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Metal Working Fluids (MWF) Aerosol in an Occupational Setting: Association with the Respiratory Symptoms and Lung Functions among Machinists.

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ABSTRACT

Objective: Metal workingfluids (MWFs) are used to lubricate, cool working pieces and to minimize corrosion and wash away metal chips, in a wide range of machining processes. Machinist are exposed to MWFs in the form of aerosol and particulate which are smaller than 10µm which can reach the alveoli, the upper and lower respiratory tract. **Objective:** The objective was to determine the association between MWFs exposures with respiratory health and lung functions among machinists. **Methodology:** A cross-sectional study was carried out among workers exposed to MWFs. Simple random sampling was used to select 154 respondents from a name list given. A set of translated Questionnaire ATS-DLD, was used to obtain background information and respiratory symptoms. A Portable Spirometer was used to measure the lung function test among workers (Model MM-SPOO4). The individual environmental air exposure was determined using personal air sampling pump (NIOSH Method 552). **Results:** The mean for age and years of employment were 36 years and 3 years respectively. There was a significant difference between MWFs concentrations in the environment with the work sections ($p<0.001$). The environmental and individual MWFs was significantly correlated ($p<0.05$). **Conclusion:** Findings showed that the MWFs exposure was lower than the NIOSH recommended exposure limit. There was no significant association between personal exposure with respiratory symptoms and lung function, however, smoking significantly increased the frequency of respiratory symptoms and impaired the lung functions

Keywords: *Metalworking fluids, lung function, respiratory symptom, occupational exposure*

1. Introduction

Metalworking fluids (MWFs) refers to coolants and lubricants used during machining processes such as turning, milling, grinding, drilling, sawing and threading. These fluids are used to treat, protect and prolong the life metal surfaces such as tools or work pieces, to remove debris such as metal chips and to prolong the life of machine tools (NIOSH, 1998; Oudyk et al., 2003).

MWFs can be applied to the cutting part of the tool and the work. A continuous stream of MWFs delivered by a low-pressure pump can be directed through a nozzle to the cutting edge of the machine tool or through the tool and over the work to carry away the metal chips or swarf. Substantial concentrations of airborne MWFs mist can be generated during the course of metalworking operations (NIOSH, 1998; Oudyk et al., 2003).

There are many different components and additives in MWFs. There are four types of MWF made up of straight oil, soluble oil, semi-synthetic fluids and synthetic fluids. Straight oil also called "cutting" or "neat" oils. It is made up of mineral (petroleum), animal, marine, vegetable or synthetic oils. Soluble oil contains 30 to 85 percent severely refined petroleum oils, as well as emulsifiers to disperse the oil in water. Semi-synthetic fluids contain 5 to 30 percent severely refined petroleum oils, 30 to 50 percent water and a number of additives. Synthetic fluids do not contain petroleum oils. Instead, they use detergent-like components and other additives to help "wet" the work piece (Canadian Centre for Occupational, 2005)

Exposure to all types of MWFs appears to be associated with respiratory symptoms, reduced pulmonary function, and bronchial hypersensitiveness. (NIOSH, 1998) According to National Institute for Occupational Safety and Health (NIOSH, 1998), exposure to MWFs has also been associated with excess risk for non-malignant respiratory impairment. MWFs particles are smaller than 5µm that can reach the upper and lower respiratory tract and alveoli. These include airway hyper-responsiveness such as mucus production, runny of stuffed nose, sinusitis, burning or redness of eyes, wheezing, dyspnea, epistaxis, sore throat, chronic cough, bronchitis, pneumonia, occupational asthma, emphysema and lipoid pneumonitis/extrinsic allergic alveolitis (Simpson, 2000).

This study provides detailed information on the occupational exposures to MWFs among workers not previously studied. To our knowledge, no study has been carried out in Malaysia in order to determine the respiratory health status of workers at metalworking processes. However, several studies from other countries have already reported that the prevalence of respiratory symptoms were significantly associated with exposures to MWF at lower levels of 0.2 - 0.5 mg/m^3.

2. Materials and Method

2.1. Subject Selection

This is a cross-sectional study conducted at a manufacturing industry in Negeri Sembilan. The plant has 12 sections in which all used MWFs in their production. All male workers who handled the machine and MWFs were recruited in this study. During the study, participants completed the questionnaires and underwent lung function tests (spirometer) before and after shift on the first work day of the week (Monday) and on the fifth work day of the same week (Friday). Monday was chosen because any exposure-related effects were expected to be more pronounced after two days away from work. Friday was chosen so that changes occurring over a work week could be detected.

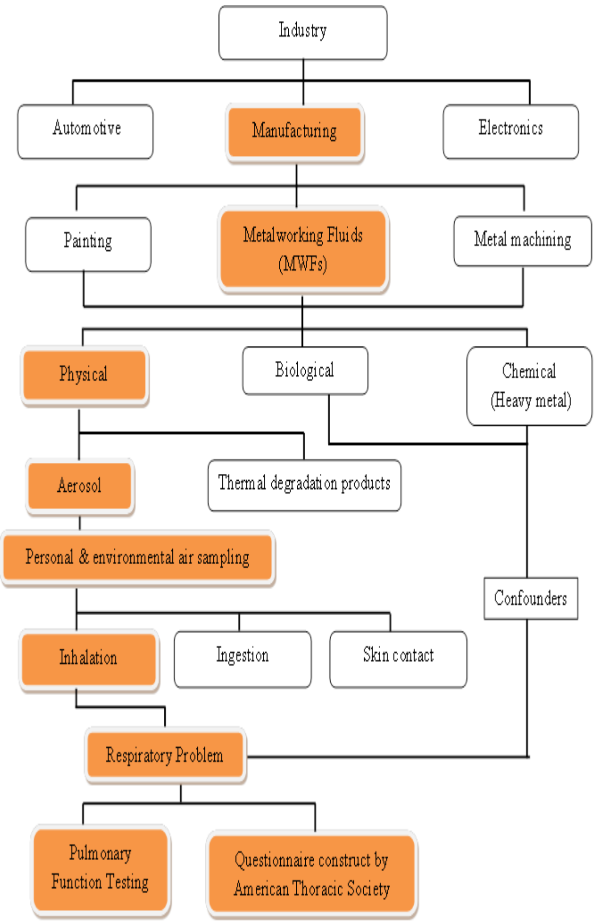

Figure 1. Conceptual Framework

2.2. Questionnaires

A questionnaire was administered to each participant prior to completion of each spirometry test. The questionnaire contained questions on demographic information, health history, workplace characteristics and exposure, and respiratory symptoms, modified from the American Thoracic Society Adult Respiratory Questionnaire (American Thoracic Society, 1978). There were also questions pertaining to current and past employment, and possible exposures to MWF in the previous jobs.

2.3. Personal Air Sampling

Personal exposures were collected and analyzed using NIOSH Method 5524 for respirable particulate. The sampler consisted of a polytetrafluoroethylene (PTFE) filter (37mm diameter; 2 µm pore size) in three-piece closed-face cassettes. The sampling flow rate was 1.6

L/min. Samples were analyzed gravimetrically for the ‘‘total’’ mass. The PTFE filters were weighed using a semi micro electro-balance with a sensitivity of 10^{-5} g and the weight were recorded. The filters were assembled in the filter cassettes and close firmly to avoid leakage. A plug was fit on to each opening of the filter cassette. A cyclone was fit into the cassette with the filter before sampling.

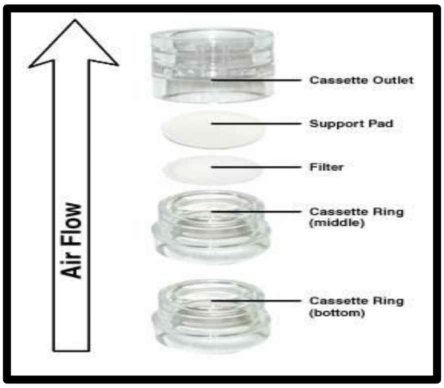

Figure 2. Setting up the filter cassette

Each personal sampling pump was calibrated at site during sampling. All air samples represented at least 6 hours of sampling. The recommended sampling was 8 hours but we had to exclude the break time for 2 hours. The devices were attached to the shirt collar. The running pump was monitored every two hours to check the flow rate.

After 6 hours, the pumps were turned off and the ending time was recorded. The pump was recalibrated after each day of sampling (before charged). The post-sampling are weighed and recorded.

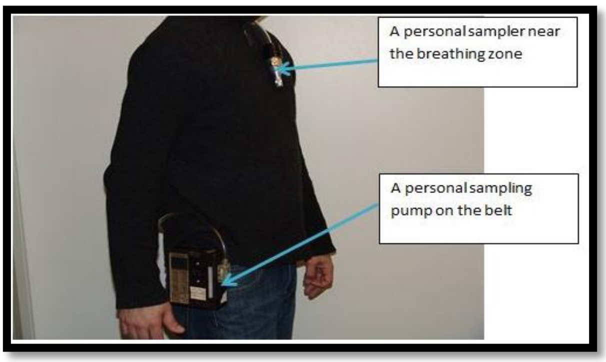

Figure 3. Example of personal air sampling set up on worker

2.4. Environment Air Sampling

Environmental air sampling was conducted to determine the MWFs level in each work sections. Samples were collected and analyzed using NIOSH Method 5524 for respirable particulate.

Figure 4. Environmental air sampling at work section

2.5. Lung Function Testing

Spirometry Model MM- SPOO4 was used with reference to the current ATS recommendations (American Thoracic Society, (1987). The respondents first breathed into the mouthpiece attached to a recording device (spirometer) for 3 times. The information collected by the spirometer was printed out on a spirogram.

Figure 5. Spirometer

3. Results

3.1. Respondents background information.

A total of 154 volunteered to participate and written consent were collected before being interviewed using the validated questionnaires. Majority in term of ethnicity, were Malay 112 (72.7%) followed by Indian 36 (23.4%) and Chinese 6 (3.9%).

Most of the respondents were educated with tertiary education (70.8%) and have income of approximately RM1000 to RM 2000 (46.1%). In addition, 44.2% were smokers. The mean age was 36.06 SD (10.36) and mean for height was 167.90 SD (6.24). The information on socio-demographic background are shown in Table 1.

Table 1. Distribution of socio-demographic background (n=154)

Variables	Frequency (n)	Percentage (%)
Ethnicity		
Malay	112	72.7
Indian	36	23.4
Chinese	6	3.9
Education Level		
Primary	5	3.2
Secondary	40	26
Tertiary	109	70.8
Income (RM)		
<1000	4	2.6
1000-2000	71	46.1
2000-3000	64	41.6
>3000	15	9.7
Smoking		
Yes	68	44.2
No	86	55.8

In this study, the minimum work employment an the current industry was six month. Whereby, majority of the respondent's employment was 6 month to 5 years (45.5%). Majority worked for 8 hours shift and followed by 12 hours. Table 2 shows the occupational background of the respondents.The results showed that found that 79.2% of respondents have work experience before being involved in the current employment. However, they were never exposed to the dust or chemicals in the previous workplace.

3.2 Exposure to MWF

The findings showed that the exposures to MWFs did not exceed the recommended exposure limit (REL) of 0.5 mg/m^3 by NIOSH, The maximum level was 0.0008 mg/m^3. From Table 3, there were significant differences between the MWF levels in the environment and the work sections ($p<0.005$).

Table 2. Distribution of occupational background (n = 154)

Variables	Frequency (n)	%	Mean(S.D)
Employment years			
6 - 5years	70	45.5	3.17(1.198)
5 - 10 years	17	11.0	
10 - 20 Years	38	24.7	
>20 years	29	18.8	
Past working experience			
0 month	32	20.8	
<6 month	28	18.2	2.77(1.76)2
6 month - 5 years	79	51.3	
5 - 10 years	11	7.1	
10 - 20 years	4	2.6	
Work duration			
8 hours	88	57.1	1.43(0.496)
12 hours	66	42.9	

Table 3. Comparison between MWF levels in the work sections environment

Work section	Mean ng/m^3	df	H	p
SABB				
SABB 1	70.00			
SABB 6	28.00			
SABB 7	28.00			
DGBB				
DGBB 2	54.00			
DGBB 3	96.50			
DGBB 4	129.00	11	138.00	<0.0001***
SRB				
SRB 1	28.00			
SRB 2	96.50			
SRB 3	28.00			
SRB Soft Ring	28.00			
SRB Hard Ring	129.00			
LSR	3.00			

H=Kruskal-Wallis test, *** *Significant at* $p<0.001$

The MWF levels in this workplace were also below the limit, based on the NIOSH Method 5524, in which the exposure limit of MWFs for thoracic particulate was 0.4 mg/m^3. After the calculation, the maximum for the thoracic particulate was 0.00012 mg/m^3 SD (0.00022). The MWF level in the environment and individual exposure correlation was statistically significant ($p = 0.04$).

3.3 Lung Function as Biomarker

Lung function tests have been conducted on all of the respondents. The median of the lung function for FVC and FEV_1 (1/min) were 3.2400 (range 2.18-4.29) and 2.9350 (range 2.18-4.43) respectively. Respondents' lung functions information are shown in Table 4. From the result, it shows that the majority had normal lung function of FVC% predicted, FEV_1% predicted and FEV_1/ FVC ratio.

Table 4. Distribution of lung function abnormality among respondents

Variables	Lung Function Abnormality	Frequency (n)	Percentage (%)
FVC% predicted	Abnormal	27	17.5
	Normal	127	82.5
FEV_1% predicted	Abnormal	15	9.7
	Normal	139	90.3
FEV_1/ FVC ratio	Abnormal	-	-
	Normal	154	100.0

(n=154)

A Spearman rho correlation test has been performed to determine the association between the individual MWF levels with the lung function among respondents. The variables tested were FVC, FEV_1, FVC% predicted, FEV_1% predicted, and FEV_1/FVC% with the individual MWF exposure levels. From the results, there was no significant association between individual MWF levels with the lung function of the respondents.

3.4 Respiratory Symptoms

Based on the questionnaire, the workers were more likely to have cough and phlegm (27.9%) followed by wheezing (22.7%) and chest tightness (7.1%). Table 5 shows the distribution of reported respiratory symptoms among respondents. There was no significant association between individual MWF levels with respiratory symptoms among respondents ($p>0.005$).

3.5 Occupational Background

In this study, the respondents were employment in the current industry for a minimum of six months. Therefore, majority respondents were employed for at least 6 month to 5 years (45.5%). Table 6 shows the occupational background of the respondents.

Table 5: Reported respiratory symptoms among respondents

Respiratory symptoms		Frequency (n)	Percentage (%)
Cough	Yes	43	27.9
	No	111	72.1
Phlegm	Yes	43	27.9
	No	111	72.1
Wheezing	Yes	35	22.7
	No	119	77.3
Chest tightness	Yes	11	7.1
	No	143	92.9

(n=154)

4.0 DISCUSSION

In this plant, there are four main types of product namely self-aligning ball bearing (SABB), deep groove ball bearing (DGBB), spherical roller bearing (SRB) and large size roller (LSR). All the products were processed in different sections of the factory. From the breathing zone were monitoring, the findings showed that the environmental exposure to MWFs did not exceed the REL with the level range of 0.0000 – 0.0008 mg/m^3.

Table 6. Distribution of occupational background

Variables	Frequency (n)	Percentage (%)	Mean (S.D)
Working experience			
6 m - 5years	70	45.5	3.17
5 - 10 years	17	11.0	SD(1.198)
10 - 20 Years	38	24.7	
>20 years	29	18.8	
Past working experience			
0 month	32	20.8	2.77
<6 month	28	18.2	SD(1.762)
6 month - 5 years	79	51.3	
5 - 10 years	11	7.1	
10 - 20 years	4	2.6	
Work duration			1.43
8 hours	88	57.1	SD(0.496)
12 hours	66	42.9	

(n=154)

4.1 Risk factors for respiratory symptoms and lung functions of exposed workers

Results for respiratory symptoms for phlegm showed that distance from home to workplace of 5-10 km (OR 2.30, 95%, 1.45 - 11.73), the shift work hours (OR 1.17, 95% CI 1.49 - 2.79) and smoking (OR 3.59, 95% CI 1.50 - 8.64) were risk factors to getting phlegm in the respiratory system. While employment years were risk factors for cough symptoms.

Multiple Linear Regression (MLR) test were used to determine which selected variables significantly influenced the FVC% predicted after adjusting for all the confounders. The result showed that all the variables were not significantly related to all the lung functions parameters except for height which influenced FVC% (p=0.018).

Table 8. The risk factors for respiratory symptoms of workers exposed to MWF aerosols.

Variable	Cough	Phlegm	Chest tightness	Wheezing
Age	0.92 (0.84 - 0.99)	1.05 (0.96 - 1.13)	1.10 (0.98 - 1.22)	0.99 (0.92 - 1.07)
Worker's income (RM)				
<1000	-	-	-	0.14 (0.00 - 12.69)
1000-2000	2.17 (0.28 - 17.08)	1.17 (0.17 - 8.17)	-	0.54 (0.08 - 3.84)
2000-3000	0.93 (0.19 - 4.57)	0.26 (0.06 - 1.27)	-	0.78 (0.18 - 3.30)
Distance from home to workplace (km)				
<1	0.31 (0.06 - 1.60)	0.91 (0.17 - 4.78)	-	0.32 (0.07 - 1.51)
1-5	0.11 (0.02 - 0.79)	1.25 (0.20 - 7.71)	-	0.16 (0.03 - 0.96)
5-10	0.61 (0.13 - 2.93)	**2.30 (1.45 - 11.73)**	-	0.35 (0.08 - 1.56)
Work shift (hours)	0.71 (0.30 - 1.68)	**1.17 (1.49 - 2.79)**	2.49 (0.53 – 11.69)	1.30 (0.53 - 3.16)
Employment years				
<5	0.34 (0.06 - 1.97)	0.74 (0.20 - 2.77)	-	2.77 (0.68 - 11.30)
5-10	5.46 (0.98 - 30.57)	0.62 (0.13 - 3.04)	0.43 (0.05 - 3.54)	1.99 (0.41 - 9.60)
10-20	**14.63 (1.67 - 128.34)***	0.14 (0.02 - 1.19)	0.07 (0.00 - 1.51)	1.26 (0.18 - 8.93)
Smoking	2.10 (0.89 - 4.97)	**3.59 (1.50 - 8.64)***	2.17 (0.58 - 8.18)	0.87 (0.34 - 2.23)
Exposure of MWFs	0.73 (0.48 - 1.09)	0.89 (0.61 - 1.31)	0.90 (0.47 - 1.73)	1.19 (0.82 - 1.72)

Multiple Logistic Regression, * *p is significant when < 0.05*

In this study, no significant association between MWFs exposure lung functions among workers for FVC, FEV_1, FVC% predicted, FEV_1% predicted, and FEV_1/FVC ratio (p>0.005). This is because of the exposure itself was very low at 0.0008 mg/m^3 There was also no significant association between MWF levels with respiratory symptoms. The findings by Ameille (1995), in the study of chronic respiratory symptoms among 308 workers in a French automobile manufacturing plant, showed that those exposed to straight oil MWFs had a significant higher prevalence of chronic cough, chronic phlegm and dyspnea. These observations were made from the exposure levels of 2.6 mg/m3, which was half of the recommended values of 5 mg/m3. In this study, the low MWF exposure would not impair the respiratory functions which are considered as were chronic effects. Moreover, this study was just a cross sectional study carried over a short period of time. As for the respiratory symptoms which were considered as the acute effects and can be seen relatively immediately, the risk factors found were the confounders such as the employment years, duration of shift work, distance travelled from homes and smoking.

The association between environmental MWF level of and individual exposure showed significant correlation between the MWF levels in the environment and individual exposure (p = 0.040). These findings were similar to the study by Piacitelli et al. (2010) which in general, showed the trends of thoracic exposures to operation and fluid types similar to that seen for total particulate exposures. The exposure levels correlated with the environmental MWF levels.

The respondents in this study have worked directly with the machines which were fully enclosed or guarded, in order to avoid the fluid splashing directly onto those in the area. The respondents were only exposed during the maintenance of the machines. During maintenance, they would open up the guarding and thus, exposed directly to the MWFs. The machines emitted aerosols and particles in the air from which the workers would inhale the particles into their respiratory system.

5.0 CONCLUSION

Findings showed the low MWF levels were not significantly associated with lung function impairment and reported respiratory symptoms. However, the risk factors for the phlegm production were mainly the distance travelled from home to workplace, duration of shift work, and smoking. In particular, the MWF levels in the workplace did not exceed the recommended exposure limit (REL) by NIOSH (0.4 mg/m^3). There were significant differences in the MWF levels between the work sections. Results also showed significant correlation between the environmental MWF and the individual exposures. Therefore, it can be concluded that MWF in the workplace were at permissible level and the outdoor air pollution as well as smoking contributed to the respiratory symptom especially the phlegm production. The respondents who smokes are advised to stop smoking

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