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HAZEN RESEARCH, INC.
GOLDEN, COLORADO

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I. SUMMARY

In April 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate employee exposures to lead at Hazen Research, Inc. located in Golden, Colorado. The company uses lead oxide to extract precious metals from mining samples in a process known as "fire assaying."

In June 1989, NIOSH investigators conducted an environmental and medical survey at the facility, which is run by one full-time assayist. One personal breathing-zone (PBZ) sample, 3 general area air samples, and 4 short term area samples were collected in the fire assay laboratory to determine concentrations of airborne lead. The assayist, and 1 office employee completed a self-administered questionnaire, and provided a blood sample for blood lead and free erythrocyte protoporphyrin (FEP) analysis.

The 8-hour time-weighted average (TWA) PBZ concentration of lead for the assayist was 10 micrograms per cubic meter (ug/M^3); below OSHA's Permissible Exposure Limit (PEL) of 50 ug/M^3, and OSHA's Action Level of 30 ug/M^3. The 3 general room samples had 8-hour TWA of 30, 30 and 10 ug/M^3. The 4 short term samples were all below the sampling and analytical limit of quantification (3.3 ug/M^3).

Neither the assayist or the management employee reported symptoms associated with lead toxicity. Both had blood lead levels less than 40 ug/dl, the level above which the OSHA standard requires more frequent monitoring. In addition, both had FEP levels within the normal range (<50 ug/dl).

On the basis of the data collected during this survey, a potential for employee exposure to lead existed in this company's fire assay laboratory, although the one measured personal exposure was below OSHA's action level. At the time of this survey some aspects of the OSHA lead standard needed implementation.

KEY WORDS: SIC 1041 (Gold Ores), Fire Assay, Gold Assay, Lead, Blood Lead, FEP, ZPP, Litharge

II. INTRODUCTION

In April 1989, NIOSH received a request from Golden Research Labs in Golden, Colorado to evaluate employee exposures to lead in the company's fire assay operations.

On June 6 1989, NIOSH personnel conducted an environmental and medical survey of the facility. On June 7, 1989, a copy of the OSHA lead standard, a list of OSHA approved laboratories for analyzing blood lead, and a copy of NIOSH's Guide of Industrial Respiratory Protection was sent to the laboratory's manager. On June 24, 1989, the environmental results were telephoned to the manager, and individual blood test results were sent to participating employees.

III. BACKGROUND

A. General Description of Fire Assaying

The fire assaying process separates noble metals, such as gold and silver, from their ores using dry reagents and heat. The process, which can be traced back to 2600 B.C., is still used today due to its ability to concentrate minute amounts of precious metals from relatively large ore samples.[1] Despite its long history, the exact chemical reactions involved in the process are not completely understood.

The first step in the fire assay process is "sample preparation". During this step the various ore samples are ground, milled, and crushed to approximately 5 mesh size.

The second step is "charge" preparation. "Charges" are prepared in a fireclay crucible by adding dry reagents (flux) to a finely crushed sample of the ore. The dominant reagents used in this operation are lead oxide and wheat flour. Other flux reagents include sodium carbonate, silica, borax, and potassium nitrate in varying concentrations.[1] To extract all the precious metals from each ore sample, the flux's composition needs to be "adjusted" to accommodate the ore's oxidizing, reducing, or neutral characteristics. This delicate process of "adjusting" the flux to accommodate the ore's characteristics makes assaying more of an art than a science. During this mixing procedure a small quantity of oil was added to the flux to keep dust levels down.

The third step is called crucible fusion. In this process approximately 24 of the "charged" fire clay crucibles are placed in a furnace. As the temperature reaches approximately 1600°F, the carbon contained in the flour reduces a portion of the lead oxide to lead droplets. These droplets then alloy with the noble metals

released from the decomposed ore. The remaining litharge forms silicates and other compounds which mix with the slag produced from the ore. After 44 to 55 minutes, the crucibles are removed from the oven and the molten contents are quickly poured into iron molds. The lead droplets then settle through the slag to form a "button" at the bottom of each mold. After cooling, the slag is broken away from the molds using a small hammer, and the lead buttons containing the noble metals are collected.[1]

The fourth step involves separating the noble metals from the lead by a process called "cupellation". The lead buttons obtained from the crucible fusion are hammered into squares and placed in small containers made from compressed bone ash (cupels). The cupels are reintroduced into the furnace at approximately 1500°F for 60-75 minutes. The lead button oxidizes into molten lead oxide, of which 98.5% is absorbed into the porous cupel, and 1.5% is volatilized.[1] The bone ash cupel absorbs the molten lead oxide, but is impermeable to the noble metals. Thus, when the cupels are removed from the oven, small beads of the noble metals remain in the center of each cupel. These beads are weighed and further analyzed for their gold and silver content.[1]

B. Description of Company Operations

The Hazan assay laboratory operates out of one small room, separate from the company's main research offices and labs. This assay room contains one crucible fusion furnace, one cupel furnace, a work area/table to prepare the flux and crucible charges, a second work table for pouring the crucibles into the molds, and the scale area to weigh the precious metals extracted. At the time of this survey, the assay lab employed one assayist, with the ore samples being prepared by employees working in the separate "sample preparation" building. This building contains one preparation employee, one chemist, and two office employees. The daily workload varies widely, but typically the lab analyzes 40 ore samples per day.

C. Personal Protection, Administrative and Engineering Controls

Personal protective equipment worn by the employees when in the assay laboratory included gloves, face shields, and respirators.
Employees wear disposable dust masks (TC-21C-344) or HEPA #9920 in the furnace rooms while performing the following procedures: mixing flux, preparing charges, removing the crucibles from the furnace, and removing the cupels from the furnace. The company does not provide coveralls and the employees are responsible for laundering their own clothes. Hand-washing facilities are located in the assay lab; however a shower is not provided.

No local exhaust ventilation was provided for controlling lead exposure during the scooping of litharge from the drums, preparing the fluxes, or charging the crucibles. A new assay laboratory is under construction which will provide local exhaust ventilation for these procedures.

IV. MATERIALS AND METHODS

A. Environmental

On June 6, 1989, an environmental survey was conducted to determine employee exposures to lead. During this survey, one personal breathing-zone (PBZ) air sample was collected near the worker's breathing-zone, and 3 general area air samples were collected at following locations: above the flux mixing area, above the cupullation furnace, and in the scale area. The four short-term samples were taken during the following procedures: mixing flux, mixing sample, pouring hot sample. Samples were obtained using battery-powered sampling pumps operating at 2.0 or 3.0 liters of air per minute. The pumps were attached by Tygon tubing to the collection media (37-millimeter, 0.8-micron pore size, mixed-cellulose ester membrane filters contained in 3-piece plastic cassettes).

The samples were analyzed for lead by atomic absorption spectroscopy according to NIOSH method 7082.[2] Air flow measurements of the local exhaust ventilation hoods were taken with a Kurz Model 490 mini-anemometer.

B. Medical

The assayist and 1 management employee were invited to participate in the survey. The survey consisted of: 1) a self-administered questionnaire, and 2) a blood sample analyzed for lead and free erythrocyte protoporphyrin (FEP). The questionnaire was designed to gather demographic information and data on symptoms associated with lead poisoning. The blood leads and FEPs were analyzed in a laboratory approved by the Occupational Safety and Health Administration (OSHA), based on proficiency testing, for blood lead analysis.[4] Blood lead concentrations were determined utilizing anodic stripping voltametry, and FEP levels were determined by photofluorometric techniques.[5]

V. EVALUATION CRITERIA

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 important, however, 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 often are 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 becomes available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor/Occupational Safety and Health Administration (OSHA) occupational health standards [Permissible Exposure Limits (PELs)]. A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday.

A brief discussion of the toxicity and evaluation criteria for inorganic lead follows. A summary of the lowest blood levels causing observable effects in adults are listed in Table 1.

A. Toxicological

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 kidneys, peripheral and central nervous systems, and blood forming organs (bone marrow). These effects may be manifested as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, cognitive impairment, or slowed reaction times. Chronic lead exposure is associated with infertility and with fetal damage in pregnant women. There is some evidence that lead can also impair fertility in occupationally exposed men.[6]

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. Adults not exposed to lead at work usually have a blood lead concentration less that 30 ug/dl; the average is less than 15 ug/dl.[7,8] In 1985, the Centers for Disease Control (CDC) recommended 25 ug/dl as the highest acceptable blood level for young children.[9] Since the blood lead concentration of a fetus is similar to that of its mother, and since the fetus's brain is presumed to be at least as sensitive to the effect of lead as a child's, the CDC advised that a pregnant woman's blood lead level be below 25 ug/dl.[9] Recent evidence suggests that the fetus may be adversely affected at blood lead concentrations well below 25 ug/dl.[10] Furthermore, there is evidence to suggest that levels as low as 10.4 ug/dl affect the performance of children on educational attainment tests, and that there is a dose-response relationship with no evidence of threshold or safe level.[11] Aside from fetal effects, lead levels between 40-60 ug/dl in lead-exposed workers indicate excessive absorption of lead and may result in some adverse health effects. Levels of 60-100 ug/dl represent unacceptable elevations which may cause serious adverse health effects. Levels over 100 ug/dl are dangerous and require medical treatment.

Free erythrocyte protoporphyrin (FEP) levels measure the effect of lead on heme synthetase, the last enzyme involved in the process of heme synthesis. FEP levels increase abruptly when blood lead levels reach about 40 ug/dl, and they tend to stay elevated for several months. The FEP can also be elevated as a result of iron deficiency. A normal FEP level is less than 50 ug/dl.[12]

B. Occupational Exposure Criteria

The current OSHA PEL for airborne lead is 50 ug/m^3, calculated as an 8-hour TWA for daily exposure.[13] 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. For example, if an employer's initial determination shows than any employee may be exposed to more than 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). The standard also dictates that a worker with blood lead levels greater than 60 ug/dl, or averaging more than 50 ug/dl, must be removed from further lead exposure until the blood lead concentration is at or below 40 ug/dl. Removed workers have protection for wages, benefits, and seniority for up to 18 months.[13]

VI. RESULTS AND DISCUSSION

A. Environmental

The assayist had an 8-hour TWA PBZ lead concentration of 10 ug/m^3. Short-term samples during 3 procedures were below the sampling and analytical limit of quanitation (3.3 ug/M^3). The eight-hour TWA lead concentration for the furnace area was 30 ug/m^3. The scale area had 30 ug/m^3, and the mixing area had 10 ug/m^3.

B. Medical

Neither the assayist or the management employee reported symptoms associated with lead toxicity. Both had blood lead levels less than 40 ug/dl, the level above which the OSHA standard requires more frequent monitoring. In addition, both had FEP levels within the normal range (<50 ug/dl).

VII. DISCUSSION

Although the OSHA lead standard does not require continued environmental and medical monitoring for airborne lead levels below the action level, given the general area sample results showing the potential for employee lead exposure, we recommend annual environmental and medical monitoring be performed. Other aspects of the OSHA lead standard needing implementation at the time of this survey included: a formalized respirator program, shower facilities, and the provision of protective clothing with laundry service. The company is planning to implement these programs and items when its new facility becomes available. A complete description of these programs and items is addressed in the following recommendations section.

VIII. CONCLUSIONS

The environmental survey revealed lead exposure below the OSHA PEL and action level for the assayist. The medical survey revealed a blood lead level below the OSHA lead standard, and no symptoms consistent with lead exposure.

IX. RECOMMENDATIONS

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 presented in the OSHA lead standard mailed to the laboratory on June 7, 1989. The OSHA lead standard contains information on PELs for airborne exposure, frequency of environmental monitoring, provisions for mechanical ventilation, respirator usage, protective clothing, housekeeping, hygiene facilities, employee training, and medical monitoring. The implementation of these provisions will help ensure continued employee protection from potential adverse health effects of lead exposure. The following programs needed implementation at the time of this survey.

A. Respiratory Protection

In order to ensure the effective use and function of the respirators, a comprehensive respiratory protection plan should be put in place. Such a program is outlined by the American National Standard Institute in ANSI Standard Z88.6-1984.[15] The program should include a written standard operating procedure which addresses respirator selection, training, fitting, testing, inspection, cleaning, maintenance, storage, and medical examinations.[16]

B. Work Clothing

Wherever lead dust is present, there is a possibility that the employee's skin and clothing may become contaminated. This can lead to subsequent inhalation or ingestion of the lead, which can substantially increase the employee's overall absorption of lead. In addition, lead contamination on skin or clothing may be transported to other areas of the facility, and possibly to the worker's home where secondary exposure of co-workers or family members can occur. In one recent study, blood lead levels were found to be markedly higher in household members residing in homes of workers with occupational lead exposure than in homes of people not occupationally exposed to lead.[17] In order to prevent this secondary source of lead exposure, the appropriate use of dedicated work clothing is required.

C. Hygiene Facilities and Practices

For workers exposed to air lead concentrations above the OSHA PEL, a separate change room, free from lead contamination, must be provided to the employees to store their "street" clothing. Street clothing must be stored separately from clothing worn during work. Showers must be taken at the completion of the work shift to remove any lead that may have reached the employees' skin. Clothing worn at work must not be worn home. The employer must provide work clothing to workers exposed to air lead concentrations above the PEL, and the employer must assure that contaminated clothing is laundered or discarded.[13]

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 ingestion or inhalation during eating, drinking, or smoking. Employees should also eat their lunch in a lunchroom separate from the assay lab. All protective clothing should be removed prior to entering the lunchroom, and hands and face should be thoroughly washed.

X. REFERENCES

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XII. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Services (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from the NIOSH publications office at the Cincinnati, address. Copies of this report have been sent to:

A. Hazen Research, Inc.
B. Occupational Safety and Health Administration - Region VIII
C. NIOSH Regional Offices/Divisions
D. 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

Lowest Blood Lead Levels Reported To Cause Various Health Effects In Adults

Blood Lead Level	Health Effect
100-120 ug/dl	Central nervous system toxicity (encephalopathy)
100 ug/dl	Chronic renal damage
80 ug/dl	Low blood count (anemia)
60 ug/dl	Pregnancy complications
50 ug/dl	Decreased hemoglobin production mild central nervous system symptoms
40 ug/dl	Decrease peripheral nerve conduction pre-term delivery
30 ug/dl	High blood pressure