HETA 97–0292–2678
General Electric — Bridgeville Glass Plant
Bridgeville, Pennsylvania

Ronald M. Hall
Elena Page, M.D., M.P.H.
Dino Mattorano
Kevin Roegner, M.P.H.

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Ronald M. Hall, Elena Page, Dino Mattorano, and Kevin Roegner of the Hazard Evaluations and Technical Assistance Branch (HETAB), Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Analytical support was provided by Data Chem Laboratories, Salt Lake City, Utah. Desktop publishing was performed by Ellen E. Blythe. Review and preparation for printing was performed by Penny Arthur.

Copies of this report have been sent to employee and management representatives at General Electric — Bridgeville Glass Plant and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self–addressed mailing label along with your written request to:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800–356–4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Health Hazard Evaluation Report 97–0292–2678
General Electric — Bridgeville Glass Plant
Bridgeville, Pennsylvania
March 1998

Ronald M. Hall
Elena Page, M.D.
Dino Mattorano
Kevin Roegner

SUMMARY

On August 15, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the International Union of Electrical, Radio, and Machine Workers. This request centered on a union concern that employees at General Electric — Bridgeville Glass Plant (GEBGP), Bridgeville, Pennsylvania, were exposed to hazardous concentrations of mercury (Hg) during glass tubing manufacturing and maintenance activities.

An industrial hygiene and medical evaluation was conducted on October 6–7, 1997. Hg concentrations were determined using a Jerome® model 431–x Hg vapor analyzer and solid sorbent tube techniques. Six employees were interviewed and the results of the company's urine monitoring were reviewed.

Full–shift area air samples collected in the cullet processing building ranged between 3.3 micrograms (µg) of Hg per cubic meter of air (µg/m^3) and 775 µg/m^3. Two of these results were above the NIOSH recommended exposure limit (REL) of 50 µg/m^3 and four were above the American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Value (TLV®) of 25 µg/m^3. Two area samples were greater than the Occupational Safety and Health Administration (OSHA) ceiling limit of 100 µg/m^3.

The Jerome® Hg vapor analyzer indicated concentrations between 6 and 19 µg/m^3 in the general area outside the dryer containment area with the dryer off. Inside the dryer containment area (around the dryer) concentrations ranged from 50 to 330 µg/m^3 with an average of 170 µg/m^3. With the dryer operating (without cullet being processed) for 15 minutes, concentrations were between 40 and 300 µg/m^3 with an average 150 µg/m^3. With the dryer operating and cullet being processed, concentrations ranged from 400 to 900 µg/m^3. Hg concentrations upstairs (near the elevator) with the dyer operating and cullet processed ranged from 300 to 900 µg/m^3. The operation was shut down following these readings.

Bulk samples of dust and cullet (collected in the cullet processing areas of the plant) indicate that there is currently Hg contamination. The most contaminated area was inside the dryer containment. Hg concentrations in this area ranged from 49 µg of Hg per gram of material (µg/g) to 51,000 µg/g. Bulk sample results confirm that the cullet processing system is still contaminated with Hg even after the system had been thoroughly cleaned. Bulk samples were also analyzed for lead and cadmium. In the cullet processing building, lead concentrations ranged between 160 µg/g and 9,900 µg/g, and cadmium concentrations ranged between 0.11 µg/g and 65 µg/g. Lead and cadmium air samples at the plant ranged from 1.6 to 51 µg/m^3 and 0.06 to 4.8 µg/m^3, respectively. One personal breathing zone (PBZ) sample measured cadmium at 1.5 µg/m^3 and lead at 14 µg/m^3 in the cadmium building. The results of the PBZ sample were below the OSHA exposure limits for lead (50 µg/m^3) and cadmium (5 µg/m^3).

The medical evaluation consisted of reviewing medical records for six employees who had been evaluated for Hg poisoning at the University of Pittsburgh and at West Virginia University. Also, six employees were interview. Of those interviewed two had undetectable urine Hg levels, one had a level below 35 micrograms per gram creatinine (µg/g–Cr) and asked to be interviewed, two had elevated urine Hg levels, and one was a former employee. The former employee had previously been responsible for the loading and transporting of cullet (with a front end loader) from the storage area to the cullet processing building for more than 10 years. Urine Hg levels were done by the company on 192 of the 200 employees at the plant. Eight employees either declined testing or were out on long term leave. All results were reviewed. Sixty–five (33.8%) had urine Hg levels below the limit of detection. The range of urine Hg levels among those employees with detectable levels was 1.4 µg/g–Cr to 345.4 µg/g–Cr. The World Health Organization (WHO) recommends a threshold level of 50 µg/g Cr, and ACGIH® has set a Biologic Exposure Index (BEI®) of 35 µg/g Cr. Twenty–nine employees (15.1%) had levels greater than (>) 35 µg/g–Cr, and twenty (10.4%) had levels > 50 µg/g–Cr.

Serious Hg contamination exists at the plant even after extensive clean–up. Samples indicate a potential for over–exposure to cadmium and lead. Recommendations are included in the body of this report to protect workers from Hg, lead, and cadmium exposures. Biological monitoring for Hg should continue for those employees with elevated urine Hg levels.

Keywords: SIC 3229 (Pressed and Blown Glass and Glassware), mercury, urine mercury, central nervous system, renal system, kidneys, cullet, glass recycling, lead, cadmium.

TABLE OF CONTENTS

INTRODUCTION

On August 15, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the International Union of Electrical, Radio, and Machine Workers with the support of General Electric—Bridgeville Glass Plant (GEBGP) management. This request centered on the concern that employees at the GEBGP in Bridgeville, Pennsylvania, were exposed to hazardous concentrations of mercury (Hg) during the manufacture of glass tubing and related maintenance activities. In response to this request, NIOSH investigators conducted a site visit on October 6–7, 1997.

The NIOSH investigation consisted of concurrent industrial hygiene and medical evaluations. Hg exposure monitoring was conducted on October 7, 1997, using a Jerome® model 431–x Hg vapor analyzer, and by collecting solid sorbent tube samples. Bulk dust samples from the cullet (scraps of broken or waste glass) processing areas were collected and analyzed for Hg, lead, and cadmium. The medical evaluation consisted of interviews with several employees. Blood and urine Hg levels on file for all employees were reviewed. In addition, the physician responsible for the medical evaluations of employees with urine Hg > 50 micrograms per gram creatinine (µg/g–Cr) as well as any other employees who desired medical evaluation, were interviewed about the extent of the work–up being performed.

BACKGROUND

The GEBGP operates 3 shifts a day, 7 days a week , 365 days a year. The plant occupies 11 acres and employs approximately 200 workers. Last year the plant manufactured 45 million pounds of glass and produced over 750 different glass products.

During the flourescent lamp manufacturing process, Hg is inserted into glass tubes. The change in electron levels of the Hg generates an ultraviolet light that is absorbed by the white coating (phosphor) on the inside of the glass tube. The white coating inside the glass tube then re–emits the light as visible light. During production, the tips of the glass tubes are removed after the Hg has been inserted. These tips (cullet) are then collected and sent to lead glass manufacturing plants for recycling. The cullet from the flourescent lamp manufacturing process may be contaminated with trace amounts of Hg.

The GEBGP recycled cullet from three flourescent lamp assembly plants. The cullet was stored on a cement slab inside a storage building (P–4). A front end loader would remove the cullet from the storage building and transport it to a loading chute located outside of the cullet processing building. From the chute, the cullet was transported through the building by a system of conveyor belts to an enclosed elevator and then to storage bins. From the storage bins, the cullet was conveyed to a crusher and then a dryer (located downstairs inside the building). The cullet would then be transferred to another series of storage bins. At this point, raw batch materials (i.e., sand, lead, and cadmium) were mixed into the cullet. The cullet was then melted in a furnace and formed into new glass tubes.

Past environmental sampling by GEBGP did not detect elevated Hg levels. However, on June 11, 1997, contract workers discovered Hg in the ventilation system originating from the dryer. During the removal of duct work, located on the roof of the building, workers noticed a visible amount of Hg fall from the duct work to the roof below. GEBGP contacted an environmental consultant to clean this area, who responded on the day of the request. Although GEBGP considered this to be an isolated event, contract workers at the site on June 17, 1997, reported feeling ill and one worker reported that his gold necklace turned silver after working at the plant that day. These employees were interviewed by the company in an effort to determine where the exposures had occurred. Work activities were suspended and medical appointments were scheduled at a local university medical center for the symptomatic employees.

On June 18, 1997, the environmental consultant was again contacted, and requested to identify all Hg – contaminated areas. Based on the consultants evaluation, GEBGP notified employees of the Hg contamination, and established control areas to isolate the Hg contamination. In addition, the company implemented personal protective equipment measures (i.e., respirators with Hg cartridges) to help protect employees that may be exposed to Hg.

On June 19, 1997, the company initiated various strategies and procedures to isolate and clean Hg – contamination, including hand wiping, and vacuuming, pressure wash, acid wash, and barrier coating techniques on all exposed surfaces (floors, walls, and ceilings). Equipment cleaned in the cullet processing building included conveyor systems, elevators, storage bins, cement floors, crushers, dryer, and equipment used to handle cullet (i.e., carts, and shovels). Company readings obtained with the Jerome® Hg analyzer indicated Hg concentrations as high as 900 µg of Hg per cubic meter of air (µg/m^3) in the dryer area. This area was isolated with plastic barriers and maintained under negative pressure (relative to areas outside the enclosure) with three negative air–pressure inducing machines equipped with high efficiency particulate air (HEPA) filters and charcoal filters. No employees currently work inside the isolated area around the dryer. Once the Hg contamination problem was identified, GEBGP stopped receiving the Hg–contaminated cullet from the flourescent lamp manufacturing plants. During our evaluation, no cullet from flourescent lamp manufacturing plants was stored or used at GEBGP. GEBGP has reported that it will not accept this type of cullet in the future.

Cadmium glass manufactured at GEBGP makes up approximately three percent of the total production. Cadmium is used to manufacture glass that is within Department of Transportation (DOT) specifications for amber turn signals used in the automobile industry. Cadmium oxide and cadmium sulfide are delivered to the cadmium building in 50–pound cans. A worker will place one of the 50–pound containers in an enclosed, ventilated glove box where it is mixed into the batching system, and transported through an enclosed pneumatic system to the building where the furnace is located. At this point, the material is mixed with the cullet and fed to the furnace. Lead oxide is also mixed into the cullet to induce pliability for use in manufacturing various types of lamps. The lead oxide for the 539 glass is mixed in the 539 mixing area, located in the cullet processing building. No lead oxide mixing was conducted during the evaluation.

METHODS

Industrial Hygiene

A walk–through inspection of the facility was conducted to familiarize NIOSH personnel with the process, specifically the flow of the Hg–contaminated cullet through the facility. After the walk–through inspection, full–shift area samples for Hg were collected in eight separate locations. Seven of these area samples were located inside the building where the cullet is processed and one was located in the P–4 building where the cullet is stored prior to processing. Area samples were collected in the cullet processing building as indicated in Table 1. Outdoor and indoor background samples were collected in the parking lot (hanging on the visitor parking sign) and in the office area, respectively.

NIOSH Method 6009 was used for airborne solid sorbent samples of Hg.[1] Air was drawn through a solid sorbent tube containing 200 milligrams (mg) of hopcalite at a nominal flow rate of 200 cubic centimeters per minute (cc/min). The samples were prepared by adding 2.5 milliliters (mL) of concentrated nitric and hydrochloric acids to a vial containing the hopcalite granules and glass wool plugs. After this preparation, the samples were diluted to volume and analyzed using a Leeman Labs PS200 Hg Analyzer.

A Jerome® model 431–x Hg vapor analyzer was used to collect real–time measurements of Hg. Measurements were collected in the containment area around the dryer, through–out the cullet processing building, and in the P–4 building. The dryer was not in production during the survey. However, it was operated briefly (for a few minutes) to determine the potential for vaporization of any latent Hg contamination.

Seven full–shift area samples for lead and cadmium were collected at the locations indicated in Table 2. Area samples for lead and cadmium were also collected in the P–4 storage building and the cadmium processing building (above the enclosed glove box near the worker's breathing zone). Indoor and outdoor background samples for lead and cadmium were collected in the office area and the parking lot (hanging on the visitor parking sign). One personal sample was collected for lead and cadmium while the worker performed assigned tasks in the cadmium building, including mixing cadmium in the enclosed glove box. Air samples for lead and cadmium were analyzed quantitatively using a Thermo Jarrell Ash ICAP–61 inductively coupled plasma emission spectrometer according to NIOSH Method 7300.[1] These samples were collected on 37–mm diameter mixed cellulose ester (MCE), 0.8–µm pore–size filters using sampling pumps calibrated at 3.0 liters per minute (Lpm).

Bulk samples of cullet, dirt, and dust were collected and analyzed for Hg, lead, and cadmium, from the following locations: (1) dust on the conveyor in the dryer containment area; (2) dust at the exit of the dryer; (3) dust at the entrance of the dryer; (4) dirt and cullet outside the cullet processing building near the cullet chute; (5) cullet in a hopper that had been processed through the elevator; (6) "clean" cullet outside on the storage pad (front left of cullet storage pile); and (7) "clean" cullet outside on the storage pad (middle of cullet storage pile). The cullet on the storage pads was not from flourescent lamp manufacturing plants, and thus, was considered to be "clean" (not contaminated). Bulk dust samples were analyzed for Hg according to the Environmental Protection Agency (EPA) SW–846 Method 7471, modified for matrix. The bulk samples were also analyzed for lead and cadmium by means of atomic absorption spectroscopy according to NIOSH Method P&CAM 173 and NIOSH Method 7105 modified for hot plate.[1]

Medical

Upon realizing that employees had been exposed to Hg, GEBGP offered Hg testing to all employees, regardless of work area. While they had no medical surveillance program for Hg in place at the time, the medical department obtained an appropriate protocol from another plant. Based on that protocol, employees with urine Hg levels $\geq$ 50 µg/g–Cr were referred for medical evaluation. Initially, employees were referred to the University of Pittsburgh, however employees felt these evaluations were biased since the company doctor arranged for them. Subsequently, these employees were referred to West Virginia University. Finally, a local occupational medicine physician was selected to do all the evaluations. Employees were referred for evaluation for levels $\geq$ 50 µg/g–Cr or for symptoms regardless of the level.

Urine Hg samples were collected by the company on 192 of the 200 employees at the plant. Eight employees either declined testing or were out on long–term leave. All results were reviewed. The NIOSH physician reviewed medical records for six employees who had been evaluated for Hg poisoning at the University of Pittsburgh and at West Virginia University. In addition, six employees were interviewed. The purpose of the interviews was to determine if there were symptoms that could be related to Hg exposure, as well as to determine if and how work practices may have contributed to exposure. Of those interviewed, two had undetectable urine Hg levels and were asymptomatic. They were selected by the NIOSH physician from a list of employees. One had a level below 35 µg/g–Cr but reported numerous symptoms (i.e., rash, headache, confusion, and fatigue). This individual asked to be interviewed. Another was selected because of an elevated urine Hg level. Another employee was selected for having the highest urine Hg level measured in the plant. This individual was responsible for loading cullet with a front end loader in the P–4 storage building and transporting it to the cullet processing building. The last employee interviewed was a former employee who had previously been responsible for loading cullet in the storage area and transporting it to the cullet processing building for more than 10 years.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the 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 even though 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 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 Recommended Exposure Limits (RELs),[2] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[3] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs).[4] In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA–approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

Evaluation criteria for chemical substances are usually based on the average worker breathing zone exposure to a specific airborne substance over an entire 8– to 10–hour workday, expressed as a time–weighted average (TWA). Personal exposures 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 supplement the 8–hr TWA where there are recognized adverse effects from short–term exposures, some substances have a short–term exposure limit (STEL) for 15–minute peak periods; or a ceiling limit, which is not to be exceeded at any time. Additionally, some chemicals have a "skin" notation to indicate that the substance may be absorbed through direct contact of the material with the skin and mucous membranes.

For some substances, a biological marker exists that can be used in workplace exposure investigations or studies. In order to measure these markers, a biologic specimen (*e.g.*, exhaled breath, blood, or urine) must be obtained from the participating worker through informed consent. A biological marker can measure acute or chronic exposures, provide an estimation of the dose of a substance in the body or an organ, integrate exposures from more than one exposure route into a dose estimation, measure damage to a target cell and/or organ, or indicate the presence of a disease process. Two sources of reference values for biological markers are the ACGIH Biological Exposure Indices (BEIs®)[3] and the various guidelines developed by the World Health Organization (WHO). In addition, the clinical medicine literature contains reference values for tests used by practicing physicians.

Mercury Exposure–Related Health Effects and Exposure Criteria

Since metallic Hg is volatile at ambient temperatures, the majority of human exposure is by inhalation. In fact, inhalation exposure accounts for more than 95% of the absorbed Hg dose, whereas dermal exposure and ingestion contribute only 2.6% and 0.1% to this dose, respectively.[5] Eighty percent of inhaled Hg is retained in the lungs, while the remainder is exhaled. Due to its high degree of lipophilicity, 74% of inhaled Hg rapidly diffuses across the alveolar membranes into the blood.[6,7,8] Mercury's high level of lipophilicity aids in its distribution to the many tissues and organs throughout the body; it can readily cross the blood–brain and placental barriers, and has a high degree of affinity for red blood cells. Mercury absorbed into the blood and other tissues is quickly oxidized into divalent Hg via the hydrogen peroxide–catalase pathway, and accumulates in the renal cortex of the kidney.[5,9] After a substantial exposure, Hg reaches peak levels within the various tissue reservoirs within 24 hours, except in the brain where peak levels are not reached for 2–3 days.[5,10] In fact, more than 50% of the initially–absorbed dose is deposited in the kidneys, with the brain, liver, spleen, bone marrow, muscles, and skin being minor reservoirs for absorbed Hg.[11]

The major pathways for elimination of Hg from the body are via the feces and the urine. The half–life for the whole body is 40–60 days, while the half–life for the lungs is 2 days, the blood is 2–4 days, the brain is 21 days, and the kidneys are 40–60 days.[5] Thus, urine Hg concentrations reflect chronic exposure, while blood Hg concentrations only reflect recent exposure. Urinary Hg levels in the general population generally are less than 5 µg/g Cr[12,13] or 10 µg/L[14,15] – 20 µg/L.[16] Symptoms are generally not present until levels of 200[14] –300 µg/L are reached.[12,13,15] WHO recommends a threshold level of 50 µg/g Cr, and ACGIH has set a Biologic Exposure Index (BEI) of 35 µg/g Cr.[3] These numbers reflect dose, not necessarily health effects. Background Hg levels in the blood are less than 1 µg/dL[13] – 1.5 µg/dL.[16]

The lung is the target organ with acute, high level exposure to Hg vapor. Effects include cough, shortness of breath, chest pain, interstitial pneumonitis, bronchiolitis, and pulmonary edema. Nausea, vomiting, fever, stomatitis, and gingivitis can also occur.

The nervous system is the target organ in chronic exposure to Hg vapor. Effects include emotional lability, shyness, insomnia, irritability, and memory loss. This symptom complex is called erethism. Tremor and peripheral neuropathy can also occur, as can stomatitis and gingivitis. Other symptoms include fatigue, weakness, loss of appetite, and headache. These symptoms are usually reversible with cessation of exposure.[12,13,14] Mercury accumulates in the kidneys, but rarely produces significant renal injury.[12,13]

OSHA currently enforces a PEL for Hg of 100 µg/m^3 as a ceiling limit that should not be exceeded during a workshift.[4] The NIOSH REL for Hg exposure is 50 µg/m^3 as a TWA exposure for up to 10–hours per day, 40–hours per week; NIOSH does not have a urine Hg recommendation.[2] In 1980, a WHO study group recommended an 8–hour TWA exposure limit of 25 µg/m^3.[17] In 1994, the ACGIH lowered the TLV for Hg to 25 µg/m^3 (TWA exposure, 8–hours per day, 40–hours per week).[3] The reason for lowering the TLV was a finding of pre–clinical signs of central nervous system (CNS) and renal dysfunction at worker exposure levels above 25 µg/m^3.

Lead Exposure–Related Health Effects and Exposure Criteria

Lead adversely affects a number of organs and systems in the human body. The four major target organs and systems are the CNS, the peripheral nervous system, kidney, and hematopoietic (blood–forming) system.[9] Inhalation or ingestion of inorganic lead can cause a range of symptoms and signs including loss of appetite, metallic taste in the mouth, constipation, nausea, colic, pallor, a blue line on the gums, malaise, weakness, insomnia, headache, irritability, muscle and joint pains, fine tremors, and encephalopathy. Lead exposure can result in distal motor neuropathy ("wrist drop"), anemia, proximal kidney tubule damage, and chronic kidney disease.[18,19] Lead exposure is associated with fetal damage in pregnant women.[9,19] Finally, elevated blood pressure has been positively related to blood–lead levels.[20,21] A summary of the lowest observable effect levels of lead in humans is given in Table 1.

Under the OSHA general industry lead standard (29 CFR 1910.1025), the PEL for airborne exposure to lead is 50 µg/m^3 (8–hour TWA).[24] The standard requires lowering the PEL for shifts exceeding 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 µg/m^3 (8–hour TWA), medical removal of employees whose average blood lead level (BLL) is 50 µg/dL or greater, and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL. ACGIH has proposed a TLV for lead of 50 µg/m^3 (8–hour TWA), with worker BLLs to be controlled at or below 20 µg/dL, and designation of lead as an animal carcinogen.[3]

Cadmium Exposure–Related Health Effects and Exposure Criteria

Early symptoms of cadmium exposure may include mild irritation of the upper respiratory tract, a sensation of constriction of the throat, a metallic taste and/or cough.[25] Short–term exposure effects include cough, chest pain, sweating, chills, shortness of breath, and weakness if enough cadmium dust has been inhaled. Short–term exposure effects of cadmium ingestion may include nausea, vomiting, diarrhea, and abdominal cramps.[19] Long–term exposure effects of cadmium may include loss of the sense of smell, ulceration of the nose, emphysema, kidney damage, mild anemia,[19] an increased risk of cancer of the lung, and possibly of the prostate.[25] The OSHA PEL for cadmium is 5 µg/m^3 TWA.[25] Cadmium is an agent recommended by NIOSH to be treated as a potential occupational carcinogen. NIOSH recommends that exposures to cadmium be controlled to the lowest feasible concentration.[2]

RESULTS

Industrial Hygiene

The results for the Hg area samples in the cullet processing building ranged between 3.3 µg/m^3 and 775 µg/m^3 (see Table 1). Samples taken inside the containment area near the dryer indicated the highest Hg concentrations of 206 µg/m^3 and 775 µg/m^3. A sample collected in the P–4 storage building had a Hg concentration of 2 µg/m^3. The indoor and outdoor background samples for Hg were both below the minimum detectable concentration (MDC). The analytical limit of detection (LOD) is 0.05 µg/sample, which equates to a MDC of 0.59 µg/m^3, based on an air sampling volume of 85 liters.

In the P–4 storage building, a measurement using the Jerome® Hg vapor analyzer showed a Hg concentration of 3 µg/m^3. Measurements collected in the cullet processing building, outside the dryer containment area (when the dryer was not in operation), ranged between 6 and 19 µg/m^3. A measurement collected directly outside the dryer containment revealed a concentration of 49 µg/m^3 when the dryer was not operating. Measurements were collected at various locations inside the containment area around the dryer when the dryer was not in operation. These values ranged from 50 to 330 µg/m^3 with an average concentration of 170 µg/m^3. These results indicate that the area inside the containment is still contaminated, even after clean–up procedures. During the time of our evaluation, no one worked inside the dryer containment area.

Measurements were also collected with the Jerome® Hg vapor analyzer inside the dryer containment area when the dryer was operating (without cullet being processed) for 15 minutes. These values ranged between 40 and 300 µg/m^3 with an average of 150 µg/m^3. When the dryer was in operation (without cullet being processed) the average Hg concentration inside the containment was less than the average Hg concentration in the containment when the dryer was not in operation. Additional measurements were collected for approximately 10 minutes when the dryer was running and "clean" cullet was processed. Measurements collected inside the containment during this period ranged from 400 to 900 µg/m^3. The operation was stopped following these measurements. Measurements with an additional Jerome® Hg vapor analyzer were collected upstairs (near the elevator when "clean" cullet was processed through the system) revealing concentrations of Hg ranging from 300 to 900 µg/m^3. These values indicate that the cullet processing system (i.e., conveyors, elevators, storage bins, crushers, and dryer) remains contaminated with Hg despite cleaning.

Bulk samples of dust collected in the dryer containment area had Hg concentrations of 49 µg/g near the dryer exit (where cullet exits the dryer), 4,300 µg/g from the conveyor in the containment area, and 51,000 µg/g near the dryer entrance (where cullet enters the dryer). Bulk samples of cullet were collected in the "clean" cullet storage area, around the outside cullet chute (where "clean" cullet is dumped into the cullet processing system), and in a hopper on the first floor of the cullet processing building (this cullet had been processed through the storage bin and elevator). Two cullet bulk samples from the "clean" storage area had Hg concentrations of 0.034 and 0.017 µg/g. The bulk cullet and dirt sample collected at the cullet chute had a Hg concentration of 1,800 µg/g and the cullet bulk sample from the hopper had a Hg concentration of 29 µg/g. These results confirm Hg contamination of the cullet processing system.

Bulk samples were also analyzed for lead and cadmium. The bulk samples of dust collected in the dryer containment area had lead (Pb) and cadmium (Cd) concentrations of 2,200 µg/g (Pb) and 0.60 µg/g (Cd) near the dryer exit (where cullet exits the dryer), 2,600 µg/g (Pb) and 65 µg/g (Cd) from the conveyor in the containment area, and 9,900 µg/g (Pb) and 4.5 µg/g(Cd) near the dryer entrance (where cullet enters the dryer). Bulk samples of cullet collected in the "clean" cullet storage area had lead concentrations of 100 and 97 µg/g and cadmium concentrations of 0.015 and 0.043 µg/g. The bulk sample collected around the outside cullet chute (where "clean" cullet is dumped into the cullet processing system) had a lead concentration of 480 µg/g and a cadmium concentration of 4 µg/g. The bulk sample of cullet collected in the hopper on the first floor of the cullet processing building (this cullet had been processed through the storage bin and elevator) had a lead concentration of 160 µg/g and a cadmium concentration of 0.11 µg/g.

Area air samples for lead and cadmium were collected at nine different locations at the plant (see Table 2). The analytical limit of detection (LOD) for lead is 0.5 µg/filter, which equates to a minimum detectable concentration (MDC) of 0.4 µg/m^3, based on an air sampling volume of 1280 liters. The analytical limit of quantitation (LOQ) for lead is 2 µg/filter, which equates to a minimum quantifiable concentration (MQC) of 1.6 µg/m^3, assuming a sample volume of 1280 liters. The analytical LOD for cadmium is 0.08 µg/filter, which equates to a MDC of 0.06 µg/m^3, based on an air sampling volume of 1280 liters. The analytical LOQ for cadmium is 0.2 µg/filter , which equates to a MQC of 0.16 µg/m^3, assuming a sample volume of 1280 liters. The indoor background sample (collected in the office area) for cadmium was detected between the MDC the MQC for cadmium. The indoor background sample for lead had a concentration of 1.6 µg/m^3. The outdoor background sample (collected in visitor parking area) for cadmium was detected at the MQC. The outdoor background sample for lead was between the MDC and the MQC for lead. Lead sample results ranged from 0.5 to 51 µg/m^3. The highest lead concentration of 51 µg/m^3 was measured in the cullet processing building at the 772 mix area (near a conveyor). Cadmium concentrations ranged from 0.06 to 4.8 µg/m^3. The highest cadmium concentration of 4.8 µg/m^3 was measured directly above the enclosed glove box in the cadmium building were cadmium is mixed into the batching system.

A personal breathing zone (PBZ) sample was collected on the worker loading the 50–pound cadmium containers into the glove box and mixing the material into the batching system. This sample was analyzed for both cadmium and lead, revealing a cadmium exposure of 1.5 µg/m^3 and a lead exposure of 14 µg/m^3.

Medical

Six employees were interviewed. The purpose of the interviews was to determine if there were symptoms that could be related to Hg exposure, as well as to determine if and how work practices may have contributed to exposure. Of those interviewed, two had undetectable urine Hg levels and were asymptomatic. One had levels below 35 µg/g–Cr but reported numerous symptoms including rash, headache, confusion, and fatigue. Another employee was selected because of an elevated urine Hg level. The employee reported fatigue, insomnia, rash, and irritability that had improved as his urine Hg levels declined. Another employee was selected because of the highest level measured in the plant. This person was responsible for loading cullet in the P–4 storage building (with a front end loader) and transporting it to the cullet processing building. The employee reported a wide variety of chronic symptoms including mood swings, frequent blinking, hypersomnia, "inappropriate behavior," back pain, hand numbness, and breath that smelled like metal to others. The symptoms had mainly resolved with the exception of night sweats. The employee had very meticulous work habits and would often clean around the dryer. The last was a former employee who had previously been responsible for loading cullet in the storage area (with a front end loader) and transporting it to the cullet processing building for more than 10 years. The employee reported no symptoms consistent with Hg exposure while working and noted not as much overtime as compared to other employees, and showers were taken daily before going home.

Urine Hg levels were done by the company on 192 of the 200 employees at the plant. Eight employees either declined testing or were out on long term leave. All urine Hg results were reviewed. Sixty–five employees (33.8%) had urine Hg levels below the limit of detection. The range of urine Hg levels among those employees with detectable levels was 1.4 micrograms per gram creatinine (µg/g–Cr) to 345.4 µg/g–Cr. The World Health Organization (WHO) recommends a threshold level of 50 µg/g Cr, and ACGIH® has set a Biologic Exposure Index (BEI®) of 35 µg/g Cr. Twenty–nine employees (15.1%) had levels > 35 µg/g–Cr, and twenty (10.4%) had levels > 50 µg/g–Cr. A local occupational medicine physician was selected to do medical evaluations on employees with levels greater than or equal to (≥) 50 µg/g Cr or for symptoms regardless of the level. The evaluations consisted of a thorough history and physical exam, and appropriate laboratory and other diagnostic procedures as indicated. Employees with elevated urine Hg levels were continuing to be monitored.

DISCUSSION

Exposure to elevated levels of Hg in the cullet processing areas of the plant resulted in elevated urinary Hg levels in twenty–nine employees. Three of the interviewed employees reported symptoms such as fatigue, headache, irritability, and mood swings which could be attributable to Hg exposure. However, one had levels of Hg in his urine that were low, and not usually associated with symptoms. The employee's symptoms persisted while the other two interviewed employees had symptoms that declined as their Hg urine levels declined. Lead is another exposure present in the plant that can cause nonspecific symptoms such as fatigue, headache, irritability, and mood swings. Nonspecific symptoms are also common in the general population as well. None of the employees reported gingivitis or stomatitis.

GEBGP has devoted significant resources to cleaning areas where Hg contamination was detected. The areas cleaned included the P–4 storage building and the cullet processing building. In the cullet processing building the conveyors, hoppers (that hold cullet), crushers, elevators, and storage bins were all cleaned, inside and out, by pressurized wash and acid wash techniques. The dryer area was also cleaned with these techniques. After the areas had been cleaned, an epoxy barrier coating was applied to all exposed surfaces in an effort to reduce any Hg vaporizing off the equipment, floors, walls, or ceilings. GEBGP stopped accepting Hg contaminated cullet from flourescent lamp manufacturing plants on June 18, 1997, after recognizing the potential for Hg contamination.

During our evaluation, most of the contaminated areas had Hg vapor concentrations below NIOSH and OSHA exposure criteria. However, Hg concentrations (as shown with the Jerome® Hg vapor analyzer and solid sorbent samples) at the dryer area were elevated. This area is isolated from the rest of the plant and maintained under negative pressure relative to occupied areas of the building. The negative pressure is maintained by using blowers equipped with high efficiency particulate air (HEPA) filters and charcoal filters to exhaust air from the dryer containment. The filtered exhausted air from the containment area is directed outside, away from occupied areas and air intakes. The dryer is currently not used and no employees perform daily work activities inside the containment area. Workers that enter the containment area, to check and change filters in the blowers or to collect Hg samples, are required to wear personal protective equipment that consist of a respirator (equipped with HEPA filters and Hg vapor cartridges), disposable coveralls (with a hood and booties), gloves (nitrile or polyvinyl chloride), and safety glasses.

When the dryer was turned on (and no cullet was processed), there was no noticeable increase in Hg concentrations inside the dryer containment area compared to Hg concentrations inside the containment, when the dryer was not operating. However, when "clean" cullet was processed through the system (i.e., conveyors, elevator, storage bin, etc.) and the dryer was operating, Hg concentrations were elevated inside the dryer containment and near the elevator and storage bin areas. These data suggest that the cullet processing system and the dryer area remain contaminated with Hg despite having been cleaned. Bulk samples of dust and cullet confirm Hg contamination in the cullet processing system.

Bulk samples were also analyzed for lead and cadmium because both are used in the process to manufacture the glass tubing at the plant. The results of these samples indicate that the dust and cullet in the cullet processing system and dryer area are contaminated with lead and cadmium. Two separate area air samples collected for lead (located at the 772 mix area) and cadmium (located above the enclosed glove box in the cadmium building) indicate that there may be a potential for workers to be overexposed to these substances. However, lead and cadmium concentrations on a personal sample collected in the cadmium building were below OSHA exposure criteria. Workers in the cullet and batch processing areas of the plant are required to wear respirators equipped with HEPA filters and Hg cartridges to protect them from lead, cadmium, and Hg exposures.

CONCLUSIONS

Exposure to Hg in the plant resulted in elevated urinary Hg levels in twenty nine employees (15.1%). NIOSH investigators have documented that there is still serious Hg contamination at GEBGP, even after extensive clean–up procedures. Dust and cullet bulk samples confirm Hg contamination in the cullet processing building. During the evaluation, the highest concentrations of Hg (in both air and bulk samples) were obtained in the dryer containment area.

There are currently no production work activities inside the dryer containment.

NIOSH investigators have also documented that there may be a potential for workers to be overexposed to cadmium and lead. To protect workers from cadmium and lead exposures, the plant utilizes various engineering controls (i.e., enclosed glove box, automated pneumatic transport system for cadmium, partial enclosures, and local exhaust ventilation) and a respiratory protection program. The plant has also implemented other various programs to comply with the OSHA lead and cadmium standards.

RECOMMENDATIONS

1. The high concentrations of Hg (both air and bulk samples) measured at the plant (in the dryer enclosure area and near the cullet processing elevator when the dryer was in operation), supports the conclusion that the equipment used to process cullet is still contaminated with Hg. All equipment used to process the Hg contaminated cullet should be replaced. The dryer should remain inside the isolated containment area until all of the contaminated equipment is replaced. This area must continue to be maintained under negative pressure to reduce the possibility of cross contamination of Hg to other adjacent areas. During our evaluation, the filters on the negative air machines were clogged and not operating properly. The air flow or pressure drop on each machine should be checked daily and the filters should be replaced when the machine is operating below manufacturer specifications. The filters should also be tested to assure that they are properly sealed in the negative air machines. The perimeter of the containment area should be checked daily to make sure that the area is maintained in satisfactory condition and that negative pressure is maintained. Negative pressure can be assessed using smoke around any opening or gap in the containment.

2. Hg contaminated areas in the plant must be cleaned with appropriate methods to help eliminate Hg exposures. The following clean–up procedures are outlined in the draft Mine Safety and Health Administration (MSHA) document “Controlling Mercury Hazards in Gold Mining: A Best Practice Toolbox.”[26]

   (a) Vacuum all surfaces to remove droplets of elemental Hg and Hg contaminated debris.
   (b) Remove porous materials that cannot be completely cleaned or sealed with an epoxy paint and dispose of the debris properly.
   (c) Seal porous materials, such as cinder block or concrete with an epoxy paint.
   (d) Clean cracks and crevices that contain elemental Hg with a zinc scrubbing pad.
   (e) Wash all nonporous services with fresh water to remove dirt, wash with a sodium thiosulfate solution, and rinse with fresh water to remove the thiosulfate.
   (f) Spread Hg complexing agent or similar material on cracks and hard–to–reach places to adsorb micro–droplets of Hg and leave overnight; then remove the material using a Hg vacuum cleaner.
   (g) Seal all waste material in a plastic bag and place the bag in a disposal drum.
   (h) Use chemical indicators, scrape samples, and air monitoring to evaluate decontamination effectiveness.
   (i) Re–clean areas that are still sources of Hg vapor, as indicated by the above steps.

3. GEBGP is currently using a Jerome® Hg vapor analyzer to perform daily Hg sampling activities in various locations at the plant. This practice should be continued. Daily Hg monitoring should be conducted in and around the dryer containment, around all cullet processing equipment (crushers, elevators, storage bins, and conveyors), and near the exhaust of the negative air machines to assess Hg concentrations and possible Hg exposures.

4. A chemical cartridge respirator with Hg vapor cartridges (equipped with end of service life indicators) or a supplied air respirator is recommended for Hg vapor concentrations not exceeding 500 µg/m^3.[27] A supplied air respirator (operated in the continuous flow mode) or a powered

air purifying respirator (PAPR) equipped with a Hg vapor canister (with end of service life indicator) is recommended for Hg vapor concentrations not exceeding 1250 µg/m^3.[27] For Hg concentrations not exceeding 2500 µg/m^3 the following respirators are recommended: (1) chemical cartridge full facepiece respirator with Hg vapor cartridges (equipped with end of service life indicators); (2) gas mask full facepiece respirator with a chin style front– or back–mounted canister (that protects against Hg vapor and has an end of service life indicator); (3) any supplied air respirator that has a tight–fitting facepiece and is operated in the continuous flow mode; (4) any PAPR equipped with a tight fitting facepiece and Hg vapor canister (equipped with an end of service life indicator); (5) a self–contained breathing apparatus with a full facepiece; or (6) any supplied air respirator with a full facepiece.[27]

Workers in the cullet and batch processing areas of the plant are required to wear air–purifying respirators equipped with HEPA filters (to protect against lead and cadmium exposures) and Hg vapor cartridges. GEBGP does have a respiratory protection program. Respiratory protection programs must be consistent with the Occupational Safety and Health Administration's Respiratory Protection Standard.[28] During the evaluation it was noticed that respirators in some areas of the plant were not stored properly. For respirators to be effective and protect workers from harmful exposures they must be selected, inspected, and maintained properly. Respirators should be inspected by the worker prior to and after each use for any defects. Respiratory protective equipment should also be cleaned and disinfected after each use. Respiratory protective devices should never be worn when a satisfactory face seal cannot be obtained. There are many conditions that may prevent a good seal between the worker's face and the respirator. Some of these conditions include facial hair, glasses, or an unusually structured face. All workers required to wear a respirator must be properly trained by the company on the selection, use, limitations, and maintenance of the respirator and also be fit–tested to assure a proper seal between the worker's face and the respirator prior to performing work tasks in a contaminated area. All workers should receive annual fit–testing with a quantitative testing device. When not in use, respirators must be stored in a clean environment located away from any source of contamination.

5. Currently, employees who work in areas identified as potentially contaminated with lead and cadmium (i.e., cullet processing areas, cadmium building, and lead mixing area), gain access through a clean area of the locker room where they are supplied clean work clothes and respirator for the shift. After the work shift, employees enter the dirty side of the locker room where they remove the dirty work clothes, then the respirator. Mandatory showers are taken by each employee before entering the clean side of the locker room. A laundering service is used to clean potentially contaminated work clothing.

Before removal, work clothing should be vacuumed with a dedicated Hg vacuum, and stored in vapor–proof containers pending laundering. The operators of the laundering service should be informed that the clothes may be contaminated with Hg, lead, and cadmium. In an effort to prevent cross contamination, work and street clothing should not be stored in the same locker, and workers in contaminated areas of the plant should not wear work clothing into clean areas of the plant (i.e., glass tubing manufacturing areas and offices).

6. GEBGP currently has an exposure monitoring program for all workers potentially exposed to lead and cadmium. Hg exposure monitoring should be included in the exposure monitoring program. This program should consist of full–shift air sampling from the worker's breathing zone to measure the worker's TWA exposures. The purpose of this exposure monitoring is to determine whether exposures may exceed the applicable exposure limits or action levels. Whenever a worker's over–exposure is measured, a survey should be conducted to determine the reason behind the workplace exposure. Engineering and/or administrative controls should be implemented to effectively control this exposure, and to protect the

workers in similar jobs and processes. Hg exposure monitoring surveys should be performed whenever changes in work processes or conditions are likely to lead to a change in exposures. Lead and cadmium exposure monitoring should be conducted in accordance with the OSHA lead and cadmium standards.[24,25] Though not all workers have to be monitored, sufficient samples should be collected to characterize the workers' exposures. Variations in work habits and production schedules, worker locations, and job functions should be considered when developing exposure monitoring protocols. A given workroom or area is considered a Hg exposure hazard area whenever the industrial hygiene studies find that environmental Hg concentrations and worker exposure concentrations exceed 40% of the NIOSH REL (20 µg/m^3).[29] All workers participating in the monitoring should be informed of the results, and the employer should maintain these records for a period of 30 years.

7. During our evaluation large amounts of dust and cullet were around the processing equipment in the cullet processing building (including the area inside the dryer containment). Bulk samples of dust and cullet in some of these areas indicated Hg, lead, and cadmium contamination. Housekeeping practices must be improved to help eliminate the possibility of hazardous material contamination and cross contamination of hazardous materials into other areas of the plant. Dry–sweeping of work areas should be prohibited, as the hazardous material contamination in the dust may increase workers' exposures. Only wet clean–up methods or vacuuming with an approved vacuum for Hg, lead, and cadmium dust should be allowed during clean–up activities.

Wet clean–up methods should not be used in any area where it may cause a potential explosion hazard.

8. Biological monitoring for lead and cadmium is currently conducted by the plant for employees who are exposed to these substances. Medical evaluations conducted on employees with elevated urine Hg levels were thorough and appropriate. Biological monitoring should continue on employees with elevated urine Hg levels until they reach acceptable levels (<ACGIH BEI of 35 µg/g–Cr).

9. No eating, drinking, or smoking should be allowed in the work areas and/or process buildings. These activities should be restricted to designated areas away from contaminants. Workers should change out of contaminated clothing and wash their hands before eating, drinking, or smoking.

10. Various safety and health programs are used at the plant. Some of these programs include occupational health and safety training, a respiratory protection program, various hygiene programs, and blood lead monitoring programs. It is recommended that all these programs be continued. GEBGP should also provide workers with annual training and education on the health hazards associated with workplace exposure to Hg. At a minimum, this training should conform to the regulations set forth in OSHA's Hazard Communication Standard.[30]

REFERENCES

1. NIOSH [1994]. NIOSH manual of analytical methods, 4th ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94–113.

2. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92–100.

3. ACGIH [1997]. 1997 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

4. Code of Federal Regulations [1989]. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

5. ATSDR [1994]. Toxicological profile for mercury. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, DHHS (ATSDR) Publication No. TP–93/10.

6. Agocs M, Thomas C, et al. [1992]. Mercury toxicity. American Family Physician 46:1731–1741.

7. Barregård L, Sällsten G, et al. [1992]. Kinetics of mercury in blood and urine after brief occupational exposure. Archives of Environmental Health 47:176–184.

8. Cherian M, Hursh J, et al. [1978]. Radioactive mercury distribution in biological fluids and excretion in human subjects after inhalation of mercury vapor. Archives of Environmental Health 33:109–114.

9. Doull J, Klaassen CD, Amdur MO, eds. [1991]. Casarett and Doull's Toxicology: the Basic Science of Poisons. Fourth Edition. New York, NY: Macmillan Publishing Co., Inc.

10. Hursh J, Clarkson T, et al. [1976]. Clearance of mercury (Hg–197, Hg–203) vapor inhaled by human subjects. Archives of Environmental Health 31:302–309.

11. Wallis G, Barber T [1982]. Variability in urinary mercury excretion. Journal of Occupational Medicine 24:590–595.

12. Franzblau A [1994]. Mercury. Chapter 30.11. In: Rosenstock L, Cullen M, eds. Textbook of clinical occupational and environmental medicine. Philadelphia, PA:W.R. Saunders Co, p. 756–759.

13. Lauwerys R, Hoet P [1993]. Industrial chemical exposure — Guidelines for biological monitoring 2nd edition. Boca Raton, FL: Lewis Publishers, pp. 74–82.

14. Campbell D, Gonzales M, Sullivan JB [1992]. Mercury. Chapter 75. In: Sullivan J, Krieger G, eds. Hazardous Materials Toxicology, Clinical Principles of Environmental Health. Baltimore, MD: Williams and Wilkins Publishing, pp. 824–833.

15. Schutte NP, Knight AL, Jahn O [1994]. Mercury and its compounds. Chapter 40. In: Zenz, C, ed. Occupational Medicine. St. Louis, MO: Mosby Yearbook, Inc, pp. 549– 557.

16. ATSDR [1992]. Case studies in environmental medicine — mercury toxicity. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, DHHS.

17. WHO [1980]. Recommended health–based limits in occupational exposure to heavy metals. Technical Report, Series 647, World Health Organization, Geneva, Switzerland.

18. NIOSH [1972]. Criteria for a recommended standard: occupational exposure to inorganic lead. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. HSM 73–11010.

19. NIOSH [1981]. Occupational health guidelines for chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH)/DOL (OSHA) Publication No. 81–123 and supplements 88–118, 89–104.

20. Kristensen TS [1989]. Cardiovascular diseases and the work environment — a critical review of the epidemiologic literature on chemical factors. Scand J Work Environ Health

15:245–264.

21. Pirkle JL, Schwartz J, Landis JR, Harlan WR [1985]. The relationship between blood–lead levels and blood pressure and its cardiovascular risk implications. Am J Epidem 121(2):246–58.

22.ATSDR [1990]. Toxicological profile for lead. Cincinnati, OH: Agency of Toxic Substances and Disease Registry. TP–88/17.

23.Goldman RH, Baker EL, Hannan M, Kamerow DB [1987]. Lead poisoning in automobile radiator mechanics. N Eng J Med *317*(8):214–218.

24. CFR [29 CFR 1910.1025 (1978)]. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

25. CFR [29 CFR 1910.1027 (1993)]. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

26. MSHA [1997]. Draft document. Controlling mercury hazards in gold mining: a best practice toolbox. U.S. Department of Labor, Mine Safety and Health Administration. September.

27. NIOSH [1997]. Pocket Guide to Chemical Hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 97–140.

28. CFR [29 CFR 1910.134]. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

29. NIOSH [1973]. Criteria for a recommended standard — Occupational exposure to inorganic mercury. U.S. Department of Health, Education, and Welfare, Public Health Service, National Institute for Occupational Safety and Health. HSM 73 – 11024.

30. OSHA [1993]. Hazard communication. Title 29 Code of Federal Regulations Part 1910.1200. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration.

Table 1

Hg area sample locations and results in the cullet processing building

Area	Sample Time (Min)	Sample Volume (liters)	Hg Concentration ($\mu g/m^3$)
Above 001 Crusher	431	86	6.4
At top of stair well leading down to dryer area	424	85	3.3
Directly outside dryer containment	427	85	46
General area outside dryer containment	422	84	27
Next to conveyor in the 772 mix area	415	83	20
Inside dryer containment next to dryer outlet	388	78	206
Inside dryer containment next to dryer inlet	355	71	775

Table 2

Lead (Pb) and cadmium (Cd) area sample locations and results

Area	Sample Time (Min)	Sample Volume (liters)	Pb Concentration ($\mu g/m^3$)	Cd Concentration ($\mu g/m^3$)
Above 001 Crusher	433	1300	12	0.08 (Between the MDC and MQC)
Cadmium Building above enclosed glove box	434	1300	1.6 (MQC)	4.8
Directly outside dryer containment	429	1290	1.6 (MQC)	0.06 (MDC)
Litharge mixing area in cullet processing building (no mixing conducted)	430	1290	6.2	0.06 (MDC)
Next to conveyor in the 772 mix area	416	1250	51	0.06 (MDC)
Inside dryer containment next to dryer inlet	356	1070	42	0.21
P–4 storage building	437	1300	1.6 (MQC)	0.06 (MDC)

MDC = Minimum Detectable Concentration
MQC = Minimum Quantifiable Concentration

Table 3
Summary of Lowest Observed Effect Levels for
Key Lead–Induced Health Effects in Adults and Children[@]

BLL* (µg/dL)		HEALTH EFFECT
>100	Adults:	Encephalopathic signs and symptoms (disease of the brain)
>80	Adults:	Anemia Encephalopathic signs and symptoms
	Children:	Chronic nephropathy (kidney disease)
>70	Adults:	Clinically evident peripheral neuropathy (diseases of the nerves of the extremities)
	Children:	Colic and other Gastro–Intestinal (GI) symptoms
>60	Adults:	Female reproductive effects Central Nervous System (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, anorexia Peripheral neuropathy
	Children:	
>40	Adults:	Decrease peripheral nerve conduction Elevated blood pressure (white males, 40–59 years old) Chronic nephropathy
	Children:	Reduced hemoglobin synthesis
>25	Adults	Elevated zinc protoporphyrin levels in males
15–25	Adults	Elevated zinc 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[22], and Goldman et al.[23]
* = Blood–lead level (BLL) in micrograms per deciliter (µg/dL).
** = "Safe" blood–lead level has not been determined for fetuses.

National Institute for
Occupational Safety and Health

NIOSH

Delivering on the Nation's promise:
Safety and health at work for all people
through research and prevention