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Case Study
Worker Lead Poisoning During Renovation of a Historic Hotel Reveals Limitations of the OSHA Lead in Construction Standard

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INTRODUCTION

Lead-based paint was commonly used in buildings constructed before 1978.(1) Workers can be exposed to lead when they demolish, renovate, repair, or paint these buildings. Lead can have detrimental effects on workers' cardiovascular, central nervous, reproductive, hematologic, and renal systems.(2,3) For all tasks involving paints containing lead, construction industry employers must comply with the applicable provisions of Occupational Safety and Health Administration (OSHA)'s Lead in Construction (LIC) standard (29CFR1926.62). OSHA establishes a permissible exposure limit (PEL) of 50 μg/m^3 averaged over an 8-hr workday for construction workers.(4) The scope and potential for worker lead exposures vary among different construction projects, and employers are required to perform personal air monitoring to assess worker airborne exposures on each job. Accurate airborne exposure assessment is key to determining appropriate and adequate worker protection.

It usually takes several days or even a week for employers to receive air monitoring results after submitting the samples. For a project of short duration, the workers may have completed the project and moved to the next one by the time the air monitoring results become available. To ensure worker protection before the air monitoring results are available, the LIC standard specifies three categories of trigger tasks and assigns specific interim respiratory protection to each. OSHA assumes that the range of airborne lead concentrations generated by manual scraping and sanding is above the PEL but not in excess of 500 μg/m^3 (10 times the PEL). As interim protection, employers are required to provide workers with half-face air-purifying respirators (APRs) with P100 filters. A worker can be protected by an APR up to a maximum airborne lead concentration of 500 μg/m^3.(5) Employers are required to conduct actual personal air monitoring or use historical monitoring data (i.e., actual employee monitoring data obtained within the last 12 months), since OSHA prohibits the use of objective data for assessing worker exposures associated with these trigger tasks.

BACKGROUND

The Bureau of Occupational Health (BOH) of the New York State Department of Health investigated the causes of elevated blood lead levels (BLLs) on seven employees of a painting company. The workers' BLLs ranged from 46 to 65 μg/dL of blood. The U.S. Department of Health and Human Services recommends that BLLs among all adults be less than 10 μg/dL.(6–9) The OSHA LIC standard requires removal of a worker from further lead exposure if his or her blood lead level (BLL) exceeds 50 μg/dL.

All seven employees worked at a hotel renovation site. The hotel was a 136-room Federal style building constructed in 1909. It had undergone numerous renovations over the years. The latest renovation project involved removing all existing exterior paint with a chemical stripper and preparing surfaces by manual scraping and sanding before painting. Prior to beginning the project, the company tested the paint surface with a colorimetric lead test kit and collected three paint chips for laboratory analysis. The colorimetric test result was negative for lead, and all three paint chips contained less than 0.5% lead by weight. The Environmental Protection Agency (EPA) defines lead-based paint (LBP) as paint or other surface coatings containing lead in excess of 1 mg/cm^2 or 0.5% by weight.[10] Since all three paint chips had lead content below the EPA LBP threshold, the company classified the project as a "non-lead" project and allowed workers to remove the paint without taking any protective measures. Six months into the project, the workers developed symptoms of lead poisoning and the company had to halt the job, remove the workers who had elevated BLLs, reassess worker lead exposures, and implement a lead protection program.

At the time of the initial site visit, workers were removing paint from the ceiling of the hotel veranda. The veranda ceiling was approximately 20 feet high. Plastic sheeting was used to enclose the work area to prevent dust from migrating into the guest rooms. Workers first applied a chemical stripper and then removed the dissolved paint layers with a metal hand scraper. The process was repeated three times to remove all the paint layers. After a surface was stripped and scraped a third time, it was sanded with a pole sander to prepare it for painting. The pole sander was made of an abrasive block that was hinged on a 6-foot-long stick. Workers on three scaffolds sanded the ceiling area one section at a time. Following the OSHA interim protection requirement, the employer provided workers with half-face APRs with high-efficiency particulate air (HEPA or P100) filters. In addition to the respiratory protection, workers also wore disposable Tyvek coveralls, gloves, boots, booties (shoe covers), hats, and safety glasses. A clean changing area and washing facilities were made available to the workers.

METHODS

The sampling train for personal breathing zone (PBZ) samples consisted of a personal sampling pump (Model 2500 Constant Flow Sampler; AMETEK, Inc., Feasterville, Pa.), Tygon tubing, and a closed-face 37-mm filter cassette containing a 0.8-μm mixed cellulose ester filter with a backup pad. The filter cassette was clipped onto a worker's lapel. The pump was calibrated before and after sampling with a primary flow calibrator (Gilian Gilibrator, Part no. 800268; Sensidyne, LP, Clearwater, Fla.) at a flow rate of 2 L/min. Pump start and stop times were recorded to the nearest minute. Two sets of PBZ samples were collected to assess the magnitude of worker exposures associated with dry manual sanding and scraping paint. The first set was collected while workers were sanding and scraping paint, and the second set was collected when workers were scraping paint only. One field blank was submitted for each set to identify and assess possible contamination during handling, shipping, and analysis of the samples. Samples were analyzed by a National Environmental Laboratory Accreditation Conference-accredited laboratory. National Institute for Occupational Safety and Health (NIOSH) Method 7082, flame atomic absorption spectroscopy (FAAS) was used to analyze the samples.[11]

Paint chip samples were collected by an EPA-certified LBP risk assessor who followed the paint chip sampling method specified by the *Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing* developed by the U.S. Department of Housing and Urban Development (HUD). The same lab analyzed the paint chip samples using NIOSH Method 7082.

An X-ray fluorescence (XRF) lead paint analyzer (LPA-1; RMD Instruments, LLC, Watertown, Mass.) was used to measure the lead surface concentrations in the lead removal area. The survey was conducted by an EPA-certified LBP risk assessor. The survey range of the XRF was 0–9.9 mg/cm^2. The XRF was pre and post calibrated based on an original standard (lead concentration of 1.0 mg/cm^2) provided by the instrument manufacturer. Three calibration check readings were taken before beginning the survey.

SURVEY AND SAMPLING RESULTS

Personal Air Monitoring

The eight PBZ samples in Table I represent worker exposures associated with manual scraping and sanding during sample times ranging from 46 to 157 min. Since workers performed essentially the same job duties in the same work environment during the sampling as they would in their 8-hr shift, these samples were considered representative of their full-shift exposures.

The first four samples (Table I, Samples 1–4) were collected during the first site visit when workers sanded and scraped the ceiling surfaces that had been treated with two coats of stripper. The four workers spent approximately three-quarters of their sample time sanding and the rest of the time scraping. These workers' lead exposures ranged from 290 to 630 μg/m^3, approximately 6 to 12 times the OSHA PEL. The highest exposure with manual sanding exceeded the OSHA interim protection limit of 500 μg/m^3 by 26%.

Noticing the excessive lead dust generated by manual sanding during the first visit, the BOH industrial hygienists recommended the company reduce manual sanding to a minimum. The company adopted the recommendation by eliminating manual sanding completely. The next four samples (Table I, Samples 5–8) taken during the second site visit represented worker exposures associated with scraping without sanding. Exposures ranged from 36 to 99 μg/m^3. The average exposure of scraping without sanding was 64.75 μg/m^3, while the

TABLE I. Personal Air Monitoring Results

Sample No.	Worker Job Description	Working Surface	Working Surface Conditions	Sampling Time (min)	Lead Concentrations during Sampling Time (mg/m^3)
1	Sanding and scraping	Ceiling	Two coats of stripper applied	92	290
2	Sanding and scraping	Ceiling	Two coats of stripper applied	92	340
3	Sanding and scraping	Ceiling	Two coats of stripper applied	95	470
4	Sanding and scraping	Ceiling	Two coats of stripper applied	88	630
5	Scraping	Ceiling (SW corner)	Two coats of stripper applied	107	36
6	Scraping	Ceiling (West corner)	Three coats of stripper applied	46	58
7	Scraping	Ceiling (NE corner and middle section) and column	Two coats of stripper applied	157	66
8	Scraping	Ceiling (NE corner and middle section) and column	Two coats of stripper applied	154	99

average exposure with sanding was 432.5 μg/m^3, approximately seven times higher.

The company continued monitoring the workers' BLLs through the course of the painting project. On completion of the project, six of the seven workers' BLLs were reduced to below 30 μg/dL (one worker had left the company and was not retested).

TABLE II. XRF Lead Survey Results

Sample No.	Sampling Location	XRF Reading (mg/cm^2)
1	South wall on porch at building side (undisturbed paint)	0.1
2	Doors on porch by east wall (undisturbed)	0.3
3	Ceiling with third coat of stripper scraped off	0.2
4	SE door (undisturbed)	0.5
5	Ceiling with third coat of stripper scraped off	0.6
6	Wall wood surface (undisturbed)	0.6
7	East column (undisturbed)	1.0
8	Floor with gray paint toward the edge of the porch (undisturbed)	1.7
9	Column 2 (undisturbed)	1.8
10	Painted vertical surface on column (undisturbed)	2.0
11	Wood trim inside containment (undisturbed)	9.0
12	Fireplace in setup room (undisturbed)	9.9
13	Ceiling area with the 3rd coat of stripper (not scraped)	$>$9.9
14	Porch ceiling SE corner (undisturbed)	$>$9.9

XRF Lead Survey and Paint Chip Analysis

The XRF readings were taken, and paint chip/peel samples were collected from a variety of locations, including the floor, wall, door, porch, exterior wall, ceiling, column, and railing with conditions representing different stages of the paint removal process. Some of these surfaces had original paint, while others had been chemically stripped and manually scraped.

Both the XRF lead survey and paint chip analysis showed a wide range of lead distribution. Fourteen XRF readings are reported in Table II. The amount of lead detected ranged from 0.1 to greater than 9.9 mg/cm^2. Eight of the fourteen (57%) surfaces surveyed contained lead exceeding 1.0 mg/cm^2 (Table II, Samples 8–14). Lead concentrations in two samples (Table II, Samples 13 and 14) exceeded the maximum XRF range of 9.9 mg/cm^2 and could not be determined. The three readings taken from the ceiling that was scraped and sanded by the workers were 0.2, 0.6, and $>$9.9 mg/cm^2 (Table II, Samples 3, 5, and 13).

A total of six paint chip samples were collected, and the results are reported in lead percentage by weight in Table III. Lead concentrations ranged from less than 0.5 to 5.1% by weight. Lead concentrations in two of the six (33%) paint chip samples exceeded the EPA threshold for LBP of 0.5% (Samples 5 and 6). The highest paint chip lead concentration was 5.1%, which is 10 times the EPA threshold (Sample 6).

DISCUSSION

The OSHA LIC standard addresses worker protection measures for lead hazards in construction-related activities. Inhalation is the primary route of entry for worker lead exposure.[(2)] OSHA mandates that all worker airborne lead exposures be kept below the PEL of 50 μg/m^3, measured as an 8-hr time-weighted average (TWA). All exposure monitoring must consist of personal breathing zone samples representing workers' typical full-shift lead exposure (at least one sample for each job in each shift with the highest exposure level).

TABLE III. Paint Chip Sample Results

Sample No.	Sampling Location	Percent by Weight (%)
1	Exterior wall (cement)	< 0.5
2	Paint peel from ceiling (wood)	< 0.5
3	Paint peel after 2nd coat stripper (before scraping)	< 0.5
4	All layers of paint (no stripper) from ceiling by south wall near the west end of containment	< 0.5
5	Paint peel after 2nd coat stripper removed and scraped	2.3 (LBP)
6	Peel of 3rd coat of stripper near south wall toward the center of containment	5.1 (LBP)

Employers are required to conduct personal air monitoring to assess worker airborne exposures. Engineering and work practice controls should be implemented and appropriate personal protective equipment provided based on the personal air monitoring results. If workers perform certain high-risk tasks, such as sanding lead-based paint, that are known to generate high levels of airborne lead dust, employers are required to provide respiratory protection in the absence of personal air monitoring results.

Based on the limited exposure information and data available when the LIC standard was developed in 1993, OSHA assumed that the maximum airborne lead concentration that could be generated by manual sanding was 500 μg/m^3 and required a half-face air-purifying respirator with P100 filters for the interim worker protection. This case study found that the highest airborne lead dust concentration associated with manual sanding was 630 μg/m^3, exceeding the OSHA level by 26%. Therefore, the interim protection required by OSHA for manual sanding was inadequate.

There are many variables that can affect the magnitude of worker exposures during the manual sanding, resulting in a wide range of airborne lead concentrations. Differences in coarseness (grit size) of the sandpaper and the size of the sanding block can affect the amount of airborne lead dust generated. In this case, the length of the sanding pole as well as the worker's height dictated the distance between the worker's breathing zone and the source of the dust, directly affecting the worker's exposure. Variations in individual work practices and habits also play a role: workers who sand more vigorously may generate more lead dust. Higher exposures can be expected if multiple workers are sanding in proximity inside a tight containment.

Another major parameter affecting worker breathing zone lead exposures is the lead concentration in the paint. Lead content in paint coatings throughout a building can vary greatly, as was demonstrated in this case study (ranging from 0.1 to exceeding 9.9 mg/cm^2, and from below 0.5–5.1 by weight). Note that the three XRF readings taken from the hotel veranda ceiling where the workers were sanding (Table II, Samples 3, 5, and 13) showed a wide range of lead content—from 0.2 to greater than 9.9 mg/cm^2. When paint removal methods that generate high airborne dust such as manual sanding are applied to painted surfaces containing high lead, worker exposures could exceed 500 μg/m^3, the OSHA interim protection limit. This finding is consistent with the conclusion of a study by the California State Department of Health.[12]

Employers can assess the potential for worker lead exposure exceeding the OSHA interim protection limit based on age of the building, lead concentrations in paint surfaces, and the renovation or lead removal methods to be used. The likelihood of a building containing LBP hazards and paint with higher lead concentrations increases with the age of the building. HUD estimated that 90% of residential housing units built before 1940, 80% of the housing units built between 1940 and 1959, and 62% of the housing units built between 1960 and 1979 contain some lead-based paint. Some of the houses built prior to 1950 had paints containing up to 50% lead by dry weight.[13] The prevalence and concentrations of LBP among commercial buildings and structures in the United States can be reasonably assumed to be similar, if not higher.

Employers should consider conducting pre-job paint testing since it can identify the high lead surfaces that might generate excessive airborne lead dust. An accurate and thorough LBP risk assessment can also help building owners, project managers, and contractors to better budget the time and cost of a renovation project and avoid lead contamination and unnecessary extra costs for cleaning of contaminated areas.

During the project design stage, employers should assess the potential for worker lead exposure and select feasible paint removal methods that generate the least amount of lead dust and fumes. Dry sanding should be avoided or reduced to a minimum. Contractors should implement effective engineering controls such as using tools with a HEPA exhaust attachment, wet methods, and local exhaust ventilation. To ensure adequate worker protection in the absence of personal air monitoring results in a situation where there is high lead content in building surfaces and dry sanding cannot be avoided, contractors may have to upgrade worker respiratory protection to a full-face APR. The maximum airborne lead concentration under which a worker can be protected by a full-face APR is 2500 μg/m^3.[5]

The pre-job LBP testing in this case study missed high-lead areas. Both the contractor and hotel owner misinterpreted the LBP testing results: paint containing lead below 0.5% (the EPA threshold for LBP) was classified as non-lead paint, and the painting project was subsequently classified as a non-lead project. Based on the assumption that paint containing lead below the EPA LBP threshold presents no lead hazards to workers, employers often do not implement worker protection against lead hazards. This practice puts workers at high risk for lead poisoning because (1) the preliminary survey often misses high-lead areas or sections, and (2) significant airborne lead dust can be generated even when the surface lead concentrations are below the EPA LBP threshold.[14–16]

When different paint removal methods are applied to a surface with the same lead concentration, the resulting airborne lead concentrations can be highly variable. Certain paint removal methods such as dry scraping or sanding may generate high levels of airborne lead even when the surface lead concentration is low. According to a mathematical model developed by the state of California, wet scraping a painted surface containing 1 mg/cm^2 of lead (note that this surface concentration is below the EPA LBP threshold) would generate an approximate airborne concentration of 37 $\mu g/m^3$. In contrast, dry scraping applied to the same surface would result in an airborne exposure of 371 $\mu g/m^3$, more than seven times the OSHA PEL.[17] Since there is no statistically consistent correlation between the lead concentrations in paint and in air, the decision on worker protection should be based strictly on the personal air monitoring results, not the lead surface concentrations.

CONCLUSION

It is important for building owners, project managers, and contractors to have a basic understanding of the nature of lead paint hazards and the applicable federal, state, and local regulations so they can implement proper protective measures to ensure the safety of both building occupants and workers. Manual sanding, a widely used paint removal method, may generate airborne lead dust exceeding 10 times the OSHA PEL and the maximum protection range of a half-face APR, the OSHA-required interim respiratory protection. If a building to be renovated was constructed before 1978, employers must implement a lead safety program following the OSHA Lead in Construction Standard.

The decision on worker respiratory protection should be based on personal air monitoring results. To ensure that workers are adequately protected in the interim, employers should avoid paint removal methods that generate high dust, such as manual sanding, and use techniques with low exposure potential (e.g., encapsulation). Engineering controls that use wet methods in conjunction with HEPA vacuuming or mechanical ventilation, and shrouded power tools with HEPA vacuum attachments, should be implemented. Contractors may consider upgrading worker respiratory protection to a full-face APR in the interim if dry sanding cannot be avoided.

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