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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 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.

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Highlights of the NIOSH Health Hazard Evaluation

Exposures During Residential Lead Hazard Reduction Work

This NIOSH Health Hazard Evaluation (HHE) was requested by the Rhode Island Department of Health. It was done at 20 homes undergoing lead hazard reduction from 1996–1998. The purpose was to measure worker exposures during various tasks and determine if workers were exposed to hazardous amounts of lead–based paint.

What NIOSH Did

- Took air samples for lead on workers during 11 different tasks.
- Measured lead on workers' hands and in their personal vehicles.
- Analyzed blood lead monitoring results reported to the state.
- Determined how many licensed personnel had their blood lead tests reported to the state.

What NIOSH Found

- Lead levels during dry scraping, wet scraping, mixed surface prep, and caulking tasks were hazardous.
- Workers' lead exposures during scraping were up to 20 times greater than the acceptable exposure limit.
- Lead levels during removal, replacement, cleaning, wet demolition, yard work, and set up were within acceptable limits.
- High lead dust levels were found on workers' hands and in personal vehicles.
- Most workers who were tested had acceptable blood lead levels. Supervisors had the highest blood lead levels.

What Managers Can Do

- Provide appropriate respirators for wet or dry hand scraping.
- Offer the required blood lead testing and encourage worker and supervisor participation.
- Make sure hand–washing facilities are available at each site, and stress good hygiene practices, including hand washing, no eating or smoking in work areas, and regular cleaning of personal vehicles.
- Provide clean cotton or leather work gloves in addition to respirators and protective coveralls.

What the Employees Can Do

- Always wear the right respirator when doing a hazardous task, such as scraping lead–based paint.
- Wear clean cotton or leather work gloves to protect hands from lead dust.
- Clean off your shoes, or change your shoes, before leaving the work site.
- Participate in the medical monitoring program by getting your blood tested for lead regularly.
- Regularly clean your personal vehicle to reduce the risk of taking home dust containing lead.

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National Institute for Occupational Safety and Health NIOSH

Health Hazard Evaluation Report 96–0200–2799
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SUMMARY

At the request of the Rhode Island Department of Health (RI DOH), we evaluated worker lead exposures during U.S. Department of Housing and Urban Development (HUD)–funded residential lead hazard reduction in Rhode Island. RI DOH was concerned that workers might be unnecessarily wearing respirators and protective clothing during various tasks. The predominant work tasks in lead hazard reduction work have changed as, over the past several years, HUD has shifted the emphasis of its national program. Participating contractors are performing less on–site removal of lead–based paint (LBP) and more component replacement and lead hazard reduction, i.e., replacement and renovating structures with the existing LBP left in place.

The National Institute for Occupational Safety and Health (NIOSH) evaluated worker lead exposures during various tasks at 20 homes undergoing lead hazard reduction from 1996–1998. The study included task–based and full–shift air monitoring, measurement of the lead contamination in workers' vehicles, and a review of the medical monitoring data reported to RI DOH. Results for workers' full–shift airborne lead exposures (PbA) were highly variable, ranging from 1.5 to 1100 micrograms per cubic meter (µg/m^3, 20 samples). The maximum exposure was for dry scraping. The geometric mean (GM) full–shift lead exposure was 74 µg/m^3 among workers who performed any scraping during the work shift.

One hundred fifty–two task–based samples were obtained for 11 task categories; most of the samples were for interior work (average time 139 minutes). Task–based PbA exposures were highly variable, ranging from 0.17 to 2000 µg/m^3. The GM PbA exposures by task ranged from 1.3 µg/m^3 (yard work) to 150 µg/m^3 (dry scraping). Within–task variability was high; in spite of this variability, task category was highly associated with logged PbA exposure (one–way ANOVA $p < 0.0001$). Dry scraping and wet scraping tasks, which did not differ significantly, had the highest GM exposures. The actual full–shift exposures, which were obtained for a few single tasks, were generally similar to the GM exposures for the corresponding task–based samples. Four of the 11 tasks evaluated had estimated full–shift exposures above the Occupational Safety and Health Administration permissible exposure limit (PEL, 50 µg/m^3): dry scraping, wet scraping, mixed surface prep, and caulking. It is likely that high levels during caulking represented collateral exposures from other dust–generating work in the houses. Estimated full–shift exposure for the other seven tasks, including painting, removal, replacement, cleaning, wet demolition, yard work, and set–up, were below the PEL.

Relatively high lead dust accumulations were found on workers' hands. Lead contamination levels on the floors in workers' vehicles were high compared to a nonworker comparison group, suggesting that lead contamination may be carried into the vehicles from the work area. Among workers who had blood lead level (BLL) results reported, the results indicated that this group had higher BLLs than the general population, and 38% of workers and site supervisors had BLL results at or above 25 micrograms per deciliter.

The results of this evaluation indicate that some changes in the contractors' respiratory protection programs should be made. While the respirators provided to workers (half–mask air–purifying respirators with a protection factor of 10) were appropriate for some of the tasks, a higher protection factor respirator is needed for wet or dry scraping tasks, as performed by participating contractors. Respirators should not be routinely required for the low hazard tasks, such as removal, replacement, cleaning, yard work, and set–up.

Worker lead exposures during various lead hazard reduction tasks were highly variable. On average, lead exposures during dry scraping, wet scraping, mixed surface prep, removal, and caulking tasks were hazardous. Average lead exposures for removal, replacement, cleaning, wet demolition, yard work, and set–up tasks were below the PEL. Reported blood lead monitoring results indicated occupational exposure to lead, and that some licensed personnel, particularly site supervisors, had hazardous exposures. Hand surface levels indicated the potential for ingestion of lead, and lead contamination of workers' vehicles was measured. Recommendations are provided in this report to help prevent hazardous worker exposures to LBP.

Keywords: SIC 1521 (General Contractors–Single–Family Houses) lead, abatement, lead–based paint, lead hazard reduction, housing, residential, blood lead level

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INTRODUCTION

In 1996, we received a request from the Rhode Island Department of Health (RI DOH) for an evaluation of worker exposures to lead during residential lead hazard reduction in Rhode Island. During three site visits, in September and December 1996, and June 1998, the National Institute for Occupational Safety and Health (NIOSH) evaluated occupational lead exposures at 20 homes undergoing lead hazard reduction work. Interim reports with results were sent to RI DOH on March 20, 1997, and March 31, 1998. Workers were sent individual notification letters in March 1997, notifying them of their personal air sampling results.

BACKGROUND

Title X of the Residential Lead–Based Paint Hazard Reduction Act of 1992 prescribed national efforts to protect occupants and workers from lead–based paint (LBP) hazards in pre–1978 housing.[1] As a result of Title X, over the past several years the U.S. Department of Housing and Urban Development (HUD) has developed guidelines for the evaluation and control of residential LBP hazards and has given grants to states and municipalities to abate lead hazards in private housing.[2] In 1996, RI DOH requested a NIOSH evaluation of worker lead exposures during residential lead hazard reduction in Rhode Island. Several factors contributed to this request. RI DOH was a HUD grantee, and had established a law governing these activities: Rules and Regulations for Lead Poisoning Prevention [R 23–24.6–PB].[3] The law requires training and certification for workers and contractors, and it specifies acceptable lead hazard reduction methods and worker protection practices.

The Occupational Safety and Health Administration (OSHA) also regulates lead hazard reduction work in Rhode Island under the lead construction standard [29 CFR 1926.62 (1993)].[4] OSHA requires that, when engaged in certain "trigger tasks" (e.g., dry manual scraping and sanding), employers must presume hazardous exposure levels and provide workers specified levels of respiratory protection, protective work clothing, and equipment. Employers can downgrade worker protection during these tasks if they conduct an exposure assessment which documents that workers' exposures are below the Permissible Exposure Limit (PEL), or have objective data demonstrating the same. According to RI DOH, most of the State–certified lead hazard reduction contractors required that workers wear half–mask air–purifying respirators equipped with high–efficiency particulate air (HEPA) filters for all tasks.

RI DOH was concerned that workers might be unnecessarily wearing respirators and protective clothing during some lead hazard reduction tasks. In addition to increased costs, RI DOH was concerned that this routine practice could pose a health risk to workers due to the added cardiovascular and heat stress of working in unconditioned environments while wearing respirators and protective clothing. RI DOH asked that NIOSH assess exposures during lead hazard reduction because the worker exposures for a number of the tasks were not well documented. Previous studies by NIOSH and HUD had found that worker exposures during lead hazard reduction were generally low, but that exposures varied greatly between and within work tasks.[5,6] Since those studies, typical work practices in HUD's hazard control program had shifted from on–site LBP removal to component replacement and renovating surfaces with LBP left in place.

The primary purpose of the NIOSH study was to characterize worker lead exposure during lead hazard reduction activities in homes with LBP. Secondary objectives were: (1) to determine the potential for lead exposures among workers' families (take–home exposures) from lead contamination of workers' vehicles, and (2) to evaluate the past exposures of RI lead hazard reduction workers by reviewing medical monitoring data.

The evaluation took place in single–family residences and multi–family housing not exceeding six units. Prior to the NIOSH site visits, RI DOH had prepared specific work orders, reviewed bids, selected a contractor, notified occupants, and arranged for temporary occupant housing (all units were unoccupied during lead hazard reduction work). The contractors prepared the worksites in accordance with Level 4 of the HUD Guidelines.[2] This included placing two layers of 6–mil plastic on the entire floor, posting entry warning signs, removing furniture or sealing (large) items with a single layer of 6–mil plastic, turning the ventilation system off, sealing all vents with plastic, and sealing doorways with a simple plastic airlock flap. Hygiene facilities usually included a designated sink in the residence, running water, hand soap, and disposable towels. All of the contractors provided their employees with disposable paper coveralls and half–mask air–purifying respirators equipped with HEPA filters.

METHODS

Environmental

Activities performed in the RI DOH lead hazard reduction program were initially reviewed and categorized by NIOSH. The assigned task categories were: caulking, cleaning, dry scraping, mixed surface prep, painting, replacement, set–up, removal, wet demolition, wet scraping, and yard work. The tasks are defined in Table 1. RI DOH notified licensed contractors of the NIOSH health hazard evaluation and asked for voluntary participation. RI DOH offered participating contractors a limited increase to their billable labor hours to compensate them for the time involved in participating in the study. We measured exposures only for those contractors and workers who volunteered to participate in the study. During the NIOSH site visits, RI DOH staff and the investigators selected sites with the maximum risk for employee exposure, based on the number of employees on site and amount and type of work specified.

Personal breathing zone air samples were collected to measure airborne lead exposure (PbA) during each hazard reduction task. Wherever possible, we used two sampling pumps per worker: one for sampling the worker's exposures during specific tasks (task–based samples), and one for a full–shift sample. A limited number of area air samples were collected in areas that would represent potential PbA exposures for bystanders or neighbors. Air samples were collected and analyzed using NIOSH Method 7082 (flame atomic absorption spectrophotometry). If no lead was detected by this method, the samples were subsequently analyzed by a more sensitive method, NIOSH Method 7105 (graphite furnace atomic absorption spectrophotometry).[7] The flow rate used for personal air sampling pumps was 2.0 liters per minute (Lpm); pumps were calibrated in the field pre– and post–sampling. The limits of detection (LODs) and limits of quantitation (LOQs) for lead in air samples ranged from 0.1 to 3 micrograms (μg)/sample and 0.4 to 10 μg/sample, respectively, depending on the laboratory method used (NIOSH 7105 or 7082), and sample dilution. Results are reported in micrograms per cubic meter ($\mu g/m^3$).

Surface wipe samples were collected in workers' and nonworkers' vehicles during the first field visit to determine surface lead (PbS) levels. Nonworkers' vehicles were those vehicles used by NIOSH and RI DOH investigators at the field sites (one personal and one rental car). The eight areas sampled in each vehicle were: driver's side (DS) front seat, DS front floor, DS armrest, steering wheel, DS dashboard, passenger's side (PS) front seat, PS front floor, and PS armrest. Seats, floors, and dashboards were sampled using 6" x 6" disposable plastic templates cut from 8.5" x 11" transparency sheets. The areas of other surfaces were measured with a tape measure. Results are reported in micrograms per square foot ($\mu g/ft^2$).

Workers' hands were sampled to assess the level of lead contamination before lunch and at the end of the shift. Where possible, to assess the effectiveness of hand washing on site, separate samples were collected before and after the workers washed their hands. Samples were collected on pre–moistened towelettes (Wash'n Dri®, Softsoap Enterprises, Inc, Chaksa, Minnesota) which have been found to be suitable for surface sampling for lead.[8] Participants were given a towelette and instructed to wipe both hands for 30 seconds. Wipes were then folded by the worker, and placed in hard plastic containers. They were analyzed according to NIOSH Method 9100.[7] Results are reported in µg/sample.

Results of environmental lead inspections performed by RI DOH were requested for houses which were included in the evaluation. The inspections followed the lead inspection protocol published by HUD.[2] The reports contained results of on–site paint lead measurements, done with portable x–ray fluorescence (XRF) analyzers, which were reported in units of milligrams per square centimeter (mg/cm^2). Where available, the paint lead results were included in our analyses.

For statistical purposes, the respective LOD / $\sqrt{2}$ was used to calculate an estimated value for samples with no detectable lead.[9] Statistical analyses were performed with StatView® 5.01, SAS Institute, Inc.

Medical

Medical surveillance data for licensed lead hazard reduction personnel in RI were analyzed. The RI DOH Rules and Regulations for Lead Poisoning Prevention require that all employers engaged in lead hazard reduction provide blood lead level (BLL) monitoring to employees at least every 12 months, and repeat testing for all workers with a BLL greater than 25 µg/dL.[3] Additionally, the state requires that laboratories located in the state report adult BLLs, regardless of source, to RI DOH. For this study, we analyzed RI DOH adult blood lead surveillance data for a two–year period (August 1994 –August 1996). Prior to April 1996, the reporting level was 25 µg/dL, but the convention among laboratories in the state was to report all adult BLLs; after April 1996, reporting of all adult BLLs was required. The data came from three sources: (1) laboratory reports received by the RI Office of Occupational and Radiological Health (1182 reports); (2) laboratory reports received by RI DOH from laboratories other than RI Hospital (including RI DOH's lab) (201 reports); and (3) laboratory reports received by the RI DOH from RI Hospital (438 reports). BLLs for lead hazard reduction workers were analyzed by cross–referencing the adult surveillance data with the state personnel listings for 352 lead hazard reduction workers licensed in RI at the time of this study.

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, and thus 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, 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 95–596, 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] Overexposure to lead may also result in damage to the kidneys, anemia, high blood pressure, infertility and reduced sex drive in both sexes, and impotence. An individual's BLL is used as the best indication of recent exposure to, and current absorption of, lead.[16] Measurement of zinc protoporphyrin (ZPP) levels in blood can be a good indicator of the toxic effect of lead on heme synthesis in red blood cells.

Measurement of the ZPP level in blood reflects the toxic effect of lead on heme synthesis in the body. Elevated ZPP levels due to lead exposure, which may remain months after the exposure, are an indicator of chronic lead intoxication. Persons without occupational exposure to lead usually have a ZPP level of less than 40 µg/dL.[17] Because other factors, such as iron deficiency, can cause an elevated ZPP level, the BLL is a more specific test in the evaluation of occupational exposure to lead.

In the OSHA lead standards for general industry and construction the PEL for PbA is 50 µg/m^3 (8–hour TWA), which is intended to maintain worker BLLs below 40 µg/dL; medical removal is required when an employee's BLL reaches 50 µg/dL.[18,19] NIOSH has concluded that the 1978 NIOSH REL of 100 µg/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.[21] 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 this, voluntary standards and public health goals have established lower exposure limits to protect workers and their children. The ACGIH TLV® for PbA is 50 µg/m^3 as an 8–hour TWA, with worker BLLs to be controlled to ≤30 µg/dL. A national health goal is to eliminate all occupational exposures which result in BLLs greater than 25 µg/dL.[22]

RESULTS

Environmental

The workers' daily schedules were highly variable. In practice, sampling times for the task–based samples and full–shift samples overlapped considerably. As a result, we established an arbitrary cut off; samples designated "full–shift" which were <360 minutes (min) duration were not used for statistical analysis. In cases where a worker performed a single task during the work shift, task–based samples could have a duration of >360 min. Due to the skewed distribution of the PbA and vehicle PbS sampling data, a natural log transformation of results was used for data analyses. After natural log transformation, the distribution of the PbA sampling results was normal (Kolmogorov–Smirnov test, $p > 0.999$). One–way analyses of variance (ANOVAs) were performed to determine if the work tasks were associated with

PbA concentration; the test for significance used was the F–test, p–value <0.05. Because the distribution of hand surface lead levels was not normal, even with log transformation, nonparametric statistics (Wilcoxon signed rank and Mann Whitney U tests) were used to analyze results; the level of significance was p–value <0.05.

RI DOH lead inspection reports with XRF paint lead measurements were obtained for 14 of 20 houses at which we sampled workers' PbA exposures; the number of measurements per house ranged from 45 to 529. Ninety–four percent of the measurements (2010/2145) were for interior surfaces. We excluded exterior paint measurements because no activities which disturbed exterior LBP were included in this study. The distribution of results was bimodal with peaks at 0.0 and 9.9 mg/cm^2. This occurred because the data was truncated at both ends by the detection limits of the portable XRF instruments used (Radiation Monitoring Devices, Inc., serial numbers 1205 and 1032); the lead inspectors entered all none detected values (<0.1 mg/cm^2) as 0.0, and we entered all readings above the instrument range (>9.9 mg/cm^2) as 9.9 mg/cm^2. The arithmetic mean (AM) interior paint lead concentration for the 14 houses with inspection reports was 3.96 mg/cm^2 (range: –0.5 to 37.9 mg/cm^2). AM interior paint lead concentrations by house ranged from 1.02 to 12.64 mg/cm^2. (Random error found in XRF measurements can cause results corrected for substrate effects to be less than zero.)[2] There was insufficient information available to analyze the association between mean paint lead and PbA concentrations by work surface so the analysis was done by house. The number of houses with both paint lead and PbA data available were 5 and 12, for full–shift and task–based PbA results, respectively. Results are summarized graphically in Figure 1. AM paint lead concentration (independent variable) and GM personal full–shift and task–based PbA exposure (dependent variables), were not correlated by house, $R^2 = 0.002$ and 0.01, respectively, and the regression line slopes were not significantly different than zero, p = 0.9.

Results for 20 full–shift (≥360 min duration) personal PbA samples, representing TWA exposures for 16 different workers at six residential lead hazard reduction sites, are presented in Table 2. Sample times ranged from 364 to 477 min; all of the exposures were during interior work. Twelve results were for workers who performed a single task over the work shift: dry scraping (10), cleaning (1), and painting (1). The eight other samples represented a mixed exposure including two or more of the following tasks: caulking, dry scraping, painting, plumbing, removal, replacement, and hand sanding. Results in Table 2 are sorted in descending order for PbA exposure by task category.

The GM full–shift PbA exposure was 29 µg/m^3 (95% confidence interval [CI] 13–65 µg/m^3). Individual results were highly variable, ranging from 1.5 to 1100 µg/m^3. Eight (40%) of the full–shift PbA exposures measured were above the OSHA PEL–TWA. Seven of the 10 full–shift exposures measured for dry scraping over the entire work shift were above the PEL. The maximum exposure (1100 µg/m^3), for a worker performing dry scraping of door jams, was more than 20 times the PEL. Full–shift PbA samples (n = 11) measured among eight workers who performed any scraping during their work shift (GM = 74 µg/m^3) were significantly higher than samples (n = 9) measured for seven workers performing only other tasks (GM = 9.4 µg/m^3) (p = 0.0038, Sheffe's F test). The results should be interpreted with caution because all the full–shift dry scraping samples were obtained at two houses, identified as "C"and "A" in Table 2. These houses, however, had mean paint lead concentrations in the middle of the range for houses with lead inspection reports available, 3.49 and 2.42 mg/cm^2, respectively.

Results for 152 task–based samples, representing 49 workers, and 19 residential lead hazard reduction sites, are presented in Table 3. Results are listed in descending order for GM by task. Samples were obtained for 11 task categories; the most sampled (and number of samples) were dry scraping (25), removal (22), cleaning (18), and wet scraping (17). All of the tasked–based PbA samples were for interior work, except for the following exterior tasks (number of samples): replacement (2), wet scraping (1), and yard work (13). The average duration for all tasks was 139 min (range: 6 to 452 min). Task–based PbA exposures were highly variable, ranging from 0.17 to 2000 µg/m^3; the GM exposures by task ranged from 150 µg/m^3 (dry scraping) to 1.3 µg/m^3 (yard work). Within–task variability was high, with geometric standard deviations (GSDs) ranging from 1.9 (set–up) to 8.0 (demolition). In spite of this variability, task category was highly associated with logged PbA exposure (one–way ANOVA, $p < 0.0001$). Sample duration (minutes) did not contribute to the model; there were too many missing cells to include mean (by house) paint lead concentration as a variable in the model.

Consistent with the full–shift results, the tasks producing the highest worker exposures were dry scraping and wet scraping, with GM exposures of 150 and 140 µg/m^3, respectively. Exposures for wet and dry scraping did not differ significantly ($p > 0.999$, Sheffe's F test). Several samples in the following task categories included the worker's exposure while briefly doing either dry scraping or hand planing (number of samples): mixed surface prep (2), painting (1), removal (1), and replacement (1). As noted in Table 3, the samples which included scraping or planing were the respective maximums for the tasks. The 47 samples which included any wet or dry scraping or planing during the work period sampled had significantly higher PbA exposures (GM = 144 µg/m^3) than the 102 other task–based samples, (GM = 10 µg/m^3) ($p < 0.001$, Sheffe's F test). It was not possible to determine the effect of location (interior vs. exterior) because only interior scraping was done in this study.

The task–based GM exposures were similar in magnitude to the actual full–shift exposures we obtained for a few tasks, see Tables 2 and 3. The 95% confidence limits for the task GM exposures are presented in Table 3. The 95% upper confidence limits (UCLs) were used to conservatively calculate the times performing the tasks that would result in a worker's 8–hour TWA reaching the OSHA PEL (50 µg/m^3), assuming no other lead exposure during the shift. The times, which are presented in Figure 1, ranged from 77 min for dry and wet scraping to 387 min for caulking. The remainder of the tasks would not, on average (at 95% UCL of the geometric mean), result in an exposure equal to the PEL within an 8–hour work shift.

At the request of a participating contractor, several additional task–based samples were collected at one site on one day to assess lead exposures while workers performed interior power sawing of new replacement doors (using a 7.25–inch circular saw) and power planing of an existing door with lead–based paint. The PbA results for five samples of power sawing, over periods of six to 77 min, ranged from none detected to 49 µg/m^3. The saw was used both with and without a cloth dust collection bag, but there were insufficient samples to evaluate the bag's effectiveness. A single sample of power planing, over a period of eight minutes, had a PbA concentration of 150 µg/m^3.

Twenty–seven hand PbS samples were collected from 15 workers before lunch and at the end of the shift. Fourteen samples were paired pre– and post–hand washing hand PbS samples from the seven workers; these results are presented in Table 4. Among paired results, all hand PbS levels pre–washing (mean = 5141 µg/sample) were significantly higher than those post–washing (mean = 1220 µg/sample) (Wilcoxon signed rank test, p = 0.018). The measured percent reduction in hand PbS levels among the paired results, [(pre– minus post–washing µg/sample)/pre–washing µg/sample]x100%, ranged from 53% to 90% (mean = 76%). Paired samples were not obtained for the other eight workers; either they did not report to the sampling location on site prior to washing their hands or had only a pre–washing sample because they reportedly did not wash their hands at the worksite. In some cases, there were no on–site facilities for hand washing. For the nine unpaired results, the pre–washing hand PbS levels (mean = 1840 µg/sample, range 31–9100 µg/sample) were not statistically different than the four post–washing levels (mean = 932 µg/sample, range 23–3300 µg/sample) (Mann–Whitney µ test, p = 0.16).

Surfaces in six vehicles were sampled over a two–day period. Results are presented in Table 5 and Figure 2. The GM PbS loadings at eight areas sampled inside the vehicles varied from 5.3 µg/ft^2

(nonworkers' cars, steering wheel) to 1240 µg/ft^2 (workers' cars, DS front floor). Overall, PbS levels in worker's vehicles (GM = 185 µg/ft^2) were an order of magnitude higher than those in nonworkers' vehicles (GM = 19 µg/ft^2). Vehicle type (worker vs. non–worker) and area were together significantly associated with log PbS levels in the vehicles (two–way ANOVA, p <0.001). The highest PbS levels in workers' vehicles were on the DS front floor, PS front floor, and DS armrest, with GM's of 1239, 455, and 375 µg/ft^2, respectively.

Medical

Medical surveillance data for six categories of licensed lead hazard reduction personnel were analyzed (contractors, lead inspectors, lead inspector technicians, site supervisors, workers, and workers–in–training). The analysis found that only 40 (11%) the 352 individuals on RI lists of licensed lead hazard reduction personnel had reported medical tests results (Table 6). The percentages of licensed workers, by job category, with reported results ranged from 3% (contractors) to 23% (workers). Results were not log transformed.

Sixty BLL test results were reported for 40 licensed individuals, some of whom had more than one reported BLL test. Overall, the AM BLL was 16 µg/dL (range: 1 to 65 µg/dL). Seventeen (43%) of the 40 individuals had at least one BLL greater than 15 µg/dL. The data indicate this group of lead hazard reduction personnel had higher BLLs than the general U.S. adult population, where <2% have BLLs >15 µg/dL, and the GM is <4 µg/dL.[23] The reported BLLs varied by license category, with site supervisors having higher BLLs (AM 27 µg/dL) than the other categories. Twenty–six individuals who were licensed as workers and site supervisors had a total of 42 reported BLL tests; of these, 21% (9/42), mostly site supervisors, exceeded the ACGIH Biological Exposure Indices® (BEI®) (30 µg/dL), and 38% (16/42) exceeded the U.S. year 2000 goal for worker exposures (<25 µg/dL). Only one person, a site supervisor, had a BLL higher than the OSHA medical removal level of 50 µg/dL.

Thirty–one ZPP test results were reported, among 12 licensed personnel. The highest ZPP levels were found among the site supervisors, who had a mean ZPP level of 38 µg/dL (range: 19–80 µg/dL), see Table 6. Workers and workers–in–training had mean ZPP levels of 18 and 16 µg/dL, respectively.

DISCUSSION

The lack of correlation found between paint lead concentrations and worker airborne lead exposures in this study is consistent with previous NIOSH studies of residential LBP abatement workers, which found a poor correlation between paint lead concentrations and worker exposures.[6,26] Because frequent exposure assessment with air monitoring is a burden to small contractors, many have expressed a desire for an action level for occupational exposure based on paint lead concentrations. OSHA has concluded that it is not possible to establish an action level for occupational exposure in construction work based on paint lead concentrations.[24] NIOSH studies support OSHA's conclusion and indicate the work method or task is the best predictor of PbA exposures in construction work.[6,26]

The level of workers' full–shift exposures to lead was highly dependent on whether or not scraping was performed during the work shift. On average, workers who performed any scraping (either wet or dry) during the work shift had full–shift exposures over the PEL, while workers performing only other tasks had, on average, exposures less than 20% of the PEL. Of the full–shift exposures for workers performing any dry scraping, 73% (8/11) were above the OSHA PEL. Among nine full–shift exposures for workers performing a mix of tasks without any scraping, none were exposed above the PEL. The maximum full–shift exposure measured for dry scraping (1100 µg/ft^2) was more than 20 times the PEL. According to NIOSH policy[25] and the OSHA construction lead standard, the half–mask air–purifying respirator with HEPA–filters (which was used by participating workers) is adequate only for protection up to 10 times the PEL.

Most of the samples collected were task–based, that is, shorter duration samples collected to measure the TWA exposure during a specific task. Within–task PbA results were highly variable. Likely sources of the variability observed are variations in paint condition, paint lead concentration, existing surface dust levels, tools, and work practices. Additionally, work crews often performed two or three tasks simultaneously in a residence. When one worker was performing a high–exposure task, this sometimes resulted in collateral high PbA exposures among other workers in the residence. The high within–task variability observed in PbA exposures makes it difficult to precisely classify the hazard potential for the 11 tasks evaluated. For example, seven of the tasks had maximum exposures an order of magnitude higher than the respective geometric means. Additionally, task–based samples were collected over relatively short segments of the work day and did not include breaks or other daily periods of low exposure, such as driving between worksites. Due to these factors, using the task maximum exposures (instead of geometric means) to represent the workers' typical day–to–day full–shift exposures would lead to overestimates of risk.

Actual full–shift exposures, which were obtained for a few single tasks, were generally similar to the geometric means for the corresponding task–based samples. We used the 95% upper confidence limit for task–based geometric means to conservatively calculate typical full–shift exposures by task. Of the 11 tasks evaluated, four had estimated full–shift exposures above the PEL: dry scraping, wet scraping, mixed surface prep, and caulking. The estimated full–shift exposure for the other seven tasks, including painting, removal, replacement, cleaning, wet demolition, yard work, and set–up, were below the PEL. While lead exposures were relatively low during wet demolition, we observed that there is a potential for exposure to other irritating or toxic dusts, including plaster and drywall dust, and biologically active materials. For example, in one house undergoing interior wet demolition of walls and ceilings, there was extensive visible mold growth on the walls and ceilings. The contractor reported that the house had been unoccupied for some time, and it had extensive water damage due to structural problems.

It is notable that worker lead exposures during interior scraping were relatively high (one full–shift result was more than 20 times the PEL), and the exposures during wet and dry scraping were not different. In contrast, a previous NIOSH study of lead hazard reduction workers at a multi–unit building in Ohio found lower (but still hazardous) exposures during interior scraping, and exposures were significantly reduced with wet methods.[26] Differences between the results obtained in this study and those obtained previously may be due to a combination of several factors, which, in estimated order of importance, are: (a) the amount of water applied to surfaces, (b) the amount of paint removed, and (c) the tools used. More research is needed to determine the relative importance of these factors, which are discussed below.

1. Amount and frequency of water application: the Rhode Island workers misted the painted surfaces lightly about every 15 minutes using water in hand spray bottles, while the Ohio workers applied water with electric–powered pressure sprayers connected to one–inch hoses with adjustable nozzles every 20 to 30 minutes. These commercial sprayers were reportedly designed for wetting materials during asbestos abatement work; they applied much more water to the painted surfaces than hand sprayers and appeared to wet them more thoroughly.

2. Amount of paint removed: in RI, the workers removed all paint from door frames, door edges, and window sills, totaling more than two square feet per room, to bare wood substrate, while in the previous study, contractors scraped large areas, including the entire walls and ceilings, but only removed the loose and peeling paint. In both studies, the painted surfaces were typically coated with multiple layers from many years of repainting; with latex paint in the upper (most recent) layers and alkyd LBP in the bottom (oldest) layers.

3. Hand tools used: RI contractors used pull–handle scrapers with replaceable carbide blades (2–inch Carbide Pull Scraper, 10–inch length,

model #803, Warner™ Manufacturing Company, Minneapolis, MN) to remove all paint to bare wood, while the Ohio workers used conventional scrapers, with 8–inch or 10–inch–wide hardened steel blades, and extension poles. According to the manufacturer, the carbide blades are 10 times sharper and 100 times stronger than hardened steel blades. The manufacturer's packaging contains the following statement to consumers: "Not recommended for lead–based paint removal." While the carbide–tipped scrapers may produce more fine dust than conventional scrapers, contractors in RI (and in several other States) have informed us that they are ergonomically superior, allowing removal of paint films with less force and total physical effort, resulting in higher productivity during paint removal jobs. (The manufacturer reported that the model #803 scraper is their most popular model in the U.S.)

Both dry and wet hand scraping are approved lead hazard reduction techniques under the Rhode Island lead regulations.[3] NIOSH and HUD have recommended that residential workers perform hand scraping wet instead of dry to reduce worker lead exposures.[21,27,28] This study demonstrates that in some situations wet methods do not reduce lead exposures when compared to dry methods. Participating Rhode Island contractors reported that wet scraping has a number of disadvantages, including: (a) wetting surfaces can create additional safety hazards (slip and fall, electrical), (b) jobs are delayed because surfaces cannot be repainted while they are wet, (c) wetted dust and paint chips stick to surfaces and are more difficult to clean up, (d) treatment or proper disposal of contaminated water is an added job element, and (e) the expected exposure reduction is not sufficient to allow lowering worker protection measures, including the level of respiratory protection.

It was surprising that the results indicated caulking is a potentially hazardous task, because applying latex or silicone caulk to cracks would not seem to generate any dust. The mean exposure for this task was strongly influenced by the two highest results; without them the geometric mean for caulking would be 18 $\mu g/m^3$. It is likely that these high levels represented collateral exposures from other dust–generating work in the same houses. A review of the highest result, 92 $\mu g/m^3$ for a 212–min sample, revealed that another worker in the residence, who was exposed to 130 $\mu g/m^3$ over the same time period, was painting and dry scraping. The next highest result, 48 $\mu g/m^3$ for a 9–min sample, was for a worker who immediately before had performed mixed surface prep (83 $\mu g/m^3$, 39–min TWA) and painting (22 $\mu g/m^3$, 119–min TWA) in the same residence. Since workers reported that these sequences were typical, all of the results for caulking were used in the data analyses since they apparently represent actual exposures during caulking even if not from caulking itself. It appears that worker exposures to airborne lead during caulking (and other tasks) could be reduced simply by changing the sequencing of work activities.

The surface sampling results indicated that there were relatively high lead dust accumulations on surfaces. There are no occupational exposure standards for lead on surfaces; however, surface lead contamination can be both a source of airborne lead and a source of ingested lead (via contamination of hands, food, or tobacco products). While hand lead levels were significantly reduced by washing on site, the average pre– and post–washing hand lead levels among this group of workers was high compared to the Ohio study mentioned above. For example, the mean post–washing level in Rhode Island was 1220 µg/both hands, compared to 71 µg/both hands in Ohio.[26] The Ohio workers more frequently wore cotton or leather work gloves during paint removal activities. Lead contamination in the Rhode Island workers' personal vehicles was high compared to a nonworker control group, suggesting hygiene practices at worksites did not prevent lead contamination from being carried into the vehicles. The highest lead dust levels in vehicles were on the driver's side floors, suggesting that much of the lead dust is carried out of the worksites on shoes. Mean lead levels on the driver's side floor in workers' vehicles was high (1240 $\mu g/ft^2$) compared to the nonworker control group (100 $\mu g/ft^2$), and workers' vehicles in a previous study of renovation work in pre–1960 homes in Cincinnati (310 $\mu g/ft^2$).[29] Lead contamination in the workers' personal vehicles represents a potential health hazard to the workers' families.

Medical surveillance data indicated that a relatively low proportion of the Rhode Island licenced lead hazard reduction personnel had BLL monitoring results reported to the state. Since only a small percentage of licensed personnel had results reported, the medical monitoring results cannot be generalized to all lead abatement workers in Rhode Island. The paucity of reported monitoring results is probably due to one or more of the following factors: (1) licenced contractors not complying with State and federal rules, (2) personnel becoming licensed but not performing work in the state, (3) laboratories not reporting BLL results, and (4) licensed personnel obtaining their medical tests at an out–of–state laboratory. More investigation of active contractors would be needed to determine their level of compliance with medical monitoring requirements. Among workers who had BLL results reported, the results indicated that this group had occupational exposure to lead, with the majority having BLL results below the ACGIH BEI® of 30 µg/dL and the U.S. national health goal of 25 µg/dL. One individual (a site supervisor), had a BLL above the OSHA medical removal level (50 µg/dL). It is notable that site supervisors had higher lead exposures than other personnel categories, with an average BLL exceeding 25 µg/dL. The ZPP test results provide additional evidence that the site supervisors who had data reported to the state are at risk of occupational exposure to lead. Some of the supervisors were "working supervisors" who performed hazardous tasks at least part of the day. They may have had higher exposures because of differences in work or hygiene practices, or differences in the use of respirators. We did observe that some supervisors were less likely than other personnel to wear respirators; they may have falsely assumed that because their time in the work area was less, they did not need to wear a respirator.

There were some typical problems with the use of respirators. Some of the lead exposures we measured during interior scraping exceeded the protection range of the half–mask respirators which were used. We observed that in some cases personnel loosened or removed their respirators to alleviate discomfort and heat stress during the summer months. Many of the residences had no air conditioning, and as a result, the temperature and humidity inside were similar to outdoor conditions. One contractor, who brought a window air conditioner to the work site and temporarily installed it, reported that air conditioning increased worker productivity as well as comfort. Better compliance with respiratory protection requirements may occur if they are required only for certain tasks identified as hazardous, rather than for all lead hazard reduction tasks. Implementation of this approach will require training workers and supervisors to recognize the potentially hazardous tasks.

RECOMMENDATIONS

The following recommendations are offered to assist the RI DOH and participating contractors in protecting workers and their families from hazardous lead–based paint exposures during lead hazard reduction work. The recommendations are based on the monitoring results and observed work practices for Rhode Island lead hazard reduction workers. The recommendations should be applied to all personnel, including site supervisors, who participate in the residential lead hazard reduction work.

1. Contractors should provide appropriate respirators to any workers doing wet or dry hand scraping. Based on the results of this study, respirators with a NIOSH assigned protection factor greater than 10 should be used for this type of hand scraping; either a powered air–purifying respirator with high efficiency (NIOSH N100) filters and a loose fitting hood or helmet, or a full–facepiece air–purifying respirator with high efficiency (NIOSH N100) filters. These are NIOSH–certified for protection against exposures of up to 25 and 50 times the PEL, respectively. The former type is more costly, but is more comfortable and can be worn with facial hair.

2. At a minimum, half–mask respirators with high efficiency (NIOSH N100) filters should be worn for protection against hazardous lead exposures during other potentially hazardous tasks, including mixed surface prep (it should be possible to eliminate hazardous exposures during caulking, see below).

This type of respirator should also be worn during any wet demolition work, due to the potential for exposure to other toxic or irritating aerosols. Because heat stress and cardiovascular stress are potential health problems for respirator wearers, especially in the warm months when the heat stress index is high, RI DOH and contractors should consider use of window air conditioners with HEPA filters and providing the most comfortable respirators of the recommended type, which are single–use or maintenance–free respirators equipped with HEPA filters (NIOSH N100 certification).

3. Contractors should take additional care in the sequencing of work activities during lead hazard reduction jobs to reduce or eliminate the hazard potential of caulking and other non–dust–generating tasks. Ideally, the sequence of work in a house should be "dirty" tasks (scraping, surface preparation, and other dust–generating tasks), cleaning, and then "clean" tasks (caulking, painting, replacement, etc).

4. Respirators should not be necessary or required for routine removal, replacement, cleaning, yard work, and set–up tasks. The exception is for cases where circumstances indicate a higher exposure potential (such as a collateral exposure from a higher exposure task) is possible.

5. During tasks which disturb lead–based paint, workers and site supervisors should be provided with, and wear, cotton or leather work gloves to reduce hand contact with hazardous lead–contaminated dust. The gloves should be laundered or changed regularly to keep them clean.

6. To reduce lead contamination of workers' personal vehicles contractors should provide portable hand–washing facilities if a sink is not available at the worksite and stress improved hygiene practices. Workers and site supervisors should: (a) change shoes or clean shoes with a HEPA vacuum at the end of their shift, (b) use cleanable plastic floor mats in their vehicles, and (c) regularly clean their vehicles with a HEPA vacuum. The vacuums should be cleaned off before taking them out of the work areas.

7. More attention to respiratory protection in training courses, or oversight by RI DOH, may be needed to ensure that workers and site supervisors are using appropriate respiratory protection during hazardous tasks.

8. RI DOH should evaluate whether lead hazard reduction contractors are offering the required medical monitoring, and whether licensed personnel are participating in the programs. If participation is found to be low, RI DOH should consider instituting additional educational programs to inform licensed companies and personnel about the state medical monitoring standards and appropriate compliance activities.

9. More research is needed to determine the reason(s) for the ineffectiveness of the wet scraping method in reducing worker exposures among the Rhode Island workers. In the interim, RI DOH and contractors should discuss possible method modifications and determine if they are feasible. Applying much more water with hose–mounted sprayers or hand spraying much more frequently may reduce airborne lead exposures, but the potential safety hazards and other disadvantages of wet scraping may outweigh this benefit.

10. More research is needed to characterize exposures during power tool use and the effectiveness of power tools equipped with dust collection systems (dust bags, dust reservoirs, dust collection connected to HEPA–vacuum exhaust) for controlling worker lead exposures during paint removal. Several commercially available systems appear to be promising alternatives to manual scraping (either wet or dry) for removal of lead–based paint.

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Table 1. Description of lead hazard control tasks evaluated

Task	Work Description
Caulking	Application of caulk compound around replacement windows and other cracks in wood trim.
Cleaning	Daily and final cleanup of work areas by broom sweeping, HEPA vacuuming, or wet washing. Final cleaning included removal of containment poly and wet mopping.
Dry Scraping	Complete or partial removal of deteriorated paint by manual scraping with 2–inch carbide–tipped pull scrapers. Paint was usually removed to bare wood substrate on door jams, edges of doors, and window sills.
Mixed Surface Prep	A mix of two or more surface preparation activities which may have included caulking, plastering, manual sanding, manual scraping, or HEPA vacuuming.
Painting	Application of non–lead–based paint after surface preparation.
Replacement	Installation of new windows, wood trim, and other building components.
Set–up	Initial and daily set–up of equipment and the containment area, including covering floors and furniture with polyethylene sheeting.
Removal	Manual removal of windows, wood trim, or other painted building components prior to replacement.
Wet Demolition	Manual demolition of damaged plaster walls and ceilings. Surfaces were wetted with water using hand spray bottles (small areas) or hoses with spray heads (large areas).
Wet Scraping	Complete or partial removal of deteriorated paint by manual scraping with 2–inch carbide–tipped pull scrapers. Surfaces were misted with water prior to scraping using hand spray bottles. Paint was usually removed to bare wood substrate on door jams, edges of doors, and window sills.
Yard Work	Preparation of bare soil areas, tilling soil, planting new grass or other ground cover, watering yard areas.

Table 2. Full–shift personal lead exposures for interior lead hazard reduction work

Task	House I.D.	Worker No.	Sample Time min	PbA µg/m3
Cleaning	N	1	408	1.7
Dry scraping	C	2	378	1100
Dry scraping	C	3	364	190
Dry scraping	C	4	381	180
Dry scraping	C	5	386	110
Dry scraping	C	6	433	100
Dry scraping	C	7	421	58
Dry scraping	C	5	411	54
Dry scraping	C	2	425	26
Dry scraping	A	8	398	13
Dry scraping	A	9	388	3.5
Mixed – with scraping[A]	C	10	401	224
Mixed – no scraping[B]	S	11	369	46
Mixed – no scraping	R	11	429	20
Mixed – no scraping	R	12	371	14
Mixed – no scraping	F	13	442	14
Mixed – no scraping	F	14	465	12
Mixed – no scraping	R	12	441	11
Mixed – no scraping	F	15	477	10
Painting	N	16	409	1.5
Geometric mean				29

[A] Mixed exposure included dry scraping, removal, and vacuuming.

[B] Mixed exposure with no scraping which included two or more of the following tasks: caulking, painting, plumbing, removal, replacement, or hand sanding.

Table 3. Task–based airborne lead exposures for hazard reduction workers

Task	Count	GM[A] μg/m³	95% Confid. Limits[B] μg/m³		Minimum μg/m³	Maximum μg/m³
Dry scraping	25	150	72	310	5.5	2000
Wet scraping	17	140	65	310	4.8	1400
Mixed surface prep	6	39	13	120	8.1	129[D]
Removal	22	31	20	48	3.3[C]	340[D]
Caulking	6	28	12	62	14	92
Painting	13	12	5.8	25	1.2	130[D]
Replacement	14	9.9	3.5	28	*0.48*[E]	290[F]
Cleaning	18	6.5	2.7	16	*0.27*[E]	93
Wet demolition	9	5.8	1.2	28	*0.40*[E]	62
Set–up	9	1.4	0.85	2.2	*0.39*[E]	3.2
Yard work	13	1.3	0.58	2.9	0.17	21
All Tasks	**152**	**19**	**13**	**27**	**0.17**	**2000**

[A] geometric mean

[B] lower and upper 95% confidence limits for geometric mean

[C] semiquantitative value; the result was between the detection and quantitation limits

[D] the sample included periods of dry scraping

[E] *No lead detected;* the LOD/(2)$^{1/2}$ was used to calculate an estimated numerical value for statistical analyses

[F] the sample included periods of hand planing

Table 4. Worker hand lead levels before and after hand washing

Worker No.	Sampled at	Lead (for both hands) µg/sample:		Percent reduction, Pb
		Pre–washing	Post–washing	
1	lunch	11000	3200	71%
4	end–of–shift	3400	350	90%
6	lunch	2200	320	85%
10	end–of–shift	390	180	53%
13	lunch	13000	2800	78%
14	lunch	1600	190	88%
15	lunch	4400	1500	65%
Mean		5141	1220	76%

Table 5. Geometric mean surface lead levels in vehicles

Area in Vehicle	Workers (n=4) $\mu g/ft^2$	Nonworkers (n=2) $\mu g/ft^2$
DS[a] armrest	375	37
DS dashboard	116	8.4
DS front floor	1240	100
DS front seat	69	13
PS[b] armrest	149	40
PS front floor	455	23
PS front seat	119	8.5
Steering wheel	46	5.4
Overall	**185**	**19**

[a]DS = driver's side

[b]PS = passenger's side

Table 6. RI medical surveillance data for licensed lead hazard reduction personnel

RI License Category	No. Persons Listed[a]	No. Persons Tested (%)[b]	BLL Results (µg/dL)[c]				ZPP Results (µg/dL)[d]		
			No.[e]	AM[f]	Range	No. (%) > 15[g]	No.[e]	AM	Range
Site Supervisors	69	14 (20%)	22	27	3–65	10 (14%)	8	38	19–80
Workers	53	12 (23%)	20	12	2–34	5 (9%)	3	18	14–21
Workers–In–Training	83	5 (6%)	7	10	3–17	2 (2%)	1	16	
Contractors	58	2 (3%)	3	9	6–14	0	0		
Lead Inspector Technicians	29	4 (14%)	4	4	2–6	0	0		
Lead Inspectors	60	3 (5%)	4	3	1–4	0	0		
Total	**352**	**40 (11%)**	**60**	**16**	**1–65**	**17 (43%)**	**12**	**31**	**14–80**

[a] The number of RI licensed lead hazard reduction personnel by category, 8/94–8/96.
[b] The number and percent of licensed personnel with reported medical tests results.
[c] Blood lead level in micrograms per deciliter.
[d] Zinc protoporpyrin in micrograms per deciliter.
[e] Number of tests (some individuals had more than one test).
[f] Arithmetic mean.
[g] Number of persons with at least one BLL test > 15 µg/dL.

Figure 1. **Mean natural log (LN) Paint Lead vs. Mean LN Full–shift and Task–based PbA Concentrations, by House**

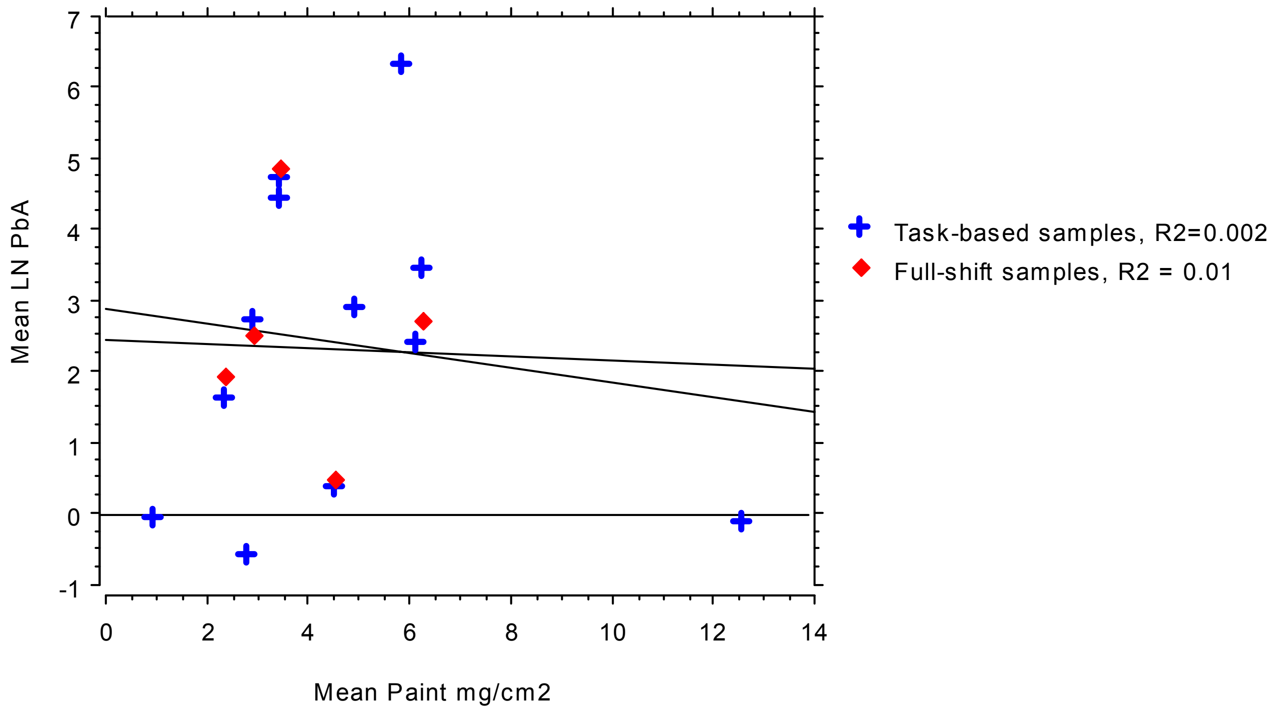


Figure 2. Time Performing Task That Would Result in TWA equal to the PEL, at 95% UCL for Geometric Mean.

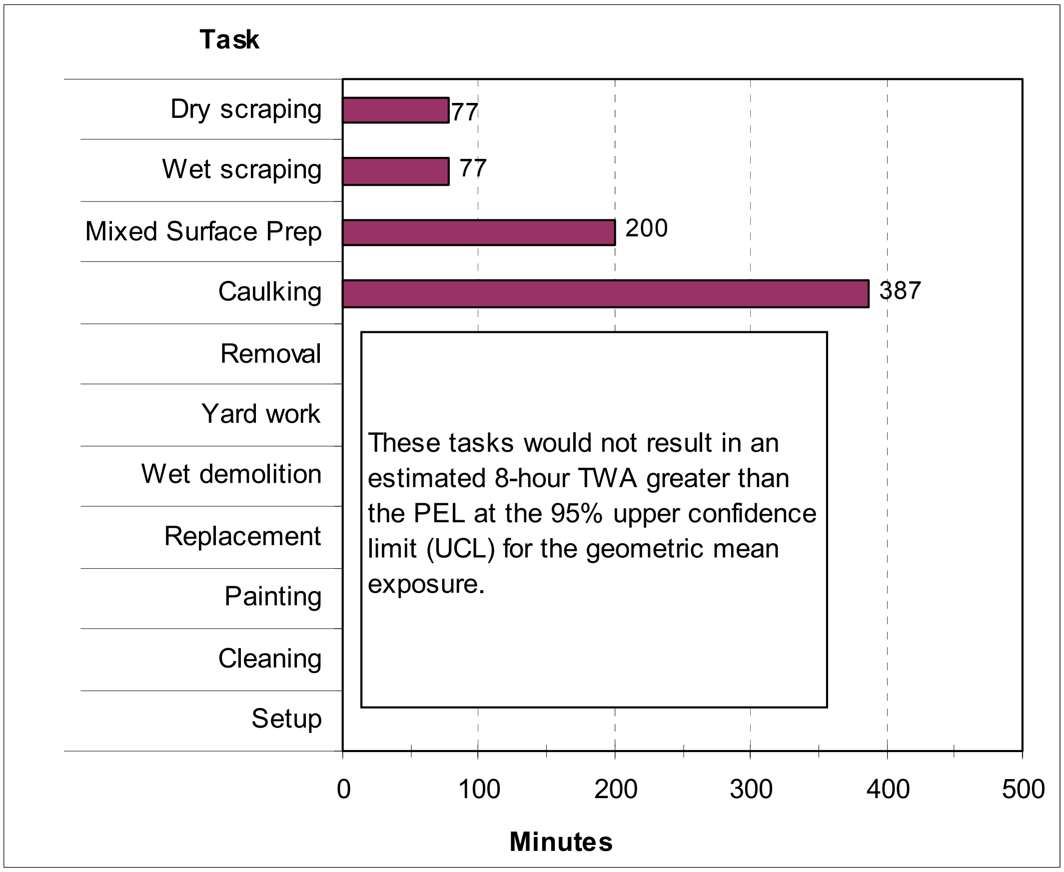
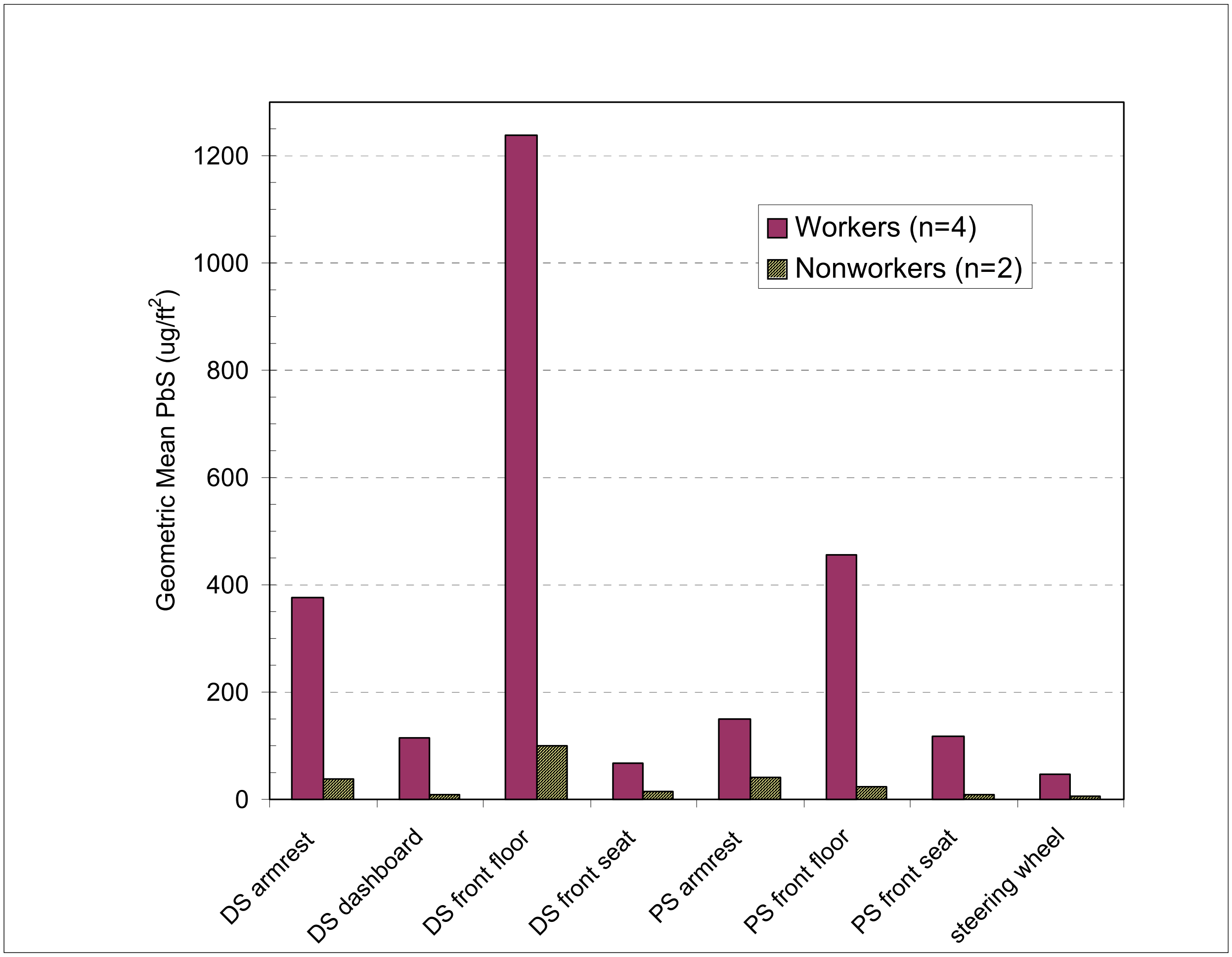


Figure 3. Geometric mean surface lead levels in vehicles



For Information on Other Occupational Safety and Health Concerns

Call NIOSH at:
1–800–35–NIOSH (356–4674)
or visit the NIOSH Web site at:
www.cdc.gov/niosh