used to remove the paint from the brick and coal slag (black beauty) was used to remove the paint from the wood.

The blast media and water consumption are both adjustable during operation. The paint coating is removed by the kinetic energy and mechanical abrasion of the blast media striking the surface. Power water rinsing (60 psi for wood and 95 psi for brick substrates) was performed on the surface to ensure that all of the abrasive-mixture was removed after blasting was completed. The rinse option uses approximately 5 gal of water per minute. The water expended during the rinse cycle either evaporated or was absorbed by the abrasive to form a sludge.

2.2. Blastox

Blastox is manufactured by TDJ Group Inc. in Cary Illinois. Blastox is an abrasive additive comprised of di- and tri-calcium silicate-based material similar in composition to type 1 cement. It is typically added at a 20–25 wt.% ratio to non-recyclable blasting media such as mineral sand or coal slag when used for lead-based paint removal.

In a study conducted in 1996 [1], the US Army Corps of Engineers concluded in concordance with TDJ Group's vendor claims that Blastox stabilizes lead-containing paint blast media wastes (i.e. reduces the leachability of lead) by a series of simultaneous reactions that result in an encapsulated lead silicate compound, which is insoluble at all pH levels. The first reaction has a pH range of 8.0–11.5 where there is limited leachability for lead. The second reaction involves the chemical form of the lead being changed from a lead oxide, carbonate, or hydroxide, to a lead silicate, which is insoluble. The US EPA (Office of Pollution Prevention and Toxics) also conducted a study [2] and concluded that Blastox appears to stabilize the lead through an immobilization mechanism, rather than by chemical reaction of lead oxide, to form a lead silicate. The third and last reaction involves hydration where the waste is encapsulated into a cementitious material, which limits the gravitational flow of water through the waste.

2.3. PreTOX 2000 fast dry

PreTox 2000 fast dry (PreTox 2000) is manufactured by NexTex, Inc. in Dubuque, Iowa. PreTox 2000 is a cementitious paint-like mixture (i.e. treatment layer) designed to be applied to lead-based paint surfaces and allowed to cure and adhere to the paint coating. It is then removed in conjunction with the underlying lead-based paint coating using the abrasive blasting or other standard techniques. PreTox 2000 is composed of sodium and potassium silicates, sodium and potassium phosphate, and calcium silicate, iron and aluminum sulfates, and an alkali metal salt [3]. It also contains toluene, acetone, and VM&P naphtha as carrier solvents. Typically, PreTox 2000 is designed to be applied at a 10–60 mil (wet) thickness depending on substrate and paint condition. The average application in this study was 40 mil (wet) thickness in which the manufacturer's representative used an airless sprayer to apply the PreTox 2000 to the substrate surface.

According to the manufacturer, PreTox 2000 stabilizes the lead through two mechanisms. The first mechanism is chemical stabilization through pH adjustment, which stabilizes the lead by adjusting the pH range (8.0–11.5) where there is limited leachability for lead. The second mechanism is a chemical fixation that changes the soluble ionic form of lead to an insoluble metallic form.

3. Study site(s) descriptions

The two abatement technologies and the wet abrasive blasting technology were demonstrated on exterior wood and brick surfaces in Ravenna, Kentucky and Elgin, Illinois, respectively. The Ravenna, Ky site was a closed/abandoned dam lock station on the Kentucky river involving a total of six wooden buildings (see Fig. 1.) of similar structure and painting



Fig. 1. Ravenna, Kentucky study site.



Fig. 2. Elgin, Illinois study site.

histories. The Lock dam site was used with the permission and cooperation of the Army Corps of Engineers, Louisville district. The Elgin, IL site was the entire rear wall of the main building of the City Campus of the Elgin Community College (see Fig. 2). The Elgin, IL study site's substrate surface was comprised of brick and reportedly had a uniform construction and painting history.

4. Study results

There were four study objectives addressed in the evaluation of the two technology combinations (Torbo w/Blastox, Torbo w/PreTox) and their overall effectiveness in removing lead-based paint from exterior surfaces:

1. Removal of lead-based paint from exterior wood/brick substrates using Torbo wet abrasive blasting with PreTox 2000 and Blastox, respectively to a lead loading of $<1 \text{ mg/cm}^2$.
2. Evaluate the effectiveness of Blastox (abrasive lead-stabilizer additive) and PreTox 2000 (surface preparation coating) to stabilize the lead in paint abrasive media waste to below the RCRA regulatory threshold of 5 mg/l in leachate.
3. Evaluate the potential for each technology combination to generate airborne lead particulate above the OSHA permissible exposure limit (PEL of 50 ug/m^3 , 8 h time weighted average (TWA)).
4. Develop comparative estimates of the cost of paint removal and disposal using the two technology combinations.

The cost estimation results are discussed in detail in this study's EPA project report entitled, "Field Demonstration of Lead Paint Removal and Inorganic Stabilization Technologies". For the purposes of this study, an effective technology is defined as one that can render the substrate "free of lead-based paint" with a lead loading of $<1 \text{ mg/cm}^2$. In addition, the technology must remove the lead-based paint down to the bare wood or brick substrate with minimal or no damage to the underlying substrate. An XRF spectrum analyzer was used to determine the lead loading on the brick and wood surfaces before and after the lead-based paint was removed from the surfaces. Both by substrate and overall, the XRF results showed that both Torbo w/Blastox and Torbo w/PreTox 2000 reduced lead concentrations on wood and brick surfaces to a level significantly below 1 mg/cm^2 (Title X threshold limit). Table 1 presents the sample results observed from XRF measurements from wood and brick surfaces before and after paint removal from both technology combinations.

Representative samples of the abrasive media paint debris, comprised of spent abrasive, stabilization product, and paint chips/particles, were collected to determine whether the material generated from a technology combination was a RCRA (40 CFR Part 261) hazardous waste based on the toxicity characteristic leaching procedure (TCLP). By definition, if the leachable lead concentration is equal to or greater than 5 mg/l, the material is classified as a

Table 1
Lead (Pb) concentrations on wood and brick measured by XRF

Technology combination	Substrate	Lead concentration (mg/cm^2)				
		N^a	Mean	S.D.	Minimum	Maximum
Before removal						
Torbo	Wood	15	36.9	9.52	15.5	51.9
w/Blastox	Brick	15	5.59	1.78	1.5	9.7
Torbo	Wood	15	29.7	9.66	13.1	41.4
w/PreTox	Brick	15	8.18	3.71	3.9	15.2
After removal						
Torbo	Wood	75	0.24	0.22	0	1.1
w/Blastox	Brick	75	0.14	0.09	0	0.4
Torbo	Wood	75	0.16	0.16	0	0.7
w/PreTox	Brick	75	0.11	0.14	0	1.1

^a N : number of XRF readings taken on wood and brick surfaces.

Table 2
Average paint removal rates from wood and brick substrates

Technology combination	Substrate	Paint removal (ft ²)	Removal time (h)	Removal rate (ft ² /h)
Torbo w/Blastox	Wood	354.3	4.26	83.2
Torbo w/PreTox 2000		370.1	5.23	70.8
Site average rates		362.2	4.74	76.4
Torbo w/Blastox	Brick	646.3	5.45	118.6
Torbo w/PreTox 2000		609.3	5.02	121.4
Site average Rates		627.8	5.24	119.8

hazardous waste. The mean leachable lead concentration (mg/l) for the Torbo w/Blastox and Torbo w/PreTox 2000 paint debris from wood substrates was 21.3 and 14.8 mg/l, respectively. Thus, the abrasive paint debris from both technology combinations was determined to be a hazardous waste. The TCLP analysis of mineral sand paint debris from the brick substrate was determined to be a hazardous waste for both technology combinations as well. The mean leachable lead levels for the Torbo w/Blastox and Torbo w/PreTox 2000 brick paint debris was 7.8 and 8.1 mg/l, respectively. Subsequently, the remaining debris from both study sites was classified and disposed of as a hazardous waste accordingly.

The average paint removal rates for both technology combinations were determined on both wood and brick substrates as presented in Table 2. The removal rates represent the average of three replicates per technology demonstration per substrate. Higher removal rates were observed on the brick and this may be attributed to the Elgin site containing one continuous surface area. In addition, the Ravenna site removal rates may have been lower because there were several surface areas involved in the removal process and extra care was taken to not damage the softer wood substrate, both of which would require more time.

The technology combinations were evaluated for their potential to generate lead-containing particulate and to determine the appropriate environmental protection required when they are being used. Personal breathing zone samples were collected on the technology operator and helper during each technology demonstration at both study sites. Area air samples were also collected during each technology demonstration at both sites from various locations in/around the actual abatement area as indicated in Table 3. Mean area samples

Table 3
Personal and area air concentrations compared to OSHA PEL

Technology combination	Substrate	Sample type	N ^a	Mean 8 h TWA (ug/m ³)
Torbo w/Blastox	Wood	Personal	3	70.9
		Area	9	20.5
	Brick	Personal	6	68.4
		Area	18	21.2
Torbo w/PreTox 2000	Wood	Personal	3	55.1
		Area	18	26.9
	Brick	Personal	6	81.5
		Area	16	24.9

^a N: number of area and personal breathing zone samples collected.

collected during paint removal from both wood and brick were significantly lower than the 50 ug/m^3 8 h time weighted average (TWA) for lead. However, the mean personal breathing zone sample results were significantly higher than the 50 ug/m^3 8 h TWA.

5. Condition of abated surfaces

The physical appearance of the abated wood and brick substrates was assessed by visual examination to determine the extent of damage and degree of repair required prior to re-painting the surface. The wood surfaces were examined to determine whether the wood grain was lifted or feathered, the edges of the boards were rounded, or the surface was pitted or grooved, as well as the general evenness of the surface. The brick surfaces were examined to determine whether the surface was spalled and the extent that the mortar in the joints was dislodged.

5.1. Wood surfaces

Overall, there did not appear to be a noticeable difference in the appearance of the abated wood substrate between the two technology combinations. Both technology combinations effectively removed the paint coating to bare substrate with minimal damage to the underlying substrate. Less than 10% of the surfaces were slightly grooved or pitted and none of the surfaces displayed lifted or feathered woodgrain. Thus, the resulting substrate would require light sanding prior to painting.

5.2. Brick surfaces

There also did not appear to be a noticeable difference in the appearance of the abated brick substrate between the two technology combinations. Both technology combinations effectively removed the paint coating to bare substrate with no apparent damage to the underlying substrate (the surface was not spalled). In general, approximately 25% of the mortar joints may require tuck pointing. It should be noted that a mineral sand abrasive was used for these demonstrations.

6. Discussion of TCLP analysis failures

The abrasive media paint debris TCLP analysis and characterization results from both the wood and brick study sites were somewhat surprising. Both technology combinations produced wastes that exceeded the TCLP threshold limit value of 5 mg/l as presented in Table 4. The leachability of lead is affected by many factors including the type of lead in paint, resins used in paint, age of the paint, particle size, as well as other factors [4,5].

The paint debris wastes were treated with product from each manufacturer and re-sampled (per the manufacturer's recommendation) for TCLP analysis at the wood study site. The re-sampling strategy was consistent with the ASTM Quartering Method [6] and involved removing 5 gal containers of Blastox w/Torbo generated debris from four 55 gal drums

Table 4
Leachable lead (TCLP) measured in paint debris from wood and brick substrates

Technology combination	Substrate	Leachable lead (Pb) concentration (mg/l)				
		N ^a	Mean	S.D.	Minimum	Maximum
Torbo w/Blastox	Wood	6	21.3	17.6	3.7	52.0
	Brick	6	7.8	2.1	3.9	10.0
Torbo w/Pre Tox 2000	Wood	9	14.8	14.1	0.3	37.0
	Brick	6	8.1	9.0	0.2	20.0

^a N: number of samples collected from paint waste debris.

at the wood study site. The same procedure was followed for PreTox w/Torbo generated debris at the Kentucky (wood) site. In both cases, the material from one 5 gal container was deposited on a hard-flat surface and thoroughly mixed using a shovel. The pile was then divided into four quarters with a shovel. A sub-sample was then collected from each quarter and combined as a single sample. This procedure was performed twice for each 5 gal container, resulting in a total of eight samples for each technology. The re-sampling results yielded a leachable lead mean concentration of 12.5 and 13.0 mg/l for the Blastox w/Torbo and PreTox w/Torbo paint debris, respectively. In addition to re-sampling at the Kentucky study site, three 5 gal containers of Blastox w/Torbo and PreTox w/Torbo generated debris were treated with additional amounts of Blastox and PreTox2000 to achieve the optimal blend ratio or simulate the mil application thickness. The paint debris treated with additional amounts of PreTox 2000 was determined to be a non-hazardous waste with a mean leachable lead concentration of 0.1 mg/l. However, the paint debris treated with additional amounts of Blastox remained a hazardous waste whose TCLP results were 21.1 mg/l. The manufacturers of both abatement/stabilization technologies speculated that the ineffectiveness of their respective products in this study was due to insufficient product being added or applied to stabilize the concentration of lead present in the paint. Ultimately, the reasons(s) why these stabilization technologies were ineffective under the conditions of this study remain unresolved.

7. Conclusions/recommendations

In terms of overall effectiveness, both stabilization technologies, when applied in combination with wet abrasive blasting, were capable of removing the lead-based paint from both exterior wood and brick masonry with minimal or no damage to the underlying substrates. The wood surfaces will require only light sanding and the brick surface will need a small amount of mortar joint tuck pointing prior to repainting them, etc. It is recommended that a silica-based abrasive media be used in place of the “black beauty” media to drastically reduce or eliminate any harmful effects on the wood substrate.

In addition, both technology combinations were effective in removing lead-based paint from wood and brick as clearly evident by the residual lead levels of the resulting surfaces measuring significantly below the HUD guideline of 1 mg/cm² at both the wood and brick study sites.

The combination technologies achieved varying levels of effectiveness in terms of occupational health and personal protection. The mean area air levels of lead-containing particulate generated during paint removal were significantly below the OSHA PEL of 50 $\mu\text{g}/\text{m}^3$ and this was determined using a standard one-tailed *t*-test. However, the mean personal breathing zone levels of lead-containing particulate were approximately three times higher than the PEL. There was no significant difference between the personal breathing zone sample levels at the wood and brick study sites, but the area sample TWAs were higher at the wood study site (Blastox, 20.5 $\mu\text{g}/\text{m}^3$, PreTox 2000, 26.9 $\mu\text{g}/\text{m}^3$) than the brick site (Blastox, 21.2 $\mu\text{g}/\text{m}^3$, PreTox 2000, 24.9 $\mu\text{g}/\text{m}^3$). The Wilcoxon Rank Sum Test was used in comparing the sample results of both the average personal breathing zone concentration levels as well as the area/perimeter lead-containing particulate levels. It is therefore, recommended that abatement personnel wear the appropriate protective equipment, and air monitoring be conducted at the perimeter work area to determine the extent of the lead-containing particulate escaping the work area.

Neither of the two stabilization technologies (Blastox and PreTox 2000) consistently stabilized the lead-based paint debris to reduce the leach-able lead content. The initial TCLP sample analysis as well as the re-sampling results all exceeded the RCRA regulatory threshold of 5 mg/l requiring the paint debris to be disposed of as a hazardous waste. The failure of these technologies to stabilize the lead was most likely due to an inadequate chemical stabilizer-abrasive blend ratio in the case of Blastox, or insufficient application of mil thickness of the pre-paint removal coating treatment in the case of PreTox 2000. Due to this study's waste analytical results, it is recommended that all debris be tested by TCLP prior to disposal/removal from abatement site when either of these stabilization technologies are utilized. To maximize the performance of these technologies in the future, the user should understand the various factors that may affect the effectiveness of the product's ability to reduce the leachable lead content in the paint debris. These factors include paint film content, paint film thickness, the condition of the paint film, the type of substrate (wood, brick, metal), as well as the resulting lead-containing particle size.

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References

- [1] V. Hock, C. Gustafson, D. Cropek, S. Drozd, Demonstration of Lead-Based Paint Removal and Chemical Stabilizer Using Blastox, US Army Corps of Engineers, Construction Engineering Research Laboratories, Technical Report FEAP-TR-96-20, October 1996.

- [2] U.S. Environmental Protection Agency, Stabilization of Lead-Based Paint Waste, US EPA, Office of Pollution Prevention and Toxics, October 1998.
- [3] Method for Removing Coatings Which Create Hazardous Products, US Patent Number 5,674,108 (1997).
- [4] P.L. Bishop, Leaching of inorganic hazardous constituents from stabilized/solidified hazardous wastes, *Hazardous Waste Hazardous Mater.* 5 (2) (1998) 129–143.
- [5] J.M. Buskowski, J.H. Boy, X. Zhu, T.D. Race, K.A. Reinhold, Immobilization chemistry in portland cement stabilized paint blast media wastes, *Environ. Waste Manage. Issues Ceram. Ind.* II 45 (1994) 155–163.
- [6] American Society of Testing Materials, Standard Practice for Reducing Samples of Aggregate to Testing Size, ASTM Standard Method C 702-93, 15 September 1993.