Occupational diseases in individuals exposed to metal working fluids

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Purpose of review
To examine the current occurrence of respiratory and skin disease in workers who do metal machining with metal working fluids (MWFs), a common work process in manufacturing.

Recent findings
A summary of the 27 recognized outbreaks of respiratory disease in workers exposed to MWFs was published. New studies have identified irritative symptoms among workers with low-level exposures. There were review articles discussing the content, measurement and control of microbial agents in MWFs.

Summary
The occurrence of work-related asthma and hypersensitivity pneumonitis appears to have diminished in the last 10 years. This is presumed to be secondary to lower air levels from the use of newer machining equipment, which are enclosed and have local ventilation as well as better control of microbial contaminants. However, clinicians need to be aware that at the minimum irritative symptoms of the upper respiratory tract are still being reported at these lower exposure levels and there remains the possibility of the development of asthma and hypersensitivity pneumonitis. Given the widespread use of MWFs in manufacturing facilities, clinicians need to consider the possibility that MWFs are the cause or are aggravating the respiratory and dermatologic conditions of their patients.

Keywords
cancer, dermatitis, hypersensitivity pneumonitis, metal working fluids, work-related asthma

INTRODUCTION

Respiratory disease caused by exposure to metal working fluids (MWFs) was last reviewed in this journal in 2009 [1]. MWFs, which may be referred to in publications as coolants, cutting compounds, fluids or oils, lubricates or metal-removal fluids, are liquids used to reduce heat and friction and remove small metal pieces during the machining (i.e. cutting, drilling, grinding and milling) of metal parts. Metal machining is a common activity in manufacturing industries involved in the production of transportation of equipment and other types of machinery (Fig. 1).

Medical conditions of concern from exposure to MWFs are work-related asthma (WRA), hypersensitivity, pneumonitis, irritative respiratory symptoms, cancer and skin diseases. Complicating the interpretations of studies on the health risks of MWFs are: the four different types of MWFs, straight (mineral oil, natural, neat), emulsified (emulsion of oil and water), semi-synthetic (contains lower concentration of oil) and synthetic (no mineral oils); changes in time over the type of MWF used as well as the recent introduction of vegetable oil as a substitute for the petroleum-based straight oils; the presence of more than one type of MWF in a single facility; the widespread use of different additives in MWFs; and confusion in terminology with the use of similar compounds in forging and stamping processes.

The respiratory conditions, asthma, irritative symptoms and hypersensitivity pneumonitis, are associated with the increasing widespread use of the water-based MWFs since the 1970s, whereas cancer is associated with the older petroleum-based MWFs and skin disease is associated with all types of MWFs,

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KEY POINTS

- Working with MWFs can cause dermal and respiratory symptoms and disease.
- MWFs are commonly used in the manufacturing of metal parts.
- The incidence of WRA and hypersensitivity pneumonitis from exposure to MWFs appears to have decreased.
- The components of MWFs that cause health problems still need further elucidation.

although more common with the petroleum-based MWFs. The potential cancer risk from exposure to MWFs is not reviewed in this article [2].

RESPIRATORY DISEASE

Cases of respiratory disease caused by exposure to MWFs peaked in the 1990s after hypersensitivity pneumonitis from exposure to MWFs was first described in workers from an auto parts manufacturer in Michigan [3]. Subsequently to that initial report, multiple outbreaks of hypersensitivity pneumonitis were described in other auto parts manufacturing facilities in the United States [4] and in the last seven years in England and France [5,6,7▪▪]. During these outbreaks of hypersensitivity pneumonitis, WRA cases were also identified and were even more common than the hypersensitivity pneumonitis cases [4]. Since 1988, there have been 319 cases of WRA caused by exposure to MWFs confirmed in Michigan. Most cases were reported in the 1990s and early 2000s. From 1988 through 2013, WRA caused by MWFs was the third most common cause (9.8%) of WRA in the state. However, there has been a marked decline in the number of WRA cases caused by MWFs. Only two to four case reports a year were confirmed after 2005, whereas from 1990 to 2005, there were 10–20 confirmed cases a year with a peak of 32 in 1992 (Fig. 2). Since 2005, WRA caused by MWFs represented about 5% vs. over 10% of cases confirmed in Michigan from 1990 to 2005 (Fig. 3). The decrease in WRA cases caused by MWF exposure in Michigan was steeper than the decline in the overall number of WRA cases confirmed from all causes (88% vs. 57%). This decline in reports received in Michigan parallels the decrease in reports in the medical literature of hypersensitivity pneumonitis from MWFs [7▪▪] and WRA cases caused by MWFs reported to the Shield surveillance system in the West Midlands

FIGURE 1. Machining operation to manufacture a mold to be used in plastic injection. Metal working fluids (MWFs) will be sprayed on the tool and the metal being machined. The MWF runoff and metal shavings will be collected in a large container located under the machine.

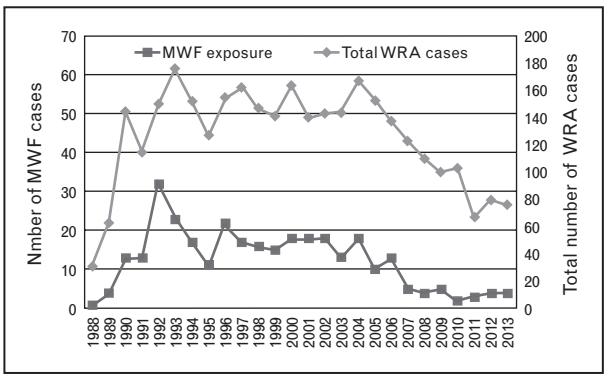

FIGURE 2. Work-related asthma (WRA) caused by metal working fluids (MWFs) exposure: Michigan 1988–2013.

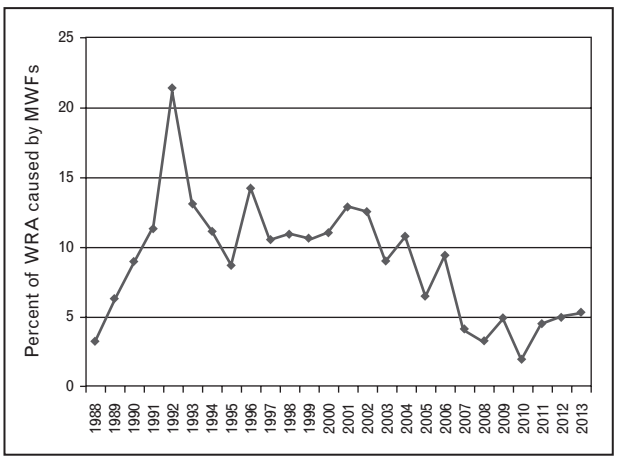

FIGURE 3. Percentage of work-related asthma (WRA) caused by metal working fluids (MWFs): Michigan 1988–2013.

of England (http://www.occupationalasthma.com/occupational_asthma_pageview.aspx?id=493).

What is the reason for the decrease in reports of WRA and hypersensitivity pneumonitis from exposure to MWFs? The existing allowable Occupational safety and Health Administration (OSHA) air standard of 5 mg/m^3 dates back to 1972. The 5 mg/m^3 level was not selected for health reasons but because at levels above 5 mg/m^3, MWFs in the air would condense on the ceiling and drip down on the workplace. In 1998, the National Institute for Occupational Safety and Health (NIOSH) recommended the standard be decreased to 0.5 mg/m^3. Although OSHA did not promulgate a new standard, OSHA in 1999 developed a best practices guide for using MWFs [8]. The feasibility of retrofitting older equipment and reducing exposure has been demonstrated and most US companies are reported to be using the 0.5 mg/m^3 level after purchasing new equipment and a 1.0 mg/m^3 level as their standard for older equipment [9]. A summary of published data on MWF exposure showed mean levels of 5.4 mg/m^3 prior to the 1970s, 2.5 mg/m^3 in the 1970s, 1.2 mg/m^3 in the 1980s and 0.5 mg/m^3 in the 1990s and 2000s [10]. Most companies in Scandinavia are maintaining levels below 0.2 mg/m^3 [11]. There has also been increased awareness about work practices and proper maintenance of MWFs. After use, MWFs are typically collected in sumps located in the area in the machining area where the individual works, the metal particles are filtered out and then the fluid is reused in the machining process. Personnel are assigned to monitor parameters of the MWF such as the concentration of the MWF in water, pH, biological contamination, levels of additives and periodically add to and change out the MWF. Presumably, better control of air levels and MWF maintenance has been important in reducing the occurrence of respiratory disease among individuals working with MWFs because the use of MWFs in manufacturing remains widespread. Also more strict standards in Europe may explain why more reports of respiratory disease have come from US facilities [11].

HYPERSENSITIVITY PNEUMONITIS

Subsequently to the recognition of hypersensitivity pneumonitis from exposure to MWF in the mid 1990s [3], there have been 27 clusters of diseases reported in the literature [7▪▪]. The largest number of reports was in the 1990s [7▪▪]. The last publication of an outbreak was in 2011 about cases from 2004 to 2007 [6].

A comparison was made of case definitions used in previous reports of respiratory disease clusters [12]. The authors concluded that the case definition used in an outbreak investigation in Wisconsin in 1999 was the one that investigators had the most experience with but that there was a need to determine whether 'a more valid and evidence-based case definitions can be developed'. In a subsequent publication, a panel of five pulmonary specialists used clinical data to categorize 37 workers with suspected hypersensitivity pneumonitis from MWF exposure identified during a previous outbreak investigation in England [5]. The expert panel classified 14 cases as definite, 12 as possible and 11 as definitely not cases. The expert panel's classification was compared with a score based on respiratory symptoms, generalized symptoms, pulmonary function results, radiographic results, bronchial lavage and biopsy results. The authors concluded that their 'MWF-hypersensitivity pneumonitis score performed well' and suggested it would be useful in investigations of future outbreaks [13]. This epidemiological case definition would not replace diagnostic criteria used by clinicians in evaluating individual patients.

WORK-RELATED ASTHMA

As discussed in the introduction, the recognition of new cases of WRA from MWFs has decreased. Better ventilation controls and enclosure of newer machines with local ventilation reduces the level of exposure and risk of sensitization to the MWF or additives in the MWFs. Unlike hypersensitivity pneumonitis wherein a microbiological contaminant is the presumed etiologic agent, the MWF or a chemical additive is the presumed etiologic agent for WRA.

A cross-sectional questionnaire of workers performing machining in 64 companies from southern Finland reported that 195 of 757 (25.8%) had work-related respiratory symptoms [14▪]. One hundred and thirteen of these 195 symptomatic individuals agreed to an occupational medical interview and 25 of the 113 who were suspected based on the interview as having an occupational disease were invited for a clinical evaluation including specific inhalation challenge testing. One individual had a positive inhalation challenge test to MWF and was diagnosed with occupational asthma. If the criteria for WRA had been new-onset asthma with work-related symptoms, then another five individuals would have been diagnosed with WRA. This low occurrence of WRA can be attributed to studying a working (survivor) population and the tighter controls on air levels required in Finland.

IRRITATIVE SYMPTOMS

Exposure to MWFs can cause irritation of mucosal tissue and irritative symptoms. Prevalence of irritative symptoms is more common than WRA or hypersensitivity pneumonitis. Two recent cross-sectional studies document irritative symptoms at relatively low levels of MWF exposure.

A cross-sectional questionnaire was performed by NIOSH as part of a health hazard evaluation of 183 employees exposed to MWFs and 224 unexposed workers at an aircraft engine manufacturer [15▪]. The facility used 20 000 gallons of semisynthetic MWFs in 275 machines. Twenty percentage of the exposed workers vs. 11% of the control workers reported WRA symptoms in the last 12 months [prevalence ratio 1.92, 95% confidence interval (CI) 1.19–309] and work-related nasal symptoms (prevalence ratio 1.36, 95% CI 1.003–1.86). All air levels in the facility were below the NIOSH-recommended standard of 0.5 mg/m^3. This study was limited by its cross-sectional design and the absence of any clinical exams or breathing tests. However, this study would suggest that health problems can occur even within the more stringent NIOSH-recommended standard that is 10 times lower than the enforceable OSHA standard.

A cross-sectional study [16] from Sweden was reported on 102 workers who performed machining with MWFs, 169 workers from the machining area of the factory but who did not do machining and 24 workers with no exposure to MWF. There was a control group of 4780 school and office workers. Workers with direct exposure to MWFs, who operated the machines, had a higher prevalence of work-related nasal irritation 37% vs. 21% vs. 8% and coughing 17% vs. 6% vs. 4% as compared with the two other groups of factory workers. Skin problems were more common in the factory workers compared with the office/school workers but not different between the exposed and nonexposed factory workers. Nasal lavage and nitric oxide measurements were performed on nine symptomatic and six asymptomatic exposed workers. No significant difference in exhaled nitric oxide levels was found, although there was a difference in the protein pattern in nasal lavage fluid between the symptomatic and asymptomatic exposed workers. This survey was initiated after the facility changed to a water-based MWF because of skin problems from an oil-based MWF. This change was successful in reducing skin problems, but the change was associated with the development of respiratory irritative symptoms. Insufficient testing was performed to evaluate the occurrence of WRA. The highest oil mist levels measured were 1.2 mg/m^3.

EXPOSURE/MICROBIOLOGICAL CONTAMINANTS

Reduction of airborne levels of MWFs is thought to be an effective strategy to reduce respiratory diseases and symptoms. Newer machines are enclosed with local ventilation. A report from Iran found that keeping the temperature in the machining area of an auto manufacturing facility between 68° and 86° Fahrenheit reduced mists from an emulsified MWF by 30–40% [17].

An additional approach is good maintenance of water-based MWF to reduce growth of gram-negative bacteria and overgrowth of mycobacteria or fungi if biocides are used. The motivation for controlling microbiological growth is important not only because their presence is associated with clusters of hypersensitivity pneumonitis cases but to maximize the time period over which the MWF can be used before it degrades and becomes less effective in production. The microorganisms typically grow in biofilms, a polysaccharide matrix that adheres to walls of pipes and containers and protects the organisms from the actions of biocides added to the MWFs. Two review articles on the microorganisms that grow in MWFs, molecular testing to identify them, their susceptibility to biocides and approaches to control microorganism growth were published [18,19▪]. No definite approach has been adopted to manage microbial growth, and the use of biocides markedly varies throughout industry. There was a report of a laboratory assay to determine the ability of microorganisms to develop a biofilm and their susceptibility to different biocides [20].

An in-vitro study [21] using a murine alveolar macrophage cell line reported that the inflammatory effect of *Mycobacterium immunogenum*, an organism identified as the presumed etiological agent in a number of hypersensitivity pneumonitis outbreaks, was primarily mediated by p38 and jun kinase inhibitor.

There has been increased use of vegetable oil-based MWFs in response to identifying an MWF that is biodegradable and can be obtained from a renewable source [22]. There are no data to suggest that a vegetable oil-based MWF has a lower risk for respiratory disease. These vegetable oil-based MWFs can contain the same additives such as ethanolamine, suspected to be an etiologic factor for WRA in the semisynthetic and synthetic MWFs.

DERMATOLOGICAL CONDITIONS

The cross-sectional questionnaire of workers performing machining in 64 companies from southern

Finland not only assessed respiratory symptoms but was also used to assess work-related skin conditions [14▪]. Ninety-one of 757 (12.0%) had work-related skin symptoms. Fifteen of the 18 individuals, who based on an occupational medicine interview had suspected occupational skin disease, had a clinical evaluation with patch testing. Five of the 15 were diagnosed with occupational allergic contact dermatitis and three of the 15 with occupational irritant contact dermatitis. The substances in MWFs, which tested positive on patch testing and were felt to be the cause of allergic contact dermatitis; a biocide which was a mixture of chloromethylisothiazolinone and methylisothiazolinone; colophony and fatty acid fraction; and nickel dissolved in the MWF. Two other individuals with allergic contact dermatitis had positive patch tests to chemicals in hand creams and hand cleansing agents, dimethylaminopropylamine, coconut diethanolamine and cetyl stearylalcohol.

Twenty-two percent of the exposed workers from the study [15▪] of an aircraft engine manufacturer discussed in the section on irritative symptoms vs. 11% of the control workers reported dermatitis in the last 12 months (prevalence ratio 1.86, 95% CI 1.20–2.90). No clinical evaluation or patch testing was performed.

CONCLUSION

Machining with the use of MWFs is a common process performed in manufacturing facilities. The recognition of WRA and hypersensitivity pneumonitis caused by exposure to MWFs has decreased in the last 10 years. It is possible that this observed decrease is not a true decrease in the incidence of disease, but rather a consequence of deficiencies in surveillance systems, lack of recognition by healthcare providers that a patient has hypersensitivity pneumonitis or that their asthma is work-related, or secondary to publication bias in that the association with MWFs has been identified and no longer of sufficient interest to report. However, both the Shield surveillance system in England and the SENSOR system in Michigan show a similar decrease in cases of WRA secondary to MWFs.

Despite the downward trends in the surveillance systems, clinicians need to remain aware that MWFs' use is common and workers who work in machining areas are at risk for developing hypersensitivity pneumonitis, WRA and skin disease as well as irritative symptoms. Improvements in controls to reduce exposures at least in the United States are voluntary and likely to vary more between companies than if they were based on regulations. Further evaluation of the health effects of the additives used in MWFs, vegetable oil-based MWFs and microbial contaminants in water-based MWFs is needed.

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Conflicts of interest

There are no conflicts of interest.

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- ▪ of special interest
- ▪▪ of outstanding interest

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