Investigation of Respiratory and Dermal Symptoms Associated With Metal Working Fluids at an Aircraft Engine Manufacturing Facility

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Background *Each year, 1.2 million metalworkers are exposed to metalworking fluids (MWFs), which can cause dermal and respiratory disease. The National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation of MWF exposures at an aircraft engine manufacturing facility. The objectives were to determine employee exposures to endotoxin and MWFs in the air, characterize symptoms experienced by employees working with MWFs, compare them to symptoms of employees unexposed to MWFs, and make recommendations for reducing exposures based on results.*

Methods *Four hundred seven workers were categorized as MWF exposed or MWF unexposed and completed questionnaires. Estimated prevalence ratios (PR) of dermatitis, asthma, and work-related asthma (WRA) symptoms were calculated. Airborne concentrations of MWF and endotoxin were measured, and work practices observed.*

Results *MWF exposed workers had a significantly higher prevalence of dermatitis on wrists/forearms (PR 2.59; 95% CI 1.22, 5.46), asthma symptoms (PR 1.49; 95% CI 1.05, 2.13), and WRA symptoms (PR 2.10; 95% CI 1.22, 3.30) than unexposed workers. Airborne concentrations of MWF were below the NIOSH recommended exposure limit (REL) for MWF aerosols (thoracic particulate mass).*

Conclusions *Despite MWF exposures below the NIOSH REL, exposed workers had a higher prevalence of asthma, WRA, and dermatitis symptoms than unexposed workers. Recommendations to reduce exposure included configuring mist collectors to automatically turn on when the machine is in use, and enforcing enclosure use. Am. J. Ind. Med.* © *2013 Wiley Periodicals, Inc.*

KEY WORDS: metalworking fluid; MWF; thoracic particulates; asthma; dermatitis; endotoxin; mycobacteria; microbial contamination; fungi; aircraft engine manufacturing

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from the union at an aircraft engine manufacturing facility to evaluate the possible health hazards of exposure to metalworking fluids (MWFs). In January 2010, a new formulation of a semisynthetic MWF was introduced because it had lower foaming properties than the previous formulation. The union was interested in determining if employees experienced symptoms with this new MWF and to contribute information that could be used in standard setting. The new

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MWF was used in the three central supply systems which fed approximately 275 machines in one large building.

Various types of aircraft engines were manufactured in the 70-year old, one storey facility of approximately one million square feet. Approximately 360 employees worked in 11 cells (areas) over 3 shifts. Most machines in these cells were served by three central MWF supply systems: north, south, and shaft. These systems used approximately 20,000 gallons of MWFs. Machining operations included grinding, cutting, milling, and drilling. The most common machines on the production floor were vertical turret lathes, which removed material from a rotating work piece with cutting tools, mills, and drills. Other machines on the production floor included turning centers and grinders. MWFs were used to cool the cutting tools and machined parts and to remove metal shavings. Several machines not connected to the central supply systems operated on their own stand-alone MWF system. The MWFs in these stand-alone systems had different formulations from those in the central supply systems and were selected based on the requirements for specific tasks. Machines with various types of enclosures (fully enclosed, partially enclosed, no enclosure), with and without mist collectors, and different cutting methods (ceramic or carbide) were spread throughout the work area. Older machines had splash guards and were partially enclosed, whereas newer machines were typically fully enclosed and computer operated. Employees were usually assigned to one or two machines at a time during their shift. Employees reported that ceramic cutting was performed at faster speeds and could cause more misting of MWFs. Employees had opportunity for inhalational exposure to MWF when using machines with either no or a partial enclosure, or when opening an enclosed machine. There was opportunity for dermal exposure primarily when handling parts that had been machined or when maintaining or adjusting the machine.

Metalworking Fluids

MWFs, complex mixtures of synthetic, semisynthetic, and soluble oils, are used to cool, lubricate, and remove metal chips from tools and parts during machining of metal stock. MWFs often contain other substances including biocides, corrosion inhibitors, metal fines, tramp oils, and biological contaminants [NIOSH, 1998; Burton et al., 2012]. Inhalation of MWF aerosols may irritate the throat, nose, and lungs and has been associated with chronic bronchitis, asthma, worsening of pre-existing respiratory problems, and hypersensitivity pneumonitis (HP) [Burton et al., 2012]. HP is a spectrum of granulomatous, interstitial lung diseases that occurs after repeated inhalation and sensitization to a wide variety of microbial agents (i.e., bacteria, fungi, amoebae), and low-molecular weight chemical antigens that can be contaminants of MWFs [CDC, 1996; Kreiss and Cox-Ganser, 1997; Zacharisen et al., 1998]. NIOSH recommends limiting exposures to MWF aerosols to 0.4 mg/m^3 for the thoracic particulate mass, as a TWA concentration for up to 10 hr/day during a 40-hr work week [NIOSH, 1998]. Skin contact with MWFs may cause allergic contact dermatitis or irritant contact dermatitis depending on the chemical composition, additives and contaminants, type of metal being machined, and the exposed individual's tendency for developing allergies [WISHA, 2001].

MWFs are usually diluted with water and bacteria can grow if an inadequate amount of biocide is present. According to the Health and Safety Executive in the United Kingdom, well-maintained MWFs have bacterial concentrations below 10^3 colony-forming units per milliliter (CFU/ml) of fluid [HSE, 2006]. Concentrations between 10^3 and 10^6 CFU/ml indicate reasonable control, and concentrations greater than 10^6 CFU/ml indicate poor control [HSE, 2006]. The outer cell walls of Gram-negative bacteria may release lipopolysaccharide compounds called endotoxin when the bacteria die or multiply. Endotoxin is believed to cause adverse respiratory effects such as chronic bronchitis and asthma. In 2010, the Dutch Expert Committee on Occupational Safety recommended a health-based occupational exposure limit for airborne endotoxin of 90 EU/m^3 [DECOS, 2010]. Contaminated water in MWFs may contain fungi. Some fungi may infect susceptible hosts, such as immune compromised persons, and some fungi may cause HP. At this time, health data are insufficient to recommend a specific limit for fungal contamination in MWFs.

The objectives of this evaluation were to determine employee exposures to endotoxin and MWFs in the air, characterize symptoms experienced by employees working with MWFs and compare them to symptoms of employees unexposed to MWFs, and make recommendations for reducing exposures based on results.

MATERIALS AND METHODS

Questionnaire

We recruited employees in the aircraft manufacturing building and employees who worked in another building where MWFs were not used. Comparison employees performed assembly work, packing, and shipping. Parts were washed prior to assembly to remove MWFs. Participants were defined as exposed to MWFs if they reported that they usually worked with MWF in their current job. Participating employees completed a questionnaire about demographics, work practices and location, personal protective equipment (PPE) use, hand hygiene, smoking status, and dermal and respiratory symptoms. This evaluation was conducted under a blanket institutional review board approval for the health hazard evaluation program because health hazard evaluations

are generally not considered research but workplace evaluations. Written informed consent was not obtained because only a questionnaire was administered. Potential participants were told orally by NIOSH personnel that filling out the questionnaire was voluntary, and this was written on the cover of the questionnaire as well. The company was required to post the final report in a place accessible to all involved employees for 30 days.

The dermal questions included questions modified from the Nordic Occupational Skin Questionnaire [Susitaival et al., 2003]. Three questions from the Nordic Occupational Skin Questionnaire pertaining to a previous history of asthma, eczema, or allergic rhinitis were used to determine if participants were atopic.

The respiratory questions included validated questions on asthma symptoms from the European Community Respiratory Health Survey [Grassi et al., 2003]. The questions were: (1) Have you been woken up with a feeling of tightness in your chest at any time in the last 12 months? (2) Have you had an attack of asthma in the last 12 months? (3) Are you currently taking any medicine (including inhalers or pumps, aerosols, or tablets) for asthma? and (4) Have you had wheezing or whistling in your chest at any time in the last 12 months? If a participant answered yes to (4) they were asked (a) Have you been at all breathless when the wheezing or whistling noise was present? and (b) Have you had this wheezing or whistling when you did not have a cold? If a participant answered yes to any of these questions, they were classified as having asthma symptoms. Being classified as having asthma symptoms by the survey has a sensitivity of 75% and a specificity of 80% for asthma based upon a clinical examination with IgE testing against common allergens, spirometry, and methacholine challenge testing [Grassi et al., 2003]. We modified these questions by adding the following, "or since beginning your current position if in that position less than 12 months," since some participants had not been in their current position for 12 months. We asked additional questions regarding work-relatedness. These questions included changes in symptoms or medication used on days off work or on vacation. If the participant responded that symptoms improved on days off work or on vacation, or that medication use was less frequent on days off or on vacation, then their symptoms were classified as work-related.

A question regarding problems with sneezing, runny nose, or blocked nose in the last 12 months probed work-related rhinoconjunctivitis and was adapted from the International Study of Asthma and Allergies in Childhood [Asher et al., 1995]. These questions included changes in symptoms on days off work or on vacation. If the participant responded that symptoms improved on days off work or on vacation, then their symptoms were classified as work related.

A question regarding more than one episode of illness in the last 12 months with at least two of the following symptoms: cough, wheeze, shortness of breath, or chest tightness was based on diagnostic criteria for HP identified in two prior studies [Fox et al., 1999; Lacasse et al., 2003]. If participants answered yes to this question, they were asked if they had fever or weight loss with these episodes. If they answered yes, they were classified as having symptoms of HP. Participants were also asked if they had pneumonia or chest flu in the last 12 months, and if yes, how many times. This was asked because HP is often misdiagnosed as pneumonia or chest flu. We compared the number of times these illnesses were reported between exposed and unexposed participants.

Metalworking Fluid Sampling

Full-shift personal breathing zone (PBZ) air samples for MWF aerosols (thoracic particulate mass and extracted MWF) were collected over 2 days of sampling. Air samples for MWFs were collected using 37 mm closed-faced three-piece cassettes containing a tared 2 μm pore size polytetrafluoroethylene filter and the supporting pad. The sampling train consisted of the 37 mm cassette, a BGI thoracic cyclone (BGI Incorporated, Waltham, MA), and Tygon® tubing connecting the sampling assembly to SKC Air Check® 2000 air sampling pumps (SKC, Inc., Eighty Four, PA). A sampling rate of 1.6 liters per minute (lpm) was used to collect the thoracic fraction of the aerosol. Each pump was calibrated before and after use. The sampling media were attached to the employee's lapel within the breathing zone (breathing zone is defined as an area in front of the shoulders with a radius of 6–9 in.). The samples were analyzed by gravimetric analysis for the thoracic fraction of MWF particulates per NIOSH Method 5524 [NIOSH, 2012]. After the filter was gravimetrically weighed, a ternary solvent blend was used to extract the MWF fraction from each sample.

We collected bulk samples of MWFs from each of the central supply systems, unused MWFs, and the water that was mixed with the concentrated MWFs. Eight bulk MWF samples were collected and analyzed by culture for bacteria, mycobacteria, and fungi by a contract laboratory.

Endotoxin Sampling

We collected area endotoxin air samples at the employees' work stations where the employees spent the majority of the work day instead of PBZ samples because the employees were already wearing two PBZ pumps. Background concentrations of endotoxin were collected in a meeting room of a separate building. Air samples were collected using an endotoxin free 3-piece 37-mm closed-face cassette, preloaded with 0.45 μm pore-size filters. Samples were collected with SKC AirCheck2000 personal air sampling pumps calibrated at 2 lpm. Each pump was calibrated before and after use. Endotoxin analysis was performed by a contract

laboratory. Samples were analyzed for endotoxin content with the kinetic-chromogenic procedure using the limulus amebocyte lysate assay [Cambrex, 2005]. For these analyses, one endotoxin unit (EU) was equivalent to 0.053 ng of endotoxin. The limit of detection was 0.025 EU/sample.

Microbial Sampling

MWF samples were collected by filling 1 L sterile bottles, leaving at least 2 in. of headspace. Samples were kept at ambient room temperature and shipped within 2 days to the laboratory for analysis. Each sample was concentrated by a 30-min centrifuge and excess fluid was poured off. The concentrate was vortexed for 1 min and then plated to the appropriate media. For aerobic bacteria, the media was tryptic soy agar with polysorbate 80 and lecithin and buffered charcoal yeast extract agar. Plates were incubated at 23 ± 2°C for 5–7 days and read daily. The media for fungi was yeast malt extract, inhibitory mold agar with gentamicin and chloramphenicol, and buffered charcoal yeast extract agar. These plates were incubated at 23 ± 2°C for 10 days. Plates were read on day 3 to see if they were overgrown, and on days 5 or 7 and 10. The media for mycobacteria was buffered charcoal yeast extract agar, Middlebrook 7H10, and Mitchison 7H11S. Plates and broth were incubated at 32 ± 2°C in 7–10% CO_2 for 4 weeks. Cultures were read at 3–5 days and 7 days. If specimens were overgrown, additional dilutions were made. A Ziehl–Neelsen stain of broths was performed at 2–3 weeks and 4 weeks [MSI, 2011].

Statistical Analysis

All data were analyzed using SAS 9.2 (SAS Institute, Inc., Cary, NC). Symptoms were analyzed by age, sex, smoking status, hours worked per week, work area, and job title. A log binomial model directly modeled the prevalence ratio (PR) [Skov et al., 1998], and was used to estimate PR with 95% confidence intervals (95% CI) for dermal and respiratory outcomes. Fitted models for dermal outcomes were adjusted for atopy and fitted models for respiratory outcomes were adjusted for smoking status. Chi square or Fisher's exact tests were calculated to determine if there was an association between exposure to MWFs and dermal and respiratory symptoms. The Fisher's exact test was used for sparse data. A *P*-value equal to or less than 0.05 was considered significant.

RESULTS

Questionnaire

Four hundred seven employees completed the questionnaire. The participation rate was 82% (183/223) among the exposed group and 87% (224/257) among the unexposed group. Ninety-four percent of participants were aged 45 years or older (Table I). A higher proportion (64%) of exposed participants worked more than 40 hr/week than did unexposed participants (45%). The proportion of participants who currently smoked was similar between groups, although more exposed participants (43%) were former smokers. The proportion of participants who were atopic was similar between exposed (60%) and unexposed (53%).

The prevalence of dermatitis in the last 12 months was statistically significantly greater in the exposed group than in the unexposed group after controlling for atopy (PR 1.86; 95% CI 1.20, 2.90; Table II). The most common location of dermatitis in both groups was the hands or fingers (16% exposed and 9% unexposed). Almost half of those reporting dermatitis in the past 12 months in both the exposed and unexposed groups reported having dermatitis currently. A significantly higher proportion of exposed participants reported that their dermatitis symptoms were reduced with more than 5 days away from work (PR 2.50; 95% CI 1.39, 4.49; Table II).

Exposed and unexposed participants reported similar frequency of glove use, but exposed participants were significantly more likely to wear synthetic rubber (51% vs. 41%, $P = 0.049$) and leather gloves (49% vs. 27%, $P < 0.01$). Unexposed participants wore gloves to protect against cuts and abrasions during assembly work. Hand hygiene practices

TABLE I. Characteristics of Participants by Exposure Group (n = 407)

Characteristics	Total number (%)	Exposed number (%), n = 183	Unexposed number (%), n = 224
Age in years			
18–24	2 (<1)	1 (1)	1 (<1)
25–34	11 (3)	—	11 (5)
35–44	10 (2)	5 (3)	5 (2)
45–54	163 (40)	88 (48)	75 (33)
55–64	212 (52)	83 (45)	129 (58)
65+	8 (2)	5 (3)	3 (1)
Unknown	1 (<1)	1 (1)	—
Sex			
Male	340 (84)	174 (95)	166 (74)
Female	67 (16)	9 (5)	58 (26)
Smoking status			
Never	190 (47)	75 (41)	115 (51)
Former	152 (37)	79 (43)	73 (33)
Current	59 (15)	26 (14)	33 (15)
Unknown	6 (1)	3 (2)	3 (1)
Hours worked/week			
Up to 40	192 (47)	69 (36)	123 (55)
41+	214 (53)	113 (64)	101 (45)
Atopy	228 (56)	110 (60)	118 (53)

TABLE II. Prevalence of Dermatitis by Metalworking Fluid Exposure Group

	Exposed number (%), n = 183	Unexposed number (%), n = 224	Prevalence ratio (95% confidence interval)[a]
Dermatitis in the last 12 months	41 (22)	25 (11)	1.86 (1.20–2.90)
Location of dermatitis[b]			
Hands or fingers	30 (16)	21 (9)	1.61 (0.97–2.68)
Wrists or forearm	20 (11)	9 (4)	2.45 (1.16–5.17)
Face or neck	12 (7)	8 (4)	1.65 (0.70–3.90)
Dermatitis currently	20 (11)	12 (5)	1.89 (0.96–3.72)
Dermatitis better when away from work more than 5 days	31 (17)	14 (6)	2.50 (1.39–4.49)
Changed job due to dermatitis	2 (1)	1 (<1)	2.15 (0.20–23.33)
Changed glove type or began wearing gloves because of dermatitis	15 (8)	0 (0)	—

[a]Adjusted for atopy.
[b]Some participants reported more than one location of dermatitis.

(use of barrier cream, hand washing, use of hand-wipes or solvents to clean hands) did not differ significantly between exposed and unexposed participants. For the most part, hand hygiene practices, glove use, and glove type did not differ significantly between those who reported dermatitis on their hands or fingers, or wrists or forearms in the last 12 months and those who did not (Table III). However, participants with dermatitis on their hands or fingers, or wrists or forearms in the last 12 months were significantly more likely to apply barrier cream at work (PR 4.64; 95% CI 2.29, 9.37; Table III). Only 22% (9/41) of exposed participants with dermatitis in the last 12 months reported seeing a doctor for their dermatitis. Of these, none had patch testing.

The proportion of participants who reported ever having asthma was similar between the exposed (11%) and unexposed groups (9%). One-third of those who reported ever having asthma reported that their asthma began during their current job (33% exposed and 32% unexposed). The asthma symptoms listed by exposure group in Table IV were taken from the European Community Respiratory Health Survey. A positive response to any one symptom indicates potential asthma. The prevalence of work-related wheezing or whistling in the chest was significantly higher for the exposed than the unexposed participants after controlling for cigarette smoking status (PR 2.84; 95% CI 1.56, 5.18; Table IV). The prevalence of participants who reported at least one asthma symptom (PR 1.49; 95% CI 1.05, 2.13) was significantly higher for participants exposed to MWFs than unexposed participants after controlling for cigarette smoking status, as was the prevalence of participants who reported at least one work-related asthma (WRA) symptom (PR 1.92; 95% CI 1.19, 3.09; Table IV). Because the REL is for a 40-hr work week, we compared the prevalence of asthma symptoms and WRA symptoms between exposed participants who worked 40 hr/week or less and those who worked more than 40 hr/week. There was no significant difference between these groups.

The proportion of sneezing, runny nose, or blocked nose was similar between exposed (52%) and unexposed participants (41%); however, the prevalence of work-related

TABLE III. Hand Hygiene Practices and Glove Use by Dermatitis on the Hands or Fingers, or Wrists or Forearms, in the Last 12 Months for Exposed and Unexposed Participants Combined

	Dermatitis in the last 12 months number (%), n = 58	No dermatitis in the last 12 months number (%), n = 348–349[a]	Prevalence ratio (95% confidence interval)[b]
Applies barrier cream at work	12 (21)	20 (6)	4.64 (2.29–9.37)
Wash hands at least once per shift	58 (100)	345 (99)	—
Use hand-wipes to clean hands at least once per shift	33 (57)	186 (53)	1.13 (0.87–1.46)
Applies moisturizing lotion to hands or arms at work	31 (53)	190 (55)	0.98 (0.75–1.28)
Uses solvents to clean hands at work	8 (14)	24 (7)	2.23 (1.00–4.96)
Use gloves all of the time	19 (33)	90 (26)	1.33 (0.87–2.04)
Use gloves at least some of the time	56 (97)	320 (92)	1.07 (0.98–1.17)

[a]Denominators vary due to missing information.
[b]Adjusted for atopy.

TABLE IV. Prevalence of Asthma Symptoms by Exposure Category[a]

Symptoms	Exposed number (%), n = 183	Unexposed number (%), n = 224	Prevalence ratio (95% confidence interval)
Wheezing or whistling in chest[b]	46 (25)	35 (16)	1.54 (1.03–2.29)
Breathless when wheezing or whistling	18 (10)	19 (9)	1.13 (0.61–2.10)
Wheezing or whistling without a cold	37 (20)	26 (12)	1.66 (1.04–2.66)
Wheezing or whistling better on days off/vacation	32 (17)	14 (6)	2.84 (1.56–5.18)
Attack of asthma[b]	6 (3)	6 (3)	1.22 (0.40–3.76)
Attacks of asthma less often on days off/vacation	5 (3)	5 (2)	1.21 (0.35–4.13)
Woken up with feeling of tightness in chest[b]	26 (14)	13 (6)	2.47 (1.30–4.69)
Episodes of chest tightness less often on days off/vacation	18 (10)	10 (4)	2.22 (1.05–4.72)
Currently taking any medicine for asthma[b]	10 (5)	12 (5)	1.05 (0.46–2.39)
Take medicine less often on days off/vacation	5 (3)	3 (1)	2.28 (0.55–9.42)
Asthma symptoms[c]	54 (30)	43 (19)	1.49 (1.05–2.13)
Work-related asthma symptoms	37 (20)	24 (11)	1.92 (1.19–3.09)

[a]Controlled for smoking status.
[b]Derived from European Community Respiratory Health Survey; positive answer to any one indicates potential asthma.
[c]Asthma symptoms based upon a positive answer to one or more of four European Community Respiratory Health Survey questions.

nasal symptoms was significantly higher among the exposed participants (PR 1.36; CI: 1.003–1.86).

The prevalence of reported symptoms of HP by either of our definitions did not differ between exposed and unexposed participants. Six percent of exposed and unexposed participants reported one or more episodes of fever and weight loss in the last 12 months plus at least two episodes of cough, wheeze, shortness of breath, or chest tightness. Less than 1% of participants in each group reported having pneumonia or chest flu more than twice in the last 12 months.

Metalworking Fluid Sampling

We collected 48 PBZ air samples and 9 area air samples for MWFs. Each sample was analyzed for thoracic particulates and the extractable fraction of MWFs. Thoracic particulates include all dust and other aerosols in the air (such as bioaerosols) in addition to the MWFs. The extractable fraction represents the portion of the sample that was MWFs.

Overall, concentrations of thoracic particulates and extracted MWFs were very low and did not exceed the NIOSH REL for thoracic particulates of 0.4 mg/m^3. Eighteen of 43 PBZ air samples analyzed for thoracic particulates were quantifiable (mean of 0.16 mg/m^3; range: 0.11–0.29 mg/m^3) and 25 had concentrations between the minimum detectable concentration of 0.03 mg/m^3 and minimum quantifiable concentration of 0.12 mg/m^3. None of the air samples had quantifiable concentrations of extracted MWFs and only 4 of 43 PBZ air samples had extracted MWF concentrations between the minimum detectable concentration of 0.14 mg/m^3 and the minimum quantifiable concentration of 0.5 mg/m^3. Three air samples were taken on employees who did not work directly with MWF from the central systems (i.e., they worked on a machine on a stand-alone system or in hot oil flush), but their work stations were surrounded by machines that were on the central systems. These concentrations were comparable to those found in the other air samples.

Endotoxin Sampling

We took 20 area air samples for endotoxin throughout the plant; two samples were taken in a meeting room in a completely separate area. Endotoxin concentrations in the areas with MWF use ranged from 0.42 to 2.7 EU/m^3 with a mean of 1.2 EU/m^3. The meeting room sample concentrations were 0.23 and 0.24 EU/m^3.

Microbial Sampling

Two bulk samples from each of the central systems were collected for microbial analysis. An unused sample of MWFs mixed from concentrated MWFs and deionized water to the manufacturer's recommended concentration, and a sample of the deionized water used to dilute the MWFs were also collected and analyzed. Bacteria counts ranged from 3 to 401 CFU/ml. Two types of bacteria were found in the deionized water. All bacterial concentrations were low, below 10^3 CFU/ml of fluid. The deionized water contained four types of fungi. Although the shaft central system had no bacteria isolated, *Penicillium* spp. (a fungus) was isolated. The north and shaft central systems had mycobacteria; these were identified as a Ziehl–Neelsen stain species, but the

laboratory was unable to identify the exact species. Bulk samples collected by the company at the same time as the NIOSH samples had similar results; however, the company's results showed higher bacteria counts (up to 4,000 CFU/ml). Fungi were not detected except in the deionized water sample (30 CFU/ml). Both sets of results showed that the deionized water used to dilute the MWF concentrate for the central systems had low levels of bacteria.

Other Observations

We observed that some machines had mist collector systems, enclosures, and splash guards which operators did not always use when the machines were in use. In specific instances, enclosures and splash guards were not closed completely when the machines were in use. In other cases, mist collectors were not turned on. Most employees wore short sleeve shirts when working in areas where MWFs were present.

DISCUSSION

Despite the low airborne concentrations of MWF, exposed participants were significantly more likely to report asthma symptoms as well as WRA symptoms than unexposed participants. Case reports of occupational asthma have demonstrated that the NIOSH REL for MWFs does not consistently protect against allergic respiratory sensitization [Kreiss and Cox-Ganser, 1997; Mapp et al., 2005]. NIOSH recognized and stated that the REL might not be protective of all employees when the REL was introduced [NIOSH, 1998]. Recent Finnish studies have similar findings to this evaluation. A study that compared machine workers using mainly water-miscible MWFs to office workers from 64 Finnish companies found very low respirable aerosol concentrations (geometric mean of 0.12 mg/m^3) in the breathing zones of the machine workers, yet still found a significant excess of upper and lower respiratory symptoms and current asthma among the machine workers [Jaakkola et al., 2009]. There was no significant difference between exposed and unexposed participants in our evaluation when were asked if they ever had asthma. This discrepancy between reporting symptoms and history of a diagnosis of asthma in this workforce may indicate an underdiagnosis of asthma. Lack of recognition and identification of work relatedness are likely for diseases with symptoms common to non-occupational disorders or those with multiple causal factors [Milton et al., 1998].

In our evaluation, exposed participants were significantly more likely to report dermatitis in the last 12 months. Dermatitis on the wrist and forearm was significantly more prevalent among exposed participants. We noted many employees wearing short sleeves, which may allow wrist and forearm contact with MWFs while the hands are protected by gloves. We recommended use of protective sleeves to prevent forearm contact with MWFs. Barrier creams were used by some employees, presumably to prevent dermatitis. However, the evidence of the protective nature of these topical products during actual working conditions is limited [Schwanitz et al., 2003; Loffler et al., 2006; Weisshaer et al., 2006]. In our evaluation, those with dermatitis were significantly more likely to report using barrier creams than those without dermatitis. It is unclear if they are using the cream because they have dermatitis or if the dermatitis is caused or exacerbated by the barrier cream.

This evaluation has several limitations. The cross-sectional design of the evaluation means that exposures and symptoms were captured at the same time. Thus the study does not provide strong evidence of causality. Inquiring about symptoms over a year's period may introduce recall bias. Industrial hygiene sampling can only document exposures on the days of sampling in the locations sampled. We did not perform clinical examinations to diagnose dermatitis and asthma. However, the European Community Respiratory Health Survey questions have a sensitivity of 75% and a specificity of 80% for asthma symptoms based upon a clinical examination with IgE testing against common allergens, spirometry, and methacholine challenge testing, and the dermal questions include standardized questions modified from the Nordic Occupational Skin Questionnaire which is widely used in studies of dermatitis [Grassi et al., 2003; Susitaival et al., 2003]. The European Community Respiratory Health Survey questionnaire was validated among 20- to 44-year olds, however, while an older group of 45- to 70-year-old subjects were studied in the Netherlands [Kerkhof et al., 1994 in Abramson et al., 2002]. Our population was mostly over age 45 years. However, our participants were healthy enough to be fully employed, and the European Community Respiratory Health Survey has been previously used in a published study of asthma in older adults [Abramson et al., 2002]. Another limitation of this evaluation was a lack of similar data for prior MWF exposure. It would be beneficial for the company to have been able to compare employee symptoms before and after the introduction of the new MWF formulation.

In conclusion, participants exposed to MWFs reported significantly higher prevalence rates of work-related dermatitis and WRA symptoms in the previous 12 months than participants not exposed to MWFs despite airborne exposure to MWFs being below the REL. Following a preventive maintenance program for the mist collectors and appropriate use of engineering controls (i.e., machine enclosures, splash guards, mist collectors) could lower airborne levels of MWFs. We recommended configuring mist collectors to automatically turn on when the machine is in use, and enforce enclosure use. Instituting a medical surveillance program would enable earlier identification of work-related respiratory and skin symptoms.

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