

Lead Poisoning Among Construction Workers Renovating a Previously Deleaded Bridge

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This study evaluated lead poisoning among construction workers renovating a previously deleaded bridge. Twelve of 44 tested workers had blood leads exceeding 20 µg/dL. One was 50 µg/dL and two exceeded 40 µg/dL. Following medical intervention, blood leads dropped significantly, while ZPPs did not. Renovation released lead that had been inaccessible during deleading. Workers did not use engineering controls or respirators, change clothes, wash hands, or shower. Intervention included a lead-compliance program with provisions for exposure evaluation, training, hygiene, and engineering controls. Construction contractors and workers need to be aware that deleading of bridges and other structures may not remove lead from inaccessible locations. In particular, owners of these structures should specify provisions for anticipating and controlling this hazard in contracts. Am. J. Ind. Med. 31:319-323, 1997. © 1997 Wiley-Liss, Inc.

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INTRODUCTION

Occupational exposure to lead has been recognized as a serious problem for certain construction trades. It is estimated that over 900,000 U.S. construction workers are at risk for lead poisoning [Occupational Safety and Health Administration, 1993]. While the true extent of lead exposure among trades involved in different types of construction is unknown, reports to date have indicated that renovation of bridges coated with lead-based paint can result in severe lead poisoning for workers, their family members, and nearby communities [Occupational Safety and Health Administration, 1993; Robinson et al., 1990; Grandjean and Bach,

1986; Landrigan et al., 1982; Pollock and Ibels, 1986; Fischbein et al., 1984; National Institute for Occupational Safety and Health, 1991; Centers for Disease Control, 1992; Piacitelli et al., 1995]. At selected construction sites where air monitoring has been performed, 65% of airborne concentrations of lead have exceeded OSHA's pre-1993 Construction Lead Standard of 200 µg/m³ [Robinson et al., 1990]. Airborne lead concentrations as high as 29,000 µg/m³ have been reported inside confined areas during abrasive blasting, and lower levels associated with demolition (200-300 µg/m³), steel cutting, and rivet busting (1500 µg/m³) still greatly exceed the current OSHA PEL of 50 µg/m³ [Occupational Safety and Health Administration, 1993; Robinson et al., 1990; National Institute for Occupational Safety and Health, 1991].

While lead poisoning during renovation of bridges coated with lead-based paint has been reported [Robinson et al., 1990; Landrigan et al., 1982; Pollock and Ibels, 1986; Piacitelli et al., 1995], this is the first report on the problem of lead poisoning among workers renovating a bridge that had been previously deleaded. In addition to presenting the results of biological testing and worksite evaluation, the unique collaborative implementation of control measures is described.

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METHODS

Project Description

The project involved removing and replacing the concrete deck and portions of the steel infrastructure of a four-lane bridge spanning the Mississippi River. The contractor was informed that lead-based paint had been removed from the bridge by sand blasting several years before, and that the bridge had been repainted with a non-lead-based paint. Within the first 30 working days on the site, several workers complained of symptoms, including headaches, stomach pain, irritability, and muscle aches. They were seen by an occupational medicine physician, who diagnosed lead poisoning and initiated a worksite evaluation.

Intervention

The sequence of intervention was as follows: steel cutting and rivet busting were stopped, initial blood samples were collected on workers with symptoms, and medical follow-up and clinical treatment were initiated (9/8/95); assessment of job tasks and potential exposures were conducted on the bridge site (9/15/95); an awareness level training session on lead was conducted and blood samples were collected from the remaining workers (9/19/95); a written Lead Compliance Program was developed and implemented (completed 10/27/95).

Study Participants

All workers at the site (50 total) were eligible to participate in this study. Blood samples for lead and ZPP were collected from the initial group of 14 workers with complaints on September 8, 1995, and tests were repeated on this group on October 5, 1995. Blood samples were collected from an additional 26 workers on September 19, 1995, and four more on October 5, 1995. Workers were also asked to complete a questionnaire developed for the study of Elevated Blood Leads in Iowa Construction Workers which was used to ascertain data concerning demographics, work habits, work history, home environment, symptoms, and specific details concerning tasks and implementation of control measures on this job site.

Blood Samples

Venous blood samples were collected in separate 3cc vacuum tubes containing either ethylenediamine tetraacetic acid (EDTA) for the lead analysis or heparin for the zinc protoporphyrin (ZPP) analysis. Lead analysis was performed by Graphite Furnace Atomic Absorption (GFAA) following a method recommended by the Centers for

Disease Control and Prevention (CDC) for blood lead analysis [New York State Department of Health, 1991].

Worksite Evaluation

On-site observations and discussion with supervisors and employees were used to gather information on the specific tasks and work practices implemented.

Statistical Methods

Statistical analysis of blood lead and ZPP data was conducted using Sigma Stat 1.0 (Jandell Scientific). Descriptive statistics were used to evaluate the distributions of the data. If the data were not normally distributed, they were log transformed prior to conducting further analyses. Paired Signed Rank Tests (nonparametric T-Test) were used to test for differences in blood lead and ZPP measures over time. T-Tests were used to test for differences in blood lead and ZPP for cases reporting symptoms compared to non-cases. Questionnaire data were entered in EpiInfo and analyzed using SAS 6.1. Descriptive statistics were used to summarize the distributions of demographic variables and proportions of categorical responses were evaluated over all workers and by construction trade.

RESULTS

Demographics

A total of 44 workers out of the 50 eligible participated in this study. Blood samples were obtained from 44 and 21 completed the questionnaire. Of those who provided blood samples, 29 were identified by trade: 14 laborers, seven carpenters, three ironworkers, three operator/engineers, one engineer in charge, and one safety director. Ten of the subjects originally providing blood samples on September 8 did not complete questionnaires, nor did the four additional workers tested for the first time on October 5. The four from these groups completing questionnaires had the 2nd, 4th, 8th, and 33rd ranking blood lead concentrations. The blood lead concentrations of those not answering questionnaires ranged from 3.2 to 50.0 $\mu\text{g}/\text{dL}$.

Based on the data obtained with the questionnaire, the overall age of participants ranged from 23–60 years with a mean of 39.4 and a standard deviation of 10.6. All who answered the questionnaire were male, with one of Hispanic origin and the rest Caucasian. One white female participated in the blood sampling. The average level of experience in construction was 18 years with a standard deviation of 11.8 years. Three were college graduates, five had some college, seven were high school graduates, one had some high school, and two had only completed grade school. Six had worked only for the current contractor

TABLE I. Summary of Blood Lead and ZPP Measurements Before and After Intervention in a Study of Workers Renovating a Deleaded Bridge, 1995

	Blood lead ($\mu\text{g}/\text{dL}$)		ZPP ($\mu\text{g}/\text{g Hg}$)	
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
N	14	41	14	41
Geometric mean	27.2	9.7	28.9	20.0
GSD	1.8	2.6	1.2	1.7
Range	6.3–50.0	1.0–45.1	19.0–39.0	9.0–92.0

N total was 44 individuals.

Pre-intervention blood tests were collected on September 8, 1995. Cutting of steel also stopped at this point. Post-intervention blood samples were collected on September 19, 1995, and October 5, 1995.

during the previous year, while nine had worked for two employers, and two had worked for three different employers. Five workers had children under the age of six at home. Seven were current smokers.

Blood Lead and ZPP

Table I summarizes the results of blood lead and ZPP measurements before and after intervention. Geometric means are presented since the data were not normally distributed and blood lead results are often log-normally distributed. The geometric mean of pre-intervention blood leads (27.2 micrograms per deciliter - $\mu\text{g}/\text{dL}$) and ZPPs (28.9 micrograms per gram of hemoglobin - $\mu\text{g}/\text{g Hgb}$) collected on September 8, 1995, were much higher than the geometric means for the post-intervention data collected on September 19 and October 5 (BLL = 9.7 $\mu\text{g}/\text{dL}$, ZPP = 20 $\mu\text{g}/\text{g Hgb}$). One individual had a blood lead at the current OSHA allowable level of 50 $\mu\text{g}/\text{dL}$. Two other individuals had blood leads exceeding 40 $\mu\text{g}/\text{dL}$. A total of 12 individuals had blood leads exceeding 20 $\mu\text{g}/\text{dL}$, the level recently recommended by the American Conference of Governmental Industrial Hygienists to prevent adverse reproductive effects. By trade group, the geometric mean blood lead concentrations (the initial test for each subject regardless of sample date) were 26.3 $\mu\text{g}/\text{dL}$ for laborers ($n = 14$), 11.2 $\mu\text{g}/\text{dL}$ for ironworkers, ($n = 3$), 7.9 $\mu\text{g}/\text{dL}$ for carpenters ($n = 8$), 4.4 $\mu\text{g}/\text{dL}$ for operator/engineers ($n = 3$), 3.1 $\mu\text{g}/\text{dL}$ for the supervising engineer and safety director, and 6.9 $\mu\text{g}/\text{dL}$ ($n = 2$) for those who did not indicate a trade ($n = 14$).

Eleven individuals had repeated measures of blood lead and ZPP (9/8/95 and 10/5/95). Within 28 days, blood leads had dropped for all individuals except for one subject whose blood lead concentration rose from 11.4 to 21.1 $\mu\text{g}/\text{dL}$. The decrease in blood lead concentrations was statistically significant ($p = 0.03$). ZPP levels also dropped for eight

individuals, but they rose for three. ZPP for one subject rose initially and then dropped. Using a Signed Rank Paired T-Test, there was no significant difference between the initial and last ZPP measurements.

Symptoms Reported

The questionnaire was used to gather information on symptoms that workers had experienced for more than one week during the previous three months. Of the 20 individuals responding to this question, six indicated that they had experienced a variety of symptoms, with stomach pain, headache, irritability, and muscle aches being most common. These were also the most common symptoms verbally reported by the individuals initially complaining, but who did not complete the questionnaire. Although only 20 individuals completed this section of the questionnaire, there was a significant difference between the mean blood lead for the six workers reporting three or more symptoms (29.7 $\mu\text{g}/\text{dL}$) and the mean blood lead for those with no symptoms (9.5 $\mu\text{g}/\text{dL}$) at $p = 0.0005$, T-Test. There was no significant difference in mean ZPP (symptoms = 26.2 $\mu\text{g}/\text{g Hg}$, no symptoms = 22.0 $\mu\text{g}/\text{g Hgb}$).

Work Habits

Information on personal work habits was obtained from 21 individuals answering the questionnaire. Not all individuals answered every question, however. None of the respondents used disposable clothing, changed work clothes, or showered at work before going home. Few washed their hands before: eating (seven of 19 never did); drinking (10 of 17 never did); or smoking (three of five smokers responding) while at work. Seven smoked at work, and four bit their nails.

Task Descriptions

Observations and discussions with supervisors and workers identified several tasks with high potential for exposure to lead: concrete demolition; steel cutting; rivet busting; deck forming; structural repair; and cleanup of debris. Prior to the site visit on September 15, workers reportedly did not use respirators.

Concrete demolition

An operator/engineer using a hoe ram (300 lb. air hydraulic air hammer) broke up the concrete roadway, or deck, exposing underlying steel beams. These steel beams were coated with lead-based paint (37% lead determined by contractor after initial blood testing was conducted) in a deteriorated, powdery condition. After breaking up concrete, workers attached steel cables to the exposed rebar and pulled

it up off the steel beams. Concrete and other debris were observed to fall below the bridge and visible clouds of dust were raised. A worker wearing a half/mask air-purifying respirator with HEPA cartridges then used compressed air to blow remaining debris and dust off the steel support beams. Extensive clouds of dust were raised using this process, which enveloped nearby workers and the cooler with drinking water placed at the site.

Steel Cutting

After pulling up the rebar it was cut into manageable pieces using acetylene torches. Workers doing the cutting were not observed wearing respiratory protection. Ironworkers and laborers also cut steel beams and medians using torches, coming into contact with lead-containing dust as they crawled out on the exposed steel beams. Cutting of medians was not observed, but this was reportedly the activity performed over a half-mile span (about half the bridge) just before several workers complained of health problems. The median itself acted as a semi-enclosed space constraining air flow, and axial fans set up to provide ventilation were likely to move fumes from one worker to another. Reportedly, workers did not use respirators when cutting. Cutting was reportedly conducted for up to five weeks.

Rivet Busting

Ironworkers and laborers also used torches to 'bust' or remove rivets. Restriction of airflow was again a potential problem leading to buildup of lead-containing fumes. Even on rivets where lead has been removed from the surface, lead-based paint was observed to be present under the rivets.

Deck Forming

Carpenters and laborers formed decks out of plywood frames into which new concrete is poured. To do this, the workers slid out onto steel beams coated with the lead-containing dust. The orangish-colored lead-paint dust was visible on the clothing and hands of most workers performing this task.

Structural Repair

Ironworkers were engaged in cutting and welding on exposed steel structural elements that were found to be in need of repair. Some of these elements had lead-based paint coatings which had not been removed in the previous deleading process because they were not accessible.

Cleanup

Laborers used brooms and shovels to clean up debris that had fallen below the bridge. Clouds of visible dust were

generated, and workers were not observed wearing respiratory protection. While much of the debris was concrete, the proportion of lead in this waste had not been determined.

DISCUSSION

The history of lead abatement on this bridge resulted in a false sense of security on the part of the bridge owner, the construction contractor, and workers. Under the assumption that all lead-based paint had been removed, no precautions were taken to protect either workers or the local environment from lead. It is noteworthy that although the bridge owner has control of the contract specifications, the construction contractor is held responsible for compliance with OSHA requirements.

The initial group of workers reporting symptoms had been cutting the steel median with torches. No respiratory protection was used and it was likely that the median acted as a semi-confined area that would have prevented wind from dispersing lead-containing fumes. Lead levels as high as 1,564 $\mu\text{g}/\text{m}^3$ have been reported for similar operations on other structures, far in excess of the OSHA standard of 50 $\mu\text{g}/\text{m}^3$ (Occupational Safety and Health Administration, 1993; Robinson et al., 1990). Observation of visible dust emissions, lack of engineering controls or hygienic facilities, and personal habits such as smoking, eating, and drinking in the work area indicated that potential exposure to lead via inhalation or ingestion was also likely during other tasks, such as concrete demolition, rivet busting, deck forming, structural repair, and cleanup. Differences in blood lead concentrations were found by trade with laborers, who did most of the median cutting, blow-off of lead-containing dust from exposed beams, and cleanup having the highest levels. The geometric mean blood lead levels for ironworkers (cutting and structural steel work) and carpenters (deck forming) were next highest, while the levels for other trades did not differ greatly from the U.S. norms [National Center for Health Statistics, 1984].

In addition to the cessation of torch-cutting the median, workers with elevated blood leads were removed from the job site and one was chelated. The significant drop in blood lead concentrations over 28 days indicates that the intervention was successful. The fact that ZPP levels did not decrease in the same time period suggests a short-term exposure probably limited to this job site. The difference in mean blood lead concentration for those reporting symptoms (29.7 $\mu\text{g}/\text{dL}$) and those without symptoms (9.5 $\mu\text{g}/\text{dL}$), while there was no difference in ZPP, may also support the acute nature of this exposure.

Observations of work practices and reported non-compliance with the OSHA Construction Lead Standard suggested that not only workers but their families and the community near the bridge site were at risk for exposure to lead-containing dust. Visible emissions of dust were ob-

served, especially during use of compressed air to blow concrete debris and lead-paint dust from steel beams exposed when the concrete deck was removed. Lead-containing dust was also observed on workers' clothing and hands. None of the workers changed clothes or showered before returning home after the workday. Intervention for work practices involved development of a written Lead Compliance Program which included provisions for: exposure assessment; hazard determination and engineering and work practice controls; respiratory protection; protective clothing and equipment; housekeeping; hygiene facilities and practices; medical surveillance; employee notification and training; documentation; and enforcement. Specific engineering controls, such as use of vacuum systems to remove lead-containing dust from exposed beams, rather than compressed air, were identified, and training was provided for workers and managers on the hazards of lead and how to work safely with it.

CONCLUSION

It is clear that deleading of bridges and other structures may leave behind residues of lead-based paint in inaccessible locations. Workers proceeding with renovation or demolition may then disturb these residues, resulting in exposures not only to themselves but to their families and the surrounding communities. Construction contractors and workers need to be aware that this is a potential problem, and should be prepared to evaluate and control any potential lead-containing emissions. In particular, the owners of these structures should specify provisions for anticipating and controlling this hazard in their contracts.

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