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I. SUMMARY

A request was received from the Kentucky Cabinet for Health Resources for a National Institute for Occupational Safety and Health (NIOSH) Health Hazard Evaluation (HHE) to evaluate occupational safety and health hazards during repainting of the Brent Spence Bridge, a double-level highway bridge over the Ohio River in Covington, Kentucky. The request concerned exposures of construction workers to lead during abrasive blasting removal of lead-based paint from the bridge within containment structures. Recently, containment of abrasive blasting has been used to reduce fugitive lead emissions, but resulting worker lead exposures may have increased. At this worksite a crew, typically 10 employees, performed abrasive blasting and painting inside containment, and support functions outside containment. Workers exposed to lead were not protected by regulatory or contractual requirements for medical monitoring.

Six NIOSH site visits were made in association with this HHE during seasonal work on the bridge; in November 1990 and in March, April, June, and July 1991. NIOSH investigators measured workers' exposure to lead in air and surface dust, noise, and carbon monoxide. Medical monitoring of exposed workers was conducted during the four site visits in 1991.

Ranges for personal exposures to airborne lead were 3,690 to 29,400 micrograms per cubic meter (µg/m^3) for abrasive blasters and 5 to 6720 µg/m^3 for other job categories. All eight actual or extrapolated 8-hour (8-hr) time-weighted average (TWA) personal lead exposures for blasters, and two of fourteen 8-hr TWA exposures for other job categories exceeded the Occupational Safety and Health Administration (OSHA) general industry Permissible Exposure Limit (PEL) for lead of 50 µg/m^3. Respirators provided to, and used by, workers were not sufficiently protective. For example, two of six 8-hr TWA lead exposures measured inside type CE respirators exceeded 50 µg/m^3. All surfaces sampled outside the containment structure were contaminated with dust containing lead.

Personal exposures to noise, expressed as 8-hour TWAs, ranged from 89.6 A-weighted decibels (dBA) to 105.4 dBA. All seven workers, and six of seven, workers surveyed had 8-hr TWA noise exposures exceeding the NIOSH recommended exposure limit (REL)-TWA of 85 dBA, and the OSHA permissible exposure limit (PEL)-TWA of 90 dBA, respectively. All workers were provided, and used, hearing protection devices (earplugs); but were not protected by a comprehensive hearing conservation program. Personal exposures to carbon monoxide measured during abrasive blasting operations (and non-peak vehicular traffic hours) were less than 8 parts per million (ppm), the limit of detection.

The mean blood lead level (BLL) increased from 29 micrograms per deciliter (µg/dl) to 36 µg/dl among eight workers (with paired results) after approximately one month of work on the bridge. Over the four site visits (four months) no significant trend was apparent in worker BLLs. However the blasting work was not continuous during this period and only two of 17 workers had test results for all four visits. Overall, no correlation was found between airborne lead exposures and BLLs collected on the same day. However, a significant positive correlation between inside-respirator airborne lead exposures and subsequent BLLs was found among abrasive blasters (r^2=0.876).

Environmental and medical monitoring indicated that a health hazard existed during paint removal by abrasive blasting on a highway bridge due to worker overexposes to lead and noise. The respiratory protection program, and personal hygiene facilities were not adequate to prevent worker overexposure to lead. Recommendations for improved engineering controls, work practices, respiratory protection program, and personal hygiene facilities are presented in this report.

KEYWORDS: SIC 1622 (bridge, tunnel, and elevated-highway construction), lead, abrasive blasting, construction, bridge workers, type CE respirators.

II. INTRODUCTION

On October 4, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Kentucky Cabinet for Health Resources for a NIOSH Health Hazard Evaluation (HHE) to evaluate occupational health hazards during repainting of the Brent Spence Bridge, a double-level highway bridge over the Ohio river between Covington, Kentucky and Cincinnati, Ohio. Due to the recent introduction of partial containment around abrasive blasting work areas, health officials were concerned about high airborne lead concentrations at the work site. A number of cases of clinical lead poisoning had occurred at similar sites in other states.[1] Additionally, workers were not protected by regulatory or contractual requirements for medical monitoring of workers exposed to lead. To evaluate worker exposures to lead NIOSH investigators conducted site visits on November 1, 1990, and March 20, April 23, June 6, June 12, and July 7, 1991. Interim reports, dated May 16 and August 13, 1991, with preliminary observations and recommendations were provided to Kentucky and Ohio officials, and the bridge painting contractor, M & J Painting Company.

III. BACKGROUND

M & J Painting Company received contracts from the State of Kentucky Department of Transportation (KDOT) and the Ohio Department of Transportation (ODOT) to re-paint the Brent Spence Bridge, which conducts interstate highway traffic (I-71 and I-75 combined) over the Ohio River between Covington, Kentucky and Cincinnati, Ohio. The steel through-truss bridge was constructed in 1960, and painted with two coats each of an alkyd lead-based primer (red lead) and alkyd paint of unknown composition. The contractor estimated that the surface areas to be repainted, including the bridge superstructure and highway deck support beams, were approximately 1.3 million and 110,000 square feet (ft^2), in Kentucky and Ohio, respectively. When the contractor began work in April 1990, the original paint on the bridge had deteriorated to the point that spotty surface corrosion had appeared over much of the surface areas. Blasting and painting work at the site was restricted to spring, summer and fall; as repainting was dependent on certain specified ambient temperature and humidity conditions.

The painting contractor was responsible for removal of the existing lead-based paint and corrosion with abrasive blasting to prepare all the steel surfaces to a specified near-white grade (Steel Structures Painting Council (SSPC) Grade SP-10).[2] The abrasive blasting material used was a coal-fired boiler slag, commonly known as "black beauty." Black beauty is a by-product of burning powdered coal in electric utility boilers and may contain a number of potentially hazardous trace elements.[3] The abrasive material was conducted from a mobile blasting pot to hand-held #7 blasting nozzles, typically held 2-6 feet from the surface, with compressed air at 100 pounds/square inch (psi). During blasting, the high velocity and pressure of the abrasive blast directed at the steel surface produced an aerosol comprised of corrosion, paint, metal and abrasive material particles. The surface preparation was followed immediately by State inspection and then repainting with a zinc-oxide primer (to prevent "flash rust" formation). The final coat, a (non-lead) vinyl based paint, was applied later.

Partial containment of abrasive blasting work was in effect at the worksite when the NIOSH investigation began. No environmental containment during abrasive blasting had been originally specified by the KDOT. The work began in Kentucky (April 1990) without containment. Work was halted by Kentucky officials in August 1990, after more than half the blasting work was completed, due to concern about environmental lead contamination near the bridge. The KDOT contract was renegotiated to include a requirement for partial containment (free-hanging nylon mesh tarpaulins of 85% opacity) during blasting. Work resumed after the contractor provided it on site. Two bulk samples of settled dust were collected by the Southwestern Ohio Air Pollution Control Agency near the worksite (under the bridge) in September 1990. The dust samples contained relatively high levels of lead: 3,420 and 4,140 parts per million (ppm), respectively. The U.S. Environmental Protection Agency (EPA) Offices of Emergency and Remedial Response and Waste Programs Enforcement currently use an interim guideline for Superfund hazardous waste sites which specifies cleanup of soil to a total lead concentration in the range of 500 to 1,000 ppm.[4] The ODOT contract, which began in 1991, required partial containment at the outset.

The partial containment, as implemented by the contractor in Kentucky and Ohio, appeared to effectively capture only the largest particles such as fragments of paint and abrasive grit. During abrasive blasting, dense clouds of finer dust particles (resembling a brown fog) were observed to pass through the nylon mesh containment tarpaulins, creating a plume of visible contamination up to 150 yards in length downwind. Vehicular traffic on the bridge often passed directly through this plume of contamination; no signs warning of the potential lead hazard were visible to the public.

A fenced staging area for use by the painting contractor was located directly underneath the bridge in Covington, Kentucky. The bare soil throughout this area had been visibly contaminated with used abrasive material prior to the November 1990, NIOSH site visit, as the bridge supports directly above the area had been blasted without environmental containment. The area was used to house the mobile office and equipment trailers, which contained painting and abrasive blasting equipment. At the beginning of a workshift, workers (who resided in local hotels during the job) arrived at the office and changed into cotton work clothing. Initially, the area provided for worker clothes changing and respirator storage was in one of the equipment trailers. This area was visibly dirty, had no benches, chairs, shelving, or lockers; and was also used for the storage of a large quantity of flammable paint products. A portable toilet was provided on site, but there was no running water on site for hand washing or showering. Portable plastic water containers were used to store water used for both hand washing and drinking. Workers used employer-provided trucks to access the work area on the bridge, and their private vehicles to leave the site during lunch breaks.

Respirators were provided by the employer. During the NIOSH investigation, NIOSH approved type CE respirators (continuous-flow supplied-air respirators equipped with helmets, Bullard® 77 Series) were provided to blasters, and half-face air-purifying respirators to workers in other job categories. NIOSH investigators did not attempt to determine if respirators were used or maintained according to the manufacturer's instructions.

The work crew on-site during abrasive blasting of the bridge typically included a foreman, a helper, four groundsmen, and four blasters (who also typically performed painting). Daily set up at the site was variable, but included moving scaffolding or decking, erecting or moving containment tarpaulins, and blasting equipment maintenance. Daily set up typically required 1-2 hours. The blasters would then don heavy protective coveralls and gloves, single-use dust masks, and continuous-flow type CE respirators. Blasting usually lasted a total of 4-6 hours per day. Simultaneously, groundsmen would tend the air compressors supplying breathing air and the blasting hoses, and keep the blasting pots filled with clean abrasive material. The helper's job was primarily to look after equipment and fetch supplies. After the day's blasting was completed, blasters removed the dust remaining on the steel surfaces with compressed air. The primer coat of paint was then applied with compressed-air spray guns. On some days one or more workers painted for the full workshift to apply finish coat to an area which had been previously prepared. Groundsmen were responsible for daily vacuuming and sweeping of used abrasive material which had fallen to the floor of the contained area, or had escaped containment.

There was a high turnover of workers during the NIOSH evaluation at the site. Of the 12 workers present at the beginning of the 1991 painting season (March 20, 1991), nine (75%) were not on this job at the end of the season four months later (July 9, 1991). Only two of 17 workers who participated in medical monitoring were present for all four NIOSH medical monitoring visits in 1991.

IV. EVALUATION METHODS

A. Environmental evaluation

During site visits, work practices were observed, and walk-through surveys of work areas were conducted. Environmental monitoring was conducted during site visits on November 1, 1990, April 23, 1991, and June 6, 1991.

Personal breathing zone (PBZ) and area air samples, surface dust wipe samples, and bulk material samples were collected to assess worker exposures to airborne lead, and to lead-contaminated surface dust. Personal monitoring was conducted to assess exposure to carbon monoxide and noise during the June 6, 1991 site visit. NIOSH monitoring was designed to cover those portions of the workshift where all or nearly all the exposure of concern was expected.

Paired PBZ samples were collected inside and outside of the type CE respirators to measure the program protection factor (PPF), a measure of respiratory protection program efficacy. The PPF of a respirator is defined as the ratio of the contaminant concentration outside the respirator to the contaminant concentration inside the respirator; measured as the respirator is worn in the context of the existing respiratory protection program.[5] PPF measurements were compared to the respective NIOSH assigned protection factor (APF). The NIOSH APF is defined as the minimum anticipated protection (ratio of outside/inside contaminant concentration) provided by a properly functioning respirator, or class of respirators, to a given percentage (usually 95%) of properly fitted and trained users, based on test data.[6]

The methods used for collecting environmental samples were as follows:

1. Air Samples

Area and PBZ air samples were collected with appropriate sampling media connected via Tygon® tubing to Gillian Hi Flow Sampler® battery-operated personal sampling pumps calibrated immediately, prior to, and after, sampling. The PBZ samples were collected in the breathing zone (at the shirt collar), unless otherwise noted.

For blasters, the inside-respirator samples were collected inside the helmet next to the worker's face. The sampling filter cassette was connected to a belt-mounted sampling pump via flexible (Tygon®) tubing placed next to the blaster's neck inside the elastic neck collar of the helmet. The outside-respirator samples were collected behind at the back of the blaster's neck to reduce sample loss from direct contact with high-velocity abrasive blast.

Calibration of the sampling pumps on-site before and after sampling; and periodic flow checks during sampling were accomplished with Kurz Pocket Flow Calibrator™ mass flowmeters, which had been calibrated with a primary standard (bubble flowmeter). For subsequent calculation of sample volumes, the mean of the pre- and post-sampling flow rates was used. A minimum of two field blanks (sample media carried into the field, and handled like the other media, with the exception that they were not used to collect samples), representing at least 10% of samples, were prepared and submitted with each sample set.

The analytes, initial pump flow rates, sample collection media, and methods of analysis for the samples are listed below. The respective limit of detection (LOD) and limit of quantitation (LOQ) for each kind of laboratory analysis are reported with the sampling results in tables later. Results reported as not detected (ND) were below either the LOD or LOQ, as indicated in the data tables.

Lead: Sample collection with a flow rate of 2 liters per minute (ℓ/min) through 37-millimeter (mm), 0.8-micron (µm) pore size, cellulose ester membrane filters in closed-face cassettes; analysis of the filters for lead by flame atomic absorption spectroscopy (AAS)-NIOSH Method 7082, or for lead and other trace metals by inductively coupled argon plasma, atomic emission spectrometry (ICP-AES)-NIOSH Method 7300.[7]

Carbon monoxide: Long-term PBZ air samples for carbon monoxide (CO) were collected with Dräger® diffusion detector tubes (tube 50/a-D). At the beginning of each sampling period a tube was opened, placed in a Dräger® tube holder, and attached to the worker's collar. The ppm-hours for each samples was read from the length of colored stain on the graduated tubes immediately after sampling; ppm CO was determined by dividing by the sampling time (hours) as per the manufacturer's directions.

2. Bulk Samples

Bulk material samples were collected in clean glass vials (abrasive material and paint) or new plastic bags with a zip-lock mechanism (surface samples).

Lead and other metals: Bulk samples of abrasive and paint were collected by transferring 1-10 grams of material into clean 20-milliliter (ml) glass vials with disposable wooden tongue depressors. Samples were ground with a mortar and pestle prior to taking aliquots for analysis. Three replicate aliquots of each bulk sample were weighed, wet-ashed with concentrated nitric and perchloric acids, and dissolved in dilute solutions of the same acids. The resulting sample solutions were analyzed for trace metals by inductively coupled argon plasma, atomic emission spectrometry (ICP-AES), according to NIOSH Method 7300.

Lead, surface dust: Samples were collected using commercial pre-moistened baby wipes using a modification of the Department of Housing and Urban Development (HUD) "Laboratory Testing for Lead in Dust" procedure.[8] Surface dust samples were collected by: a) measuring off and marking a flat surface of about one square foot (ft^2); b) donning disposable gloves; c) taking a wipe from the container (the first wipe each day was discarded); d) folding the wipe in half and wiping the entire marked area with a series of horizontal strokes in an "S"-pattern (the wipe is not lifted); e) refolding the wipe with the dust side in and wiping the area in an "S"-pattern a second time at a 90° angle to the first pattern; f) folding the wipe again and wiping the area a third time in an "S"-pattern at a 90° angle to the previous pattern; and g) placing the folded baby wipe in a new sealable plastic bag. To reduce possible cross-contamination, the disposable gloves were changed after each sample was collected. Care was taken to use the same technique and wiping pressure for each sample to reduce variation in collection efficiency.

The wipes were wet-ashed with concentrated nitric and perchloric acids. Since a significant amount of unashable material remained after wet-ashing, these samples were leached overnight in dilute solutions of the same acids, centrifuged. The supernatant solutions were used for analysis. The solutions were analyzed for trace metals by inductively coupled argon plasma, atomic emission spectrometry (ICP-AES), according to NIOSH Method 7300.[3]

3. Noise Exposure

Personal noise exposures were measured with Metrosonics Model dB301/26 Metrologgers®; which are small noise level recording devices (dosimeters). The dosimeters were clipped to a waist belt, with a ¼ inch microphone attached to the worker's shirt collar, or the shoulder area if the shirt had no collar. For the blasters measured in the survey, the microphone was threaded through the cloth collar of the blasting helmet and anchored to the worker's hood inside of the helmet near his ear. This dosimeter is designed to measure noise levels in decibels, A-weighted (dBA) four times per second. The noise measurements are integrated according to the Occupational Safety and Health Administration (OSHA) noise regulation (see Evaluation Criteria section of this report--pages 14-16) for an entire minute and stored separately in the Metrologger for later analysis and final storage. Each dosimeter was calibrated according to the manufacturer's instructions before being placed on the worker. After the recording period was completed, the dosimeter was removed from the worker and placed in the standby mode of operation. The data was transferred to a Metrosonics Model dt-390 Metroreader/Data Collector® following the workshift noise sampling. Prior to turning off the dosimeter, it was again calibrated to assure that the device had not changed during the sampling period. The dosimeter information was finally transferred to a personal computer with supporting Metrosonics Metrosoft computer software for permanent data storage and later analysis.

B. **Medical evaluation**

The medical evaluation of the workers consisted of baseline and followup occupational health questionnaires; and blood tests for BLL and zinc protoporphyrin (ZPP). Informed, signed consent was obtained from each worker prior to administration of the questionnaire and blood draw. The medical evaluation was conducted during site visits on March 20, April 23, June 12, and July 7, 1991. A site visit was conducted on November 1, 1990, but the medical evaluation was interrupted because workers were sent home due to imminent safety hazards identified by NIOSH investigators. Only two workers were interviewed and had their blood tested on this November 1, 1990 visit. These results were reported to the individuals. All 12 workers present on March 20, 1991, completed the questionnaire. However, one worker refused the blood tests throughout the survey.

Occupational health questionnaires were administered individually to the workers by NIOSH investigators. The baseline questionnaire consisted of sections on basic demographics (age, sex, race, education, etc.); history of current and prior occupational and non-occupational exposure to lead; medical history of symptoms and conditions potentially related to lead exposure; and a description of work practices and personal hygiene. Followup questionnaires contained questions on changes in work assignments or health status since the date of the baseline interview. Questionnaire data were entered and analyzed in EPIINFO, Version 5.0, a epidemiological statistical software application developed by the Centers for Disease Control (CDC) and the World Health Organization (WHO).

NIOSH investigators obtained all blood samples by antecubital venipuncture (veins in the arms). Baseline blood testing consisted of measurements of blood lead level (BLL), and zinc protoporphyrin (ZPP). Blood samples were sent to an OSHA-listed laboratory (a listing is available from the OSHA Analytical Laboratory in Salt Lake City, Utah; telephone 801-524-4270).

V. EVALUATION CRITERIA

A. **General guidelines**

As a guide to the evaluation of exposures to chemical and physical agents in the workplace, NIOSH employs criteria which are intended to suggest levels of (airborne) exposure to which most workers may be exposed up to 10 hours/day, 40 hours/week for a working lifetime without experiencing adverse health effects. It is important to note; however, not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the levels set by the evaluation criteria. Some substances are absorbed by direct contact with the skin and mucous membranes, or by ingestion, and thus the overall exposure may be increased above measured airborne concentrations. Evaluation criteria typically change over time as new information on the toxic effects of an agent become available.

The primary sources of evaluation criteria for the workplace are: NIOSH Criteria Documents and Recommended Exposure Limits (RELs),[9] the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),[10] and the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[11] These values are usually based on a time-weighted average (TWA) exposure, which refers to the average airborne concentration of a substance over an entire 8-hour (PELs, TLVs) or up to 10-hour (RELs) workday. Concentrations are usually expressed in parts per million (ppm), milligrams per cubic meter (mg/m^3), or micrograms per cubic meter ($\mu g/m^3$). To compare results with the NIOSH, OSHA, and ACGIH criteria that are TWAs, it is sometimes useful to extrapolate 8-hr TWA exposures from sampling times of less than eight hours. In extrapolating 8-hr TWAs, an assumption is made that there was no other exposure to the compound(s) of interest over the remainder of the 8-hr workshift.

In addition, for some substances there are short-term exposure limits or ceiling limits which are intended to supplement the TWA limits where there are recognized toxic effects from short-term exposures.

1. Lead

Inhalation (breathing) of dust and fume, and ingestion (swallowing) resulting from hand-to-mouth contact with lead-contaminated food, cigarettes, clothing, or other objects are the major routes of worker exposure to lead. Once absorbed, lead accumulates in the soft tissues and bones, with the highest accumulation initially in the liver and kidneys.[12]

It is stored in the bones for decades, and may cause toxic effects as it is slowly released over time. Overexposure to lead results in damage to the kidneys, gastrointestinal tract, peripheral and central nervous systems, and the blood-forming organs (bone marrow).

The frequency and severity of symptoms associated with lead exposure increase with increasing blood lead levels (BLLs). Signs or symptoms of acute lead intoxication include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort, colic, anemia, high blood pressure, irritability or anxiety, fine tremors, and "wrist drop."[13,14,15]

Overt symptoms of lead poisoning in adults generally begin at BLLs between 60 and 120 µg/dl. Neurologic, hematologic, and reproductive effects; however, may be detectable at much lower levels, and the World Health Organization (WHO) has recommended an upper limit of 40 µg/dl for occupationally exposed adult males.[16] The mean serum lead level for U.S. men from 1976 to 1980 was 16 µg/dl.[17,18] However, with the implementation of lead-free gasoline and reduced lead in food, the 1991 average serum lead level of U.S. men will probably drop below 9 µg/dl.[19]

An increase in an individual worker's BLL can mean that the worker is being overexposed to lead. While the BLL is a good indication of recent exposure to, and current absorption of lead, it is not a reliable indication of the total body burden of lead.[20] Lead can accumulate in the body over time and produce health effects long after exposure has stopped. Long-term overexposure to lead may cause infertility in both sexes, fetal damage, chronic kidney disease (nephropathy), and anemia.

Under the OSHA standard regulating occupational exposure to inorganic lead in general industry, the PEL is 50 µg/m^3 as an 8-hr TWA.[21] The standard requires semi-annual monitoring of BLL for employees exposed to airborne lead at or above the Action Level of 30 µg/m^3 (8-hour TWA), specifies medical removal of employees whose average BLL is 50 µg/dl or greater, and provides economic protection for medically removed workers. The construction industry was exempted from this regulation when it was promulgated in 1978. The current OSHA PEL for the construction industry is 200 µg/m^3. The NIOSH REL for lead is less than 100 µg/m^3 as a TWA for up to 10 hours. This REL is an air concentration to be maintained so worker blood lead remains below 60 µg/100 grams of whole blood. NIOSH is presently reviewing literature on the health effects of lead and may re-evaluate its REL. The OSHA PEL for general industry is currently recommended by the NIOSH investigators as a more protective criteria.

Recent studies suggest that there are adverse health effects at BLLs below the current evaluation criteria for occupational exposure. A number of studies have found neurological symptoms in workers with BLLs of 40 to 60 µg/dl. Male BLLs are associated with increases in blood pressure, with no apparent threshold through less than 10 µg/dl. Studies have suggested decreased fertility in men at BLLs as low as 40 µg/dl. Prenatal exposure to lead is associated with reduced gestational age, birthweight, and early mental development at prenatal maternal BLLs as low as 10 to 15 µg/dl.[22]

In recognition of the health risks associated with exposure to lead, a goal for reducing occupational exposure was specified in *Healthy People 2000*, a recent statement of national consensus and U.S. Public Health Service policy for health promotion and disease prevention. The goal for workers exposed to lead is to eliminate, by the year 2000, all exposures that result in BLLs greater than 25 µg/dl.[23]

Lead dust may be carried home on clothing, skin, and hair, and in vehicles when a family member is occupationally exposed to lead. High BLLs in resident children, and elevated concentrations of lead in the house dust, have been found in the homes of workers employed in industries associated with high lead exposure.[24] Particular effort should be made to ensure that children of workers with lead poisoning, or who work in areas of high lead exposure, are tested for lead exposure (BLL) by a qualified health-care provider.

NIOSH and OSHA have recently published recommendations for construction workers potentially exposed to lead.[1,25] Prior to job placement, these workers should receive a complete baseline health evaluation from an examining physician which includes medical and work histories, a physical examination, and appropriate physiologic and laboratory tests (pulmonary status, blood pressure, blood testing, urinalysis, etc). Findings of this examination unrelated to lead exposure must not be revealed to the employer. Engineering and work practice controls should be used to reduce employee exposures below the OSHA PEL for general industry (50 µg/m^3, 8-hr TWA). Medical notification and medical removal practices and protection, as specified in the OSHA general industry standard, should be applied to construction workers.

2. Lead in surface dust

There are no Federal standards governing the level of lead in surface dust in either occupational or non-occupational (i.e., residential settings). However, lead-contaminated surface dust in either setting represents a potential exposure to lead through ingestion, especially by children. This may occur either by direct hand-to-mouth contact with the dust, or indirectly from hand-to-mouth contact via clothing, cigarettes, or food contaminated by lead dust. The U.S. Department of Housing and Urban Development (HUD) has recommended the following final clearance standards for lead in house dust on specific interior surfaces following abatement: floors, 200 micrograms per square foot (µg/ft^2); window sills, 500 µg/ft^2, and window wells, 800 µg/ft^2. HUD also recommends the standard for floors be applied to exterior porches.[8]

3. Noise

Occupational deafness was first documented among metalworkers in the sixteenth century.[26] Since then, it has been shown that workers have experienced excessive hearing loss in many occupations associated with noise (undesired sound). Noise-induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise-induced loss is caused by irreversible damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[27]

While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is insidious. Typically, it begins to develop at 4,000 or 6,000 Hertz (Hz) (the hearing range is 20 Hz to 20,000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2,000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have still higher frequency components.[28]

The A-weighted decibel (dBA) is the preferred unit for measuring sound levels. The unit is dimensionless, and represents the logarithmic relationship of the measured sound pressure level to an arbitrary reference sound pressure (20 micropascals, the normal threshold of human hearing at 1,000 Hz). The dBA scale is weighted to approximate the sensory response of the human ear. Because the dBA scale is logarithmic, increases of 3 dBA, 10 dBA, and 20 dBA represent a doubling, tenfold increase, and 100-fold increase of sound levels, respectively.

Duration (hrs/day)	Exposure limit (dBA)	
	NIOSH/ACGIH	OSHA
16	80	85
8	85	90
4	90	95
2	95	100
1	100	105
1/2	105	110
1/4	110	115*
1/8	115*	**

* No exposure to continuous or intermittent noise in excess of 115 dBA.

** Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

The OSHA standard for occupational exposure to noise (29 CFR 1910.95)[29] specifies a PEL of 90 dBA (slow response) for a duration of 8-hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship. This means that in order for a person to be exposed to noise levels of 95 dBA, the amount of time allowed at this exposure level must be cut in half in order to be within the PEL. Conversely, a person exposed to 85 dBA is allowed twice as much time at this level (16 hours) to be within the daily PEL. The NIOSH REL[30] and the ACGIH TLV for noise specify an exposure limit of 85 dBA for 8 hours, 5 dB less than the OSHA standard. Both of these latter two criteria also use a 5 dB time/intensity trading relationship in calculating exposure limits.

Time-weighted average (TWA) noise limits as a function of exposure duration are shown in the table above.

The OSHA regulation has an additional Action Level (AL) of 85 dBA which stipulates that an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the AL. The program must include monitoring, employee notification, observation, an audiometric testing program, hearing protectors, training programs, and recordkeeping requirements. All of these stipulations are included in 29 CFR 1910.95, paragraphs (c) through (o).

The OSHA noise standard also states that when workers are exposed to noise levels in excess of the PEL of 90 dBA, feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. Also, a continuing, effective hearing conservation program shall be implemented.

There is some evidence that lead and noise can act together on a worker's hearing. In one of these studies, it was observed that workers exposed to lead stearate had high frequency hearing losses. No excessive exposures to noise were noted in the group.[31] Other research has found that workers in the manufacture of lead had moderate auditory loss with only slight signs of lead intoxication.[32] The author concludes that detailed audiological examinations be used to detect early signs of lead poisoning.

VI. RESULTS AND DISCUSSION

A. Environmental

Bulk samples of unused and used abrasive blasting material (one each) were collected on November 1, 1990 and April 23, 1991, and subsequently analyzed for trace elements; results are presented in Table 1. The primary trace elements detected in the unused abrasive were aluminum, calcium, iron, magnesium, sodium, and titanium, with concentrations (by weight) ranging from 0.01-1.65 percent (100-16,500 ppm). These elements were found in approximately the same concentrations in the used abrasive. However, the concentrations of barium, lead, and zinc were increased in both samples of used abrasive; these concentrations ranged from 0.02-1.15 percent (200-11,500 ppm). For example, no lead was detected (<0.01 percent or <100 ppm) in the unused abrasive, but the used abrasive contained a potentially hazardous amount of lead--0.71 to 1.15 percent (7,100-11,500 ppm). Typically, by contractual agreement, the bridge painting contractor has the responsibility to test and dispose of the used abrasive material. Under the Federal Resource Conservation and Recovery Act (RCRA), solid waste material with a leachable lead concentration of 5 ppm or greater is classified and regulated as a characteristic hazardous waste (40 CFR 260)[33].

The results of area and PBZ air sampling for lead are presented in Tables 2 and 3. Eighteen PBZ air samples were collected on November 1, 1990 and April 23, 1991 (Table 2). On a follow-up visit June 6, 1991, four area and 12 PBZ air samples were collected (Table 3). Ranges for PBZ exposures to lead by job category (as TWAs for sampling periods, irrespective of respiratory protection) were: foreman, 53-108 $\mu g/m^3$; painter, 17 $\mu g/m^3$; helper, 36-202 $\mu g/m^3$; groundsman, 5-6720 $\mu g/m^3$; and blaster 3,690-29,400 $\mu g/m^3$. Six personal air samples were collected for lead inside blasting respirators during use; the PBZ exposures measured ranged from 9 to 194 $\mu g/m^3$.

The sampling periods for most of the air samples collected were of 6- to 9- hour duration. Eight-hr TWA exposures were extrapolated for the PBZ samples of less than 8-hr duration which represented nearly all the expected workshift exposure. Actual and extrapolated 8-hr TWA exposures measured are presented in Tables 2 and 3 (extrapolation was not applicable for two samples). Personal 8-hr TWA lead exposure ranges (actual or extrapolated) were 2,117-14,060 $\mu g/m^3$ for blasters; and 4-6,720 $\mu g/m^3$ for other job categories. All eight actual or extrapolated 8-hr TWA personal lead exposures for blasters, and two of fourteen 8-hr TWA exposures for other job categories exceeded the OSHA general industry PEL for lead of 50 $\mu g/m^3$. All eight, and one of 14 8-hr TWA exposures for blasters and other job categories, respectively, exceeded the OSHA construction PEL for lead of 200 $\mu g/m^3$. Two of six inside-respirator 8-hr TWA extrapolated exposures for blasters (81 and 119 $\mu g/m^3$) exceeded the OSHA general industry PEL.

General area airborne lead concentrations measured ranged from ND-8,170 µg/m^3, as TWAs over the sampling periods. An area TWA airborne lead concentration of 8,170 µg/m^3 measured inside the containment structure was reduced to 652 µg/m^3 outside the structure, 15 feet downwind; indicating that containment was partially effective. However, the TWA concentration of lead in the airborne plume of dust escaping from containment (652 µg/m^3) represents a health hazard to workers outside containment, as well as the general public.

Twelve paired PBZ air samples were collected inside and outside the continuous-flow type CE blasting respirators worn by five blasters to measure the PPF of the respirators. The results are presented in Table 4. These PPF values should be considered approximate, as most of the paired sampling periods were unequal due to pump faults. PPFs measured in five paired samples were 106 to 622, with an additional estimated value of 97 (estimate due to non-concurrent inside/outside measurements).

The NIOSH recommended maximum airborne concentration for a respirator is the respective NIOSH APF multiplied by the applicable exposure limit.[6] All of the airborne lead exposures for blasters (range: 42-281 times the OSHA PEL) exceeded the NIOSH recommended maximum airborne concentration (25 times the OSHA PEL) for the type CE respirators used. The PPFs measured for the type CE respirators in use at this worksite (range: 106-622) were greater than the NIOSH APF of 25 for type CE respirators. However, two of six inside-respirator exposures exceeded the OSHA PEL (extrapolated 8-hr TWAs of 81 and 119 µg/m^3); indicating that workers using type CE respirators were not adequately protected from airborne lead exposures. Perhaps in recognition of the need for greater respiratory protection, all blasters at this worksite wore single-use dust masks under their type CE blasting respirators.

Workers in other job categories (outside containment) used half-face air-purifying respirators (NIOSH APF of 10) during abrasive blasting, and while handling waste abrasive material. Their exposures did not exceed the NIOSH-recommended maximum use concentration (10 times the OSHA PEL) for half-face air-purifying respirators; with the exception of one exposure for a groundsman (134 times the OSHA PEL).

Results of surface sampling for lead are presented in Table 5. Ten wipe samples of various surfaces outside the containment structure were collected during normal abrasive blasting; including equipment truck windows, dashboards, and steering wheels; portable water coolers; and portable lunch coolers. The lead concentration in these samples was 137-4,200 µg/sample. Where the wiped surface areas could be accurately measured, lead concentrations were converted to micrograms per square foot (µg/ft^2). The range for five samples was 377-5150 µg/ft^2. As an indication of the degree of surface lead contamination at this site, results were compared to the HUD criteria for surface dust after lead abatement. All of the five samples, including the top of a portable lunch cooler, exceeded the HUD clearance criteria of 200 µg/ft^2 for lead in dust on floors, and four of the five exceeded the HUD criteria of 500 µg/ft^2 for walls.

During the June 6, 1991, site visit six PBZ and two area samples were collected during abrasive blasting on the bridge to measure TWA carbon monoxide (CO) concentrations. Potential sources of CO were the vehicular traffic on the bridge (which is on a major interstate route), and gasoline- or diesel-powered abrasive blasting equipment used by the contractor. All of the samples were collected with long-term passive detector tubes. The portion of the workshift monitored was from approximately 8:00 p.m. to 2:00 a.m.; thus vehicular traffic on the bridge was reduced from peak daytime hours. Both vehicular traffic and equipment operation appeared to be fairly constant during the period monitored. No CO was detected in the samples. The LOD was 8 ppm for six PBZ and one area sample (6 hr-duration), and 10 ppm for one area sample (5-hr duration). These results indicate that workers were not exposed to levels of CO in excess of the NIOSH REL-TWA of 35 ppm.

Four blasters, and four workers performing support functions outside containment were sampled for noise exposure. The summary results are presented in Table 6. Two short-term exposures for one of the blasters (employee #8) were not converted to an 8-hr TWA or dose percentages because they did not represent all or nearly all of the workshift. Among the eight workers, the mean 1-minute peak period of noise exposure in the measurement periods ranged from 110-121 dBA. All seven, and six of seven, workers surveyed for 8-hr TWA noise exposures had exposures exceeding the NIOSH REL of 85 dBA, and the OSHA PEL of 90 dBA, respectively (range: 89.6-105.4 dBA). The 8-hr TWA noise exposures, expressed as dose percentages of the OSHA PEL, ranged from 95% (89.6 dBA) to 850% (105.4 dBA). All workers were provided, and used, hearing protection devices (earplugs), but were not protected by a hearing conservation program.

Consistently high measured noise exposures were due to the location of the work relative to support equipment and vehicular traffic. Even when the workers were able to take breaks from abrasive blasting during the workshift, they were exposed to constant noise from air compressors and the vehicle traffic on the bridge. It should be noted that the noise exposures for the blasters were measured inside of a type CE blasting respirator (an air-supplied hard helmet) next to the worker's ear. These helmets do offer some attenuation of the noise. If other workers were to enter the containment area during blasting, it is likely that they would be exposed to noise levels greater than measured exposures of 110-115 dBA.

B. **Medical**

Analyses were performed on data collected during all site visits. Baseline occupational health questionnaires were administered to 17 workers. The average age of the workers was 35 years old. There were 16 males and one female. Fifteen of the workers were white, one was Hispanic, and one was a native American. Two workers reported previous episodes of lead overexposure at other work sites. On March 20, 1991, none of the workers reported symptoms consistent with lead intoxication. However, subsequently (prior to the April 23rd visit), the worker with the highest measured BLL (61 µg/dl, measured April 23rd) was treated by a physician for "tiredness" and "a sore throat" (no work days were missed). Tiredness is a symptom consistent with lead intoxication, though not specific for it.

The results of BLL and ZPP monitoring of 16 workers at the worksite who participated in medical monitoring during four NIOSH site visits in 1991, are shown in Tables 7 and 8, respectively (one worker refused blood testing). Paired results over approximately one-month monitoring intervals were analyzed for workers with non-missing values. The medical monitoring results should be interpreted with caution due to the relatively high number of cases with missing values for one or more of the site visits.

The mean BLL increased from 29 µg/dl to 36 µg/dl between the March 20th and April 23rd site visits among the eight workers tested both times (9 workers were not included). This mean BLL increase was statistically significant (p=0.0059, paired two-tailed t-test); which is consistent with the employer's report that abrasive blasting (of lead-based paint) was performed about 23 of the 34 total days. The mean BLL decreased from 31 µg/dl to 24 µg/dl between the June 12th and July 7th site visits among the four workers tested both times (13 workers were not included). This mean BLL decrease, though not statistically significant (p=0.0585, paired two-tailed t-test), was consistent with the contractor's report that little abrasive blasting was performed during this period.

No overall trend for mean BLL was apparent over the four-month study period. However, the medical monitoring was incomplete. Only two of 17 workers had a BLL test on all four site visits. Because of this, a trend analysis would not be meaningful. Two of 16 workers tested had peak BLLs of 50 µg/dl or more (55 and 61). An average BLL of $\geq$ 50 µg/m^3, or a single BLL of $\geq$ 60 µg/m^3 trigger mandatory medical removal protection under the OSHA general industry lead standard.

The ZPP level in blood is a non-specific indicator of chronic exposure to lead. The mean ZPP level increased from 36 to 55 µg/dl between the March 20th and April 23rd site visits among the eight workers tested both times. However, the increase was not statistically significant (p=0.096). Between the March 20th and July 7th site visits the mean ZPP level increased significantly, from 52 to 75 µg/dl, among the four workers tested both times (p=0.0069). These increases are indicative of chronic exposure to lead sufficient to impair heme synthesis. However, the hemoglobin and hematocrit values for all workers were within the laboratory-reported reference range for men, indicating that anemia had not developed in any of the workers.

Six of 17 workers (35%) at the worksite who were interviewed were not aware of the signs and symptoms of lead poisoning. Nine of 17 (53%) workers consumed food or drink at the work site, at which there was no clean lunch room. There were 8 cigarette smokers. Cigarette smokers had a mean peak BLL of 38 µg/dl as compared to 29 µg/dl for non-smokers. The mean peak ZPP was 58 µg/dl for smokers and 38 µg/l for non-smokers. Neither difference was statistically significant (p>0.05).

C. Correlation Analyses, Airborne Lead vs. BLL

Personal airborne lead exposure and BLL data obtained in this evaluation on two site visits were analyzed to determine if the observed BLLs were correlated with measured personal (actual or extrapolated) 8-hr TWA airborne lead exposures (irrespective of respiratory protection).

Overall, no correlation was found (r^2=0.003) between ten paired BLLs and 8-hr TWA airborne lead exposures, representing all job categories, collected on April 23, 1991 (see Figure 1). The much higher airborne lead exposures in the blasters job category compared to all other job categories indicated separate correlation analyses for these two groups. No correlation was found between paired BLLs and 8-hr TWA exposures among four blasters (r^2=0.002), or among six workers in other job categories (r^2=0.274). These results are consistent with high variability of airborne lead exposures, different levels of respiratory protection among workers, variable and elevated baseline BLLs, and potential lead exposures via ingestion; all of which were found during this evaluation.

However, a significant positive correlation was found (r^2=0.876, $p<0.05$) between paired inside-respirator 8-hr TWA airborne lead exposures (collected June 6, 1991) and subsequent BLLs (collected June 12, 1991) for blasters wearing type CE respirators. The correlation is presented graphically in Figure 2. The non-parametric ranked correlation (Spearman) was also significant (coefficient of determination=1.0). This result should be interpreted with caution due to the small sample size (n=4). However, it suggests that inside-respirator exposures may be a primary predictor of lead exposures and subsequent BLLs for workers performing abrasive blasting. It should be noted that NIOSH recommends that BLL testing be conducted within two weeks of air sampling for lead, as the BLL is only an indication of recent exposure.[20]

D. **Observations**

On the first visit (November 1, 1990), NIOSH investigators observed that workers accessing the blasting areas on the bridge were exposed to a serious safety hazard, which was referred immediately to the Kentucky Labor Cabinet as an imminent hazard. The safety hazard was lack of protection from falls during work at heights greater than 25 feet above the ground and over water (maximum unprotected exposure was approximately 130 feet). Two additional safety hazards were observed on the second visit and reported to the company and the Kentucky Labor Cabinet (May 16, 1991 interim report). These hazards were failure to protect employees from falls (unprotected exposure 15 feet directly over vehicular traffic); and a fire hazard resulting from use of a portable electric heater in an equipment trailer that was designated for worker clothes changing, respirator storage, and flammable materials storage.

During site visits, NIOSH investigators observed that a comprehensive respiratory protection program as recommended by NIOSH, and required by OSHA standard (29 CFR 1910.134), was not established. Problems observed included improper respirator storage, lack of respirator cleaning and maintenance, improper respirator selection, and inconsistent use of respirators by employees outside the containment area. Initially (November 1990) it was observed that the contractor had provided half-face air-purifying respirators with organic vapor cartridges and snap-on low-efficiency particulate filters for all jobs except blasting. The contractor was informed that the organic vapor cartridges were not NIOSH approved for protection from toxic dusts and fumes, such as lead. By the next visit (April 1991) the contractor provided NIOSH approved half-face air-purifying respirators with high-efficiency particulate air (HEPA) filters.

During site visits NIOSH investigators observed plumes of airborne dust escaping from the containment structure, and depending on ambient conditions, extending up to several hundred feet downwind. On several of the site visits, the interstate vehicular traffic on the bridge was observed to pass directly through the escaping plumes of dust from abrasive blasting, which had the appearance of a thick, brown fog. No signs warning the general public of potential exposure to lead were posted.

VII. CONCLUSIONS

The results indicate that workers were overexposed to airborne lead during the abrasive blasting of lead-based paint from the bridge. Blasters were exposed to consistently high levels of airborne lead. All seven 8-hr TWA exposures measured or extrapolated for blasters (irrespective of respiratory protection) exceeded the OSHA general industry PEL. Groundsmen, helpers, and other job categories were exposed to widely varying concentrations of airborne lead; two of 14 8-hr TWA exposures measured or extrapolated exceeded the OSHA general industry PEL.

The results indicated that airborne lead exposures, even within a job category, were highly variable. For example, the exposure range (5 - 6,720 $\mu g/m^3$) for groundsmen, who worked exclusively outside the contained blasting area, represented three orders of magnitude. The maximum personal exposure measured outside containment (6,720 $\mu g/m^3$) was roughly 30 times greater than the next highest personal exposure measured in this area. The reason for this unusually high exposure measurement is unknown, but should be investigated by the employer. Possible causes are a periodic maintenance activity, the location of the worker with respect to the plume of abrasive blasting dust, improper work practices, or contamination of the sample.

As the primary method of controlling lead exposures, the contractor provided respirators to all the employees on site. However, the respirators were not provided in the context of a comprehensive respiratory protection program meeting NIOSH recommendations and OSHA requirements. Air sampling results indicated that workers were not adequately protected from overexposure to lead by the respiratory protection program provided.

It is likely that inhalation was the primary route of worker lead exposure, particularly for blasters. However, the bulk and surface sampling results indicated that ingestion was a potential route of exposure at this worksite. The used abrasive blasting material, which was present in large quantities after abrasive blasting, was contaminated with lead in sufficient quantity to represent a health hazard by ingestion. During blasting operations fine airborne dust was observed to pass through the containment tarpaulins, which resulted in significant surface contamination with lead outside the containment. Lead contamination was measured on portable water cooler spigots, on the top of a portable lunch box, and in work vehicles. Workers who consumed food, drink, or tobacco products at the worksite were at greater risk for exposure to lead by ingestion. Workers' hands and clothing may have become contaminated with lead during work activities, or by touching the ground, equipment, respirators and other surfaces.

Given the magnitude of lead contamination on this site, the available personal hygiene facilities were inadequate. No running water was available for hand washing on site, and no showers were provided. Initially, the area provided for clothes changing and respirator storage was an equipment trailer unsuitable for this purpose. By June 1991, the contractor had provided a separate trailer with a clean side and dirty side for changing (NIOSH investigators did not verify that it was actually used).

Air sampling indicated that exposure to CO did not represent a health hazard during non-peak hours for vehicular traffic on the bridge.

Sampling for personal noise exposures during abrasive blasting indicated that full-shift average noise levels consistently represented a health hazard, both inside and outside containment. Workers were provided, and used hearing protection devices (earplugs). However, they were not protected by a comprehensive hearing conservation program.

VIII. RECOMMENDATIONS

The following recommendations are offered with respect to abrasive blasting of lead-based paint during bridge maintenance, or other similar construction worksites. They are offered to minimize worker exposures to lead, and increase effective medical monitoring and surveillance. Implementation of these recommendations will help achieve one of the national health objectives specified by *Heathy People 2000*, which is to eliminate exposures that result in lead concentrations greater than 25 µg/dl of whole blood. Some of these recommendations were previously provided to M & J Painting Company in an interim report released in August 1991.

1. At this worksite, the contract for bridge maintenance used by the State departments of transportation did not adequately address either the qualifications of the contractor in regard to environmental and occupational health protection, or the real costs of such protection. NIOSH recommends that all new contracts of Federal, State, or local departments of transportation include specifications for a mandatory program of worker protection from lead poisoning during the maintenance, repainting, or demolition of bridges and other steel structures. Recommendations for such a worker protection program can be found in recent NIOSH and OSHA publications.[1,25]

2. Engineering controls should be used to minimize exposures to airborne lead at the worksite. The use of less dusty techniques for removal of lead-containing paint from the structure, such as centrifugal blasting (using rotating blades to propel the abrasive, which is recovered and recycled), wet blasting (using high-pressure water with or without an abrasive, or surrounding the blast nozzle with a ring of water), and vacuum blasting (shrouding the nozzle with local exhaust ventilation) should be implemented wherever feasible. Other methods that reduce dust include scraping, use of needle guns, and chemical removal.

3. Although the containment structure used at this worksite probably reduced lead contamination of the environment to some degree (an important goal--as fugitive lead contamination is a source of public exposure to lead), it may have increased worker airborne lead exposures. Whenever containment is used during abrasive blasting removal of lead-based paint, ventilation should be provided to reduce the airborne concentration of lead and increase visibility inside containment structure. Containment structures should be designed to optimize the flow of air past the

workers. Insofar as possible, workers should be upstream from the blasting operation to reduce exposure to lead dust entrained in the ventilation air.

4. Since respirators were provided and used to protect workers from airborne lead exposure, the employer (M & J Painting Company) should establish a comprehensive respiratory protection program as outlined in the NIOSH Guide to Industrial Respiratory Protection, and as required by the OSHA Respiratory Protection Standard (29 CFR 1910.134). Without a complete respiratory protection program, workers will not receive the anticipated protection from respirators. This program, which should be directed by a knowledgeable person, should include medical evaluation of the worker's ability to perform the work while wearing a respirator, appropriate respirator selection, training of personnel, environmental monitoring, and respirator fit testing, maintenance, inspection, and storage.

5. During similar abrasive blasting operations, the contractor should provide NIOSH-approved respirators with a higher NIOSH APF, such as type CE continuous-flow blasting hoods with tight-fitting full-facepieces, for use by blasters wherever feasible. These respirators have a NIOSH APF of 50, twice the protection factor of the type CE continuous-flow helmets which were used at the worksite. Currently approved respirators of this type are listed in the *NIOSH Certified Equipment List*.[34]

6. In light of the high airborne lead exposure measured for a groundsman (6,720 µg/m^3), this job should be evaluated with respect to modification of work practices and engineering controls. If the contractor cannot insure that similar exposures will be prevented with these controls, groundsmen should be provided a higher level of respiratory protection; at minimum a powered-air-purifying respirator with a full facepiece operated in positive pressure mode equipped with high-efficiency particulate air filters.

7. The contractor should provide improved facilities for personal hygiene on site, and enforce personal hygiene requirements to prevent the accumulation of lead dust in workers' cars or homes, and thereby preventing family members from exposure to lead. On a job of this duration, washing and changing facilities should include:

   ! hot and cold running water.

   ! showers and changing areas.

   ! waste water filtration, collection, and proper disposal.

   ! separate lockers, or storage facilities for storage of clean and contaminated work clothing.

8. At the outset of abrasive blasting work, a restricted work area should be defined as: the immediate abrasive blasting area and all adjacent areas which could be lead-contaminated by airborne dust or fallout of used abrasive blasting material. The boundaries of the lead-contaminated work area should be clearly marked with warning signs. These signs should follow the example presented in the OSHA general industry standard (29 CFR 1910.125), which warns about the lead hazard and prohibits eating and drinking in the area. Such signs should also specify any PPE required (e.g., respirators). If vehicular traffic on the bridge crosses the lead-

contaminated work area, these warning signs should also be clearly visible to the general public.

9. Workers should change into work clothes at the job site prior to entering the restricted work area. Street clothing should be stored separately from used work clothing. The employer should provide disposable or reusable protective coveralls (made of breathable material) to reduce the lead contamination of other work clothing by blasters and groundsmen. The disposable coveralls should be properly disposed of after each shift, or more often if they are torn or damaged. If coveralls or work clothing are re-used, the contractor should arrange for laundering by an industrial laundry that has been notified of the lead contamination. Work clothing should never be carried home by the workers, as it represents a hazard to both the workers and their families.

10. Workers should be prohibited from consuming food, drink, or tobacco products in the restricted work area. After leaving the restricted work area, workers should wash their hands and faces before eating, drinking, or smoking. Grossly contaminated outer work clothing should be removed and stored before entering designated "clean" areas such as: eating areas, the office, and personal vehicles. Workers should wash or shower, and change back into their street clothes before leaving the job site at the end of the workshift.

11. The contractor should insure that designated clean areas, such as changing areas, the office, and washing facilities are cleaned and maintained daily to prevent the accumulation of lead-contaminated dust. Work vehicles should be cleaned more frequently to reduce the accumulation of contaminated dust. Lead hazard warning signs should be affixed to all work vehicles which enter the work area. Personal cars should not be used where they will be subject to contamination from lead dust.

12. A comprehensive hearing conservation program must be implemented at this company. The program should minimally be tailored to meet the requirements set forth in the Department of Labor's OSHA noise regulation.[29] Included in the regulation are sections addressing the need for audiometric testing, noise surveys, worker training, hearing protection devices, and recordkeeping. These requirements, as well as suggestions for engineering controls and program evaluation are included in a recent NIOSH publication.[35]

13. The use of hearing protection devices (HPD) should be made mandatory in all locations where noise levels exceed 85 dBA. The results of the dosimeter survey show that this includes nearly all of the areas of the lead abatement project. Workers should be given the opportunity to choose from among the available, effective types of HPDs. Supervisors must consistently enforce the use of the HPDs for all employees, including workers assigned to the area, workers assigned to other areas who are visiting the area, state officials, and visitors, while they are in the noise areas.

14. Audiometric testing must be done on an annual basis at this company. The recorded noise exposure levels are of sufficient intensity to regulate this practice, according to OSHA. The tests will identify individual employees who have changes in their hearing over their work history. The audiometric test program may identify workers who are experiencing greater hearing losses from the risk of lead and noise working

in concert with each other. The testing program will allow for intervention to slow down the progression of loss before it becomes a more severe handicap to the employee. These annual audiometric tests can also be used to evaluate the effectiveness of the hearing conservation program. New methods of audiometric database analysis are being developed in order to accomplish this kind of feedback on how the program is working.[36,37,38,39]

15. The practice of installing worker enclosures as a noise engineering control should be pursued wherever it is possible. It may be possible to put a portable noise attenuation chamber on the job site to offer the workers a quiet area to escape from the noise during break periods. This enclosure can also be kept free from lead-containing dust. If the workers can escape the noise in for even a portion of the workday, then their TWA noise exposures will be reduced.

Actions required by the OSHA general industry standard for various BLLs

Number of tests	BLL Result (µg/dl)[1]	Action required
1	$\geq$ 40[2]	Worker notification in writing; medical examination of worker and consultation
3 (average)	$\geq$ 50	Removal of worker from job with potential lead exposure
1	$\geq$ 60	Removal of worker from job with potential lead exposure
2	< 40[3]	Reinstatement of worker in job with potential lead exposure

1 In the OSHA general industry standard, BLLs are reported in micrograms per 100 grams of whole blood, which is approximately equal to micrograms per deciliter of whole blood (µg/dl).
2 Greater than or equal to 40.
3 Less than 40.

16. NIOSH recommends the use of medical monitoring provisions in the OSHA general industry standard (29 CFR 1910.1025)[21] for construction workers. However, NIOSH acknowledges that these workers may require more frequent blood lead monitoring (for example, monthly) than specified in the OSHA standard because of their highly variable, unpredictable exposures to lead. The OSHA general industry lead standard requires that certain actions be taken at various BLLs (see table above on right). These actions should be taken to prevent many of the adverse health effects of lead exposure.

17. Periodic biological monitoring for lead exposure will identify inadequacies in the worker protection program. Cases of significant BLL increase or BLL exceeding 25 µg/dl should trigger timely investigation of potential exposures, work practices, and PPE.

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