

Work-Related Asthma and Respiratory Symptoms Among Workers Exposed to Metal-Working Fluids

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The objective of this work was to determine whether the prevalence of respiratory symptoms differed among workers exposed to different types of metal-working fluids.

As part of a mandatory surveillance system for occupational illness, from 1988-1994, the Michigan Department of Public Health received, 86 occupational disease reports of work-related asthma secondary to exposure to metal-working fluids. As part of a public health program, follow-up industrial hygiene inspections, including medical interviews of the workforce, were performed at companies where the reported cases had become ill.

Metal-working fluids were the second most common cause of work-related asthma reported in the state. Most of the reports were from the automobile industry. Follow-up inspections were conducted at 37 facilities where the individuals with work-related asthma had worked. Seven hundred and fifty-five workers at these facilities were interviewed. Only one facility was above the allowable oil mist standard. Despite the exposure levels being within the legal limits, approximately 20% of the fellow workers of the reported cases had daily or weekly respiratory symptoms suggestive of work-related asthma.

Workers exposed to emulsified, semisynthetic, or synthetic machining coolants were more likely to have chronic bronchitis; to have visited a doctor for shortness of breath; to have visited a doctor for a sinus problem; to be bothered at work by nasal stuffiness, runny nose, or sore throat; and to have an increased prevalence of respiratory symptoms consistent with work-related asthma, compared to workers exposed to mineral oil metal-working fluids. These findings were found in individuals who currently smoked, had never smoked or were ex-cigarette smokers. Further research to determine the chemical components or microbial contaminants responsible for these findings is needed. Am. J. Ind. Med. 32:325-331, 1997. © 1997 Wiley-Liss, Inc.

KEY WORDS: *asthma; metal-working fluids; amines; occupational disease*

INTRODUCTION

Exposure to metal-working fluids [Hendy et al., 1985; Robertson et al., 1988] and ethanalamines found in metal-

working fluids [Savonius et al., 1994; Ng et al., 1995] has been associated with work-related asthma. More recently there have been reports of outbreaks of hypersensitivity pneumonitis among workers exposed to metal-working fluids [Bernstein et al., 1995; Rose et al., 1996].

There are four types of metal-working fluids: (1) straight mineral oil, which contains no water; (2) emulsified or soluble oil, which are emulsions of mineral oil and water; (3) semisynthetic oils, which contain smaller amounts of mineral oil than the emulsified oils; and (4) synthetic oils, which contain no mineral oil. Different substances, such as dyes, corrosion inhibitors, and biocides, are found in the various types of metal-working fluid. The type of fluid used depends on the metal-working operation. However, there has been an overall shift in the last 20-30 years away from use of the straight mineral oil.

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Because of increased concern about the health effects of metal-working fluid, we reviewed the data from a statewide surveillance system for work-related asthma to identify individuals with asthma from exposure to metal-working fluids. Additionally, we reviewed respiratory symptoms among fellow workers at the facilities where the individuals with work-related asthma worked.

METHODS

In 1988, the Michigan Department of Public Health (MDPH), with financial assistance from the National Institute for Occupational Safety and Health (NIOSH), instituted a surveillance program for work-related asthma. This program is part of the Sentinel Event Notification System for Occupational Risks (SENSOR) [Matte et al., 1990]. Three sources were used to identify persons with work-related asthma: (1) reports from physicians; (2) workers' compensation claims filed with the Michigan Department of Labor; and, since 1989, (3) reports from hospitals. Both physicians in private practice and those working for industry send reports to the State Department of Public Health. Reports from hospitals were requested once each year. Hospital discharge summaries for individuals with a primary or secondary diagnosis of a respiratory condition due to chemical fumes and vapors (ICD 506.0-.9) or a primary or secondary diagnosis of asthma where the payor was workers' compensation were obtained and the medical chart was reviewed to determine whether the patient had asthma and if the condition was work-related. Reporting by both Michigan practitioners and hospitals is required under part 56 of Public Act 360 of 1978, which requires the reporting of all known or suspected occupational disease.

A person was considered to have new-onset work-related asthma from exposure to metal-working fluids if: (1) they had a physician diagnosis of asthma, and (2) onset of respiratory symptoms associated with a particular job that then improved or were relieved when the patient was not working, and (3) they worked with a metal-working fluid, or had evidence of an association between metal-working fluid exposure and a decrease in pulmonary function testing [Matte et al., 1990].

In addition to the individuals who first developed asthma after hire, a person was considered to have new onset work-related asthma if they had childhood asthma and their asthma became asymptomatic for a year or more before beginning work with metal-working fluids and their symptoms then reoccurred at work. If a person had physician diagnosed asthma and was symptomatic or required asthma medication in the year before beginning work and their asthma became worse at a particular job, the person was not considered to have new-onset asthma and was not included in the analyses.

After the reported individual was interviewed and the work-relatedness of their condition evaluated, an industrial hygiene investigation was conducted at the subject's work place. At this follow-up investigation, co-workers from the same area as the index case who were present during the industrial hygiene inspection were asked to complete a short confidential questionnaire. It included a brief work history at the facility being inspected, cigarette smoking history, brief medical history on lung conditions and questions regarding respiratory symptoms (the respiratory symptom questions are in the Appendix). Because of staff limitations, not all work sites were followed up and when an investigation was conducted, interviews were not always obtained. Whether or not an inspection occurred or interviews were conducted was random and no selection criteria were used to determine follow-up.

All workers on the shift when the inspector was in the plant from the work area of the index case were offered the opportunity to complete a questionnaire. No attempt was made to contact workers who were not working on the day of the inspection.

The type of metal-working fluid used at the facility was determined at the time of inspection using standard criteria by an experienced industrial hygienist who reviewed the material safety data sheets [O'Brien and Frede, 1978]. The manufacturer of the metal-working fluid was contacted when questions about classification could not be resolved by review of the material safety data sheet. When grouping facilities by metal-working fluid type, we considered a facility to be in the synthetic category if any synthetic fluid was used. A facility was considered to be in the semisynthetic category if it used semisynthetic metal-working fluid and any other fluid but synthetic. A facility was considered to be in the emulsified category if it used emulsified alone or emulsified and mineral metal-working fluids. To be in the mineral oil category, the facility could only use a mineral oil metal-working fluid (method 1). Another group of investigators categorized facilities giving precedence to mineral oils (i.e., considered in the mineral oil category if used any mineral oil) [Ameille et al., 1995]; analysis was done using their classification system (method 2) as well as using facilities that used only one type of metal working fluid (method 3). Most of analyses, however, were done using method 1 since this provided a relatively equal distribution of the facilities by metal-working fluid type.

Occupational Safety and Health Administration (OSHA) Injury and Illness logs, which employers are required to complete on all occupational injuries and illnesses that require more than first-aid, were reviewed for the previous 5 years to identify workers with work-related asthma. An industrial hygienist conducted air monitoring for any suspected allergens and reviewed the company's health and

TABLE I. Results of Industrial Hygiene Inspections of 37 Facilities Using Metal-Working Fluids: Michigan 1988–1994

Air sampling status	Number of facilities	Number of interviews	Workers with new-onset asthma or symptoms suggestive of work-related asthma	
			Number	Percent
No. Air Sampling ^a	15 ^b	306	77	25.2
Air Sampling				
ND-<.5	7 ^c	113	13	11.5
.5-<1.0	8 ^d	145	34	23.4
1.0-<5.0 mg/m ³	6 ^e	171	30	17.5
≥5.0 mg/m ³	1	8	0	—
Total	37 ^f	743	154	20.7

^aAir sampling was not performed because in the industrial hygienist's opinion the oil mist standard would not have been exceeded.

^bInterviews were conducted in 13 facilities.

^cInterviews were conducted in 6 facilities.

^dInterviews were conducted in 7 facilities.

^eInterviews were conducted in 5 facilities.

^fInterviews were conducted in 32 facilities.

safety program. At the conclusion of the investigation, a report was compiled, which included when appropriate: air sampling results, OSHA citations, and recommendations.

Pearson chi-squares were calculated to examine differences between the companies using the four categories of metal-working fluids.

RESULTS

From 1988–1994, the Michigan Department of Public Health received 86 occupational disease reports of work-related asthma from exposure to metal-working fluids at 45 different facilities. These individuals were exposed to metal-working fluids from machining operations in manufacturing facilities, mostly of automotive parts.

Among the 45 facilities identified, 37 were inspected (Table I). Among the 37 facilities inspected, air sampling for oil mist was performed in 22. Among the 22 facilities where air sampling was performed, only one facility was identified with exposure levels above the OSHA (MIOSHA) standard of 5 mg/m³. Both fellow worker interviews and air sampling were conducted at 19 of the companies inspected. Oil mist exposures to employees in the 18 facilities below the OSHA standard ranged from nondetected (<0.1 mg/m³) to 3.57 mg/m³. Of the 67 air samples analyzed, only 11 were greater than 1.0 mg/m³. Interviews of 429 workers were conducted at the 18 facilities where exposure levels were below 5 mg/m³, and showed that 77 had either developed physician diagnosed asthma since beginning work at the facilities or

had daily or weekly shortness of breath, wheezing or chest tightness associated with work. These latter symptoms are typical of those seen with work-related asthma. At 13 facilities, interviews were conducted but no sampling was done because, in the industrial hygienist's opinion, the oil mist levels would not have exceeded the MIOSHA standard. Interviews of 306 workers at these 13 facilities indicated that 75 had either developed physician-diagnosed asthma since beginning work at the facility or had the respiratory symptoms listed above at work that are consistent with work-related asthma (Table I). In 5 facilities inspected, no interviews of workers were obtained.

At 36 facilities, the type of metal-working fluid was characterized: 12 used only mineral oil; 9 used an emulsified oil (two also used a mineral oil); 2 used a semisynthetic (1 also used emulsified oil, 1 also used a mineral and emulsified oil); and 13 used a synthetic (4 also used an emulsified oil, 1 also used a mineral oil, 1 also used a semisynthetic oil, 1 also used semisynthetic and emulsified oils; and 2 also used mineral, emulsified and semisynthetic oils).

Table II shows the average number of years worked, average year of birth, history of allergies and cigarette smoking status by metal-working fluid type for the interviewed fellow workers of the index case. Only cigarette smoking status differed among the four metal-working fluid categories. There were more nonsmokers in the mineral oil only exposed group (mineral oil, 37.3%; emulsified, 27%; semisynthetic, 15.4%; synthetic; 30%).

Table III shows that workers exposed to only mineral metal-working fluids had the lowest, and workers exposed to any synthetic metal-working fluid the highest, prevalence of chronic bronchitis (productive cough most days of the week for at least 3 months of the year for at least 2 years), visits to a doctor for shortness of breath, and visits to a doctor for sinus problems, as compared to the other types of machining fluids. No difference was found for visits to the doctor for a skin rash.

Table IV shows that daily or weekly symptoms at work of nasal stuffiness, runny nose, and sore throat were less frequent among mineral oil exposed workers. No difference was seen for eye symptoms or cough.

The average percentage of symptomatic individuals by metal-working fluid type is shown in Table V. The mineral oil only exposed workers had fewer individuals with new onset asthma or symptomatic individuals. Most of the index cases worked in facilities using a synthetic metal-working fluids. Because of differences in the percentages of cigarette smokers in the four metal-working fluid groups, the percentage of new onset asthma or symptomatic individuals were reanalyzed by cigarette smoking category. The results remain the same when controlling for cigarette smoking status (Table VI).

TABLE II. Characteristics of 755 Workers Completing Questionnaires: Michigan 1988–1994^a

Fluid type	Facilities (n)	Individuals interviewed (n)	Average years worked (%)	Average age (n)	Cigarette smoking status ^b						History before beginning work with current employer						Family history of allergies	
					Current		Ex		Non		Allergies		Hay fever		Eczema			
					n	%	n	%	n	%	n	%	n	%	n	%	n	%
Mineral only	10	183	14.5	42	63	38	41	24.7	62	37.3	27	15.5	17	10.2	9	5.6	36	21.6
Emulsified (no semi- or synthetic)	7	115	15.4	43	36	32.4	45	40.5	30	27.0	9	8.3	8	7.4	5	4.6	28	25.9
Semisynthetic (no synthetic)	2	14	20.9	45	8	61.5	3	23.1	2	15.4	0	—	0	—	1	7.7	5	38.5
Synthetic	12	420	14.1	40	158	38.8	127	31.2	122	30.0	56	17.2	40	12.9	19	6.3	74	22.0

^aThe denominator varies for each question, as not all workers completed all questions.
^bP < 0.05.

TABLE III. Number and Percentage of Individuals With Medical Conditions by Type of Metal-Working Fluid: Michigan 1988–1994^a

Fluid type	Chronic bronchitis ^b		Saw doctor for shortness of breath ^b		Saw doctor for sinus problem ^b		Saw doctor for skin rash	
	n	%	n	%	n	%	n	%
Mineral only	19	10.4	27	15.1	52	29.4	41	23.3
Emulsified (no semi- or synthetic)	18	15.7	20	18.5	41	37.3	28	25.2
Semisynthetic (no synthetic)	1	7.1	3	23.1	6	42.9	4	30.8
Synthetic	83	19.8	111	28.5	191	48.1	77	20.3

^aThe denominator varies for each question, as not all workers completed all questions.
^bP < 0.05.

TABLE IV. Number and Percentage of Individuals Bothered at Work by Daily or Weekly Symptoms: Michigan 1988–1994^a

Fluid type	Nasal stuffiness ^b		Runny nose ^b		Burning of eyes		Redness of eyes		Sore throat ^b		Cough	
	n	%	n	%	n	%	n	%	n	%	n	%
Mineral only	46	25.1	18	9.8	21	11.5	17	9.3	10	5.5	27	14.8
Emulsified (no semi- or synthetic)	44	38.3	21	18.3	26	22.6	22	19.1	10	8.7	21	18.3
Semisynthetic (no synthetic)	6	42.9	3	21.4	4	28.6	3	21.4	0	—	4	28.6
Synthetic	163	38.8	92	21.9	93	22.1	71	16.9	57	13.6	90	21.4

^aThe denominator varies for each question, as not all workers completed all questions.
^bP < 0.05.

Ten other workers were identified by the companies on the OSHA Injury and Illness log as having work-related asthma: four workers were from two facilities using mineral oil only; and six were from four facilities using synthetic oils.

Facilities characterized as using mineral oil metal working-fluids by any of the three different methodologies

had the lowest percentage of new-onset asthma or symptomatic individuals (Table III).

DISCUSSION

Metal-working fluids were the second most common cause of work-related asthma, after isocyanates, reported in

TABLE V. Number and Percentage of Individuals With New-Onset Asthma or Symptoms Suggestive of Work-Related Asthma by Type of Metal-Working Fluid: Michigan 1988–1994

Fluid type	No. of work-related asthma reports received	No. of facilities	Range and average % of new-onset asthma or symptomatic individuals, by facility		No. of individuals interviewed (n)	No. and % of new-onset asthma or symptomatic individuals	
			% range	Avg. %		n	%
Mineral oil only	17	12 ^a	0.0–23.8	8.7	183	18	9.8
Emulsified (no semi- or synthetic)	13	9 ^b	0.0–44.4	24.5	115	27	23.5
Semisynthetic (no synthetic)	2	2	0.0–50.0	25.0	14	4	28.6
Synthetic	44	13 ^c	0.0–49.5	20.3	420	105	25.0
Total:	76	36 ^d	0.0–50.0	17.8	732	154	21.0

^aInterviews were conducted at 10 facilities.^bInterviews were conducted at 7 facilities.^cInterviews were conducted at 12 facilities.^dInterviews were conducted at 31 facilities, where we were able to characterize the type of metal-working fluid.**TABLE VI.** Number and Percentage of Individuals With New-Onset Asthma or Symptoms Suggestive of Work-Related Asthma by Metal-Working Fluid Type and Cigarette Smoking Status: Michigan 1988–1994

Fluid type	Total no.	Current ^a		Total no.	Ex-smoker		Total no.	Non-smoker ^a	
		New-onset asthma or symptomatic individual n	%		New-onset asthma or symptomatic individual n	%		New-onset asthma or symptomatic individual n	%
Mineral only	63	6	9.5	41	5	12.2	61	5	8.1
Emulsified (no semi- or synthetic)	36	13	36.1	45	9	20.0	30	5	16.7
Semisynthetic (no synthetic)	8	3	37.5	3	0	—	2	1	50.0
Synthetic	158	37	23.4	127	35	27.6	119	32	26.2
Total:	265	59	22.3	216	49	22.7	212	43	20.3

^a $P < 0.05$.**TABLE VII.** Percentage of Individuals with New-Onset Asthma or Symptoms Suggestive of Work-Related Asthma by Type of Metal-Working Fluid and Three Different Methods of Determining How to Assign a Fluid Type to a Facility: Michigan 1988–1994^a

Fluid type	Method 1		Method 2		Method 3	
	Companies (n)	New-onset asthma or symptomatic individuals (%)	Companies (n)	New-onset asthma or symptomatic individuals (%)	Companies (n)	New-onset asthma or symptomatic individuals (%)
Mineral only	10	9.8	15	11.7	10	9.8
Emulsified (no semi- or synthetic)	7	23.5	12	24.7	6	22.6
Synthetic and semisynthetic (no synthetic)	14	25.1	4	30.4	3	34.4

^aSee Methods section for description of methods 1–3.

the state of Michigan from 1988-1994. A majority of the reports were on workers from facilities using synthetic metal-working fluids. Follow-up investigations at the workplaces where the reported cases became ill show high percentages of symptomatic individuals even though exposures in the workplaces are within the legal air standards for oil mist. Work with emulsified, semisynthetic or synthetic metal-working fluids was associated with a higher percentage of symptomatic individuals than work with mineral oil metal-working fluids (Tables III-VI). These results differ from those reported in a recent study among French automobile workers where more respiratory symptoms were found among workers exposed to straight mineral oil [Ameille et al., 1995]. The difference in our results cannot be explained by how we assigned a facility to a fluid type, since our results were unchanged when we followed the method used in the French study (Table VII).

There are limited reports in the medical literature of occupational asthma after exposure to metal-working fluids. One patient who developed asthma after exposure to an emulsified oil reacted on specific bronchoprovocation to unused emulsified oil and a specific pine oil additive of the oil [Hendy et al., 1985]. In a second report, 13 of 25 workers exposed to metal-working fluids who were referred to an occupational respiratory clinic were found on peak flow monitoring to have definite work-related asthma [Robertson et al., 1985]. Nine of the 13 were exposed to emulsified alone, two to emulsified and mineral, one to mineral, and one to various types. Six of the 13 had specific bronchoprovocation [Robertson et al., 1988], including the one patient reported in the first case report [Hendy et al., 1985]. Among the other five, one worker only reacted to the used metal-working fluid while the others reacted to unused fluid [Hendy et al., 1985].

In one study, higher percentages of workers with acute decreases in FEV₁ post-shift results compared to pre-shift results were reported among machinists exposed to either mineral, emulsified or synthetic metal working fluids as compared to a control group of non-exposed assemblers. There were approximately 32 workers exposed to each type of fluid. Although a similar response was found for each type of metal-working fluid, the response was greatest among those workers exposed to synthetic than either mineral or emulsified fluids [Kennedy et al., 1989].

It is possible that additives in the metal-working fluids, such as the amines, are the etiologic agents for the reported cases of work-related asthma and/or respiratory symptoms. Amines are commonly used as corrosion inhibitors in both emulsified and synthetic metal-working fluids. There are multiple case reports of occupational asthma after exposure to various amine compounds. Typically in these reports, the

diagnosis has been confirmed by specific bronchoprovocation [Savonius et al., 1994; Ng et al., 1995].

Possible limitations of our data include: physicians who report work-related asthma rarely confirm their diagnosis with pulmonary measurements performed in relationship to exposures at work although we administered an extensive questionnaire regarding the timing and diagnosis of asthma in relation to work at the facility in question; confirmation of work-related asthma is not performed on fellow workers who are identified by questionnaires administered at the workplace; only 82% of identified companies were inspected, and in only 86% of inspected companies were interviews of fellow workers conducted (therefore in only 70% of identified companies were fellow worker interviews conducted); and other individuals with respiratory symptoms or workplace asthma who may have left the workplace or did not wish to complete a questionnaire were not included during the follow-up interviews. These limitations on participation apply equally to workers exposed to all four types of metal-working fluid and would not be expected to affect the differences in respiratory symptoms found between the different categories.

Another limitation is that the workplace level of exposure and type of metal-working fluid may have changed between time of onset of the reported cases of work-related asthma and time of inspection. A final limitation of our data is that some other characteristic of the workplace associated with the type of metal-working fluid (i.e., type of machining, age of facility) may explain the differences found among workers with different types of metal working fluids.

Additional work is needed to determine what particular chemical components and/or microbial contaminants are the cause of the respiratory symptoms and work-related asthma associated with exposure to metal-working fluids.

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APPENDIX: RESPIRATORY QUESTIONS FROM ADMINISTERED QUESTIONNAIRE

1. Have you ever seen a doctor regarding:
 Shortness of breath? No 1 Yes 2
 If yes, what year? _____
year

2. Do you bring up mucus most days of the week (4 out of 7 days) for a period of 3 months straight? No 1 Yes 2
 If yes, year began? _____
year

3. Have you ever had asthma? No 1 Yes 2
 If yes, do you still have it? No 1 Yes 2
 Was your asthma confirmed by a doctor? No 1 Yes 2
 At what age did your asthma start? _____
age

 If you no longer have asthma, at what age did it stop? _____
age

4. Do you currently require medicine or treatment for asthma? No 1 Yes 2
 If Yes, what type of medicine? _____

5. Circle how often any of the following symptoms have bothered you at your current job. Note area of plant that you suspect may cause or make the symptoms worse.
 How often are you bothered? (circle answer)

	Never	Seldom	Monthly	Weekly	Daily	Mo/yr symptom started	Area of plant
Wheezing	1	2	3	4	5	_____/_____ _____	_____ _____
Chest tightness	1	2	3	4	5	_____/_____ _____	_____ _____
Shortness of breath	1	2	3	4	5	_____/_____ _____	_____ _____