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Hexavalent Chromium Exposure and Nasal Tissue Effects at a Commercial Aircraft Refinishing Facility

To the Editor:

The National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation request from a commercial aircraft refinishing facility concerned about employee exposure to hexavalent chromium and chromium during aircraft refinishing operations.[1] Management was particularly concerned with uncontrolled hexavalent chromium exposures, which coincided with changes in the paint stripping process. Management reported that stripping was a step in aircraft refinishing necessary before painting to comply with aircraft safety aviation regulations. The facility had replaced methylene chloride with a new stripper product, due to environmental emission concerns and adverse health effects associated with the use of methylene chloride. However, management reported that the new stripper was less effective than methylene chloride, and required more sanding after the stripper was applied to remove any residual paint.

This letter summarizes the key methods and findings during this evaluation as it pertains to the hexavalent chromium and chromium assessment, as well as recommendations made to reduce exposure. Furthermore, this letter discusses results with a particular focus on: (1) the unanticipated hexavalent chromium hazards found after replacing methylene chloride with an alternative stripper that was considered to be safer, and (2) clinical implications for occupational health practitioners who evaluate workers with hexavalent chromium exposure as part of a medical surveillance program.

EVALUATION SITE: AIRCRAFT REFINISHING FACILITY

We evaluated one of the facilities operated by the aircraft refinishing company that performed exterior refurbishment (painting) and some interior refurbishment. At this facility, the painting department consisted of a stripping bay where employees chemically and abrasively removed paint, and two painting bays that applied primer, anti-corrosive, and finish coatings. The stripping and painting bays had mechanical downdraft (ceiling to floor) general ventilation to dilute and remove air contaminants. In the stripping bay, the following processes were performed: stripping (Fig. 1), and etching (ie, acid cleaning of the surface), and application of alodine solution (a chromate-containing coating used as a corrosion inhibitor and primer adhesion promoter). In the painting bays the following processes were performed: sanding, wiping down surfaces with a solvent, priming, and painting (Fig. 2). Depending on the aircraft and the type of paint applied, a protective clear coat was applied over the base coat. Forty employees worked at the aircraft refinishing facility at the time of our evaluation.

EVALUATION METHODS

Medical, industrial hygiene, ventilation, and observational assessments were conducted during two visits: December 2012 and November 2013, and details are presented in the NIOSH report.[1] The main objectives of this evaluation were to: (1) document general work-related health concerns among employees and perform nasal examinations, (2) assess exposure to hexavalent chromium and chromium by collecting air, surface and skin wipes, and urine samples, and (3) evaluate the effectiveness of engineering controls, work practices, and use of personal protective equipment (PPE).

Twenty six employees were interviewed about their health and also workplace health and safety issues. All interviewed employees reported engaging in painting (spraying or detailing), stripping, sanding, or application of an anti-corrosive and primer coating of the aircraft. Nasal passages of 38 employees were visually examined by two occupational physicians to check for signs of irritation, scarring, or ulceration that could be associated with hexavalent chromium exposure. We collected hand wipes on the 38 employees to measure chromium levels.

Urine was collected from 36 employees to determine the levels of chromium at the end-of-shift and end-of-workweek, per the recommendation for hexavalent chromium exposure assessment outlined by the American Conference of Governmental Industrial Hygienists (ACGIH) biological exposure index (BEI).[2] Urine samples for chromium were unadjusted for creatinine levels. Creatinine levels of participants were measured for each sample and were within the acceptable range ($0.3\ g/L \leq creatinine \leq 3.0\ g/L$), according to the World Health Organization.[3] End of work week urine levels were compared with appropriate BEIs.

Personal and area air samples, along with surface wipes for hexavalent chromium and chromium were collected using NIOSH standard methods 7300, 7605, and 9102, respectively.[4] Personal air levels were compared with occupational exposure limits (OELs)[5,6] to determine the magnitude of exposure according to specific tasks and across a full shift. A bulk sample of the stripper product was collected and analyzed for hexavalent chromium. Safety data sheets of materials used at the facility, industrial hygiene plans, and medical surveillance program for hexavalent chromium were reviewed. The ventilation systems in the paint stripping area, two painting bays, and the paint mixing room were also evaluated using an air velocity meter and fog machine. We observed use of PPE. Respirator assigned protection factors

Clinical Significance: As part of a comprehensive medical surveillance program, occupational health practitioners should routinely conduct nasal examinations for employees exposed to hexavalent chromium; they may present with nasal irritation, ulcerations, and bleeding even when low levels of urinary chromium biomarkers are measured.

Disclaimer: The findings and conclusion in this report are those of the authors and do not necessarily represent the official position of NIOSH policy. Mention of trades names and or commercial products does not constitute endorsements or recommendations for use. The authors have no known conflicts of interest in conducting and reporting this research.

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FIGURE 1. Liquid paint stripper applied to an airplane inside the stripping bay.

FIGURE 2. Employees wearing coveralls with a hood, goggles, gloves, and a full facepiece air purifying respirators while sanding an airplane inside a painting bay with pneumatic sanders that do not have dust control.

(APFs) were calculated using both the Occupational Safety and Health Administration (OSHA) and NIOSH criteria for hexavalent chromium (contaminant with the lowest OEL) by task and full shift time-weighted-average (TWA) to determine respiratory protection adequacy.[7,8]

All statistical analyses were made using SAS version 9.3 (SAS Institute, Cary, NC). Spearman correlation coefficients were calculated for 11 comparable environmental and biological sampling results. Logistic regression models were constructed to examine the relationship between nasal examination results and work duration while adjusting for cigarette smoking. For the urine samples with results below the analytical limit of detection (LOD), the concentration was estimated by dividing the LOD by the square root of two.[9] Statistical significance was set at the 5% level using a two-tailed distribution for all tests. The research protocol used during this evaluation was approved by the NIOSH Human Subjects Review Board.

EVALUATION RESULTS

Nasal tissue damage was observed in 14 of the 38 (37%) employees consistent with irritation symptoms. Six of the nasal examinations showed evidence of septal ulceration and eight showed evidence of redness, swelling, or bleeding. We also measured the presence of chromium on the hands of employees during breaks and just before leaving the workplace, which indicated that different routes of exposure were present and there was a need for improved hygiene.

The average age of the 26 interviewed employees was 37 years (range: 25 to 52 years). Employees had worked for this employer an average of 9 years (range: 1 month to 21 years). Half of the employees reported they had never smoked; of the employees who reported past smoking history, a quarter of employees were current smokers. Half of employees reported currently having sinus congestion, nasal irritation, and nosebleeds. A quarter of employees reported respiratory symptoms (eg, nasal congestion, runny nose, sore throat, cough) that occurred at work along reported shortness of breath, chest tightness, and/or wheeze. Almost a quarter of employees reported ever having dermatitis.

The geometric mean chromium concentration in employees' urine was 0.74 μg/L of urine (range: 1.0 to 7.8 μg/L), well below the BEI of 25 μg/L of urine.[2] Chromium was not detected in 10 of the 36 urine samples (less than 1.0 μg/L). No statistically significant positive correlation was found between urine and airborne chromium levels ($r = 0.21$). The probability of having an abnormal nasal examination was not significantly associated with length of employment (P-value = 0.96) or urine chromium levels, unadjusted for creatinine (P-value = 0.38), before and after controlling for smoking.

We found that sanders and painters were overexposed to airborne hexavalent chromium. The full-shift air concentrations ranged from 4.6 to 330 $\mu g/m^3$ for hexavalent chromium and 2.0 to 340 $\mu g/m^3$ for chromium. All 11 personal full-shift TWA's for hexavalent chromium air samples exceeded the NIOSH recommended exposure limit (REL) and 2018 ACGIH threshold limit value (TLV) time weighted average (TWA) of 0.2 $\mu g/m^3$, and 10 full-shift samples exceeded the 5 $\mu g/m^3$ OSHA permissible exposure limit (PEL).[5,6] None of the 15 full-shift personal air samples for chromium exceeded any OEL (NIOSH REL of 500 $\mu g/m^3$ or OSHA PEL of 1000 $\mu g/m^3$, or TLV of 500 $\mu g/m^3$).[6] On a task basis, the highest air exposures were for hexavalent chromium when employees applied the chemical stripping agent (up to 1100 $\mu g/m^3$) or the primer (up to 1500 $\mu g/m^3$). Further, the tasks that produced the highest air concentrations for chromium involved employees performing hand and power sanding in the stripping and painting bays.

Surface and area air contamination in non-production areas were found, suggesting migration from production areas. Analysis of a bulk sample of the stripper product confirmed the presence of hexavalent chromium (8.5 mg/kg—0.00085%). The level of ventilation in all bays were inadequate. Turbulent airflow patterns and variable air velocities, along with multiple areas of little air movement indicate a buildup of air contaminants in all bays was possible. Some but not all of the pneumatically-powered vacuum hand sanders used in the stripping and painting bay were equipped with fabric bags (unknown collection efficiency) to capture dust. There was no clearly delineated ''clean'' and ''dirty'' areas that separated production from non-production areas.

Employees working in the stripping bay used either a full-facepiece respirator (when applying stripper, etcher, or Alodine) or a half-mask air purifying respirator equipped with N95 prefilters and organic vapor cartridges for protection against particulate and vapors when sanding or solvent wiping. Employees in the spraying bays used an elastomeric full-facepiece respirator with organic vapor cartridges and N95 prefilters (or) a full-facepiece pressure-demand airline respirator (depending on the extent of the paint job). Elastomeric half-mask (APF of 10) or full facepiece (APF of 50) respirators did not sufficiently reduce employee exposure to hexavalent chromium during sanding tasks in the stripping and painting bays. The respiratory protection program did not have a defined cartridge change out schedule. Personal protective equipment (PPE) was also stored improperly in lockers alongside personal items.

Recommendations Made to the Facility

Following the hierarchy of controls in industrial hygiene, the first recommendation was for the facility to try another alternative product that does not contain hexavalent chromium. In terms of engineering controls, it was recommended to use locally-exhausted (filtered) hand sanders to reduce the release of dust contaminants and to consult a qualified ventilation engineer to re-design or adjust the ventilation systems to ensure better control of airborne contaminants.[10,11] More detailed recommendations were described in the NIOSH report.[1]

Administrative control recommendations included a requirement of reporting health concerns to supervisors or the director of the medical monitoring program. The medical monitoring program for hexavalent chromium should include the elements described in the NIOSH hexavalent chromium criteria document.[12] Furthermore, the company should evaluate how employees move between production and nonproduction areas and store PPE to reduce the spread of contamination. It was also advised to modify and enforce a more effective respiratory protection program and include periodic training, respirator cartridge-change out schedule, accessibility to higher protection respirators in all bays (ie, PPE recommendation of ideally using a full facepiece supplied-air respirator), and compliance enforcement.

DISCUSSION

While chromium is an essential trace element in humans, hexavalent chromium is extremely toxic and is designated a human carcinogen.[12–15] Hexavalent chromium is associated with lung, nasal, and sinus cancer as well as nonmalignant respiratory effects such as irritated, ulcerated, or perforated nasal septa.[12–14] Dermal exposure to hexavalent chromium can result in skin irritation, skin sensitization, and allergic contact dermatitis.[12] Therefore, the most significant finding from this evaluation was employee overexposure to airborne hexavalent chromium, along with evidence of nasal tissue irritation and ulceration symptoms consistent with hexavalent chromium exposure.

The level of respiratory protection was not adequate for the high airborne hexavalent chromium exposures measured, although the biomonitoring results suggest that they did afford some protection. For example, although high airborne exposures to hexavalent chromium were measured (up to 1500 times the REL), urine levels of chromium were below the BEI of 25 μg/L of urine.[2]

We found no association between nose ulcerations and work tenure at this facility. However, some of the nose irritation effects could be caused or exacerbated by the high, short-term exposures to hexavalent chromium dust produced during certain tasks. These findings agree with that of Gibb et al,[16] which found irritated and ulcerated nasal septa occurring less than 3 months from date of hire. We also acknowledge the small sample size of our evaluation may have prevented a more in depth analysis of the data. When comparing our findings with other studies, the urine chromium concentration geometric mean of 0.74 μg/L was lower than that of Italian assembly workers performing aircraft painting (3.14 μg/L of urine).[17] However, a major difference between these studies was that in the Italian study, no nasal tissue examinations were conducted.[17]

The personal air levels found during our evaluation were lower than levels measured in other studies of aircraft refinishing. While we measured levels of hexavalent chromium up to 330 $\mu g/m^3$, higher exposures have been reported by Bennett et al[18,19] measuring up to 640 $\mu g/m^3$ at US military aircraft refinishing facilities. Pesch et al[20] documented spray painters exposure in Germany to be up to 884 $\mu g/m^3$, which included aerospace and other spray painting using chromium pigments. Highest exposures for our evaluation and that of Bennett et al[18,19] were reported when spraying primer. However, it should be noted that our assessment is, to our knowledge, the first study documenting such exposures at a commercial aircraft refinishing facility.

Air levels measured during our evaluation were comparable to other occupations typically exposed to hexavalent chromium. For example, in Germany,[20] welders were exposed to hexavalent chromium up to 348 $\mu g/m^3$, while chromium chemical workers up to 156 $\mu g/m^3$, metal sprayers up to 120 $\mu g/m^3$, and foundry workers up to 83.2 $\mu g/m^3$. In Italy,[21] metal finishing, plating, coating, machine workers, structural metal preparers, and erectors operators had hexavalent chromium exposure up to 1000 $\mu g/m^3$, while manufacturing laborers up to 940 $\mu g/m^3$, welders and flame cutters up to 910 $\mu g/m^3$, and painters up to 500 $\mu g/m^3$. However, the median airborne hexavalent chromium concentration in a study of US workers in a chromate production plant exposed to hexavalent chromium, of which 60% of the cohort experienced nasal ulceration and irritation, was only 20 $\mu g/m^3$.[16] Risk of nasal tissue damage and irritation symptoms increased with each year worked at the chromate production plant.[16]

Overall, our findings demonstrate the need for improved control measures in similar workplaces where aircraft refinishing is conducted in order to prevent acute and long-term adverse health effects from exposure to hexavalent chromium and other metals. Although, a before and after substitution evaluation at this facility was not performed, we determined based on management and employee reports that the process change (ie, replacing methylene chloride with a new stripper product) coincided with exposure concerns. The new stripper product added a source of hexavalent chromium to the overall refinishing process and increased the exposure potential above that produced during previous sanding operations.

Aircraft refinishing often requires large volumes of methylene chloride when used as a stripper. However, the Environmental Protection Agency has imposed limitations in the use of methylene chloride as a paint stripper.[22] Methylene chloride is a solvent known to be toxic to the central nervous system, kidneys, lungs, liver, and is a potential occupational carcinogen.[23] Also, acute exposures to methylene chloride in some instances may be fatal.[23,24] Therefore, use of an alternative stripper product at this facility was desirable. Any alternative product substitution in the future clearly warrants an evaluation of such a change to assess the potential for unexpected hazards. This strategy is considered a good practice in industrial hygiene and occupational health.[25]

Our findings have clinical implications for occupational health practitioners who oversee or monitor employees exposed to hexavalent chromium as part of a medical surveillance program. Nasal irritation symptoms are typical of hexavalent chromium exposure and can occur despite low levels of urinary total chromium. Urine chromium levels are quantified as total chromium because the soluble form of Cr (III), as Cr (VI) is enzymatically reduced to Cr (III), may not be rapidly excreted.[2] The hexavalent chromium BEI is based on the observed correlation with exposure to soluble hexavalent chromium and applies to employees with a history of chronic hexavalent chromium exposure.[2] However, the total chromium in urine BEI is not known to be predictive of nor is it related to skin or respiratory irritation, including local irritant effects.[2] It is important then to encourage employees as part of a medical surveillance program to report to supervisors or occupational health providers, any symptoms such as nasal swelling or congestion, frequent nosebleeds, or nasal ulcerations.

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