CDC Workplace Safety and Health ™

NIOSH HEALTH HAZARD EVALUATION REPORT:

HETA #99–0305–2878
Lead Safe Services, Inc.
Neenah, Wisconsin

August 2002

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Aaron Sussell, Greg Piacitelli, and Zulfi Chaudhre of the NIOSH Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS) and Kevin Ashley of the NIOSH Division of Applied Research and Technology. Charles A. Mueller, DSHEFS, provided valuable statistical consultation and advice for analyses of the data.

This study would not have been possible without the support and cooperation of Jon Halverson of Lead Safe Services, Inc., Neenah, Wisconsin, and Carol Sewyer Brown of the City of Oshkosh, Wisconsin. We gratefully acknowledge the planning time and labor provided by Jon Halverson.

Brad King, John McKernan, and Tami Wise of NIOSH provided invaluable assistance and support during the field investigation. The authors would like to thank NIOSH reviewer Richard Hartle for his valuable comments. Field lead analyses were performed by Tami Wise and Kevin Ashley; laboratory analytical support was provided by DataChem Laboratories. Desktop publishing was performed by Ellen Blythe. Review and preparation for printing were performed by Penny Arthur.

Copies of this report have been sent to employee and management representatives at Lead Safe Services, Inc., and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

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Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Lead Exposures during Residential Lead Hazard Reduction

This NIOSH Health Hazard Evaluation was requested by management of Lead Safe Services, Inc. In 1999, we did a study of lead hazard reduction work at two houses in Oshkosh, Wisconsin. The purpose was to measure worker lead exposures, as well as lead levels (air and dust) in nearby areas during six tasks. Two tasks, wet and dry scraping, involved removing exterior lead-based paint to prepare surfaces for repainting.

What NIOSH Did

- Took air samples for lead on five workers performing six tasks.
- Collected air and settled dust samples to measure lead in nearby areas during the same work periods.
- Collected paint chip samples from the work surfaces, and measured the area treated for scraping tasks.

What NIOSH Found

- Task, worker, and house are associated with the workers' lead exposures.
- Tasks with high worker lead exposures were dry scraping, wet scraping, cleaning, and demolition.
- Tasks with lower worker lead exposures were set-up and removal.
- All of the tasks can result in lead dust contamination on the ground to distances of at least 25 feet from the work surface.

What Lead Safe Services Managers Can Do

- Use engineering controls and work practices to reduce worker exposures when performing lead paint removal. Random-orbital sanders and other power tools equipped with high efficiency particulate air (HEPA) local exhaust ventilation are effective methods for controlling dust during lead paint removal. It is prudent to scrape wet where possible, as the practice has been shown to reduce airborne lead in some circumstances.
- Use respirators for protection during high exposure tasks on lead paint, such as cleaning, demolition, dry scraping, and wet scraping.
- To protect the ground from lead contamination when scraping on second story or above, plastic sheeting should be extended farther than 10 ft from the work surface; the distance needed will depend on local conditions.
- Require workers to wear protective clothing and use good hygiene practices for all tasks when lead paint is present.
- Where renovation work will disturb lead paint, follow federal and state guidelines for lead-safe work, including dust containment and clean-up in homes with lead paint.

What Lead Safe Services Employees Can Do

- Use protective clothing and good hygiene when doing any work on surfaces with lead paint.
- When working on surfaces with lead paint, clean shoes and equipment daily, and clean your personal vehicle often with a HEPA vacuum.

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #99–0305–2878

Health Hazard Evaluation Report 99–0305–2878
Lead Safe Services, Inc.
Neenah, Wisconsin
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Aaron Sussell
Greg Piacitelli
Zulfi Chaudhre
Kevin Ashley

SUMMARY

At the request of a state-licensed contractor, the National Institute for Occupational Safety and Health (NIOSH) conducted a study of residential lead hazard reduction work. Workers' task-specific and full-shift personal airborne lead (PbA) exposures were measured on three consecutive days during exterior work at two single-family homes in Oshkosh, Wisconsin. Tasks assessed were cleaning, demolition, dry scraping, component removal, set-up, and wet scraping. Additionally, we measured surface paint lead concentrations and, for dry scraping and a mix of other tasks, concomitant lead concentrations in settled dust (PbS) at 10, 15, and 25 feet (ft) (3.1, 4.6, and 7.6 meters [m]) from work surfaces. Mean exterior paint lead concentrations at the two houses were high: 22 percent (%) and 37% Pb by weight. The 79 task-specific worker PbA exposures measured were highly variable; range 1.4–2240 micrograms per cubic meter ($\mu g/m^3$), geometric mean (GM) = 71 $\mu g/m^3$, geometric standard deviation (GSD) = 4.6. Within-task variability of PbA exposures was high (GSDs = 1.9–5.4). PbA exposures were significantly associated with task, worker, and house variables ($p < 0.0001$). High-exposure tasks were cleaning (GM = 108 $\mu g/m^3$), dry demolition (77 $\mu g/m^3$), dry scraping (136 $\mu g/m^3$), and wet scraping (90 $\mu g/m^3$); the means did not differ significantly in paired comparisons. The low-exposure task was set-up (GM = 12 $\mu g/m^3$); the GM for removal also appeared to be low (30 $\mu g/m^3$) but is uncertain due to small sample size (n = 3). Nearly all (14/15) of the full-shift PbA exposures collected for workers performing scraping and a mix of other tasks were above the permissible exposure limit (PEL) (GM = 100 $\mu g/m^3$, range: 39–526 $\mu g/m^3$). Results for five full-shift area PbA samples collected to measure potential bystander exposures on work days were relatively low, ranging from 0.83 to 6.1 $\mu g/m^3$. Seventeen PbS samples collected at 10 ft (3.05 m), sixteen samples at 15 ft (4.57 m), and twelve samples at 25 ft (7.62 m) had respective GMs of 1716, 458 and 65 milligrams per square meter (mg/m^2). PbS levels were significantly associated with distance from the work surface, $p < 0.0005$. PbS levels were not significantly associated with the two task categories (dry scraping and a mix of other tasks).

Almost all of the full-shift PbA exposures for workers performing exterior scraping and a mix of other tasks were greater than the PEL. Task-specific PbA exposures were highly variable both within and between tasks. High-exposure tasks were cleaning, demolition, dry scraping, and wet scraping, with mean exposures exceeding the PEL. Mean exposures for set-up and component removal were below the PEL. The

respirators used were adequate to protect workers from the exposures measured. Recommendations are provided in this report to assist the contractor in controlling worker exposures to hazardous levels of lead-based paint.

Keywords: SIC 1521 (General Contractors-Single-Family Houses) lead, abatement, hazard reduction, painters, lead-based paint, painting, construction, housing, residential

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INTRODUCTION

In 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request from the management of Lead Safe Services, Inc., Neenah, Wisconsin, a certified lead abatement contractor, for assistance in evaluating worker lead exposures during residential lead hazard reduction work. The contractor was employed on U.S. Department of Housing and Urban Development (HUD)-funded projects in Wisconsin designed to control lead-based paint (LBP) hazards in private single-family housing. During a three-day site visit in September 1999, NIOSH investigators collected air and settled dust samples during Lead Safe Services jobs at two single-family homes in Oshkosh, Wisconsin. The homes were located within a few blocks of each other, which allowed sampling at the two sites on the same days.

BACKGROUND

Residential lead hazard reduction contractors and renovators in the United States commonly encounter LBP in their work, as 83 percent (%) of U.S. private housing units built before 1980 have LBP.[1] Houses built before 1950 are more likely to contain LBP and have higher levels of lead in the paint. NIOSH has found that similar tasks and lead hazards occur during lead hazard reduction and home renovation work.[2,3] Homeowners doing their own renovation and remodeling may also be exposed to lead hazards. During the past decade the mix of work tasks used by lead hazard reduction contractors has changed as the emphasis of HUD's national residential lead hazard control program shifted from abatement (i.e., permanent measures, designed to last >20 years, such as removal, enclosure, or encapsulation) to a combination of abatement and interim controls.[4] Interim controls are measures designed to temporarily control LBP hazards, including renovation, repairs, paint film stabilization, painting, and specialized cleaning.

Lead Safe Services requested that NIOSH conduct a task-based assessment of worker exposures to airborne lead (PbA) and nearby lead in settled dust levels during lead hazard reduction work. The contractor was interested in comparing worker PbA exposures during exterior wet (hand) scraping and dry scraping on the same jobs. Hand scraping is often used to prepare wood surfaces with deteriorated LBP for priming and repainting (also called paint film stabilization). Based on the general industrial hygiene principle that wetting surfaces reduces airborne dust, federal agencies have recommended sanding and scraping of LBP be done wet instead of dry to reduce lead dust exposures.[4,5] The feasibility and effectiveness of wet scraping has been controversial.

The workplaces were two unoccupied two-story wood frame single-family private homes in the city of Oshkosh, Wisconsin, which had received HUD funding for lead hazard control projects. Previous lead inspections at the houses found deteriorated LBP on most of the exterior wood siding, trim, rain gutters, and downspouts. The exterior siding on both houses was scheduled for surface preparation (removal of deteriorated paint), priming, and repainting. As part of this work, exterior painted building components with LBP (i.e., gutters, downspouts, front portico) would be removed at both houses and a vestibule at the rear of one of the houses would be demolished.

METHODS

The primary objective of the study was to measure workers' task-specific and full-shift PbA exposures during lead hazard reduction work performed by the contractor at two houses (designated as house "A" and "B" in this report). Secondary objectives were to (1) measure dispersion of lead in settled dust (PbS) 10 to 25 feet (ft) (3.1 to 7.6 meters [m]) from work surfaces, and (2) use NIOSH methods for field-portable analysis of lead in PbA and paint chip samples by ultrasonic extraction and anodic stripping voltammetry (UE-ASV) and compare results obtained on site to subsequent laboratory analysis of the same samples.[6]

Tasks performed by Lead Safe Services during the three-day period were categorized by NIOSH investigators. The task categories were: (1) cleaning, (2) demolition, (3) dry scraping, (4) removal, (5) set-up, and (6) wet scraping. The tasks descriptions and photographs are in Table 1 and Figure 1, respectively. Lead Safe Services employed five workers during the study period, which included the owner. About half of the scraping work was done from ladders at the second floor level; the rest was done at ground level. All of the participating Lead Safe Services workers had been previously trained and certified in lead hazard reduction practices. The workers wore disposable paper coveralls and half-mask air-purifying respirators with NIOSH type N100 cartridge filters during all tasks. The contractor provided portable hygiene facilities at both houses. A field laboratory for on site lead analyses was set up in a clean area inside house A.

Personal PbA exposures were sampled on three consecutive days. Each worker wore two portable sampling pumps to collect consecutive task-specific samples and one full-shift sample per day. The surface areas (square feet [ft^2]) scraped by workers were measured during task PbA sample times for wet and dry scraping tasks. Full-shift area PbA samples were collected in areas that would represent potential PbA exposures for bystanders.

PbA samples were collected using NIOSH Method 7082. The flow rate used for PbA sampling pumps was 3.0 liters per minute. Pump flow rates were checked daily in the field pre- and post-sampling (Dry-Cal® DC-Lite Primary Flow Meter, BIOS Intn'l). The average of the two flow measurements was used in calculating results (all differences between pre- and post-sampling flow rates were less than 5 percent [%]). Filters were removed from 37-millimeter (mm) cassettes and placed in 30-milliliter (mL) polypropylene copolymer centrifuge tubes with sealing caps (Nalgene® No 3139-0030) for on-site analysis by NIOSH 7701 (UE-ASV). Filters in extract solution were subsequently shipped in the same tubes to a laboratory for lead analysis by NIOSH 7082 (flame atomic absorption spectrophotometry). If no lead was detected by 7082, the samples were subsequently analyzed using NIOSH Method 7105 (graphite furnace atomic absorption spectrophotometry).[7] Only laboratory results are used in this report. The laboratory limit of detection (LOD) and limit of quantitation (LOQ) for PbA samples were 0.1 and 0.4 micrograms (µg)/sample, respectively (NIOSH Method 7105). PbA results are reported in micrograms per cubic meter ($\mu g/m^3$).

PbS sampling was done concurrently with PbA sampling, but due to time constraints and analytical method limitations typically one PbS sample was collected during several consecutive PbA task samples. PbS samples were collected during work periods at distances of 10 ft, 15 ft, and 25 ft (3.1, 4.6, and 7.6 m) from the work surface, measured perpendicular to the exterior siding. PbS samples were collected on pre-moistened 5.5-inch by 8.0-inch (0.029 square meter [m^2]) towelettes (Wash'n Dri®, Softsoap Enterprises, Inc, Chaksa, Minnesota), which have been found to be suitable for this purpose.[8] To collect a sample, a clean towelette was unfolded and placed flat in a 6-inch by 9-inch rectangular plastic storage tray (EKCO® Consumer Plastic Inc., model No. 514–1). At the end of the sampling period the towelette was folded inward upon itself to contain any dust adhering to it, and placed in a 50-mL centrifuge tube. The samples were analyzed for lead according to NIOSH Method 7105. The LOD and LOQ for PbS samples were 0.07 and 0.2 µg/sample, respectively. Results are reported in milligrams per square meter (mg/m^2).

Several bulk paint samples were collected from the siding on each side of the two houses, according to American Society for Testing and Materials (ASTM) Method E1729–99.[9] Paint chips were collected from areas where the paint was peeling, or, if there was no peeling paint, by cold scraping with a stainless steel scraper. After weighing, approximately 0.2 gram (g) of each sample was prepared and analyzed on-site using NIOSH Method 7701 (UE-ASV). Sealable centrifuge tubes (Nalgene® No 3139-0030) containing paint chip samples in extract solution were subsequently shipped to a laboratory for lead analysis by NIOSH Method 7082.[7] Results were reported as % by weight. The LOD for lead was 0.001% and the LOQ was 0.004%.

Laboratory results were reported with a precision of two significant digits. All of the laboratory analyses had detectable levels of lead. Statistical analyses were performed with StatView® 5.01 and SAS® ver. 8, SAS Institute, Inc.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, which potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[10] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[11] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[12] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Lead Exposure

Occupational exposure occurs via inhalation of lead-containing dust and fume, and ingestion from contact with lead-contaminated surfaces. Symptoms of lead poisoning include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort (colic), fine tremors, and "wrist drop."[13,14,15] Exposure to lead over time can cause harm gradually, with no obvious symptoms or clinical effects. Chronic exposure to lead may cause damage to the kidneys, anemia, hypertension, infertility and reduced sex drive in both sexes, and impotence.

Exposure to lead before or during pregnancy can alter fetal development and cause miscarriages. The developing nervous system of the fetus is particularly vulnerable to lead toxicity.[2]

A person's lead exposure can be readily determined by biological monitoring. The blood lead level (BLL) is the best indication of recent exposure to, and current absorption of, lead.[16] Measurement of zinc protoporphyrin (ZPP) level in blood is a good indicator of chronic lead exposure because the toxic effect of lead on heme synthesis in red blood cells causes elevated ZPP levels. Persons without occupational exposure to lead usually have a ZPP level of less than 40 micrograms per deciliter (µg/dL).[17] Elevated ZPP levels due to lead exposure may remain months after the exposure. Because other factors, such as iron deficiency, can also cause an elevated ZPP level, the BLL is a more specific test in the evaluation of occupational exposure to lead.

OSHA has established a PEL for PbA of 50 $\mu g/m^3$ as an 8-hour TWA, which is intended to maintain worker BLLs below 40 µg/dL.[18,19] OSHA has also established an action level for PbA of 30 $\mu g/m^3$ as an 8-hour TWA. OSHA requires that employers provide protective measures to employees exposed above the action level, such as medical surveillance including BLL and ZPP sampling and analysis. Medical removal protection is required when an employee's BLL reaches 50 µg/dL.

NIOSH has concluded that the 1978 NIOSH REL of 100 $\mu g/m^3$ as an 8-hour TWA does not sufficiently protect workers from the adverse affects of exposure to inorganic lead.[20] NIOSH intends to analyze the feasibility of developing an REL that would provide better protection for workers. NIOSH has conducted a literature review of the health effects data on inorganic lead exposure and finds evidence that some of the adverse effects on the adult reproductive, cardiovascular, and hematologic systems, and on the development of children of exposed workers can occur at BLLs as low as 10 µg/dL.[2] At BLLs below 40 µg/dL, many of the health effects would not necessarily be evident by routine physical examinations, but represent early stages in the development of disease.

In recognition of the toxic effects of lead, voluntary standards and public health goals have established lower occupational exposure limits to protect workers and their children. The ACGIH TLV® for PbA is 50 $\mu g/m^3$ as an 8-hour TWA, with worker BLLs to be controlled to $\leq$30 µg/dL. A national health goal is to eliminate all occupational exposures which result in BLLs greater than 25 µg/dL.[21]

Lead in Surface Dust and Soil

Lead contamination in dust and soil, which is commonly found in the U.S. due to the past use of lead in gasoline and paints, and also industrial emissions, is a risk to young children. Lead-contaminated surfaces may be a source of occupational exposure for workers. Lead exposure may occur either by direct hand-to-mouth contact, or indirectly through contamination of hands, cigarettes, cosmetics, or food.

In the workplace, generally there is little or no correlation between lead in surface dust or soil and employee exposures. The amount of lead ingested by workers depends primarily on the effectiveness of administrative controls (i.e., hazard communication), hygiene practices, and hygiene facilities. There is no federal standard for surface lead contamination in workplaces, but there are standards for lead in residential dust and soil designed to protect young children. The U.S. Environmental Protection Agency (EPA) has defined a dust-lead hazard as a surface in a residential dwelling or child-occupied facility that contains a lead loading equal to or greater than 40 micrograms per square foot ($\mu g/ft^2$–equivalent to 0.43 mg/m^2); on floors or 250 $\mu g/ft^2$ (equal to 2.7 mg/m^2) on interior window sills based on wipe samples.[22]

Similarly, there are no federal standards for soil lead contamination in the workplace. EPA has defined a soil-lead hazard as bare soil on a residential real property or on the property of a child-occupied facility that contains total lead equal to or exceeding 400 parts per million (ppm) (equal to micrograms per gram [µg/g]) in a play area or average of 1,200 ppm in the rest of the yard based on soil samples.[22]

RESULTS

From two to four paint chip samples were collected from each side of the two houses, and from the porch of house A. Twenty-three paint samples were collected at house A and eighteen at house B. The distribution of paint lead concentrations was approximately normal (Kolmogorov-Smirnov test). The exterior paint lead concentrations at house A (arithmetic mean 22%, range 1.1–46.5%) were significantly lower those at house B (mean 37%, range 2.4–53.6%), (t-test, p = 0.0085). Average lead concentrations in paint on both houses was high compared to the federal action level for LBP of 0.5%. "House" was used as a two-level categorical variable in analyses of PbA task-specific samples to control for differences between houses, such as paint condition and lead concentration.

Seventy-nine task-specific PbA samples were obtained; the number per task ranged from 3 to 28 (see Table 2) and the number per worker ranged from 11 to 18. The average task-specific sample time was 66 min (range 10–202 min). Three full-shift PbA samples were collected per worker per day for a total of 15 samples, with a mean sample time of 426 min (range 312–521 min). A total of 45 PbS samples were collected at 10, 15, and 25 ft (3.1, 4.6, and 7.6 m) from the work surfaces for dry scraping and a mix of other tasks. PbA and PbS results were natural log transformed for data analyses; after transformation the distributions for task-specific and full-shift results was approximately normal.

Weather conditions on the three days of environmental sampling in mid-September were cloudy to partly cloudy, with winds of 3 to 10 miles per hour, with temperature ranging from 52 to 66° F, and relative humidity of 54% to 75%.

Air Lead Results

Task-specific Samples

Personal PbA results for 79 task-specific samples were highly variable overall, ranging from 1.4 µg/m^3 to 2240 µg/m^3, geometric mean (GM) = 71 µg/m^3, geometric standard deviation (GSD) = 4.6. Within-task variability of PbA results was moderate to very high, with task-specific GSDs ranging from 1.9 to 5.4 (Table 2). Personal PbA exposures were highly associated with task, worker, and house variables in a model using raw values (ANOVA, p value <0.0001).

Because workers and houses were not equally balanced among the tasks, the task means were adjusted to control for the imbalances of these covariates (least squares means, SAS® GLM procedure). Adjustment changed the GMs for cleaning, demolition, and wet scraping; the effect of adjustment on other tasks was minimal. The unadjusted and adjusted task means are presented in Table 2. The model was highly significant (p <0.0001). The most important variable for PbA exposures was task (p <0.001), followed by house (p = 0.044) and worker (p = 0.093). The surface area treated was not included as a variable because reasonably accurate measurements could only be obtained for the two scraping tasks, which were done on areas of flat siding. A separate analysis was done for those tasks (see below).

The adjusted GMs and 95% confidence limits (CL) (Table 2 and Figure 2) were used for comparing PbA exposures between pairs of tasks. The six tasks evaluated appear to fall into two exposure groups. Four high-exposure tasks, with adjusted geometric means greater than 50 µg/m^3, were cleaning (GM = 108 µg/m^3), demolition (77 µg/m^3), dry scraping (136 µg/m^3), and wet scraping (90 µg/m^3). The mean for dry scraping was not statistically different from wet scraping (p = 0.336) or any of the other high-exposure tasks (two sample t-tests, α = 0.05). The similar distributions of (log) PbA exposures for dry and wet scraping are shown graphically in Figure 3. The low-exposure task group included only set-up (GM = 12 µg/m^3), which was significantly lower than the four high-exposure tasks in paired comparisons (t-tests, α = 0.05). The mean for removal (30 µg/m^3) was less than those for the four high exposure tasks, but it is uncertain due to the sample size (n = 3). The differences between the means for removal and the high exposure tasks failed to reach statistical significance (t-tests, range of p-values: 0.064–0.32).

The surface area treated (ft^2) during PbA sampling time was measured for all (40/40) dry and wet scraping task samples. The area treated ranged from 8-225 ft^2 (mean: 98 ft^2, ± 63 standard deviation [SD]). Linear regression analysis revealed that treated ft^2 was poorly associated with (log) personal PbA levels resulting from manual scraping tasks (r^2 = 0.159, see Figure 4). The linear model (Ln PbA = 4.113 +0.008 area ft^2) would not be useful in predicting worker exposures. The association was not improved substantially by using raw PbA values (r^2 = 0.16), by analyzing results for houses A and B separately (r^2 = 0.2 and 0.11), or by using production rate (area ft^2/hour) as the independent variable.

Full-shift Samples

Fifteen full-shift personal PbA samples were collected for five workers performing a mix of exterior manual scraping and other tasks on three consecutive days (Table 3). All of the samples included a mix of manual scraping (wet, dry, or both) and other tasks. Most (14/15) of the actual full-shift exposures measured were above the PEL (range: 39–526 µg/m^3). The GM full-shift PbA exposure of 100 µg/m^3 (95% CL 65–152 µg/m^3) was significantly greater than the PEL (p = 0.002, one-tailed t-test, 14 d.f.). No significant differences among full-shift exposures by worker or house were found.

Five full-shift PbA area samples were collected near work areas both inside and outside the houses to measure potential bystander exposures on work days (Table 3). Two samples collected across the street from house A on consecutive days were 2.9 and 0.29 µg/m^3. One sample collected at the property line at house B (downwind of work) was 6.1 µg/m^3. Two samples collected on consecutive days in the field laboratory were 0.83 and 1.0 µg/m^3.

Dust Lead Results

PbS sampling was limited to two task categories: dry scraping and a mix of other tasks. Results for 17 PbS samples at 10 ft (3.1 m), 16 samples at 15 ft (4.6 m), and 12 samples at 25 ft (7.6 m) were obtained. The average PbS sample duration was 188 min (range 41–207 min). PbS results by task are summarized in Table 4 (means were not adjusted for covariates).

PbS concentrations were very highly variable overall, GSD = 10.7. GMs for results at 10, 15, and 25 ft from work surfaces were 1716 mg/m^2, 458 mg/m^2, and 65 mg/m^2. Distance from the work surface (categorical variable) was significantly associated with PbS levels, p = 0.0005. PbS levels at 10 ft and at 15 ft were significantly higher than those at 25 ft (p-values = 0.0001 and 0.0157, respectively); the difference between PbS levels at 10 ft and 15 ft was not statistically significant (p = 0.0683, Bonferroni paired t-tests with total α = 0.05). Task category was not significantly associated with PbS results (p = 0.32). Dry scraping appeared to have a lower mean PbS level at each distance compared to the mix of other tasks, but the differences were not statistically significant.

DISCUSSION

PbA and PbS levels were measured during lead hazard reduction work on the exterior of two pre-

1950 homes. The painted surfaces undergoing work had average paint lead concentrations 44 and 74 times the federal action limit for LBP, respectively. In considering the study results it is important to recognize that the work took place under specific conditions, and results may not be representative of work under different conditions.

Task-specific PbA exposures were significantly associated with task, worker, and house variables. Of these, task was most associated with the workers' PbA exposures. However, even within the task categories, the PbA exposures were highly variable, suggesting factors associated with the worker and house, and unmeasured environmental factors are important determinants of PbA exposures. Other environmental factors could be the hourly changes in humidity and surface moisture, and differences in natural ventilation rate between work locations due to the worker's position with respect to the building and the prevailing wind direction. The treated area and production rate (area treated/hr) were poorly associated with task-specific PbA exposures during scraping, and did not have predictive value.

The high-exposure tasks, all of which could result in a worker's exposure exceeding the PEL during an 8-hour day, were cleaning, demolition, dry scraping, and wet scraping. Low worker exposures were measured during set-up. A worker performing only set-up would not have a mean exposure reaching the PEL, and this task should not routinely require respiratory protection. Removal (of building components) appeared to have a mean exposure below the PEL, but the point estimate is uncertain due to the small sample size. None of the paired differences between task-specific worker PbA exposures among these tasks were statistically significant, including the difference between wet scraping and dry scraping.

This result for scraping tasks is not consistent with previous NIOSH studies in Ohio and California which found that mean PbA exposures during scraping tasks were significantly reduced with wet methods, in the California study to below the PEL.[23,24] On the other hand, consistent with this study, no significant difference between PbA exposures for dry and wet scraping was found in a NIOSH study of Rhode Island lead hazard reduction workers who used very similar work practices indoors.[25] The reason for these apparently conflicting results may be due to variations in both sites (paints and substrates) and the work practices used. For example, the amount of water applied, and the frequency with which it is applied, are important factors for how effectively a painted surface is wetted during wet scraping.

The workers' full-shift PbA exposures during a mix of tasks, including scraping, were potentially hazardous (all workers wore appropriate respiratory protection). Nearly all of the full-shift exposures measured (14/15) were above the PEL, ranging from roughly 1 to 10 times the PEL, with a geometric mean exposure two times the PEL. Full-shift area samples revealed that generally potential bystander exposures were relatively low (and no bystanders were actually present at those locations).

Half-mask air-purifying respirators rated by NIOSH as N100 (or high efficiency particulate air [HEPA]) were provided by the contractor and used by workers for protection against hazardous PbA levels during cleaning, demolition, and scraping tasks. This type of respirator is adequate for PbA exposures up to 10 times the PEL (500 $\mu g/m^3$) and would provide adequate protection for the average exposures encountered while performing these tasks.

PbS results (average sample time 3 hours) show that exterior scraping and other tasks on LBP can potentially contaminate soil at least 25 ft (7.6 m) from the house. About half of the work took place on the second-story levels of the houses, and light winds were present. It is likely that these factors aided dispersion of the LBP dust. As expected, the mean PbS levels decreased exponentially as distance from the work surface increased. The mean PbS levels for dry scraping at all three distances were lower than those for other tasks, although the differences did not reach statistical significance. A possible explanation for this is that dry scraping produced finer particles which remained airborne longer and were more widely dispersed. The health significance of the PbS levels measured at the two houses is not clear, as this study did not include pre- and post-job soil sampling, and most of the PbS fell on yard areas covered by lawn grass. A large federal study of residential lead abatement work found an average increase in bare soil lead levels at the roof drip line (3–5 ft from siding) pre- to post-job in spite of containment and clean up procedures.[26] However, the study also found that before the jobs started, average soil lead levels at the urban homes scheduled for abatement were hazardous–nearly twice the current EPA standard of 400 ppm for lead in bare residential soil.

Federal and state guidelines for renovation of homes with LBP recommend that plastic sheeting be used to protect the ground and shrubbery from the base of the walls to a distance of at least 10 ft.[4,27] The HUD pamphlet, "Lead Paint Safety," states that "When working on the second story or above, extend the sheeting farther out."[4] Our results are consistent with this advice, and suggest that "farther out" might need to be 25 ft or more in some cases. Further study of the impact of exterior residential LBP work on soil contamination levels is needed to better define the work practice guidelines.

RECOMMENDATIONS

The following recommendations are offered to assist Lead Safe Services, Inc., in protecting workers and home occupants from hazardous LBP exposures during future work. They are based on the study results and previous NIOSH studies.

1. Use work practices and engineering controls to reduce airborne lead during LBP removal. It is prudent to scrape wet where possible, as it has been shown to reduce airborne lead in some circumstances. Random-orbital sanders and other power tools equipped with HEPA local exhaust ventilation are effective methods for controlling dust during LBP removal, and may provide higher productivity.

2. To protect the ground from lead contamination when scraping on second story or above, plastic sheeting should be extended farther than 10 ft from the work surface; the distance needed will depend on local conditions. Pre- and post-job soil sampling around the house is advisable to determine the effectiveness of containment procedures.

3. Regardless of airborne lead levels, to minimize take home of lead contamination, workers and site supervisors should: (a) use protective clothing and not mix lead-contaminated clothing with other laundry, (b) clean work shoes daily, (c) use washable plastic floor mats in their vehicles, and (d) regularly HEPA vacuum the interior of their vehicles.

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Table 1. Description of Renovation Tasks Evaluated

Task No.	Task Name	Work Description
1	Cleaning	Daily cleaning of work areas including picking up tools and plastic sheeting, broom sweeping paint chips, dust, and debris, and vacuuming with high-efficiency particulate air (HEPA) filter vacuum.
2	Demolition	Dry manual demolition of an exterior porch including sawing, pulling structure down with ropes, pulling boards apart with wrecking bar and other tools.
3	Dry scraping	Complete or partial removal of deteriorated paint by manual scraping with pull scrapers fitted with replaceable 2-inch tungsten-carbide blade. (2-inch carbide Pull Scraper, 10-inch handle length, model #803, Warner® Manufacturing Company, Minneapolis, MN)
4	Removal	Removal of exterior painted building components , including metal rain gutters and windows.
5	Set-up	Daily set-up of equipment and the containment area, including covering the ground within 10 feet of the house with plastic sheeting.
6	Wet scraping	Complete or partial removal of deteriorated paint by manual scraping with pull scrapers fitted with replaceable 2-inch tungsten-carbide blade. (2-inch carbide Pull Scraper, 10-inch handle length, model #803, Warner® Manufacturing Company, Minneapolis, MN). Painted surfaces were wetted with water before scraping using hand-pump spray bottles or garden sprayers with nozzle-tip wands.

Table 2. TWA Personal PbA Exposures for Six Lead Hazard Reduction Tasks (µg/m^3)

Task No.	Task	Count	Range of Values	Raw Values GM[A]	Raw Values GSD[B]	Adjusted Values† GM[A]	Adjusted Values† 95% Confid. Limits[C] (lower)	Adjusted Values† 95% Confid. Limits[C] (upper)	Adjusted Values† Not Significantly ($p<0.05$) Different Than Tasks:
1	Cleaning	13	5.1 – 1490	93	5.4	108	55	211	2,3, 4, 6
2	Demolition	9	23 – 193	64	1.9	77	32	188	1,3, 4, 6
3	Dry scraping	26	1.9 – 2240	140	3.6	136	83	217	1,2, 4, 6
4	Removal	3	11– 73	31	2.6	30	6.9	135	1,2,3,5,6
5	Set-up	14	1.4 – 117	12	4.2	12	6.5	23	4
6	Wet scraping	14	7.5 – 756	111	2.9	90	46	176	1,2,3,4
	Total	79	1.4 – 2240	22	4.6				

† least squares means adjusted for the imbalances of worker and house between tasks

[A] geometric mean

[B] geometric standard deviation

[C] lower and upper 95% confidence limits for the GM

Table 3. Full-shift personal PbA exposures for five workers and area PbA concentrations at two houses undergoing exterior lead abatement.

Worker	Day	House	Sample time (min)	PbA µg/m^3	Tasks performed[A] or Location
A	1	A	455	150	3,4,5
	2	A	474	66	4,5,6
	3	B	375	91	2,3,5
B	1	A	521	430	3,5,6
	2	both	415	526	1,3,5
	3	B	312	67	3,5,6
C	1	A	518	85	3,5,6
	2	both	521	65	2,3,5
	3	B	323	55	2,5,6
D	1	A	440	199	1,3,5,6
	2	both	413	53	3,4,5
	3	B	349	53	2,3,5
E	1	A	508	117	1,3,4
	2	both	408	39	1,5,6
	3	B	361	89	2,3,5
Area Samples	1	A	447	1.0	Indoor laboratory
	1	A	472	2.9	Across street
	2	A	197	**0.29**[B]	Across street
	2	A	516	0.83	Indoor laboratory
	3	B	420	6.1	Property line (downwind)

[A] Tasks: (1) cleaning; (2) demolition; (3) dry scraping; (4) removal; (5) set-up; (6) wet scraping

[B] semiquantitative value (**bold text**), the result was between the LOD and LOQ

Table 4. PbS Concentrations (mg/m²) at 10, 15, and 25 ft from Work Surfaces

Task	PbS 10 ft			PbS 15 ft			PbS 25 ft			Total
	Count	Range of Values	GM[A] (GSD)[B]	Count	Range of Values	GM[A] (GSD)[B]	Count	Range of Values	GM[A] (GSD)[B]	
Dry scraping	10	28 – 24490	1331 (7.6)	9	7.2 – 5520	331 (10.7)	7	3.2 – 517	51 (6.3)	
Other tasks	7	210 – 29640	2465 (5.7)	7	31 – 12760	693 (8.6)	5	5.2 – 1000	91 (9.2)	
Total	17	28 – 29640	1716 (6.6)	16	7.2 – 12760	458 (9.3)	12	3.2 – 1000	65 (6.9)	448 (10.7)

[A] geometric mean

[B] geometric standard deviation

Figure 1. Six lead hazard reduction tasks sampled, Lead Safe Services, Inc.

Clockwise from upper left: cleaning, demolition, dry scraping, removal, set-up, wet scraping.

Figure 2. Geometric means and their 95 % confidence intervals (CI) for task-specific PbA exposures (µg/m³), adjusted for imbalance of worker and house variables.

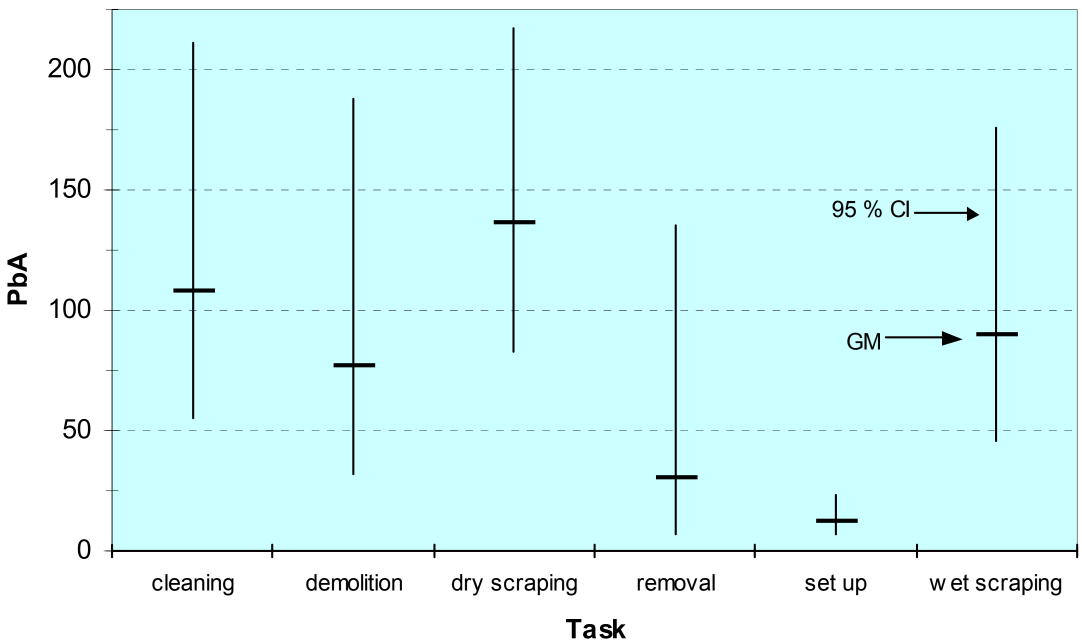


Figure 3. Distributions of (log) task-specific PbA exposures for dry and wet scraping.

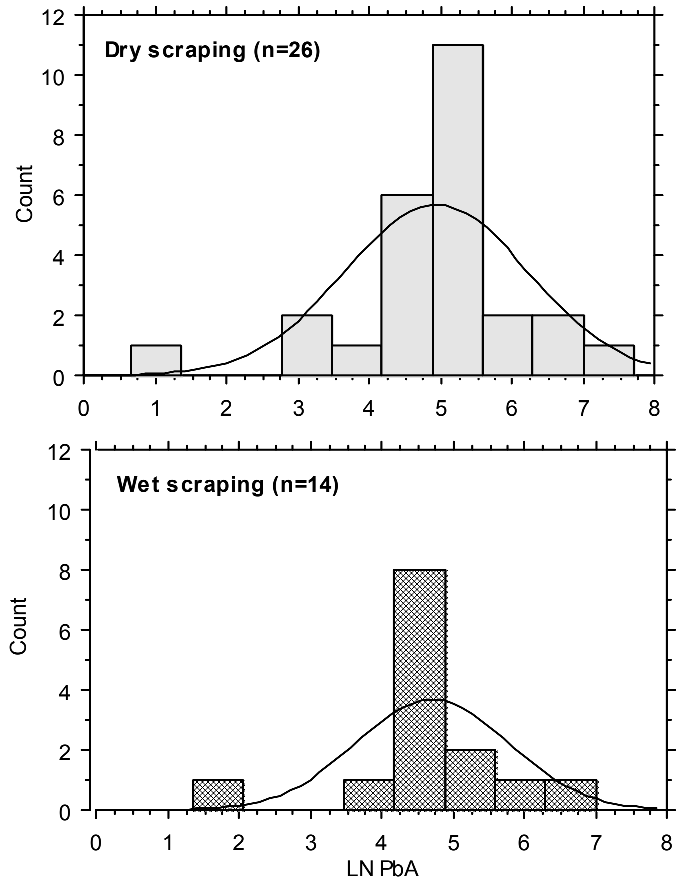
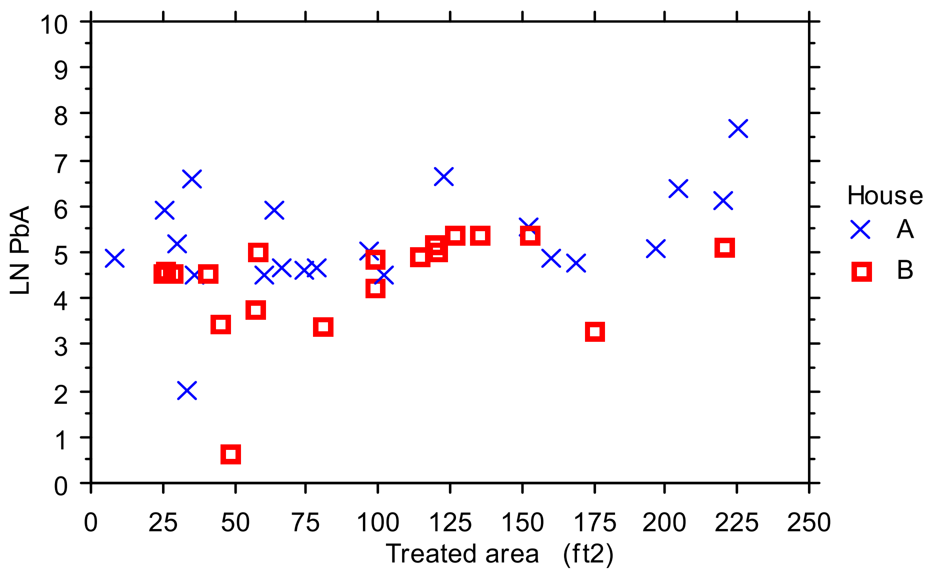


Figure 4. Surface area treated vs. natural log (Ln) personal PbA exposures for manual scraping tasks at two houses.



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