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Evaluation of Skin and Respiratory Symptoms Among Employees With Occupational Exposures to Cobalt and Chromium at an Orthopedic Implant Manufacturer

To the Editor:

The National Institute for Occupational Safety and Health (NIOSH) Health Hazard Evaluation Program received a request from employees at an orthopedic implant manufacturer. Employees were concerned about respiratory symptoms thought to be caused by occupational exposures to metals and metalworking fluids (MWFs). The company manufactured surgical instrumentation and medical devices including cobalt-chromium femoral implants for use in joint replacement surgeries. At the time of the evaluation, the company employed 400 employees spread across nine buildings, working two 8-hour shifts per day, 5 or 6 days per week. Twenty-six employees worked in the building where the implants were machined.

Although cobalt is an essential element and is present in the human diet in tiny amounts, occupational exposure has been associated with the development of occupational asthma and allergic contact dermatitis.[1–3] In addition, some studies have shown that low levels of cobalt can lead to a decrease in lung function,[4] in addition to irritation of the mucous membranes in the respiratory tract.[5] There is also evidence that skin exposure to cobalt and other sensitizing chemicals may lead to an asthma-like response.[1,6]

Hexavalent chromium is carcinogenic to humans and is associated with cancer of the lung, nose, and nasal sinuses.[7,8] A 2015 study suggests that hexavalent chromium is associated with an increased risk for stomach cancer.[9] Occupational hexavalent chromium exposure has also been associated with irritation or damage to the nose, throat, lungs, eyes, and skin, including allergic contact dermatitis.

NIOSH investigators collected personal air samples for aluminum, chromium, cobalt, hexavalent chromium, and titanium, and surface wipe samples for cobalt and chromium in the implant machining building. Personal air samples were also collected for MWFs and particulates. Because MWFs were detected in only one of the three personal air samples at less than 10% of the NIOSH REL and the highest particulate concentrations was approximately 13% of the NIOSH REL, this case study focuses on the cobalt and chromium exposures. The final report with the results of our entire evaluation is available at https://www.cdc.gov/niosh/hhe/reports/pdfs/2013–0033–3238.pdf.[10]

Process Description

Four automated grinding machines using MWF-processed cobalt-chromium femoral implants. After grinding, machinists manually removed the implants, wiped off excess MWF with a paper towel, and washed the implants in an open basin with an alkaline cleaner. The machinists did not wear gloves when handling the implants. The company did not use biocides in their MWFs.

After cleaning, machinists transferred the implants to a coarse polishing station where finishing operators removed surface irregularities using a belt sander. Next, finishing operators transferred the implants to a second polishing station called the box polish (Fig. 1). At this station, employees used a small belt sander to polish the sharper angles and bends on the implants. For all activities, employees were required to wear safety glasses and steel-toed boots, an N95 filtering-facepiece respirator, and company-issued coveralls; earplugs were optional.

Following the box polish, employees placed the implants in a centrifuge filled with a ceramic abrasive for polishing. After centrifugal polishing, operators manually polished and buffed the implants using a cloth wheel and aluminum oxide buffing compound to remove surface scratches and abrasions. Employees then cleaned the parts, dipped them by hand into a 350°F molten plastic sealant, and sandblasted the exposed surface of the implant in an enclosed cabinet. The operators then inspected each part, removed imperfections with a hand-held tool, cleaned the parts with methyl ethyl ketone, and then dipped them in a nitric acid passivation tank to prevent corrosion. For these activities, employees were required to wear latex gloves, steel-toed boots, safety glasses, and a disposable apron; an N95 filtering-facepiece respirator and earplugs were optional.

METHODS

Observations and Ventilation Assessment

In February 2013, NIOSH investigators observed work practices and examined the local exhaust ventilation systems in the implant machining building using ventilation smoke tubes to help visualize airflow.

Interviews and Record Review

All 26 employees working in the building in February 2013 participated in confidential interviews about their medical and work history. Medical records of employees with possible health problems, the OSHA Form 300 Logs of Work-Related Injuries and Illnesses, workers' compensation claims from 2010 through 2012, the facility's safety and health program, hazard communication program, and respiratory protection program were reviewed.

Personal Air Sampling

Ten personal air samples for chromium and cobalt were collected in February 2013 during two work shifts. The air samples were analyzed according to NIOSH Manual of Analytical Methods number 7303.[11] Four personal air samples for hexavalent chromium were collected and analyzed according to NIOSH Method number 7605. In June 2013, an additional 17 personal air samples across three work shifts were collected for cobalt and chromium.

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FIGURE 1. An employee polishes the inside of a square femoral implant with a thin band of sandpaper at the box polish station (photo by NIOSH).

Surface Wipe Sampling

To evaluate housekeeping effectiveness, 15 surface wipe samples were collected in February 2013 throughout the plant and analyzed for metals according to Method 9102. In June 2013, an additional 11 surface wipe samples were collected for cobalt and chromium.

Bulk Sampling

Four MWF samples of Blasomill 10 (Blaser Swisslube Inc., Goshen, NY) and Sintogrind TTS (Oelheld GmbH, Stuttgart, Germany) were analyzed for cobalt and chromium using Method 7303, modified for a liquid matrix.[12]

Questionnaire

The 26 employees working in the implant machining building in June 2013 were asked to complete a written questionnaire. This questionnaire included questions about demographics, work and medical history, personal protective equipment use, tobacco use, and nonwork exposures that could interfere with the urine tests (see next section) such as hobbies and vitamin B12 ingestion. Questions on skin and respiratory symptoms were included and if these symptoms changed on days off work.

Biomonitoring

In June 2013, informed consent was obtained from 24 employees (two declined) to collect urine samples to assess the body burden of cobalt and chromium exposures. Employees provided an end-of-shift, end-of-workweek urine sample. The urine samples were submitted in acid-washed containers to Pacific Toxicology Laboratories in Chatsworth, California, and analyzed for cobalt and chromium using inductively coupled plasma mass spectrometry. The cobalt and chromium urine concentration results were compared to the American Conference of Governmental Industrial Hygienists (ACGIH) biological exposure indices (BEIs) for cobalt and chromium.

Statistical Analysis

Employee exposure groups were based on employee job titles and observations; those with exposure to chromium and cobalt dust were compared with those having minimal or no chromium and cobalt dust exposure. Work-related symptoms were defined as those that improved on days away from work. A combination variable, ‘‘respiratory symptoms,’’ was defined as those with wheezing in the chest, or chest tightness upon awakening, or attacks of asthma. Relationships between workplace exposure groups and symptoms were evaluated by using Fisher exact test. The correlation between air and urine cobalt levels was evaluated with Spearman correlation coefficient, and employees’ urine cobalt levels were compared for workplace exposure groups by using Wilcoxon tests. All statistical analyses were done with SAS statistical software version 9.3 (SAS Institute Inc., Cary, NC). All tests were two-tailed, and statistical significance was set at P value less than 0.05.

RESULTS

Observations and Ventilation Assessment

During the first site visit in February 2013, employees wore latex gloves throughout the plant. Some employees voluntarily wore either a nuisance dust mask or a disposable N95 filtering facepiece respirator when polishing parts, but did not wear them correctly. For example, the respirator’s metal nose clip was not shaped around the wearer’s nose, facial hair interfered with a proper respirator to face seal, or the bottom neck strap was not used. Some disposable respirators were used beyond the time limit recommended by the manufacturer. Employees properly wore the other required personal protective equipment including steel-toed boots and safety glasses. Finally, employees used compressed air to clean parts and to blow dust off their clothing, practices that can generate airborne particulate.

In February 2013, each of the cobalt-chromium femoral polishing and buffing operations had capture hoods connected by flexible plastic duct to a rigid metal duct (Fig. 2). The box polish station at the far end of the cobalt-chromium polish area was also attached by flexible duct to the rigid metal exhaust ducts and had a gate damper that had to be manually opened by the

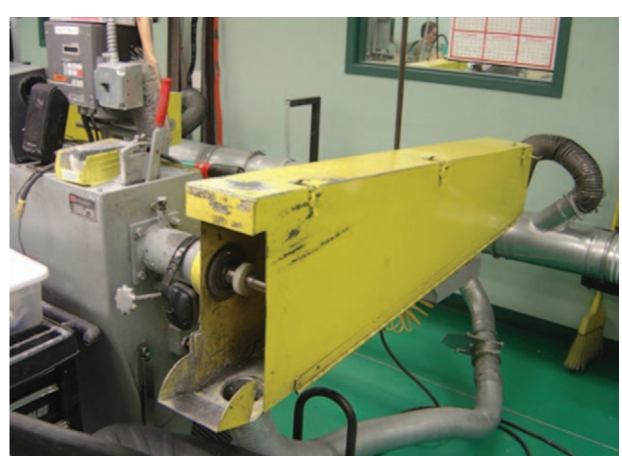

FIGURE 2. Local exhaust ventilation hood at one of the polishing and buffing stations (photo by NIOSH).

FIGURE 3. Local exhaust ventilation flexible ductwork connected with a T-junction at the box polish station with (photo by NIOSH).

employee when one or more of the polishers in the station were used. Due to the configuration of the connecting exhaust ducts, when more than one polisher in the station was in use, the total local exhaust volume was split three ways among all the three polishers in use. The exhaust ducts terminated at an outdoor baghouse.

Observing airflow at the box polish station using ventilation smoke tubes revealed that the local exhaust ventilation was ineffective in capturing dusts generated from the process. The flexible exhaust ducts connected to polishers in the box polish station had 90° turns and multiple twists (Fig. 3), conditions that can diminish the efficiency an exhaust ventilation system. Similarly, the flexible duct connected to the slot hood for the nitric acid wash in the passivation room was excessively long and twisted. These conditions diminish efficient vapor capture.

On the basis of our preliminary recommendations before our June 2013 site visit, the company moved the box polish station, improved the efficiency of the local exhaust by eliminating the 90° turns and using hard ductwork instead of flexible ductwork, and provided each box polishing station with a dedicated exhaust instead of sharing it between the stations. The company also gave employees the option to wear nitrile or latex gloves.

Interviews and Medical Record Review

In February 2013, seven of the 26 employees (five finishers and two machinists) interviewed (27%) reported having nasal and/or sinus symptoms (nasal congestion, runny nose, sinus headache, postnasal drip) they thought were work-related; five of the seven (all finishers) reported that symptoms were aggravated by work or improved away from work. Some employees reported blowing ‘‘black’’ material from their noses. Three of the seven employees (all finishers) also reported respiratory symptoms (cough, shortness of breath, chest tightness, or wheezing) that improved away from work, and one (finisher) reported skin symptoms that improved away from work.

Medical records of seven employees reporting health symptoms were reviewed. Five of the seven employees were evaluated for sinus symptoms; three (all finishers) were diagnosed with sinusitis. Three of the five with sinus symptoms were also evaluated for respiratory symptoms (shortness of breath, wheezing, and chest tightness). Medical diagnoses for these three employees included pneumonia, ‘‘asthma-like symptoms,’’ reactive airway disease, and chemical inhalation (one of the employees had more than one diagnosis). Two of these three employees were referred to a lung specialist and told to avoid workplace chemicals. The remaining two employees' records did not provide evidence of a work-related health condition.

Personal Air Sampling

Personal air sampling results for chromium and cobalt are provided in Table 1. One of the box polisher's personal air sampling results for cobalt (26 μg/m^3), exceeded the ACGIH threshold limit value, which is the most protective occupational exposure limit (OEL). That employee spent most of his time working at the box polish station. Two other box polishers worked intermittently at the station that day. An air sample for cobalt collected the following day when only one of the polishers in the station was in use and the exhaust airflow was not shared by two other

TABLE 1. Time-Weighted Average Personal Air Sampling Results for Chromium and Cobalt, February 2013

Department	Job Title	Chromium Concentration, μg/m^3	Cobalt Concentration, μg/m^3	Sample Duration, min
Machining	Machinist	0.24	0.35	452
Finishing	Box polisher	10	26	228
	Box polisher	2.2	4.9	439
	Femoral buffer	Not detected	0.55	439
	Titanium sandblaster	0.26	0.56	447
Maintenance	Maintenance technician	0.50	1.4	383
	Maintenance tech	1.3	3.1	376
	Maintenance tech	Not detected	0.25	429
Inserts	Patella processor	0.99	2.6	423
	Lathe operator	0.65	(0.17)	446
NIOSH REL		500	50	—
OSHA PEL		1,000	100	—
ACGIH TLV		500	20	—

The MDC and MQC were determined on the basis of an average sampling duration of 406 min and sample volume of 812 L. The value in parentheses is between the MDC and MQC, meaning that there is more uncertainty associated with this result.

MDC, minimum detectable concentration (0.04 for chromium and 0.06 for cobalt); MQC, minimum quantifiable concentration (0.15 for chromium and 0.19 for cobalt); NIOSH, National Institute for Occupational Safety and Health.

polishers showed that the box polisher's exposure was lower (4.9 μg/m^3).

A full-shift personal air sample for hexavalent chromium (0.14 μg/m^3), collected on a box polisher, was 70% of the NIOSH REL of 0.2 (μg/m^3).[8] Because of day-to-day variability, it is possible that exposure to hexavalent chromium could exceed the REL. In contrast, full shift air samples collected on a finisher, polisher/buffer, and during use of hand tools for trim and blast showed hexavalent chromium exposures were less than the minimum quantifiable concentration of 0.05 μg/m^3.

During the second site visit in June 2013, all personal air samples for chromium and cobalt were well below their respective occupational exposure limits. The highest cobalt concentrations (7.6 and 5.0 μg/m^3) were measured on the femoral finishers working the first and second polishing stations. The chromium concentrations were also highest on these employees (2.7 and 2.2 μg/m^3).

Surface Wipe Sampling

Chromium and cobalt were detected in most of the surface samples collected in February 2013, including those from nonproduction areas. The floor in front of the men's restroom (9.4μg/100 cm^2 chromium, 22 μg/100 cm^2 cobalt), the break room floor (3.1 μg/100 cm^2 chromium, 7.0 μg/100 cm^2 cobalt), the break room door handle (2.9 μg/100 cm^2 chromium, 5.1 μg/100 cm^2 cobalt), and the refrigerator handle in the break room (2.3 μg/100 cm^2 chromium, and 1.0 μg/100 cm^2 cobalt) had detectable levels of chromium (1.0 μg/100 cm^2).

In June 2013, chromium and cobalt were again found in nonproduction areas, including areas where employees ate and drank. These metals were also found inside employees' gloves. The highest chromium (5.0 and 4.8 μg/100 cm^2) and cobalt (11 and 11 μg/100 cm^2) levels were found on the break room counter by the coffee maker and the top stair to the break area, respectively.

Bulk Sampling

The unused Blasomill 10 MWF contained 0.17 mg/L chromium and 0.02 mg/L cobalt. The used Blasomill 10 from the Haas grinder contained 0.13 mg/L chromium and 0.13 mg/L cobalt. The unused Sintogrind TTS MWF contained 0.1 mg/L chromium and less than 0.01 mg/L cobalt. The used Sintogrind TTS from the Walter grinder contained 1.5 mg/L chromium and 3.4 mg/L cobalt. The used Blasomil MWF showed higher concentrations of cobalt than the unused Blasomil MWF. The used Sintogrind showed a higher concentration of both cobalt and chromium than the unused Blasomil. These findings indicate that a small amount of chromium and cobalt leached into or was present in particulate form in the MWF during machining use. Persons who are sensitized to chromium or cobalt may experience an allergic reaction if these metals touch the skin or are inhaled.

Questionnaire

All 26 employees working in the implant machining building participated in the June 2013 questionnaire. Responses showed that their average age was 43 (range, 25 to 62 years), and the average number of years worked at the company was 5 (range, 2 months to 20 years). Two were female. When asked about smoking history, 12 employees reported never smoking, 8 reported being former smokers, and 6 reported being current smokers.

When asked at what job they spent the most time during the previous 12 months, employees reported the following: finishing ($n = 13$; a group that included femoral polishing and buffing and box polishing ($n = 11$) and titanium stem finishing ($n = 2$)); machining ($n = 6$); maintenance ($n = 3$); passivation ($n = 2$); laser operating ($n = 1$); and inserts ($n = 1$). Thirteen employees reported handling used MWF or parts wet with MWF in the past 12 months; eight reported usually wearing gloves when handling used MWF or parts wet with MWF. Seventeen reported polishing or buffing parts in this time period; 13 reported usually wearing gloves, two reported sometimes wearing gloves, and two reported not wearing gloves when polishing or buffing parts.

Four employees reported having episodes of illness in the 12 months before the evaluation, with two or more of the following symptoms: cough, wheeze, shortness of breath, or chest tightness. None had fever or weight loss with these symptoms. Table 2 summarizes the number of employees who reported specific symptoms within the 12 months before this evaluation and the number who reported that the symptom improved away from work (Table 2).

The prevalence of work-related wheeze, chest tightness, asthma, nasal symptoms, and dermatitis for employees with ($n = 17$) and without ($n = 9$) buffing/polishing exposure in the 12 months before the evaluation was compared. Buffing or polishing exposure was not statistically significantly associated with this group of employee's reports of skin or respiratory symptoms. However, Table 3 summarizes that when comparing the 11 employees who reported spending the most time finishing femoral implants versus other job groups in the 12 months before this evaluation, a statistically significant association ($P < 0.01$) was found between working as a femoral finisher and having work-related nasal symptoms. Statistically significant associations between working in this job and having work-related dermatitis ($P < 0.04$), and work-related respiratory symptoms ($P = 0.02$) was also found (Table 3). All five of the employees reporting dermatitis in the prior 12 months were femoral finishers. Reported dermatitis locations included fingers, hands, wrists, forearms, face, and neck. Three of the five reported that their dermatitis was better when away from work more than 5 days. Two reported that they had not been away from work more than 5 days and therefore could not say whether it was better away from work. Two of the five had dermatitis at

TABLE 2. Reported Symptoms Among 26 Employees in the 12 Months* Before the Evaluation

Symptom	Number of Employees Reporting Symptom	Number Reporting Work-Related Symptom†
Nasal congestion, runny nose, or sneezing (not from cold or flu)	12	5
Nasal symptoms with itchy, watery eyes	6	Not applicable‡
Wheezing in chest	5	3
Pneumonia or chest flu	4	Not applicable‡
Chest tightness upon waking	3	3
Attack of asthma	2	2

*Or since hired if employee worked less than 12 months.
†Symptoms that improved on days away from work.
‡We did not ask about days away from work for these symptoms.

TABLE 3. Reported Symptoms Among Employees Who Spent the Majority of Their Time in Femoral Finishing ($n = 9–11$) Versus Other Job Groups ($n = 15$) in the 12 Months* Before the Evaluation

Symptom	Number of Employees Reporting Work-Related Symptom†		P
	Femoral Finishers ($n = 9–11$)	Other Job Groups ($n = 15$)	
Nasal congestion, runny nose, sneezing (not from cold or flu)	5	0	<0.01
Nasal symptoms with itchy, watery eyes	3	0	0.052
Dermatitis (hands, fingers, wrists, forearms, face, or neck)	3	0	0.04
Wheezing in chest	3	0	0.06
Chest tightness upon waking	3	0	0.06
Attack of asthma	2	0	0.17
Respiratory symptoms‡	4	0	0.02

*Or since hired if employee worked less than 12 months.
†Symptoms that improved on days away from work.
‡Included any of the following work-related symptoms: wheezing in chest, chest tightness upon waking, and/or attack of asthma.

the time of the questionnaire. Two employees had seen a doctor for their dermatitis in the 12 months before the evaluation.

Biomonitoring

The 24 employees who participated in the June 2013 biological sampling reported spending the most time during the week of the evaluation at the following jobs: finishing ($n = 12$), machining ($n = 5$), maintenance ($n = 3$), passivation ($n = 2$), laser technician ($n = 1$), and inserts ($n = 1$). One participant who reported ''machining and finishing femorals'' was put into the machining group. Fourteen employees reported polishing or buffing parts during the week of this evaluation; 11 of the 14 reported usually wearing gloves during that workweek when polishing or buffing parts. Three employees had creatinine levels outside the range that ACGIH has suggested is valid (0.5 to 3 g/L), so accurate interpretation of their urine cobalt or chromium levels was not possible. The median urine concentration of cobalt among the remaining 21 employees was 0.6 (range, 0.3 to 2.0) μg/L, which is well below the BEI for end-of-shift, end-of-workweek urine cobalt (15 μg/L).[13] The 21 employees had urine concentrations of chromium less than 1.0 μg/L (the limit of detection), which is well below the BEI for end-of-shift, end-of-workweek total urine chromium (25 μg/L).[14] In the general population of western countries, the average concentration of cobalt in adult urine ranges between 0.1 and 2 μg/L, and the average concentration of chromium in the urine ranges from 0.24 to 1.8 μg/L.

Comparing Questionnaire Data With Air and Urine Cobalt Data

Those spending the most time in femoral finishing during the week of the second visit had higher personal-air cobalt levels (median = 1.2 μg/m^3; range, 0.13 to 7.6 μg/m^3; $n = 8$) than those working at other jobs (median = 0.11 μg/m^3; range, 0.045 to 2.8 μg/m^3; $n = 9$) ($P = 0.03$). When comparing urine cobalt levels for these two job groups, femoral finishers had higher urine cobalt levels (median = 0.95 μg/L; range, 0.30 to 2.0 μg/L; $n = 8$) than those working most of the time in other jobs (median = 0.50 μg/L; range, 0.50 to 1.0 μg/L; $n = 13$), but the difference was not statistically significant ($P = 0.10$).

Comparing Urine Cobalt Data With Air Cobalt Data

The relationship between personal air cobalt sampling results and urine cobalt results was evaluated for the 12 participants who had both types of samples collected. Four of these 12 participants had two air sample measurements each. The average of the two air measurements was used to obtain a single measurement to use in calculations. The correlation coefficient for the air and urine cobalt measurements was positive ($r = 0.41$), but it was not statistically significant ($P = 0.18$).

DISCUSSION

The reports of nasal, respiratory, and skin symptoms among femoral finishers are consistent with several types of occupational exposures, including MWF and metal dusts. However, because of the cobalt dust exposure present at this site, we believe the evidence points to allergic and irritative response among employees to this exposure.[15,16] Respiratory mucous membrane irritation can occur at low air cobalt levels.[5] Inflammation of the nasopharynx has been thought to be a result of either nonspecific irritation by cobalt-containing particles or an immunologically mediated reaction (allergic rhinitis).[16] More serious effects from exposure to cobalt and cobalt compounds can include respiratory irritation, and occurrence of wheezing and asthma, with chronic exposure leading to fibrosis. These changes have been shown to occur at exposure levels ranging from 7 to 893 (μg/m^3).[17]

This evaluation found statistically significant relationships between working as a femoral finisher (finishing cobalt-chromium parts) and having work-related nasal, respiratory, and skin symptoms, along with one elevated cobalt air sampling result at the box polishing station in February 2013, before ventilation improvements. The number of work-related skin and respiratory symptoms, defined as symptoms that ''improved on days off work'' by questionnaire responses, may be underestimated, as chronic symptoms are less likely to improve over a few days or a week. During the June 2013 site visit, and after the local exhaust ventilation was improved at the polisher stations, low air and urine cobalt levels were found among employees. Despite these low levels, exposure can result in allergic reactions in sensitized individuals, in addition to irritation of respiratory mucous membranes. In addition, chronic exposure to levels of cobalt below OELs have been associated with respiratory disorders.

Dermal exposure to cobalt and to MWF remains possible if the employees touch the MWF or parts coated with MWF. Many types of MWFs contain potential skin allergens and irritants. The lack of glove use among some employees increases their chance of developing allergic contact dermatitis, and potentially respiratory allergy, to metals or other sensitizers. In addition, dermal or ingestion exposure may be possible from the metals that were transferred outside of the production area.

Employees can be exposed to hexavalent chromium as a by-product of heat-producing tasks such as welding, sanding, or grinding on products containing chromium.[18] The personal air sampling result at the box polish station, although below OELs, resulted in an airborne hexavalent chromium exposure at 70% of the NIOSH REL.

Employees could also have cobalt and chromium exposure from the tungsten carbide machining tools, which are used in the grinding area. Studies have found that machining with these tools can potentially leach cobalt and chromium into MWFs,[1,3] which can then be inhaled via MWF mist or transferred to the employee's skin. Although personal air samples on machinists revealed low exposures to MWF, cobalt, and chromium, the bulk sample results showing the presence of cobalt and chromium in used MWF samples support this as a potential exposure pathway. Persons who are sensitized to chromium or cobalt may experience an allergic reaction if these metals touch the skin or are inhaled.

This study has some limitations. The sampling results do not reflect the variability in exposures that occur over time, and therefore, exposures on different days could be higher or lower. Employees may have had other occupational exposures, such as latex or MWF exposures, which could have contributed to their reported symptoms. Latex has been known to cause irritant contact dermatitis, allergic contact dermatitis, and immediate hypersensitivity reactions.[19] Current recommendations state to use nonlatex gloves for all activities except handling infectious materials to prevent allergic reactions, such as skin rashes, hives, nasal, eye, or sinus symptoms, asthma, and anaphylactic shock in sensitized individuals. MWF are known to cause irritation and illnesses of the skin, nose, throat, and lung.[20,21]

CONCLUSION

Before improvements to the local exhaust ventilation, an employee working at the femoral finishing box polishing station had exposures to cobalt above the ACGIH threshold limit value, and to hexavalent chromium at 70% of the NIOSH REL. Variability in day-to-day air levels suggest overexposures may have occurred. After improvements, airborne cobalt levels were reduced and employees' urine cobalt and chromium levels were low. Despite these low urine levels, reported nasal, respiratory, and skin symptoms among femoral finishing employees appear to be associated with cobalt dust exposure and is consistent with evidence in the scientific literature that chronic, low level cobalt air exposure can lead to respiratory mucous membrane irritation and possibly asthma. Furthermore, in sensitized individuals, extremely low concentrations of metals can produce symptoms. Femoral finishers had significantly higher prevalences of work-related dermatitis, respiratory, and nasal symptoms than other job groups. Cobalt and chromium surface contamination in the employee break room posed a risk to employees from skin contact and ingestion. Dermal exposure to MWF contaminated with cobalt and/or chromium could result in skin sensitization if employees touch the MWF or parts coated with MWF.

Recommendations

On the basis of our findings, we made the following recommendations to the plant:

(1) Improve the effectiveness of the local exhaust ventilation at the nitric acid passivation tank by replacing flexible duct with hard duct; removing unnecessary ductwork; and eliminating sharp (90°) turns. These ventilation improvements had been made at the box polishing station before our second site visit. In addition, each polisher should have a dedicated local exhaust. Ensure that the ventilation system has adequate capture velocity to keep airborne metal concentrations low. Re-evaluate after making these changes to ensure that the ventilation system is adequately capturing airborne contaminants.

(2) Perform periodic preventive maintenance on all local exhaust ventilation units.

(3) Improve hazard communication training to include the hazards and potential health effects associated with cobalt, chromium, solvents, and other chemical exposures in the workplace. Emphasize proper work practices, hand hygiene, and skin protection techniques that prevent exposure to these substances.

(4) Stop using compressed air to clean work clothing and femoral implants. Instead, use a vacuum equipped with a high-efficiency particulate arresting air filter to clean work clothing and parts.

(5) Collect additional personal air samples for hexavalent chromium to further characterize worker exposures and to determine whether exposure controls and medical monitoring programs should be implemented.

(6) Conduct periodic air sampling for cobalt around the box polishing station to ensure that concentrations remain below OELs.

(7) Improve housekeeping procedures in nonproduction areas and encourage personal hygiene such as hand washing after glove removal and before eating and drinking to reduce the risk of ingesting metals.

(8) Encourage employees to report potential work-related health conditions to their supervisor. Employees with persistent symptoms should be evaluated by an occupational medicine physician or a medical provider specializing in workplace illnesses. The Association of Occupational and Environmental Clinics has an online directory of such providers at http://www.aoec.org/directory.htm.

(9) Look for health problem or injury trends reported in company injury and illness logs that may be related to particular job duties, work materials, machines, or areas of the facility. Evaluate areas or jobs that show an increase in injuries or health problems and develop an intervention to reduce exposures.

(10) Stop using latex gloves. Because of potential allergic reactions from wearing latex gloves, provide nitrile gloves to protect employees' skin from dermal exposures, including MWFs, parts covered with MWF, and metal dusts. Train employees on proper glove wear and on visual signs that the glove material is worn out, so that they recognize when they need new gloves. Additional information on the occupational hazards associated with latex exposure can be found in the NIOSH Alert *Preventing Allergic Reactions to Natural Rubber Latex in the Workplace*, available at http://www.cdc.gov/niosh/docs/97–135/.

(11) Require employees who voluntarily use disposable filtering facepiece respirators to wear them properly and provide them with information from OSHA Section 1910.134, Appendix D, found at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9784. Guidelines for putting on and taking off a disposable respirator are available at http://www. cdc.gov/niosh/docs/2010–133/pdfs/2010-133.pdf.

(12) Use a labor-management health and safety committee or working group to discuss recommendations and develop an action plan to reduce the risk of cobalt and chromium exposure.

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REFERENCES

1. Sjogren I, Hillerdal G, Andersson A, Zetterstrom O. Hard metal lung disease: importance of cobalt in coolants. *Thorax*. 1980;35:653–659.
2. Gheysens B, Auwerx J, Van den Eeckhout A, Demedts M. Cobalt-induced bronchial asthma in diamond polishers. *Chest*. 1985;88:740–744.
3. Walters GI, Moore VC, Robertson AS, et al. An outbreak of occupational asthma due to chromium and cobalt. *Occup Med*. 2012;62: 533–540.
4. Rehfisch P, Anderson M, Berg P, et al. Lung function and respiratory symptoms in hard metal workers exposed to cobalt. *J Occup Environ Med*. 2015;54:409–413.
5. Chang LW. *Toxicology of Metals.* Boca Raton, FL: Lewis Publishers; 1996. p. 99.
6. Arrandale VH, Liss GM, Tarlo SM, et al. Occupational contact allergens: are they also associated with occupational asthma? *Am J Ind Med*. 2012;55:353–360.
7. International Agency for Research on Cancer (IARC). *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans.* Lyon, France: World Health Organization, IARC; 2012, 147–167.
8. National Institute for Occupational Safety and Health (NIOSH). NIOSH Criteria for a Recommended Standard: Occupational Exposure to Hexavalent Chromium. DHHS (NIOSH) Publication No. 2013-128. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, NIOSH; 2013.
9. Welling R, Beaumont J, Petersen S, et al. Chromium VI and stomach cancer: a meta-analysis of the current epidemiological evidence. *Occup Environ Med*. 2015;72:151–159.
10. Beaucham C, Tapp L, Mueller C, Oza A. Evaluation of Skin and Respiratory Symptoms Among Employees with Exposure to Metals, Metalworking Fluids, and Noise at an Orthopedic Implant Manufacturer. Health Hazard Evaluation Report 2013-0033-3238. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; 2015. Available at: https://www.cdc.gov/niosh/hhe/reports/pdfs/2013-0033-3238.pdf. Accessed September 10, 2018.
11. National Institute for Occupational Safety and Health (NIOSH). NIOSH Manual of Analytical Methods (NMAM). Schlecht PC, O'Connor PF, eds. 4th ed. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention; 2014a.
12. National Institute for Occupational Safety and Health (NIOSH). NIOSH manual of analytical methods (NMAM). Consideration of Sampler Wall Deposits. Inclusion of Material Adhering to Internal Cassette Surfaces During Sampling and Analysis of Airborne Particles. Available at: https://www.cdc.gov/niosh/docs/2003-154/cassetteguidance.html. Accessed September 10, 2018.
13. American Conference of Governmental Industrial Hygienists (ACGIH). *Recommended BEI for Cobalt, all Inorganic Forms, Except Cobalt Oxides.* Cincinnati, OH: ACGIH; 2001.
14. American Conference of Governmental Industrial Hygienists (ACGIH). *Recommended BEI for Chromium and Inorganic Compounds.* Cincinnati, OH: American ACGIH; 2005.
15. Lauwerys R, Lison D. Health risks associated with cobalt exposure: an overview. *Sci Total Environ*. 1994;150:1–6.
16. Nordberg GF, Fowler BA, Nordberg N. *Handbook on the Toxicology of Metals.* 4th ed. Vol.2 Waltham, MA: Academic Press; 2015.
17. ATSDR. Toxicological Profile for Cobalt. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Agency for Toxic Substances and Disease Registry; 2004. Available at: https://www.atsdr.cdc.gov/toxprofiles/tp33.pdf. Accessed September 10, 2018.
18. Occupational Safety and Health Administration (OSHA). Safety and Health Topics: Chromium. Washington, DC: U.S. Department of Labor, OSHA; 2015. Available at: https://www.osha.gov/SLTC/chromium/index.html. Accessed September 10, 2018.
19. National Institute for Occupational Safety and Health (NIOSH). NIOSH Alert: Preventing Allergic Reactions to Natural Rubber Latex in the Workplace. DHHS (NIOSH) Report No. 97-135. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, NIOSH; 1997.
20. National Institute for Occupational Safety and Health (NIOSH). Criteria for a Recommended Standard: Occupational Exposure to Metalworking Fluids. DHHS (NIOSH) Publication No. 98-102. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, NIOSH; 1998.
21. Burton CM, Crook B, Scaife H, Evans GS, Barber CM. Systematic review of respiratory outbreaks associated with exposure to water based metalworking fluids. *Ann Occup Hyg*. 2012;56:374–388.