American Journal of Industrial Medicine 26:693–702 (1994)

Lead Exposure in a Tank Demolition Crew: Implications for the New OSHA Construction Lead Standard

Kirsten Waller, MD, MPH, Ana Maria Osorio, MD, MPH, and Jeff Jones, CIH

The Federal Occupational Safety and Health Administration (OSHA) has recently extended the basic health and safety provisions of the OSHA lead standard for general industry to workers in the construction industry. In this report we describe a tank demolition worksite that midway through the project strengthened its lead exposure control activities to a level that approximated the current lead standard. Of 12 tested ironworkers and laborers who worked at the site before the change, zinc protoporphyrin levels increased and seven developed blood lead levels (BLL) >50 μg/dL. After the change these workers' BLLs declined. Six workers hired after the change did not experience increases in zinc protoporphyrin and none developed BLL >25 μg/dL. The experience at this worksite demonstrates the usefulness and feasibility of implementing the current lead standard in construction settings.

Key words: construction industry, flame cutting, General Industry Lead Standard, medical surveillance, biological monitoring

INTRODUCTION

A new interim final Federal Occupational Safety and Health Administration (OSHA) standard on "Lead Exposure in Construction" has recently extended the basic health and safety provisions of the OSHA lead standard for general industry to workers in the construction industry [OSHA, 1993]. Previously, the construction industry, which includes demolition workers, ironworkers, painters, and electricians, among others, had been exempt from the OSHA general industry lead standard [OSHA, 1978, 1982]. Although this change has long been advocated by many in the occupational health field [Landrigan, 1990; Marino et al., 1989], the effectiveness of the components mandated by the lead standard in limiting lead exposure in the construction setting has not been well documented. In this report, we describe a tank

Division of Field Epidemiology, Epidemiology Program Office, Centers for Disease Control, Atlanta, GA (K.W., A.M.O.).
Division of Occupational and Environmental Disease Control, California Department of Health Services, Emeryville (J.J.).
Dr. Waller is currently with the Environmental Health Investigations Branch, California Department of Health Services, Berkeley.
Jeff Jones is currently with Crawford Risk Control Services, Lafayette, CA.
Address reprint requests to Dr. Waller, 2151 Berkeley Way, Annex 11, 5th floor, Berkeley, CA 94704.

demolition worksite that midway through the project strengthened its lead exposure control activities to a level that approximated the current lead standard, thus allowing a comparison of the effectiveness of different degrees of lead exposure control. The experience at this worksite may be useful in evaluating the potential impact of the new lead standard in the construction trades.

BACKGROUND

The new OSHA lead standard for construction includes exposure assessment, engineering and work practice controls, respiratory protection, medical surveillance, and medical removal protection components. Briefly, an employer must monitor the workplace for airborne lead when lead is suspected to be present in any quantity. Until air monitoring results are obtained, the level of respiratory protection required is determined by task. Tasks for which respirators are required (unless adequate air monitoring proves that exposures are <50 μg/m^3) include spray painting with lead, using lead-containing mortar, and scraping, sanding, burning, welding, or cutting surfaces with lead coatings or paint. In addition, any worker who performs any of these tasks, or who is exposed to airborne lead ≥ 30 μg/m^3 for at least 1 day, must have a baseline physical exam, blood lead level (BLL), and zinc protoporphyrin (ZPP) measurement performed by a licensed physician. Workers exposed at this level for >30 d/year must be enrolled in a medical surveillance program which includes follow-up BLLs and ZPPs at least every 2 months for 6 months, then at least twice yearly. Workers with BLLs >50 μg/dL must be retested within 2 weeks. Immediate removal to a job position with air lead exposure <30 μg/m^3 is required for any worker with a BLL and follow-up of ≥ 50 μg/dL, or who, in the physician's estimation, is at high risk of adverse effects from lead exposure. The worker may be returned to his or her position when two consecutive BLLs are ≤ 40 μg/dL.

WORKSITE DESCRIPTION

In October 1988, demolition workers began preparing to dismantle a steel natural gas storage tank. The tank was 40 years old, approximately 75 feet in diameter and 380 feet high, and partially open at the top. The tank was first cut from its foundation and then lifted onto hydraulic jacks. The actual demolition began in early December. Workers with acetylene torches burned the paint coating the tank and then made cuts around the bottom of the tank, lowering it by approximately 20 feet per day. Precision cutting was performed by ironworkers using short (18″) torches; scrap production was performed by laborers using long (36–40″) torches. The tank demolition was completed in April 1989.

Aware that the paint was approximately 10% lead by weight, the owner of the tank had specified to the contractor that plans to control lead exposure be incorporated into the project. Initially, cutters were equipped with half-mask respirators with organic vapor/HEPA cartridges. There were no showers or laundry provided, and workers were not monitored for handwashing before eating or smoking. Initial plans for exposure assessment included performing breathing-zone air lead monitoring on at least two workers in each job category every 2 weeks. Finally, each worker was examined by a physician and had a blood sample taken for ZPP determination before starting work on the tank. Baseline urine lead levels were obtained, but BLLs were not. Original plans were to retest workers at the conclusion of the job.

Air monitoring performed in December and January indicated that workers were being exposed to extremely high levels of lead (measurements are described in the Results section). Thus, on January 26, the employer strengthened both the exposure control and medical surveillance components of the lead control program. As part of this more stringent program (which will henceforth be referred to as the "intervention"), respirators for cutters were upgraded to powered air-purifying respirators (PAPRs) and a technician was hired to maintain the equipment and ensure that respirators were worn correctly. New work practice controls included encouraging cutting to be done from the unpainted tank interior, the installation of showers and portable handwashing stands, and company laundering of the workers' coveralls. Workers were monitored to make sure that they did not smoke, eat, or drink before handwashing, and that they showered at the end of their shift. Training regarding the new lead control program was conducted at weekly on-site safety meetings. As for medical surveillance, the physician discontinued urine lead measurements and began testing cutters' BLLs on January 23 and 24 (however, baseline BLLs were still not obtained on new workers). A medical removal component was also added: workers whose BLLs exceeded 50 μg/dL were temporarily reassigned to noncutting tasks.

The worksite came to the attention of state health authorities in March 1989, when 10 workers with BLLs >25 μg/dL were reported to the California Occupational Lead Registry. In response, state investigators visited the demolition site and conducted a review of the worksite's lead exposure control program.

MATERIALS AND METHODS

Information Obtained From the Employer

Air lead measurements were obtained from the employer's industrial hygiene consultant. Samples had been collected using MCE filters and Gillian personal sampling pumps. The collection filter was attached to a collar or lapel within the employee's breathing zone. Samples were analyzed by an American Industrial Hygiene Association–accredited laboratory using National Institute for Occupational Safety and Health Method 7082 [NIOSH, 1984]. The consultant calculated 8 hr time-weighted averages (TWAs) assuming zero exposure outside the sampling time.

Company medical monitoring records were abstracted to obtain the workers' medical histories, and ZPP and BLL measurements collected through March 1989. Subsequent blood measurements were obtained directly from the company medical consultant. All blood samples had been analyzed at a single reputable laboratory.

Information Obtained From the Workers

We attempted to administer a standardized telephone questionnaire to each cutter employed at the site. Information ascertained included demographic data, work history, symptoms, and sources of non-occupational lead exposure. Workers who reported muscle or joint pain, numbness in the extremities, nausea or abdominal pain, frequent headaches, extreme fatigue or weakness, and/or difficulty concentrating that first occurred during work at the demolition site and that could not be attributed to an underlying medical condition were considered to have possible lead-associated symptoms [WHO, 1986].

Analysis

The EpiInfo package for the personal computer was used to calculate descriptive and analytic statistics [Dean et al., 1990]. The non-parametric two-tailed Kruskal–Wallis rank sum test was used to compare groups of continuous variables [Siegel, 1956]. To evaluate the effect of the intervention, we calculated the change in ZPP (divided by the number of days elapsed between measurements) for cutters hired before and after the intervention. We also compared final preintervention ZPPs and BLLs from cutters hired before the intervention to final post-intervention ZPPs and BLLs from cutters hired after the intervention. These measurements represented individual exposure to lead after approximately 60 d of working on the tank. For ZPPs, final values were adjusted for baseline values and number of days elapsed between measurements by linear regression. Baseline BLLs were not available, so final BLLs were adjusted for number of days on-site only.

RESULTS

Study Population

There were 29 men employed at the tank demolition site; 23 began working at the site before the intervention, and six began afterwards. Company medical records were available for all workers. The workers ranged in age from 24 to 68 years, with a mean of 45 years. Forty-five percent of the workers were non-Hispanic white, 38% were black, and 10% were Hispanic (race was unknown for two workers). Of the 24 workers who were employed in cutting the tank ("cutters"), 10 were ironworkers and 14 were laborers. All six workers hired after the intervention were cutters. Five "noncutters" included an engineer, two supervisors, and two heavy equipment operators.

Air Lead Measurements

Nineteen preintervention breathing-zone air samples were taken while cutting (December 28–January 3, and January 24–25). Sampling times ranged from 9 to 445 min, with an average of 284 min. The mean exposure to lead was 3,248 $\mu g/m^3$ (range 684–11,000 $\mu g/m^3$). Eight hour TWAs were calculated for 15 samples with sampling times of >180 min; the mean TWA was 2,051 $\mu g/m^3$ (range 665–5,338 $\mu g/m^3$). All samples contained levels of lead well over the new construction Permissible Exposure Limit (PEL) of 50 $\mu g/m^3$ (Fig. 1).

Sixteen additional air samples were taken while cutting after the intervention (January 30–February 6). Sampling times ranged from 185 to 466 min, with an average sampling time of 376 min. The mean lead measurement was 1,059 $\mu g/m^3$ (range 108–3,270 $\mu g/m^3$). The mean 8 hr TWA for cutters was 838 $\mu g/m^3$ (range 63–2,119 $\mu g/m^3$). Thus, air lead levels while cutting appeared to decrease after the intervention (Kruskal–Wallis, $p = 0.003$), but they remained far above the new construction standard PEL.

Six breathing-zone air samples were taken during noncutting activities (one before and five after the intervention). All three TWAs obtained from laborers (164, 87, and 31 $\mu g/m^3$) exceeded the new construction action level of 30 $\mu g/m^3$, and two exceeded the PEL. The TWAs obtained from a supervisor, engineer, and equipment operator were all <30 $\mu g/m^3$ (Fig. 1).

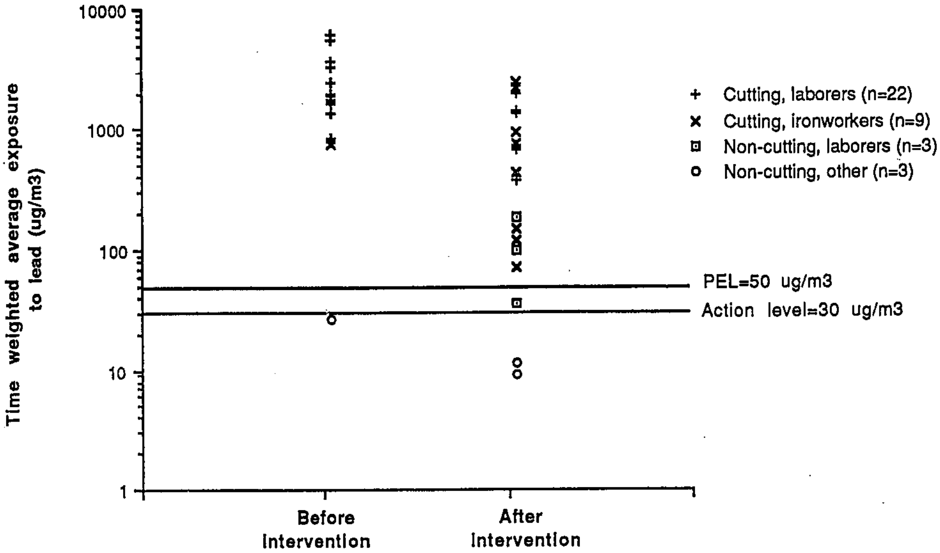

Fig. 1. Breathing-zone air lead measurements (μg/m^3) among tank demolition workers before and after the intervention. Eight hour time-weighted average exposures calculated assuming zero exposure outside of the sampling time. For a description of the intervention, refer to the text.

Biological Monitoring

Baseline ZPPs were obtained on all but one cutter, and three of five noncutters (Tables I and II). Baseline ZPPs for the cutters hired before the intervention were somewhat higher than baseline ZPPs for the cutters hired after the intervention (35.9 vs. 22.2 μg/dL). The 12 cutters on-site before the intervention who had both baseline and pre-intervention ZPPs measured experienced a mean change in ZPP of +0.49 μg/dL/day (mean change equal to zero, $p = 0.07$). Conversely, the three cutters hired after the intervention who had both baseline and final values obtained experienced a mean change in ZPP of +0.02 μg/dL/day (mean change equal to zero, $p = 0.40$).

Final preintervention ZPPs for cutters who were hired before the intervention were on average 37.4 μg/dL higher than final post-intervention ZPPs of cutters hired after the intervention (61.1 vs. 23.7 μg/dL; Kruskal–Wallis, $p = 0.61$). After adjustment for baseline ZPP and the number of days between measurements, the difference between final pre- and postintervention ZPPs decreased, but remained large (19.9 μg/dL, $p = 0.52$). Small numbers in the "after" group prevented the difference from being statistically significant.

With three exceptions, workers were not tested for BLL until January 23 and 24, immediately before the intervention. Of the 14 cutters who had been employed at the site for at least 1 week, 12 were tested; seven (58%) had BLLs >50 μg/dL (Table I). Of these seven, one worker was transferred off-site, and six stayed on-site but were reassigned to noncutting tasks for 1–4 weeks (one was subsequently injured and moved off-site, and one was later sent to another site for 1 month). Of the workers who stayed on-site, subsequent BLLs declined, but for two workers final postintervention BLLs remained >40 μg/dL.

TABLE I. Biologic Monitoring Results for Tank Demolition Workers Employed Before the Intervention*

Worker number	Baseline ZPP	Final pre-intervention ZPP[a]	Final pre-intervention BLL[a]	Removed?	Final post-intervention BLL[b]	Job title
Cutters						
1	11	125	83	Y, off-site	—	ironworker
2	28	102	69	Y, on-site	50	laborer
3	79	192	59	Y, on-site	34	laborer
4	59	106	53	Y, on/off	46	ironworker
5	36	51	52	Y, on/off	32	ironworker
6	57	50	51	Y, on-site	39	laborer
7	31	35	50	Y, on-site	32	ironworker
8	24	19	48	Y, on-site	30	laborer
9	10	10	43	N, quit	—	laborer
10	17	15	34	N	21	laborer
11	18	20	24	N	10	ironworker
12	25	8	21	N, quit	—	ironworker
13	18	—	—	N	36	sporadic laborer
14	128	—	—	N	39	laborer (foreman)
15	21[c]	—	—	N, quit	—	laborer
16	18[c]	—	27[d]	N, quit	—	laborer
17	21	quit	—	—	—	laborer
18	12	quit	—	—	—	ironworker
Noncutters						
19	19	—	—	N	12	supervisor
20	16	—	—	N	—	equipment operator
21	—	—	—	N	19	supervisor
22	—	4	5	N	5	engineer
23	15	—	—	N	11	equipment operator

*ZPP (zinc protoporphyrin) and BLL (blood lead level) measurements are in μg/dL.
[a]Measurements obtained January 23–24, 1988.
[b]Measurements obtained February 13–April 21, 1989.
[c]These workers were hired less than 1 week before the intervention.
[d]Actually a baseline value (see above).

None of the cutters hired after the intervention developed BLLs >25 μg/dL. As with the ZPP measurements, final preintervention BLLs taken from cutters hired before the intervention were 32.7 μg/dL higher than final postintervention BLLs obtained from cutters hired after the intervention (48.9 vs. 16.2 μg/dL; Kruskal–Wallis, $p = 0.002$). Adjustment for length of time on-site before measurement did not alter the difference in final BLL. However, without any information regarding baseline BLL, this information is somewhat difficult to interpret.

Four of five noncutters had at least one BLL obtained during the tank demolition. All were <20 μg/dL.

TABLE II. Biologic Monitoring Results for Tank Demolition Workers (All Cutters) First Employed After the Intervention*

Worker number	Baseline ZPP	Final post-intervention ZPP[a]	Final post-intervention BLL[a]	Job title
24	22	21	21	ironworker
25	18	—	18	laborer
26	—	—	18	laborer
27	18	20	16	ironworker
28	28	30	8	ironworker
29	25	—	—	laborer

*ZPP (zinc protoporphyrin) and BLL (blood lead levels) measurements are in µg/dL.
[a]Measurements obtained March 31–April 16, 1989.

Symptoms

Fourteen of 24 cutters (58%) were successfully interviewed by phone. Of the 10 cutters not interviewed, six failed to return repeated messages, and four were unable to be traced.

The prevalence of probable lead-associated symptoms among the 14 interviewed workers is listed in Table III. The most common symptom reported was extreme fatigue or generalized weakness (7/14). Muscle or joint pain was reported by six workers. Nine workers (64%) complained of at least one symptom. There appeared to be no relationship between the number of symptoms reported by the worker and his maximum BLL (data not shown). All workers denied any nonoccupational lead exposure.

Although most of the interviewed workers reported experiencing at least one probable lead-associated symptom, no worker had presented to the company physician with symptoms.

DISCUSSION

Although it may be unfair to judge the workplace by a standard that was not in force at the time, it is useful for our purposes to compare the practices at the tank demolition site to practices mandated by the current lead standard. For approximately the first half of the tank demolition, the level of respiratory protection for workers was inadequate for the degree of exposure and there were insufficient administrative and engineering controls. However, many air monitoring and medical surveillance components were in place. After the intervention, the level of respiratory protection for the workers improved, but was still inadequate by the current standard, which requires that workers engaged in cutting or burning leaded paint or exposed to air lead concentrations of 2,500–50,000 $\mu g/m^3$ be provided with at least half-mask, supplied-air respirators in positive-pressure mode. In addition, some engineering controls were adopted (primarily cutting from the unpainted interior of the tank), and hygienic practices greatly improved. Thus, the tank demolition worksite presented a unique opportunity to examine the impact of two varying levels of lead exposure control programs in a construction setting.

Although the worksite's initial lead control program was substandard, air and

TABLE III. Lead-associated Symptoms Reported by 14 Interviewed Tank Demolition Workers

Symptom[a]	Number (%) of workers with symptom	
Extreme fatigue or weakness	7[b]	(50)
Muscle or joint pain	6[b]	(43)
Frequent headaches	3[b]	(21)
Difficulty concentrating	3[b]	(21)
Nausea or abdominal pain	2	(14)
Numbness of the hands or feet	2	(14)

[a]Probable lead-associated symptom; for definition, see text.
[b]Two of the 14 interviewed workers began working on the tank after the institution of the more stringent lead control program. One of these workers reported fatigue, muscle pain, and headaches; the other reported difficulty concentrating.

biological monitoring was successful in alerting the employer that workers were being exposed to significant levels of lead. Of the cutters employed before the intervention, several exhibited increases in ZPP and 58% were found to have BLLs >50 μg/dL after an average of 59 d on-site. In response to these findings, the level of respiratory protection was increased, work processes were modified, and workers with elevated BLLs were temporarily removed to jobs with less lead exposure. Subsequently, the workers' BLLs declined, probably primarily due to being transferred to other jobs. Given the level of exposure, the worksite's air and biologic monitoring program, followed by corrective action, probably prevented some workers from becoming more severely lead intoxicated.

Cutters who were not employed at the site until after the intervention worked under conditions that more closely approximated those mandated by the current lead standard. These workers had smaller, nonsignificant increases in ZPP and also had lower final BLLs than did the cutters employed before the intervention. Comparison of biologic monitoring results between workers employed before and after the intervention is limited by a number of factors, including the small number of workers in the "after" group, and our inability to ensure that time spent cutting was comparable between the two groups (although management stated that workers became more productive as work on the tank progressed). The BLL comparison was further hampered by lack of baseline BLLs, especially in light of evidence that workers employed before the intervention had higher baseline lead burdens than workers hired afterwards. Nevertheless, this limited evidence suggests that improvements in the level of respiratory protection and other engineering and administrative controls, though still not completely compliant with the current lead standard, were effective in lessening the amount of lead absorbed by the workers.

Although the tank demolition worksite's practices fell short of meeting the current lead standard, it should be noted that in the absence of a regulatory mandate, it has been very uncommon for construction employers to conduct any sort of lead exposure control program. A recent review of construction workers reported to the California Occupational Lead Registry indicated that most workers had not even been aware of the presence of lead at their workplace [Waller et al., 1992]. Furthermore, a survey of 161 construction employers indicated that none had ever conducted medical surveillance for lead exposure [Rudolph et al., 1990].

Construction workers represent a large group potentially at risk for lead exposure. OSHA estimates that >900,000 employees are exposed to at least some level of lead during construction work [OSHA, 1993]. There have been several reports of significant lead exposure in this industry, particularly among workers repainting old homes, cutters and burners, and shipyard workers [Booher, 1988; Campbell and Baird, 1977; Fischbein et al., 1984; MMWR, 1989, 1992, 1993, Pollock and Ibels, 1986; Spee and Zwennis, 1987; Zimmer, 1961]. The number of construction workers exposed to lead may grow with the increasing prevalence of leaded paint abatement and highway infrastructure repair [Feldman, 1978; Landrigan et al., 1982].

The worksite described in this report represents the sort of construction setting in which it will be the easiest to implement the current lead standard: a tank owner willing to pay for a lead control program, a large and experienced contractor, and a relatively stable work force that was employed at a single site for several months. However, many construction workers move from employer to employer and spend a limited amount of time on any one job. It is well recognized that unprotected workers cutting or burning through leaded paint can become acutely lead toxic within days. Thus, the current lead standard, which mandates follow-up blood lead testing 2 months after baseline, may be of limited utility in identifying many situations where workers need more aggressive protection from lead exposure. In the construction setting there needs to be a particular emphasis on those components of the lead standard that facilitate anticipating and preventing lead exposure (e.g., testing materials for presence of lead before beginning work and ensuring adequate respiratory and other protection). Other strategies may need to be devised for effective medical surveillance of transient construction workers.

CONCLUSIONS

The elimination of occupational lead poisoning is one of the objectives of the U.S. Public Health Service [US DHHS, 1980]. The experience at this tank demolition worksite suggests that enforcement of the new construction lead standard will help to achieve this goal. However, further modifications may be necessary to fully protect construction workers who work in more transient settings.

ACKNOWLEDGMENTS

We acknowledge the support and assistance of the employees and management of the tank demolition companies, the industrial hygienist and safety consultant, and the ironworkers' and laborers' unions. We also thank Robert Harrison, MD, Margaret Handley, MPH, and Elizabeth Abello, MA, for their support of this project.

REFERENCES

Booher LE (1988): Lead exposure in a ship overhaul during paint removal. Am Ind Hyg Assoc J 49:121–127.

Campbell BC, Baird AW (1977): Lead poisoning in a group of demolition workers. Br J Ind Med 34:298–304.

Dean AG, Dean JA, Burton AH, Dicker RC (1990): "Epi Info, Version 5: A Word Processing, Database, and Statistics Program for Epidemiology on Microcomputers." Georgia: USD, Incorporated.