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ABSTRACT. An evaluation of lead, cadmium, and chromium exposure was conducted during abrasive blasting of a steel bridge to remove paint in preparation for repainting. Airborne lead concentrations were measured at several locations inside the containment structure, as well as near the workers' breathing zones. Airborne cadmium and chromium were also measured in the containment area. Blood lead levels were monitored in each worker. Airborne lead and cadmium levels in containment exceeded the Occupational Safety and Health Administration's permissible exposure limits by factors of 219 and 3.1, respectively. The use of supplied air-blasting helmets will not effectively reduce workers' lead exposure to the permissible exposure limits when airborne levels are as high as were measured in this study. Studies are needed to evaluate additional engineering controls and alternative paint removal methods. Evaluation of workers' exposure to lead and other hazardous metals is needed for projects involving abrasive blasting. Medical surveillance for cadmium *and* lead may be necessary for similar projects.

THE OCCURRENCE of lead toxicity in the construction industry has been documented in several case-series reports of bridge demolition workers exposed to leaded paint during the demolition process.[1–4] Bridge renovation and repainting also require removal of degenerating, lead-containing paint; such removal is frequently achieved by blasting steel grit at the bridge surface. This process removes the paint completely, and a smooth surface for repainting results. The U.S. Environmental Protection Agency (EPA) requires that the blasting process be enclosed completely, and that the lead-containing dust generated is to be hauled to a hazardous waste site. Use of this enclosure can raise ambient air lead and other paint additives to such high levels that even use of a half-mask, dual-cartridge respirator underneath an air-supplied, positive-pressure hood does not protect workers adequately from exposure by inhalation.[5,6] In addition, the practical difficulties of providing running water and a clean area for breaks on a construction site also allow for ingestion.

In addition to lead, other metal alloys (e.g., chromium, cadmium), may be contained in the steel or paint that is removed. Exposure to cadmium and chromium during bridge demolition has not been reported previously. This investigation was designed to evaluate the hazard potential of the abrasive blasting operation by (a) quantifying ambient air levels of lead within enclosures, (b) determining personal air lead levels for several job categories of exposed workers, (c) evaluating the efficacy of respiratory protection typically used for preventing excessive lead exposure and toxicity, and (d) quantifying ambient air levels of chromium and cadmium within enclosures.

Study Location

The site was a 16 400-ton double-deck bridge and connecting viaduct. All sites where blasting occurred were enclosed with plastic tarps to prevent release of lead dust to the surrounding environment. Blasting materials consisted of cast steel shot and grit, which contained carbon, silicon, manganese, and iron. Grit was added by hand vacuum three times per day, cleared of paint chips, and reused. Abrasive blasting was powered by compressed air. A mobile baghouse filter and air mover was used to create a negative pressure system for filtering and exhausting interior, dusty air prior to release into the environment.

Respiratory protection was worn during abrasive blasting. The types of respiratory protection available were type CE supplied-air abrasive blasting helmets and half-mask dust/mist air-purifying respirators. The type and consistency of use varied with job description and crew. Blasters and sweepers, who spent most of the day inside the containment area, wore both types of respirators simultaneously. Other workers on the site (i.e., foremen, helpers, equipment operators, and supervisors) used no respirators or occasionally would use the half-mask air-purifying respirators. In addition, the sweepers on one of the two crews wore only half-mask air-purifying respirators while they were in containment during abrasive blasting. The employer had a written respiratory protection program and reported that training and qualitative fit testing were provided for all new employees. The training and fit testing were not observed by the researchers.

Method

Personal and area monitoring of lead was performed on two crews, 8–10 h/d, for 23 d over two construction seasons (i.e., 8 mo). The activities of the crews were recorded during each day that sampling was performed. Results are reported for the primary activity for each day. Blasting was usually performed for the entire shift on days that blasting occurred. Area sampling was performed for chromium during the first season and for cadmium during the second season. Area samples were collected at three locations inside the containment, using small battery-operated pumps. Personal sampling pumps were attached to workers' belts with the filters placed near the workers' breathing zones, inside the supplied air helmets but outside the half-mask air-purifying respirators. Both types of samples were collected on 37-mm mixed-cellulose ester filters and were analyzed using atomic absorption spectrophotometry (AAS).[7]

Approximately one venous blood sample per month was taken from each of 22 workers, and the samples were analyzed for blood lead (PbB), using standard

Table 1.—Blood Lead Levels of Each Worker

		Blood lead levels (μg/dl)		
Employee	Job title	Before season 1 (05/18/91–10/01/91)	Season 1 (10/02/91–12/07/91)	Season 2 (05/28/92–11/12/92)
1	Blaster	—	39	—
2	Blaster	—	47/45/38	28/34/57/41
3	Blaster	—	45	—
4	Blaster	—	—	—
5	Blaster*	5/39/60/60/64/82	50	29/24/33/39
6	Blaster*	—	39	—
7	Blaster*	12/23	21	—
8	Sweeper	—	9/26	—
9	Sweeper	—	9/10/26	—
10	Sweeper	111†/102/85/44	8/6/22	—
11	Sweeper*	63/25/48/47/40/36/56/58/48	—	38/28/27
12	Sweeper*	37/55	45	—
13	Sweeper*	—	—	30/22/34
14	Sweeper*	—	—	39
15	Sweeper*	—	—	—
16	Foreman	—	39/38	—
17	Foreman*	78/73/77/72/72/54/88/81/81/86	74†	36/37/54
18	Equipment operator*	14/52/41/54/74/77/89	67	47/35/62‡/43
19	Equipment operator	—	—	18/21/42
20	Equipment operator	—	—	18/33
21	Equipment operator	—	—	5
22	Helper	—	—	—
23	Helper*	15/33	28	—
24	Helper	—	12	—
25	Supervisor	9	—	—

*Prior to season 1, these individuals were working on another project that involved abrasive blasting.
†These workers were chelated following this blood sample.
‡This worker went on vacation following this blood sample.

Table 2.—Personal Air Lead Exposure for Each Worker

Employee	Job title	Activity*	Air lead concentration (μg/m³) Median	Range	Q1–Q3†	Number
1	Blaster	Blasting	733	372–2 147	634–1 147	5
2	Blaster	Blasting	253	56–4 200	180–1 086	8
		Other	120	110–130	—	2
3	Blaster	Blasting	460	145–1 463	173–1 091	4
4	Blaster	Blasting	119	—	—	1
5	Blaster	Blasting	326	36–1 774	85–705	8
		Other	135	42–1 800	86–970	4
6	Blaster	Blasting	398	77–583	152–576	4
7	Blaster	Blasting	2 241	81–4 401	—	2
8	Sweeper	Blasting	507	101–1 944	287–521	5
9	Sweeper	Blasting	2 547	12–3 678	172–2 722	6
10	Sweeper	Blasting	2 177	220–3 548	466–3 493	5
11	Sweeper	Blasting	99	14–180	29–169	6
		Other	80	43–2 500	43–2 500	3
12	Sweeper	Blasting	319	50–606	103–544	4
13	Sweeper	Blasting	780	—	—	1
		Other	190	—	—	1
15	Sweeper	Blasting	340	60–850	86–492	5
		Other	90	—	—	1
16	Foreman	Blasting	116	26–3 423	47–199	6
17	Foreman	Blasting	203	48–750	148–220	11
		Other	46	12–180	19–140	6
18	Equipment operator	Blasting	237	39–1 400	120–1 000	10
		Other	590	79–1 900	260–1 320	4
19	Equipment operator	Blasting	260	—	—	1
20	Equipment operator	Blasting	14	—	—	1
21	Equipment operator	Other	13	—	—	1
22	Helper	Blasting	1 439	—	—	1
23	Helper	Blasting	262	39–501	138–394	4
24	Helper	Blasting	188	—	—	1
25	Helper	Blasting	78	22–129	30–121	5

*Activities: "blasting" included abrasive blasting and using compressed air to blow dust off structure prior to painting; "other" included painting, cleaning-up, and setting-up or moving containment.
†Q1–Q3 = twenty-fifth percentile to seventy-fifth percentile.

techniques.[8] The blood sampling was performed by the employer, and the data were made available to the authors.

Informed consent was obtained from each study participant after the nature of the procedures had been explained fully.

Results

The blood lead levels for each worker are shown in Table 1. Personal air sampling results for lead during blasting and nonblasting activities are shown in Table 2. Summary results for each group of workers and for blasting and nonblasting activities are given in Table 3. Blasting activities included abrasive blasting and blow-off, using compressed air to blow dust off of the structure prior to painting. Nonblasting activities included painting, cleaning, and setting-up or moving the containment. Area sampling results for inside containment concentrations of lead, chromium, and cadmium are shown in Table 4.

Lead levels in personal air samples collected inside the supplied air helmet (but outside the half-mask respirators) ranged from 14 to 4 401 μg/m³. Absent consideration of respiratory protection, 106 of 125 air samples contained lead levels that exceeded the 50-μg/m³ level currently allowed by the Occupational Safety and Health Administration (OSHA). If a protection factor of 10 is assumed for the half-mask respirator,[9] the range of direct exposure is 1.4 to 440 μg/m³. If respiratory protection for those workers who wore half-mask respirators is considered, lead levels in 63 of 125 air samples exceeded the current OSHA permissible exposure limit (PEL).

Medical surveillance was performed voluntarily by the employer. The OSHA standard that requires medical surveillance was not in place at the time of this study. Eighteen of 22 workers had average blood lead levels that exceeded 25 μg/dl, requiring reporting of the findings to the Illinois Department of Public Health for follow-up. Five workers had lead levels sufficiently high to require medical removal—had the current OSHA standard been in place at the time of the study. Thirteen workers demonstrated an increase in blood lead levels while they worked on abrasive-blasting projects. Median blood lead levels for groups of workers, over all three seasons, were highest for foremen. The median blood lead level in the 1970s for American white males was 16.6 μg/dl.[10]

Table 3.—Personal Exposure to Lead (by Job Title and Activity) and Blood Levels (by Job Title and Season)

Activity	Job title	Median	Range	Q1–Q3*	Number
		Airborne lead concentration (μg/m³)			
Blasting	Blasters and sweepers†	366	12–4 401	151–815	64
	Equipment operators‡	219	14–1 400	115–699	12
	Foremen‡	160	26–3 423	83–214	17
Other§	Blasters and sweepers†	130	42–2 500	80–190	11
	Equipment operators‡	440	13–1 900	79–740	15
	Foremen‡	46	12–180	19–140	6
		Blood lead levels (μg/dl)			
Before season 1//	Blasters and sweepers†	48	5–111	37–63	23
	Equipment operators‡	54	14–89	41–77	7
	Foremen‡	77	22–88	72–81	11
Season 1	Blasters and sweepers†	26	6–50	10–45	10
	Equipment operators‡	67			1
	Foremen‡	39	38–74		3
Season 2	Blasters and sweepers†	33	22–57	28–39	15
	Equipment operators‡	34	5–62	18–43	10
	Foremen‡	37	36–54		3

*Q1–Q3 = twenty-fifth percentile to seventy-fifth percentile.
†Half-mask dust/mist air-purifying respirators and type-CE supplied air-blasting helmets—air samples collected inside blasting helmets during blasting; intermittent or no use of half-mask/dust/mist air-purifying respirators—samples collected near workers' breathing zones (outside respirators) during other activities.
‡Intermittent or no use of half-mask dust/mist air-purifying respirators—samples collected near workers' breathing zones (outside respirators).
§Moving containment, painting, cleaning, equipment maintenance.
//No air sampling was performed before season 1.

Table 4.—Area Concentrations of Lead, Chromium, and Cadmium during Abrasive Blasting

	Area concentration (μg/m³)							
	Bridge				Viaduct			
	Median	Range	Q1–Q3*	Number	Median	Range	Q1–Q3*	Number
Lead	10 970	196–29 950	3 241–20 300	9	3 277	533–18 200	1 797–7 205	10
Chromium	23.5	1.26–43.7	7.96–38.0	4	369	9.41–657	36.0–430	5
Cadmium	15.7	13.5–18.3	14.6–17.1	4	1.31	1.06–1.60	—	3

*Q1–Q3 = Twenty-fifth percentile to seventy-fifth percentile.

Discussion

The recently revised OSHA Standard for lead in construction lowered the PEL to 50 μg/m³.[11] The ambient air levels demonstrated in this project were in extreme excess of the PEL; use of a supplied air helmet, in addition to a half-mask filter respirator, operating at published protection factors of 25 and 10, respectively, would not prevent inhalation of lead-containing particles.[9] In the most extreme case (lead concentration = 29 950 μg/m³), the concentration at the workers' breathing zone would be more than twice the exposure allowed.

The blasting grit was reused and was, therefore, a potential source of exposure resulting from resuspension of contaminants. Blasting grit, however, was not thought to be a major source during abrasive blasting. The inside containment concentrations measured on the bridge and viaduct were substantially different (median = 10 970 μg/m³ and 3 277 μg/m³, respectively). However, the same blasting equipment and grit were used on both structures. The blasting grit could have been a significant source of exposure during maintenance or general operation of the blasting equipment, as evidenced in the exposures and blood lead levels of the equipment operators.

The tarps used for containment and the blasting equipment can become contaminated with lead dust during blasting. Equipment maintenance or moving or handling of the tarps results in release of lead dust. Lead exposures measured during nonblasting activities exceeded the PEL in most cases. Respiratory protection was seldom worn during these activities.

All workers who were sampled were members of the Painters Union and were employed regularly in abrasive blasting operations. Whereas high ambient air lead levels could explain blood lead elevations, elevated body burdens of lead in these individuals may have accounted, at least in part, for the rapid rise of blood lead during the renovation project. Other contributing factors may have included lack of running water, as well as eating and smoking, at the construction site.

The lead and chromium content and the thickness of the paint accounted for the differences in area concentrations measured on the bridge versus the viaduct. Although the measured chromium concentrations were below the OSHA PEL (i.e., 1 000 μg/m^3),[1] measurable concentrations were detected, indicating that airborne chromium can be a potential hazard in these types of projects.

In addition, the toxicity of chromium depends on valence state, with hexavalent chromium considered to be the most toxic. Atomic absorption spectroscopy identifies only total chromium and does not allow for analysis of the valence state. The OSHA PEL for chromic acid and chromates is 100 μg/m^3; however, the National Institute for Occupational Safety and Health (NIOSH) -recommended exposure limit (REL) for all hexavalent chromium compounds is 1 μg/m^3. Also, NIOSH considers all hexavalent chromium compounds to be potential human carcinogens.[12]

Airborne cadmium was measured only during season 2. The median airborne concentration inside the bridge containment was 15.7 μg/m^3, which exceeded the OSHA PEL of 5 μg/m^3 by a factor of 3.1. A medical surveillance program is required at the action level of 2.5 μg/m^3.[13]

The EPA requirement to enclose bridge renovation and demolition projects was designed to protect the environment from lead contamination. However, abrasive blasting operations, such as the one described, clearly expose workers to hazardous levels of lead. Additional studies are needed to evaluate local exhaust ventilation alternatives, such as a glove-box-type of enclosure, waterless soap, and alternative forms of paint removal. There is also a need to analyze paint chips and ambient air for chromium and cadmium during renovation and demolition projects. Analysis of the valence state of chromium should also be considered. A medical surveillance program for cadmium, as well as for lead, may be required during projects similar to the one described.

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