HETA 91-076-2164
DECEMBER 1991
SILVER DEER
BOULDER, COLORADO

NIOSH INVESTIGATOR:
Steven A. Lee, CIH

I. SUMMARY

In December 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request from Silver Deer, Boulder, Colorado, to evaluate lead exposure among workers in the leaded crystal grinding room. The company produces crystal art objects that contain 32% lead.

A previous NIOSH study conducted in 1984 found a mean air lead exposure of 50 micrograms per cubic meter (ug/m^3), and a mean blood lead level (BLL) of 29 micrograms per deciliter (ug/dl) among 7 grinding room workers. Under the Occupational Safety and Health Administration's (OSHA) lead standard, the permissible exposure limit for airborne lead is 50 ug/m^3 and BLLs should not exceed 40 ug/dl. Following the NIOSH survey, the company installed local exhaust ventilation (LEV) in the grinding room.

On January 23, 1991, NIOSH evaluated the effectiveness of the LEV system. Full-shift personal breathing-zone air samples were collected from all four of the grinding room employees present during the evaluation. In addition, NIOSH reviewed 18 BLLs of six grinding room employees collected and analyzed by the company between 10/89 and 12/90.

Air lead exposures ranged from 6.6 to 35 ug/m^3 with a mean of 18 ug/m^3 during the 1991 NIOSH visit. The highest exposure was apparently caused when leaded crystal was ground on a section of a grinder that had inadequate exhaust ventilation. The other lead exposures were below the OSHA action level of 30 ug/m^3. OSHA requires routine air sampling and medical monitoring for workers exposed to lead concentrations above the action level.

The mean BLL in grinding room workers from 10/89 to 12/90 was 12 ug/dl (range <10 to 24). These results show a statistically significant (P value <.01) decrease in BLLs after the installation of local exhaust ventilation.

Based on the results of this investigation, a health hazard from lead was not found in the grinding room at the time of the NIOSH visit. However, some further improvement regarding engineering controls and work practices were recommended to keep lead exposure as low as possible.

Keywords: SIC 3231 (art glass, made from purchased glass) leaded crystal, inorganic lead, blood lead, followback.

II. INTRODUCTION

In December 1990, a representative of Silver Deer, Ltd., requested that the National Institute for Occupational Safety and Health (NIOSH) conduct a Health Hazard Evaluation (HHE) at the plant to evaluate employee exposure to lead. A previous NIOSH HHE (HETA 84-384-1580) conducted in 1984, showed excessive exposure to lead among workers in the leaded crystal grinding room.[1] The company requested that NIOSH conduct a follow-up assessment of lead exposures after the addition of a local exhaust ventilation system to the grinders.

On January 23, 1991, NIOSH conducted air sampling and ventilation measurements in the grinding room and reviewed the company's blood lead levels for grinding room workers.

The air lead sample results were provided to the company by phone on March 4, 1991.

III. BACKGROUND

A. Process Description

The facility was built in 1982 and currently employs 65 people. Swarovski crystal, which contains about 32% lead, is imported from Austria and cut, ground, and polished into various art objects. Four people worked in the grinding room at the time of the NIOSH evaluation.

The grinding room has six grinding stations equipped with 8-inch (in) diameter horizontal disk grinders operated counterclockwise at 3450 revolutions per minute (rpm). The wheels are fitted with 3M 431Q TRI-M-ITE sandpaper ranging from number 120 to 320 grit. A constant stream of water runs onto the grinders to prevent burning the crystal. In 1986, the grinders were enclosed with local exhaust hoods consisting of 15-in x 15-in x 15-in plastic cases with a 5-in x 10-in opening cut into the front of each hood. The branch duct enters at the rear of the enclosure. The operator places one hand inside the exhaust hood to grind small pieces of crystal on top of the grinders.

The grinding room also contains a roughing wheel, a polishing wheel, and a cutting wheel. The rougher is a 30-in horizontal wheel coated with wet 180 grit silicon carbide and operated at 1740 rpm. The polisher is a 28-in horizontal wheel coated with wet cerium oxide and operated at 1740 rpm. The cutter is a 3-in metal vertical cutting wheel that is partially enclosed and ventilated with a slot local exhaust hood at the bottom of the wheel. The rougher and the polisher do not have local exhaust ventilation.

B. Previous Evaluation

In August 1984, an environmental and medical evaluation was conducted by NIOSH. Personal breathing-zone full-shift air samples were collected from four grinding room workers and analyzed for lead, total particulate, and crystalline silica. Blood samples were collected from 7 grinding room workers and 5 non-exposed workers and analyzed for lead.

Air lead exposures ranged from 30 to 60 micrograms per cubic meter (ug/m^3) with a mean of 50 ug/m^3. Three of the four grinding room employees were exposed to levels exceeding the OSHA permissible exposure limit (PEL) of 50 ug/m^3. Actual lead exposure may have been higher since the analytical method would not have detected lead bound by glass powder (e.g. lead silicate). There was no local exhaust ventilation in the grinding room during this evaluation. Exposure to total particulate ranged from 0.1 to 2.5 milligrams per cubic meter (mg/m^3) with a mean of 0.6 mg/m^3. No crystalline silica was detected in air or bulk samples.

Blood lead levels ranged from 22 to 36 micrograms per deciliter (ug/dl) with a mean of 29 ug/dl. The non-exposed workers had a mean blood lead of 7.2 ug/dl. The medical investigator found no evidence of lead poisoning among workers during the medical interviews. However, it was concluded that the average blood lead level among grinders was "at the upper limit of levels acceptable for pregnant women whose fetus needs protection." Therefore, it was recommended that "lead exposure be reduced so both men and women can have equal opportunity to work in the grinding room without concern for effects on possible pregnancies."[1]

IV. METHODS

A. Environmental

On January 23, 1991, an environmental survey was conducted to determine employee exposure to lead. Full-shift personal breathing-zone (PBZ) air samples were collected from three workers that operated grinders and one worker who operated the polisher for most of the shift. Short-term PBZ air samples were collected during the use of the rougher and the cutting wheel. Samples were collected on mixed-cellulose ester membrane filters using battery-powered sampling pumps operating at 2.0 liters of air per minute.

Atomic absorption spectroscopy was used to analyze the samples for "free" lead and lead bound by glass powder. The samples were ashed with nitric acid and the suspension was filtered. The filtrate was analysed for free lead according to NIOSH Method 7082.[2] This method normally would not detect lead from compounds, such as some lead silicates that are not soluble in nitric acid. Therefore, the remaining filter and residue were digested with hydrofluoric acid and analyzed for "bound" lead.

Air flow measurements of the local exhaust ventilation hoods were taken with a Kurz Model 490 mini-anemometer. Smoke tubes were used to observe air flow patterns near the hoods.

B. Medical

The results of the last three sets of blood samples from 6 grinding room workers were reviewed by the NIOSH investigator. The samples were collected in October 1989, May 1990, and December 1990, by Boulder Community Hospital and analysed for blood lead and zinc protoporphyrin (ZPP) by Nichols Institute Reference Laboratory, San Juan Capistrano, California. This laboratory is certified by OSHA to conduct blood lead analysis.[3]

V. EVALUATION CRITERIA

A. Environmental

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that 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 level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommended exposure limits (RELs), 2) the American Conference of GovernmentalIndustrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH RELs and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH RELs and ACGIH TLVs usually are based on more recent information than are the OSHA permissible exposure limits (PELs). The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STELs) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

A brief discussion of the toxicity and evaluation criteria for inorganic lead follows.

1. Inorganic Lead

Inhalation (breathing) of lead dust and fume is the major route of lead exposure in the industrial setting. A secondary source of exposure may be from ingestion (swallowing) of lead dust deposited on food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the peripheral and central nervous systems, gastrointestinal system, kidneys, reproductive system, hematopoietic system (blood forming organs), and virtually all other systems of the body.[4] The acute effects may manifest as weakness, tiredness, irritability, reduced intelligence, slowed reaction times, abdominal pain, or high blood pressure.[5] Chronic lead exposure can cause infertility, kidney damage, and, in pregnant women, fetal damage manifested as prematurity, reduced birth weight, reduced red blood cell production, and reduced intelligence.[6-10] The blood lead test is one measure of the amount of lead in the body and is the best available measure of recent lead absorption. The mean serum lead level for US men between 1976 and 1980 was 16 ug/dl;[11,12] 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 ug/dl.[4] A summary of the lowest observable effect levels of lead are listed in Table 1.

2. Lead Silicates

The toxicity of lead silicate compounds has been studied to determine if their low solubility makes them less toxic than other inorganic lead compounds. In an animal study comparing the toxicity of four lead silicates, no correlation was found between in-vitro solubility and absorption of lead from the lung. It was concluded that all of the compounds must be regarded as equally toxic.[13]

In a study comparing the toxicity of lead silicate in enameling plant workers to lead oxide in battery plant workers, it was determined that lead silicate was only slightly less toxic than lead oxide.[14]

The OSHA lead standard includes all inorganic lead compounds, metallic lead, and organic lead soaps.[15]

3. Medical Exposure Criteria

The OSHA lead standard requires annual blood lead testing for employees exposed to lead above the action level (30 ug/m^3).[15] If an employee's blood lead level is at or above 40 ug/100 grams of whole blood, the employee must have his blood lead checked every 2 months. If an employee's blood lead level averages 50 ug/100 grams of whole blood or more, he must be removed from areas containing more than 30 ug/m^3 airborne lead, and have monthly blood lead tests.[15] For employees removed from lead exposure, the OSHA lead standard requires the employer to maintain the earnings, seniority, and other employment rights and benefits of an employee as though the employee had not been removed. For an employee to return to work in the area with excessive lead exposure, their blood lead level must be below 40 ug/100 grams of whole blood on two consecutive tests if the original blood lead was between 50-60, or drop at least 20 ug/100 grams of whole blood on two consecutive tests if the original blood lead was greater than 60.[15] The blood samples must be analyzed by a laboratory that has been approved by OSHA.[3]

Zinc protoporphyrin (ZPP) levels measure the effect of lead on the red blood cell enzyme ferrochelatase, the last enzyme involved in the process of heme synthesis. In men, ZPP levels increase abruptly when blood lead levels rise above 35 ug/dl, and they tend to stay elevated for several months.[16] In women, ZPP level rise at a BLL of 25 ug/dl.[5] ZPP levels vary between laboratories, however most laboratories consider 50 ug/dl to be the upper limit of normal.[17]

4. Occupational Exposure Criteria

The current OSHA PEL for airborne lead is 50 ug/m^3 calculated as an 8-hour TWA for daily exposure.[15] In addition, the OSHA lead standard establishes an "action level" of 30 ug/m^3 TWA which initiates several requirements of the standard, including periodic exposure monitoring, medical surveillance, and training and education. If the initial determination shows that any employee's 8-hr TWA PBZ results are above 30 ug/m^3, air monitoring must be performed every six months until the results show two consecutive levels of less than 30 ug/m^3 (measured at least seven days apart).[15]

VI. RESULTS AND DISCUSSION

A. Environmental

The four grinding room employees had "free" (unbound) air lead exposures ranging from 6.6 to 30 ug/m^3 with a mean of 17 ug/m^3 (Table 2). Comparing these exposures to those found during the 1984 NIOSH visit shows a significant reduction ($p<.03$) for both normally distributed data (Student's t-Test) and non-normally distributed data (Kruskal-Wallis H).[18] Short-term samples collected during roughing and cutting were below the sampling and analytical limit of detection (<50 ug/m^3). "Bound" air lead exposures ranged from non-detectable (<3 ug/m^3) to 5 ug/m^3. The OSHA 8-hour PEL for all inorganic lead compounds is 50 ug/m^3.

The grinding wheel exhaust hoods each had face velocities ranging from 200 feet per minute (fpm) on the left side of the opening to 600 fpm on the right side of the opening. The American Conference of Governmental Industrial Hygienists recommends a capture velocity of at least 500 fpm for contaminants released at high velocities.[19] The counter clockwise motion of the wheels appeared to cause air flows that reduced capture efficiency at the far left side of the hood openings. Also, smoke generated in the hoods generally showed good capture except at the far left side of the wheels, where small amounts of smoke could occasionally be observed to escape the left side of the hood opening. Most grinding particles are much larger than smoke particles and, therefore, would be more likely to escape the exhaust hood due to their greater momentum.

The exhaust system appeared to work well for the two right-handed grinders who tended to use the 2 or 3 o'clock positions on the grinding wheels. However, one ambidextrous employee tended to use the 9 or 10 o'clock position of the wheel when he used his left hand. This grinder also had the highest air lead exposure during the NIOSH visit.

The cutting wheel exhaust hood had a face velocity of 1000 fpm and smoke tube observations indicated that it was effective. The roughing and polishing wheels do not have local exhaust ventilation. However, the slower speed of these wheels combined with the use of wet abrasives appeared to reduce the potential for high lead exposure.

In 1984, the NIOSH investigator observed a considerable amount of dust and water mist being emitted from the grinding wheels, however, these conditions were not apparent during the 1991 visit. Also, since the addition of the ventilation systems, the employees reported that the grinding room is much cleaner and more comfortable due to the lower humidity.

B. Medical

Eighteen blood lead levels (BLL) from 6 grinding room workers ranged from less than 10 to 24 ug/dl, with a mean of 12 ug/dl. Comparing these BLL to those collected by NIOSH in 1984 shows a significant reduction ($p<.01$) for both normally distributed data (Student's t-Test) and non-normally distributed data (Kruskal-Wallis H).[18] ZPP levels ranged from less than 16 to 20 ug/dl with a mean of 16 ug/dl.

VII. CONCLUSIONS

There was no overexposure to lead among grinding room workers at the time of the 1991 NIOSH visit. Exposure to airborne lead was below the OSHA PEL and BLL were within acceptable limits. Both air lead exposure and BLL were significantly lower than those found by NIOSH in 1984. The addition of local exhaust ventilation was probably responsible for this decrease.

VIII. RECOMMENDATIONS

The actions taken to reduce lead exposure are commendable; however, to ensure that workers are adequately protected from the adverse effects of lead, a comprehensive program of prevention and surveillance is needed. The requirements for such a program are clearly presented in the OSHA lead standard.[15] In addition to specifying PELs for airborne exposure, the OSHA lead standard contains specific provisions dealing with mechanical ventilation, respirator usage, protective clothing, housekeeping, hygiene facilities, employee training, and medical monitoring.

A copy of the OSHA lead standard was provided to the employer and will not be repeated in detail in this report. However, to assist the employer in implementing the standard's key provisions, a brief overview related to the NIOSH findings follow.

A. Mechanical Ventilation

It may be possible to increase the efficiency of the grinder exhaust ventilation by redesigning the hoods as recommended by the American Conference of Governmental Industrial Hygienists (Figure 1).[19] This hood provides a much tighter enclosure with only one inch of clearance around the sides and the top of the grinder. The opening is over the top of the grinder and could be made considerably smaller since the operator would not place his entire hand through the opening. A smaller opening would result in a greater face velocity and reduce the possibility of lead dust escaping from the hood. Due to the close clearances, however, problems might be encountered in accommodating the flow of water over the grinder or in working with larger pieces of crystal.

Actually, the local exhaust ventilation system currently being used appeared to be effective as long as the operators used the portion of the grinder where the ventilation capture velocity was highest. Either blocking off the left side of the grinding wheel or worker training should be used to ensure that lead exposure is controlled below the OSHA action level of 30 ug/m^3.

OSHA requires that ventilation measurements, such as capture velocity, duct velocity, or static pressure, be conducted at least every 3 months. Also, measurements of the systems effectiveness must be made within 5 days of any change in production, process, or control which might result in a change in employee exposure to lead.[15]

B. Air Monitoring

Periodic monitoring for airborne lead is needed to ensure that engineering controls operate effectively. Air monitoring can also be used to identify the need for further employee protection (i.e., respirators) in certain areas or during certain procedures. When airborne exposures are found to be above the OSHA action level of 30 ug/m^3, the OSHA lead standard calls for repeat monitoring every 6 months. This monitoring must be continued until such time as concentrations are found to be below this level in two consecutive measurements conducted at least 1 week apart. Additional monitoring is required whenever there has been a production, process, control, or personnel change which may result in a change in employee exposure to lead. Employees must be informed of the monitoring results.[15]

C. Hygiene

Food, beverages, or tobacco must not be used or stored in lead-contaminated areas. These items can become contaminated with lead and cause subsequent absorption of lead through inhalation or ingestion during eating, drinking, or smoking. Employees should also eat their lunch in a lunchroom separate from the grinding room. All protective clothing should be removed prior to entering the lunchroom, and hands and face should be thoroughly washed.

D. Housekeeping

Housekeeping plays an important role in controlling lead exposures. Dust which has accumulated on surfaces can be reintroduced into the air, thereby increasing airborne lead exposures. Also, dust accumulated on chairs or work surfaces can cause unnecessary contamination of the employees' clothing. Therefore, all surfaces in the grinding room should be kept as free as practical of the accumulation of dust. Vacuuming, using a high efficiency particulate aerosol (HEPA) filter, is the preferred means of removing lead dust. Sweeping should not be used except in areas where vacuuming is not feasible. A regular housekeeping program should be established to ensure that all areas are periodically cleaned. Pertinent specifications to consider when selecting vacuum cleaners are included in

Appendix 1.[20]

E. Medical Monitoring

While the previously discussed recommendations have been designed to prevent or minimized lead exposure, medical monitoring plays a supplemental role in that it ensures that the other provisions of the program have effectively protected the individual. The OSHA standard for inorganic lead places significant emphasis on the medical surveillance of all workers exposed to levels of inorganic lead above the action level of 30 ug/m^3 TWA. Even with adequate worker education on the adverse health effects of lead and appropriate training in work practices, personal hygiene and other control measures, the physician has a responsibility for evaluating potential lead toxicity in the worker. It is only through a careful and detailed medical and work history, physical examination and appropriate laboratory testing, that an accurate assessment can be made. Many of the adverse health effects of lead toxicity are either irreversible or only partially reversible, so early detection of disease is very important.[6]

The OSHA lead standard provides detailed guidelines on the frequency of medical monitoring, the important elements in medical histories and physical examinations as they relate to lead, and the required laboratory testing for evaluating lead exposure and toxicity. This standard should be consulted by plant management and the local physician for guidance in carrying out an ongoing medical monitoring program.[15]

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X. AUTHORSHIP AND ACKNOWLEDGMENTS

Report Prepared By:	Steven A. Lee, M.S., C.I.H. Industrial Hygienist NIOSH - Denver Regional Office Denver, Colorado
Environmental Laboratory Analysis:	Datachem Salt Lake City, Utah
Originating Office:	Hazard Evaluation and Technical Assistance Branch Division of Surveillance, Hazard Evaluations and Field Studies Cincinnati, Ohio
Report Typed By:	Marile F. DiGiacomo Secretary NIOSH - Denver Regional Office Denver, Colorado

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1. Silver Deer
2. Occupational Safety and Health Administration - Region VIII
3. NIOSH Regional Offices/Divisions
4. Colorado Department of Health

For the purposes of informing the affected employees, copies of the report should be posted in a prominent place accessible to the employees, for a period of 30 calendar days.

TABLE 1
Summary of Lowest Observed Effect Levels for
Key Lead-Induced Health Effects in Adults and Children[@]

BLL[*] (ug/dl)		HEALTH EFFECT	
>100	Adults:	Encephopathic signs and symptoms	
>80	Adults:	Anemia	
	Children:	Encephopathic signs and symptoms	
		Chronic nephropathy (aminoaciduria, etc)	
>70	Adults:	Clinically evident peripheral neuropathy	
	Children:	Colic and other Gastro-Intestinal (GI) symptoms	
>60	Adults:	Female reproductive effects	
		CNS symptoms:	sleep disturbances, mood changes, memory and concentration problems, headache.
>50	Adults:	Decrease hemoglobin production	
		Decreased performance on neurobehavioral tests	
		Altered testicular function	
		GI symptoms:	abdominal pain, constipation, diarrhea, nausea, annorexia
	Children:	Peripheral neuropathy	
>40	Adults:	Decrease peripheral nerve conduction	
		Elevated blood pressure (white males, 40-59 years old)	
		Chronic nephropathy	
	Children:	Reduced hemoglobin synthesis	
>25	Adults	Elevated erythrocyte protoporphyrin levels in males	
15-25	Adults	Elevated erythrocyte protoporphyrin levels in females	
	Children:	Decreased IQ and Growth	
>10[**]	Fetus:	Pre-term Delivery	
		Impaired Learning	
		Reduced Birth Weight	
		Impaired Mental Ability	

[@] Adopted from ATSDR[6], and Goldman et al.[27].
[*] Blood Lead Level (BLL) in micrograms per deciliter (ug/dl)
[**] Current research has not defined a "safe" level for fetuses.

TABLE 2

Air Lead Exposure (ug/m^3)
Silver Deer, LTD.
Boulder, CO
HETA 91-076

January 23, 1991

Job/Location	Sample Time	Free Lead	Bound Lead
Long-Term Samples			
Grinder, Rayt 2	0645 - 1425	6.6	N.D.*
Grinder, Rayt 3	0743 - 1430	11	N.D.
Grinder, Rayt 8	0650 - 1422	30	5.0
Polisher	0648 - 1419	19	N.D.
Short-Term Samples			
Roughing	1015 - 1045	N.D.	N.D.
Roughing	1330 - 1345	N.D.	N.D.
Cutting	1415 - 1430	N.D.	N.D.

Evaluation Criterion 50

* N.D. = Below the sampling and analytical limit of detection (approximately 3 ug/m^3 for long-term samples and 50 ug/m^3 for short-term samples)

APPENDIX 1

VACUUM CLEANING SPECIFICATIONS

The following specifications should be used as a guide in selecting industrial vacuum cleaning equipment:

1. Hose and tools may be 1 1/2 inches or 2 inches. 1 1/2 inches requires 75 CFM and 2 inches requires 150 CFM per nozzle. The smaller size hose is easier to use and less expensive but does not clean as fast.

2. The exhaust blower should be capable of developing one inch of mercury (13.6" of water) static pressure at the cleaning nozzle.

3. The dust container should have adequate holding capacity so that it does not have to be emptied frequently.

4. The pre-filter should be made of standard industrial filter cloth with an air to cloth ratio of less than four to one.

5. HEPA filters must be used where lead dust is being handled.