NIOSH HEALTH HAZARD EVALUATION REPORT:

HETA #99–0113–2853
University of California, Berkeley
Berkeley, California

July 2001

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

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 and Greg Piacitelli of the NIOSH Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Zulfi Chaudhry, DSHEFS, provided data entry and data management. Charles A. Mueller, DSHEFS, provided statistical analyses of the data.

This study would not have been possible without the support and cooperation of the Department of Environment, Health & Safety, UC Berkeley, and California members of the Painting and Decorating Contractors of America (PDCA). We gratefully acknowledge the planning time, labor, and materials provided by participating contractors including Burt Olhiser of Hazard Management Services, Inc.; Steve Jeffress, Jeffco Painting & Coating, Inc.; Bob Spurgeon, Spurgeon Painting; Bob O'Brien, O'Brien Painted to Last; Don O'Brien, O'Brien Painting; David and Jeanne Moore, North Coast Painting, and the Golden Gate Chapter of the Associated Builders and Contractors (ABC).

The following persons provided invaluable assistance and support during the field investigation: Kevin Roegner, Zulfi Chaudhry, and Tami Wise, NIOSH; Gary Bayne and Christine Little, Department of Environment, Health & Safety, UC Berkeley, and Jennifer Portera, industrial hygienist. Analytical support was provided by DataChem Laboratories. Desktop publishing was performed by Ellen E. Blythe. Review and preparation for printing were performed by Penny Arthur.

Copies of this report have been sent to employee and management representatives at UC Berkeley 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:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800–356–4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Lead Exposures During Renovation of Building with Lead Paint

This NIOSH Health Hazard Evaluation was requested by the University of California, Berkeley. We measured exposures during a 1999 demonstration project at three unoccupied campus buildings. The purpose was to measure worker lead exposures, as well as lead levels (air and dust) in nearby areas during eight renovation tasks. All of the tasks involved removing exterior lead-based paint, which is typically done prior to repainting.

What NIOSH Did

- Took air samples for lead on workers for eightdifferent tasks used to remove lead paint on building exteriors.
- Collected air and settled dust samples to measure lead in nearby areas during the same work periods.
- Collected a paint chip sample from each surface, and measured production rate for each work period.

What NIOSH Found

- Task, worker, and paint lead concentration are associated with renovation workers' lead exposures.
- Tasks with high worker lead exposures were dry manual sanding, dry manual scraping, power finish sanding, and power finish sanding with bag.
- Tasks with lower worker lead exposures were power sanding with HEPA exhaust, flame burning, wet manual sanding, and wet scraping.
- All of the tasks can produce lead contamination in nearby areas. Flame burning and power finish sanding resulted in the highest levels of lead in air and settled dust in nearby areas.

What University of California, Berkeley Managers Can Do

- Whenever possible, use tasks with low worker exposures for renovating surfaces with lead paint.
- When lead paint is present, avoid the tasks which had the highest worker lead exposures and lead levels in nearby areas.
- 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 the University of California, Berkeley Employees Can Do

- Use protective clothing and good hygiene when doing any tasks on surfaces with lead paint.
- When working on surfaces with lead paint, clean shoes and equipment daily, and clean your personal vehicle often.
- Wear respirators when using high exposure tasks on lead paint.

CDC Workplace Safety and Health

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 #99–0113–2853

National Institute for Occupational Safety and Health NIOSH

Health Hazard Evaluation Report 99–0113–2853
University of California, Berkeley
Berkeley, California
July 2001

Aaron L. Sussell
Greg M. Piacitelli

SUMMARY

At the request of the University of California, Berkeley, the National Institute for Occupational Safety and Health (NIOSH) conducted a study of lead–based paint (LBP) exposures during exterior renovation work on campus buildings. Workers' personal airborne lead (PbA) exposures were assessed for eight renovation tasks during a three–day demonstration project. Additionally we measured concomitant area PbA concentrations 6 feet (ft) from the work surfaces, lead in settled dust (PbS) at three distances (6, 10, and 20 ft) from work surfaces for five tasks, and determined if these measures were correlated with the workers' PbA exposures. Five workers performed assigned renovation tasks during limited work periods (average time 28 minutes [min]) on 22 painted exterior surface areas (wood windows, wood doors, and metal stairs). A total of 132 work periods were sampled; the work took from 2 to 12 work periods per designated work surface, depending on the area. Lead concentrations in paint chip samples (one per work surface) ranged from 0.23% to 34% lead (Pb) by weight (average 11.3%). Personal PbA exposures were highly variable; range, none detected to 660 micrograms per cubic meter ($\mu g/m^3$), geometric mean (GM) = 22 $\mu g/m^3$, geometric standard deviation (GSD) 4.3. Personal PbA exposures were significantly associated with task, worker, and paint lead concentration ($p < 0.001$). High–exposure tasks were dry manual sanding (GM = 49 $\mu g/m^3$), dry manual scraping (53 $\mu g/m^3$), power finish sanding (44 $\mu g/m^3$), and power finish sanding with bag (68 $\mu g/m^3$). Low–exposure tasks were power sanding with high–efficiency particulate air (HEPA) exhaust (GM = 6.9 $\mu g/m^3$), wet manual sanding (6.2 $\mu g/m^3$), wet manual scraping (16 $\mu g/m^3$), and flame burning (23 $\mu g/m^3$). The area PbA concentrations at 6 ft distance, which were also highly associated with task, were roughly an order of magnitude below the personal exposures, ranging from none detected to 37 $\mu g/m^3$, GM = 1.5 $\mu g/m^3$, GSD = 3.3. GMs for PbS samples were 3.2 milligrams per square meter (mg/m^2) at 6 ft (n=69), 1.4 mg/m^2 at 10 ft (n=67), and 0.66 mg/m^2 at 20 ft (n=39). Overall PbS levels decreased significantly as distance increased ($p < 0.0001$). At each distance PbS levels were significantly associated with task (p–values 0.024, 0.0015, and <0.0001, respectively). Flame burning was among the tasks associated with the highest area PbA and PbS levels, although personal exposures were relatively low. Surface paint lead concentrations were poorly correlated with the PbA exposures (R = 0.30). Personal and area PbA levels were significantly correlated (R = 0.49, $p < 0.0001$). Both area and personal PbA concentrations were significantly correlated with PbS levels measured 6 ft and 10 ft from the work surfaces (R values 0.34 to 0.73). Area PbA levels were significantly correlated with the PbS levels at 20 ft as well (R = 0.67).

Worker lead exposures for eight renovation tasks on building exteriors with LBP were highly variable. Based on workers' exposures, the eight renovation tasks evaluated fell into two exposure groups. Estimated average exposures during dry manual sanding, dry manual scraping, power finish sanding, and power finish sanding with bag would exceed the permissible exposure limit (PEL) within an 8–hr period. Estimated average exposures for power sanding with HEPA exhaust, flame burning, wet manual sanding, and wet scraping would be below the PEL. Although it resulted in relatively low worker exposures, flame burning was among the tasks associated with the higher lead levels in air and settled dust levels in nearby areas. The power finish sander with a cloth dust bag was not effective in controlling worker exposures; the random–orbital power sanding equipped with HEPA–filtered exhaust ventilation appeared to be highly effective. Recommendations are provided in this report to help prevent hazardous worker exposures to LBP during renovation of surfaces with LBP.

Keywords: SIC 1521 (General Contractors–Single–Family Houses) lead, renovation, remodeling, painters, lead–based paint, painting, lead hazard, housing, residential

TABLE OF CONTENTS

INTRODUCTION

In 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Office of Environment, Health and Safety (EH&S) at the University of California, Berkeley (UC Berkeley) for an evaluation of worker lead exposures during various renovation tasks requiring the disturbance of lead–based paint (LBP). LBP is defined by federal statute as paint with lead levels equal to or exceeding 1.0 milligrams per square centimeter (mg/cm^2) or 0.5% by weight [see the Toxic Substances Control Act (TSCA) Section 401(9) (15 U.S.C. 2681(9)], U.S. Environmental Protection Agency(EPA)). During a site visit in March 1999, NIOSH investigators collected air and settled dust samples during a three–day renovation demonstration project which took place at unoccupied university buildings.

BACKGROUND

Renovators and painters throughout the United States commonly encounter LBP in their work on buildings and other structures. A national survey determined that 83 percent of U.S. private housing units built before 1980 have LBP.[1] Lead hazards are a concern not only to residential renovation contractors but also homeowners who work on their own houses.

The UC Berkeley EH&S department wanted to determine which tasks which could be commonly used to renovate campus buildings were the safest for workers and occupants. Local members of the Painting and Decoration Contractors of America (PDCA) also had an interest in obtaining an objective assessment of lead exposures for the work tasks commonly performed by their members. Therefore, the EH&S department and local PDCA members arranged to conduct a demonstration project to evaluate worker exposures to lead during eight renovation tasks of interest. All of the tasks involve removal of loose and deteriorated LBP from exterior wood and steel surfaces on buildings to prepare the surfaces for repainting. UC Berkeley requested NIOSH technical assistance to conduct a task–based assessment of worker exposures and environmental lead levels resulting from these renovation tasks. The tasks selected by UC Berkeley and the local PDCA members were designated (task number, name): (1) dry manual sanding, (2) dry manual scraping, (3) flame burning, (4) power finish sanding, (5) power finish sanding with bag (with cloth bag dust collector), (6) power sanding with high–efficiency particulate air (HEPA) (with HEPA filtered local exhaust ventilation), (7) wet manual sanding, (8) and wet manual scraping. The task categories are described in more detail in Table 1; photographs of the demonstration project are in Figure 1.

Uncontrolled power random–orbital sanding was not included in this evaluation because the task is well known to generate high lead exposures and UC Berkeley policy prohibited its use on surfaces with LBP. Federal guidelines for residential lead paint work require that all orbital power sanders and grinders be controlled with HEPA vacuum attachments.[2,3] The same guidelines also recommend against using open flame burning. However, participating PDCA members requested that open flame burning be included in the study. They reported that open flame burning is the best method for certain renovation jobs, especially removal of exterior LBP from decorative wood trim on historic Victorian homes, and is used successfully by many of their professional members not only in the San Francisco Bay area but also across the country.

The primary purpose of the NIOSH study was to assess worker personal airborne lead (PbA) exposures for eight renovation tasks. Secondary objectives were to (1) measure concomitant area PbA levels 6 ft from the work surfaces, (2) measure lead in settled dust (PbS) 6 to 20 feet from work surfaces for five tasks, and (3) determine if area air and settled dust levels were correlated with the workers' PbA exposures.

The project took place at three unoccupied buildings on the UC Berkeley campus which were scheduled for demolition: two 2–story multifamily residences (Smyth–Fernwald Buildings C and D), and an adjacent 1½–story multipurpose building (known as the "Daycare Center"). The building exteriors were stucco, with painted wood windows (including sashes, sill, and casing), wood doors (including casing), and metal stairs and railings. Previous LBP inspection had found that most of the exterior surfaces, except the stucco siding, were coated with LBP. The windows, door, and stair surfaces were prepared as they normally would be for repainting using the eight renovation tasks. After the demonstration project was completed UC Berkeley planned to demolish the buildings and perform a clean up of the site.

Participating PDCA contractors provided five workers, personal protective equipment, and the tools needed. All of the participating workers had previously completed training required by the California Department of Health Services for workers performing residential lead hazard reduction work. The workers wore disposable paper coveralls and half–mask air–purifying respirators with NIOSH type N100 filters during all tasks. Hygiene facilities, including running water, hand soap, disposable paper towels, and a clean lunch room, were provided inside the Daycare Center.

METHODS

The demonstration project was conducted during a three–day period. Seventeen exterior work locations of approximately equal area were marked out on the buildings. The locations included one or more painted wood windows or doors (15 locations), and exterior open metal stairs with LBP (two locations). During the demonstration we discovered that the buildings did not have enough painted work surfaces to complete the scheduled number of work periods. As a result, five surplus wood doors with LBP were brought from another construction site. Since the paint appeared to be in the same general condition, both sides of each door was considered to be a single work surface. The doors were treated by leaning them against a wall at two of the designated locations. With the addition of the doors, a total of 22 work surfaces (windows, doors, or stairs) were used. The surfaces used generally had similar paint condition, with minimal to moderate deterioration. Stucco siding did not have LBP and was not included as a work surface. The work was done on the first story of the buildings, or on open stairs between floors. It was necessary for some of the workers to use ladders to reach the tops of windows and their casings.

During each work period, workers performed an assigned task at one location for approximately 30 minutes. The five workers worked simultaneously; to minimize cross–contamination, the locations which were used were at least 50 ft apart. After each work period, workers rotated between locations. Each location was used for multiple work periods involving different workers, and many were used for multiple tasks. The surface area treated by the worker, and the work time in minutes was measured for each work period; the results were used to calculate the production rate in square feet per hour (ft^2/hr).

Task–based air sampling was conducted during separate work periods on three consecutive days. During each work period, a breathing zone air sample was collected on the worker to measure personal airborne lead (PbA) exposure, and a paired area PbA sample was collected 6 ft away (perpendicular to wall) at the approximate midpoint of the treated area. PbA 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 using NIOSH Method 7105 (graphite furnace atomic absorption spectrophotometry).[4] The flow rate used for PbA samples was 4.0 liters per minute (Lpm). Pumps were calibrated in the field pre– and post–sampling daily; the average of the two flow measurements was used in calculating results (differences between pre– and post– were less than 5%). The 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 ($\mu g/m^3$).

Limited sampling for lead in PbS was done concurrently with PbA sampling. Due to time and resource limitations PbS sampling was limited to five tasks (dry manual scraping, flame burning, power finish sanding, power sanding with HEPA exhaust, and wet manual scraping) on the first day and part of the second day. On the first day, PbS samples were collected during work periods at distances of 6 ft, 10 ft, and 20 ft from the work surface, measured perpendicular to the wall. On the second day, PbS samples were collected in the same manner but at the 6 ft and 10 ft distances only (no dust was visible on samples collected at the 20 ft distance on the first day). All of the 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 PbS sampling.[5] 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). The towelette was re–wetted with distilled water from a hand spray at intervals to keep the towelette moist. At the end of each 30–min work period, the towelette was folded inward upon itself to contain any dust adhering to it, and placed in a 50–milliliter (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).

At each work location, and for each of the surplus wood doors used, one bulk paint sample was collected according to American Society for Testing and Materials (ASTM) Method E1729–99.[6] 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, a 0.2 gram (g) portion of each sample was prepared and analyzed by NIOSH Method 7082 (flame atomic absorption spectrometry).[4] Results were reported as percent by weight. The LOD for lead was 0.001% and the LOQ was 0.004%.

All of the laboratory lead analyses were reported with a precision of two significant digits. Accordingly, calculated results were rounded off to two significant digits. For statistical purposes, the respective LOD/($2^{(0.5)}$) was used to calculate an estimated value for samples with no detectable lead.[7]

Statistical analyses were performed with StatView® 5.01 and SAS® for Windows, version 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).

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[8] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[9] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[10]

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)]. 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 recognized 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."[11,12,13] 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.[14]

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.[15] 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).[16] 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 lead in air (PbA) of 50 µg/m^3 as an 8–hour TWA, which is intended to maintain worker BLLs below 40 µg/dL.[17,18] OSHA has also established an action level for PbA of 30 µg/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 µg/m^3 as an 8–hour TWA does not sufficiently protect workers from the adverse affects of exposure to inorganic lead.[19] 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.[14] 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 µg/m^3 as an 8–hour TWA, with worker BLLs to be controlled to $\leq$30 µg/dL.[20] 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 from 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. 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

Lead concentrations in 22 paint chip samples (1 per work surface) ranged from 0.23% to 34% Pb by weight. Twenty–one of the 22 paint samples (95%) had a lead concentration above the federal action level of 0.5% Pb.[23] The distribution of the results adequately fit normal (Kolmogorov–Smirnov test). The average paint lead concentration was 11.3% (standard deviation [SD] 10%). Work surfaces were used from 2 to 12 work periods depending on the size of their area. Since surface areas available for renovation were limited, workers maximized the use of each surface area by performing the designated task on all of the available area. The surface–weighted average lead concentration ((∑[surface Pb concentration x no. of times surface was used]) ÷total no. of work periods) was 14.0% (SD 10.8).

A total of 132 work periods were sampled for PbA. Some samples were lost due to sampling errors, leaving 128 personal and 130 area PbA samples for eight renovation tasks. The number of work periods sampled per task ranged from 8 to 26. The number of work periods sampled per worker ranged from 25 to 27: worker 1 was sampled 27 times, workers 2, 3, and 4, were sampled 25 times, and worker 5 was sampled 26 times. PbA, PbS, surface area treated, and production rate results were natural log transformed for data analyses; after transformation the data distributions adequately fit normal (Kolmogorov–Smirnov test).

Weather conditions on the three days of environmental sampling were cloudy to partly cloudy, with light and variable winds. Although the objective was to sample work periods of 30–min duration, in practice the work periods varied from 13 to 76 min due to sampling or equipment problems (mean 28 min, SD 6.0). The geometric mean (GM) surface area treated was 5.2 ft^2 (geometric standard deviation [GSD] 2.3, range 0.29 to 42 ft^2). Production rates, expressed as ft^2/hour, are summarized by task in Table 2. The production rate data should be interpreted with caution. This data was collected during a demonstration project where workers did not have the time pressures of a real job. Among 128 work periods with personal PbA results, the GM production rate was 15 ft^2/hr (GSD 13, range 0.5 to 100 ft^2/hr). Flame burning (GM = 21 ft^2/hr) and dry manual scraping (18 ft^2/hr) had similar production rates which were higher than the other tasks evaluated. However, with one exception the differences between task production rates did not reach statistical significance. Flame burning had a significantly higher production rate (GM = 21 ft^2/hr) than power finish sanding (10 ft^2/hr),(p–value = 0.0058).

Air Lead Results

Personal PbA exposures during 128 work periods were highly variable, ranging from none detected (estimated numeric value *0.39* $\mu g/m^3$) to 660 $\mu g/m^3$, GM = 22 $\mu g/m^3$, GSD 4.3. An analysis of covariance (ANCOVA) was done to examine the association of task, worker, paint lead concentration, and production rate with the (log) personal PbA levels. The overall model was highly significant. However, since the production rate variable neither contributed significantly to the model (p value = 0.56) nor varied significantly between workers (p=0.40), this variable was dropped.

PbA means were adjusted for the effects of task, worker, and paint lead concentration (SAS® GLM procedure, with least squares means). Personal PbA exposures were jointly highly associated with task, worker, and paint lead concentration variables ($p < 0.001$) in the final (adjusted) model. The most important association in the final model was task ($p < 0.001$), followed by paint lead concentration ($p = 0.027$) and worker ($p = 0.042$). The adjusted and unadjusted means were very similar, with the exception of two tasks: power finish sanding (task 4) and power finish sanding with bag (task 5). The surface paint lead concentration had an effect on the means for tasks 4 and 5 because the mean paint Pb levels for these two tasks (32% and 2.0%, respectively) were quite different than means for the other six tasks (range 9.4 – 13.9%). Differences in personal PbA exposures between tasks 4 and 5 did not reach statistical significance either before or after adjustment.

The GM and 95% CLs (adjusted and unadjusted), and minimum and maximum values for personal PbA exposures by task are presented in Table 3. As can be seen graphically in Figure 2, although PbA exposures were highly variable, the tasks fall roughly into two exposure groups. High–exposure tasks were dry manual sanding (GM = 49 $\mu g/m^3$), dry manual scraping (53 $\mu g/m^3$), power finish sanding (44 $\mu g/m^3$), and power finish sanding with bag (68 $\mu g/m^3$). Exposures during these four tasks were not statistically different from each other but were significantly higher than those during tasks 6–8. Low–exposure tasks were power sanding with HEPA exhaust (GM = 6.9 $\mu g/m^3$), wet manual sanding (6.2 $\mu g/m^3$), wet manual scraping (16 $\mu g/m^3$), and flame burning (23 $\mu g/m^3$). Among the four low–exposure tasks, only flame burning was significantly different than any of the others. Flame burning had significantly higher personal PbA exposures than power sanding with HEPA exhaust and wet manual sanding. Maximum exposures for six of the eight tasks evaluated were greater than 50 $\mu g/m^3$; however, due to the high variability of exposures within tasks they are not representative of the workers' average exposures for those tasks. The maximum individual exposures for two low–exposure tasks, power sanding with HEPA and wet manual sanding, did not reach 50 $\mu g/m^3$.

For each task the 95% upper confidence limit (UCL) for the adjusted GM was used to conservatively estimate the time, on average, that a worker could perform the task before his personal PbA exposure reached the OSHA PEL–TWA (50 $\mu g/m^3$). The estimated times are presented graphically in Figure 3. It was estimated that the high–exposure tasks (dry manual sanding, dry manual scraping, power finish sanding, and power finish sanding with bag) would result in a worker's exposure reaching the OSHA PEL in less than 8 hours. Estimated times to reach the PEL ranged from 2.4 hours for power finish sanding with bag to 4.4 hours for dry manual scraping and power finish sanding. It was estimated that the four low–exposure tasks (flame burning, power sanding with HEPA exhaust, wet manual sanding, and wet manual scraping) would not, on average, result in a worker's exposure reaching the PEL within an 8–hour work shift.

Results for the 130 TWA area PbA samples collected 6 ft from work surfaces are summarized by task in Table 4. As a secondary outcomes, area PbA results were not adjusted for the effects of other variables. The area PbA concentrations overall were roughly an order of magnitude below the personal exposures, ranging from none detected (estimated value *0.08* $\mu g/m^3$) to 37 $\mu g/m^3$, GM = 1.5 $\mu g/m^3$, GSD = 3.3. Area PbA concentrations were highly associated with task, (analysis of variance, $p < 0.0001$); the associations of other variables with area PbA levels were not examined. Tasks associated with the highest area PbA concentrations were power finish sanding (GM = 5.9 $\mu g/m^3$), and power finish sanding with bag (7.6 $\mu g/m^3$). These two tasks, which were not statistically different from each other, had higher area PbA levels than all the other tasks. Flame burning (2.6 $\mu g/m^3$) was among the tasks with high area PbA concentrations; it had significantly higher area PbA concentrations than tasks 2, 6, 7, and 8. Tasks associated with low area PbA levels were power sanding with HEPA exhaust (GM = 0.60 $\mu g/m^3$), wet manual sanding (0.73 $\mu g/m^3$), and wet manual scraping (0.65 $\mu g/m^3$). These three tasks, which were not statistically different from each other, also had the lowest personal PbA exposures.

Dust Lead Results

PbS samples were collected for five of the tasks (numbers 2, 3, 4, 6, and 8). Results for 69 PbS samples at 6 ft, 67 samples at 10 ft, and 39 samples at 20 ft were obtained (two 10 ft samples were lost). The average PbS sample duration was 31 min. At all of the sample locations detectable amounts of lead were measured; the PbS results by task are summarized in Table 5. PbS results were not adjusted for the effects of other variables.

PbS concentrations overall were highly variable, ranging from 0.13 to 380 mg/m^2. Overall PbS levels decreased significantly with distance at 6 ft (GM = 3.2 mg/m^2, GSD = 4.4), 10 ft (1.4 mg/m^2, GSD = 3.3), and 20 ft (0.66 mg/m^2, GSD = 2.3), ANOVA, p–value <0.0001. At all three distances, the GM PbS levels, resulting from an average work period of 30.6 min, were higher than the EPA standard for lead loading on interior residential floors (0.43 mg/m^2). At each distance, PbS levels were significantly associated with task (ANOVA p–values 0.024, 0.0015, and <0.0001, respectively). Flame burning and power finish sanding were associated with higher PbS levels than the other tasks at all distances. The differences at 6 ft and 10 ft did not reach statistical significance; at the 20 ft distance PbS levels from flame burning (GM = 1.7 mg/m^2) and power finish sanding (1.0 mg/m^2) were significantly higher than levels from all other tasks (range of GMs: 0.26 – 0.66 mg/m^2) in paired comparisons. PbS levels did not differ significantly between power sanding with HEPA exhaust and wet manual scraping at any distance.

Correlations

As shown in Figure 4, surface paint lead concentrations were relatively poorly correlated with the (log) PbA exposures (R = 0.30). Personal and area PbA levels were significantly correlated, R = 0.49, p <0.0001, see Table 6. Both area and personal PbA concentrations were significantly correlated with PbS levels at 6 ft and 10 ft from the work surfaces, R values 0.34 to 0.73. Area PbA levels were significantly correlated with the PbS levels at 20 ft as well, R = 0.67. The PbS levels at 6 ft and 10 ft levels were more highly correlated with the area PbA concentrations than with the personal PbA levels. This is an expected result because the area PbA sample locations (6 ft from the work surfaces) were closer to the PbS sample locations than the worker personal sample.

DISCUSSION

Lead levels in personal and area air, and settled dust samples were measured for eight renovation tasks performed on exterior windows, doors, and staircases with LBP. Nearly all of the work surfaces had lead concentrations greater than the EPA statutory limit for LBP (≥ 0.5% Pb), and the average surface lead concentration, weighted by the number of times each surface was used, was 28 times the statutory definition of LBP.

In considering these results it is important to recognize that the study took place on exterior surfaces of buildings and the results **cannot be generalized to interior work**. It is likely that the airborne lead concentrations and settled dust levels would have been higher if the work was done indoors. Indoors typically there is less ventilation and less air volume for dispersion of lead–containing dust.

Employers have expressed interest in having an action level for lead in construction based on paint lead concentrations. Previous NIOSH studies have concluded that worker lead exposures during LBP abatement and renovation work are highly variable and that when paint lead concentrations and task–based worker exposures are compared, there is little or no correlation between these two variables.[14,24] This study found the same result; worker exposures during some of the renovation tasks were highly variable, and overall they were poorly correlated with paint lead concentrations. OSHA has concluded that is not possible to establish an action level for construction work based on paint lead concentrations; instead the OSHA action level is based on personal PbA exposure monitoring.[25]

When task, worker, and paint lead concentration were analyzed, these variables were jointly significantly associated with the workers' lead exposures. Of these variables, the one which the employer can readily control is the selection of task, and the task clearly had the most important effect on workers' personal exposures. The significant differences between workers suggest that individual variations in work practices can be important, even among trained workers. The production rate (surface area treated per hour) was not associated with the workers' lead exposures under study conditions.

The high–exposure tasks were dry manual sanding, dry manual scraping, power finish sanding, and power finish sanding with bag. It was estimated that, on average, these four tasks would result in a worker's exposure exceeding the OSHA PEL within an 8–hour work shift. Lower worker exposures were measured during power sanding with HEPA exhaust, flame burning, wet manual sanding, and wet scraping. It was estimated that, on average, none of these methods would result in a worker's exposure reaching the OSHA PEL during the work shift. Flame burning had significantly higher personal exposures than power sanding with HEPA exhaust and wet manual sanding. Of the tasks evaluated, power sanding with HEPA exhaust and wet manual sanding had the lowest worker lead exposures and area airborne lead levels 6 ft from work surfaces.

On some jobs where LBP is present, workers are reportedly required to wear respirators all the time. These results indicate that such a blanket requirement is not appropriate for work on exterior surfaces with LBP. Wearing air–purifying respirators should only be required when they are necessary to protect against an airborne toxic exposure, because wearing a respirator (a) stresses the worker's cardiovascular and respiratory systems, (b) reduces worker comfort, productivity, and safe communication with other workers, and (c) can increase the potential for heat stress.

Tasks which were associated with the highest area airborne lead concentrations were power finish sanding, power finish sanding with bag, and flame burning. Overall the area airborne lead concentrations at 6 ft from the work surfaces were highly correlated with lead in settled dust collected at 6, 10, and 20 ft from the work surfaces.

It is puzzling that flame burning was among tasks associated with high area air and settled dust lead levels but not one of the methods with the highest worker lead exposures. More detailed investigation would be needed to determine the reason for this. It may be that workers kept the open flame torch further from their faces than the other tools. Increased distance between the paint removal tool and workers' breathing zones may have reduced personal lead exposures without affecting nearby area air and settled dust levels. The use of open flame burning or heat guns above 1100° F for paint removal is not recommended under HUD's federal guidelines for lead paint safety.[2] The recommendation is based in part on a presumption that high levels of lead dust will result. This study confirms that flame burning can produce relatively high air and settled dust lead levels in nearby areas (6 to 20 ft from work surfaces). Additionally, both flame burning and heat gun can produce other toxic vapors from decomposition of paint and can be a serious fire hazard.

The average amounts of lead found in settled dust after short work periods (average PbS sample time of 31 min) decreased significantly with distance from 6 to 20 ft from the work surfaces. Overall, the average lead loadings at all three distances (6, 10, and 20 ft) exceeded the current EPA standard for lead dust on interior floors of residences. Tasks which were associated with the highest levels of lead in settled dust, particularly at 20 ft from work surfaces, were power finish sanding and flame burning. It is likely that these tasks produced fine particles more easily carried by the natural ventilation which occurs outside.

While the results show that renovation work can potentially contaminate soil up to 20 ft from work exterior work surfaces, the health significance of the settled dust lead levels cannot be determined from this study. The samples were collected from ground level after short work periods and do not reflect the accumulated total lead levels on the soil after job completion and site clean up. A previous NIOSH study of renovation work in homes with LBP found that average PbS levels in homes undergoing renovation, and in workers' and volunteers' vehicles, represented a potential health hazard to young children.[24] A 1991 federal study of residential lead abatement work found that soil lead levels next to homes undergoing LBP abatement were increased by the work in spite of contractors' efforts to contain the dust.[26] However, that study also found that even before work began, average soil lead levels near urban homes with LBP were high—nearly twice the current EPA soil lead standard of 400 ppm.

Federal and California 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.[2,27] Additionally, these guidelines recommend that specialized clean up procedures be used at the end of the renovation jobs to reduce lead contamination.

The effectiveness of the engineering controls evaluated was mixed. The power finish sander with perforated sandpaper and a dust collection bag was ineffective in controlling worker exposures or nearby area airborne lead concentrations. In contrast, the random–orbital power sander, equipped with perforated sandpaper and HEPA–filtered local exhaust ventilation, appeared to be highly effective in controlling worker exposures and area lead concentrations. Previous studies of LBP removal by uncontrolled power sanding have found worker exposures up to 100 times the PEL.[14] The results show that worker exposures and area lead levels during power sanding with HEPA exhaust were not significantly different from the other low exposure methods, wet manual scraping and wet manual sanding. The power sander with HEPA exhaust ventilation also was associated with relatively low levels of lead in settled dust at distances of 6 to 20 ft from the work surfaces.

RECOMMENDATIONS

The following recommendations are offered to assist UC Berkeley and the participating contractors in protecting workers and occupants from hazardous lead–based paint exposures during future exterior renovation work on surfaces with LBP. They are based on the study results and previous NIOSH evaluations of similar LBP work.[28,29]

1. Whenever possible, use low–exposure methods, i.e., power sanding with HEPA exhaust, wet manual sanding, or wet scraping. For exterior work, respirators should not be routinely required for these tasks. Where circumstances create, or observations indicate, a potential for higher exposures, provide respirators until an initial exposure assessment is done to confirm the actual exposure levels.

2. Avoid prolonged use of high–exposure tasks, i.e., exterior dry manual scraping, dry sanding, power finish sanding, and power finish sanding with bag. If it is necessary to use one of these high–exposure tasks, workers should be routinely provided with, and wear, appropriate respirators in the context of a respiratory protection program. Half–mask air–purifying respirators (either single–use or reusable) with high efficiency (NIOSH N100) filters provide adequate protection for these tasks during exterior work (a higher level of respiratory protection should be provided for interior work).

3. Based on its potential to contaminate nearby areas (air and settled dust) with high levels of lead, and create other hazards for the worker, open flame burning should be avoided. Federal guidelines for renovation work (published by the U.S. Department of Housing and Urban Development [HUD] and EPA) mandate that this method is never acceptable for removing LBP on federally–supported projects due to the combined hazards of airborne lead, and other toxic emissions from heating/burning paint, and the fire hazard.[2,3]

4. For all renovation work where LBP is present, contractors should provide lead hazard training, and require workers to wear protective clothing and use good hygiene practices.[2,3] Portable handwashing facilities should be provided by the contractor if acceptable hygiene facilities are not available at the work site. To prevent take home of lead via personal vehicles, workers and site supervisors should: (a) clean shoes daily, (b) use washable

plastic floor mats in their vehicles, and (c) regularly clean their vehicles.

5. Where renovation work will disturb lead paint, follow federal and state standards and guidelines for lead–safe work, including accepted procedures for dust containment and site clean up in homes with lead paint.[2,3,18]

REFERENCES

1. EPA [1995]. Report on the national survey of lead–based paint in housing: Base report. Washington, DC: U.S. Environmental Protection Agency. Publication No. EPA 747–R95–003.

2. HUD [1999]. Lead paint safety, a field guide for painting, home maintenance and renovation work. Washington, DC: U.S. Department of Housing and Urban Development, Office of Lead Hazard Control. Publication No. HUD 1779–LHC.

3. EPA [1994]. Reducing lead hazards when remodeling your home. Washington, DC: U.S. Environmental Protection Agency. Publication No. EPA 747–R–94–002.

4. NIOSH [1994]. NIOSH manual of analytical methods, 4th edition. Eller, P and Cassinelli, ME, Eds. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

5. Millson M, Eller PM, Ashley K [1994]. Evaluation of wipe sampling materials for lead in surface dust. Am Ind Hyg Assoc J *55*:339–342.

6. ASTM [2000]. E1729–99 Standard Practice for Field Collection of Dried Paint Samples for Lead Determination by Atomic Spectrometry Techniques. West Conshohocken, PA: American Society for Testing and Materials.

7. Hornung RW, Reed LD [1990]. Estimation of average concentration in the presence of non detectable values. Appl Occup Environ Hyg *5*:46–51.

8. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92–100.

9. ACGIH [2001]. 2001 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

10. CFR [1997]. 29 CFR 1910.1000. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

11. Hernberg S, et al. [1988]. Lead and its compounds. In: Occupational Medicine. 2nd ed. Chicago, IL: Year Book Medical Publishers.

12. Landrigan PJ, et al. [1985]. Body lead burden: summary of epidemiological data on its relation to environmental sources and toxic effects. In: Dietary and environmental lead: human health effects. Amsterdam: Elsevier Science Publishers.

13. Proctor NH, Hughes JP, Fischman ML [1991]. Lead. In: Chemical Hazards of the Workplace. 3rd ed. Philadelphia, PA: J.B. Lippincott Company, pp 353–357.

14. Sussell A, et al. [1998]. Protecting workers exposed to lead–based paint hazards: A report to Congress. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98–112. January 1998–revised with minor technical changes.

15. NIOSH [1978]. Occupational exposure to inorganic lead. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 78–158.

16. Lauwerys RR and Hoet P [1993]. Industrial chemical exposure: guidelines for biological monitoring, Second Edition. Ann Arbor, MI: Lewis Publishers, p. 62.

17. CFR. Code of Federal regulations. OSHA lead standard for general industry. 29 CFR, Part 1910.1025. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

18. CFR. Code of Federal Regulations. OSHA construction industry lead standard. 29 CFR, Part 29 CFR 1926.62. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

19. 62 Fed. Reg. 206 [1997]. National Institute for Occupational Safety and Health: occupational exposure to inorganic lead: request for comments and information.

20. ACGIH [2001]. 2001 TLVs® and BEIs®. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

21. DHHS [2000]. Healthy people 2010–conference edition; National health promotion and disease objectives. Washington, DC: U.S. Department of Health and Human Services. Available on the internet at: www.health.gov/healthypeople/Document/default.htm

22. 66 Fed. Reg. No. 4 [2001]. U.S. Environmental Protection Agency: Lead–based paint hazards, January 5, 2001. (To be codified at 40 CFR Part 745)

23. HUD [1995]. Guidelines for the evaluation and control of lead–based paint hazards in housing. Washington, DC: U.S. Department of Housing and Urban Development, Office of Lead Hazard Control.

24. Sussell A, Gittleman J, Singal M [1998]. Worker lead exposures during renovation of homes with lead–based paint. Applied Occ and Env Hygiene 13(11):770–775.

25. 58 Federal Register No. 84 [1993]. Occupational Safety and Health Administration: Supplementary information, (E) Reasons for differences with HUD Guidelines on certain provisions. Lead exposure in construction; Interim final rule, pp. 26593–94.

26. HUD [1991]. The HUD lead–based paint abatement demonstration (FHA). Washington, DC: U.S. Department of Housing and Urban Development, Dewberry & Davis contract report HC–5831, August 1991.

27. CDHS [1999]. Painting contractor's guide to lead safety. Berkeley, CA: California Department of Health Services, Occupational Lead Poisoning Prevention Program.

28. Sussell A, Gittleman J, Singal M [1998]. Worker lead exposures during renovation of homes with lead–based paint. Applied Occ and Env Hygien 13(11):770–775.

29. NIOSH [2000]. Hazard evaluation and technical assistance report: Rhode Island Department of Health, Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 96–200–2799.

Table 1. Description of Renovation Tasks Evaluated

Task No.	Task Name	Work Description
1	Dry manual sanding	Hand sanding of painted surfaces with 80–grit aluminum oxide sandpaper with folded full sheet or with a hand sanding block.
2	Dry manual scraping	Complete or partial removal of paint by manual scraping with pull scrapers fitted with replaceable 2–inch tungsten–carbide blades.
3	Flame burning	Complete removal of paint by heating with propane torch flame and then manual scraping with a steel blade with 2–inch triangular tip.
4	Power finish sanding	Power sanding painting surfaces with 80–grit aluminum oxide sandpaper on a quarter sheet palm grip sander (Dewalt® model DW411). Non perforated sandpaper was used, so the sander's integral cloth dust bag was not functional.
5	Power finish sanding with bag	Power sanding painting surfaces with 80–grit, 9–hole aluminum oxide sandpaper on a quarter sheet palm grip sander with cloth dust bag (Dewalt® model DW411).
6	Power sanding with HEPA	Power sanding painted surfaces with 100– or 120–grit, 5–inch, 8–hole aluminum oxide sanding discs on a 5–inch random–orbital sander (Bosch® model 3107 DVS) connected to a HEPA vacuum (Pullman–Holt® model 102) rated at 100 cubic feet per minute.
7	Wet manual sanding	Hand sanding of painted surfaces with 80–grit sandpaper with folded full sheet or with a hand sanding block. Surfaces (small areas) were wetted with water using trigger–spray bottles.
8	Wet manual scraping	Complete or partial removal of paint by manual scraping with pull scrapers fitted with replaceable 2–inch tungsten–carbide blades. Surfaces (small areas) were wetted with water using trigger–spray bottles.

Table 2. Production Rates for Eight Renovation Tasks, 128 Work Periods

Task No.	Task	Count	Production Rate ft^2/hr GM[A]	95% Confid. Limits [B]		Pairs with Significant Difference
1	Dry manual sanding	8	13	0.68	25	
2	Dry manual scraping	17	18	5.8	30	
3	Flame burning	26	21	17	25	3,4 p = 0.0058
4	Power finish sanding	18	10	7.5	13	3,4 p = 0.0058
5	Power finish sanding with bag	7	13	8.2	18	
6	Power sanding with HEPA exhaust	24	15	10	19	
7	Wet manual sanding	8	12	0.92	22	
8	Wet manual scraping	20	14	9.8	18	
	All Tasks	**128**	**15**	**13**	**18**	

† least squares means adjusted for the effects of paint lead concentration and worker.

[A] geometric mean

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

Table 3. TWA Personal PbA Exposures for Eight Renovation Tasks (μg/m^3)

Task No.	Task	Count	Range of Values	Unadjusted Values			Adjusted Values†			Significantly Different (p<0.05) than Other Tasks
				GM[A]	95% Confid. Limits [B]		GM[A]	95% Confid. Limits [B]		
1	Dry manual sanding	8	11 – 220	44	19	100	49	22	108	6–8
2	Dry manual scraping	18	12 – 660	56	31	99	53	31	90	3, 6, 7, 8
3	Flame burning	26	1.8 – 160	20	13	32	23	15	37	2, 5, 6, 7
4	Power finish sanding	18	*0.39*[C] – 380	75	35	160	44	22	90	6–8
5	Power finish sanding with bag	7	31 – 81	44	32	59	68	28	167	3, 6–8
6	Power sanding with HEPA exhaust	25	1.6 – 37	6.8	4.8	9.9	6.9	4.4	11	1–5, 8
7	Wet manual sanding	8	1.8 – 13	5.9	3.3	10	6.2	2.8	14	1–5, 8
8	Wet manual scraping	18	**0.13**[D] – 200	14	6.8	29	16	9.3	27	1, 2, 4–7
	All Tasks	128	**0.13**[D] – 660	22	17	28				

† least squares means adjusted for the effects of paint lead concentration and worker.

[A] geometric mean

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

[C] None detected result; the LOD/2$^{(0.5)}$ was used to calculate an estimated numerical value.

[D] Semi–quantitative value, analytical result was between the LOD and LOQ.

Table 4. TWA Area PbA Concentrations 6 ft Away from Work Surfaces for Eight Renovation Tasks, (µg/m^3)

Task No.	Task	Count	Range of Values	Unadjusted Values GM[A]	Unadjusted Values 95% Confid. Limits [B]		Significantly Different (p<0.05) than Other Tasks
1	Dry manual sanding	8	*0.57*[C] – 7.2	1.5	0.74	3.2	4–6, 8
2	Dry manual scraping	18	*0.49*[C] – 4.1	0.90	0.64	1.3	3–5
3	Flame burning	26	*0.36*[C] – 13	2.6	1.8	3.8	2, 4–8
4	Power finish sanding	18	**0.92**[D] – 37	5.9	3.5	10	1–3, 6–8
5	Power finish sanding with bag	7	4.8 – 16	7.6	5.0	12	1–3, 6–8
6	Power sanding with HEPA exhaust	25	*0.31*[C] – 2.7	0.60	0.47	0.76	1, 3–5
7	Wet manual sanding	8	*0.40*[C] – 2.5	0.73	0.45	1.2	3–5
8	Wet manual scraping	20	**0.08**[D] – 1.9	0.65	0.48	0.90	1, 3–5
	All Tasks	130	**0.08**[D] – 37	1.5	1.2	1.8	

[A] geometric mean

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

[C] None detected result; the LOD/2$^{(0.5)}$ was used to calculate an estimated numerical value.

[D] Semi–quantitative value, analytical result was between the LOD and LOQ.

Table 5. PbS Concentrations at 6 ft, 10 ft, and 20 ft Perpendicular from Work Surfaces, Eight Renovation Tasks (mg/m²)

Task No.	Task	PbS 6 ft			PbS 10 ft			PbS 20 ft		
		Count	Range of Values	GM[A] (95% Cls)[B]	Count	Range of Values	GM[A] (95% Cls)[B]	Count	Range of Values	GM[A] (95% Cls)[B]
2	Dry manual scraping	14	0.42 – 380	3.8 (1.2, 12)	14	0.19 – 23	1.1 (0.40, 2.1)	8	0.13 – 0.63	0.26 (0.17, 0.42)
3	Flame burning	13	0.32 – 248	5.8 (1.5, 17)	13	0.32 – 24	2.6 (1.2, 5.9)	7	0.73 – 5.1	1.7 (0.91, 3.1)
4	Power finish sanding	14	2.5 – 19	5.8 (4.0, 8.4)	14	1.2 – 8.2	3.0 (2.2, 4.3)	8	0.46 – 2.6	1.0 (0.63, 1.7)
6	Power sanding with HEPA exhaust	15	0.56 –2.7	1.3 (0.95, 1.7)	13	0.42 – 1.8	0.81 (0.61, 1.1)	9	0.34 – 0.97	0.57 (0.42, 0.76)
8	Wet manual scraping	13	0.35 – 160	2.4 (0.93, 6.4)	13	0.18 – 7.4	0.87 (0.43, 1.7)	7	0.17 – 1.6	0.54 (0.26, 1.1)
All Tasks		69	0.32 – 380	3.2 (2.3, 4.6)	67	0.18 – 24	1.4 (1.0, 1.9)	39	0.13 – 5.1	0.66 (0.50, 0.87)

[A] geometric mean

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

Table 6. Correlations Between Log PbA and Log PbS Measurements for Eight Renovation tasks. Pearson R values (number of paired observations).

	PbA, personal	PbA, area	PbS 6 ft	PbS 10 ft	PbS 20 ft
PbA, personal		0.49** (128)	0.34* (65)	0.45* (63)	0.14† (35)
PbA, area			0.55** (67)	0.73** (65)	0.67** (37)
PbS 6 ft				0.78** (67)	0.67** (39)
PbS 10 ft					0.82** (39)

** p value <0.0001

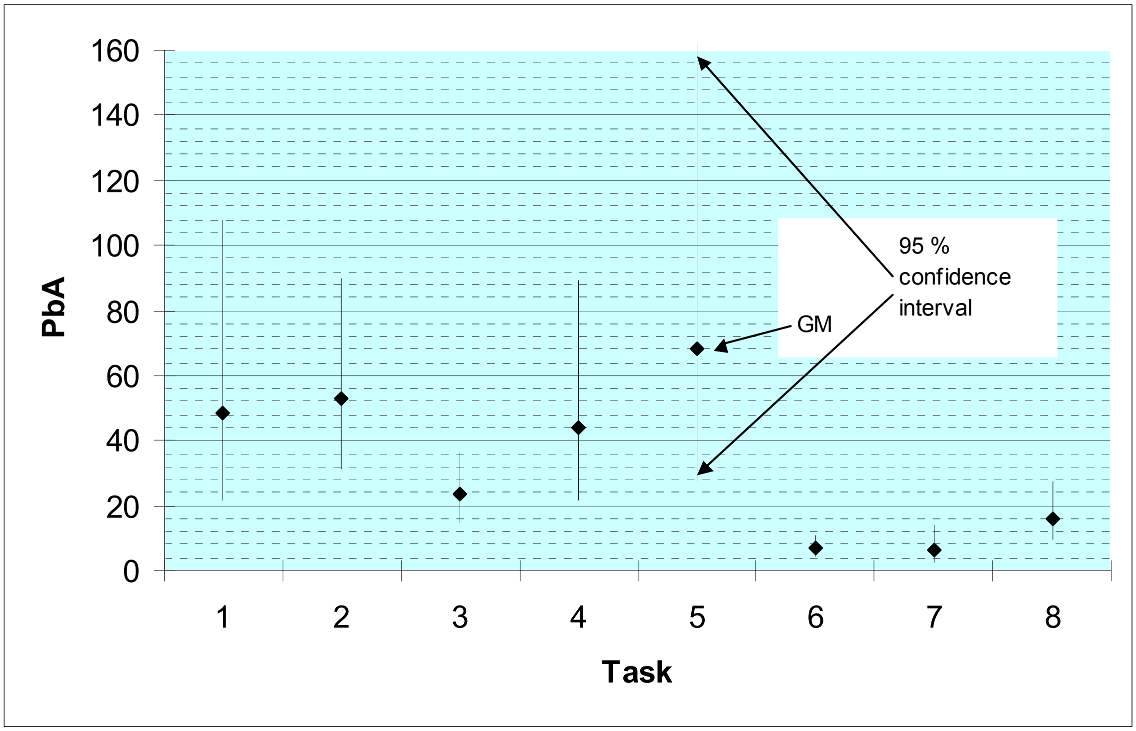
* p value <0.01

† p value = 0.44

Figure 1. Sampling set up and tasks, study of lead exposures during renovation, UC Berkeley.

Clockwise from upper left: task 1 with personal and 6–ft PbA samples; task 8 with 6– and 10–ft PbS samples; task 1; task 2; task 3; tasks 4 and 5; task 6; task 7; and task 8.

Figure 2. Geometric means and 95 % confidence intervals for personal PbA exposures (µg/m^3), eight renovation tasks. Task means were adjusted for the effects of worker and paint lead concentration.



Task
s: (1) dry manual sanding; (2) dry manual scraping; (3) flame burning; (4) power finish sanding; (5) power finish sanding with bag; (6) power finish sanding with HEPA exhaust; (7) wet manual sanding; (8) wet manual scraping.

Figure 3. Average time performing task that would result in worker's exposure reaching the PEL, at 95% UCL for geometric mean.

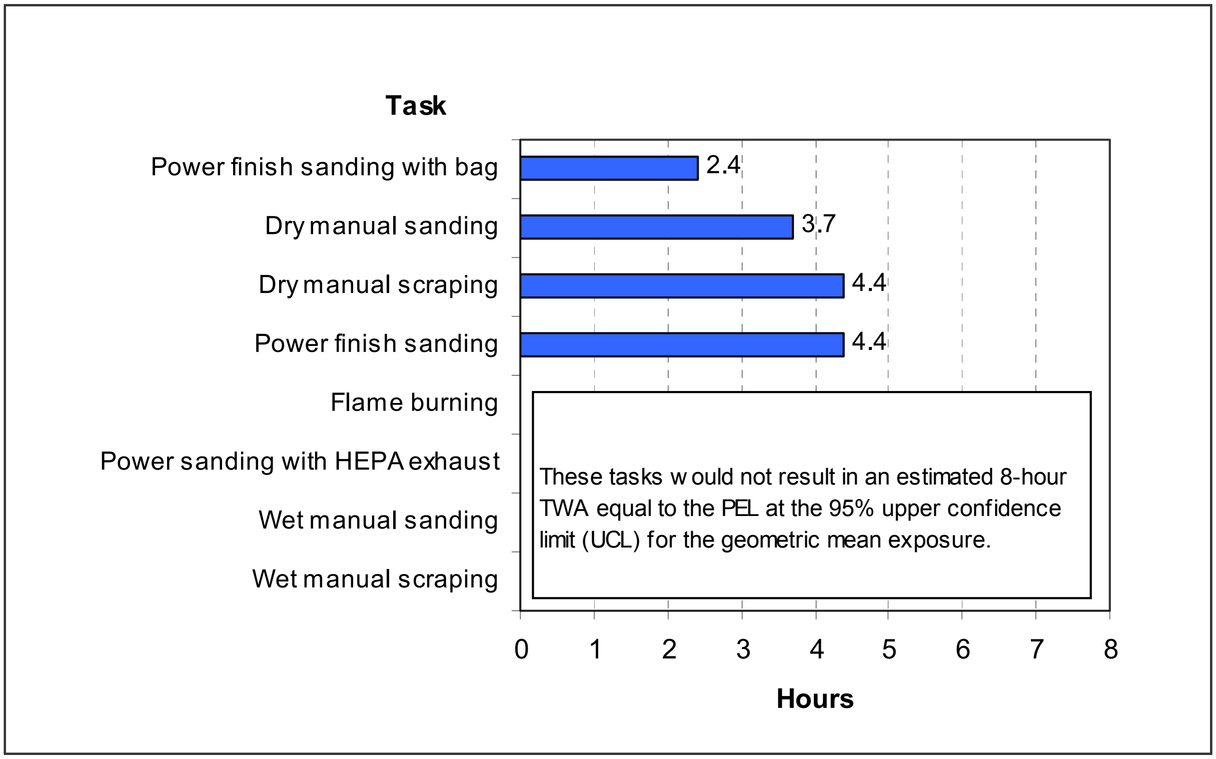
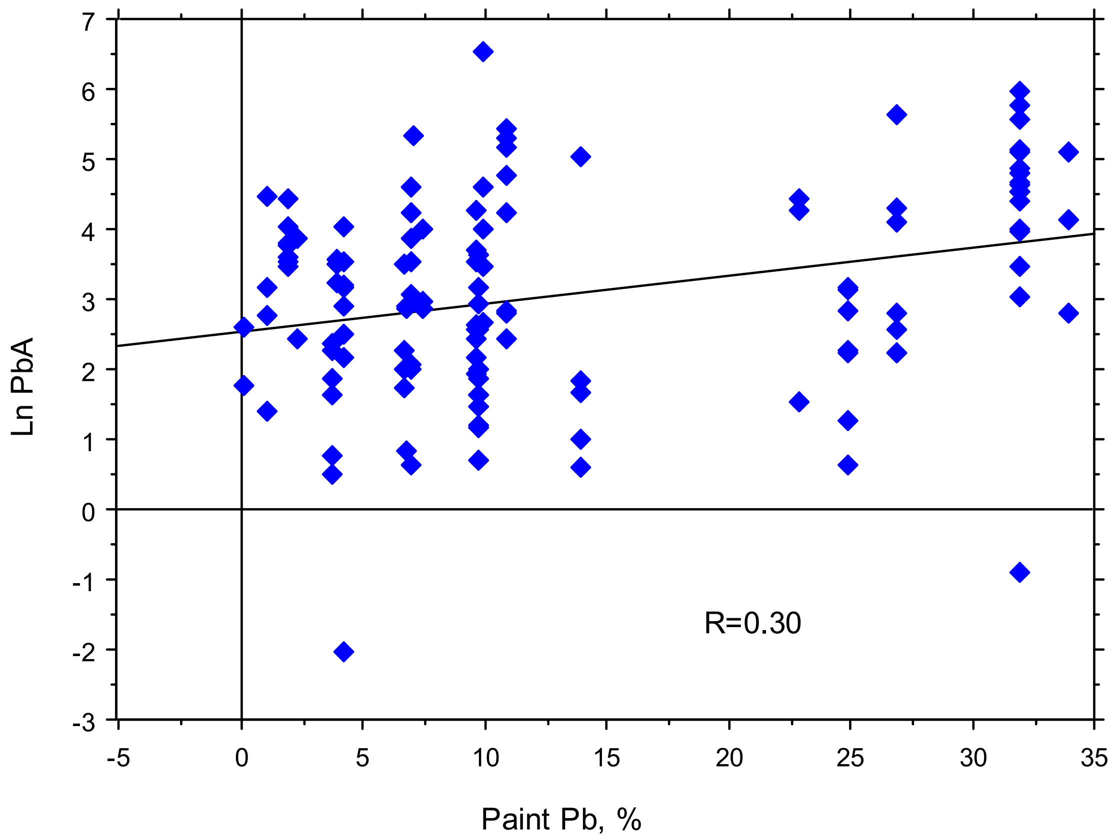


Figure 4. Surface paint lead concentrations vs. natural log (Ln) personal PbA exposures for eight renovation tasks, 128 PbA samples.



DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, OH 45226-1998

OFFICIAL BUSINESS
Penalty for private use $300

National Institute for Occupational Safety and Health
NIOSH

Delivering on the Nation's promise:
Safety and Health at work for all people
through research and prevention

To receive NIOSH documents or information about occupational Safety and Health topics contact NIOSH at:

1-800-35-NIOSH (356-4675) Fax:
1-513-533-8573 E-mail: pubstaft@cdc.gov
or visit the NIOSH web site at:
www.cdc.gov/niosh/homepage.html

SAFER • HEALTHIER • PEOPLE™

SAFER • HEALTHIER • PEOPLE™ SAFER • HEALTHIER • PEOPLE™