WATER OPERATION AND MAINTENANCE

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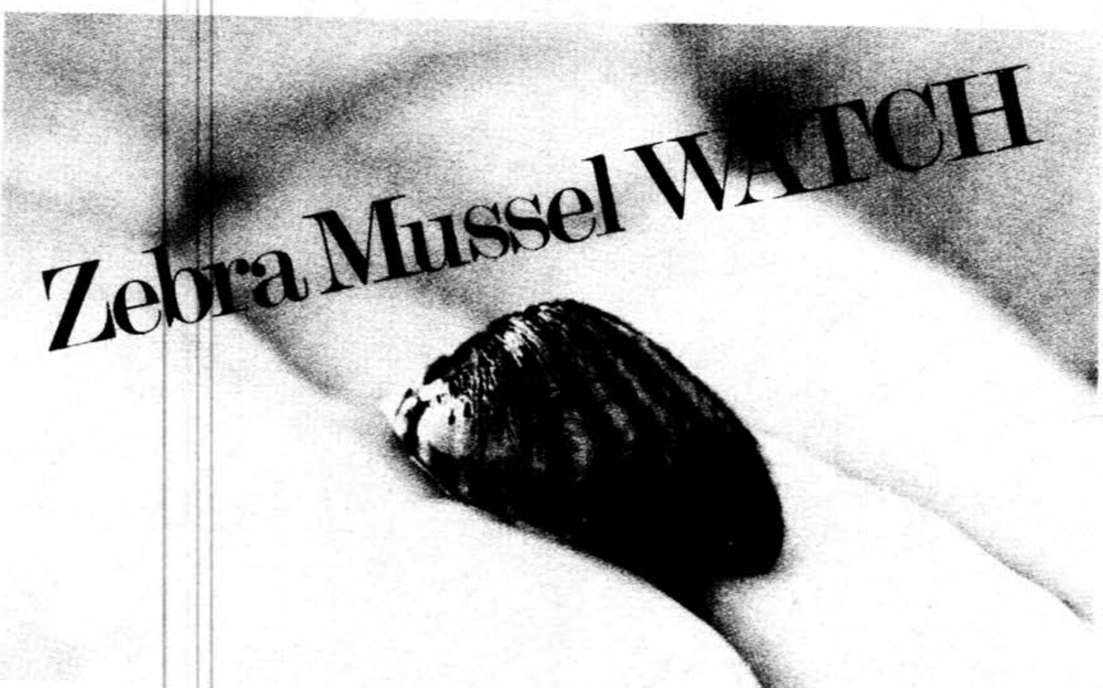

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UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

The Water Operation and Maintenance Bulletin is published quarterly for the benefit of those operating water supply systems. Its principal purpose is to serve as a medium of exchanging information for use by Bureau personnel and water user groups for operating and maintaining project facilities.

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Cover photograph:

Zebra Mussel

(photo University of Wisconsin Sea Grant Institute)

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THE ZEBRA MUSSEL MENACE

A Problem Species in the Great Lakes Makes Its Move Toward Prominence in the West

by Cal McNabb[1], Fred Nibling[2], and Charles Liston[3]

A prolific clam-like creature has plugged up the works in multimillion dollar state-of-the-art electric power and water treatment facilities on the Great Lakes. Also, its voracious feeding has stripped suspended particles from the water, including food that supports the billion dollar commercial and recreational fisheries on the Great Lakes. Maintenance costs for infested structures and intakes at individual facilities are currently running at millions of dollars annually. The overhaul of water systems and damage to fisheries are estimated to cost $4–$5 billion in the Great Lakes region during the next decade.

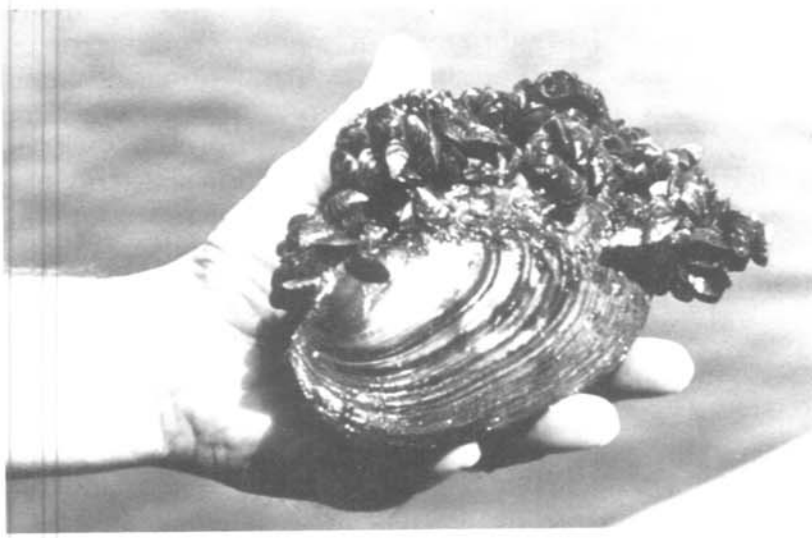

Photo 1.–In addition to impacts on industrial water supplies, zebra mussels have profound effects on native aquatic fauna. For example, this picture shows smaller zebra mussels crowded around the food intake of a larger native clam. In this position, zebra mussels rob native clams of their food, and cause native clam extinctions.

Severe economic losses will occur at several locations in the Mississippi River basin if native clams are destroyed. They are harvested from rivers in the region for their shells, used as raw materials in the button industry.

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Adult zebra mussels (*Dreissena polymorpha*) were first found in North America in 1988 at a location in the Great Lakes near Detroit. The animal had recently arrived from Europe. Adapted to life in fresh or slightly brackish water, it jumped the salt water barrier between Europe and the Great Lakes in the ballast of an inbound commercial freighter. It became established after the ballast was discharged. In the past 3 years, the mussel has shown it is not just another run-of-the-mill pest limited to the Great Lakes region. It is expected to encounter few geographical or environmental barriers to prevent colonization of freshwater habitats throughout temperate North America. Predictions are that it will be common in the West in the next 3–5 years. Both structures and fisheries in Reclamation's highly automated networks of water delivery systems are at serious risk from this pest, if it goes unattended in early stages of invasion.

Pest Characteristics

There are several aspects of zebra mussel ecology that make it a menace of national significance. The animal is adapted to live in the great majority of freshwater habitats in the continental United States. No predators are naturally effective in controlling zebra mussels in either North America or Europe. Parasites and organisms that can cause it disease are also uncommon. The zebra mussel is unique among the clans of freshwater clams; it is the only one that, as an adult, grows firmly attached to solid objects. Adult animals have the tendency to grow attached to one another, forming dense clusters. Because of this tendency, it is not uncommon to find 40,000–100,000 adult mussels per square meter (33,400–83,500 per square yard) in good habitat on intake cribs, concrete channel linings and the like. The zebra mussel's rate of reproduction is tremendously high; each mature female produces 30,000 to 40,000 eggs per year. Young mussels are formed in parental colonies. They are very small in size, and travel about unnoticed. Distances over which they can move away from parental colonies are astounding. They drift about on water currents or attached to barges, boats, boat trailers, anchors, bait buckets, waders, wet swimming suits; and perhaps among the feathers of waterfowl.

Young zebra mussels eventually settle down and attach to solid surfaces. Almost any kind of surface will do. They feed by filtering small algae, bacteria, and bits of decomposing material out of the water. Zebra mussels live for 3–5 years, and older animals reach a length of 2.5–4.0 cm (1.0–1.6 inches). They grow best down in the water, or in and around pipes and structures where they are out of bright light. They favor a moderate current which brings their food to their doorstep. Reclamation's water conveyance systems abound with prime habitat of this kind.

Photo 2.–Small floating larvae of zebra mussels are drawn into water intake pipes where they settle down, grow, and block waterflow to critical components of cooling systems in industrial plants and on ships and pleasure boats. (Photo by Peter Yates)

Natural Restrictions

The zebra mussel is coming west, but it will not grow everywhere. In general, they are adapted to live in relatively clean waters in locations with a temperate zone climate, where the seasons come and go. As with other species, their genetics and physiology will put limits on their ability to infest certain kinds of habitats, some of which may be found in the West. For example, they will generally not develop infestations where:

* Water temperature in summer is 29–30 °C (84–86 °F) for extended periods of time.

* Calcium in the water (required for shell formation and maintenance) averages less than 10 milligrams per liter.

* Dissolved oxygen is low (less than 20–30 percent of atmospheric saturation) or absent.

* Turbidity is high enough to impair gill function.

* Salinity is greater than 4–5 parts per thousand parts of water.

* Velocities of currents are greater than 1–1.5 meters per second (3–5 feet per second).

* Toxic pollutants are abundant.

Where habitats are suitable in regard to these conditions, and free of effective predators and disease organisms, the size of zebra mussel infestations will be largely a function of the abundance of permanently submerged solid substrates for colonization, and the amount of food (small algae, bacteria) available for the young and adults.

Photo 3.-Water at high pressure has been used to blow zebra mussels off walls of invested chambers at electric power stations, municipal waterworks, and pumping stations. Freed mussels must be collected to prevent them from washing downstream into screens, nozzles, and other constrictions when cleanup is over and plant operation resumes.

Early Action: The Key To Control

History has shown that the American Great Lakes, as well as water intake structures on their shorelines, were ideal habitats for zebra mussels to colonize. With few exceptions, the industrial and scientific communities of the Great Lakes region were caught by surprise at the speed at which mussel infestations developed, and the size of infestations. Measures to minimize their effects were not undertaken until clusters of two to three generations of animals, one generation growing on top of the other, had plugged screens and trashracks and smaller diameter pipes, reduced flows in conduits with larger cross sections, blocked control gates, interfered with pumps, disrupted gauging and flow rate instrument networks, piled up in wet wells, fouled fire control systems and accelerated corrosion. In retrospect, regular maintenance inspection of structures and timely mechanical removal could have alleviated a considerable portion of these problems.

Prospects

An alarming aspect of the North American zebra mussel invasion has been the speed at which mussels have spread and colonized new habitats. In the 3 years since they were first noted, zebra mussels have spread into an area with a radius of about 600 miles around the point of origin near Detroit. They have, for example, moved east to the Hudson River, south to the TVA system, and northwest to the upper Mississippi River. There is no evidence to suggest they will not continue to move very rapidly into the West and infest lakes, streams, and reservoirs across the continent.

Early detection and manual maintenance are the first line of offense to minimize zebra mussel impacts on Reclamation facilities. In areas of heavy infestation, manual maintenance may need to be used as part of an integrated approach that incorporates other control procedures. For example, fish predators may be confined in infested canals to reduce breeding populations of mussels and thereby their densities on critical water control structures downstream. Chlorine, hot water, and commercial biocides may have application in closed or semi-closed portions of water systems. Copper and zinc surface coatings, which inhibit mussel attachment and/or development, may be used effectively in key trouble spots along water distribution lines. Sonic waves, ultraviolet rays, and electrical shock are other alternatives for control. The Applied Sciences Branch at the Denver Federal Center is undertaking research related to early detection and control under Project EE025: Control of Exotic Molluscs.

In the long-term, American water works are likely to be adapted to operate with a high level of tolerance for the presence of the zebra mussel. In Europe, the animal was present nearly 100 years before modern urban and industrial development began. As a result, water systems were designed early-on to manage infestations with minimum disruption of service. Similar structural modifications will likely be made to existing facilities in infested drainage basins in the United States, and new designs will appear for facilities yet to come. Looking ahead, zebra mussels are likely to find accommodations in American facilities, including those of Reclamation, much less hospitable than they have been to date.

Reclamation's Regional Offices have been furnished with information for distribution to personnel and others, as well as a VCR tape on these mussels.

Zebra Mussel Watch

The great majority of Western waters meet all the ecological requirements of suitable habitat for zebra mussels. Early detection will be the key to maintaining efficient operation of Reclamation's water delivery structures in areas that become infested by the animal. It will also set the stage for implementation of new management strategies to promote recreational fisheries and endangered fish species in lakes, streams, reservoirs, and tail waters impacted by zebra mussels.

We invite you to participate in Reclamation's ZEBRA MUSSEL WATCH, a program aimed at early detection in western waters. Zebra mussels are easy to capture. They are also easy to identify because adults are the only clam-like animals in inland waters that attach themselves to solid objects. First-time detection at a particular location is most often made by finding animals on objects that are retrieved from a water depth of several feet.

Hang a Rope

A rope tied to a brick anchor makes a great device for detecting zebra mussels. Any kind of rope will do; however, nylon is preferred because small mussels are easier to distinguish on its smooth surface than they are on ropes with rough surfaces. Adult animals produce young mussels in the spring when the water warms up, and they continue to produce young until fall. Young mussels float about in the water and eventually attach themselves to ropes or other objects. They are smaller than the head of a common straight pin and quite transparent when first attached. They grow to 1/4 inch in

2–3 months, and take on the appearance of small, dark-colored clams. They commonly grow to 1/2 inch before their first winter.

Hang a rope in 8 feet or less of well-oxygenated water. Select a spot where wave action will not move the bottom of the rope to any great degree. Zebra mussels like slow currents. They will not attach where the current is moving 4–5 feet per second or faster. Young zebra mussels settle down on surfaces that are coated with algae and other microscopic organisms. Leave your rope in the water for 2–3 weeks to allow these microorganisms to grow. Thereafter, lift the rope at 2–3 week intervals and examine it for young mussels. If adults are around, the young will eventually show up. Remember, it is as important to know that adult mussels are not around as it is to know that they are!

Reclamation's Zebra Mussel Program coordinates information on geographical distribution of zebra mussels with offices of Reclamation and other public agencies. Report your work whether or not you find zebra mussels. If you think you have found zebra mussels, record the place found and lengths of their shells. Have the identification of your specimens confirmed. Preserve them in rubbing alcohol, wrap them in a piece of tissue, and send them to:

Dr. Cal McNabb
Reclamation's Zebra Mussel Program
PO Box 25007, Code D-3742
Denver CO 80225-0007
Telephone: (303) 236-6007

You will receive a reply regarding your specimens and a summary of information gathered by others participating in this program.

GUIDELINES ON SAFETY DURING LEAD PAINT OPERATIONS[1]

Editor's Note: In response to an increase in the incidence of lead poisoning among construction workers, including blasters and painters, the National Institute for Occupational Safety and Health (NIOSH) issued a NIOSH Alert entitled Request for Assistance in Preventing Lead Poisoning in Construction Workers in the Fall of 1991.

The document is a guidance document and as such it does not have the force of law or regulation behind it.

OSHA is in the process of developing a regulation for worker exposure to lead in the construction industry, but until that document is complete, the NIOSH Alert and the OSHA/NIOSH Interim Guidelines, reprinted in the July 1991 JPCL, pp. 44–55, are the most current documents from Federal health and safety agencies on protecting construction workers from overexposure to lead.

Readers are permitted to photo-copy the reprinted Alert without seeking permission from JPCL or NIOSH.

NIOSH Alert: Request for Assistance in Preventing Lead Poisoning in Construction Workers

The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing the lead poisoning[2] of workers engaged in the maintenance, repainting, or demolition of bridges or other steel structures coated with lead-containing paints. NIOSH recently learned of 42 workers who developed lead poisoning while working on bridges. Operations such as abrasive blasting, sanding, burning, cutting, or welding on steel structures coated with lead-containing paints may produce very high concentrations of lead dust and fumes. Furthermore, the recent introduction of containment structures (enclosures designed to reduce environmental contamination by capturing particles of paint and used blasting material) may result in even higher airborne concentrations of lead. Lead dust at the worksite may also result in contamination of workers' homes and automobiles.

WARNING!

Lead poisoning may occur in workers during abrasive blasting, sanding, cutting, burning, or welding of bridges and other steel structures coated with lead-containing paints.

For the construction industry, NIOSH and the Occupational Safety and Health Administration (OSHA) have recently recommended that exposure to lead dust and fumes be minimized by the use of engineering controls and work practices, and by the use

[1] Reprinted from an article in *JPCL* (Journal of Protective Coatings & Linings), 2100 Wharton Street, Suite 310, Pittsburgh PA 15203; January 1992 issue, pp. 40-54.

[2] For the purposes of this document, NIOSH has defined lead poisoning as a concentration of lead in whole blood (known by OSHA as a blood lead level, or BLL) exceeding 50 micrograms per deciliter (μg/dl). See table 4 for a list of actions required by the Occupational Safety and Health Administration (OSHA) general industry standard for various BLL's.

of personal protective equipment (PPE)—including respirators—for additional protection [OSHA/NIOSH 1991]. Airborne lead concentrations and blood lead concentrations should be monitored to determine the effectiveness of controls and PPE. All new contracts of Federal, State, and local departments of transportation *should* include specifications for a mandatory program of worker protection from lead poisoning during the maintenance, repainting, or demolition of bridges and other steel structures.

NIOSH requests that the recommendations in this Alert be brought to the attention of workers and employers (including subcontractors) by general construction contractors, State departments of transportation (including worksite inspectors), labor union representatives, labor associations, editors of appropriate trade journals, and safety and health officials. Your assistance in this effort will help to achieve one of the national health objectives specified by *Healthy People 2000* [DHHS 1990], a statement of national goals for health promotion and disease prevention. These goals are the product of a national effort involving State health departments, national organizations, and many individuals. The goal for workers exposed to lead is to eliminate exposures that result in blood lead concentrations greater than 25 $\mu g/dl$ of whole blood.

BACKGROUND

Workers are potentially exposed to lead during work on bridges or other steel structures such as water and fuel storage tanks. Workers who may be exposed to lead include abrasive blasters, inspectors, iron workers (welders and cutters), painters, and laborers. In 1987, an estimated 44,000 persons worked in bridge, tunnel, and elevated-highway construction (Standard Industrial Classification Code [SIC] 1622), and an estimated 14,000 persons worked in wrecking and demolition (SIC 1795) [Bureau of the Census 1990].

An estimated 90,000 bridges in the United States are coated with lead-containing paints [Katauskas 1990]. According to a survey of State departments of transportation, lead-containing coatings were found on approximately 77 percent of U.S. bridges [*Editor's Note: The revised estimate is 83 percent.*] that were repainted between 1985 and 1989 [Steel Structures Painting Council 1991].

Maintenance of Steel Structures

Before new coating may be applied to bridges and other steel structures, deteriorated paint and corrosion must be removed and the metal surface must be properly prepared [Katauskas 1990]. In addition, all coatings of lead-based paints must be removed before another type of paint can be applied [Katauskas 1990]. This process is most commonly accomplished by using a portable device for abrasive blast cleaning. These devices are designed to deliver a high-velocity stream of abrasive to the metal surface. Compressed air is generally used, but some devices use water to deliver the abrasive. A variety of nonmetallic and metallic abrasives have been used, including silica sand, slag, and steel grit. The worker performing the blasting directs the blasting nozzle at the surface to be cleaned. As the paint is removed, small particles become airborne, and the used abrasives become contaminated with lead-containing paint particles.

Containment structures are used to reduce the release of lead into the environment by capturing paint chips, dust, and used abrasive. Where possible, containment structures are designed so that the used abrasives and debris are directed through chutes or tubes into a barge or hopper. Because the recovery systems in the containment structures are not completely effective, some of the material must be recovered manually by sweeping, shoveling, or vacuuming. Under the Resource Conservation and Recovery Act (RCRA), waste material must be tested, and if the leachable lead concentration is 5 parts per million (p/m) or greater, the material is classified as a hazardous waste [40 CFR[3] 260].

Containment structures are designed to reduce the dispersion of lead into the environment, but they may increase worker exposure to airborne lead. Current techniques for containment are not well defined and vary in their efficiency in preventing lead from being released into the environment. Some containment structures consist of tarpaulins or open mesh fabrics placed over the blasting area; some use rigid materials of wood, metal, or plastic to enclose the blasting area; and some use a combination of flexible and rigid materials. Large air-moving devices may be mounted on trucks and connected to the containment structures to exhaust dust-laden air. The exhausted air is passed through dust separation devices and filters before it is released to the atmosphere. This ventilation technique may also create a negative pressure within the containment structure and help reduce environmental contamination.

Workers may receive additional exposure at some sites when the containment structures (which may contain residual lead dust and debris) are disassembled and moved. Workers should be adequately protected while performing these operations.

Potential for Exposure to Airborne Lead

At sites where workers performed bridge, tunnel, and elevated-highway construction (SIC 1622), OSHA reported airborne lead concentrations exceeding 200 micrograms per cubic meter ($\mu g/m^3$) for 65 percent of the samples collected between April 1984 and April 1988 [OSHA 1988]. Tables 1 and 2 summarize cases of occupational exposures to lead reported during abrasive blasting, sanding, burning, cutting, and welding. Most of the operations described were conducted outside containment structures. These data indicate that persons working at the jobsite outside the containment structure are also at risk of exposure to lead. *Workers who do not shower and change into clean clothing before leaving the worksite may contaminate their homes and automobiles with lead dust.* Other members of the household may then be exposed to harmful amounts of lead [Grandjean and Bach 1986; Kaye et al. 1987; Matte et al. 1989; Baker et al. 1977].

HEALTH EFFECTS OF LEAD EXPOSURE

The frequency and severity of medical symptoms increase with the concentration of lead in the blood. Many adults with blood lead levels (BLL's) of 80 $\mu g/dl$ or greater have symptoms or signs of acute lead poisoning, although in some individuals, symptoms may be so mild that they are overlooked [NIOSH 1978; Rosenstock and Cullen 1986]. Common symptoms of acute lead poisoning are loss of appetite, nausea, vomiting, stomach cramps, constipation, difficulty in sleeping, fatigue, moodiness, headache, joint or muscle aches, anemia, and decreased sexual drive. Severe health effects of acute lead exposure include damage to the nervous system, including wrist or foot drop, tremors, and convulsions or seizures. Acute lead poisoning from uncontrolled occupational exposures has resulted in fatalities [Hayhurst, 1915].

[3] Code of Federal Regulations. See CFR in references.

Table 1 Airborne Lead Concentrations Reported during Operations on Bridges and Other Painted Steel Structures

Operation	Job	Exposure range during task (μg/m³)	Comments
[illegible] [New Jersey Department of Health [illegible]]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
Bridge demolition (no containment structure) [New Jersey Department of Health 1988b]	Torch burner	110-1,200	Workers were cutting beams on bridge
	Burner helper	330	These workers assisted burners who were cutting the bridge
	Power tool use	5-50	
Bridge demolition (no containment structure) [New Jersey Department of Health [illegible]]	Burner	[illegible]	
	[illegible]	[illegible]	
Paint removal from boiler (no containment structure) [Adkison 1989]	Blaster	230-860	Samples were taken inside respirator
		640-1,400	Samples were taken outside respirator
	Power tool operators	80-790	Workers were spot cleaning an existing surface
Power plant (no containment structure) [Rekus 1988]	Burner	2,100-22,400	
Bridge repair (no containment structure) [Rekus 1988]	Welder Blaster Burner Blaster	2,200-4,200 10,400 840-4,900 1,070-1,120	
Paint removal from a tank [Lippy et al. [illegible]]	Abrasive blasting	[illegible]	Work conducted inside containment structure
	[illegible]	[illegible]	Work conducted outside containment structure
	[illegible]	[illegible]	Work conducted outside containment structure
	[illegible]	[illegible]	Work conducted inside containment structure

Table 2 Airborne Lead Concentrations Reported for Case Studies

Case No.*	Location and description	Job	Range of airborne lead concentration during task ($\mu g/m^3$)	Comments
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
3	Louisiana, paint removal from bridge (with containment structures)	Blaster	2-730	Work conducted inside containment structure
[redacted]	[redacted]	[redacted]	[redacted]	
6	Kentucky, paint removal from bridge (with containment structures)	Blaster	3,690-29,400	Work conducted inside containment structure; samples taken outside respirator
		Blaster	9-190	Work conducted inside containment structure; samples taken inside respirator
		Groundsman	5-6,720	Work conducted outside containment structure

**No samples were collected for Cases 2 and 4.*

†Area samples.

Chronic lead poisoning may result after lead has accumulated in the body over time, mostly in the bone. Long after exposure has ceased, some physiological event such as illness or pregnancy may release this stored lead from the bone and produce adverse health effects such as impaired hemoglobin synthesis, alteration in the central and peripheral nervous systems, hypertension, effects on male and female reproductive systems, and damage to the developing fetus [Landrigan, 1989]. These health effects may occur at BLL's below 50 $\mu g/dl$.

RELEVANT EXPOSURE CRITERIA AND REGULATIONS

In 1978, OSHA promulgated a comprehensive standard regulating occupational exposure to inorganic lead in general industry [29 CFR 1910.1025]. Under this standard, the permissible exposure limit (PEL) for inorganic lead is 50 $\mu g/m^3$ of air as an 8-hour time-weighted average (TWA). However, the construction industry was exempted from this regulation and has a 200-$\mu g/m^3$ PEL for inorganic lead [29 CFR 1926.55]. Unlike the OSHA standard for general industry, the construction standard does not require medical monitoring of workers exposed to lead or removal of workers from the job when they show elevated concentrations of lead in the blood. Specific medical monitoring recommendations for these workers are discussed in the section on conclusions and recommendations.

The NIOSH recommended exposure limit (REL) for lead is less than 100 $\mu g/m^3$ of air as a TWA for up to 10 hours per day during a 40-hour workweek. This air concentration is to be maintained so that the worker's lead concentration remains below 60 $\mu g/100$ grams of whole blood (approximately equivalent to 60 $\mu g/dl$) [NIOSH 1988c; CDC 1990]. NIOSH is presently reviewing the data on the health effects of lead to determine whether our current recommendations need to be updated.

Several States have instituted programs to protect construction workers from the hazards of occupational lead exposure. For example, Maryland enacted in 1984 (and modified in 1988) a comprehensive standard regulating occupational lead exposure in construction work [Maryland Regulations Code 1988]. Under this standard, the permissible exposure limit for lead is 50 $\mu g/m3$ as an 8-hour TWA. This standard must be incorporated in all contracts involving bridge work in Maryland. Connecticut is currently preparing similar requirements for inclusion in contracts [Connecticut Department of Transportation 1991].

CASE REPORTS OF LEAD POISONING

NIOSH recently learned of 42 construction workers at 8 different worksites who developed lead poisoning (BLL's exceeding 50 $\mu g/dl$ of blood) while working on bridges [Mintz 1990; Rae 1990; Johnson 1990; CDC 1989; Marino et al. 1989; NIOSH 1991b]. The BLL's for these workers ranged from 51 to 160 $\mu g/dl$. The mean BLL for the U.S. population is 13.9 $\mu g/dl$, and the upper 95 percentile is 25.0 $\mu g/dl$ [NCHS 1984]. The airborne concentrations of lead ranged from 2 to 29,000 $\mu g/m^3$ (see table 2). At least 26 of the 42 cases of lead poisoning (62 percent) were workers employed at a site using a containment structure. The actual number of cases of occupational lead poisoning nationwide is much larger than 42, but it cannot be accurately determined since employers are not required to routinely measure lead concentration in the blood of exposed construction workers.

Case No. 1

A study now being conducted in Connecticut has identified four workers with lead poisoning at three different bridge sites [Mintz 1990]. Containment structures were used at all three sites. The workers' BLL's ranged from 51 to 66 $\mu g/dl$, but none reported symptoms of lead intoxication. Personal breathing zone samples indicated airborne lead concentrations of 4 to 640 $\mu g/m^3$. All workers wore respiratory protection (abrasive blasting, half-mask, or disposable respirators).

Case No. 2

In 1989, eight workers at a bridge site in Monroe, Louisiana, developed lead poisoning while working in a containment structure [Rae 1990]. The BLL's of these workers ranged from 56 to 146 $\mu g/dl$. Their complaints included malaise, arm numbness, abdominal discomfort, joint and muscle aches, headache, and diarrhea. Airborne concentrations of lead were not reported.

Case No. 3

In May 1990, 12 bridge workers in Baton Rouge, Louisiana, developed lead poisoning while working in a containment structure [Johnson 1990]. The BLL's of affected workers ranged from 52 to 102 $\mu g/dl$. Reported airborne concentrations of lead ranged from 2 to 730 $\mu g/m^3$. The worker with the BLL of 102 $\mu g/dl$ developed joint pains and required hospitalization for intravenous chelation therapy.

Case No. 4

In March 1988, five workers developed lead poisoning during demolition of a bridge in Massachusetts [CDC 1989]. The BLL's of affected workers ranged from 67 to 160 $\mu g/dl$. All five workers reported symptoms consistent with lead poisoning. Four of the five workers were treated with intravenous chelation therapy. Airborne lead concentrations were not reported.

Case No. 5

In 1987, 11 workers who wore positive-pressure, air-supplied respirators developed lead poisoning during demolition of a bridge in New York [Marino et al. 1989]. The BLL's of these workers ranged from 52 to 120 $\mu g/dl$. One worker with a BLL of 120 $\mu g/dl$ reported symptoms of muscle soreness, weakness, lack of appetite, nausea, and vomiting. Another worker with a BLL of 105 $\mu g/dl$ reported symptoms of headache, tiredness, and abdominal discomfort. Both workers required intravenous chelation therapy. Personal breathing zone concentrations of lead ranged from 600 to 4,000 $\mu g/m^3$.

Case No. 6

In March 1991, NIOSH investigators began a study of lead exposures in 12 workers engaged in abrasive blasting and repainting of a bridge in Kentucky [NIOSH 1991b]. BLL's were measured during the first week of work and ranged from 5 to 48 $\mu g/dl$. The BLL's were measured again after 1 month of exposure and ranged from 9 to 61 $\mu g/dl$. Two workers had BLL's exceeding 50 $\mu g/dl$. The airborne concentration of inorganic lead ranged from 5 to 29,400 $\mu g/m^3$. Blasters wore continuous flow abrasive blasting respirators. Other workers used half-mask, air-purifying respirators with high-efficiency particulate air (HEPA) filters. However, there was no complete respiratory protection program consistent with OSHA requirements [29 CFR 1910.134] and NIOSH recommendations [NIOSH 1987a; NIOSH 1987b]. Running water, coveralls, and clean change-rooms were not available at the site.

CONCLUSIONS AND RECOMMENDATIONS

Lead poisoning may occur when workers inhale or ingest lead dust and fumes during abrasive blasting, sanding, cutting, burning, or welding of bridges and other steel structures coated with lead-containing paints. Data presented in this document reveal lead poisoning among workers who were wearing respirators. Therefore, a prudent policy is to minimize the risk of adverse health effects by keeping lead concentrations as low as possible and by using all available controls—including engineering controls, work practices, and respiratory protection. To help achieve the *Healthy People 2000* [DHHS

1990] objective of limiting worker blood lead concentrations to 25 $\mu g/dl$, NIOSH recommends the following measures for reducing lead exposure and preventing lead poisoning among workers involved in demolishing or maintaining bridges and other steel structures.

Air Monitoring

An industrial hygienist or other qualified professional should perform an initial hazard assessment of the worksite to determine the composition of the paint. Environmental monitoring should also be performed to (1) measure worker exposure to airborne lead and other hazardous agents (e.g., silica and solvents), and (2) select the engineering controls and PPE required. Environmental monitoring should be performed as needed to measure the effectiveness of controls and to determine whether the proper respiratory protection is being worn. Air samples should be collected and analyzed according to NIOSH methods [NIOSH 1984] or their equivalent.

Engineering Controls

Engineering controls should be used to minimize exposures to lead at the worksite. At a minimum, airborne lead exposures should not exceed the current OSHA PEL for general industry (50 $\mu g/m^3$). Whenever possible, engineering controls should include material substitution (i.e., repainting of structures with less toxic material), process and equipment modification, isolation or automation, and local and general exhaust ventilation. The appropriate types of controls vary with the operation.

Welding, Cutting, or Burning

Before welding, cutting, or burning any metal coated with lead-containing materials, remove the coating to a point at least 4 inches from the area where heat will be applied [29 CFR 1926.354]. When removal of lead-containing paint is not feasible, use engineering controls (e.g., local exhaust ventilation) to protect workers who are welding, cutting, or burning lead-bearing materials. Such controls should be used to remove fumes and smoke at the source and to keep the concentration of lead in the breathing zone below the OSHA PEL. Contaminated air should be filtered before it is discharged into the environment well away from the source of intake air and other workers. Replace contaminated air with clean air [29 CFR 1926.353].

Surface Preparation

When performing abrasive blasting, scaling, chipping, grinding, or other operations to remove lead-containing paint, use work practices that minimize the amount of dust generated. Less dusty blasting techniques include centrifugal blasting (using rotating blades to propel the abrasive, which is recovered and recycled), wet blasting (using high-pressure water with or without an abrasive, or surrounding the blast nozzle with a ring of water), and vacuum blasting (shrouding the nozzle with local exhaust ventilation) [Rex 1990]. Other methods that reduce dust include scraping, heating and scraping, use of needle guns, and chemical removal.

Materials containing crystalline silica should not be used as abrasives for any blasting operation, including paint removal [NIOSH 1988b]. Crystalline silica is associated with silicosis and is classified by NIOSH as a potential occupational carcinogen [NIOSH 1988d].

Lead-containing dust and abrasive materials should be removed daily by using vacuums equipped with HEPA filters or by using wet methods to prevent lead-containing particles from becoming airborne [Steel Structures Painting Council 1991].

Work Inside Containment Structures

Containment structures are often used to reduce environmental contamination by capturing particles of paint and used blasting materials. Although such structures reduce environmental contamination, they may also increase lead exposures for workers. Ventilation should be provided to reduce the airborne concentration of lead and increase visibility. Containment structures should be designed to optimize the flow of ventilation air past the worker(s). Insofar as possible, workers should be upstream from the blasting operation to reduce exposure to lead dust entrained in the ventilation air and to improve visibility. Designs for the containment structure and ventilation systems should be specific to each task because of varied conditions at the worksite (i.e., the type of steel structure being blasted, the type of blasting methods, and the type of materials used for construction).

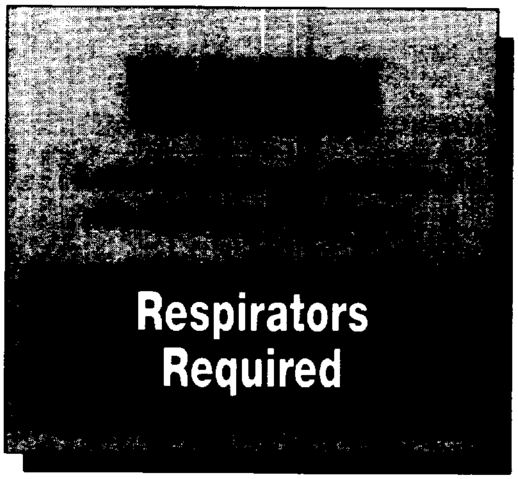

Figure 1.–Sample of warning sign for lead work area requiring respirators.

Contract Specifications

All new contracts of Federal, State, and local departments of transportation should include specifications for a mandatory program of worker protection from lead poisoning during the maintenance, repainting, or demolition of bridges and other steel structures.

Personal Hygiene Practices

Personal hygiene is an important element of any program for protecting workers from exposure to lead dust [Ulenbelt et al. 1990]. OSHA requires employers to provide adequate washing facilities at the worksite so that workers can remove lead particles that accumulate on the skin and hair [29 CFR 1926.51]. Showers should also be available [OSHA/NIOSH 1991].

All workers exposed to lead should wash their hands and faces before eating, drinking, or smoking, and they should not eat, drink, or use tobacco products in the work area. Tobacco products (cigarettes, cigars, chewing tobacco, etc.) and food items should not be permitted in the work area. Contaminated work clothes should be removed before eating.

Workers should change into work clothes at the worksite. Work clothes include disposable or washable coveralls. Street clothes should be stored separately from work clothes

LEAD POISONING IN CONSTRUCTION WORKERS

WARNING!

Workers are at risk of lead poisoning during the maintenance, repainting, or demolition of bridges or other steel structures coated with lead-containing paint.

Take the following steps to protect yourself and your family from lead exposure:

- **Be aware of the health effects of lead exposure (see p. [44] of the NIOSH Alert, Request for Assistance in Preventing Lead Poisoning in Construction Workers) and discuss with your doctor any symptoms or concerns that may be related to lead poisoning.**
- **Participate in any blood lead or air monitoring program offered by your employer.**
- **Use engineering controls such as source containment and local exhaust ventilation to minimize exposure to lead.**
- **Be aware that the highest lead concentrations may occur inside containment structures.**
- **Use respirators when blasting, sweeping, vacuuming, or performing other high-risk jobs (as determined by an industrial hygienist or other qualified professional).**
- **Change into disposable or washable coveralls at the worksite.**
- **Do not eat, drink, or use tobacco products in the work area.**
- **Wash your hands and face before eating, drinking, or smoking outside the work area.**
- **Shower and change into clean clothing before leaving the worksite to prevent contaminating homes and automobiles.**

in a clean area provided by the employer. Separate lockers or storage facilities should be provided so that clean clothing is not contaminated by work clothing and shoes. Workers should change back into their street clothes after washing or showering before leaving the worksite to prevent the accumulation of lead dust in the workers' cars and homes and thereby protect family members from exposure to lead. Cars should be parked where they will not be contaminated with lead.

Employers should arrange for the laundering of protective clothing; or, if disposable protective clothing is used, the employer should maintain an adequate supply at the worksite and arrange for its safe disposal according to applicable Federal [40 CFR 260] and State regulations.

Warning Signs

Warning signs should be posted to mark the boundaries of lead-contaminated work areas. These signs should follow the example presented in the OSHA general industry standard [29 CFR 1910.1025], which warns about the lead hazard and prohibits eating and drinking in the area. Such signs should also specify any PPE required (for example, respirators). The sample sign in figure 1 contains all the information needed for a lead-contaminated work area where respirators are required.

Personal Protective Equipment (PPE)

Engineering controls and good work practices should be used to minimize worker exposure to lead. Because of the variable exposure concentrations in the construction industry and the difficulty of monitoring a mobile workforce, PPE should be used whenever workers are potentially exposed to lead [OSHA/NIOSH 1991]. The use of PPE should supplement the continued use of engineering controls and good work practices.

Protective Clothing

Protective clothing not only shields workers from the hazards of welding and abrasive blasting, but it also minimizes the accumulation of lead on the worker's skin and hair. Workers should change into washable coveralls or disposable clothing before entering the contaminated work area. Because wearing PPE (especially protective clothing) can contribute to the development of heat stress [NIOSH/OSHA/USCG/EPA 1985], a potentially serious illness, regular monitoring and other preventive measures are vital [NIOSH 1986].

To minimize the amount of lead that may accumulate in the worker's car and home and to protect the members of the worker's household, lead-contaminated clothing (including work shoes) should be left at the worksite for cleaning or disposal. Workers who are welding, cutting, or burning should wear nonflamable clothing [NIOSH 1988a].

Respiratory Protection

Effective source control measures (such as containment or local exhausting ventilation) should be implemented to minimize worker exposure to lead. NIOSH prefers such measures as the primary means of protecting workers; but source control at construction sites is often ineffective, and airborne lead concentrations may be high or may vary unpredictably. Therefore, respiratory protection is also necessary for certain operations such as blasting, sweeping, and vacuuming, and for other jobs as determined at the worksite by an industrial hygienist or other qualified professional. However, respirators are the least preferred method of controlling lead exposure, and they should not be used as the only means of preventing or minimizing exposures. The use of respirators should supplement the continued use of engineering controls and good work practices [OSHA/NIOSH 1991].

When respirators are used, the employer must establish a comprehensive respiratory protection program as outlined in the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a], and as required in the OSHA respiratory protection standard [29 CFR 1910.134]. Important elements of the OSHA respiratory protection standard are (1) an evaluation of the worker's ability to perform the work while wearing a respirator, (2) regular training of personnel, (3) periodic environmental monitoring, and (4) respirator fit testing, maintenance, inspection, cleaning, and storage. The program should be evaluated regularly by the employer. Without a complete respiratory protection program, workers will not receive the protection anticipated.

Respirators should be selected by the person who is in charge of the program and knowledgeable about the workplace and the limitations associated with each type of respirator. Because exposures to lead during construction may vary substantially throughout a workshift and between days, the highest anticipated exposure should be used to determine the appropriate respirator for each job.

Respirator selection should be made according to the guidelines in table 3. Employers must use respirators that are certified by NIOSH and the Mine Safety and Health Administration (MSHA) [NIOSH 1991a].

NIOSH-type CE respirators are required for use by abrasive blasting operators [29 CFR 1910.94]. Currently, only continuous-flow respirators are certified by NIOSH for abrasive blasting [29 CFR 1910.94], but positive-pressure, supplied-air respirators would provide greater protection [NIOSH 1987b; 30 CFR 11]. The continuous-flow respirators are recommended by NIOSH only for airborne concentrations less than or equal to 25 times the OSHA PEL for general industry—50 $\mu g/m^3$ [NIOSH 1987b]. Furthermore, manufacturer's instructions regarding quality of air, air pressure, and inside diameter and length of hoses must be strictly followed. Use of longer hoses, hoses having a smaller inside diameter, or hoses with kinks and bends may restrict the flow of air to the respirator.

In all cases, respiratory protection should be donned before entering the contaminated work area, and it should be removed only after the worker has left that area.

Medical Surveillance—Medical Monitoring

BLL's are currently the best indicator of personal lead exposure. Workers potentially exposed to lead should therefore be monitored for the presence of lead in blood and the effects of lead on the blood-forming system. This assessment is necessary to ensure that engineering controls, personal hygiene practices, and PPE are preventing lead exposure.

The OSHA general industry standard contains provisions for the medical monitoring of workers exposed to lead [29 CFR 1910.25]. NIOSH supports the use of these provisions for construction workers but acknowledges that these workers may require more frequent blood lead monitoring (for example, monthly) than specified in the OSHA standard because of their highly variable, unpredictable exposures to lead. Similar provisions for more frequent monitoring have also been specified by the Connecticut Department of Transportation to be included in bid specifications for construction work involving lead exposure [Connecticut Department of Transportation 1991].

Lead concentration in the blood should be measured for any exposed worker who experiences symptoms or signs of lead poisoning. Analyses of blood should be performed only by OSHA-listed laboratories (a listing is available from the OSHA Analytical Laboratory in Salt Lake City, Utah; telephone (801) 524-4270).

The results of all laboratory analyses, a description of the worker's job, and any available data on possible exposures should be evaluated by a physician with experience and training in occupational health. To detect the health effects of excess lead exposure and to provide a baseline for comparison with future results, an occupational health interview and a physical examination should be performed before job placement, before returning to work after being removed from the job because of elevated blood lead concentrations, and annually for all workers exposed to lead.

Table 3 NIOSH-Recommended Respiratory Protection for Workers Exposed to Inorganic Lead

Condition	Minimum respiratory protection*
[illegible]	[illegible]
≤1.25 mg/m^3 (25 x PEL)	Any powered, air-purifying respirator with a high-efficiency particulate filter, or Any supplied-air respirator equipped with a hood or helmet and operated in a continuous-flow mode (for example, type CE abrasive blasting respirators)
[illegible]	[illegible]
≤50 mg/m^3 (1,000 x PEL)	Any supplied-air respirator equipped with a half-mask and operated in a pressure-demand or other positive-pressure mode
[illegible]	[illegible]
Planned or emergency entry into environments containing unknown concentrations or concentrations above 100 mg/m^3 (2,000 x PEL)	Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode, or Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode
[illegible]	[illegible]
Escape only	Any air-purifying, full-facepiece respirator with a high-efficiency particulate filter, or \ny appropriate escape-type, self-contained breathing apparatus

**Only NIOSH/MSHA-approved equipment should be used.*
†Less than or equal to 0.5 mg/m^3.
††Multiple of the OSHA PEL for general industry.

Medical Protection

The OSHA lead standard for general industry [29 CFR 1910.1025] requires that certain actions be taken at given concentrations of lead in the blood (see table 4). These actions are designed to prevent many of the adverse health effects of lead exposure.

Table 4 **Actions Required by the OSHA General Industry Standard for Various Lead Concentrations in Blood (BLLs)**

Number of tests	BLL* (µg/dl)	Action required
1	≥40†	Notification of worker in writing; medical examination of worker and consultation
3 (average)	≥50	Removal of worker from job with potential lead exposure
1	≥60	Removal of worker from job with potential lead exposure
2	<40§	Reinstatement of worker in job with potential lead exposure

**In the OSHA general industry standard for lead, BLLs are reported in micrograms per 100 grams (µg/100g) of whole blood, which is approximately equal to µg/dl.*

†Greater than or equal to 40.

§Less than 40.

Mandatory Reporting

Presently, 15 states require laboratories and health care providers to report cases of elevated blood lead concentrations to the State health department [Freund et al. 1989]. Table 5 provides a list of the States that require such reporting and the concentration that requires reporting for each State. To monitor progress in achieving the *HealthyPeople 2000* objective for lead concentrations in blood [DHHS 1990], cases of elevated BLL's should be reported to all State health departments.

Training

Workers should receive training [29 CFR 1926.21] that includes the following:

- Information about the potential adverse health effects of lead exposure
- Information about the early recognition of lead intoxication
- Information in material safety data sheets for new paints or coatings that contain lead or other hazardous materials [29 CFR 1926.59]
- Instruction about heeding signs that mark the boundaries of lead-contaminated work areas

Table 5 State Agencies that Require the Reporting of Individuals with Elevated Lead Concentrations in Blood (BLLs)* [as of August 1991]

State and contact person	Concentration that requires (μg/dl) reporting	State and contact person	Concentration that requires (μg/dl) reporting
Alabama Charles Woernle, M.D., M.P.H. State Epidemiologist Department of Public Health 434 Monroe Street Montgomery, AL 36130; 205-242-5131	25	Michigan [illegible] [illegible] [illegible] [illegible] [illegible] Lansing, [illegible]	[illegible]
California Neil Maizlish, Ph.D. Occupational Health Program California Department of Health Services 2151 Berkeley Way, Room 504 Berkeley, CA 94704; 415-540-2115	25	New Jersey Barbara Gerwel, M.D. Occupational Disease Prevention Program New Jersey Department of Health C N 360, John Fitch Plaza Trenton, NJ 08625; 609-984-1863	25
Colorado Jane McCammon Colorado Department of Health Epidemiology Division 4210 E. 11th Avenue Denver, CO 80220; 303-331-8330	25	New York [illegible] New York State Department of Health [illegible] Albany, NY [illegible]	[illegible]
Connecticut Narda Tolentino, M.P.H. Connecticut Department of Health Services Environmental Epidemiology and Occupational Health (EEOH) 150 Washington Street Hartford, CT 06106; 203-566-8167	25	Oregon Jane Gordon, Ph.D. Deputy State Epidemiologist Oregon Health Division 1400 SW 5th Avenue Portland, OR 97201; 503-229-5821	25
Illinois Jane Keller Occupational Disease Registry Illinois Department of Public Health Division of Epidemiologic Studies 605 W. Jefferson Springfield, IL 62761; 217-785-1873	25	Texas [illegible] Texas Department of Health [illegible] Austin, TX [illegible]	[illegible]
Iowa Joann Muldoon Environmental Epidemiology Section Iowa Department of Public Health Lucas State Office Building Des Moines, IA 50319; 515-281-5643	25	Utah David J. Thurman, M.D., M.P.H. Bureau of Epidemiology Utah Department of Health P.O. Box 16660 Salt Lake City, UT 84116-0660 801-538-6191	30 (≥18 years of age) 20 (≥18 years of age)
Maryland Ellen Coe, R.N., M.P.H. Health Registries Division Maryland Department of the Environment 2500 Broening Highway Baltimore, MD 21224; 301-631-3851 fax: 301-631-3198	25	Wisconsin [illegible] Wisconsin Department of Health and Social Services One W. Wilson Street Box [illegible] Madison, WI [illegible]	25
Massachusetts Richard Rabin Massachusetts Department of Labor and Industries Division of Occupational Hygiene 1001 Watertown Street Newton, MA 02165; 617-969-7177	15		

**Questions regarding these reporting requirements should be directed to the contact person in each State.*

- Discussion of the importance of personal hygiene practices in reducing lead exposure

- Instruction about the use and care of appropriate protective equipment (including protective clothing and respiratory protection)

- Information about specific work practices for working safely with lead-containing paints

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29 CFR 1926.55. *Code of Federal Regulations*; Washington, D.C.; U.S. Government Printing Office, Office of the *Federal Register*.
29 CFR 1926.59. *Code of Federal Regulations*; Washington, D.C.; U.S. Government Printing Office, Office of the *Federal Register*.
29 CFR 1926.353. *Code of Federal Regulations*; Washington, D.C.; U.S. Government Printing Office, Office of the *Federal Register*.
29 CFR 1926.354. *Code of Federal Regulations*; Washington, D.C.; U.S. Government Printing Office, Office of the *Federal Register*.
30 CFR 11. *Code of Federal Regulations*; Washington, D.C.; U.S. GovernmentPrinting Office, Office of the *Federal Register*.
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FINDING EQUIPMENT FOR PROTECTING WORKERS

by the *JPCL* Staff

JPCL has compiled a list of manufacturers that include safety and hygiene equipment for lead paint removal in their product lines. The list is based on information available to JPCL at press time. Companies not listed are invited to submit information for an update to The Editor, *JPCL*, 2100 Wharton Street, Suite 310, Pittsburgh PA 15203.

- Abatement Technologies (Lawrenceville, GA); Portable showers, air and water filtration products, and HEPA vacuums; 1-800-634-9091
- Aerospace America, Inc. (Bay City, MI); Portable showers; (517) 684-2121
- Anderson Instruments (Atlanta, GA), Environmental air monitoring equipment; (404) 691-1910
- BGI Inc. (Waltham, MA); Personal air sampling pumps; (617) 891-9380
- E. D. Bullard (Cynthiana, KY); Respiratory protection equipment; (800) 827-0423
- Cabot Safety Corp. (Southbridge, MA); Respiratory protection equipment; (508) 764-5500
- Eagle Industries (New Orleans, LA); Decontamination trailers and portable showers; (504) 733-3510
- Environmental Express (Mt. Pleasant, SC); Personal air monitoring cassettes; (803) 881-6560
- Gilian Instrument Corp. (West Caldwell, NJ); Personal air monitoring equipment (201) 808-3355
- 3M Company OHSP (St. Paul, MN); Respiratory protection equipment; 1-800-666-6477
- Mine Safety Appliances (Pittsburgh, PA); Protective clothing and respiratory equipment; (412) 967-3000
- Neoterik Health Technologies Inc. (Woodsboro, MD); Respiratory protection equipment; (301) 845-2777
- North (Siebe North) Inc. (Cranston, RI); Respirator protection equipment; (401) 943-4400
- Northstar Manufacturing (Spring, TX); Respiratory protection equipment; (713) 353-3753
- Nuclepore (Cambridge, MA); Personal air monitoring cassettes; (617) 868-6200
- Racal Health & Safety Inc. (Frederick, MD); Respiratory protection equipment; (301) 695-8200
- Regency International Group Inc. (West Chester, PA); Portable showers and decontamination units; (215) 344-0637
- Sensidyne (Clearwater, FL); Particulate air detection and monitoring equipment; (813) 530-3602
- Spectrex (Redwood City, CA); Personal air sampling pumps and calibrators; 1-800-842-3940
- Survivair (Santa Ana, CA); Respiratory protection equipment; (714) 545-0410.