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CDC Workplace Safety and Health™

NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2003-0171-2925
PCC Schlosser
Redmond, Oregon

January 2004

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

PREFACE

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (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 (OSHA) 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 employers 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.

HETAB 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 NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was written by Eric J. Esswein, MSPH, CIH and Yvonne Boudreau, MD, MSPH. Analytical support was provided by Ardith Grote and Charles Neumeister of the NIOSH Division of Applied Research and Technology (DART); and Data Chem Laboratories, Salt Lake City, Utah. Desktop publishing was performed by Suzanne Eugster. Review and preparation for printing were performed by Penny Arthur.

Copies of this report have been sent to employee and management representatives at PCC Schlosser, the OSHA Regional Office, and Oregon OSHA. This report is not copyrighted and may be freely reproduced. The report may be viewed and printed from the following internet address: www.cdc.gov/niosh/hhe/hhesearch.html. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

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

Highlights of the NIOSH Health Hazard Evaluation

Evaluation of the Finishing Area of PCC Schlosser in Redmond, Oregon

Employees at PCC Schlosser asked the National Institute for Occupational Safety and Health (NIOSH) to investigate exposures to metals at their workplace. Employees in the finishing area reported that digestive tract problems, kidney failure, and liver failure or bad liver function were believed to be related to workplace exposures to metals, including titanium, antimony, vanadium and aluminum. NIOSH conducted a health hazard evaluation in June, 2003.

What NIOSH Did

- We collected air samples for respirable dusts, respirable vanadium pentoxide, and elements (metals) in the finishing areas.
- We collected wipe samples from employees' hands and collected settled dust samples from the finishing area and analyzed them for elements.
- We provided employees with information about hair analysis for metals noting that this is not a standard medical test.
- We requested medical records from concerned employees.

What NIOSH Found

- Employees working in the cut-off shed had the highest exposures to dusts and metals. Employees in the final finishing booths had the lowest exposures.
- A lack of effective ventilation controls in the cut-off shed led to air concentrations of dusts and metals exceeding Oregon OSHA limits.
- Because employees wore respirators during this investigation, their actual exposures would have been below the OSHA limits, provided their respirators fit well.
- The one medical record that was provided showed liver function abnormalities that were not specific and could not be attributed to exposures at the facility.
- Elemental hair analysis is not an accepted standard medical test and does not provide enough information to make any connection with workplace exposures.

What PCC Schlosser Managers Can Do

- Install local exhaust ventilation controls for operations in the cut-off shed.
- Isolate the pneumatic hammer in a separate area with exhaust ventilation, noise control engineering, and remote control operation.
- After engineering controls have been installed, conduct another industrial hygiene study to make sure exposures are controlled below the OSHA limits.
- Encourage employees to seek qualified medical care for their health concerns.

What the PCC Schlosser Employees Can Do

- Wash hands thoroughly before breaks and at the end of shifts.
- Continue to wear respirators in the cut-off area until engineering controls have been installed and tested.
- Seek medical attention from a qualified health care provider if concerned about health symptoms.

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What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #2003-0171-2925

NIOSH

Health Hazard Evaluation Report 2003-0171-2925
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SUMMARY

In February 2003, employees at PCC Schlosser, a titanium investment casting plant in Redmond, Oregon, sent the National Institute for Occupational Safety and Health (NIOSH) a confidential request for a health hazard evaluation (HHE) to investigate exposures to metals in their workplace. Employees in the finishing area reported that "liver and kidney failure or bad liver function levels and digestive tract problems" were related to workplace exposures to metals including titanium, antimony, vanadium, and aluminum. Employees reported that they sent hair samples to a private laboratory for analysis and results indicated the presence of a variety of metals that employees believed were related to occupational exposures. Some employees reported that medical tests by their physicians also suggested they were overexposed to certain metals in their workplace.

Full-shift, personal breathing sampling was conducted on nine employees working in the finishing and cut-off areas of the plant. Samples were collected for respirable dust (particulates not otherwise regulated), airborne elements and vanadium pentoxide wipe samples were collected on hands and surfaces. Medical records provided by one employee and hair analysis reports provided by five employees were reviewed. Employee job tasks included torch cutting, operating a pneumatic hammer and a water cannon, and finishing cast parts using rotary hand tools.

The majority of exposures measured during this HHE were below Oregon Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs), but three samples exceeded these limits. One air sample collected in the pneumatic hammer area exceeded the PEL for yttrium, and two samples (both collected from the same employee while torch cutting) exceeded Oregon OSHA's PELs for respirable dusts and respirable vanadium pentoxide. Respirable dust exposures ranged from 0.2 milligrams per cubic meter of air (mg/m^3) to 5.9 mg/m^3, compared to the PEL of 5 mg/m^3. Yttrium exposures ranged up to 1.14 mg/m^3, compared to the PEL of 1 mg/m^3. Respirable vanadium pentoxide exposures ranged up 0.123 mg/m^3, compared to the PEL of 0.05 mg/m^3. The workplace exposures that were found to exceed the Oregon OSHA PELS were related to lack of effective ventilation controls in the cut-off area.

The medical record provided by one employee showed nonspecific liver function abnormalities that could not be attributed to workplace exposures. The five hair analysis reports were not conclusive because elemental hair analysis is not currently considered to be a standard medical test and the results of such testing cannot be directly related to specific exposures.

Two PCC Schlosser employees working in the cut-off area of the plant had workplace exposures to respirable dusts, respirable vanadium pentoxide, and to the element yttrium in excess of the Oregon OSHA PELs. Recommendations are included in this report to control employee exposures by installing effective local exhaust ventilation to control exposures to torch fume (the source of the respirable dust and vanadium pentoxide) at the cut-off area, and to yttrium at the pneumatic hammer station. Until effective engineering controls are in place, employees working in the cut-off area should continue to wear N-95 or greater efficiency (N-99 or N-100) filtering face-piece respirators or elastomeric half-face respirators with P-100 cartridges to protect them against exposures to torch fume and metal-containing dusts. PCC Schlosser management should insure that employees do not have facial hair that comes in contact with the sealing surface of the respirator. Employees should carefully wash their hands before breaks and lunch and before leaving the plant to remove metal dusts that may be on their hands.

Keywords: <u>SIC 3369, (nonferrous foundries)</u> investment casting, titanium, yttrium, vanadium pentoxide, respirable dusts, elements, local exhaust ventilation, respiratory protection.

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INTRODUCTION

On February 26, 2003, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation (HHE) at PCC Schlosser, a titanium investment casting plant in Redmond, Oregon. Employees working in the finishing area reported to NIOSH that they believed "liver, kidney failure or bad liver function levels and digestive tract problems" were related to workplace exposures to metals such as titanium, antimony, vanadium, and aluminum. Employees also reported that results from samples of hair they submitted to a private laboratory indicated the presence of a variety of metals, and results from medical tests indicated that employees had been exposed to a variety of metals from their workplace.

BACKGROUND

PCC Schlosser is located in Redmond, Oregon, and produces a variety of metal parts using the "lost wax" or investment casting process. Wax is injected into an aluminum die to produce a pattern that is a replica of the desired part. Wax gating sections are added to the pattern to create pathways into and out of the mold to ensure the even flow of molten metal around the model. The model is then serially dipped into ceramic slurry to create a shell around the model. The shells are heated and the wax model and gating melt away, leaving a mold cavity. The shells are fired in an oven and various titanium-containing alloys are poured into the cavity of the shells. According to the operations manager, the parts cast at this plant are 65% Ti 6-4 alloy (consisting of 90% titanium, 6% aluminum, and 4% vanadium), and 35% Ti 6-2-4-2 (consisting of 86% titanium, 6% aluminum, 2% tin, 4% zirconium, and 2% molybdenum).

When the cast parts have cooled, the majority of the ceramic shell is mechanically removed using a stationary pneumatic hammer that is mounted upon a vibrating table. Final cleaning is done using a high-pressure water cannon enclosed in a booth. Workers in the cut-off shed use an oxy-acetylene cutting torch to cut away gating and excess metal. A band saw, a small swing frame belt grinder, and hand grinders are used to remove smaller metal pieces from the parts. Workers in the final finishing area use small hand-held rotary tools (similar in design to Dremel® brand rotary tools) to grind and finish the part to acceptable tolerances.

Engineering controls in the cut-off shed consist of a vane axial fan mounted on the north wall. The axial fan is designed to exhaust torch cutting emissions outside of the shed through a downward-facing louvered hood connected with a short duct to the exterior wall of the cut-off shed. Because the shed does not have floor-to-ceiling walls and the sliding doors to the shed on the west side of the building are often left open for natural ventilation, wind currents can re-entrain torch fume back to the torch operator after it is exhausted. No controls other than natural ventilation are in place at the pneumatic hammer.

The final finishing area is located inside the plant. Each finishing booth has a perforated downdraft table for local exhaust ventilation. Small axial fans are also located above each finisher in each of the booths for cooling and comfort. All booths but one are open to the top and back. The exception is a booth with a hard ceiling and a cloth curtain that can be pulled across the back to limit light entering this workstation when a black light is used for parts inspection.

METHODS

Industrial Hygiene

NIOSH conducted an opening conference, a plant walkthrough and three days of industrial hygiene sampling during July 7-10, 2003. Area and personal breathing zone (PBZ) air samples were collected to evaluate for employee exposures to respirable dust, metals, (hereafter referred to as "elements") and vanadium pentoxide. Employee hand wipe samples, and bulk samples of settled dust were also collected for analysis.

Personal breathing zone exposures of nine PCC employees working in the finishing and cut-off areas (torch cutting, pneumatic hammer, water blast, and the five finishing workstations) were measured through full-shift air sampling for respirable dust and airborne elements, including vanadium pentoxide (V_2O_5). All sampling trains were calibrated on-site and in-line using a Gilibrator™ primary flow calibrator. Calibration was conducted before the sampling trains were placed on the workers and immediately after the work shift had ended. Samplers were attached to the employees' clothing (in the employees' breathing zones) and checked throughout the day for correct positioning and to insure that the sampling pumps functioned correctly. Air sampling trains were turned off and removed from workers during breaks and during lunch.

Air sampling for respirable dusts and respirable V_2O_5 was performed simultaneously using pre-weighed 37 millimeter (mm) PVC filters (5 micrometer pore size) installed in new SKC™ aluminum cyclones. These sampling trains were calibrated to a flow rate of 2.5 liters per minute (LPM). Any values for vanadium that were above the Limit of Detection (LOD) were converted into vanadium pentoxide (V_2O_5). A conversion factor was calculated by dividing the molecular weight of V_2O_5 by the molecular weight of V_2 and using the resultant conversion factor to derive concentrations of V_2O_5 for each sample. Samples for respirable dust were analyzed gravimetrically using NIOSH Manual of Analytical Methods (NMAM) Method 0600 (Particulates, not otherwise regulated).[1]

Sampling for airborne elements was conducted using 37-mm mixed-cellulose ester filters (0.8 micrometer pore size) in plastic filter cassettes. These sampling trains were calibrated to a flow rate of 2 LPM. Elements were analyzed using inductively coupled plasma spectroscopy using NMAM 7300. [2]

Samples of settled dust were collected from the vibrating table/pneumatic hammer area, the "gate shelves," and from several of the workstations in the finishing booths.

Eight employees working in finishing and cut-off were asked to wipe their hands (using a Ghost Wipe™ brand wipe for metals analysis) for 30 seconds at the end of the work shift on July 8, 2003. Employees were also asked to do the same the next day before the start of the shift, but because five of the eight employees arrived early that day, only three pre-shift samples could be collected on July 9, 2003. The purpose of collecting post-shift and pre-shift hand wipe samples was to identify what metals were present after a full shift of work and then to screen for metals the following morning before work began. Results of hand wipe sampling were intended to raise employee awareness of the need for good hand hygiene after work by demonstrating differences in pre-shift and post-shift levels.

Medical

Employees reported they submitted hair samples to private laboratories requesting the hair be analyzed for various metals known to be associated with titanium investment casting. NIOSH requested that employees provide these and any other relevant medical records related to health concerns referred to in the request.

Five employees provided hair analysis reports and one employee provided medical records for NIOSH review. Hair analysis is not a standardized biological sampling method to detect occupational exposures to elements. NIOSH provided employees with guidance and medical information including copies of articles from the scientific literature describing the inaccuracies and problems encountered with interpreting results of hair analyses for metals.[3,4]

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 this 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 environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[5] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[6] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[7] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever is 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 [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). 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 recommended STEL or ceiling values that are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Particulates Not Otherwise Regulated, Respirable

Often the chemical composition of the airborne particulate does not have an established occupational health exposure criterion. It has been the convention to apply a generic exposure criterion in such cases. Formerly referred to as nuisance dust, the preferred terminology for the non-specific particulate ACGIH TLV criterion is now *"particulates, not otherwise classified (n.o.c.)"* [or *"not otherwise regulated"* (n.o.r.) for the OSHA PEL].

The Oregon OSHA PEL for total particulate, n.o.r., is 15.0 mg/m^3 and 5.0 mg/m^3 for the respirable fraction, determined as 8-hour averages.[8] The ACGIH recommended TLV for exposure to a particulate, n.o.c., is 10.0 mg/m^3 (total dust, 8-hour TWA). These are generic criteria for airborne dusts which do not produce significant organic disease or toxic effect when exposures are kept under reasonable control.[9]

Elements

Exposures to elements can manifest a variety of human health effects and are influenced by many factors including the dose and the route of exposure (e.g., manganese has a very low order of toxicity when ingested, but is much more toxic when inhaled as a fume). Toxicity can also be influenced by the state of the element (e.g., methyl mercury is much more toxic by ingestion than the elemental form).

Health Effects and Evaluation Criteria for Metals:

Aluminum: Metallic aluminum dust is considered a relatively benign "inert dust."[10] The Oregon OSHA PEL is 10 mg/m^3.[11] The ACGIH TLV and the NIOSH REL for aluminum metal as a total dust is also 10 mg/m^3.

Chromium: Chromium (Cr) exists in a variety of chemical forms, and toxicity varies among the different forms. For example, elemental chromium is relatively non-toxic.[12] Other chromium compounds may cause skin irritation, sensitization, and allergic dermatitis. In the hexavalent form (Cr (VI)), Cr compounds are corrosive, and possibly carcinogenic. Until recently, the less water-soluble Cr (VI) forms were considered carcinogenic while the water-soluble forms were not considered carcinogenic. Epidemiological evidence indicates carcinogenicity among workers exposed to soluble Cr (VI) compounds.[13,14,15,16] Based on this evidence, NIOSH recommends that all Cr (VI) compounds be considered as potential carcinogens. The NIOSH REL for chromium II and III compounds is 0.5 mg/m^3, the REL for chromium VI is 0.01 mg/m^3.[5]

Iron: Inhalation of iron oxide dust may cause a benign pneumoconiosis called siderosis.[17]

Lead: Chronic lead exposure has resulted in nephropathy (kidney damage), gastrointestinal disturbances, anemia, and neurologic effects.[18] These effects may be felt as weakness, fatigue, irritability, high blood pressure, mental deficiency, or slowed reaction times. Exposure also has been associated with infertility in both sexes and fetal damage.[18]

Magnesium: Magnesium can cause eye and nasal irritation.[19] Exposure has been associated with the development of metal fume fever.

Manganese: Manganese fume exposure has been associated with chemical pneumonitis and central nervous system effects.[5, 12]

Nickel: Metallic nickel compounds cause sensitization dermatitis.[10] NIOSH considers nickel a potential carcinogen, as nickel refining has been associated with an increased risk of nasal and lung cancer.[5]

Titanium: NIOSH considers titanium dioxide ($Ti0_2$) to be an occupational carcinogen and has an REL of 0.2 mg/m^3 (or the lowest feasible concentration). Oregon OSHA regulates titanium as $Ti0_2$ with a PEL of 10 mg/m^3.[8]

Yttrium: Toxicity data and industrial experience reports for yttrium or its compounds are limited. Yttrium compounds embedded in the eye have caused eye damage in humans. Animal studies have shown yttrium compounds to cause irritation to the lungs, and lung and liver damage. Intratracheal administration of a single very large dose of yttrium caused respiratory fibrosis in rats.[20,21] The Oregon OSHA PEL, NIOSH REL, and ACGIH PEL for yttrium is 1 mg/m^3.

Zinc: Zinc has been associated with shortness of breath, minor lung function changes, and metal fume fever.[10]

Vanadium Pentoxide

Occupational exposure to vanadium and vanadium poisoning was reported as early as 1911. Vanadium pentoxide is a respiratory and eye irritant. The fume is generally recognized as being more toxic than the dust due to a smaller particle size, which allows deeper penetration into the small airways of the lung. The pentavalent form of vanadium, V_2O_5 is more toxic than the lower oxides. The target organ for vanadium and vanadium compounds is the respiratory tract. Tracheitis, bronchitis, pulmonary edema, or bronchial pneumonia may be observed among those overexposed, depending on the dose and duration of exposure. No pneumoconiosis, specific chronic lung lesions, or permanent pulmonary dysfunction (such as emphysema) have been conclusively linked to V_2O_5 exposures.[22] The presence of a green to blackish tongue has been reported in some exposed workers along with a metallic taste in the mouth, although these symptoms were reported as more of an annoyance than a pathological effect.[23]

ACGIH recommends a TLV-TWA of 0.05 mg/m^3 for V_2O_5 to minimize the potential for respiratory tract irritation, cough, bronchitis, and discoloration of the tongue. NIOSH does not have a REL for V_2O_5, but recommends a 15-minute ceiling REL of 0.05 mg/m^3 for respirable elemental vanadium dust and fume. The Oregon OSHA PEL for respirable V_2O_5 is 0.05 mg/m^3 as a TWA, and for elemental vanadium is 0.1 mg/m^3.[24]

RESULTS

PBZ Respirable Dust (particulates not otherwise regulated)

Eleven full-shift PBZ samples indicated that employee exposures ranged from less than detectable (based on a calculated minimum detectable concentration (MDC) of 0.2 mg/m^3) to 5.9 mg/m^3. Three workers in cut-off experienced the highest exposures while torch cutting (1.03 mg/m^3, 4.64 mg/m^3 and 5.9 mg/m^3). The sample collected in cut-off with the lowest concentration (1.03 mg/m^3) was collected only for a short time because the employee left work at 8:30 a.m. seeking medical care for a non-occupational condition. Employees with the lowest exposures were the finishers in the final finishing booths. These employees' exposures all were less than 0.5 mg/m^3 of respirable dusts, with all samples in a range of 0.2 mg/m^3 to 0.38 mg/m^3.

These results indicate that one employee was exposed in excess of the Oregon OSHA respirable dust PEL and one exposure approached the Oregon OSHA limit. Both samples were collected in the cut-off area during torch cutting.

Elements

Thirteen PBZ total dust samples were analyzed for elements. Analysis was performed for the 27 different elements in NIOSH Analytical Method 7300. The method detects aluminum, arsenic, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, lithium, magnesium, manganese, molybdenum, nickel, lead, phosphorus, platinum, selenium, silver, sodium, tellurium thallium, titanium, vanadium, yttrium, zinc, and zirconium. Many of the metals analyzed by NIOSH Method 7300 are not used in alloying titanium and consequently were not detected, or were detected at "trace" (between the limit of detection and the limit of quantitation) concentrations; these were: arsenic, lithium, lead, platinum, phosphorous, selenium, silver, tellurium, and thallium. Other metals were detected in either trace concentrations or were detected at very low concentrations (well below any occupational health criterion) and are expected to be toxicologically insignificant; these were: copper, beryllium, cadmium, cobalt, iron, magnesium, manganese, and nickel. Two elements were detected at extremely low concentrations and are not toxicologically relevant, calcium and sodium. The elements of concern included aluminum, titanium, vanadium, and yttrium.

Full-shift total dust PBZ aluminum exposures ranged from 0.003 to 0.98 mg/m^3, all significantly less than the Oregon OSHA PEL, NIOSH REL, or the ACGIH TLV criterions of 10 mg/m^3.

Exposures to elemental titanium ranged from 0.0067 to 0.19 mg/m^3. The three highest exposures to elemental titanium occurred in cut-off during torch cutting: 0.019 mg/m^3, 0.028 mg/m^3 and 0.19 mg/m^3. Because torch cutting is an oxidative process, exposures to $Ti0_2$ in cut-off are possible. However, exposures to $Ti0_2$ cannot be directly inferred from these data presented here because NIOSH Analytical Method 7300 does not use hydrofluoric acid (HF) for digestion of the samples and HF is necessary to totally digest $Ti0_2$.[25] These data suggest that exposures to $Ti0_2$ do not exceed the Oregon OSHA PEL, but they could approach the NIOSH REL in torch cutting if the elemental titanium is converted to the dioxide.

Exposures to the element yttrium ranged from not detected (based on a minimum detectable concentration of 0.000005 mg/m^3) to 1.14 mg/m^3. The three highest exposures to yttrium occurred in the cut-off area during torch cutting: 0.017 mg/m^3, 0.48 mg/m^3 and 1.14 mg/m^3. One sample exceeded the Oregon PEL, the NIOSH REL and the ACGIH TLV of 1 mg/m^3 for yttrium.

Vanadium Pentoxide

Exposures to elemental vanadium (as total dust) ranged from 0.00042 to 0.022 mg/m^3. Initial sampling results for respirable V_2O_5 received from the laboratory indicated that all samples were not detectable, based on an analytical limit of detection of 0.07 mg per sample and a limit of quantitation of 0.2 mg per sample. MDC's for V_2O_5 were calculated for the sample set by using the analytical LOD divided by the average air sample volume for the sample set. The calculated MDC was determined to be 0.07 mg/m^3, which is a concentration greater than the Oregon OSHA PEL of 0.05 mg/m^3. This means that NMAM 7504 was insufficiently sensitive to detect V_2O_5 at the current Oregon PEL. After discussions with analytical chemists at the NIOSH Division of Applied Research and Technology, it was determined that the original samples had been archived by the NIOSH contract analytical laboratory and therefore the samples could be re-analyzed. A request was submitted for reanalysis of the samples using NMAM 7300 (for elements). Any values for elemental vanadium that were above the LOD were converted into V_2O_5. A conversion factor was calculated by dividing the molecular weight of V_2O_5 by the molecular weight of V_2 and using the resultant factor to derive concentrations of V_2O_5 for each air sample.

Twelve samples for respirable V_2O_5 were collected in the finishing and cut-off areas. Full-shift PBZ results ranged from trace to 0.123 mg/m^3. The highest concentration was measured in the torch cutting area and was the only sample found to exceed the Oregon OSHA PEL. The remaining 10 samples all were well below the PEL, ranging from 0.0005 mg/m^3 to 0.0089 mg/m^3.

Employee hand wipes for elements

Hand wipe samples were collected to determine if metals were present on employees' hands, and to identify what metals were present in the greatest concentrations and if concentrations varied from the end of one work day to the beginning of the next work day.

Aluminum, copper, manganese, nickel, titanium, vanadium, yttrium, and zinc were detected in all the samples collected, ranging from concentrations in the tenths of a microgram (μg) up to 290 μg. Arsenic, platinum, selenium, silver, tellurium, and thallium were not detected. The hand wipe with the highest concentration of any metal was 1200μg of yttrium collected from a cut-off employee at the end of the shift on July 8, 2003. Arithmetic average concentrations for the metals detected in all hand wipe samples were: yttrium 216 μg, aluminum 192 μg, titanium 180μg, zinc 67μg, copper 30μg, vanadium 13μg, nickel 9μg and manganese 4.5μg. Post-shift hand wipe concentrations for aluminum were surprisingly consistent; 5 of 8 employees had aluminum concentrations ranging from 220 to 290 μg. The pre- and post-shift samples that were collected on three employees showed reductions in pre-shift concentrations of virtually all elements of an order of magnitude (a factor of ten) or more.

Settled dust samples for elements

Three samples of settled dust were collected from the top of the "gate shelves", the vibrating table at the pneumatic hammer, and a workstation in finishing. The highest concentrations of metals in settled dust from the horizontal surface atop the gate shelves included the following: aluminum, 25,000 micrograms per gram (μg/g) or 2.5%; iron, 7500 μg/g or 0.75%; yttrium, 4800 μg/g or 0.48%; titanium, 3500 μg/g or 0.35%; zirconium, 1700 μg/g or 0.17%; and magnesium, 1700 μg/gr or 0.17%. Other metals were also detected and included: arsenic, 79 μg/g or 0.0079%; cobalt, 15 μg/g or 0.0015%; chromium, 99 μg/g or 0.0099%; and phosphorus, 490 μg/g or 0.049%.

The sample collected from the vibrating table included the following: yttrium, 180,000 μg/g or 18%; titanium, 3300 μg/g or 0.33%; aluminum, 1,100 μg/g or 0.11%; iron, 1000 μg/g or 0.10%; and detectable concentrations (20 μg/g or less) of cobalt, chromium, manganese, nickel, lead, and zinc.

Medical Records

The medical record provided by one employee showed evidence of nonspecific liver dysfunction, but nothing that could be attributed to any exposures in the workplace.

DISCUSSION

One employee's exposure exceeded the Oregon OSHA PEL for yttrium while he operated the pneumatic hammer. Another employee's exposure exceeded the occupational health criterion for respirable dust and for respirable V_2O_5 when the employee used a cutting torch to remove excess metal from a part. Finishers working in the cut-off area had the highest exposures because engineering controls in this area were either absent (the pneumatic hammer area) or did not effectively control exposures (the torch cutting area). The lowest PBZ exposures were to finishers working in the final finishing booths. Engineering controls in these booths are effective under normal circumstances (based on smoke tube tracer testing) but their effectiveness may be substantially diminished when the part being worked on completely covers and blocks the intake plenum for the down draft tables.

The target organs for the regulated substances (elements and respirable dust) investigated and identified in this HHE are the lungs, with the primary health effects being pulmonary irritation, bronchitis, and possible exacerbation of any pre-existing pulmonary diseases. During this HHE, employees working in the cut-off area wore either half-face elastomeric respirators with P-100 cartridges or N-95 filtering face-piece respirators; therefore, they would have been protected well below the respective PELs for these exposures provided their respirators fit properly.

Hand wipes from all finishers revealed the presence of a variety of elements that are used in alloying, casting, and finishing parts produced at this foundry, including the following: aluminum, titanium, vanadium, yttrium, and zinc. Other metals not used in alloying titanium were also detected: copper, manganese, nickel, iron, and beryllium.

The toxicological significance of the metals detected on employee hand wipes is unclear because the amount of ingestion exposure (if any) is unknown. Although occupational exposure standards do not exist for dermal concentrations of elements, the presence of elements on worker's hands can increase risks for exposures by ingestion. Careful hand washing before breaks and upon leaving the workplace at the end of the shift can help to reduce this risk.

CONCLUSIONS

Confidential employee reports of "liver, and kidney failure or bad liver function levels and digestive tract problems" are unlikely to be related to any of the elemental exposures investigated and identified during this HHE. Employees who submitted hair samples to private laboratories for analysis of various elements should not consider these results as representative biological samples or indicative of any specific disease or pathology. While hair samples may be used for certain forensic investigations, the current scientific literature does not support the use of hair analysis as a definitive method for biological exposure assessment in the occupational environment.

While most of the exposures that were investigated during this HHE were below applicable occupational health standards, exposures to the element yttrium in the pneumatic hammer area and to respirable dusts and respirable V_2O_5 at the cut-off station are not adequately controlled. Fume generated in the torch cutting area is removed to some degree from the employee's breathing zone but on many occasions, torch fume was observed to be re-entrained back to the workstation and the employee's breathing zone from wind and eddy currents created by the building. The lack of ventilation engineering controls in the pneumatic hammer area explains why yttrium concentrations exceeded the Oregon OSHA PEL in this area.

RECOMMENDATIONS

The following recommendations are based on the results of this HHE and are provided in the interests of improved health and safety at the PCC Schlosser plant.

1) Ventilation controls should be designed and installed in the cut-off area to effectively capture and remove torch fume from the workers' breathing zone. Such controls should be designed specifically for torch cutting operations and should be appropriately ducted to exhaust contaminants away from areas occupied by workers and away from any outside air intakes for the plant. Until effective engineering controls are in place, employees should continue to wear N-95 or greater efficiency (N-99 or N-100) filtering face-piece respirators or elastomeric half-face respirators with P-100 cartridges to protect them against inhalation exposures to respirable torch fume, smoke, and dusts. PCC Schlosser management should insure that employees do not have facial hair that comes in contact with the sealing surface of the respirator.

2) To reduce exposures to yttrium, the pneumatic hammer/vibrating table area should be located in a separately enclosed area, with dedicated ventilation and, referably, noise control engineering systems. Remote control of this operation should be considered to better isolate the worker from noise and dusts produced when the pneumatic hammer is operated. Employees should continue to wear personal protective equipment in this area until engineering controls have been installed and industrial hygiene sampling demonstrates that exposures are controlled below all applicable PELs.

3) Employees should thoroughly wash their hands using warm water and soap before breaks and lunch, and when leaving the plant at the end of the shift. The use of hand cleansers specially designed to remove metals from dermal surfaces might also be considered.

4) Employees concerned about their health should be evaluated by a qualified health care professional.

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