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Eagle-Picher Industries
Joplin, Missouri

Melody M. Kawamoto, MD, MS
Alan Echt, MPH, CIH
Christopher M. Reh, PhD, CIH

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 Melody Kawamoto, Alan Echt, and Christopher Reh, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Eric J. Esswein and Barbara A. MacKenzie. Specimens for quality assurance of biological monitoring for lithium were provided by Peter M. Eller, Ph.D. Arrangements for analysis of biological specimens of lithium and mercury were made by Alexander W. Teass, Ph.D. Correlation analysis of the lithium data was performed by Charles A. Mueller, M.S. Desktop publishing was performed by Kathleen Mitchell and Patricia McGraw. Review and preparation for printing was performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Lithium and Mercury Exposures at Eagle-Picher

NIOSH was asked by the union to assess worker exposure to several chemical hazards, including lithium and mercury. Several site visits were made between December 1995 and April 1996.

What NIOSH Did

Measured the air in the process room, pill room, and dry room 108 for lithium.

Measured lithium in employees' blood in the process room, pill room, and dry room 108.

Measured lithium on employees' hands in the pill room and dry room.

Measured mercury in the air in the treatment and negative pasting areas.

Measured mercury in employees' urine in the treatment and negative pasting areas.

What NIOSH Found

Lithium levels in air and blood were highest in the process room, similar but a little lower in the pill room, and even lower in the dry room.

Lithium levels in blood were well below levels known to be toxic.

Lithium levels on employees' hands were higher in the pill room than in the dry room.

Mercury levels in air were a little higher in the negative pasting area than the mercury treatment area, but most mercury levels were below recommended exposure limits.

Urine mercury levels did not show overexposure to mercury.

What Managers Can Do

Install local exhaust ventilation to control mercury exposure in the processors' work stations.

Provide and launder work clothes for mercury-exposed employees.

Provide a comprehensive medical surveillance program for mercury-exposed workers.

What the Employees Can Do

Avoid eating, drinking, or smoking in work areas.

Wash hands and face on leaving the lithium areas.

Shower and change into street clothes after working in mercury-exposed areas.

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NIOSH National Institute for Occupational Safety and Health

Health Hazard Evaluation Report 96-0016-2777
Eagle-Picher Industries
Joplin, Missouri
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Melody M. Kawamoto, MD, MS
Alan Echt, MPH, CIH
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SUMMARY

On October 20, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at Eagle-Picher Industries, Inc., in Joplin, Missouri. The request was submitted by a representative of the United Steelworkers of America Rubber/Plastic Industry Conference, in Akron, Ohio. The request concerned potential employee exposures to a number of chemical hazards, particularly lithium, mercury, and lead chromate, in various operations at the facility. Following a walkthrough survey at the plant on December 12-13, 1995, the NIOSH investigators focused on lithium exposures in the process room, pill room, and dry room 108; mercury exposures in the pit and pasting room; identifying an orange substance on the walls in the potting area; and investigating the cause of eye irritation in the solder room. NIOSH investigators returned to the plant on April 17, 1996, and conducted another walkthrough survey to plan for two full days of industrial hygiene and biological monitoring of employee exposures to lithium and mercury, which took place on April 18-19, 1996.

For lithium, NIOSH investigators conducted an exposure assessment for all day-shift employees working in the process room, the pill room, and dry room 108. The exposure assessment was comprised of biological monitoring, full-shift personal breathing zone air monitoring, and hand-wipe sampling. In addition, a self-administered questionnaire was used to assess other factors that could affect serum lithium concentrations.

Collection of serum specimens from 41 participants giving informed consent was conducted near the end of the day shift at the end of a work week, when serum lithium concentrations are expected to be at or near steady state. The geometric mean serum lithium concentration was 1.75 micrograms per liter (µg/l), with a range of "not detected" to 11.2 µg/l. These serum lithium concentrations were well below therapeutic and toxic concentrations established for patients taking lithium medication. Serum lithium concentrations, however, differed by work area, showing that occupational exposure was occurring. Workers in the process room (5.59 µg/l) and pill room (4.14 µg/l) had higher mean concentrations than workers in the dry room (1.09 µg/l).

Over a 2-day period, NIOSH industrial hygienists collected full-shift personal breathing zone (PBZ) samples for lithium among 39 employees in the process room, the pill room, and dry room 108. The overall geometric mean concentration of lithium in air was 1.79 micrograms per cubic meter (µg/m^3), with a range of "not detected" to 121.8 µg/m^3. As with the serum concentrations, the air sampling indicated higher mean exposures for process room (25.9 µg/m^3) and pill room workers (15.3 µg/m^3) compared with dry-room workers (0.45 µg/m^3).

On the second day of sampling, hand-wipe samples for lithium were collected from 10 employees in the pill room and 14 employees in dry room 108. Samples were collected as employees left their work to go to lunch. The geometric mean of lithium on the wipe samples was 61.7 µg, with a range of 9 to 649 µg. The mean result among pill room workers (174.9 µg) was higher than those among dry-room workers (29.3 µg).

Additional environmental samples were collected to address other issues raised in the request. Analysis of a bulk sample of dust collected from a diffuser in the potting area showed that the majority of the sample was composed of a variety of phthalate esters. Bis-phenol A and some of its derivatives, which are consistent with the presence of epoxy resins, were also major components. The presence of the constituents of the potting compounds on the diffuser may indicate that these substances are being recirculated in the workroom air.

A wipe sample was collected from the exterior of a duct near the diffuser. The sample was analyzed for metals. Results showed the presence of aluminum, barium, cadmium, cobalt, chromium, copper, iron, lithium, magnesium, manganese, mercury, molybdenum, nickel, lead, phosphorous, silver, titanium, vanadium, yttrium, zinc, zirconium. Two short-term PBZ air samples were collected to assess employee exposure to rosin solder flux decomposition products, specifically aldehydes and formaldehyde. The results indicated that none of these products were present in amounts greater than the limits of detection for the method.

Mercury (Hg) exposure monitoring and urine Hg concentrations were determined among workers in the Hg treatment and negative pasting areas. The overall average Hg full-shift time weighted average (TWA) exposure concentration was 18.3 $\mu g/m^3$, and the TWA exposure concentrations ranged from 3.5 to 48.3 $\mu g/m^3$. Only 2 of 17 full-shift TWA Hg exposure measurements exceeded the American Conference of Governmental and Industrial Hygienists (ACGIH) TLV for Hg of 25 $\mu g/m^3$, and both of these were from processors in the negative pasting area. In general, Hg exposures in the negative pasting area were slightly higher than those in the Hg treatment area. No Hg over-exposures were found during short-term, task-based air sampling. Only 1 of 17 workers had a urine Hg concentration above the ACGIH Biological Exposure Index, and the reasoning behind this high level could not be determined in this survey.

Results of the NIOSH health hazard evaluation show that there is no health hazard from lithium exposures at this Eagle Pitcher facility. In addition, though mercury exposures were generally low, there was some indication that processing jobs had the potential to pose a mercury hazard. Recommendations are made to continue to keep lithium exposures at low levels and to better protect mercury-exposed workers.

KEYWORDS: SIC no.3692 (Primary Batteries, Dry and Wet), thermal battery manufacturing, lithium [CAS 7439-93-2], lithium alloy, lithium aluminum, lithium silicon, lithium salt, lithium chloride, lithium fluoride, mercury [CAS 7439-97-6], rosin solder flux, colophony, biological monitoring, industrial hygiene sampling, hand-wipe sampling, exhaust ventilation

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INTRODUCTION

On October 20, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at Eagle-Picher Industries, Inc., in Joplin, Missouri. The request was submitted by a representative of the United Steelworkers of America Rubber/Plastic Industry Conference, in Akron, Ohio. The request concerned potential employee exposures to a number of chemical hazards, particularly lithium, mercury, and lead chromate, in various operations at the facility. Following a walkthrough survey at the plant on December 12-13, 1995, the NIOSH investigators focused on lithium exposures in the process room, pill room, and dry room 108; mercury exposures in the pit and pasting room; identifying an orange substance on the walls in the potting area; and investigating the cause of eye irritation in the solder room. A lead chromate battery manufacturing operation was to have been included, but this process was shut down permanently in February 1996. NIOSH investigators returned to the plant on April 17, 1996, and conducted another walkthrough survey to plan for two full days of industrial hygiene and biological monitoring of employee exposures to lithium and mercury, which took place on April 18-19, 1996. Individual results of the biological monitoring were sent to participants in August (mercury) and October (lithium) 1996.

BACKGROUND

The Eagle-Picher Industries Couples Department plant in Joplin develops and produces high performance special purpose battery systems, especially for military or aerospace applications. Products manufactured at the plant include thermal batteries, lithium-metal sulfide batteries, sodium-sulfur batteries, lead fluoroboric batteries, nickel-iron batteries, electroexplosive devices (e.g., squibs, wire cutters, matches, etc.), and mechanical actuators.

Thermal Battery Production

Workers in thermal battery production were primarily concerned about their exposures to lithium powder. They were aware of the use and toxicity of lithium medications and wondered whether cases of depression or diabetes among some of the workers and cases of attention-deficit disorders among some of the workers' children could be related to lithium. They also wanted to know the significance of results of the air sampling conducted by the company in 1992, which showed concentrations of total lithium from 0.07 to 0.475 milligrams per cubic meter (mg/m^3) as time-weighted averages. Potentially exposed employees were estimated to number 4 in the process room, 23 in the pill room, and 48 in dry room 108.

In thermal battery systems, lithium-based electrolyte is a solid at room temperature and has a very low conductivity. The electrolyte becomes ionically conductive when raised above its melting point. The cell is then capable of delivering energy for long periods of time. Pyrotechnic heat sources are the principal means of heating thermal batteries. A percussion-type primer or electrical impulse to an integral electrical match activates the battery.[1] The electrolyte in batteries is in the form of pills, which vary in density, diameter, and composition. Lithium compounds used in battery pills include lithium aluminum, lithium silicon, lithium chloride, lithium fluoride, and lithium oxide.

Lithium Area

Powder for the pills is mixed in the process room. Operators open sealed cans containing mason jars filled with 600-gram aliquots of powdered materials. They empty the jars into a clean can on a scale under a hood then vacuum each empty mason jar to remove any remaining material. A lift raises the can of weighed material (a charge) to a V-blender, which blends the powder. Each charge contains 25,000 grams of powder. After blending, the operators dispense the powder into clean mason jars, which are stored in the process area until needed for pill production. The process operators wear cotton coveralls and a half-mask respirator. Operations in this area are performed over two shifts, with two employees per shift.

The pill room, located in building 108, houses eight large hydraulic presses (six 175-ton presses, one 350-ton press, and one 410-ton press) that produce battery pills. Due to the reactive nature of the materials used and strict quality control requirements, the relative humidity in the pill room is maintained between 1% and 3%. Press operators fill feed hoppers located on the rear of the presses, typically every 30 to 45 minutes (this frequency varies with the type of pill being produced), monitor the operation of the presses, remove pills by raking them out of the press area and placing them into containers, and weigh the pills. Operators are also responsible for cleaning the presses. The group leader stacks and counts the pills, places them in vacuum ovens overnight, and puts the dry pills in mason jars. Press operators wear latex gloves (Satari or Safeskin brands), and cotton glove liners are available (these were used by one operator). The group leader uses cloth gloves with leather palms. Gerson 1710 dust and mist respirators (TC-21C-271) are available for use, but not required. The operators and group leader wear cotton coveralls. During the week of this study, 9 press operators, 3 technicians, 1 group leader, and 1 quality control employee were working the day shift in the pill room. Approximately the same number of employees work the evening shift.

Batteries are assembled by hand in dry room 108. Utility battery builders stack and wrap battery components. These are loaded in casings by a battery loader. Welders seal the casings. Some parts fabrication, such as Fiberfrax cutting, takes place in dry room 108 as well. Use of gloves is mandatory in dry room 108. During the week of this study, 18 battery builders, 3 welders, 1 technician, 1 group leader, and 5 quality control employees were working in dry room 108. The room is occupied only during the day shift.

Potting Area

In the potting area for thermal battery production, potting compounds are mixed in hoods and heated before use to make them pourable. The mixed potting compounds are poured over parts (battery headers) held in jigs on tables in the work area. Ovens are used to cure the potting compounds. The exhaust air, including the exhaust air from the ovens, is cleaned in the air handler with a carbon filter and electrostatic precipitator, tempered, and recirculated in the potting area, where eight employees work. Potting compounds include methyl cyanoacrylate in an adhesive, salicylic acid, diethyltoluenediamine, epoxy resins, diethanolamine, and bisphenol A diglycidyl ether.

Soldering Area

The soldering operation evaluated during this investigation takes place in a clean room. Contacts are soldered on batteries using soldering irons, 70/30 tin lead solder, a rosin flux, and small amounts of isopropanol. Air in the room is recirculated after being cleaned with a carbon filter and electrostatic precipitator and tempered. Ten employees work in this area.

Mercury Area

Mercury exposures can potentially occur in the mercury treatment and negative pasting areas at Eagle-Picher. The mercury treatment process consists of dipping negative battery plates into a mercuric chloride solution. After dipping, the plates are soaked and rinsed, and the soaking/rinsing cycle is dependent on the type of battery being built. Finally, the plates are dried in an oven. The oven operator wears an air-purifying respirator with mercury canisters.

Negative pasting is the manufacture of negative battery plates from a zinc/mercuric oxide blend. The zinc and mercuric oxides are weighed into standard volumes depending on battery type, and water and latex are added to the blend produce a slurry. The slurry is poured on perforated paper, and a vacuum is pulled through the paper to remove excess water and form the paste. The pasted paper is attached to a grid assembly and wet pressed. Finally, the pressed plates are dried in an oven, and given a final dry press.

METHODS

Thermal Battery Area

Lithium Area

Biological monitoring for serum lithium was conducted on employees in thermal battery production to determine their absorption of lithium in the workplace. Sampling of full-shift personal breathing zone (PBZ) exposures to lithium was conducted to assess the potential contribution of inhalation exposure. Hand-wipe monitoring for lithium was conducted to assess the potential contribution of ingestion via hand-to-mouth exposure. A self-administered questionnaire was used to assess other factors that could affect serum lithium concentrations. All day-shift employees working in the process room, the pill room, and dry room 108 were eligible to participate.

Collection of serum specimens from participants giving informed consent was conducted near the end of the day shift on April 18-19, 1996 (Thursday and Friday, at the end of a work week, when serum lithium concentrations are expected to be at or near steady state). For quality control, duplicate specimens were collected on 10% of employees participating on each day. In addition, on each day, a specimen from an individual with low exposure potential was split into three parts. Two of the three split specimens were spiked with lithium at one and two times the limit of quantitation, while the remaining split specimen was not spiked with lithium. Serum lithium was measured by inductively coupled plasma-mass spectroscopy (ICP-MS), which is capable of measuring lithium in micromole per liter (µmole/L) concentrations. The limit of quantitation (LOQ) for this method is 0.07 µmole/L (which is equivalent to 0.5 µg/L). Less sensitive methods are used to analyze clinical specimens to determine whether patients' lithium concentrations are above the minimum therapeutic limit and below the toxic limit, both of which are on the order of milligrams per liter (mg/L). Because lithium concentrations among non-patient populations have been in ***micro***grams per liter (which is on the order of a thousand times *lower* than the milligram-per-liter concentrations found among patients taking lithium medicines), the more sensitive method was used to quantify the serum lithium concentrations of Eagle-Pitcher employees.

All biological monitoring participants were asked to complete a self-administered questionnaire at the time of the specimen collection to evaluate factors that could not be measured by environmental sampling but could affect serum lithium concentrations. The questionnaire covered factors that could have affected exposure potential during the previous week, such as changes in work schedule or task assignment, use of gloves and coveralls, handwashing after exposure (specifically before eating, smoking, and leaving work), and showering at the end of the workday. The questionnaire also covered non-work-related factors that could affect serum lithium concentration, such as medication use, kidney disease, and mineral water consumption.

The serum lithium results were compared with those of several populations with no occupational exposures (described later in the Evaluation Criteria section). Serum lithium concentrations were also analyzed for correlation with results of PBZ air and hand-wipe samples to determine the potential contributions by inhalation and ingestion. For the analyses, results of PBZ air levels were averaged if an individual was sampled for more than one day. Results by work area were also compared.

Industrial hygiene sampling for potential inhalation exposure was conducted in each area. On April 18, NIOSH industrial hygienists collected full-shift PBZ samples for lithium in the process room, the pill room, and dry room 108. On April 19, NIOSH industrial hygienists again collected samples for lithium in the pill room and in dry room 108. The samples were collected and analyzed in accordance with NIOSH Method 7300 modified for microwave digestion.[2] The samples were collected on 37 millimeter (mm) diameter, 0.8 micrometer (µm) pore-size mixed cellulose ester filters in three-piece cassettes clipped to the front of the employee's shirt, connected via a length of Tygon® tubing to a battery-powered personal sampling pump worn at the employee's waist. The sampling pumps were calibrated to operate at a flow rate of 2 liters per minute (L/min). The filters were digested in the microwave in the presence of 10 milliliter (mL) 1:1 nitric acid. Following digestion, the samples were allowed to cool and 13 mL of ASTM Type II water[3] were added to each sample. Samples were shaken, transferred to 25-mL volumetric

flasks, diluted to volume with ASTM Type II water, and shaken again. Samples were analyzed by inductively coupled plasma, atomic emission spectroscopy (ICP-AES). The LOQ for this sample set was 1.2 micrograms (µg) per filter for each element. This equates to a minimum quantifiable concentration (MQC) of 0.0014 milligram per cubic meter (mg/m^3), based upon a maximum air sample volume of 848 liters (L) for this sample set. For this sampling method, the LOQ is essentially equal to the limit of detection (LOD).

Hand-wipe sampling for potential hand-to-mouth exposure was conducted on a group of employees in the pill room and in dry room 108. On April 19, 1996, NIOSH industrial hygienists collected 24 hand-wipe samples for lithium. Samples were collected as employees left their work area to go to lunch. Samples were collected from 10 employees in the pill room and 14 employees in dry room 108. Employees were asked to open the hand wipe packet, wipe both hands for 30 seconds, and deposit the wipe in a plastic bag held open for them by a NIOSH industrial hygienist. Samples were collected using "Wash n Dry" brand wipes, which were digested and analyzed according to NIOSH Method 7300 modified for wipes.[2] The wipes were digested on a hotplate in the presence of 20 mL of concentrated nitric acid and 2 mL of 30% hydrogen peroxide. After the samples were reduced to 1 mL and allowed to cool, they were transferred to 25 mL volumetric flasks and diluted to volume with American Society for Testing and Materials (ASTM) Type II water. The samples were shaken and transferred to clean dilution vials, and analyzed using inductively coupled plasma, atomic emission spectroscopy (ICP-AES). The LOD of the method was 0.2 µg/wipe, with a LOQ of 0.45 µg/wipe.

Potting Area

On April 18, a bulk sample of dust was scraped from a diffuser in the potting area to address employee concerns about the recirculation of exhaust air in that area, and to identify the components of the orange deposits on the walls in the area. The sample was analyzed by extracting a 50 milligram (mg) portion with 1 mL of methylene chloride which contained 40 µg/mL of internal standard d10-ethylbenzene. The extract was screened using gas chromatography/mass spectroscopy.

On April 19, a wipe sample was collected from the exterior of a duct near the diffuser, in an area which was stained orange. The wipe sample was split into two halves. One half of the wipe sample was digested and analyzed for metals according to NIOSH Method 7300 modified for wipes as noted above, except that two quarters of the original wipe were handled separately until just prior to analysis, when they were shaken and combined.[2] The LODs and LOQs for the metals are provided in Table 1. The other half of the wipe sample was prepared and analyzed for mercury by cold vapor atomic absorption spectrophotometry according to NIOSH Method 6009,[2] modified for wipes as follows: the wipe sample was transferred to a clean 50 mL class A volumetric flask, to which 2.5 mL of concentrated nitric acid and 2.5 mL of concentrated hydrochloric acid were added, mixing after each addition. The sample was allowed to sit unstoppered in a hood for one hour. The sample was then diluted to volume with ASTM Type II water. A preparation blank was prepared along with the sample. The LOD for mercury was 0.01 µg/sample. The LOQ for mercury was 0.033 µg/sample.

Soldering Area

Two samples were collected on April 19 to assess employee exposure to rosin solder flux decomposition products. One sample was collected in the morning, the other in the afternoon. The short-term samples were collected while an employee soldered contacts on batteries by placing the sampler on the table in front of the employee, between the employee and the work, with the sampling inlet in the employee's breathing zone. Samples were collected on solid sorbent tubes (10% 2-[hydroxymethyl] piperidine on XAD-2 resin) in plastic holders connected via a length of Tygon® tubing to battery-powered personal sampling pumps operating at a flow rate of 50 mL/min. The sample collected in the morning was analyzed for formaldehyde by gas chromatography according to NIOSH Method 2539[2] with the oven conditions modified as

follows: 70°C for 1 min up to 110°C for 2 min at rate of 6°C/min, increased to 270°C for 2.34 min at rate of 40°C/min.[2] The LOD for this sample set was 1 µg/sample, which equates to a minimum detectable concentration (MDC) of 1.0 ppm, based upon the 0.8 L air sampling volume for this sample. The LOQ for this sample set was 4.9 µg/sample, which equates to a MQC of 5.0 parts per million (ppm), based on the sample volume of 0.8 L. The sample collected in the afternoon was analyzed for the aldehydes listed in Table 2 using NIOSH Method 2539, with the same modifications to the oven conditions noted above.[2] The LODs, LOQs, MDCs, and MQCs are provided in Table 2. These are based on a sample volume of 0.75 L.

Mercury Area

A mercury (Hg) exposure assessment study was conducted in the Hg-treatment area on April 18, and the negative pasting area on April 19. Workers' Hg exposure concentrations were assessed by sampling the air from the workers' breathing zone; these were full shift samples used to determine the workers' time-weighted average (TWA) exposure concentrations. In addition, two short-term breathing zone air samples were collected to determine specific task-based Hg exposure concentrations. The air sampling and analysis method used to determine Hg exposures was NIOSH Method 6009.[2] In this method, air is drawn through a solid sorbent tube containing 200 mg of hopcalite at a nominal flow rate of 200 mL/min. The samples were prepared by adding 2.5 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 cold vapor atomic absorption spectrometer. The MDCs, and MQCs associated with this method are listed on Tables 8 and 9 of this report.

The employees participating in the Hg exposure assessment study of the Hg-treatment and negative formation areas were asked to submit a urine sample for Hg analysis. The urine samples were collected before the start of the shift on the last day of the Hg exposure monitoring study. Each urine sample was analyzed for Hg and creatinine. The ideal method for determining urine Hg concentrations is to collect all the urine over a 24-hour period in order to determine the mass of Hg excreted per day. Because 24-hour urine sampling is not feasible in many situations, spot urine samples often are collected in workplace studies. When collecting spot urine samples, the investigator assumes that workers with chronic Hg exposure excrete Hg at a constant rate. Since the water output is not constant, a dilution correction is used to normalize the volume portion of the urine Hg concentration. A common method for dilution correction is to express the urine Hg concentrations as micrograms of Hg per gram of creatinine (µg/g-Cr). Creatinine is a metabolic product normally found in urine, and is excreted at a fairly constant rate.

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 increases 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 evaluation criteria for the workplace are: (1) NIOSH recommended exposure limits (RELs)[4], (2) the American

Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®)[5], and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs)[6]. Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm.[7] Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STEL). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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 STELs or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Lithium

Chemistry

Lithium, atomic number 3, is the lightest solid element. It is widely distributed in nature, generally in very low concentrations.[8] However, it may be found in concentrations of up to about 1 milliequivalent/L in some natural mineral waters.[9] The solubility of lithium depends on the compound and the medium.[10] Lithium forms intermetallic compounds with various metals. Some are not highly soluble. Others, such as lithium aluminum, may be soluble in biological media, depending on contact time.[11] Lithium salts, such as lithium carbonate, lithium chloride, lithium fluoride, and lithium oxide decompose or are soluble in water.[10]

Biokinetics

The gastrointestinal system absorbs lithium ion completely. Because lithium ion is water soluble, its distribution is basically the same as the distribution of water in the body. It crosses the blood-brain barrier slowly. One- to two-thirds of an absorbed dose is excreted in the urine within 6 to 12 hours after absorption. Nearly all of the remainder is excreted in the urine over the following two weeks. Four to five percent is excreted in sweat, and a smaller amount in feces. Lithium is also secreted in saliva, tears, and breast milk. Its half-life is from 20 to 24 hours. With repeated intake, concentrations in the body reach steady state in five to six days.[12]

General Population

In the general population, lithium is found in biological tissues as a result of oral intake of natural sources such as food and water. Lithium concentrations among individuals who are not clinically or occupationally exposed to lithium compounds have been reported at 0.1 to 0.3 µmole/L (0.7 to 2.1 µg/L) serum,[13] 0.3 ± 0.01 microgram per kilogram (µg/kg) (approximately 0.3 µg/L) plasma,[14] and 0.6 to 3.4 µg/L serum.[15]

Exposed Workers

Biological monitoring of workers exposed to lithium was reported in two previous investigations. A NIOSH health hazard investigation was conducted at a lithium extraction plant where airborne concentrations of lithium carbonate for five workers ranged up to 0.42 mg/m^3 (over 407 to 415 min sampling time), and 0.90 to 4.4 mg/m^3 (120 and 121 min sampling time). Serum lithium concentrations among workers at the plant were below the limit of detection of 0.05 milliequivalent per liter (meq/L) (0.35 mg/L).[16] Bencze et al. studied subjects working on lithium aluminum alloy components and found airborne lithium aluminum dust concentrations to be less than 50% of the West German maximum workplace concentration for aluminum dust (6 mg/m^3).[11] Specimens for pre- and post-work serum lithium were collected from six exposed workers. Their serum lithium concentrations ranged from 0.6 to 4.6 µg/L and urinary lithium ranged from 1 to 40 µg/L.[17]

Medical Use

Lithium has been used in a variety of medicines and as a salt substitute. In the nineteenth century, lithium was used to treat gout, and lithium bromide was used as a sedative and anticonvulsant.[9,12] In the late 1940s, unlimited use of lithium chloride as a salt substitute resulted in human toxicity and death[9,12] and its withdrawal from medical use. However, in 1949, lithium carbonate was noted to cause lethargy in guinea pigs,[18] leading to its eventual use in the treatment of bipolar conditions.[9,12] Because of its known toxicity, lithium carbonate was not approved for use in the United States until 1970.[19]

Because toxicity can occur at concentrations only slightly higher than therapeutic concentrations, patients taking lithium carbonate are routinely monitored for serum or urinary lithium. Blood or urine specimens are collected 6 to 12 hours after a dose to assure that the patient's lowest concentration remains in the therapeutic range. Therapeutic ranges depend on the laboratory, but the lowest concentrations for therapeutic ranges generally are between 0.5 to 1.3 mmole/L serum (3.5 to 9.0 mg/L). Because concentrations are higher before the time of the specimen collection, concentrations above the therapeutic range are considered potentially toxic. The maximum therapeutic concentrations vary from 1.5 to 2.0 mmole/L serum (10.4 to 13.8 mg/L), depending on the laboratory.

Side Effects and Toxicity

Lithium carbonate has been well studied for side effects and toxicity because of its medical use. For this reason, studies and reports have focused on side effects and toxicity of serum lithium concentrations in the therapeutic and toxic ranges, which is on the order of a thousand times higher than concentrations found in populations not taking lithium medication.

The reported side effects of lithium at therapeutic levels include reversible benign, diffuse, nontender thyroid enlargement, reversible polydipsia (increased thirst) and polyuria (increased urine output), benign reversible electrocardiogram changes, and benign increase in circulating polymorphonuclear leukocytes (a type of white blood cells).[12,19] Allergic reactions, such as dermatitis (skin reaction) and vasculitis (blood vessel reaction), can also occur.[12,19]

Acute toxic effects have been associated with the amount or rate of increase of plasma (or serum) lithium concentrations. Serum lithium concentrations higher than maximum therapeutic concentrations (greater than 10.4 to 13.8 mg/L, depending on the laboratory) are considered toxic. Mild symptoms of intoxication include nausea, vomiting, abdominal pain, diarrhea, sedation (drowsiness), and fine tremor. More serious effects include mental confusion, hyperreflexia (increased deep tendon reflexes), gross tremor, and dysarthria (slurred speech) progressing to coma and convulsions. Other toxic effects include heart dysrhythmia (abnormal heart rhythm), hypotension (abnormally low blood pressure), and albuminuria (albumin, a protein, in the urine).[12]

Lithium is known to affect carbohydrate metabolism, and new onset diabetes has been reported among patients taking lithium medication.[19] The diabetes appears to be reversible.[19] Lithium is also known to affect the kidney, and cases of nephrogenic diabetes insidipus (which causes increased urine output, thus increasing thirst) among patients taking lithium medication have been reported.[19]

Use of lithium during pregnancy has been associated with congenital heart abnormalities and reversible goiter (thyroid condition), central nervous system depression, hypotonia (decreased muscle tone), and heart murmur in newborn infants.[12,19] Animal studies have shown that birth defects may be related to the dose and scheduling of the medication. No abnormalities were seen when lithium levels were maintained in the therapeutic range, but were seen when higher "pulse" doses were given, causing lithium levels to rise into the toxic range.[19]

Certain drugs and medical conditions may increase the possibility of lithium toxicity. These include certain medicines used for treating high blood pressure or heart conditions (such as angiotensin-converting enzyme [ACE] inhibitors, calcium-channel blocking agents, and some diuretics), non-steroidal anti-inflammatory agents which are commonly used for treating headaches and musculoskeletal conditions, and certain medicines used for treating psychiatric disorders

(such as chlorpromazine).[20] Other factors that can contribute to lithium toxicity include severe dehydration (such as fluid loss from fever, heavy exercise, saunas, hot baths, sweating, diarrhea, or vomiting), renal insufficiency (kidney problem), urinary retention, and a salt-restricted diet.[20]

Evaluation Criteria

Most of the lithium compounds used at the Eagle-Picher plant do not have evaluation criteria for airborne exposures. The American Industrial Hygiene Association (AIHA) has established a Workplace Environmental Exposure Level Guide (WEEL) of 1 mg/m^3 for lithium oxide as a 1-minute time weighted average. At the recommended WEEL, the maximum daily intake would be considerably below the therapeutic or toxic doses. Documentation for the WEEL further states that workers' actual intake would probably be considerably below the WEEL.[21] Another workplace criterion is based on the Bencze et al. study conducted to determine if the West German exposure standard of 6 mg/m^3 for fine aluminum dust was applicable to lithium aluminum alloy dust in air. The study found that lithium aluminum alloy dust was irritating at 2 mg/m^3. The authors recommended an exposure limit of 1 mg/m^3 for total dust of lithium aluminum alloys containing up to 2.5% lithium.[11]

Mercury

Biokinetics

Since metallic Hg is volatile at ambient temperatures, the majority of occupational 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.[22] 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.[23,24,25] 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.[22,26] 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.[22,27] 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.[22,28]

The feces and urine are the primary pathways for the elimination of Hg from the body, though it is unclear which is the dominant pathway.[21,24,25,26] Elimination through sweat, saliva, nails, hair, and bile also contribute a small portion to the excretion process. The elimination kinetics (measured in half-lives) for the major compartments involved with the uptake, distribution, and elimination of Hg are as follows: lungs - 2 days, blood - 2 to 4 days, brain - 21 days, kidneys - 40 to 60 days, and whole body - 40 to 60 days.[21] Thus, blood Hg concentrations are considered markers of recent or acute Hg exposures; whereas urinary Hg concentrations tend to integrate exposures over several weeks; *i.e.*, are markers of chronic exposure. Some evidence exists suggesting that Hg elimination via urine occurs in two exponential phases. Under steady state conditions, a fast phase with a half-life of 2 days accounts for the elimination of 20 to 30% of the Hg body burden. The majority of the Hg body burden is eliminated through a slow phase with a half-life of 40 to 60 days. Because of this slow phase, urine Hg excretion is slightly dependent on temporal variability in Hg airborne exposure.[29]

Effects

Acute or short-term exposure to high concentrations of elemental Hg causes erosive bronchitis, bronchiolitis, and diffuse interstitial pneumonia. Symptoms include tightness and pain in the chest, cough, and difficulty breathing.[30] Other acute effects include nausea, abdominal

pain, vomiting, diarrhea, headache, and inflammation of the mouth and gums.[31]

Chronic or long-term exposure to Hg can result in symptoms of weakness, fatigue, loss of appetite, loss of weight, gingivitis, metallic taste, disturbance of gastrointestinal functions, and discoloration of the lens in the eye.[22] The target organs for Hg toxicity are the central nervous system (CNS) and the kidneys. A wide variety of CNS-related symptoms, *e.g.*, cognitive, sensory, personality, and motor disturbances, have been reported in humans exposed to Hg. Early symptoms of CNS effects include increased irritability, loss of memory, loss of self-confidence, weakness, reflex abnormalities, emotional instability with depressive moods, and insomnia. At higher exposure levels, fine tremor and coarse shaking can appear, as well as severe behavioral changes including delirium and hallucination. Tremor progresses in severity with duration of exposure. Although the symptoms in cases of slight poisoning regress and disappear when exposure has ceased, nervous system effects may persist in cases of long-term exposure.[4,23,26]

The kidneys are sensitive target organs due to the large proportion of the absorbed Hg dose that accumulates in the renal cortex.[22] Acute Hg exposure has produced proteinuria, hematuria, oliguria, necrosis of the proximal tubule, and acute renal failure. Chronic exposure is characterized by proteinuria (albumin, β-2-microglobulin, retinol-binding protein, *etc.*) and enzymuria (β-galactosidase, β-glucuronidase, N-acetyl-β-D-glucosaminidase, *etc.*).[32,33,34,35,36,37,38,39,40,41] In severe cases, a nephrotic syndrome has been observed, consisting mostly of hematuria, oliguria, urinary casts, edema, and the inability to concentrate urine.[22,40,42,43,44,45,46] In addition, chronic Hg exposure can lead to an increase in proximal tubular cell turnover, and microdamage to specific segments of the proximal tubule's cell wall.[47,48,49,50,51,52] These manifestations can diminish the ability of proximal tubular segments to reabsorb water, proteins, and other glomerular filtrates; thus, affecting the kidneys' ability to maintain volume and composition of body fluids within normal limits.

Evaluation Criteria

OSHA currently enforces a PEL for Hg of 100 µg/m^3, as a ceiling limit that should not be exceeded during a work shift.[6] 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 urinary Hg recommendation.[4] In 1980, the World Health Organization (WHO) Working Group recommended an 8-hour TWA exposure limit of 25 µg/m^3, and a urine Hg limit of 50 µg/g-Cr.[30] The WHO TWA exposure limit was set at 25 µg/m^3 because the WHO Working Group "felt that a health-based occupational exposure limit of 25 µg/m^3 . . . would ensure a reasonable degree of protection not only against tremor but also against Hg-induced nonspecific symptoms."[30] In 1994, the ACGIH lowered the TLV and BEI for Hg to 25 µg/m^3 (TWA exposure, 8-hours per day, 40-hours per week) and 35 µg/g-Cr, respectively.[5] The reason for lowering the TLV was a finding of pre-clinical signs of CNS and renal dysfunction at worker exposure levels above 25 µg/m^3. People without occupational exposure to Hg generally have urinary Hg concentrations of 5 µg/g-Cr or less.[22,30]

Rosin (Colophony)

Rosin, or colophony, is a natural resinous product obtained from pine trees.[53] Colophony is composed of about 90% resin acids, the remainder chiefly consisting of the corresponding ester, aldehydes, and alcohols. The acids are mainly the abietic and primaric types. The use in soldering fluxes is one of the most important uses for rosin today. Soldering fluxes remove corrosion from the metal surface, providing a tarnish-free surface to allow the solder to bond. The flux is destroyed by heat as the solder fills the joint, allowing good surface contact between the solder and the metal. Colophony has been reported to cause both occupational asthma and contact dermatitis.[54] The most commonly reported cases associated with occupational exposure are caused by solder fluxes resulting either from direct contact with the flux or from exposure to solder fume. Less commonly, it has also been reported to cause upper respiratory tract irritation at high concentrations, as well as alveolitis and rhinitis, with and without asthma. The NIOSH REL for rosin flux pyrolysis products (measured as formaldehyde) is 0.1

mg/m^3 (0.08 ppm) as a 10-hr TWA.[4] NIOSH considers rosin flux pyrolysis products to be a carcinogen in the presence of formaldehyde, acetaldehyde, or malonaldehyde.[4] There is no OSHA PEL for rosin flux decomposition products.[6] The ACGIH TLV states "sensitizer; reduce exposure to as low as possible."[5] Prior to 1993, the ACGIH TLV was 0.1 mg/m^3 of formaldehyde, 8-hr TWA.[55]

Exhaust Ventilation Recirculation

When a large volume of air is exhausted from a room or building in order to remove contaminants, an equivalent amount of fresh tempered replacement air must be supplied to the room. The energy costs of tempering large volumes of air can be quite high. These energy costs can be reduced by recirculating thoroughly cleaned exhaust air. Whether or not it is acceptable to recirculate exhaust air depends on the extent of the health hazard associated with the contaminant which is being exhausted, as well as a number of other safety, technical, and economic factors. The ACGIH and the American National Standards Institute/American Industrial Hygiene Association have published guidelines for recirculation.[56,57]

RESULTS

Thermal Battery Area

Lithium Area

Of the 44 eligible workers, 41 (93%) participated in the biological monitoring for lithium, 39 (89%) participated in the PBZ air sampling, and 24 (55%) in the hand-wipe sampling. Table 3 shows the results for serum, PBZ, and hand-wipe lithium by work area. Serum and PBZ lithium concentrations of process room workers fell within the range of the results of the pill room workers. Geometric means of serum and PBZ lithium concentrations of process room and pill room workers were higher ($p = 0.0001$ and $p = 0.0009$, respectively) than those of dry-room workers. Hand-wipes samples for lithium were collected from a subgroup of pill room and dry room employees who were monitored for serum and PBZ lithium. The geometric mean of hand-wipe results of pill room workers was higher than that of dry-room workers ($p = 0.0021$).

Tables 4 and 5 show the results for serum, PBZ, and hand-wipe lithium by job title within the pill room and the dry room, respectively. PBZ lithium among press operators in the pill room was highly variable. In the pill room, both serum and PBZ concentrations, on average, tended to be lower among press operators than among press technicians. In the dry room, job title differences for serum, PBZ, and hand-wipe lithium results were not noted.

Results of the 36 workers who participated in both the PBZ air sampling and biological monitoring showed a correlation between PBZ results and serum lithium (Pearson coefficient 0.51, $p<0.01$ for the natural log transformations of all values). Results of the 23 workers who participated in both hand-wipe sampling and biological monitoring showed a correlation between hand-wipe results and serum lithium (Pearson coefficient 0.68, $p<0.01$ for the natural log transformations of all values).

All 44 eligible workers completed the questionnaire. All reported that they use gloves almost always (5, 11%) or all the time (39, 89%). Thirty five (80%) reported that they changed into new gloves almost always or all the time. Thirty seven (84%) reported that they washed hands almost always or all the time before taking breaks and after work. All but four reported that they used coveralls while working in the lithium area. Thirty seven (84%) reported that they took showers or baths daily. However, only eight of these workers reported taking showers or baths shortly after leaving work. Most reported showering or bathing later at night or the next morning.

Heart disease or high blood pressure was reported by 7 (15.9%) of the 44 lithium area workers, respiratory disorders by 7 (15.9%), gastrointestinal disorder by 4 (9.0%), diabetes by 2 (4.5%), musculoskeltetal disorders by 7 (15.9%), and depression or bipolar condition by 6 (13.6%). One person was taking medications for high blood pressure. All seven who reported respiratory conditions were taking medications for

allergy, rhinitis, or asthma. Six of the seven who reported musculoskeletal problems were taking over-the-counter anti-inflammatory medications. None of the workers who reported heart disease, diabetes, depression, or bipolar condition were taking medications for these conditions. For each type of health condition except for diabetes and musculoskeletal disorders, workers in the process and pill rooms (where exposures to lithium were relatively higher than in the dry room) were less likely than dry-room workers to report the health condition. Both workers reporting diabetes worked in the pill room. Process and pill room workers were more likely to report musculoskeletal conditions than dry-room workers.

Potting Area

The results of the analysis of the bulk sample of material removed from the diffuser in the potting area are provided in Table 6. These results are not quantitative, yet they are more than qualitative in that they were compared against a standard but their identities could not all be established. The majority of the sample was composed of a variety of phthalate esters. Bis-phenol A and some of its derivatives, which are consistent with the presence of epoxy resins, were also major components. A fluorocarbon polymer series was present in the sample, as well as a fatty acid series. Other components included butyl esters of palmitic and stearic acids, several unknown alkyl aromatics, and 23 to 29 carbon paraffins.

The results of the analysis of the wipe sample collected on the duct near the diffuser in the potting area are presented in Table 7. The metals found in the sample include aluminum, barium, cadmium, cobalt, chromium, copper, iron, lithium, magnesium, manganese, molybdenum, nickel, lead, phosphorous, silver, titanium, vanadium, yttrium, zinc, and zirconium. Mercury was found in the portion of the wipe subjected to analysis for mercury.

Soldering Area

The results of the analyses of the short-term samples for aldehydes and formaldehyde indicated that none of the aldehydes were present in amounts greater than the LODs for the method, or the MDCs for these samples. The LODs and MDCs for the aldehyde screening sample are provided in Table 2. The LOD and MDC for formaldehyde for the other sample were 1µg/sample and 1 ppm, respectively.

Mercury Area

Tables 8 and 9 contain the data from the Hg exposure assessment study. Overall, a total of 20 workers participated in the study, 9 from the Hg-treatment area and 11 from the negative pasting area. One worker did not participate in the exposure assessment study, three workers participated in the exposure assessment study but did not provide a urine sample, and one worker refused to participate in both the exposure assessment and urine monitoring portions of this study. Hence, 19 of 21workers from both areas participated in the Hg exposure assessment study, and 17 of 21 participated in the urine Hg monitoring.

The overall mean (average) Hg full-shift TWA exposure concentration was 18.3 $\mu g/m^3$, and the TWA exposure concentrations ranged from 3.5 to 48.3 $\mu g/m^3$. Three of the 18 full-shift, TWA Hg exposure measurements were above the ACGIH TLV. Hg exposure measurements of 48.3, 33.6, and 27.7 $\mu g/m^3$ were found on three processors in the negative pasting area. One oven runner in the negative pasting area had a Hg exposure above the ACGIH TLV (42.1 $\mu g/m^3$), but this is based on a partial shift sample (less than 8-hours) during active oven use, and does not reflect the worker's full-shift TWA Hg exposure. The Hg exposures were slightly higher in the negative pasting area (mean exposure concentration of 22.1 $\mu g/m^3$) when compared to the Hg-treatment area (13.6 $\mu g/m^3$).

In addition to the above partial shift sample, three short-term or task-based Hg exposure measurements were made on workers performing some suspected high exposure tasks. The Hg exposure for the worker operating the Hg-treatment ovens was 38.9 $\mu g/m^3$; this task lasted approximately 18 minutes. Also, a Hg exposure of 22.4 $\mu g/m^3$ was measured from the worker performing the mercury/zinc mixing operation. This task was performed in approximately 20 minutes. Finally, a task-based Hg exposure of

16.4 µg/m^3 was measured in the worker performing the Hg treatment dip tank operation.

Spot urine samples were obtained from 17 workers from the Hg-treatment and negative pasting areas. The urine Hg data for all participating workers are shown in Tables 8 and 9. All but one of the workers had urine Hg levels below the ACGIH BEI of 35 µg/g-Cr. A urine Hg level of 86.4 µg/g-Cr was found in a processor who did not participate in the Hg exposure assessment study. Hg was not detected in five of the workers' urine samples.

DISCUSSION

Thermal Battery Area

Lithium Area

Although ten (24%) Eagle-Picher workers had serum lithium concentrations higher than reference ranges[13,14,15] for populations not taking lithium medication, all serum lithium concentrations were on the order of a thousand times lower than therapeutic concentrations of patients who regularly take lithium medication. Except for diabetes and musculoskeletal disorders, process and pill room workers reported fewer health problems than dry-room workers, who had generally lower exposures. The two workers who reported diabetes are not currently on any treatment for diabetes. This is consistent with reversible diabetes, which has been reported in patients taking lithium medication.[19] However, if lithium was responsible for the diabetic episodes of these Eagle-Picher workers, their exposures would have had to have been much higher than the lithium exposures measured during this study. This study was not meant to determine past exposures. Thus, it cannot determine whether workplace lithium exposures contributed to the diabetic episodes reported by these workers. If past exposures were similar to exposures during the time of this study, it is unlikely that lithium exposures at Eagle-Picher caused the medical conditions that worried some Eagle-Picher workers. It is also unlikely that lithium exposures at Eagle-Picher would have caused the types of side effects or toxic effects that are known to occur with lithium.

Although all serum lithium concentrations were well below therapeutic levels, this study shows that lithium area workers were absorbing workplace lithium. Serum lithium correlated with PBZ exposures, and workers in the process and pill rooms generally had higher serum lithium concentrations than dry-room workers, where PBZ exposures were generally lower. These findings indicate that PBZ exposures can contribute to workers' serum lithium concentrations. Serum lithium also correlated with hand-wipe results, indicating that hand contamination can also contribute to the workers' serum lithium concentrations. Lithium-contaminated hands can contaminate food, beverages, chewing gum, and tobacco, and thus increase exposure. Since glove use was common, this suggests that lithium can contaminate workers' hands despite the use of gloves. Although the relationship of bathing time and serum lithium concentrations was not analyzed, the questionnaire results showed that most workers did not bathe or shower immediately after leaving work. This could contribute to continued after-work exposure to lithium through contaminated hair, skin, and clothing.

Potting Area

The presence of the constituents of the potting compounds on a supply diffuser in the potting area may indicate that these substances are being recirculated in the workroom air. In the absence of surface-based evaluation criteria for these compounds, it is difficult to determine whether their presence in a bulk sample collected on a surface is a cause for concern. However, their presence can be evaluated in light of the criteria for recirculation of workroom air. Based upon the absence of airborne evaluation criteria for some of the substances used in the potting area and the health effects noted for some of these compounds, recirculation of exhaust air is not recommended.

Soldering Area

The air sampling results indicated that aldehydes were not present in the workroom air in amounts greater than their limits of detection on the day of the survey. Rosin core solder decomposition products have been classified as a sensitizer, with a relatively long symptom-free period before the

onset of asthma. In the absence of a validated analytical procedure for determining colophony concentration in workplace air the ACGIH TLV committee recommends that exposure be maintained as low as possible using engineering controls and appropriate personal protective equipment.[58]

Mercury Areas

In general, the Hg exposures and urine Hg levels measured during this survey were relatively low. The two over-exposures found among processors indicate that this has the potential to be a hazardous job, and exposure controls should be used to better protect these workers. All but one of the urine Hg concentrations were below the ACGIH BEI. The reason the one worker had a high concentration could not be determined, since this worker did not participate in the Hg exposure assessment study. Though a high Hg exposure concentration was found on one of the two oven runners, the measurement was not a full-shift air sample and the other oven runner had a low Hg exposure. In addition, both workers had low urine Hg levels. Short term exposure measurements which were task-based indicate that workers are not exposed to hazardous Hg concentrations when opening the Hg Treatment Ovens, when mixing Hg and zinc, and when performing the Hg treatment dip tank operation.

RECOMMENDATIONS

Thermal Battery Area

Lithium Area

Although Eagle-Picher employees' serum lithium concentrations were well below those of patients taking lithium medicines, the following practices may decrease individual exposures.

In lithium areas—
- Good housekeeping practices.
- No food, beverages, chewing gum, or cigarettes.

On leaving lithium areas—
- Handwashing before eating, drinking, or smoking—even if gloves were used.
- Face washing before eating, drinking, or smoking.
- Showering, hair washing, and changing into clean clothes as soon as possible after work.

Potting Area

Eagle-Picher should determine whether continued recirculation of Potting Area air is wise in light of the Guidelines given above in the Evaluation Criteria section. Alternatives to recirculation might include venting oven exhaust air outside and recirculating room air, or increasing the volume of outside air introduced. Any alternative to recirculation should be evaluated in light of accepted guidelines for recirculation and air sampling for contaminants generated by the potting process.

Mercury Area

Although the Hg exposures and urine Hg levels measured in the Hg-treatment and negative pasting areas were generally low, the following general recommendations are offered to better protect Hg-exposed workers:

• The processors' work stations should be equipped with local exhaust ventilation to capture and remove Hg vapors from the work areas. Recommended local exhaust ventilation for such work stations can be found in the ACGIH book titled "*Industrial Ventilation: A Manual of Recommended Practice.*"[56] This book can be purchased by contacting the ACGIH in Cincinnati, Ohio.

• Workers should not be allowed to wear work clothing home at the end of the work shift. Work and street clothing should not be stored in the same locker. Before removal, work clothing should be vacuumed with a dedicated mercury vacuum, and stored in vapor–proof containers pending laundering. All work clothing should be laundered onsite, or sent to a laundering service with the capability to clean potentially contaminated work clothing. If a laundering service is used, the operators of the service should be informed that the clothes are potentially contaminated with Hg.

• Adequate shower facilities with hot and cold water should be available for use by the workers before they change into their street clothes. Workers should be required to shower before changing into street clothes and leaving the facility.

• A medical surveillance program should be made available to all employees exposed to inorganic Hg at or above the action level of 20 µg/m^3 (40% of the NIOSH REL) for more than 30 days each year.[59] This program should include pre-placement and periodic medical exams, along with a biological monitoring program. The pre-placement exam should consist of a medical evaluation for signs and symptoms associated with Hg toxicity, a spot urine Hg determination, and a urinalysis with microscopic exam. In addition, this evaluation should also include detailed histories of previous Hg exposure, central nervous system disorders, and renal disease.[60]

NIOSH does not have an official policy or recommendation regarding biological monitoring for Hg; therefore more stringent guidelines should be continued if already in place to better protect workers. The following recommendations are proposed by the authors of this report and are based on existing scientific information and recommendations of other organizations regarding inorganic Hg.

1. The urine Hg level of all employees exposed to Hg at or above the action level of 20 µg/m^3 should be determined at least every 6 months. The frequency of urine monitoring should be increased to at least every 2 months for employees whose last urine Hg level was between 35 and 50 µg/g-Cr.

2. If the urine Hg level is above 50 µg/g-Cr, the following measures should be taken:

A) the worker should be removed from exposure until the urine Hg level is below 35 µg/g-Cr.
B) the urine Hg levels should be measured monthly until the level is below 35 µg/g-Cr.
C) an industrial hygiene assessment should be performed and measures taken to reduce Hg exposures.
D) medical testing should include 24-hour urine Hg levels, serum creatinine, and urinalysis with microscopic exam.

3. An annual medical examination should be performed on workers with a urine Hg level above 35 µg/g-Cr during the preceding year.

4. Workers with symptoms suggestive of Hg toxicity or a urine Hg level above 35 µg/g-Cr should be offered a medical examination.

5. Acute exposure to Hg should be assessed by blood Hg levels.[61] This test can be used to assess the worker's short-term exposure after an unplanned or infrequent event, *i.e.* a spill or maintenance procedure. The ACGIH BEI for blood Hg is 15 µg/L.[5]

6. If workers are assigned different job duties because of an elevated urine Hg level or other occupational reasons, they should retain their wages, seniority, and benefits to which they would have been entitled had they not been reassigned. Also, when medically eligible to return to their former jobs, the workers should be entitled to the position, wages, and benefits they would have had had they not been removed.

7. All employee health information must be kept confidential and in a secure location. This information should be released only when required by law or overriding public health considerations; when needed by other health professionals for pertinent reasons; and when provided to designated individuals at the request of the employee.[62]

8. Physicians qualified in the practice of occupational medicine should provide the expertise for developing a medical surveillance program. The conduct of the medical aspects of such a program may be provided by other physicians or other health care professionals.[63]

• NIOSH recommends that every worksite with potential Hg exposures have an exposure monitoring program.[59] This program should consist of full–shift air sampling from the worker's breathing zone to measure the worker's TWA exposures to specific chemicals or substances. The purpose of this exposure monitoring is to determine whether exposures may

exceed the applicable exposure limits. Whenever a worker over–exposure is measured, a survey should be conducted to determine the reason behind the hazardous 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. Exposure monitoring surveys should be performed on a semi–annual basis, or whenever changes in work processes or conditions are likely to lead to a change in exposures. 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 an Hg exposure hazard area whenever the industrial hygiene studies find that environmental Hg concentrations and worker exposure concentrations exceed action level (40% of the NIOSH REL).

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

REFERENCES

1. Linden D [1992]. Primary battery. In: McGraw-Hill encyclopedia of science & technology. 7th ed. Vol. 14. New York, NY: McGraw-Hill Inc.

2. NIOSH [1994]. NIOSH manual of analytical methods. 4th rev. ed., Eller PM, 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.

3. ASTM [1985]. 1985 Annual Book of ASTM Standards, Vol. 11.01, "Standard Specification for Reagent Water." Philadelphia, PA: ASTM, D1193-77.

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

5. ACGIH [1998]. 1998 TLVs® and BEIs®: Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

6. Code of Federal Regulations [1997]. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

7. Public Law 91 – 596 Occupational safety and Health Act of 1970, Sec. 5.(a)(1).

8. Schou M [1957]. Biology and pharmacology of the lithium ion. *Pharmacology Reviews 9*:17-58.

9. Birch NJ [1988]. Ch. 32. Lithium. In: Seiler HG, Sigel H. Handbook on toxicity of inorganic compounds. New York and Basel: Marcel Dekker, Inc., pp. 383-393.

10. Weast RC (ed.) [1985]. CRC handbook of chemistry and physics. Boca Raton, FL: CRC Press, Inc, pp. B-108-B-109.

11. Bencze K, Pelikan CH, *et al.* [1991]. Lithium/aluminum alloys: A problem material for biological monitoring. *The Science of the Total Environment 101*:83-90.

12. Baldessarini RJ [1985]. Drugs and the treatment of psychiatric disorders. In: Gilman AG, Goodman LS, Rall TW, Murad F (eds.). Goodman and Gilman's The pharmacological basis of therapeutics. 7th ed. New York: Macmillan Publishing Company, pp. 426-430.

13. Baselt R [1988]. Lithium. In: Baselt R. Biological monitoring methods for industrial chemicals. 2nd ed. Littleton, MA: PSG Publishing Co., Inc., pp. 188-190.

14. Iyengar V, Woittiez J [1988]. Trace elements in human clinical specimens: Evaluation of literature data to identify reference values. *Clinical Chemistry 34*:474-481.

15. Pacific Toxicology [1996]. Personal communication.

16. NIOSH [1978]. Hazard evaluation and technical assistance report: Kerr-McGee Chemical Corporation, Trona, CA. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Center for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 77-59-496.

17. Schierl R [1996]. Personal communication about the serum lithium results of exposed workers studied by Bencze *et al*. [1991].

18. Cade JFJ [1949]. Lithium salts in the treatment of psychotic excitement. *Medical Journal of Australia 2*:349-352.

19. Simard M, Gumbiner B, *et al*. [1989]. Lithium carbonate intoxication: A case report and review of the literature. *Archives of Internal Medicine 149*:36-46.

20. United States Pharmacopeia [1997].

21. AIHA [1984]. Workplace Environmental Exposure Level Guide, Lithium Oxide. Akron, Ohio: American Industrial Hygiene Association.

22. ATSDR [1998]. Toxicological profile for mercury. Draft for Public Comment (Update). Atlanta, GA: U.S. Department of Health & Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, DHHS (ATSDR).

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

24. 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.

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

26. Doull J, Klaassen CD, Amdur MO, eds. [1991]. Casarett and Doull's Toxicology: The basic science of poisons. 4th ed. New York, New York: Macmillan Publishing Co., Inc.

27. 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.

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

29. Piotrowski J, Trojanowska B, *et al*. [1975]. Excretion kinetics and variability of urinary mercury in workers exposed to mercury vapour. *International Archives of Occupational and Environmental Health 35*:245-256.

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

31. Clayton G, Clayton F, eds. [1981]. Patty's industrial hygiene and toxicology. New York: John Wiley and Sons, Inc.

32. Buchet J, Roels H, *et al*. [1980]. Assessments of renal function of workers exposed to inorganic lead, cadmium, and mercury. *Journal of Occupational Medicine 22*:741-750.

33. Stonard M, Chater B, *et al*. [1983]. An evaluation of renal function in workers exposed to mercury vapour. *International Archives of Occupational and Environmental Health 52*:177-189.

34. Meyer R, Fischbein A, *et al*. [1984]. Increased urinary enzyme excretion in workers exposed to nephrotoxic chemicals. *The American Journal of Medicine 76*:989-998.

35. Rosenman K, Valciukas J, *et al*. [1986]. Sensitive indicators of inorganic mercury toxicity. *Archives of Environmental Health 41*:208-215.

36. Himeno S, Watanabe C, *et al*. [1986]. Urinary biochemical changes in workers exposed to mercury vapor. *Industrial Health 24*:151-155.

37. Barregård L, Hultberg B, *et al*. [1988]. Enzymuria in workers exposed to inorganic mercury. *International Archives of Occupational and Environmental Health 61*:65-69.

38. Piikivi L, Ruokonen A [1989]. Renal function and long-term low mercury vapor exposure. *Archives of Environmental Health 44*:146-149.

39. Roels H, Gennart J, *et al*. [1985]. Surveillance of workers exposed to mercury vapour: Validation of a previously proposed biological threshold limit value for mercury concentration in urine. *American Journal of Industrial Medicine 7*:45-71.

40. Langworth S, Elinder C, *et al*. [1992]. Renal and immunological effects of occupational exposure to inorganic mercury. *British Journal of Industrial Medicine 49*:394-401.

41. Ehrenberg R, Vogt R, *et al*. [1991]. Effects of elemental mercury exposure at a thermometer plant. *American Journal of Industrial Medicine 19*:495-507.

42. Danziger SJ, Possick PA [1973]. Metallic mercury exposure in scientific glassware manufacturing plants. *Journal of Occupation Medicine 15*:15-20.

43. Dyall-Smith DJ, Scurry JP [1990]. Mercury pigmentation and high mercury levels from the use of a cosmetic cream. *Medical Journal of Australia 153*:409-415.

44. Friberg L, Hammarstrom S, *et al*. [1953]. Kidney injury after chronic exposure to inorganic mercury. *Archives of Industrial Hygiene and Occupational Medicine 8*:149-153.

45. Kanluen S, Gottlieb CA [1991]. Clinical pathologic study of four adult cases of acute mercury inhalation. *Archives of Pathology and Laboratory Medicine 115*:56-60.

46. Tubbs R, Gorden D, *et al*. [1982]. Membranous glomerulonephritis associated with industrial mercury exposure - study of pathogenic mechanisms. *American Journal of Clinical Pathology 77*:409-413.

47. Mutti A, Lucertini S, *et al*. [1985]. Urinary excretion of brush border antigen revealed by monoclonal antibody: early indicator of toxic nephropathy. *Lancet ii*:914-917.

48. Verpooten GF, Etienne EJ, *et al*. [1989]. Segment-specific localization of intestinal-type alkaline phosphatase in human kidney. *Kidney International 36*:617-625.

49. Mutti A [1989]. Detection of renal diseases in humans: Developing markers and methods. *Toxicology Letters 46*:177-191.

50. Lauwerys R, Bernard A [1989]. Preclinical detection of nephrotoxicity: Description of the tests and appraisal of their health significance. *Toxicology Letters 46*:13-29.

51. Nuyts GD, Debroe ME [1992]. Correspondence. *British Journal of Industrial Medicine 49*:873-874.

52. Cárdenas A, Roels H, *et al*. [1993]. Markers of early renal changes induced by industrial pollutants. Application to workers exposed to mercury vapor. *British Journal of Industrial Medicine 50*:17-27.

53. Sadhra S, Foulds IS, *et al.* [1994]. Colophony - uses, health effects, airborne measurement and analysis. *Annals of Occupational Hygiene 38*:385-396.

54. 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. 94-116.

55. ACGIH [1992]. 1992-1993 threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

56. ACGIH [1995]. Industrial ventilation: a manual of recommended practice. 22nd ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists. pp. 7-15 - 7-16.

57. AIHA [1998]. American national standard for recirculation of air from industrial process exhaust systems. ANSI/AIHA Z9.7-1998, Fairfax, Virginia: American Industrial Hygiene Association.

58. ACGIH [1996]. Rosin core solder thermal decomposition products. In: Documentation of the threshold limit values and biological exposure indices. 6th ed. Vol III. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, Supplement: Rosin core solder, pp. 2-3.

59. NIOSH [1973]. Criteria for a recommended standard: Occupational exposure to inorganic mercury. DHEW (NIOSH) Publication No. 73-11024. Cincinnati, Ohio: U.S. Department of Health, Education, and Welfare, Public Health Service, National Institute for Occupational Safety and Health.

60. NIOSH/ OSHA [1981]. Occupational health guide for chemical hazards: inorganic mercury. DHHS, National Institute for Occupational Safety and Health, Publication No. 81-123.

61. Lauwerys RR, Hoet R [1993]. Chapter 15. Mercury. In: Lauwerys RR, Hoet eds. Industrial exposure: guidelines for biological monitoring. Boca Raton, FL: Lewis Publishers, p. 74-82.

62. ACOEM [1997]. AAOHN and ACOEM consensus statement for confidentiality of employee health information. http://www.acoem.org/paprguid/papers/aaohnconf.htm.

63. ACOEM [1989]. Medical surveillance in the workplace. Position statement. American College of Occupational and Environmental Medicine http://www.acoem.org/paprguid/papers/msurv.htm.

Table 1
Detection and Quantitation Limits for Metals in Wipe Samples, Potting Area
HETA 96-0016
Eagle-Picher Industries
Joplin, Missouri

Analyte	Limit of		Analyte	Limit of	
	Detection (µg/wipe)[a]	Quantitation (µg/wipe)		Detection (µg/wipe)	Quantitation (µg/wipe)
Silver	0.3	1.0	Molybdenum	0.5	1.7
Aluminum	4	14	Sodium	8	27
Arsenic	2	6.7	Nickel	0.3	1.0
Barium	0.2	0.67	Phosphorous	5	17
Beryllium	0.04	0.14	Lead	2	6.7
Calcium	9	30	Platinum	9	30
Cadmium	0.3	1.0	Selenium	5	17
Cobalt	0.5	1.7	Tellurium	3	10
Chromium	2	6.7	Thallium	3	10
Copper	0.3	1.0	Titanium	0.5	1.7
Iron	3	10	Vanadium	0.3	1.0
Lithium	0.5	1.5	Yttrium	0.05	0.17
Magnesium	2	6.7	Zinc	2	6.7
Manganese	0.04	0.14	Zirconium	0.3	1.0

[a] µg = microgram.

Table 2
Detection and Quantitation Limits for Aldehydes in Air Samples, Soldering Area
HETA 96-0016
Eagle-Picher Industries
Joplin, Missouri

Analyte	LOD[a] (µg/sample)[b]	MDC[c] (ppm)[d]	LOQ[e] (µg/sample)	MQC[f] (ppm)
Acetaldehyde	0.6	0.44	2.1	1.6
Formaldehyde	1	1.1	4.9	5.3
Valeraldehyde	0.6	0.23	2.2	0.83
Hexanal	0.6	0.20	2.1	0.68
Hepatanal	0.8	0.23	2.7	0.77
Butyraldehyde	1	0.45	3.4	1.5
Propionaldehyde	0.7	0.39	2.4	1.3
Acrolein	0.7	0.41	2.5	1.5
Iso-Valeraldehyde	0.3	0.11	1.0	0.38

[a] LOD = limit of detection
[b] µg = microgram
[c] MDC = minimum detectable concentration
[d] ppm = parts per million
[e] LOQ = limit of quantitation
[f] MQC = minimum quantifiable concentration (0.75 liters)

Table 3
Lithium Concentrations by Thermal Battery Work Area
HETA 96-0016
Eagle-Picher Industries
Joplin, Missouri

	All Areas	Process Room	Pill Room	Dry Room
Number of eligible workers	44	2	14	28
Serum samples[a]				
Number of workers sampled	41	2	12	27
Geometric mean (g.s.d.)[b] in µg/L[c]	1.75 (2.87)	5.59 (2.41)	4.14 (2.26)	1.09 (2.34)
Range in µg/L	ND[c] - 11.2	3.0 - 10.4	1.3 - 11.2	ND[d] - 6.4
Personal-breathing-zone samples				
Number of workers sampled	39	2	13[e]	24
Geometric mean (g.s.d.) in µg/m^3 [(f)]	1.79 (9.99)	25.94 (1.47)	15.26 (3.11)	0.45 (5.41)
Range in µg/m^3	ND - 121.8	19.8 - 34.0	2.3 - 121.8	ND - 11.3
Hand-wipe samples				
Number of workers sampled	24	0	10	14
Geometric mean (g.s.d.) in µg[g]	61.7 (3.9)		174.9 (3.0)	29.3 (2.6)
Range in µg	9 - 649		44 - 649	9 - 169

[a] For comparison, concentrations found in populations not taking lithium medication: up to 3.4 µg/L serum;[13,14,15] therapeutic concentrations for patients taking lithium medication: 3.5 to 13.8 mg/L, depending on the laboratory.
[b] Geometric means and geometric standard deviations (g.s.d.) are presented because the results were not normally distributed.
[c] Micrograms lithium per liter of serum. For calculations, nondetectable results were set to 0.4, which is equal to the limit of detection (0.5 µg/L) divided by the square root of two.
[d] Not detected at the limit of detection.
[e] Nine pill-room employees were sampled on both sampling days. For calculations, the results for each of these individuals were averaged.
[f] Micrograms lithium per cubic meter of air. For calculations, nondetectable results were set to the limit of detection (0.2 µg per sample) divided by the square root of two, then adjusted by a laboratory analysis correction factor.
[g] Micrograms lithium per hand-wipe sample. The limit of detection (LOD) was 0.2 µg/sample and the limit of quantitation (LOQ) was 0.45 µg/sample. The results greater than 500 µg were reported from 10-fold dilutions, thus the LOD and LOQ were 2 and 4.5 µg/sample for those samples. One of the results less than 15 µg was reported from a 2-fold dilution, thus the LOD and LOQ were 0.4 and 0.90 µg for that sample.

Table 4
Lithium Concentrations in the Pill Room by Job Title
HETA 96-0016
Eagle-Picher Industries
Joplin, Missouri

	All	Press Operator	Press Technician	Other [a]
Number of eligible workers	14	9	3	2
Serum samples[b]				
Number of workers sampled	12	7	3	2
Geometric mean (g.s.d.)[c] in µg/L[d]	4.14 (2.26)	3.38 (2.27)	7.70 (1.04)	3.32 (3.77)
Range in µg/L	1.3 - 11.2	1.3 - 11.2	7.4 - 8.0	1.3 - 8.5
Personal-breathing-zone samples				
Number of workers sampled	13[e]	9	2	2
Geometric mean (g.s.d.) in µg/m^3 [f]	15.26 (3.11)	17.41 (3.63)	20.01 (1.78)	6.44 (1.06)
Range in µg/m^3	2.3 - 121.8	2.3 - 121.8	13.3 - 30.0	6.2 - 6.7
Hand-wipe samples				
Number of workers sampled	10	7	2	1
Geometric mean (g.s.d.) in µg[g]	174.9 (3.0)	112.4 (2.8)	490.4 (1.4)[h]	
Range in µg	44 - 649	44 - 649	349 - 639[h]	

[a] Group leaders and quality control.
[b] For comparison, concentrations found in populations not taking lithium medication: up to 3.4 µg/L serum,[13,14,15] therapeutic concentrations for patients taking lithium medication: 3.5 to 13.8 mg/L, depending on the laboratory.
[c] Geometric means and geometric standard deviations (g.s.d.) are presented because the results were not normally distributed.
[d] Micrograms lithium per liter of serum.
[e] Nine pill-room employees were sampled on both sampling days. The results for each of these individuals were averaged.
[f] Micrograms lithium per cubic meter of air.
[g] Micrograms lithium per hand-wipe sample. The limit of detection (LOD) was 0.2 µg/sample and the limit of quantitation (LOQ) was 0.45 µg/sample. The results greater than 500 µg were reported from 10-fold dilutions, thus the LOD and LOQ were 2 and 4.5 µg/sample for those samples.
[h] Results of the press technicians and a group leader were combined.

Table 5
Lithium Concentrations in Dry Room 108 by Job Title
HETA 96-0016
Eagle-Picher Industries
Joplin, Missouri

	All	Battery Builder	Quality Control	Other [a]
Number of eligible workers	28	18	5	5
Serum samples[b]				
Number of workers sampled	27	17	5	5
Geometric mean (g.s.d.)[c] in µg/L[d]	1.09 (2.34)	1.09 (2.54)	1.14 (2.34)	1.10 (1.87)
Range in µg/L	ND[e] - 6.4	ND - 6.4	ND - 3.0	ND - 2.8
Personal-breathing-zone samples				
Number of workers sampled	24	16	4	4
Geometric mean (g.s.d.) in µg/m^3 [f]	0.45 (5.41)	0.61 (5.77)	0.53 (1.67)	0.11 (5.82)
Range in µg/m^3	ND - 11.3	ND - 11.3	0.3 - 0.9	ND - 0.5
Hand-wipe samples				
Number of workers sampled	14	9	3	2
Geometric mean (g.s.d.) in µg[g]	29.3 (2.6)	25.8 (2.9)	36.9 (3.2)	36.7 (1.6)
Range in µg	9 - 169	9 - 169	13 - 129	27 - 50

[a] Group leader, thermal techician, and welders.
[b] For comparison, concentrations found in populations not taking lithium medication: up to 3.4 µg/L serum;[13,14,15] therapeutic concentrations for patients taking lithium medication: 3.5 to 13.8 mg/L, depending on the laboratory.
[c] Geometric means and geometric standard deviations (g.s.d.) are presented because the results were not normally distributed.
[d] Micrograms lithium per liter of serum. For calculations, nondetectable results were set to 0.4, which is equal to the limit of detection (0.5 µg/L) divided by the square root of two.
[e] Not detected at the limit of detection.
[f] Micrograms lithium per cubic meter of air. For calculations, nondetectable results were set to the limit of detection (0.2 µg per sample) divided by the square root of two, then adjusted by a laboratory analysis correction factor.
[g] Micrograms lithium per hand-wipe sample. The limit of detection (LOD) was 0.2 µg/sample and the limit of quantitation (LOQ) was 0.45 µg/sample. One of the results less than 15 µg was reported from a 2-fold dilution, thus the LOD and LOQ were 0.4 and 0.90 µg for that sample.

Table 6
Results of the Analysis of a Bulk Sample of Material from the Potting Area Diffuser
HETA 96-0016
Eagle-Picher Industries
Joplin, Missouri

Analyte	Concentration (µg/g)	Analyte	Concentration (µg/g)
Amylene	40	A fluorocarbon oligomer	5
Cyclohexene	200	A fluorocarbon oligomer	3
Methyl styrene (tentative)	0.5	Unknown (poor spectra)	4
A fluorocarbon oligomer	0.6	Unknown aromatic or hydroaromatic	9
A siloxane	0.6	Unknown (poor spectra)	3
A fluorocarbon oligomer	0.5	Dibutyl phthalate	7
A fluorocarbon oligomer	0.9	Unknown fatty acid	30
A fluorocarbon oligomer	3	Unknown aromatic or hydroaromatic	70
A fluorocarbon oligomer	4	Nitrogen aromatic/ hydroaromatic	50
A fluorocarbon oligomer	6	Fluoranthene + a fluorocarbon	20
A fluorocarbon oligomer	30	Unknown (poor spectra)	7
β-Nicotyrine (tentative)	7	Nitrogen aromatic/hydroaromatic	4
A fluorocarbon oligomer	30	Bisphenol A, des-hydroxy (tentative)	10
A fluorocarbon oligomer	2	Unknown aromatic or hydroaromatic	2
A fluorocarbon oligomer	20	Bisphenol A methyl ether (tentative)	10
A fluorocarbon oligomer	9	Unknown fatty acid	20
Diethyl phthalate	6	Pyrene	10
A fluorocarbon oligomer	5	Butyl palmitate, plasticizer	40
Unknown aromatic	10	Bisphenol A	200
C_9 alkyl or C_8 oxyalkyl aromatic	5	Unknown (poor spectra)	8
Phenyl alkyl indane or similar	10	Unknown (poor spectra)	5
A fluorocarbon oligomer	8	Unknown dialkyl phthalate	9
Unknown alkyl phenol	4	Paraffin (possibly C_{23})	6

Table 6
Results of the Analysis of a Bulk Sample of Material from the Potting Area Diffuser
HETA 96-0016
Eagle-Picher Industries
Joplin, Missouri

Analyte	Concentration	Analyte	Concentration
Unknown dialkyl phthalate	6	Unknown dialkyl phthalate	30
Unknown dialkyl phthalate	8	Unknown dialkyl phthalate	4
Unknown dialkyl phthalate	10	Paraffin (possibly C_{27})	20
Unknown aromatic or hydroaromatic	7	Unknown dialkyl phthalate	6
Butyl stearate	10	Unknown dialkyl phthalate	2
Paraffin (possibly C_{24})	20	Unknown chlorinated compound, MW = 320	20
Triphenyl phosphoramide (tentative)	10	Unknown dialkyl phthalate	6
Unknown dialkyl phthalate	4	Paraffin (possibly C_{28})	7
Unknown dialkyl phthalate	7	Unknown dialkyl phthalate	20
Unknown dialkyl phthalate	5	Paraffin (possibly C_{29})	20
Unknown benzoate or salicylate	10	Unknown dialkyl phthalate	10
Paraffin (possibly C_{25})	10	Unknown dialkyl phthalate	10
Unknown dialkyl phthalate	4	Unknown dialkyl phthalate	20
Dioctyl phthalate	500	Unknown dialkyl phthalate	20
Unknown aromatic or hydroaromatic	10	Unknown dialkyl phthalate	20
Unknown aromatic or hydroaromatic	4	Unknown dialkyl phthalate	8
Unknown dialkyl phthalate	8	Unknown dialkyl phthalate	5
Homolog of peak at 22.435 minutes	100	Unknown dialkyl phthalate	7
Paraffin (possibly C_{26})	3	Unknown phalate + paraffin	10
Unknown (poor spectra)	8	Paraffin (possibly C_{30})	6
Isomer of compound at 28.986 minutes	50	Notes: µg/g means micrograms of analyte per gram of sample. These results are listed in order of retention time. Retention time is the length of time required for each of the peaks representing the eluted analyte in the carrier stream to appear on the chromatogram. It is characteristic for each of the substances present under a given set of chromatographic conditions. Therefore, it identifies the substance.	

Table 7
Results of the Analysis of a Wipe Sample from the Duct Near the Potting Area Diffuser
HETA 96-0016
Eagle-Picher Industries
Joplin, Missouri

Metal	Concentration (ug/wipe)	Metal	Concentration (ug/wipe)
Aluminum	3500	Nickel	360
Arsenic	ND	Lead	210
Barium	54	Phosphorous	150
Beryllium	ND	Platinum	ND
Cadmium	29	Selenium	ND
Cobalt	20	Silver	220
Chromium	670	Tellurium	ND
Copper	290	Thallium	ND
Iron	8800	Titanium	17
Lithium	180	Vanadium	7.3
Magnesium	1100	Yttrium	0.88
Manganese	77	Zinc	3400
Mercury	3.3	Zirconium	34.2
Molybdenum	15		

Note: ND means not detected

Table 8
Mercury (Hg) Exposure Assessment Data for April 18, 1995
Hg Treatment Area
HETA 96-0016
Eagle-Picher Industries
Joplin, Missouri

Job Title/Task	Sample		Concentration of Mercury	
	Time[a]	Volume[b]	in Air[c]	in Urine[d]
Hg Treatment/Opening Ovens	08:41-08:59	3.6	38.9[e]	NA
Processor - Tank Operator	08:18-13:26	61.4	5.2	29.2
Processor - Tank Operator	08:12-15:55	81.0	18.5	9.9
Processor - Tank Operator	08:10-15:55	68.6	16.0	16.4
Supervisory	08:14-15:55	86.5	20.8	NS
Press Operator	10:35-15:55	63.0	3.5	NS
Hg Treatment	08:19-15:55	89.5	15.6	11.7
Processor - Tank Operator	10:05-15:55	69.0	7.5	NS
Processor - Tank Operator	08:15-15:55	80.6	18.6	13.1
Processor - Tank Operator			NS	86.4
Hg Treatment/Dip Tank Operation	10:25-12:35	26.1	16.4[e]	NA
NIOSH REL			50.0	
ACGIH TLV			25.0	35.0
WHO Standard			25.0	50.0
MDC - TWA		75.0	0.13	
MQC - TWA		75.0	0.44	
MDC - STEL		3.6	2.78	
MQC - STEL		3.6	9.17	

[a] Start and stop times (in military time) for the sampling device.
[b] Expressed in units of liters of air.
[c] Personal breathing zone airborne concentration of mercury, expressed in micrograms of mercury per cubic meter of air ($\mu g/m^3$). NS - no air sample collected from worker.
[d] Urine concentration of mercury, expressed in micrograms of mercury per gram of creatinine ($\mu g/g$-Cr). NA - not applicable, NS - no urine sample provided by the worker.
[e] Short-term or task-based Hg exposure measurement. In order to determine an over-exposure, these concentrations should not be above the NIOSH and OSHA ceiling limits of 100 $\mu g/m^3$.

Table 9
Mercury (Hg) Exposure Assessment Data for April 19, 1995
Negative pasting Area
HETA 96-0016
Eagle-Picher Industries
Joplin, Missouri

Job Title/Task	Sample		Concentration of Mercury	
	Time[a]	Volume[b]	in Air[c]	in Urine[d]
Processor	08:42-12:52	49.9	20.0	ND
Processor	08:41-15:00	70.6	17.0	4.8
Supervisory	08:04-15:52	92.0	7.4	29.3
Processor	08:29-15:52	82.9	48.3	33.5
Processor	08:46-15:52	84.6	9.7	ND
Processor	08:13-15:52	90.4	27.7	2.5
Oven Runner	08:23-15:52	88.6	15.8	ND
Oven Runner	12:30-15:52	40.4	42.1	15.3
Processor	08:10-15:52	91.0	12.1	ND
Processor	08:21-15:52	88.7	9.4	ND
Processor	08:45-15:52	80.4	33.6	21.6
Mercury/Zinc Mixer	14:14-14:34	4.2	22.3[e]	NA
NIOSH REL			50.0	
ACGIH TLV			25.0	35.0
WHO Standard			25.0	50.0
MDC - TWA		78.1	0.13	
MQC - TWA		78.1	0.42	

[a] Start and stop times (in military time) for the sampling device.
[b] Expressed in units of liters of air.
[c] Personal breathing zone airborne concentration of mercury, expressed in micrograms of mercury per cubic meter of air ($\mu g/m^3$).
[d] Urine concentration of mercury, expressed in micrograms of mercury per gram of creatinine ($\mu g/g$-Cr). ND - no mercury detected in the worker's urine sample, NA - not applicable.
[e] Short-term or task-based Hg exposure measurement. In order to determine an over-exposure, these concentrations should not be above the NIOSH and OSHA ceiling limits of 100 $\mu g/m^3$.

For Information on Other
Occupational Safety and Health Concerns

Call NIOSH at:
1–800–35–NIOSH (356–4674)
or visit the NIOSH Web site:
www.cdc.gov/niosh

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