# Protecting Workers Exposed to Lead-Based Paint Hazards

## A Report to Congress


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# FOREWORD

In 1992, Congress passed the Housing and Community Development Act (Public Law 102–550), which included as Title X the "Residential Lead-Based Paint Hazard Reduction Act of 1992." Title X is a comprehensive law designed to direct the Nation's response to the public health problem of lead-based paint hazards in housing. This law directed the Occupational Safety and Health Administration to increase the protection for workers exposed to lead hazards throughout the construction industry. Title X, by amending the Toxic Substances Control Act, also directed the National Institute for Occupational Safety and Health (NIOSH) to:

> "...conduct a comprehensive study of means to reduce hazardous occupational lead abatement exposures. This study shall include, at a minimum, each of the following—
>
> (A) Surveillance and intervention capability in the States to identify and prevent hazardous exposures to lead abatement workers.
>
> (B) Demonstration of lead abatement control methods and devices and work practices to identify and prevent hazardous lead exposures in the workplace.
>
> (C) Evaluation, in consultation with the National Institute of Environmental Health Sciences, of health effects of low and high levels of occupational lead exposures on reproductive, neurological, renal, and cardiovascular health.
>
> (D) Identification of high risk occupational settings to which prevention activities and resources should be targeted.
>
> (E) A study assessing the potential exposures and risks from lead to janitorial and custodial workers."

This report results from that study. It focuses not only on lead abatement exposures but also on other important exposures to lead-based paint (LBP) in residential and industrial construction work. This comprehensive NIOSH report should be of interest to legislators, public health agencies, industrial hygienists, occupational medicine practitioners, industry associations, unions, employees and employers interested in reducing occupational lead hazards related to LBP.

Current information is summarized in this report regarding the health effects of occupational lead exposures, high-risk exposure settings, surveillance and intervention capabilities, and methods for control, sampling and analysis of lead exposures. This report also provides recommendations for reducing hazardous occupational lead abatement exposures. Implementation of these recommendations will contribute to the overall mission of NIOSH, i.e., delivering on the Nation's promise: safety and health at work for all people—through research and prevention.

Linda Rosenstock, M.D., M.P.H.
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# EXECUTIVE SUMMARY

## KEY RECOMMENDATIONS

- State surveillance programs should be expanded to all states where workers are exposed to lead-based paint (LBP) hazards to identify high-risk workplaces and conduct follow-up investigations where needed.

- Research and education are needed to assist small businesses involved in LBP activities in developing low-cost controls for reducing worker lead exposures and environmental releases of lead.

- Research is needed to determine better the extent of take-home lead exposures among workers who are exposed to low airborne lead levels, but who work in lead-contaminated environments. Until more data are available, protective clothing and hygiene facilities should be considered for workers in lead-contaminated workplaces, regardless of their airborne lead exposure levels.

- Research and education are needed to improve worker protection during maintenance and repainting of steel structures coated with LBP. This should include the use of improved engineering controls and design of highly protective respirators for abrasive blasting.

- Research is needed to provide a set of objective data that would be useful for employers' initial exposure assessments of common residential lead abatement methods, and renovation and remodeling activities involving LBP.

- To reduce worker lead exposures during residential work, safer methods such as enclosure, encapsulation, and replacement should be used where possible instead of LBP removal by torch burning, heat gun, or abrasive methods.

- A system for evaluating the quality of analyses of lead in paint, dust, and soil, done in-place with portable instruments, is needed.

## THE HEALTH EFFECTS OF LEAD EXPOSURE AND OCCUPATIONAL EXPOSURE CRITERIA

The toxic effects of lead are well documented in both children and adults. Workers' exposure to lead can damage the central nervous system, cardiovascular system, reproductive system, hematological system, and the kidney. Workers' lead exposure can also harm development of their children. Lead has been shown to be an animal carcinogen, and authors of recent studies suggest that occupational lead exposure increases the risk of cancer. Lead poisoning often goes undetected since many of the symptoms, such as stomach pain, headaches, anxiety, irritability, and poor appetite, are nonspecific and may not be recognized as symptoms of lead poisoning.

Because of national efforts to reduce environmental lead exposures, general population lead exposures in the United States have dropped significantly in the past two decades. In 1978, the Occupational Safety and Health Administration (OSHA) promulgated a lead standard to protect workers in general industry. In 1993, as required by Title X, OSHA provided an equivalent level of protection to workers in the construction industry. Lead exposures in the workplace, however, continue to be a significant public health problem.

Research studies on lead toxicity in humans indicate that current OSHA standards should prevent the most severe symptoms of lead poisoning, but these standards do not protect workers and their developing children from all of the adverse effects of lead. In recognition of this problem, voluntary standards and public health goals have been established to lower exposure limits for workers exposed to lead. The Department of Health and Human Services has established a national goal to eliminate, by the year 2000, all occupational lead exposures that result in blood lead levels (BLLs) greater than 25 µg/dL.

## NIOSH SURVEILLANCE, INTERVENTIONS, AND EVALUATIONS

NIOSH conducts surveillance, intervention, and health hazard evaluation projects to identify and reduce occupational lead exposures. In the late 1980s, NIOSH started working with states to develop Adult Blood Lead Epidemiology and Surveillance (ABLES) programs at the state level. Currently, NIOSH is working with 34 states, with 25 states reporting adult BLLs regularly to NIOSH.

## LEAD EXPOSURE OF WORKERS' FAMILIES

Families of construction workers can be exposed to lead brought home from the workplace. NIOSH and New Jersey Department of Health studies indicate that a higher percentage of construction workers' children, especially those under six years of age, have elevated BLLs when compared to age-specific averages for the United States and neighbors' children.

## METHODS TO CONTROL OCCUPATIONAL LEAD EXPOSURES DURING LEAD-BASED PAINT ACTIVITIES

Thousands of water storage tanks, fuel storage tanks, and other industrial steel structures coated with LBP are repainted annually. Typically, all of the existing LBP on the structures is removed with open abrasive blasting inside containment structures prior to repainting. This process exposes the workers to severe LBP hazards. Lead exposures are generally much lower during residential LBP work, but some tasks produce hazardous worker exposures. The work tasks and lead exposures during residential lead abatement and home renovation are similar.

## METHODS FOR SAMPLING AND ANALYSIS OF ENVIRONMENTAL LEAD

To accurately identify the presence of lead in the workplace and occupational lead exposure hazards, appropriate standardized methods for sampling and analysis are essential. The sampling and analytical methods for assessment of lead in air, paint, soil, and surface dust, recommended by NIOSH in this report, are in many cases based on national consensus standards of the American Society for Testing and Materials (ASTM). Wherever possible, performance-based requirements for analytical testing are recommended.

## EXPOSURE RISKS AMONG JANITORIAL AND CUSTODIAL WORKERS

NIOSH conducted an evaluation of lead exposures among custodial employees. Based on the results from this study, it would be reasonable to assume that routine janitorial tasks (such as sweeping, vacuuming, emptying trash receptacles, cleaning fixtures, and other related activities) in buildings with LBP generally would not produce hazardous worker lead exposures. However, one cannot conclude from this study that lead is never a hazard in janitorial and custodial work where LBP is present.

# ABBREVIATIONS

| | |
|---|---|
| ABLES | Adult Blood Lead Epidemiology and Surveillance |
| ACGIH | American Conference of Governmental Industrial Hygienists |
| AIHA | American Industrial Hygiene Association |
| APF | assigned protection factor |
| ASTM | American Society for Testing and Materials |
| BLL | blood lead level |
| CDC | Centers for Disease Control and Prevention |
| ELPAT | Environmental Lead Proficiency Analytical Testing |
| EPA | U.S. Environmental Protection Agency |
| FTE | full-time equivalent (employee) |
| HEPA | high-efficiency air filter |
| HHE | health hazard evaluation |
| HUD | U.S. Department of Housing and Urban Development |
| LBP | lead-based paint |
| LEV | local exhaust ventilation |
| MDC | minimum detectable concentration |
| mg/m$^3$ | milligrams per cubic meter |
| mg/cm$^2$ | milligrams per square centimeter |
| MMWR | Morbidity and Mortality Weekly Report |
| MQC | minimum quantifiable concentration |
| ND | none detected |
| NHANES | National Health and Nutrition Examination Survey |
| NIOSH | National Institute for Occupational Safety and Health |
| NLLAP | National Lead Laboratory Analytical Proficiency |
| NTIS | National Technical Information Service |
| OSHA | Occupational Safety and Health Administration |
| PAPR | powered air-purifying respirator |
| PAT | Proficiency Analytical Testing |
| Pb | lead (symbol for the element) |
| PBZ | personal breathing-zone |
| PEL | Permissible Exposure Limit |
| PHS | U.S. Public Health Service |
| ppm | parts per million |
| REL | Recommended Exposure Limit |
| SHARP | Safety and Health Assessment and Research for Prevention |
| SIC | standard industrial classification |
| TWA | time-weighted average |
| µg/m$^3$ | micrograms per cubic meter |
| µg/dL | micrograms per deciliter of (whole) blood |
| µg/ft$^2$ | micrograms per square foot |
| µg/g | micrograms per gram |
| ZPP | zinc protoporphyrin |

# GLOSSARY

Some major definitions from Title IV of the Residential Lead-Based Paint Hazard Reduction Act of 1992 are presented here; additional definitions are contained in Title IV, Section 401.

- **“Lead-based paint”** (LBP) means paint or other surface coatings that contain lead in excess of 1.0 milligrams per square centimeter ($mg/cm^2$) 0.5 percent by weight.

- **“Lead-based paint hazard”** means any condition that causes exposure to lead from lead-contaminated dust, lead-contaminated soil, lead-contaminated paint that is deteriorated or present in accessible surfaces, friction surfaces, or impact surfaces that would result in adverse human health effects.

- **“Abatement”** means any set of measures designed to permanently eliminate LBP hazards in accordance with established federal standards and includes removal, replacement, encapsulation, and all associated preparation, cleanup, and disposal activities.

- **“Lead hazard reduction”** means measures designed to reduce or eliminate human exposure to LBP hazards through methods including interim controls and abatement.

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# CHAPTER 1

## HEALTH EFFECTS OF LEAD EXPOSURE AND OCCUPATIONAL EXPOSURE CRITERIA

### INTRODUCTION

The health effects of lead have been previously extensively reviewed by the federal public health agencies: Agency for Toxic Substances and Disease Registry (ATSDR), Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH).[1,2,3] There are thousands of scientific articles on the adverse health effects of lead in either children or adults. This chapter is a synopsis of the cardinal adverse health effects of lead in adults.

Lead is a bluish-gray metal used since ancient times because of its useful properties, such as low melting point, pliability, and resistance to corrosion. The ancient Romans and Greeks first discovered its toxic effects. Hippocrates (370 B.C.) attributed a severe case of colic in a worker who extracted metals to lead exposure, and Pliny the Elder (A.D. 23–79) wrote that workers painting ships with native ceruse (white lead) wore loose bags over their faces to avoid breathing noxious dust.[4] Lead is ubiquitous in older American homes and lead exposures in the workplace are common because of the widespread use, during the past century, of lead compounds in paints, gasoline, and industry.

Human lead exposure occurs when dust and fumes are inhaled and when lead is ingested via lead-contaminated hands, food, water, cigarettes, and clothing. Lead entering the respiratory and digestive systems is released to the blood and distributed throughout the body. More than 90 percent of total body burden of lead is accumulated in the bones, where it is stored for decades. Lead in bones may be released into the blood and re-exposes organ systems long after the original environmental exposure. This process can also expose the fetus to lead in pregnant women.

There are several biological indices of lead exposure. Lead concentrations in blood, urine, teeth, and hair can be used as biological indicators of lead exposure. Recent advances in the measurement of skeletal bone lead levels more accurately measure cumulative lead exposure and the total body burden of lead. At present, however, the best available method for monitoring biological exposure to lead is measurement of the blood lead level (BLL). The severity of symptoms associated with lead exposure generally increases as the BLL increases (see Table 1.1). No such relationship between symptoms and the other indices of lead exposure have been as well established.

A recent national survey found that the geometric mean BLL for the United States adult population (ages 20 to 74 yrs) declined significantly between 1976 and 1991, from 13.1 to 3.0 micrograms per deciliter (µg/dL).[5] This decline was largely the result of stricter federal regulations and changes in regulated industries which reduced workplace exposures and the lead content of gasoline, paint, drinking water, and soldered food containers. To protect workers from lead poisoning, the Occupational Safety and Health Administration (OSHA) promulgated a lead standard for general industry in 1978 and an interim lead standard for the construction industry in 1993. More than 90 percent of adults now have a BLL < 10 µg/dL, and more than 98 percent have a BLL < 15 µg/dL.

Although much progress has been made in reducing lead exposures, exposures in the workplace continue to be a significant public health problem. Even with the federal regulations, thousands of adult elevated BLLs    25 µg/dL are reported each year to NIOSH by states participating in a NIOSH surveillance program (see Chapter 2 for a more complete discussion). Elimination of worker BLLs    25 µg/dL by the year 2000 is a health goal of the United States.[6]

The toxic nature of lead is well documented. The most important aspects of lead toxicity are its effects on the central nervous system, which may be irreversible; however, lead affects all organs and functions of the body to varying degrees. The frequency and severity of symptoms among exposed workers depend upon the level of exposure. A summary of the lowest-observed-effect levels for key lead-induced health effects in adults is presented in Table 1.1.

The remainder of this chapter summarizes the NIOSH evaluation of the scientific literature regarding health effects of high- and low-level lead exposures and occupational exposure limits. In preparing this section, NIOSH consulted with the National Institute of Environmental Health Sciences.

## Table 1.1 Summary of Lowest-observed-effect Levels for Key Lead-induced Health Effects in Adults*

| Lowest-observed-effect level (PbB)[a] (µg/dL) | Heme synthesis and hematological effects | Neurological effects | Effects on the kidney | Reproductive function effects | Cardiovascular effects |
|---|---|---|---|---|---|
| 100–120 | | Encephalopathic signs and symptoms | Chronic nephropathy | | |
| 80 | Frank anemia | | | | |
| 60 | | | | Female reproductive effects | |
| 50 | Reduced hemoglobin production | Overt subencephalopathic neurological symptoms | | Altered testicular function | |
| 40 | Increased urinary ALA and elevated coproporphyrins | Peripheral nerve dysfunction (slowed nerve conduction) | | | |
| 30 | | | | | Elevated blood pressure (White males, aged 40–59) |
| 25–30 | Erythrocyte protoporphyrin (EP) elevation in males | | | | |
| 15–20 | Erythrocyte protoporphyrin (EP) elevation in females | | | | |
| < 10 | ALA–D inhibition | | | | ? [b] |

*Adapted from ATSDR 1990.[1]

[a]PbB = Blood lead concentration.
[b]ATSDR indicates there may be no threshold for this effect.

## NEUROTOXIC EFFECTS

One of the major targets of lead toxicity in adults is the nervous system, including the central and peripheral nervous systems. Lead damages the blood-brain barrier and, subsequently, brain tissues. Severe exposures resulting in BLLs > 80 µg/dL may cause coma, encephalopathy, or death. Historically, the most severe damage to the peripheral nervous system from high, chronic, workplace exposures to lead (two or more times higher than the current OSHA Permissible Exposure Limits [ PEL] of 50 $\mu g/m^3$) resulted in local paralysis described as "wrist drop" or "foot drop."[7] Because of the improved control of occupational lead exposures in recent decades, such overt symptoms of lead toxicity are rare today in the United States. Occupational lead exposures allowable under the current OSHA lead standards will not produce these obvious neurologic clinical symptoms; however, lead exposures permissible under the OSHA standards may be harmful to the central nervous system. Workers with BLLs of 40 to 50 µg/dL may experience fatigue, irritability, insomnia, headaches, and subtle evidence of mental and intellectual decline.[8,9] BLLs as low as 30 to 40 µg/dL decrease motor nerve conduction velocity in workers, although these lead exposure levels are not associated with clinical symptoms.[10] These subclinical symptoms represent early stages of neurologic damage to the central and peripheral nervous system.

## HEMATOLOGIC AND RENAL EFFECTS

Anemia is one of the most characteristic symptoms of high and prolonged exposures to lead associated with BLLs > 80 µg/dL. This anemia results from the damaging effects of lead on the formation and functioning of red blood cells. Lead inhibits the synthesis of heme (the nonprotein, iron-containing component of hemoglobin) and damages the ion transport system in red blood cell membranes. Measurement of protoporphyrin (free or zinc protoporphyrin [ZPP]) concentration in red blood cells can be a good indicator of inhibition of heme synthesis by lead. There are, however, other causes (e.g., iron deficiency) of elevated protoporphyrin levels. Effects on heme synthesis can be observed at BLLs below 15 µg/dL, but the clinical significance of these effects at low BLLs is undetermined.[11] As part of the medical evaluation for lead-exposed workers, OSHA requires measurement of blood lead and ZPP levels, hemoglobin and hematocrit determinations, red cell indices, and examination of the peripheral blood smears to evaluate red blood cell morphology.

Chronic high exposure to lead, above the OSHA PEL, may cause chronic nephropathy and, in extreme cases, kidney failure. There is substantially less evidence of kidney disease at lower exposures to lead.[12]

## REPRODUCTIVE AND DEVELOPMENTAL EFFECTS

Historical studies indicate that high exposures to lead produce stillbirths and miscarriages.[13] Several studies conducted in the United States and abroad indicated that exposures to lower concentrations of lead, with BLLs at or below 15 µg/dL may result in adverse pregnancy outcomes, such as shortened time of gestation and decreased fetal mental development and growth.[14,15]

The developing nervous system of the fetus is particularly vulnerable to lead toxicity. Neurological toxicity is observed in children of exposed female workers as a result of the ability of lead to cross the placental barrier and to cause neurological impairment in the fetus.[16] A special concern for pregnant women is that some of the bone lead accumulation is released into the blood during pregnancy. Several studies conducted concurrently in the United States and other countries provided evidence that even low maternal exposures to lead, resulting in BLLs as low as 10 µg/dL, produce intellectual and behavioral deficits in children.[17,18,19]

BLLs of 60 µg/dL may be associated with male infertility.[20] Studies in male workers indicate that exposures to lead resulting in BLLs as low as 40 µg/dL may cause decreased sperm count and abnormal sperm morphology.[21,22] Several reports indicate that decreased sperm quality and hormonal changes can occur among male workers exposed to lead with BLLs of 30 to 40 µg/dL.[23,24]

In promulgating its general industry lead standard in 1978, OSHA recognized that children of lead-exposed workers are more likely to have birth defects, mental retardation, behavioral disorders or to die during the first year, and that these effects could occur at parental BLLs below the 50 µg/dL BLL allowed under the standard.[25] At that time, OSHA determined it was not feasible to establish a lead standard that would protect workers from all physiologic changes, symptoms, and reproductive effects in men and women. As a result, OSHA said that men or women planning to have children should be advised to limit their BLLs   30 µg/dL. Subsequently, at least several large corporations developed "fetal protection" policies that excluded all fertile women from lead-exposed jobs, which were often high-paying. In March 1991, the U.S. Supreme Court (UAW, et al. *v.* Johnson Controls, Inc.) banned employers from barring women from hazardous jobs, finding that fetal protection policies constitute illegal sex discrimination in violation of the Civil Rights Act.

## CARDIOVASCULAR EFFECTS

Chronic high exposures to lead that existed earlier in this century were associated with an increased incidence of hypertension and cardiovascular disease.[26] Today these severe effects of lead exposure are rarely observed in the United States.[27] Several studies reported modest increases in blood pressure among workers exposed to concentrations of lead allowable under the OSHA lead standards.[28,29] Studies conducted in the general population, where lead exposures are much lower, have also indicated that increased BLLs are associated with small increases in blood pressure. This relationship appears to extend to BLLs below 10 µg/dL.[30,31,32,33] A recent study suggests that long-term lead exposure, as measured by the bone lead level, is an independent predictor of development of hypertension in men in the general population.[34]

## CARCINOGENIC EFFECTS

Lead has been shown to be an animal carcinogen. Animal studies clearly indicate that some lead compounds ingested or administered by subcutaneous or intraperitoneal injection, in quantities approaching the maximally tolerated dose, cause cancers in rodents.[35,36]

Several studies have examined the relationship between workers' lead exposure and the occurrence of cancer among these workers.[37,38,39] Results from two recent studies indicate that lead may increase the risk of cancer among workers exposed to high levels of lead.[40,41]

The International Agency for Research on Cancer (IARC) has designated lead and inorganic lead compounds as *possibly carcinogenic to humans (Group 2B)*, based on evidence for carcinogenicity in animals.[42] The American Conference of Governmental Industrial Hygienists (ACGIH) has designated lead as an *animal carcinogen*, indicating that lead has been shown to be carcinogenic in animals.[43]

## OCCUPATIONAL EXPOSURE CRITERIA

Under the OSHA general industry lead standard (29 CFR 1910.1025), the PEL for personal exposure to airborne inorganic lead is 50 micrograms per cubic meter ($\mu g/m^3$) as an 8-hour time-weighted average (TWA). Maintaining the concentration of airborne particles of lead in the work environment below the PEL represents a preventive measure intended to protect workers from excessive exposure, which OSHA defines as a BLL > 40 µg/dL. The OSHA general industry lead standard requires lowering the PEL for shifts longer than 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 $\mu g/m^3$, medical removal of employees whose average BLL is 50 µg/dL or greater, and pay retention for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL.

In the 1978 general industry standard, OSHA advised that men or women planning to have children should limit their exposure to maintain a BLL less than 30 µg/dL. At that time, OSHA said that feasibility constraints prevented it from establishing a lead standard that would prevent all physiologic changes, reproductive effects, and mild signs and symptoms in exposed workers.[44] As required by Title X of the Residential Lead-Based Paint Hazard Reduction Act, in 1993 OSHA provided an equivalent level of protection to construction workers in an interim final rule for lead in the construction industry (29 CFR 1926.62). OSHA did not reexamine the feasibility of reducing the 1978 exposure limits for lead in this interim rule.

ACGIH has recommended that worker lead exposures be kept below 50 $\mu g/m^3$ (as an 8-hour TWA), with worker BLLs to be kept 30 µg/dL. To protect lead-exposed workers, a World Health Organization study group recommended a biological exposure limit of 40 µg/dL in 1980, and further recommended that BLLs in women of reproductive ages should not exceed 30 µg/dL.[45] In 1991, the U.S. Department of Health and Human Services established a national goal to eliminate, by the year 2000, all occupational lead exposures that result in BLLs greater than 25 µg/dL.[46]

## CONCLUSIONS

Research studies on lead toxicity in humans indicate that current OSHA standards should prevent the most severe symptoms of lead poisoning, but these standards do not protect workers and their developing children from all of the adverse effects of lead. In recognition of this problem, voluntary standards and public health goals have established lower exposure limits for workers exposed to lead, which offer increased protection for workers and their children.

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# CHAPTER 2

## NIOSH SURVEILLANCE, INTERVENTIONS, AND EVALUATIONS

### INTRODUCTION

NIOSH conducts surveillance, interventions, and health hazard evaluations (HHEs) to identify and reduce occupational lead exposures. Surveillance of adult BLLs has allowed NIOSH and other health agencies to identify high-risk workplaces, and to disseminate data for planning, implementing, and evaluating occupational lead poisoning prevention programs and interventions. In this context, *intervention* refers to activities designed to reduce the frequency of worker lead poisoning or elevated BLLs.[1,2] NIOSH HHEs provide another way to assess occupational exposures in the workplace and identify new and emerging hazards. The recent increase in lead abatement and lead-based paint (LBP) removal activities has created new hazardous circumstances for workers.

### THE ADULT BLOOD LEAD EPIDEMIOLOGY AND SURVEILLANCE PROGRAM (ABLES)

The NIOSH ABLES program was started in the late 1980s by NIOSH investigators working with health departments in several states, including California, New Jersey, New York, and Texas. The objective of the ABLES program is to assist states in establishing surveillance systems for laboratory-based reporting of adult elevated BLLs, which are usually caused by occupational exposures. Standardized reporting to the NIOSH national surveillance database began in 1992. Since then, the numbers of participating states have increased each year.[3]

NIOSH is currently working with 35 states which collect and disseminate information on adult BLLs. Twenty-seven states contribute data to the national adult blood lead data maintained and reported by NIOSH. In addition, eight states are developing ABLES programs (Figure 2.1 and Appendix A).[*] The states which provide data to NIOSH have regulations that specify a reportable BLL for adults (see Appendix A for reporting levels) and require laboratories to report BLLs to appropriate state agencies. Twenty-one of the 27 states had ABLES programs supported by NIOSH cooperative agreements in 1997 (Alabama, Arizona, Connecticut, Iowa, Massachusetts, Maryland, Michigan, Minnesota, New Jersey, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Texas, Washington, Wisconsin, and Wyoming).

[*] Information on ABLES activities is available on the Internet at: http://www.cdc.gov/niosh/ables.html

NIOSH reports ABLES data on a quarterly basis in the Morbidity and Mortality Weekly Report (MMWR), a weekly publication of the Centers for Disease Control and Prevention.*

In 1995, 23 states reported 12,664 adults with elevated BLLs   25 µg/dL.[4] These 23 states represented 64 percent of the U.S. population (U.S. Bureau of the Census, 1993).

The ABLES data may represent only the tip of the iceberg with respect to the extent of occupational lead exposure in the United States. The Third National Health and Nutrition Examination Survey, NHANES III (1988–1991), estimated that as many as 700,000 adults (20 to 74 years of age) may have elevated BLLs   25 µg/dL.[5]

Investigations by NIOSH and others suggest that one of the most important factors contributing to the large disparity between the NHANES III estimate and the actual numbers of persons with elevated BLLs reported to ABLES is infrequent medical monitoring by employers, especially in the construction industry. Studies conducted before the OSHA construction lead standard took effect in 1993 found a lack of lead exposure assessment, periodic medical monitoring, or both, among residential and industrial painting and lead abatement contractors.[6,7,8] However, a recent analysis of surveillance data by the California Department of Health Services suggests that the vast majority of construction companies still do not test employees' BLLs, even though this is required by law.[9] Similarly, an OSHA analysis of inspection data for a recent one-year period (October 1994 through September 1995) found that the most frequently violated OSHA standard in standard industrial classification (SIC) codes 1622 (bridge, tunnel, and elevated highway contractors), 1721 (painting and paper hanging), and 1795 (wrecking and demolition) was the construction lead standard (29 CFR 1926.62).** Another factor is nonoccupational exposures. In one NIOSH study (described in Chapter 2, State-based Research—Overview), nonoccupational exposures were responsible for approximately 14 percent of persons with BLLs   40 µg/dL.

*MMWR issues are available on the Internet at: http://www.cdc.gov/epo/mmwr/mmwr.html

**Statistics for most frequently violated OSHA standards by SIC code are available on the Internet at: http://www.osha.gov/oshstats/std1.html

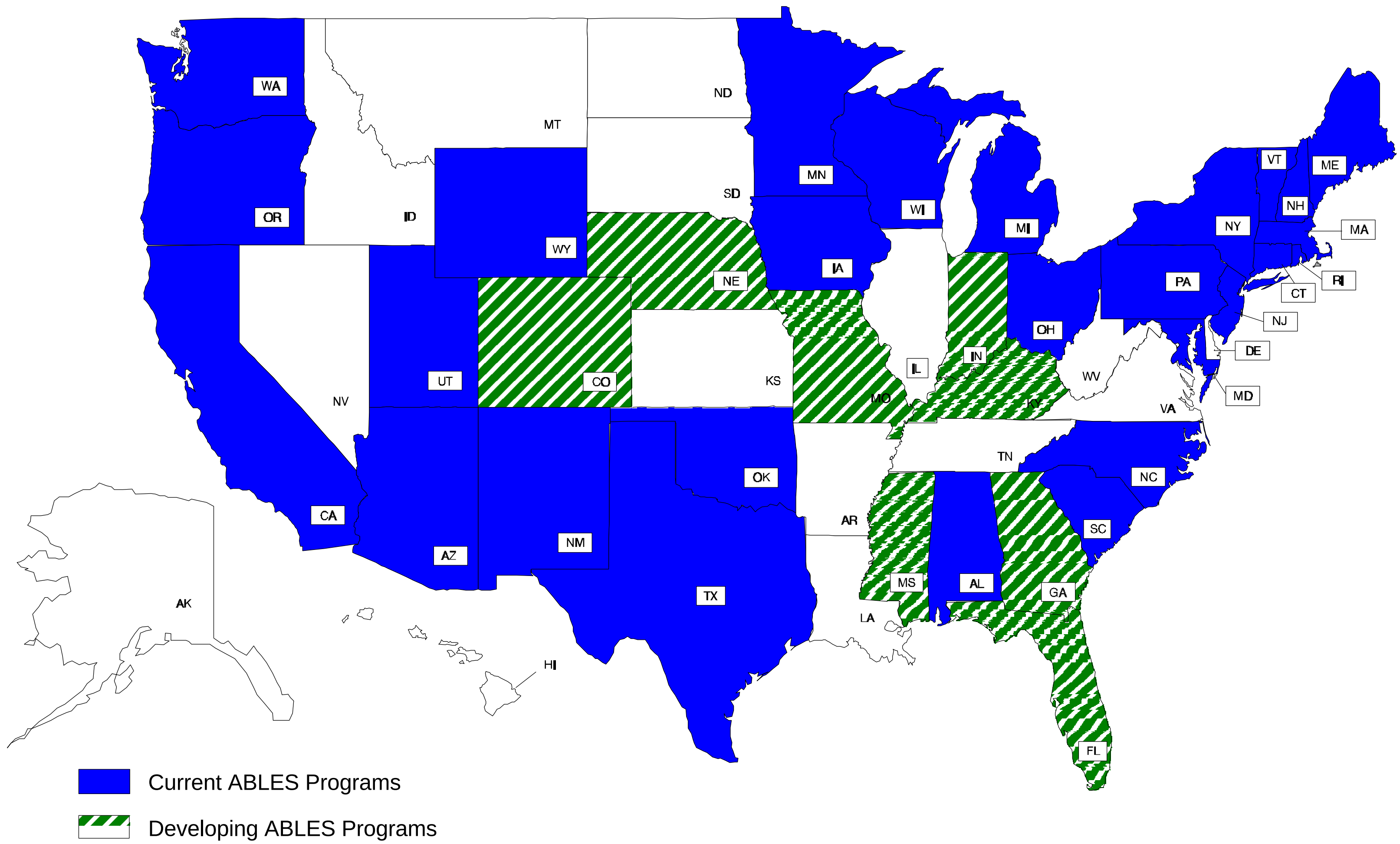


**Figure 2.1 States Participating in NIOSH Adult Blood Lead Epidemiology and Surveillance (ABLES) Program, 1997.**


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## State Intervention Capacity

ABLES states funded by NIOSH have protocols for investigating reported elevated BLL cases and mechanisms for linking elevated BLL case reports with follow-up activities. NIOSH currently provides about $25,000 to $30,000 per year to 16 states to assist in conducting surveillance and intervention activities. Resource constraints require the states to prioritize their intervention efforts.

Intervention capacity varies considerably among the ABLES states. Several states, including California, Connecticut, New Jersey, Massachusetts, and Washington, are good models for identifying high-risk industries and responding with interventions. These states have developed educational materials for workers and employers in high-risk industries. More elaborate state intervention activities include interviews with the workers' physicians and workplace follow-up visits. Employers may be contacted to determine if the employer is aware of regulatory requirements to protect workers from occupational lead poisoning. Intervention includes technical consultation for employees, employers, and physicians and educational outreach through workshops and printed materials. In the worst circumstances (e.g., an employer fails to correct problems resulting in elevated BLLs), the case may be referred to the OSHA consultation or compliance programs. States with minimal intervention resources typically limit their follow-up activity to contacting only those workers with the highest BLLs, usually 50 µg/dL, to provide information and medical referrals.

## State-Based Research—Overview

In 1993, NIOSH-supported research projects began in Illinois, Washington, Connecticut, and New Jersey. These projects targeted workers exposed to lead in the construction industry. Findings from these projects are discussed in the next section. The New Jersey study regarding take-home lead exposures is discussed in Chapter 3. In 1994, a NIOSH-funded intervention project for preventing lead poisoning among residential and commercial painters started in California. Preliminary results are reported in the next section. In 1995, NIOSH-funded research projects were begun in Washington and Iowa to develop model interventions to prevent occupational lead poisoning. These ongoing projects are expected to produce intervention models that will be applicable to general industry and construction.

Information on the source of lead exposure is not currently available in the national ABLES database maintained by NIOSH. However, in 1991, due in part to the reports of lead poisoning among bridge workers from several states, NIOSH published and distributed nationally a NIOSH Alert to prevent lead poisoning in construction workers.[10] Since the ABLES program was begun, NIOSH, in collaboration with the CDC's National Center for Health Statistics, has held several workshops for state personnel regarding appropriate techniques and data sources for coding the industry and the occupation of persons with elevated BLLs reported to ABLES registries. This information will eventually allow NIOSH to routinely identify high-risk occupations for lead poisoning.

The utility of this type of information is illustrated by a 1994 Massachusetts study. From 1991 to1993, 1,320 individuals, age 15 or older, with BLLs 25 µg/dL, were reported to the Massachusetts Occupational Lead Registry.[11] State investigators followed up on the 381 registrants (29%) with BLLs 40 µg/dL. An exposure source was determined for 362 people, and 313 (86%) were found to be occupationally exposed to lead. Of those occupationally exposed, 196 (63%) were employed in the construction industry, primarily as residential or industrial deleaders[*] and bridge or house painters. Of the 49 workers with BLLs 60 µg/dL, 39 (80%) were construction workers, and painters comprised approximately one-half of that group.

Among the other 49 registrants with BLLs 40 µg/dL who had nonwork lead exposures, the primary sources were shooting at firing ranges and renovation and repair of their own homes.

## State-Based Research Projects—Progress and Results to Date

### *Lead Exposure Assessment of Residential Home Painters (Washington)*

The primary goals of the project were to identify residential painting contractors and to assess lead exposures and worker protection at typical job sites.[12] The grantee, the Safety and Health Assessment and Research for Prevention (SHARP) program, is a part of the Washington State Department of Labor and Industries, which is the sole provider of workers' compensation insurance in Washington State.

SHARP initially identified 597 painting contractors in the two most populated counties (King and Pierce) with SIC code 1721 (painting and paper hanging) and a similar risk classification in the State's workers' compensation insurance database. The contractors were mostly very small businesses; 50 percent had fewer than one full-time equivalent (FTE) employee, 73 percent had five or fewer, and 82 percent had fewer than 10.

Eighty-eight contractors were contacted for a telephone survey, 61 (69%) of which agreed to participate. The contractors surveyed estimated that, on average, they spent 15 percent of their time in pre-1950 homes, 18 percent of their time in 1950–1977 homes, and 68 percent of their time in 1978 and newer homes. The contractors reported using the following high-risk surface preparation methods frequently or occasionally (percent): power sanding/grinding (51%), chemical stripping (35%), and heat gun (15%).

SHARP conducted five site visits at pre-1950 single-family homes to assess employee lead exposures during surface preparation work. Exposures for nine painters were measured, four of whom (44%) were overexposed to lead on the days of the survey (see Table 2.1). The hazardous exposures were during power sanding/grinding (range: 100 to 2142 µg/m$^3$) and hand scraping (108 µg/m$^3$).

[*]Massachusetts deleading regulations require blood lead monitoring of workers employed as deleaders.

**Table 2.1 Worker Lead Exposures During Surface Preparation for Residential Painting***

| House number | Task | Worker number | Lead exposure 8-hr TWA (μg/m$^3$) | Paint lead concentration (%)[†] |
|---|---|---|---|---|
| 1 | Power sanding/grinding | 1 | 2142 | 5–17 |
| | | 2 | 1007 | |
| 2 | Hand scraping | 3 | 108 | 1.2–3.3 |
| | | 4 | 31 | |
| 3 | Hand scraping/painting | 5 | 4.1 | 5.7 |
| | | 6 | 1.2 | |
| 4 | Hand scraping/sanding | 7 | 1.2 | < 0.001 |
| | | 8 | 0.4[‡] | |
| 5 | Power sanding/grinding | 9 | 100 | < 0.001 |

***Pre-1950 homes in King and Pierce counties, Washington State.**

[†]Paint lead, from 1 to 3 samples per unit, may not be representative of all surfaces disturbed.

[‡]None detected. A value of ½ the minimum detectable concentration is reported for statistical purposes.

SHARP concluded that painters have hazardous LBP exposures, use of personal protective equipment and hygiene practices were often inadequate, and painters may increase surface lead contamination in residences. The results were consistent with other research, which has found little correlation between paint lead concentrations and workers' health risk (see "Occupational Exposure Assessment" in Chapter 4).

Eight of the nine painters agreed to participate in BLL monitoring; and all had relatively low BLLs (range: 2 to 18 μg/dL). These workers were probably protected primarily by the relatively low frequency with which they performed high-risk work. All reported spending no more than one-half their time in pre-1950 homes, and only occasionally using the hazardous power sanding/grinding method.

***Health and Safety Contract Specifications for Bridge Repainting (Connecticut)***

The goal of this project, conducted by the Occupational Health Surveillance Program of the Connecticut Department of Public Health and Addiction Services, was to monitor the effectiveness of health and safety specifications in state contracts for bridge repainting.[13] After an interstate highway over the Mianus River collapsed in 1983, Connecticut began an intensive bridge repair program. In 1992, the Connecticut Department of Transportation implemented specifications in all contracts for bridge painting that required contractors to have approved programs to protect workers from lead poisoning (see summary in Appendix B).

The investigators used two methods for evaluating the effectiveness contract specifications in reducing worker lead exposures: comparison of data from Connecticut bridge sites before and after the contract specifications took effect, and a prospective study of worker lead exposures at a large bridge painting job.

Evaluations at five bridge painting sites, conducted in 1990, were compared to similar evaluations of two bridge sites in 1994. The investigators found marked improvements in the contractors' safety and health programs at selected Connecticut bridge sites between 1990 and 1994 (Table 2.2). This is consistent with BLL data collected throughout the state as part of the NIOSH-supported Connecticut Road Industry Surveillance Project (CRISP), which was begun in 1990. CRISP investigators found that from 1991 to 1994 average BLLs declined from 42 µg/dL to 17 µg/dL for blasters/painters, and from 21 µg/dL to 11 µg/dL for iron workers/welders.[14] These improvements may be the result of the medical surveillance of bridge workers under CRISP and the Connecticut Department of Transportation's contract specifications for worker protection. Two other changes, which took place on the national level, may also have affected the contractors' attention to worker protection: a NIOSH Alert documenting construction lead hazards was published in 1991 and the federal OSHA construction lead standard took effect in 1993.

**Table 2.2 Contractors' Safety and Health Programs—
1990 and 1994 Connecticut Bridge Studies**

| Job site characteristics | Historical study, 1990 | Small bridges, 1994 | Comment |
|---|---|---|---|
| Respirators available | A* | A | |
| Appropriate filters in use[†] | A | A | |
| Appropriate respirators for exposure[‡] | N | U | Rigging was performed without the use of respirators on one occasion |
| Fit testing | N | A | |
| Medical certification | N | A | |
| Respirator storage & maintenance | N | A | |
| Wash-up facilities | N | A | |
| Change area provided | N | A | |
| Clothing storage—clean & dirty separate[§] | N | A | |
| Work Practices[#] | N | U | Dry sweeping done occasionally |
| Hygiene practices** | N | U | Improper handwashing for some workers |
| Employee training | N | A | |
| Shower onsite or available | N | A | |
| Clean/separate eating area | N | A | |
| IH presence on site | N | A | |
| Showers taken | N | U | Some workers did not take complete showers |

***A–always U–usually S–sometimes R–rarely N–never**

† The sections on respirator filters, fit-testing, storage and maintenance, and medical certification were judged by compliance with the OSHA construction lead standard.

**NOTES:**

‡ Respirators were either PAPRs or half-face negative pressure for all tasks except blasting, where Lancer blast helmets were used.

§ Clothing storage required separate storage for clean and dirty clothing.

# Unacceptable work practices included sweeping, shoveling, and dumping blast residue, cleaning blaster helmets with high pressure air, and depositing respiratory equipment in lead-exposed areas.

** Unacceptable hygiene practices included eating, drinking, and smoking in lead-exposed areas and failure to wash hands prior to these activities.

The prospective evaluation at one bridge painting site over a period of four months demonstrated that, even with health and safety contract specifications, bridge workers were still routinely exposed to high levels of lead. Average worker lead exposures were well above the OSHA PEL. However, the contractor's health and safety program (including personal protective equipment) was successful in preventing the most severe exposures: no worker's BLL reached 50 µg/dL. On the other hand, 10 of 46 participating workers (22%) had at least one elevated BLL > 25 µg/dL during the study, and 19 workers (41%) had BLL increases of 10 µg/dL during the study (Table 2.3).

**Table 2.3 Airborne Lead Exposures and BLLs, Connecticut Prospective Bridge Site Study**

| Job Category | Mean air lead exposure (µg/m³) | No. of workers | No. with at least one BLL > 25 µg/dL | No. with BLL increase > 10 µg/dL | No. with BLL decrease > 10 µg/dL |
|---|---|---|---|---|---|
| Laborers/ groundsworkers | 73 | 23 | 3 | 9 | 4 |
| Blasters/painters | 2720 | 23 | 7 | 10 | 2 |
| Totals | | 46 | 10 | 19 | 6 |

***Reducing Lead Exposures of Home Painters (California)***

The California Department of Health Services designed, implemented, and evaluated an intervention to improve lead poisoning worker protection among residential painting contractors who were potentially exposed to LBP hazards. The intervention included development of a comprehensive lead safety manual and training workers and contractors about lead-safe practices.

Twenty-two painting contractors with 134 employees were recruited for this study in 1994. Employers were interviewed about methods they used for surface preparation, and about their lead safety and health programs. Lead exposure assessments were conducted, and pre- and post-intervention biological monitoring and questionnaires were administered in 1994. A follow-up survey to assess retention of information about lead-safe practices was done in 1995.

Results indicated that the pre-intervention worker protection programs among the participating contractors were generally lacking and that contractors were poorly informed about the requirements of the OSHA construction lead standard. A substantial proportion (37 percent) of contractors did not test for the presence of lead at the work site. High-risk paint removal methods, including dry scraping, dry sanding, power sanding without local exhaust ventilation (LEV), open flame torch burning, and heat gun, were often used. The contractors rarely performed lead exposure assessment or medical monitoring—only one of the 22 painting contractors had ever assessed employee airborne lead exposures, and only two did routine BLL monitoring of employees. Many contractors indicated that they did not provide workers any lead safety training, the proper type of respirators or respiratory programs, or protective work clothing.

The exposure assessment, which included 11 of the 22 participating painting contractors, consisted of full-shift and task-based personal exposure monitoring, sampling of disturbed painted surfaces (all had LBP), and observation of work practices. A total of 25 full-shift employee exposures were measured, representing a mix of surface preparation activities and other daily tasks.

Fifty-four task-based exposure measurements were collected for these surface preparation tasks: power sanding with and without high-efficiency particulate air (HEPA) vacuum exhaust, manual dry sanding, wet sanding, dry scraping, open flame torch/scraping, heat gun/scraping. Hazardous exposures to LBP frequently occurred among the residential painters during surface preparation work. The mean full-shift exposure was 57 $\mu g/m^3$ (range: 1 to 548 $\mu g/m^3$), and 6 of the 25 full-shift exposures (24%) exceeded the OSHA PEL.

The results for the task-based worker exposures were categorized according to the paint lead concentration (see Table 2.4). On surfaces with low lead levels in paint (0% to 10% lead [Pb]), both power sanding without HEPA exhaust and dry scraping resulted in average exposures that were hazardous. On surfaces with medium paint lead levels (11% to 20% Pb), power sanding with or without HEPA vacuum exhaust, manual dry sanding, and dry scraping resulted in average exposures that were hazardous. Nonhazardous average lead exposures were measured for heat gun and open flame torch removal methods in this study, but larger studies have documented very high exposures for those methods (see Chapter 4).

**Table 2.4 Task-specific Lead Exposures by Percentage Lead in Paint California Home Painters**

| Surface preparation method | Average task-specific lead exposures (μg/m$^3$) by percentage lead in paint* (number of air samples) | | |
|---|---|---|---|
| | 0–10% Pb† | 11–20% Pb† | 21–45% Pb† |
| Power sanding—without HEPA vacuum exhaust | 97 (4)‡ | 899 (6)‡ | |
| Manual dry sanding | 55 (3) | 605 (6) | |
| Dry scraping | 24 (6) | 94 (12) | |
| Power sanding—with HEPA vacuum exhaust | 23 (2)§ | 52 (2)# | 26 (3) |
| Open flame torch and scraping** | 8 (1) | 10 (4) | |
| Heat gun and scraping** | 3 (3) | 2 (3) | |
| Wet sanding | | | 3 (3) |

* Air sample duration was 30 minutes unless otherwise noted.
† Average percentage by weight, mean of two bulk samples per surface.
‡ Sample duration for one sample was 20 min.
§ Sample duration for both samples was 10 min.
# Sample duration for both samples was 20 min.
** Paint was heated only to the softening point.

## Identifying Hazardous Lead Exposures with Other Data Sources

### *NIOSH Health Hazard Evaluations*

Over the past 25 years, NIOSH has responded to HHE requests from employers, employees, and authorized representatives of employees, and to technical assistance requests from federal, state, and local agencies. The requesters ask NIOSH to determine whether chemical, biological, or physical agents, used or found in the workplace, are hazardous. Many of the HHE requests have concerned lead exposures. The HHEs are conducted pursuant to Section 20(a)(6) of the Occupational Safety and Health Act of 1970 (PL 91–596) and NIOSH regulations (42 CFR Part 85).

HHE requests do not necessarily result in NIOSH site investigations. In many cases, NIOSH technical experts provide information to requesters via phone or correspondence. Site investigations generally occur when more extensive NIOSH involvement is warranted. NIOSH site investigations result in written reports, either as a letter or a published final report. Published final reports are usually done when the results are potentially of general interest, or when a new or emerging health hazard is documented. Published reports are available from NIOSH and the National Technical Information Service; abstracts of NIOSH reports are available in NIOSHTIC®, a searchable NIOSH database published in CD-ROM format.*

Between 1978 (the date of the first OSHA lead standard) and 1995, 337 lead-related HHE investigations were completed, and 179 resulted in a NIOSH final report.** A peak in the distribution of lead-related final reports occurred in 1979 after promulgation of OSHA's 1978 Lead Standard for General Industry, and another peak occurred in 1991 after publication of the U.S. Department of Housing and Urban Development (HUD) Interim Guidelines for Lead-Based Paint Abatement in Public and Indian Housing.[15] Forty-nine (27 percent) of the lead-related HHEs that resulted in final reports, conducted between 1978 and 1995, contained a positive determination of lead exposure, including worker BLL data.***

Of the 49 HHE final reports with BLL data, 31 different four-digit SIC codes were represented. The HHEs are ranked in descending order by average BLL in Table 2.5. Since 1978, HHEs in the construction industry, specifically during maintenance or repainting of steel structures coated with LBP, have been among those measuring the highest worker BLLs. The highest average worker BLLs (for HHEs completed from 1978 to 1995) were reported for the following industries: battery reclamation (66 µg/dL); storage battery manufacturing (64 and 41 µg/dL for two studies); bridge, tunnel, and elevated-highway construction (50 µg/dL); gold ores (42 µg/dL); nonferrous foundry (41 µg/dL); and shipbuilding and repair (38 µg/dL). Forty-two of the 49 HHE investigations (86 percent) reported BLLs   25 µg/dL.

From 1978 to the present, OSHA compliance inspections and NIOSH HHEs have occurred in a wide array of industries where workers are exposed to lead. Both programs have identified high-risk industries for lead exposure. In 1990, Froines et al. analyzed airborne lead exposure data from 3,884 OSHA compliance inspections conducted between 1979–1985.[16] The authors reported that there were 46 four-digit SIC codes for which more than a third of the OSHA inspections measured airborne lead exposures greater than the PEL. The 46 industries, ranked by percent of measured exposures over the PEL, are listed in Table 2.6. Comparing these SIC codes with the SIC codes from the list of lead-related HHEs (Table 2.5), there was little overlap; 80 percent of the SIC codes were different.[16]

Since the NIOSH and OSHA programs have a very different purpose, it is not surprising that different industries were identified. NIOSH HHEs result from employee and employer requests, whereas OSHA compliance inspections often result from OSHA's targeted emphasis programs in

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*Information on obtaining NIOSH publications is available by calling 1–800–35NIOSH, or on the Internet at www.cdc.gov/niosh.

**From the Hazard Evaluations and Technical Assistance Branch internal database of closed HHEs.

***Citations for these reports were obtained by searching NIOSHTIC® using the keywords: "HETA," "lead," and "blood lead level."

addition to employee complaints.  Additionally, and equally important, the NIOSH ranking was based on average BLL whereas the Froines et al. ranking was based on airborne lead exposures. In many cases, there is little correlation between airborne exposures and worker BLLs because personal protective equipment is used.  Finally, some discrepancies in the SIC codes may have occurred due to improper classification by either NIOSH or OSHA investigators.

### *HUD Lead-Based Paint Program*

Amendments to the Lead-based Paint Poisoning Prevention Act in 1987 and 1988 required HUD to perform a LBP abatement demonstration program, the primary objective of which was to demonstrate various abatement methods and their relative cost-effectiveness.  At the request of HUD, NIOSH evaluated worker protection measures and lead exposures during the HUD demonstration project in 1989 and 1990.  A NIOSH report with findings and recommendations was published in 1992.[6]  One of the NIOSH recommendations was that HUD collect and compile worker BLL data for HUD-funded work.  This surveillance data, if collected, could be used by NIOSH to supplement the ABLES program.

Due to the initiatives in Title X, HUD's lead poisoning prevention program has grown considerably in the 1990s.  Through FY96, HUD has provided grants totaling $335.6 million to states and local governments for LBP hazard reduction in private housing.

In 1995, NIOSH initiated a study to determine the magnitude and variability of lead exposures and the potential for take-home lead problems among lead abatement workers employed by HUD grantees.  Two field surveys were done in Oakland, California, in collaboration with the California Department of Health Services in 1995.  HUD and local requirements for worker protection were closely followed at both survey sites.  Additional data are being collected in Rhode Island and a location in another state is planned.

## RECOMMENDATIONS

State surveillance programs should be expanded to all states.  Surveillance programs can identify workers exposed to LBP hazards, help identify high-risk workplaces, and enable states to conduct follow-up investigations where needed.  Research and education are needed to address the special problems of the many small businesses involved in LBP activities to develop low-cost controls and reduce worker lead exposures and environmental releases of lead.

**Table 2.5 NIOSH HHE Final Reports with BLL Data, 1978–1995, Ranked by Average BLL**

| Industry | SIC Code | NIOSH Report No.¶ | No of workers tested | Blood lead levels | |
|---|---|---|---|---|---|
| | | | | Range (µg/dL) | Average (µg/dL) |
| Scrap and waste materials | 5093 | 91–213–2123 | 15 | 9–86 | 66 |
| Storage batteries | 3691 | 87–371–1989 | 32 | 28–86 | 64 |
| Bridge, tunnel and elevated-highway construction | 1622 | 80–099–859 | 32 | 25–96 | 50 |
| Gold ores | 1041 | 89–213–1992 | 11 | 23–65 | 42 |
| Nonferrous foundries (castings) | 3362 | 88–244–1951 | 18 | 10–67 | 41 |
| Storage batteries | 3691 | 91–077–2160 | 43 | 12–66 | 41 |
| Shipbuilding and repairing | 3731 | 85–132–1598 | 10 | 25–53 | 38 |
| Gold ores | 1041 | 89–052–2006 | 6 | 13–55 | 37 |
| Bridge, tunnel and elevated-highway construction | 1622 | 91–006–2193 | 11 | 9–61 | 34 |
| Heavy construction, not elsewhere classified | 1629 | 91–209–2249 | 6 | 15–44 | 34 |
| Fabricated plate work | 3443 | 91–290–2131 | 17 | 11–77 | 34 |
| Motor vehicle parts and accessories | 3714 | 89–231–2016 | 2 | 30–37 | 34 |
| Primary smelting and refining of nonferrous metals, except copper | 3339 | 81–036–1023 | 3 | 26–37 | 32 |
| Fabricated plate work | 3443 | 91–393–2171 | 9 | 10–51 | 32 |
| Motor vehicle parts and accessories | 3714 | 89–234–2014 | 7 | 17–64 | 32 |
| Motor vehicle parts and accessories | 3714 | 83–459–1465 | 14 | N/R* | 31 |
| Fabricated metal products, not elsewhere classified | 3499 | 87–262–1852 | 3 | 25–43 | 31 |
| Industrial inorganic chemicals | 2810 | 80–116–1034 | 97 | N/R–69 | 30 |
| Secondary smelting and refining of nonferrous metals | 3342 | 89–295–2007 | 12 | 5–63 | 29 |
| Storage batteries | 3691 | 84–041–1529 | 289 | N/R | 29 |
| Motor vehicle parts and accessories | 3714 | 89–232–2015 | 6 | 14–41 | 26 |
| Inorganic pigments | 2816 | 81–356–1183 | 70 | N/R | 26 |
| Motor vehicle parts and accessories | 3714 | 88–354–1955 | 10 | 8–44 | 24 |
| Motor vehicle parts and accessories (radiators) | 3714 | 81–039–1104 | 66 | 11–52 | 23 |
| Tanks, metal-plate: lined | 3443 | 91–290–2174 | 22 | 4–38 | 23 |
| Motor vehicles parts and accessories | 3714 | 89–233–2013 | 4 | 11–33 | 21 |
| Copper foundries | 3366 | 91–092–2190 | 10 | 10–39 | 21 |
| Electric Services | 4911 | 90–075–2298 | 43 | < 5–43 | 20 |

**Table 2.5 NIOSH HHE Final Reports with BLL Data, 1978–1995, Ranked by Average BLL**

| Industry | SIC Code | NIOSH Report No.[¶] | No of workers tested | Blood lead levels | |
|---|---|---|---|---|---|
| | | | | Range (µg/dL) | Average (µg/dL) |
| Scrap and waste materials | 5093 | 93–0739–2364 | 17 | 4–40 | 20 |
| Pressed and blown glass and glassware | 3229 | 84–384–1580 | 12 | 2–36 | 20 |
| Electronic components, not elsewhere classified | 3679 | 93–0955–2390 | 7 | 9–27 | 19 |
| Stained glass artists | 8999 | 86–348–1756 | 3 | 7–33 | 19 |
| Primary smelting and refining of nonferrous metals, except copper | 3339 | 94–0109–2494 | 15 | 15–54 | 19 |
| Steel works, blast furnaces (including coke) | 3312 | 89–139–2025 | 22 | N/R | 18 |
| Industrial valves | 3491 | 88–357–2042 | 25 | < 20–33 | 15 |
| Pressed and blown glass and glassware | 3229 | 86–070–1774 | 8 | 4–33 | 13 |
| Leaded glass, made from purchased glass | 3231 | 91–076–2164 | 18 | **< 10–24**[†] | **12** |
| Primary smelting and refining of copper | 3331 | 84–038–1513 | 49 | **0–24** | **11** |
| Steel works, blast furnaces (including coke) | 3312 | 80–115–1401 | 79 | 1–33 | 11 |
| General contractors—industrial buildings and warehouses | 1541 | 89–252,293–2178 | 16 | **3–21** | **10** |
| Police protection | 9221 | 89–295–2007 | 8 | **3–13** | **8** |
| Motor vehicle parts and accessories | 3714 | 87–126–2019 | 28 | < 5–43 | 8 |
| General contractors—single-family homes | 1521 | 90–070–2181 | 96[‡] | N/R – 27[‡] | 6 |
| Stained glass artists | 8999 | 92–0029–2329 | 2 | **2** | **2** |
| Gold ores, assay lab | 1041 | 89–196–2023 | 2 | N/R – < 40 | N/R |
| Nitrogenous fertilizers | 2873 | 91–073–2165 | 13 | **4–13** | N/R |
| Valves and pipe fittings, not elsewhere classified | 3494 | 81–426–1062 | 2 | N/R – < 30 | N/R |
| Motor vehicle parts and accessories | 3714 | 86–087–1686 | 5 | N/R– < 29 (2)<br>40 – 60 (3) | N/R |
| Commercial testing laboratories | 7397 | 86–438–1795 | 10 | > 17–192 | N/R |

[¶]The first two digits of the report number are the publication year.
*N/R = not reported.
[†]**Bold text indicates the HHE found no worker BLLs 25 µg/dL.**
[‡*]Of 288 workers, only 96 (33%) received follow-up BLL testing.

**Table 2.6 Airborne Lead Data from 1979–1985 OSHA Inspections for 46 Industries, Ranked by Exposure**

| Industry | SIC Code | No. Inspections/ No. Samples | Percent of measured exposures over the PEL |
|---|---|---|---|
| Bridge, tunnel and elevated highway | 1622 | 7/13 | 69 |
| Equipment rental and leasing | 7394 | 6/8 | 63 |
| Electronic capacitors | 3675 | 12/170 | 54 |
| Bottled and canned soft drinks | 2086 | 9/19 | 53 |
| Chemical preparations | 2899 | 6/15 | 53 |
| Hoists, cranes, and monorails | 3536 | 11/25 | 52 |
| Highway and street construction | 1611 | 4/6 | 50 |
| National security | 9711 | 6/24 | 50 |
| Temporary help supply services | 7362 | 6/8 | 50 |
| Pottery products | 3269 | 12/29 | 45 |
| Repair service | 7699 | 9/20 | 45 |
| Power transmission equipment | 3568 | 9/32 | 44 |
| Construction and mining machinery | 5082 | 5/7 | 43 |
| Pressed and blown glass | 3229 | 21/93 | 41 |
| Commercial testing laboratories | 7397 | 4/10 | 40 |
| Petroleum refining | 2911 | 4/5 | 40 |
| Automotive repair shop | 7539 | 30/82 | 39 |
| Armature rewinding shops | 7694 | 4/8 | 38 |
| General automotive repair shops | 7538 | 24/56 | 36 |
| Painting, paper hanging, decorating | 1721 | 20/47 | 36 |
| Malleable iron foundries | 3322 | 9/52 | 35 |
| Vitreous china and food utensils | 3262 | 5/44 | 34 |
| General industrial machinery | 3569 | 18/33 | 33 |
| Industrial trucks and tractors | 3537 | 20/33 | 33 |
| Boat building and repairing | 3732 | 15/25 | 32 |
| Industrial scrap and waste | 5085 | 6/25 | 32 |
| Plastics, materials, and resins | 2821 | 29/109 | 32 |
| Cathode ray television picture tubes | 3672 | 4/10 | 30 |

**Table 2.6 Airborne Lead Data from 1979–1985 OSHA Inspections for 46 Industries, Ranked by Exposure**

| Industry | SIC Code | No. Inspections/ No. Samples | Percent of measured exposures over the PEL |
|---|---|---|---|
| Conveyors and conveying equipment | 3535 | 14/27 | 30 |
| Electrical work | 1731 | 6/10 | 30 |
| Farm machinery and equipment | 3523 | 114/342 | 29 |
| Woodworking machinery | 3553 | 7/14 | 29 |
| Transportation equipment | 3799 | 11/18 | 28 |
| Adhesives and sealants | 2891 | 6/11 | 27 |
| Truck and bus bodies | 3713 | 80/211 | 27 |
| Lawn and garden equipment | 3524 | 11/23 | 26 |
| Railroad equipment | 3743 | 42/158 | 25 |
| Industrial inorganic chemicals | 2819 | 12/34 | 24 |
| Metal partitions and fixtures | 2542 | 11/29 | 24 |
| Truck trailers | 3715 | 54/182 | 24 |
| Coated fabrics, not rubberized | 2295 | 5/14 | 21 |
| Construction machinery | 3531 | 100/350 | 19 |
| Railroads, line-haul operating | 4011 | 5/28 | 18 |
| Ammunition, except for small arms | 3483 | 6/29 | 17 |

Adapted from Froines et al., 1990.[16]

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# CHAPTER 3

## LEAD EXPOSURE OF WORKERS' FAMILIES

### RECENT NIOSH RESEARCH

Families of construction workers, including those involved in LBP activities, may be exposed to lead brought home from the workplace. NIOSH and the New Jersey Department of Health conducted a surveillance study in 1993 and 1994 involving the voluntary participation of 46 construction workers' families. The workers, who had reported BLLs 25 µg/dL, were identified from the 510 construction workers in the New Jersey ABLES registry. BLL testing of young children indicated that the workers' children, particularly those under age six, were at greater risk of having elevated BLLs ( 10 µg/dL) than children in the general population (Table 3.1). Higher percentages of workers' children in age categories one-to-two and three-to-five years had elevated BLLs than national averages for these ages. Limitations of this study were that BLL data for worker's children were compared to national averages, not local controls, and no environmental lead measurements were made in workers' homes.

**Table 3.1 BLLs by Age for Children of New Jersey Construction Workers and in the General Population**

| Age (years) | NJ workers' families percent 10 µg/dL | U.S. population* percent 10 µg/dL |
|---|---|---|
| 1 – 2 | 40 | 11.5 |
| 3 – 5 | 24.0 | 7.3 |
| 6 – 11 | 6.5 | 4.0 |

*Source: NHANES III, 1988 to 1991[1]

To address these limitations NIOSH collaborated with the New Jersey Department of Health to conduct a more comprehensive study of take-home lead exposures in the construction industry. NIOSH investigators assessed environmental lead exposures in the homes of lead-exposed construction workers from the ABLES registry and in the homes of controls (unexposed neighbor families). Environmental sampling was done in 37 exposed workers' homes and 22 neighborhood control homes; of these, 29 exposed and 18 control families also participated in BLL testing.

The children of lead-exposed construction workers were more likely to have elevated BLLs than their neighbors' children. Thirty-one workers' children (26 percent) had elevated

BLLs    10 µg/dL compared with 19 of the neighbors' children (5 percent) (unadjusted odds ratio = 6.1, 95% confidence interval, 0.9 to 147.2).[2] The environmental evaluation suggests that the construction workers' occupational lead exposures combined with ineffective hygiene practices resulted in lead contamination of their cars and homes.[3] Significantly higher surface lead levels were found in workers' cars on the driver's floor (geometric mean [GM] = 1100 micrograms per square meter [µg/m$^2$]) than in the control group (250 µg/m$^2$). Surface lead levels were generally higher in workers' homes; the average interior entry floor lead level was 23 µg/m$^2$ in workers' homes and 9 µg/m$^2$ in control homes ($p = .08$). The lead *concentrations* (which are not affected by housekeeping) in surface dust collected in clothing change rooms were significantly higher in workers' homes (GM = 370 parts per million [ppm]) than in control homes (120 ppm), $p = .005$. The lead loadings measured on window sills, which in older homes are often due to LBP on window friction surfaces, were not different in exposed and control homes.

In 1993, NIOSH evaluated lead contamination at a Connecticut highway bridge renovation project. Prior to repainting, LBP was removed from the structure by abrasive blasting with recycled steel grit. The blasting took place inside a tarpaulin containment using ventilation to maintain negative air pressure. NIOSH found lead contamination on the hands, faces, and clothing of the 25 workers sampled at this construction site.[4] Additionally, lead dust was present in each of the 27 workers' automobiles sampled.[5] Relatively high surface lead loadings were found on the driver's side floors (GM = 1900 µg/m$^2$), armrests (1100 µg/m$^2$), and steering wheels (240 µg/m$^2$), suggesting that workers carried the lead into their cars on hands and clothing. Interestingly, workers with low airborne exposures to lead had higher lead levels in their vehicles. There was no unexposed control group in this study, but in a related study described above, the lead levels on the floors of the drivers' sides of vehicles were only 250 µg/m$^2$. Workers who were highly exposed to airborne lead, such as blasters, regularly wore protective clothing, changed out of work clothing, and showered before entering their cars. Other workers, including industrial hygiene and safety specialists, who had low airborne exposures to lead, did not regularly follow the same occupational hygiene practices, presumably because they were not felt to be necessary.

There is also potential for take-home lead exposures among families of renovation and remodeling workers. A NIOSH study of lead-exposed residential renovation and repair workers found higher surface lead levels in 20 full-time workers' vehicles (arithmetic mean: 3300 µg/m$^2$) than in those of 11 part-time volunteers (1500 µg/m$^2$ ), although the difference did not reach statistical significance.[6]

Exposure to lead in construction activities can result in workers' vehicles being contaminated and a significant amount of lead being transported into the home.

## REVIEW OF PREVIOUS STUDIES

As required by the Workers' Family Protection Act of 1992 (29 U.S.C. 671a), NIOSH prepared a comprehensive report to Congress documenting incidents of para-occupational or “take-home” exposure to toxic substances, for the purposes of developing a strategy to reduce such exposures.[7]

The report documents that, in a variety of industries, lead dust may be carried on skin and clothing from the workplace to homes and vehicles, resulting in take-home lead exposures among the workers’ families. Children of lead-exposed workers may be exposed to higher levels of lead when there are ineffective occupational hygiene facilities or practices in the workplace. A study of lead storage battery workers showed statistically significant differences in BLLs between children of workers with effective hygiene practices (e.g., showering and changing clothes before leaving work) and children of workers with ineffective hygiene practices.[8] The study recommended the employer provide more stringent enforcement of lead containment practices. The industries for which take-home lead exposure has been most frequently reported include lead smelting, battery manufacturing/recycling, radiator repair, electrical components manufacturing, pottery/ceramics production, and stained glass making. Take-home lead exposures for the construction industry have only recently been reported. This may be the result of increasing attention on construction industry lead exposures in the 1990s.

In that report to Congress, NIOSH identified 64 investigations worldwide of take-home lead exposure where children’s BLLs were measured.[7] Twenty-two were published studies for cohorts of lead-exposed workers in general industry. Researchers found in the majority of the studies that the workers’ children had significantly higher BLLs than children in the control groups. The mean BLLs for children of lead-exposed workers across all the cohort studies ranged from 10.2 to 81 µg/dL, while those for children in control groups ranged from 6.2 to 27 µg/dL.

Children of construction workers with elevated BLLs (range: 10 to 28 µg/dL) were reported in five case series or case reports. Industrial hygiene assessments of construction workers in this report were consistent with the BLL findings: high surface lead levels were found on workers’ skin and clothing, in their vehicles, or in their homes.[7]

## SUMMARY AND RECOMMENDATIONS

Families of bridge workers, residential renovation and remodeling workers, and others involved in LBP activities may have take-home lead exposures as a result of lead dust brought home from the workplace on skin and clothing. Research is needed to determine better the extent of take-home lead exposures among workers who are exposed to low airborne lead levels, but who work in lead-contaminated environments. Until more data are available, protective clothing and hygiene facilities should be considered for workers frequently exposed to lead in lead-contaminated workplaces, even for those workers whose average exposures are below the OSHA PEL.

It is the responsibility of employers to provide good hygiene facilities and encourage their use. Both employers and workers need to make sure that good hygiene practices are followed to prevent take-home lead exposures.

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# CHAPTER 4

## METHODS, DEVICES, AND WORK PRACTICES TO CONTROL OCCUPATIONAL LEAD EXPOSURES DURING LEAD-BASED PAINT ACTIVITIES

### CONTROLS FOR LBP ACTIVITIES ON STEEL STRUCTURES

The primary reason that existing highway bridges and industrial steel structures are repainted is to prevent corrosion that can cause the structures to collapse. In 1993, OSHA estimated that more than 3,700 bridges containing LBP are repainted each year.[1] The same report estimated that more than 13,000 painting jobs involving LBP are done annually on water storage tanks, fuel storage tanks, and industrial steel structures. Although the use of LBP application has declined significantly during the past five years, existing steel structures coated with LBP (approximately 90 percent of highway bridges) will need repainting and maintenance over the next 20 years.[2]

The most common method for repainting steel structures involves removing the existing coatings with open abrasive blasting. This method creates hazardous air concentrations of lead, other heavy metals, and when silica abrasives are used, silica.[3,4,5] In the past few years, contractors have been required to contain paint chips, dust, and waste abrasive materials during paint removal, typically with mesh tarpaulins or rigid structures, to protect the environment.[6,7] Unfortunately, the containment structures which control environmental emissions often increase workers' risks of hazardous exposures to lead and other materials by concentrating these agents. Lead exposures during dry abrasive blasting have been reported as high as 600 times the OSHA PEL.[8]

Below is a method-by-method evaluation of controls used in the steel structure repainting industry to reduce airborne lead and silica exposures of workers. Most of the data reported in this chapter and summarized in Table 4.1 are taken from NIOSH reports. Data from other published sources were used for those controls that NIOSH has not studied. Employers may find that occupational lead exposures in their workplaces differ from those described below. Lead exposures in the construction industry are highly variable. The most important variables for exposure measurements during construction activities are the method used, the contractor’s work practices, preexisting surface lead concentrations, environmental conditions, engineering controls used, and sampling methods.

## Alternatives to Traditional Abrasive Blasting

### *Overcoating*

Overcoating is the application of a new coating on top of existing coatings; this was made possible by the design of specific overcoating products. This is similar to interim controls or in-place management, which are common alternatives to abatement of LBP in housing. Because much less of the existing LBP is removed or disturbed during overcoating, it reduces the potential risk to worker health. In most cases, areas with corrosion or deteriorated paint are repaired before overcoating the whole structure.

The first step of the overcoating process, washing the surface, is designed to remove accumulated salts and dirt, but not the intact paint coatings. Then a penetrating primer is used to coat exposed steel and rusted areas. The final step is application of a topcoat (or coats) over the entire structure. Overcoating advantages are (1) little waste generation or disposal; (2) no containment structure; (3) no (or very little) airborne lead generated; (4) lower project costs; and (5) the lead-based coating continues to provide excellent corrosion protection. The disadvantages are that the longevity of the overcoating is dependent on the quality of the old coatings and the LBP may need to be removed at some later date.

When feasible, overcoating may be the best way of reducing hazardous lead and silica exposures during steel structure repainting and repair work. It may prove to be a satisfactory alternative over the useful life of a structure. However, overcoating cannot be used in every situation, i.e., on surfaces with poorly bonded old paint. Additional research is needed to develop and evaluate overcoating programs, to improve surface-tolerant coatings, and to evaluate life-cycle costs for steel structures such as bridges and water tanks.

### *Chemical Stripping*

Chemical stripping involves spraying an alkaline chemical on the painted surface, allowing it to react, and then scraping the decomposed paint and excess caustic from the steel surface. The surface is subsequently rinsed with water followed by quick abrasive blasting to remove traces of remaining paint and to establish a suitable surface profile, or “anchor pattern,” for repainting. Liquid runoff and solid wastes are collected using plastic sheets under the structure.

Worker lead exposures during the chemical spraying, scraping, and rinsing at one chemical stripping site evaluated were below the OSHA PEL.[9] However, during the abrasive blasting that followed, high air lead (100 times the PEL) and alkaline dust concentrations occurred. A positive factor was that the time required for this quick abrasive blasting (and thus the total lead exposures) were reduced to about half that of normal abrasive blasting. The tradeoff is that the process introduces an additional chemical exposure hazard to the eyes, skin, and upper respiratory tract.

If the final blasting step could be eliminated by painting directly after the rinsing process, the chemical stripping process would be much safer. If abrasive blasting is needed to prepare the surfaces for repainting, it may be possible to improve the rinse method to reduce the airborne lead concentrations during subsequent blasting.

### *Wet Blasting*

Wet methods have been used to reduce dustiness associated with LBP removal projects. Both high-pressure water alone and water mixed with abrasive have been used. Dust levels are reduced by the presence of water, but the extent of reduction is not presently known. Wet methods reduce the airborne lead concentration, but not necessarily below the PEL. NIOSH evaluated this process at a demonstration site and found an airborne lead concentration 30 times the PEL.[10]

Disadvantages are that the contaminated water may be difficult to contain and collect, and may be considered a hazardous waste. Also, water-soluble rust inhibitors are often used in this process to prevent rusting; however, their long-term effectiveness with new coatings is unknown.

### *Power Tools*

Power tools can be used to sand, scrape, or chip coatings from steel structures. Power tools are often used to remove deteriorated paint from specified areas of a steel structure while leaving paint in nearby areas intact. The need to apply power tools firmly against the surface at all times can create worker fatigue and musculoskeletal hazards, and some tools may not be able to clean irregular surfaces. Another limitation of power tools when compared to abrasive blasting is that the production rate for paint removal is much less.

NIOSH has measured worker lead exposures up to 70 times the PEL during use of electric wire brushes and four times the PEL during use of pneumatic hammers (chisels).[11]

Power tools equipped with HEPA-filtered LEV systems, also known as vacuum tools, are used to reduce worker exposures during LBP removal. Vacuum tools also reduce airborne lead emissions and hazardous waste volume. NIOSH has not tested the effectiveness of LEV systems on power tools, but studies indicate that vacuum tools reduce, but do not eliminate hazardous worker lead exposures. For example, airborne lead concentrations of up to 10 times the PEL have been reported for operators of vacuum needleguns.[12] On the other hand, a U.S. Environmental Protection Agency (EPA) study of LBP removal on highway bridges found that lead exposures of vacuum needlegun operators were very low (none detected), compared to exposures of 100 to 890 $\mu g/m^3$ for conventional abrasive blasting on a similar bridge.[13] In the same study, the EPA reported that the estimated project cost using vacuum needleguns was 33 percent higher than during conventional abrasive blasting, although 97.5 percent less hazardous waste was generated.

Vacuum tools are effective in controlling lead exposures when they are used properly. The tool must be held firmly against the surface at all times during paint removal for effective capture of lead dust.

Additional research is needed to provide LEV specifications for power tools, evaluate the effectiveness of LEV systems, and analyze the cost effectiveness of power tools with LEV compared to abrasive blasting with containment.

## Controls for Abrasive Blasting Removal of LBP

### *Isolation/Automation During Blasting*

Isolation is a very promising method under development for removing the worker from the airborne lead environment. The blasting process can be automated and conducted inside an enclosure while workers are stationed safely outside. At one test site, airborne lead concentrations in samples taken in the work area outside the enclosure were below the PEL.[14] Typically, as much as 80 percent of the steel on some structures can be automatically blasted, and traditional methods could be used for the remaining areas. This technology is currently being tested on a limited basis and is not generally available.

### *Vacuum Blasting*

Vacuum blasting is a method that uses specialized abrasive blasting equipment equipped with LEV. The exhaust system contains and collects dust at the generation source before the dust can escape. Vacuum blasting can greatly reduce the airborne emissions and the amount of hazardous wastes generated. This method is safer, but less productive, than traditional open abrasive blasting, and may not be suitable for irregular surfaces. The vacuum blasting nozzle must be held firmly against the work surface and therefore may cause worker fatigue and musculoskeletal hazards. A NIOSH survey of vacuum blasting found operators' lead exposures equal to the PEL.[15] Research is needed to support consensus specifications for vacuum blast equipment.

### *General Dilution Ventilation*

General dilution ventilation is used with some containment structures during LBP removal operations to provide negative pressure relative to the outside and reduce dust emissions. However, even with well-designed airflow patterns, workers near the abrasive blasting will still have hazardous lead exposures.

General ventilation designs and techniques vary greatly from site to site. In an in-depth survey at one site, NIOSH researchers found worker lead exposures as high as 400 times the PEL despite relatively good ventilation.[16] Theoretically, ventilation techniques that provide fresh air directly to the worker and remove air near the lead generation source could significantly reduce lead concentrations in the breathing zone of workers. However, even well-designed ventilation systems are difficult to implement at construction sites because workers are continually moving around the structures. Research is needed to optimize ventilation parameters for containment structures.

#### *Substitutes for Silica Sand Abrasive*

Silica has traditionally been used as a material in the abrasive blasting process. However, because hazardous levels of airborne silica may accompany LBP removal projects, NIOSH recommends against the use of silica sand (or other substances containing > 1 percent free silica) as abrasive blasting material.[4] Due to the prevalence of silicosis among blasters, the United Kingdom passed a regulation in 1949, and since then, a number of other countries, including Germany, Sweden, and Belgium have either partially or fully banned the use of silica sand for abrasive blasting material.[17,18,19,20] Substituting less toxic abrasive materials for the traditional high-silica-containing abrasive is becoming more common in the United States. The United States Navy has banned silica sand or any abrasive materials containing greater than 1 percent crystalline silica by weight for abrasive blasting on ships.[21] However, even with a low-silica-content abrasive (< 1 percent free silica), work in containment structures or in confined spaces may result in hazardous silica and lead exposures.[22]

### Respiratory Protection for Work on Steel Structures

NIOSH recommends engineering controls as the primary means of protecting workers. However, even with engineering controls, airborne lead exposures may greatly exceed the PEL during abrasive blasting and other paint removal methods. In these cases, respiratory protection is also necessary. When respirators are used, the employer must establish a comprehensive respiratory protection program as required by the OSHA respiratory protection standard (29 CFR 1910.134) and the construction lead standard (29 CFR 1926.62).

NIOSH-approved Type CE respirators are required for use by abrasive blasting operators (29 CFR 1910.94). The Type CE respirator with continuous flow and a loose-fitting hood or helmet is commonly used to protect workers during abrasive blasting. Based on the results of a simulated workplace study in 1995, OSHA indicated that for enforcement of the construction lead standard, certain Type CE respirators (Bullard Model 77 and Model 88) would be regarded as having an assigned protection factor (APF) of 1000 (protective for exposures up to 1000 times the PEL), provided that they were properly used.[23] In general, for lead exposures during abrasive blasting more than 25 times the PEL, NIOSH recommends the use of a positive-pressure, supplied-air Type CE respirator with a full (tight-fitting) facepiece, which has an APF of 2000. However, some contractors have reported that these more protective Type CE respirators are not feasible for outdoor work on steel structures because of inadequate peripheral vision and user comfort. To address these issues, manufacturers should design and seek NIOSH approval for improved respirators for outdoor abrasive blasting.

**Table 4.1 Lead Exposures during LBP Removal on Steel Structures, NIOSH Sites**

| Control type | Description of site and control | Method | No. of samples | Lead exposure during task, µg/m³ geometric mean (Range) | Comments |
|---|---|---|---|---|---|
| Substitution/ Engineering | Chemical removal with caustic paste followed either by (A) water rinsing and abrasive blasting or (B) abrasive blasting only. | Chemical removal<br>A. Rinsing<br>A. Blasting<br>B. Blasting | 8<br>1<br>2<br>2 | 10 (< 1–40)<br>18<br>3100 (2000–4700)<br>5100 (5000–5300) | With prior chemical removal of LBP (method A) abrasive blasting time was reduced by one-half.[9] |
| Substitution/ Engineering | Wet abrasive blasting with water/black beauty slurry (demonstration site). | Wet blasting<br>Blast area | 1<br>4 | 1600<br>2000 (1500–2900) | Lead exposures may be marginally reduced by adding water to the abrasive.[10] |
| Substitution/ Engineering | Power tool cleaning with wire brush and needle gun. | Power tool without local exhaust | 3 | 1000 (87–5000) | Airborne lead concentrations are hazardous and production rates are slow.[11] |
| Engineering | Isolation of workers by use of automated blasting equipment | Automated Blasting | 2 | 4 (2–5) | Worker exposures will be a function of the enclosure effectiveness.[14] |
| Engineering | Vacuum blasting with local exhaust ventilation at the blast surface. | Vacuum blasting | 4 | 60 (30–80) | There was a significant reduction in airborne lead, but also a low production rate.[15] |
| Engineering | Abrasive blasting inside large and small enclosures with general dilution ventilation. | Blasting, large encl.<br>Blasting, small encl.<br>Support | 4<br>8<br>10 | 6200 (2700–24000)<br>5600 (620–58000)<br>74 (4–2500) | Airborne lead hazards are still a significant health risk even with ventilation controls.[16, 24,25] |
| None | Abrasive blasting inside loosely fitting screen tarpaulins with natural ventilation. | Blasting<br>In blast respirator<br>Support | 21<br>17<br>23 | 5600 (340–29000)<br>46 (6–190)<br>60 (5–9100) | Lead exposures during abrasive blasting may be higher in steal structure maintenance than in any other industry.[8,26,27,28] |
| **OSHA PEL** | | | | **50** | |

## CONTROLS FOR RESIDENTIAL LEAD ABATEMENT AND RENOVATION ACTIVITIES

Lead-based paint (LBP) is widespread in U.S. housing. HUD has estimated that 74 percent of privately-owned homes built before 1980 (57 million units) have LBP, as defined by HUD ( 1 milligram per square cubic meter [$mg/cm^2$] lead). Nearly 4 million of those units house young children and have peeling paint or excessive lead-containing dust.[29] A recent national survey estimated that 4.4 percent of U.S. children aged 1–5 years, or about 930,000 children, have elevated BLLs 10 µg/dL, the CDC action level for childhood lead exposure.[30]

In 1993, OSHA estimated that each year more than 45,000 abatement workers are exposed to lead during lead abatement and in-place management projects in public and private housing.[31] As national efforts to reduce residential lead hazards progress, the number of workers exposed to lead during abatements and other lead hazard reduction activities may increase. OSHA also estimated that approximately 180,000 workers annually are exposed to lead during residential remodeling and renovation.[31]

### Occupational Exposure Assessment

NIOSH studies have found that similar work tasks and health risks occur in residential lead abatement and renovation work.[32,33] The extensive literature review conducted by OSHA in support of the Interim Final Rule for Lead in Construction (29 CFR 1926.62) also found similar worker lead exposures for residential lead abatement, renovation, and remodeling activities.[34]

Lead exposures vary significantly during residential lead abatement and renovation work. A NIOSH study of the 1990 HUD lead abatement demonstration project found that exposures were highly variable for individual abatement methods, contractors, and housing units.[32] Another NIOSH study of LBP abatement workers found that lead exposures even varied significantly among work crews and individual workers performing the same tasks who were employed by a single contractor.[35] NIOSH has found that worker lead exposures are generally low during both lead abatement and renovation work, but some tasks produce hazardous LBP exposures.

Because frequent exposure assessment with air monitoring is a burden to small contractors, many have expressed a desire for an action level for occupational exposure based on paint lead concentrations. OSHA has concluded that the relationship between paint lead concentrations and worker health risk (airborne lead exposures) is not reliable for construction work. NIOSH research is consistent with this conclusion. NIOSH studies of residential LBP abatement workers found a poor correlation between paint lead concentrations and worker exposures.[32,35] NIOSH analyzed 2635 airborne lead measurements and 5774 paint lead measurements made in houses undergoing abatement during the HUD lead abatement demonstration project.* NIOSH found only a very weak correlation (Pearson r = 0.22) between paint lead and airborne lead for 140 houses (see Figure 4.1). Three of the eight houses with an average airborne lead concentration greater than the OSHA action level (30 µg/$m^3$) had a paint lead concentration below the HUD action level (1 mg/$cm^2$).

The following is a method-by-method discussion of engineering, work practice, and administrative controls used during residential LBP activities. Lead exposure data available for this work from NIOSH studies and other sources are presented in Table 4.2.

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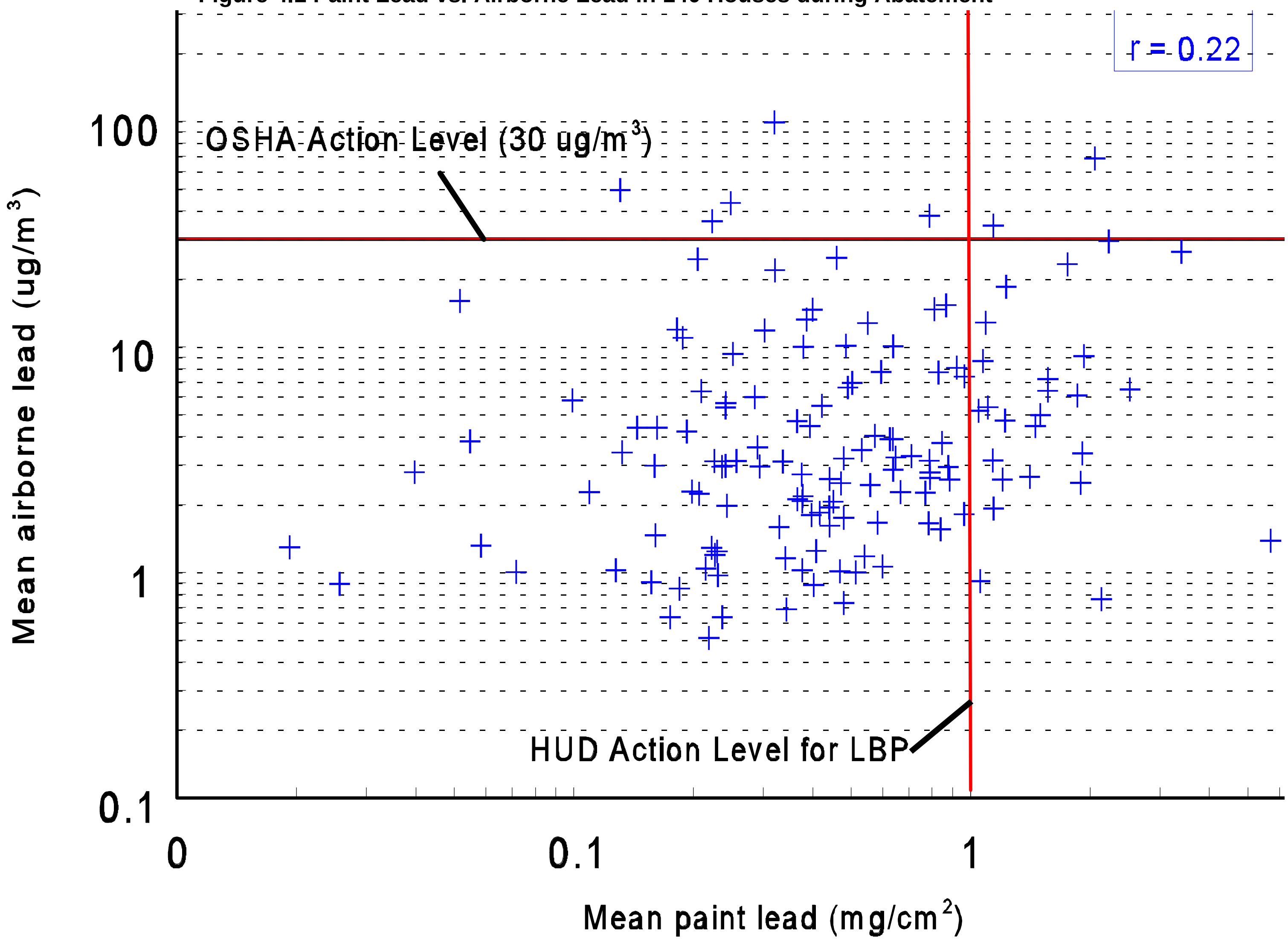
*These paint lead measurements were made using atomic absorption spectrometry (AAS) to confirm portable x–ray fluorescence (XRF) readings in the range of 0.2 to 1.8 mg/$cm^2$. Portable XRF data, which were less accurate, were excluded for this analysis.

**Figure 4.1 Paint Lead vs. Airborne Lead in 140 Houses during Abatement**



## Table 4.2 Lead Exposures during Residential LBP Activities*

| Control type(s) | Description of site and control | Method | No. samples | Lead exposure during task, µg/m3 Geometric mean (Range)[¶] | Comments |
|---|---|---|---|---|---|
| Administrative<br>Engineering | LBP removal with vacuum power tools, including needleguns and sanders. | Abrasive removal | 28 | 8.8 (< 0.4 – 399) | All workers received hazard training about lead hazards and safe work practices. |
| Substitution/<br>Engineering | Surface preparation with (A) wet scraping, HEPA vacuuming, and mopping; (B) the same method with dilution ventilation; and (C) wet scraping. | Wet method A<br>Wet method B<br>Wet method C | 6<br>6<br>7 | 24 (7.1 – 49)<br>73 (6.8 – 235)<br>8.1 (0.7 – 63) | All workers received hazard training about lead hazards and safe work practices. |
| Administrative<br>Engineering | LBP abatement in single-family homes with and without dilution ventilation provided (DV). | Heat gun<br>Heat gun–DV[†]<br>Replacement<br>Replacement–DV[‡] | 17<br>14<br>18<br>15 | 22 (0.9 – 105)<br>12 (1.9 – 48)<br>8.1 (0.7 – 67)<br>5.0 (1.3 – 23) | Values reported are means by house. Dilution ventilation was provided with HEPA-filtered exhaust fans. All workers received hazard training about lead hazards and safe work practices. |
| Administrative<br>Engineering | LBP abatement in single-family homes with prohibition of high-risk methods. | Enclosure<br>Encapsulation<br>Replacement<br>Cleaning<br>Final cleaning<br>Heat gun<br>Chemical removal<br>ALL METHODS | 50<br>83<br>110<br>138<br>56<br>360<br>291<br>1402 | 1.7 (< 0.4 – 72)<br>1.4 (< 0.4 – 26)<br>2.5 (< 0.4 – 121)<br>1.9 (< 0.4 – 588)<br>2.1 (0.9 – 36)<br>6.4 (< 0.4 – 916)<br>3.3 (0.4 – 476)<br>3.1 (< 0.4 – 916) | All workers received hazard training about lead hazards and safe work practices. |
| None | Surface preparation for home painting requiring removal of only loose and peeling LBP. | Exterior dry scraping | 15 | 28 (0.2 – 120) | |
| None | LBP removal with dry scraping and conventional power sanding. | Dry scraping<br>Power sanding | 4 | 5800 (2,300–11,800) | Mostly painted surfaces with 10 $mg/cm^2$ lead. |
| **OSHA PEL** | | | | **50** | |

*Sources: Selected NIOSH Health Hazard Evaluation reports, HUD Lead Abatement Demonstration Projects, Massachusetts DOH data.
[¶] Ranges are for individual task-based samples unless noted.
†Significant difference between mean air lead exposures with and without DV ($p < 0.05$).
[‡]No significant difference between mean air lead exposures with and without DV ($p > 0.05$).

## Alternate Abatement Processes

Selecting alternate, safer methods is one of the most effective ways to minimize worker exposures during residential lead abatement and renovation activities. Torch burning and power tools (sanders) with no LEV are common LBP removal techniques during home renovation, even though they have been found to produce worker lead exposures more than 200 times the OSHA PEL.[36] In the HUD national LBP abatement demonstration project, these methods were expressly prohibited, and the maximum lead exposures were reduced by more than 90 percent.[32] HUD subsequently prohibited these and other high-risk methods for LBP abatement in federally supported projects.

Of the LBP abatement methods demonstrated by HUD, paint removal with heat guns and abrasive power tools was associated with the highest worker exposures. Maximum worker lead exposures during the heat gun and abrasive methods were 18 and 8 times the OSHA PEL for lead, respectively, although administrative (heat gun nozzle air temperature restricted to 700  F) and engineering controls (power sanders and needleguns with LEV) were used.

NIOSH determined that worker lead exposures were generally low during enclosure, encapsulation, and replacement.[37] Over 95 percent of the worker exposures were less than the OSHA PEL during these methods of LBP abatement, and no exposure exceeded 2.5 times the PEL. HUD also found these methods to be the most promising abatement methods in terms of overall costs and efficacy.[38]

NIOSH recommends safer abatement methods, such as enclosure, encapsulation, and replacement, should be used where possible instead of LBP removal by torch burning, heat gun, or abrasive methods.

## Wet Methods

Hazardous worker lead exposures often occur in residential abatement and renovation projects during manual scraping of LBP. Abatement workers, painters, and home renovators often use dry scraping with metal scrapers to remove old paint or prepare weathered painted surfaces for repainting. Dry scraping of LBP has been found to result in worker exposures up to 70 times the OSHA PEL.[39]

During renovation or abatement work, painted surfaces may be wetted with a fine mist of water or water mixed with a surfactant before scraping to reduce generation of airborne paint dust. A NIOSH study of LBP cleaning activities in buildings with highly deteriorated LBP found that worker lead exposures were significantly reduced by using wet methods.[35] The wet methods (wet scraping and wet HEPA vacuuming) did not, however, totally eliminate hazardous LBP exposures. Workers had average short-term lead exposures ranging from 7.1 to 235 $\mu g/m^3$. In a study of single-family home repair and weatherization, NIOSH measured lead exposures during exterior manual scraping of loose and peeling paint. Worker lead exposures for dry scraping (range:  0.2 to 120 µg/m$^3$) were higher than those for wet scraping (range:  0.7 to 63 µg/m$^3$), but both techniques were potentially hazardous.[34]

While NIOSH and HUD recommend the use of wet methods to control dust during paint scraping, these techniques increase the potential for electrical hazards.  Wet methods should only be used with adequate safety controls including ground fault circuit interrupters, grounded and double-insulated tools, three-wire extension cords, nonconductive work shoes and gloves, and other appropriate electrical safety measures.

Chemical removal involves applying an organic solvent or caustic material and then scraping the dissolved LBP.  Wet caustic pastes are typically used for chemical removal during HUD projects.*  It is important that scraping be done while the materials are still wet.  The paste may be re-wetted with water mist just before manual scraping.  A NIOSH study of chemical removal during HUD projects found that while the median worker lead exposure for this method was very low (3 µg/m$^3$), the maximum exposure was nine times the OSHA PEL (476 µg/m$^3$).[32]  It is probable that the high exposures occurred because workers and contractors failed to keep the surfaces wet.

When it is necessary to scrape LBP, wet scraping is preferable to dry scraping to reduce hazardous LBP exposures.  However, wet methods will not eliminate hazardous occupational lead exposures and they should only be used with adequate electrical safety controls.

## Vacuum Power Tools

Vacuum power tools, including needleguns, sanders, and other power tools used with LEV, reduce worker exposures during residential LBP removal or surface preparation.  Vacuum power tools must be used with a portable vacuum cleaner to create the exhaust.  To prevent environmental contamination, the vacuum must contain a HEPA filter to collect the lead dust (the used filter may be a hazardous waste).

A NIOSH study of HUD work in single-family homes found that abrasive LBP removal with vacuum belt sanders and needleguns resulted in relatively low average worker exposures (8.8 µg/m$^3$), although the maximum exposures were hazardous, up to eight times the PEL.[32] Similar results were obtained during another HUD demonstration project where needleguns with LEV were used for LBP removal in public housing units.[40]  In contrast, OSHA has determined that the use of conventional power tools in housing abatement projects would result in *average* lead exposures approximately six times the OSHA PEL.[34]  NIOSH documented exposure at 24 times the OSHA PEL for a worker removing paint with a conventional power grinder.[41]

Disadvantages of vacuum power tools include the following:  (1) higher initial cost of equipment, (2) ergonomic factors (increased equipment weight and possibly vibration), and

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*HUD recommends against the use of paint strippers containing methylene chloride, which is a potential human carcinogen.

(3) dependence on proper use and maintenance by the operator. HUD reported that high lead concentrations during needlegun use in a demonstration project may have occurred because workers modified the protective shrouds on the needleguns (presumably to increase productivity).[40]

When it is necessary to use abrasive power tools to remove LBP, vacuum power tools should be used instead of conventional tools to reduce lead exposures and emissions of lead dust.

## General Dilution Ventilation and Containment Structures

Containment of work areas is often required during residential LBP abatement or renovation projects to isolate the work areas and control emissions of airborne lead to the surroundings. Interior residential work areas are usually contained by sealing all openings to the outside (doors and windows) with heavy-gauge (6-mil) clear plastic sheeting. Exterior residential areas are contained with plastic sheeting on the ground or by temporary structures made of plastic sheeting on a frame. Containment areas may be ventilated with HEPA-filtered exhaust fans (commonly known as "negative air" machines), which filter air from the work area and move it to the outside. The purpose of this ventilation is to maintain a negative air pressure inside the containment area with respect to the outside and provide general dilution ventilation to the work area.

In some cases, general dilution ventilation reduces worker exposures during abatement, but NIOSH studies have shown that this is not always true. In a study of lead abatement workers performing cleaning activities, NIOSH investigators found portable HEPA-filtered exhaust fans providing an estimated 37 air changes per hour to work areas actually increased worker lead exposures.[35] The fans generated additional lead dust in the rooms, either by air turbulence, or because they had to be moved frequently during cleaning (the rooms were relatively small). Similarly, a Massachusetts study of residential LBP removal by dry scraping found very high personal exposures, 9 to 70 times the OSHA PEL, inside a contained area that was ventilated with a HEPA-filtered exhaust fan.[11] A NIOSH evaluation of HUD lead abatement work found that HEPA-filtered exhaust fans significantly reduced average lead exposures during the heat gun method ($p < 0.05$), but had no effect on exposures during the replacement method.[32]

Although it may not be effective in reducing lead exposures, dilution ventilation may be needed to prevent accumulation of hazardous gases or vapors. Contractors sometimes use portable heaters during abatement projects because all of the utilities are turned off, but they should never be used without adequate ventilation with outside air. NIOSH found that use of portable gas-fired heaters inside contained work areas without ventilation, even for short periods, resulted in elevated concentrations of carbon monoxide and carbon dioxide.[32]

## Administrative Controls

During LBP abatement projects, administrative controls are typically employed to reduce occupational lead exposures. Administrative controls include prohibition of methods which have high lead exposure potential (torch burning, dry scraping, and conventional power tools), contractual requirements for competent persons (knowledgeable about lead hazards and controls) on each job site, and preemployment hazard training for all workers and supervisors. During the HUD lead abatement demonstration, these administrative controls were employed and lead exposures were generally low—95 percent were less than the OSHA PEL. On the other hand, worker exposures were highly variable, and personal lead exposures exceeding the OSHA PEL were measured for eight of 11 NIOSH-assigned lead abatement method categories.[32] The potentially hazardous methods were abrasive removal, chemical removal, heat gun removal, cleaning, enclosure, replacement, setup, and "other" methods. The highest exposures were generally for task-based samples of short (one to several hours) duration, rather than full-shift (8–hour) samples. The risk of these high-exposure tasks would depend on the frequency with which they were used.

Respiratory protection can be thought of as a type of administrative control. The effectiveness of respirators depends on proper selection, worker training, and usage. Respirators will be needed when other controls cannot protect workers. Respirator selection for each job category at a worksite should be determined by a certified industrial hygienist or other competent person.

Regardless of the magnitude of airborne lead exposures, good hygiene practices are needed during LBP abatement and renovation projects when surfaces become contaminated with paint chips or dust. Handwashing before eating, drinking, smoking, chewing tobacco, or applying cosmetics is especially important to prevent ingestion of lead. Lead contamination of workers' hands is substantially reduced by handwashing at the work site with soap, running water, and disposable paper towels.[35] Take-home exposures can be prevented by proper use, laundering, and disposal of protective work clothing, including disposable shoe covers.

# SUMMARY OF RECOMMENDATIONS

## Steel Structures Maintenance

General recommendations for reducing hazardous worker lead exposures during LBP removal on steel structures include the following:

- Use safer surface preparation alternatives, including overcoating, chemical stripping, wet blasting, and power tools with LEV instead of traditional abrasive blasting.

- Provide engineering controls to the extent feasible, including isolation, local exhaust and general dilution ventilation.

- Use respirators with an assigned protection factor of at least 1000 during abrasive blasting of LBP inside containment structures.

Research and education are needed to improve worker protection during maintenance and repainting of steel structures coated with LBP. This should include the use of improved engineering controls and highly protective respirators for abrasive blasting. Key research and development needs related to improving worker protection in the steel structures painting industry include the following:

- Develop automated systems for LBP removal.

- Establish specifications for local exhaust ventilation on vacuum power tools.

- Establish dilution ventilation specifications for containment structures.

- Develop chemical removal methods which do not require abrasive blasting for final surface preparation.

- Develop surface tolerant coatings that reduce the need for removal of existing LBP.

## Residential Lead Abatement and Renovation Activities

General recommendations to reduce hazardous worker lead exposures during lead abatement and residential renovation include the following:

- Use enclosure, encapsulation, and replacement methods instead of on-site paint removal methods where possible.

- Do not remove paint by torch burning, dry manual scraping, and conventional power tools; instead use vacuum power tools and wet scraping.

- Use general dilution ventilation to provide adequate outside air when working in sealed or contained work areas.

- Employ good hygiene practices and administrative controls, including worker and supervisor training.

Further research is needed to improve assessment of lead exposures during residential renovation and abatement activities. This research should include characterization of the building and workplace environments, airborne lead exposures during common tasks and jobs, pre- and post-job surface lead dust levels, paint lead measurements, documentation of task duration and square feet affected, and worker BLLs.

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# CHAPTER 5

## METHODS TO SAMPLE AND ANALYZE ENVIRONMENTAL LEAD

### INTRODUCTION

Numerous studies conducted by NIOSH and others have found that workplace air and surface dust are the primary sources of occupational lead exposures. Paint and soil are environmental lead sources in residential and commercial environments. These environmental lead sources may become occupational lead hazards when work activities generate airborne dust from lead-contaminated paint, soil, or surface dust.

In order to control worker lead exposures during LBP activities, it is necessary to be able to accurately measure environmental lead. This chapter discusses laboratory-based sampling and analytical methods, on-site lead screening methods, and evaluation of laboratories and field testing methods.

NIOSH bases its recommendations on NIOSH and EPA protocols, and consensus standards developed by the American Society for Testing and Materials (ASTM). All of the sample preparation and analytical methods recommended here meet the performance criteria specified by NIOSH and EPA.[1 – 7]

The environmental action level for the health risk of interest should be considered when selecting a method, to ensure accuracy and quality of analytical results. The detection limit for the method selected should be at least an order of magnitude below the action level of concern. The range of measured concentrations should extend at least to twice the action level.

### SAMPLE COLLECTION

Samples collected must be representative of the environmental matrix (e.g., workplace air, paint, soil, and surface dust). Samples should be collected, using consistent techniques, to assure comparability of samples among sites and among different areas at a site. Recommended methods for sample collection are listed in Table 5.1.

#### Lead in Airborne Particulate

Sampling methods for measuring worker exposure use a two-piece filter holder cassette with a 0.8-micrometer (µm) cellulose ester membrane filter. Personal air samples are collected in the worker's personal breathing zone, usually for the duration of the full-work shift. However, shorter periods may be important to assess exposures by task (task-based exposure assessment), or to prevent overloading of sample filters in very dusty environments (e.g., during abrasive blasting).

NIOSH investigators have found that personal air sampling may be inaccurate during abrasive blasting in confined areas on steel structures.[8,9] A large percentage of the personal samples may be torn off the workers as they move about in confined areas.[10] These environments are usually extremely dusty, and large particles (> 100 µm diameter) of paint or abrasive grit rebounding directly from the substrates may enter sample filter cassettes, biasing the results. Locating the sample at the back of the worker's neck will reduce entry of grit rebound in all but the most confined areas.

## Lead in Surface Dust

Lead in workplace surface dust can be collected by wipe sampling and vacuum sampling techniques. Most of these methods were originally developed to measure lead poisoning risks to children in homes.[11] Wipe sampling, which determines surface lead loading (microgram [µg] lead per unit area), is the method currently preferred by HUD for determining surface lead concentrations as part of residential lead risk assessments.[12] Wipe sampling requires systematically wiping a measured surface area (or the area within a sampling template) with a pre-wetted wipe. Some widely available commercial hand wipes are suitable for this purpose. Wipes used should have low background lead contamination and be of constituents that can be readily processed in the laboratory.[13] Wipe sampling is also used for assessing dermal lead exposures, especially lead dust on hands.[14]

Vacuum sampling requires systematically vacuuming a measured area. A commonly used portable dust vacuum method is convenient because it uses the same equipment that is routinely used by industrial hygienists for personal air sampling.[15] This method is useful for sampling dust on soft surfaces, and it can determine both lead loading and lead concentration (ppm or percent by weight) in the dust when pre-weighed filters or filter cassettes are used.

**Table 5.1. Recommended Sample Collection, Preparation, and Analysis Methods for Lead in Paint, Surface Dust, Soil, and Workplace Air**

| Matrix | Collection | Preparation[@] | Analysis[#] (all matrices) |
|---|---|---|---|
| **Air** | NIOSH 7082, 7105,& 7300<br>ASTM E1553 | *Field:*<br>EPA Field SOP<br>*Lab:*<br>NIOSH 7082 &7105<br>ASTM E1741 | *Field:*<br>Portable ASV**<br>EPA Field SOP<br><br>*Lab:*<br>NIOSH 7082<br>NIOSH 7105<br>NIOSH 7300<br>EPA Lab SOP<br>EPA SW–846 6010A<br>EPA SW–846 7420<br>EPA SW–846 7421<br>ASTM E1613 |
| **Dust Wipe** | NIOSH 9100<br>ASTM E1728 | NIOSH 7082 & 7105<br>ASTM E1644<br>EPA SW–846 3050A | |
| **Dust Vacuum** | ASTM D5438<br>ASTM PS46 | NIOSH 7082 & 7105<br>ASTM E1644<br>EPA SW–846 3050A<br>EPA SW–846 3051<br>EPA Lab SOP[f] | |
| **Paint** | ASTM E1729 | *Field:*<br>EPA Field SOP<br>*Lab:*<br>NIOSH 7082 & 7105<br>ASTM E1645<br>EPA SW–846 3050A<br>EPA SW–846 3051 | |
| **Soil** | ASTM E1727 | NIOSH 7082 & 7105<br>ASTM E1726<br>EPA Lab SOP<br>EPA SW–846 3050A<br>EPA SW–846 3051 | |

**NOTES:**
NIOSH methods include protocols for sample collection, preparation, and analysis. The EPA and ASTM methods listed are specific for one of these three elements.

[@]Hotplate digestion: NIOSH 7082, NIOSH 7105, ASTM E1741, ASTM E 644, ASTM E1645, EPA SW–846 3050A, EPA Lab SOP. Microwave digestion: ASTM E1741, ASTM E1645, EPA Lab SOP, EPA SW–846 3051. Ultrasonic extraction: EPA Field SOP.

[#]Flame atomic absorption spectrophotometry: NIOSH 7082, ASTM E1613, EPA Lab SOP, EPA SW–846 7420. Graphite furnace atomic absorption spectrophotometry: NIOSH 7105, ASTM ES 35, EPA SW–846 7421. Inductively coupled plasma atomic emission spectrophotometry: NIOSH 7300, ASTM E 1613, EPA Lab SOP, EPA SW–846 6010A.

SOP = standard operating procedure.
ASV = anodic stripping voltammetry.

## Lead in Paint and Soil

A sensitive method is needed to assess worker exposures to lead in paint and soil. Hazardous occupational exposures have been found to occur even when average paint concentrations are well below the Title X definition of LBP (0.5%) or the Consumer Product Safety Commission (CPSC) definition of lead-containing paint (0.06%).[16,17] To measure these levels accurately the sample usually must be analyzed in a laboratory. The recommended method for paint sample collection is ASTM E1729, which requires removing all of the existing paint layers. Field screening methods for testing for lead in paint in-place (*in-situ)* are mentioned later in this chapter.

The recommended practice for collection of soil samples is ASTM E1727, which involves scooping or coring methods.

## Compositing Samples

Compositing of wipe, vacuum, paint, and soil samples has been suggested to reduce analytical costs. Compositing is generally not recommended by NIOSH for lead risk assessments because it results in a loss of information about environmental variability with relatively little reduction in total project cost. Additionally, compositing of wipe samples can cause serious problems in the sample preparation because the entire sample, including all of the wipes, must be digested.

## SAMPLE PREPARATION

The recommended sample preparation methods for lead in workplace air, dust, paint, and soil are listed in Table 5.1. Air samples (filters) can be prepared in the laboratory or in the field. Laboratory preparation is done by hotplate- or microwave-based digestion in strong acid, and field preparation is done by ultrasonic extraction in dilute acid. Paint samples are ground to a powder to maximize lead recoveries, then prepared like air samples. Surface dust (wipe) samples are prepared in the laboratory by hotplate digestion in strong acid. Soil samples are sieved to remove stones and other objects, then prepared in the laboratory by hotplate- or microwave-based digestion in strong acid.

## ANALYSIS

Recommended laboratory and field analytical methods for lead in workplace air, dust, paint, and soil are listed in Table 5.1. Analysis methods in the laboratory include graphite furnace atomic absorption spectrometry, flame atomic absorption spectrometry, and inductively coupled plasma atomic emission spectrometry. In contrast to these laboratory methods which use spectrometry, field methods for lead are based on colorimetric or electroanalytical techniques.[18,19,20] Higher airflow rates (2 to 4 liters per minute) and a highly sensitive method, such as graphite furnace atomic absorption spectrometry, should be used when performing short-term (< 30 minutes) air sampling.

## SCREENING METHODS

Screening and semi-quantitative methods are used to estimate the lead content of paints and other environmental matrices. Field screening techniques include portable x-ray fluorescence (XRF) and chemical spot test kits.

Portable XRF is the most commonly used method for screening for LBP in residences and is the method recommended by HUD and EPA. NIOSH does not recommend portable XRF instruments for occupational exposure assessment until they have been shown to meet established performance criteria for quantitative analyses.[21,22] A method for the determination of lead in workplace air samples using a portable XRF instrument (with cadmium 109 source) is under development.[23]

Some chemical spot test kits are able to detect very low lead levels in a variety of environmental matrices and, therefore, may prove to be useful for screening for potentially hazardous levels of lead in the workplace.[24] A rhodizonate-based chemical spot test kit has been evaluated for screening of lead in workplace air samples.[25] ASTM standard E1753 describes the use of qualitative chemical spot test kits for screening of lead in paint, and ASTM E1828 covers the evaluation of test kits for lead in paint.

## ADDITIONAL METHODS

Additional laboratory and field sample preparation and analytical methods for lead in a variety of sample matrices are under development or evaluation by federal agencies. ASTM is continuing to develop a series of standards dealing with lead hazard identification and mitigation.[26]

## RECOMMENDATIONS FOR PERFORMANCE EVALUATION

### Laboratory Testing for Lead

NIOSH recommends, and the HUD guidelines require, the use of laboratories recognized by EPA's National Lead Laboratory Accreditation Program (NLLAP) to ensure the consistency and quality of measurement results. The Environmental Lead Proficiency Analytical Testing program (ELPAT) is part of NLLAP and is administered by the American Industrial Hygiene Association (AIHA) in cooperation with NIOSH and the EPA. ELPAT performance criteria are similar to those of the well-established Proficiency Analytical Testing (PAT) program for workplace air samples administered by AIHA and NIOSH. On a quarterly basis, NIOSH evaluates the performance of approximately 400 laboratories located throughout the United States and Canada and publishes the results in the *American Industrial Hygiene Association Journal* and *Applied Occupational and Environmental Hygiene*. Over the past three years, the ELPAT laboratories have demonstrated good agreement in lead measurements among the recommended methods for sample preparation and analysis of lead in paint, dust, and soil samples.[27]

## Field–Based Testing for Lead

With the advent of new field-portable methods for environmental lead analysis, it is anticipated that more on-site lead determinations will be performed in the future. NIOSH recommends that ASTM E1775 be used for performance evaluation of on-site extraction and analytical methods. ASTM E1583 should be used to evaluate organizations involved in field-based assessments of lead hazards. A system similar to NLLAP is needed to evaluate the quality of analyses of lead in paint, dust, and soil done in-place (*in-situ*) with portable instruments (e.g., by portable x-ray fluorescence).

## RECOMMENDATIONS

Further research is needed to evaluate the utility of chemical spot test kits for assessing worker lead exposures and to develop a sampling method to reliably measure lead exposures in confined abrasive blasting environments.

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# CHAPTER 6

## LEAD EXPOSURES AMONG JANITORIAL AND CUSTODIAL WORKERS

### EVALUATION DESIGN

NIOSH evaluated occupational lead exposures during janitorial and custodial operations, including painting, carpentry, housekeeping, plastering, plumbing, and general maintenance at the University of Maryland at College Park.[1] Originally, NIOSH investigators planned to include several representative sites in the evaluation, but difficulty in recruiting employers or workers and cost constraints led to selection of one site. The selection was based upon the following factors: (1) willingness of management and employee unions to cooperate in all phases of planning and scheduling of the evaluation; (2) availability of a variety of custodial operations at one geographic location; and (3) presence of LBP in the buildings where custodial tasks were performed.

Sixteen university workers voluntarily participated in this study. Both full-shift and task-based personal air monitoring was conducted for the janitorial and custodial workers. Some of the tasks were of very short duration, in some cases less than 10 minutes. To partially compensate for this, longer duration exposure measurements were simultaneously collected. The workers voluntarily completed a questionnaire to collect work history and personal information that could be related to lead exposure. Workers were also asked to participate in BLL testing; 13 of the 16 workers who completed a questionnaire also agreed to have a BLL test.

### RESULTS

Table 6.1 summarizes the results of the airborne lead exposure assessment. The exposures were generally very low. Of 52 personal air samples collected, 44 percent (23) had no detectable lead. The highest exposures were during the power sanding (belt sander) of a painted wooden door (36 $\mu g/m^3$), melting lead in an open ladle for a plumbing repair (26 $\mu g/m^3$), removal of lead and oakum (a type of caulk) from a plumbing joint (13 $\mu g/m^3$), and folding up and removing the plastic sheeting used to contain dust during carpentry work (8 $\mu g/m^3$). Exposures were either "none detected" or "extremely low" for housekeepers performing tasks, such as emptying trash receptacles, sweeping floors, vacuuming carpets, and other typical housekeeping activities.

Lead was commonly present in the workplace evaluated. All of the paint samples collected from work surfaces had detectable amounts of lead (mean: 1.8%, range: 0.002 to 19%).

Consistent with the air sampling results, the BLLs were low among the janitorial and custodial workers tested (mean: 5.4, range: 2.8 to 10 µg/dL). These BLLs are typical for a U.S. urban adult population.  The study participants' average length of employment at the university was 8.5 years (range:  10 months to 18.5 years) and their average age was 40 years (range:  28 to 56 years).  The majority of the study participants had received (1) a preemployment physical and BLL test, (2) training about the hazards of lead, and (3) training in the proper use of a respirator. Nine of the 16 participants indicated that they occasionally wore a respirator while performing their job.

## CONCLUSIONS AND RECOMMENDATIONS

Based on the results from this study, it would be reasonable to assume that routine janitorial tasks (such as sweeping, vacuuming, emptying trash receptacles, cleaning fixtures, and other related activities) in buildings with LBP generally do not produce hazardous occupational exposures to lead.  Available surveillance data do not indicate that janitorial and custodial workers are at high risk for lead exposure.[2]

However, custodial tasks involving the handling or removal of lead-containing material, or custodial work associated with lead abatement projects could have a much greater potential for lead exposure.  For example, previous studies have found that workers performing cleaning activities during abatement and renovation projects may have hazardous LBP exposures (see Chapter 4).  In those situations, an initial lead exposure assessment for all job categories should be conducted by the employer.

**Table 6.1 Lead Exposures for Janitorial and Custodial Activities**

**WORKER AIRBORNE EXPOSURES:**

| **Task** | **No. Samples** | **Sample Times (min)** | **Mean (µg/m³)** | **Range (µg/m³)** | **Comments** |
|---|---|---|---|---|---|
| Housekeeping | 4 | 263–449 | 0.11 | *0.02** – 0.34 | Dry sweeping tiled floors, vacuuming carpets, wet mopping, emptying trash receptacles, dusting |
| Carpentry | 14 | 6–379 | 5.9 | *0.04* – 36 | Doors, windows, and floors |
| Painting | 7 | 9–76 | 0.2 | *0.1* – **0.5**† | Windows, exterior painted columns, and a radiator |
| Plastering | 6 | 11–63 | 0.3 | *0.2* – **0.6** | Removing and replacing of drywall and plaster |
| General maintenance | 5 | 18–449 | 0.9 | *0.04* – 3.7 | Replacing and repairing fixtures |
| Automotive body work | 3 | 23–91 | 1.2 | *0.2* – 2.5 | Repairing body damage on painted vehicle |

| **WORKER BLLs:** | **No. Workers** | **Mean (µg/dL)** | **Range (µg/dL)** | **Comments** |
|---|---|---|---|---|
| | 13 | 5.4 | 2.8 – 10 | Blood lead levels were within normal range |

| **SURFACE LEAD:** | **No. Samples** | **Mean (% Pb)** | **Range (% Pb)** | **Comments** |
|---|---|---|---|---|
| | 16 | 1.8 | 0.002 – 19 | Painted surfaces, floors, and carpets in work areas |

ALL SAMPLES COLLECTED AT THE UNIVERSITY OF MARYLAND

**Italics* = none detected, ½ the respective minimum detectable concentration (MDC) was reported for statistical purposes.

†**Bold** = trace amount above the respective MDC detected; the MDC was reported for statistical purposes.

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# Appendix A

## Directory of States with Adult BLL Registries*

| State | Contact person | Reporting level (µg/dL) |
|---|---|---|
| Alabama | J.P. Lofgren, M.D.<br>State Epidemiologist, Division of Epidemiology<br>Alabama Dept. of Public Health<br>201 Monroe St, Montgomery, AL 36130–31701<br>Voice: (334) 206–5971<br>Fax: (334) 206–5967 | 15 |
| Arizona | Lee A. Bland<br>Office of Environmental Health<br>Arizona Dept. of Health Services<br>3815 N. Black Canyon Highway, Phoenix, AZ 85015<br>Voice: (602) 230–5830<br>Fax: (602) 230–5933 | 10 |
| California | Barbara Materna, Ph.D., C.I.H.<br>Occupational Lead Poisoning Prevention Program<br>California Dept. of Health Services<br>2151 Berkeley Way * Annex 11, Berkeley, CA 94704<br>Voice: (510) 540–3481<br>Fax: (510) 540–3472 | 25 |
| Colorado | Jane McCammon<br>Colorado Dept. of Health<br>4300 Cherry Creek Dr S., Denver, CO 80222<br>Voice: (303) 692–2639<br>Fax: (303) 782–0904 | 25 (> 18 years)<br>10 (≤18 years) |
| Connecticut | Carolyn Jean Dupuy<br>Connecticut Dept. of Public Health<br>Environmental Epidemiology & Occupational Health (EEOH)<br>410 Capitol Avenue, MS 110SP, Hartford, CT 06106<br>Voice: (860) 509–7744<br>Fax: (860) 509–7785 | 10 |
| Florida | Raul Quimbo, M.S.<br>Florida Dept. of Health and Rehabilitative Services<br>1317 Winewood Blvd, Tallahassee, FL 32399–0700<br>Voice: (904) 488–3370<br>Fax: (904) 922–8437 | 10 |
| Georgia | Kathleen Toomey, M.D., M.P.H.<br>Director, Epidemiology and Prevention Branch<br>2 Peachtree Street, N.W., Suite 110–P<br>Atlanta, GA 30303<br>Voice: (404) 657–2588<br>Fax: (404) 657–2586 | 10 |
| Indiana | William C. Letson<br>Epidemiology Resource Center<br>Indiana State Dept. of Health<br>2 North Meridian Street, Indianapolis, IN 46204<br>Voice: (317) 233–7207<br>Fax: (317) 233–7770 | None |

**Appendix A continued**

| | | |
|---|---|---|
| Iowa | Rita Gergely, M.S.<br>State Lead Coordinator<br>Bureau of Environmental Health<br>Division of Health Protection<br>Iowa Dept of Public Health<br>321 East 12th Street, Des Moines, IA 50319–0075<br>Voice: (515) 281–8220<br>Fax: (515) 242–6284 | All levels |
| Kentucky | Tim Struttman<br>Occupational Injury Prevention Program Manager<br>Kentucky Injury Prevention and Research Center<br>333 Waller Avenue, Suite 202, Lexington, KY 40504–2915<br>Voice: (606) 257–4955<br>Fax: (606) 257–3909 | 25 |
| Maine | Allison Hawkes, M.D.<br>Occupational Health Program<br>Maine Bureau of Health<br>State House Station #11, Augusta, ME 04333–0011<br>Voice: (207) 287–5378<br>Fax: (207) 287–6855 | 25 |
| Maryland | Ezatollah Keyvan–Larijani, M.D.<br>Office of Environmental Health Coordination<br>Maryland Dept. of the Environment<br>2500 Broening Hwy, Baltimore, MD 21224<br>Voice: (410) 631–3987<br>Fax: (410) 631–4112 | 25 ($\geq$18 years) |
| Massachusetts | Richard Rabin, M.S.P.H.<br>Massachusetts Dept. of Labor & Industries<br>Division of Occupational Hygiene<br>1001 Watertown St, Newton, MA 02165<br>Voice: (617) 969–7177<br>Fax: (617) 727–4581 | 15 |
| Michigan | Carol Hinkle<br>Childhood Lead Poisoning Prevention Project<br>Michigan Dept. of Community Health<br>3423 N. Logan/Martin Luther King Blvd.<br>Box # 30195, Lansing, MI 48909<br>Voice: (517) 335–9242<br>Fax: (517) 335–8509 | All levels |
| Minnesota | Myron Ralken, Ph.D.<br>Minnesota Dept. of Health<br>121 East 7th Place, P.O. Box 64975<br>Minneapolis, MN 55164<br>Voice: (612) 215–0877<br>Fax: (612) 215–0975 | All levels |
| Mississippi | Linda Pollock, M.D., M.P.H.<br>Office of Epidemiology<br>Mississippi Dept. of Health<br>Box # 1700, Jackson, MS 39215–1700<br>Voice: (601) 960–7725<br>Fax: (601) 960–7909 | 15 (< 6 years)<br>25 (> 6 years) |

**Appendix A continued**

| | | |
|---|---|---|
| Missouri | Carol Braun<br>Lead Poisoning Program, Missouri Dept. Of Health<br>930 Wildwood, Box 570, Jefferson City, MO 65102–0570<br>Voice: (573) 526–5872<br>Fax: (573) 526–6946 | 25 |
| Nebraska | Thomas J. Safranek, M.D.<br>State Epidemiologist<br>Dept. of Health & Human Services<br>Box 95007, Lincoln, NE 68509–5007<br>Voice: (402) 471–2133<br>Fax: (402) 471–0383 | 10 |
| New Hampshire | Brook Dupee<br>Dept. of Health and Human Services<br>Public Health Services<br>Bureau of Risk Assessment<br>6 Hazen Drive, Concord, NH 03301–6527<br>Voice: (603) 271–7093<br>Fax: (603) 271–3991 | All levels |
| New Jersey | Barbara Gerwel, M.D., Project Coordinator<br>Occupational Disease Prevention Program<br>New Jersey Dept. of Health<br>C N 360, John Fitch Plaza, Trenton, NJ 08625<br>Voice: (609) 984–1863<br>Fax: (609) 292–5667 | 25 |
| New Mexico | Retta Phrophet<br>Lead Program Manager<br>Division of Epidemiology, Evaluation & Planning<br>New Mexico Dept. of Health<br>1435 St. Francis Dr, Santa Fe, NM 87505<br>Voice: (505) 827–3709<br>Fax: (505) 827–3714 | All levels |
| New York | Elizabeth Marshall, Ph.D.<br>New York State Dept. of Health<br>2 University Pl , Albany, NY 12203–3313<br>Voice: (518) 458–6433<br>Fax: (518) 458–6436 | All levels |
| North Carolina | Susan A. Randolph, M.S.N., R.N., C.O.H.N.<br>Dept. of Environmental Health & Natural Resources<br>Occupational Health Section/Epidemiology Division<br>P.O. Box 29601, Raleigh, NC 27626–6601<br>Voice: (919) 715–3591<br>Fax: (919) 733–9555 | 40 |
| Ohio | Adeline Migliozzi, R.N.<br>Ohio State Dept. of Health<br>246 North High Street, Columbus, OH 43266<br>Voice: (614) 466–4183<br>Fax: (614) 644–7740 | All levels |
| Oklahoma | Edd Rhoades, M.D., M.P.H.<br>Oklahoma State Dept. of Health<br>Maternal and Child Health<br>1000 N.E. 10th St, Oklahoma City, OK 73117–1299<br>Voice: (405) 271–6617<br>Fax: (405) 271–4892 | 10 |

**Appendix A continued**

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| Oregon | Katerina Hedberg, M.D., M.P.H.<br>Oregon Health Division<br>800 N.E. Oregon St., Suite 730, Portland, OR 97232<br>Voice: (503) 731–4024<br>Fax: (503) 731–4082 | 25 (> 18 years)<br>10 (< 18 years) |
| Pennsylvania | James N. Logue, Dr.P.H. ,M.P.H.<br>Div. Environmental Health Assessment<br>Pennsylvania Dept. of Health<br>Box 90, Harrisburg, PA 17108<br>Voice: (717) 787–1708<br>Fax: (717) 783–3794 | ≥15 (6 years & under)<br>≥25 (6 years & over)<br>+ pregnant females |
| Rhode Island | Marie Stoeckel, M.P.H., C.I.H.<br>Rhode Island Dept. Of Health<br>Office of Occupational and Radiological Health<br>3 Capitol Hill, Room 206, Providence RI 02908<br>Voice: (401) 277–2438<br>Fax: (401) 277–2456 | 25 |
| South Carolina | Annette Gardiner-Hillian<br>Division of Health Hazard Evaluations<br>Dept. of Health & Environmental Control<br>2600 Bull St, Columbia, SC 29201<br>Voice: (803) 737–4173<br>Fax: (803) 737–4171 | 40 (> 6 years)<br>10 (≤6 years) |
| Texas | Diana Salzman, M.P.H.<br>Bureau of Epidemiology<br>Texas Dept. of Health<br>1100 W. 49th St, Austin, TX 78756<br>Voice: (512) 458–7269<br>Fax: (512) 458–7699 | 40 |
| Utah | Wayne Ball, Ph.D.<br>Bureau of Epidemiology<br>Utah Dept. of Health<br>Box 142870,<br>288 N. 1460 West, Salt Lake City, UT 84114–2870<br>Voice: (801) 538–6191<br>Fax: (801) 538–9923 | 15 |
| Vermont | Laurie Toof<br>Division of Epidemiology and Health Promotion<br>Vermont Dept. of Health, Box 70<br>108 Cherry St., Room 201, Burlington, VT 05402<br>Voice: (802) 865–7786<br>Fax: (802) 863–7483 | 10 (> 6 years)<br>All levels (≤6 years) |
| Washington | Joel Kaufman, M.D., M.P.H.<br>Safety & Health Assessment & Research Program<br>Box 44330,<br>Washington State Dept. of Labor & Industries<br>Olympia – Thurston County, WA 98504–4330<br>Voice: (360) 902–5669<br>Fax: (360) 902–5672 | All levels |

**Appendix A continued**

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| Wisconsin | Henry Anderson, M.D.<br>State Occupational & Environmental Epidemiologist<br>Division of Health, Bureau of Public Health<br>1414 E. Washington St., Madison, WI 57303<br>Voice: (608) 266–1253<br>Fax: (608) 267–4853 | ≥10 |
| Wyoming | Todd Kietz, B.S., R.E.H.S.<br>Wyoming Department of Health<br>487 Hathaway, Cheyenne, WY 82002<br>Voice: (307) 777–6951<br>Fax: (307) 777–5402 | All levels |

***The States listed above require reporting of adult elevated blood lead levels.** State-specific questions regarding these reporting requirements should be directed to the State agency and contact person in each State.

The federal source for information on the reporting of child blood lead levels is:

**LEAD POISONING PREVENTION BRANCH**
Division of Environmental Hazards and Health Effects
Centers for Disease Control and Prevention
4770 Buford Highway N.E.
Atlanta, GA 30341
Voice: (404) 488–7330
Fax: (404) 488–7335

# Appendix B

## Summary of Health and Safety Contract Specifications, State of Connecticut

- MEDICAL

Contractors awarded bridge maintenance jobs are required to participate in the Connecticut Road Industry Surveillance Project (CRISP), a NIOSH-funded project directed at preventing lead poisoning among construction workers. Each worker must be offered a physical examination and initial BLL test upon entry into the program. The worker's lead exposure is monitored thereafter by measuring the BLL monthly for 4 months; and periodically after that. If the BLL exceeds a threshold (in 1994, 35 µg/dL), brief exams are conducted monthly and at exit from the program. Medical removal protection is specified at BLL thresholds that decrease annually (in 1994 the threshold was 35 µg/dL).

- INDUSTRIAL HYGIENE

The industrial hygiene protocol incorporated into the Connecticut Department of Transportation contract specifications is comprehensive and detailed. A certified industrial hygienist (CIH) is responsible for the implementation of the industrial hygiene portions of the specification and must certify compliance with the contract requirements on a monthly basis. The detailed requirements of the specification are modeled on the OSHA lead standards, but are modified by experience in the State of Connecticut. The industrial hygiene specification includes requirements for the following:

- Air monitoring
- Wipe sampling of workers and key work site areas
- Provision of protective clothing and equipment
- Provision and maintenance of personal hygiene equipment
- CRISP medical monitoring
- Industrial hygiene intervention by the responsible CIH
- Industrial hygiene intervention by the CRISP CIH
- Medical removal requirements that move downward with time
- Reporting of generated data

- SURVEILLANCE/INTERVENTION:

If the BLL of any worker on site exceeds 25 µg/dL, a CRISP CIH visits the site and evaluates the factors that might have contributed to the problem. The site visit includes a walk–through inspection and results in verbal and written recommendations for appropriate worksite or health and safety program changes. If the walk–through does not reveal the causes for the elevated BLLs, the industrial hygienist will either arrange for environmental sampling, or if relevant, conduct a review of employee training and work practices.