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ASSOCIATION BETWEEN USE OF METALWORKING FLUIDS WITH RISK OF RESPIRATORY HEALTH AND ALLERGY SYMPTOMS IN A MACHINING INDUSTRY

Liaw Soo Hui[1], *Zailina Hashim[1], Lye Munn Sann[2] and Huda Zainuddin[2]

[1]Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, University Putra Malaysia.

[2]Department of Community Health, Faculty of Medicine and Health Sciences, University Putra Malaysia.

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***Corresponding Author**
Zailina Hashim
Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, University Putra Malaysia.

ABSTRACT

This study was aimed to determine the association between use of metalworking fluids (MWFs) with respiratory health and allergy symptoms among machining industry workers. Logistic regression analysis was used to examine the association between the uses of MWFs and each respiratory and allergy symptoms, high total IgE and cross-shift lung function decrements. Odd ratios (ORs) were adjusted for age, gender, smoking status and years of employment. The findings showed that the uses of MWFs were significantly associated with a higher risk of skin itchiness (OR 5.77, 95% CI 1.51-22.13) and high total IgE (OR 2.03, 95% CI 1.09-3.76) compared with the unexposed group who do not used any chemical at work. Analysis based on type of operation showed that the machining workers reported a significantly higher risk of cough symptoms (OR 2.54, 95% CI 1.18-5.47) and Grade 1 Dyspnoea (OR 2.28, 95% CI 1.00-5.16) compared with the administrative workers.

Keywords: Allergy, lung function, machining, metalworking fluids, respiratory, total IgE.

INTRODUCTION

Metalworking fluids (MWFs) are chemicals that are widely used in various fabricated metal product industries. The fabrication processes of metal products, such as cutting, turning,

machining, grinding, milling, drilling and stamping, require the lubrication and dispersion of generated heat. The major chemicals used include stamping oil (also known as drawing compounds), straight oils (100% petroleum oils) and soluble oils or water-based MWFs (which refer to emulsified oils that comprise of mineral oils emulsion and water; semisynthetic fluids that contain smaller amounts of mineral oils than the emulsified oils; and synthetic oils that do not contain mineral oils).[1]

Exposure to MWFs is associated with various types of respiratory symptom and disease, such as hypersensitivity pneumonitis,[2, 3] asthma,[3-5] impaired lung function,[6, 7] sinusitis,[8] allergic alveolitis[9] and dermatitis.[10] Greaves et al.[4] also found that operators who had been exposed to MWFs had a higher prevalence of cough, phlegm, wheezing and breathlessness than assembly workers who had not been exposed to MWFs. A review by Park[11] found a substantial decline in the exposure levels over time; however, the effects of other aspects, such as the type of industry, operation and MWFs, were inconsistent and could not be clearly ascertained. This suggested the need for further investigation into the effects of industries, operations and the type of MWFs.

The specific objective of this study was to assess association between the use of MWFs with the risk in reported respiratory and allergy symptoms, high total immunoglobulin E (total IgE, as exposure marker for potential respiratory allergy and allergic dermatitis) and the cross-shift decrement in lung function. In this study, we also assessed the effects of other types of chemical exposure, types of MWFs and operations. We investigated into such effects onto cross-shift decrement in lung function, high total IgE, reported allergy and respiratory symptoms among those workers who were exposed to MWFs as well as those who were unexposed. In this study, we hypothesized that there was significant association between selected factors (MWFs exposure, types of MWFs and types of operations) with reported respiratory and allergy symptoms, high total IgE and cross-shift decrement in lung function among the MWFs exposed and unexposed workers.

MATERIALS AND METHODS

Participants and study plant

The participants who fulfilled the inclusion criteria were randomly sampled to participate in this study. The inclusion criteria for selection of sampling unit were workers with the aged range of 20 to 60 years old, had worked for at least two years and performed work tasks for at least six hours daily, not pregnant, physically and mentally fit.

The participants were divided into two groups based on the exposure to MWFs: exposed and unexposed. The MWFs exposed group worked directly with MWFs and exposed to MWFs for at least one hour per week. The MWFs exposed group included machine operators who handled machining, grinding, drilling, milling, turning and stamping processes. The MWFs unexposed group included were administrative workers who routinely worked in an office environment away from the machining and stamping production section and assembly workers who did not work with MWFs for more than one hour per week. Ethical clearance was obtained from the Medical Research Ethics Committee, Faculty of Medicine and Health Sciences of University Putra Malaysia (UPM/FPSK/PADS/T7-MJKEtikaPer/F01). Written consents were obtained from the respondents who volunteered to participate.

This plant manufactures various metal parts and components for the automotive industry, household appliances, gas stoves, and the electrical and electronic industry. The plant has three main operations: precision machining, sheet metal stamping, and gas stove assembly. Table 1 summarizes the characteristics of processes, chemical exposure, chemical content, method of lubrication and ventilation according to the types of operations.

Table 1: Characteristics of processes, chemical exposure, chemical content, method of lubrication and ventilation according to the types of operations.

Operation Type	Processes	Chemical Exposure	Chemical Content	Method of lubrication	Ventilation
Machining	Turning, grinding, milling, threading, tapping and drilling	MWFs - Straight oil	100% natural mineral oil and severely solvent-refined petroleum oils	Flooding, jet or misting	Natural air ventilation
		MWFs - Soluble oil	Water-based MWFs and are categorized into emulsified, semisynthetic and synthetic depends on the contains of natural and man-made mineral oils		
Stamping	Single stroke stamping press (manual process) and progressive transfer forging (automated process).	MWFs - Stamping oil	Drawing compounds (i.e. die lubricants) that could be 100% aliphatic hydrocarbon or mixture of 60-70% aliphatic hydrocarbons, 10-20% mineral oil and 10-20% chlorinated paraffin	Rolling, spraying, dripping, manual wiping	Natural air ventilation
Gas Stove Assembly	Assembly & gas leak test	Cooking gases and grease	Liquefied petroleum gas i.e. methane, butane and propane gas and silicone compound	Turning on gas stove for gas leak test, filling up grease with grease gun	Partially air-conditioned
Administrative	Not applicable	None	Not applicable	Not applicable	Fully air-conditioned

Data collection of MWFs exposure, respiratory symptoms, reported allergy, high total IgE and lung function capacity

The respondents were interviewed using the modified American Thoracic Society (ATS) Adult Respiratory Questionnaire (ATS-DLD-78),[12] and then scheduled for intravenous blood collection and lung function tests. Classification of respiratory and allergy symptoms were categorized into the presence and absence of symptoms. Blood samples were collected from the respondents for total IgE analysis, which were measured using the capsulated hydrophilic carrier (ImmunoCAP Total IgE) by means of the ImmunoCAP assay (PHADIA® 100). Total IgE was measured to assess possible allergy in which exposure to MWF would cause high total IgE, respiratory allergy and allergic dermatitis. The measurement was carried out using the fluorescence enzyme immunoassay (FEIA) technique. The measuring range for undiluted serum is 2kU/L to 5,000 kU/L, and the normal range for serum total IgE generally used for adults is less than 100 kU/L. High serum total IgE levels are defined as equal or more than 100 kU/L.

Lung function tests were conducted at the beginning (pre-shift) and at the end of work (post-shift) using the Spirolab II model spirometer to assess the cross-shift lung function values and to explore the lung response to chemical exposure. At least three technically satisfactory measurements (within 5%) were obtained from each respondent in both measurements. The best values of forced vital capacity (FVC) and Forced Expiratory Volume in One Second (FEV_1) were used in the analysis. The FEV_1cross-shift decrement is as follows: Percentage of FEV_1 decrement = 100 x (Post-shift value – Pre-shift value)/Pre-shift value. A negative value represents a reduction in FEV_1 over the work shift. [6] The FEV_1 cross-shift decrement was assessed based on the approach of Kriebel et al.[7] and Kennedy et al.[13] that using 5% FEV_1 decrement as the cut-off point to dichotomise the cross-shift lung function values.

Statistical analysis

The data were analysed using SPSS for Windows Version 21.0. The association between exposure to MWFs with each respiratory and allergy symptoms, respiratory and dermatitis allergy (high total IgE), cross-shift lung function values (5% FEV_1 decrement) were assessed using the logistic regression model. The odds ratio (OR) and 95% confidence intervals (95% CI) were calculated by adjusting for age, gender, years of service and smoking status. Classification of respiratory and allergy symptoms were dichotomized (presence or absence of symptoms). The independent variables were classified based on the objective of the

analysis, such as exposure to MWFs, other chemical exposure, types of MWFs and operations.

RESULTS AND DISCUSSION

A total of 316 respondents in this study were made up of 166 exposed workers (stamping and machining workers) and 150 unexposed workers (assembly and administrative workers). The background characteristics of the study population varied in terms of age, gender, smoking status and duration of employment when stratified by types of operations (Table 2). The age and gender profile of both groups were similar, except for the respondents from the machining workers, who were slightly younger and had a higher proportion of male workers.

Table 2: Characteristics of respondents according to the types of operations.

Variable	Exposed Group		Unexposed Group		Total	P
	Stamping	Machining	Assembly	Administrative		
Number of respondents	46	120	28	122	316	
Age (year)[b]	38.0(11.5)	31.0(11.0)	37.0(17.3)	37.0(17.5)		<0.001***
Gender (% male)[a]	30.4	66.7	28.6	26.2	42.4	<0.001***
Smoking status (%)[a]						
Never smokers	73.9	64.2	78.6	86.1	75.3	
Ex-smokers	2.2	6.7	10.7	8.2	7.0	<0.001***
Current smoker	23.9	29.2	10.7	5.7	17.7	
Pack-years[b,c]	7.1 (8.1)	2.4 (5.1)	1.5 (3.7)	0.7 (6.6)		0.101
Duration of employment (year)[b]	16.7(13.8)	4.6 (6.4)	4.0 (5.8)	9.0 (12.4)		<0.001***

[a]*Chi Square Test: *** significant at p<0.001*

[b]*Kruskal Wallis Test, Median (IQR): *** significant at p<0.001*

[c]*Pack-years of smoking among current and ex-smokers only*

Table 3. Association between exposure to MWFs, others chemical exposure, types of MWFs and operations with respiratory and allergy symptoms, high TIgE and cross-shift lung function changes[A]

	Cough	Phlegm	Wheeze	Asthma	Grade 1 Dyspnoea	Grade 2 Dyspnoea	Skin itchiness	Sinusitis/ throat itchiness	Allergy to dust	High TIgE	Cross-shift FEV_1 changes ≥5%
MWFs Exposure (Reference: MWFs Unexposed)											
MWFs Exposed Group	1.71	0.97	0.53	0.85	1.42	1.47	4.82**	1.33	0.31*	1.46	0.74
	0.86 -3.40	0.56-1.67	0.24 -1.15	0.37 - 1.94	0.69 - 2.94	0.60 - 3.62	1.54 - 15.16	0.27 - 6.64	0.13 - 0.76	0.84 - 2.53	0.42 - 1.32
Other Chemical Exposure (Reference: Unexposed group, no use chemical at work)											
Exposed Group, used MWF at work	1.79	0.83	0.6	0.85	1.57	1.54	5.77*	2.04	0.30*	2.03*	0.54*
	0.83-3.85	0.46 - 1.50	0.26 - 1.42	0.34 - 2.11	0.71 - 3.49	0.56 - 4.22	1.51 - 22.13	0.31 - 13.45	0.12 - 0.78	1.09 - 3.76	0.29 - 0.99
Unexposed group, used other chemical at work	1.16	0.57	1.45	1.02	1.4	1.16	1.76	2.94	0.91	2.83*	0.25**
	0.40 - 3.32	0.24 - 1.35	0.53 - 4.01	0.30 - 3.49	0.49 - 4.04	0.28 - 4.8	0.27 - 11.3	0.39 - 22.44	0.33 - 2.56	1.24 - 6.43	0.09 - 0.70
Types of MWFs handled (Reference: None)											
Stamping oil	1.02	1.05	0.42	0.65	0.97	0.97	5.10*	2.61	0.39	1.54	0.87
	0.39 - 2.63	0.53 2.12	0.14 - 1.25	0.21 - 2.01	0.37 - 2.51	.30 - 3.15	1.33 - 19.61	0.42 - 16.35	0.12 - 1.27	0.77 - 3.07	0.43 - 1.76
Soluble oil	1.19	0.6	0.65	1.07	1.59	1.93	7.48**	1.25	0.41	1.28	0.42*
	0.49 - 2.89	0.28 - 1.27	0.24 - 1.78	0.38 - 3.05	0.61 - 4.13	0.64 - 5.84	1.97 - 28.38	0.15 - 10.30	0.13 - 1.29	0.62 - 2.67	0.18 - 0.99
Straight oil	4.82***	1.71	0.54	0.86	2.2	1.88	1.28	0	0	1.67	1.13
	1.97 - 11.81	0.75 - 3.88	0.15 - 2.00	0.23 - 3.28	0.80 - 6.03	0.53 - 6.65	0.13 - 12.30	0	0	0.66 - 4.25	0.46 - 2.77
Types of Operations (Reference: Administrative)											
Machining	2.54*	0.86	0.46	0.85	2.28*	2.22	4.62*	0.78	0.28*	1.64	0.8
	1.18 - 5.47	0.46 - 1.59	0.18 - 1.21	0.32 - 2.29	1.00 - 5.16	0.83 -5.91	1.28 -16.62	0.10 - 6.06	0.10 - 0.79	0.88 - 3.06	0.42 - 1.52
Stamping	0.63	1.14	1.17	1.35	0.6	0.42	5.25*	3.47	0.4	1.62	0.53
	0.18 - 2.19	0.51 - 2.55	0.39 - 3.51	0.41 - 4.45	0.17 - 2.10	0.08 - 2.24	1.24 - 22.19	0.48 - 24.89	0.10 - 1.61	0.71 - 3.70	0.22 - 1.31
Assembly	1.7	0.78	2.23	2.07	2.01	1.31	0.99	1.49	0.97	2.06	0.73
	0.55 - 5.29	0.30 - 2.03	0.75 - 6.66	0.58 - 7.35	0.64 - 6.37	0.26 - 6.70	0.10 - 10.14	0.14 - 15.81	0.29 - 3.22	0.77 - 5.50	0.26 - 2.10

[A] *Multiple logistic regression with odds ratios adjusted for age, gender, smoking status and years of employment. Values are adjusted odds ratios (top row) and 95% confidence intervals (bottom row). * significant at p<0.05, ** significant at p<0.01, *** significant at p<0.001.*

An extensive literature review of MWF exposure studies by Park[11] suggests that the epidemiologic study on exposure to MWFs should further investigate into the effect of type of industry, operation and fluid. This study aimed to provide an evidence based data for country of South East Asia specifically Malaysia on the association between the use MWFs with risk of respiratory health and allergy symptom. This study main focus was to investigate the effects of respiratory and allergy symptom, high total IgE and cross-shift lung function values from the types of operations and MWFs. .

Respiratory symptoms

Table 3 shows that there was no significant difference in the risk of respiratory symptoms between the MWFs exposed and unexposed groups. There was also no significant association between the risks of respiratory symptoms with other types of chemical exposure at work. However, this study showed that the risk of cough symptom was significantly associated with Machining workers and the use of straight oil.

Machining workers reported a significantly higher risk of cough symptoms (OR 2.54) and Grade 1 Dyspnoea (OR 2.28) compared with the administrative workers. This was in agreement with Jaakola et al.,[14] who reported that upper airway symptoms consistently increased among the machining workers - cough symptoms (adjusted OR 2.5, 95% CI 0.8-8.1) and breathlessness (adjusted OR 2.0, 95% CI 0.5-8.8) was statistically significant.

Further analysis based on the type of MWFs showed that the use of straight oil was significantly associated with cough symptoms (OR 4.82, 95% CI 1.97-11.81) among the MWFs exposed group when compared the unexposed group. . These findings were supported by Kriebel[7] who found that machinists who were exposed to straight oil reported a higher frequency of chronic cough than non-machinists (OR 2.2, 95% CI 1.1-4.6). In addition, previous studies showed that, generally, higher respiratory symptoms were associated with straight MWFs than soluble MWFs.[15, 16] Machinists with straight MWF exposure were reported to have a higher prevalence of chronic cough than those with soluble MWF exposure.[7] In our study, soluble oil was diluted with 90% or more water for machine use but the concentrated straight oil was directly used at fully automated machines. The workers might inhale straight oil aerosols when opening the shuttle door of machines to remove work pieces from the chuck. Fully automation with higher speed machines or processes might also generate a large amount of heat that produces higher concentrations of straight oil aerosols to the workers.

Skin itchiness

Table 3 shows that exposure to MWF was significantly associated with the increased risk of skin itchiness (OR 4.82, 95% CI 1.54-15.16). When we explored the effect of other types of chemical exposure, it showed that there was a significant increased risk of skin itchiness among the exposed group that used MWFs at work (OR 5.77, 95% CI 1.51-22.13). Further analysis based on the types of MWFs showed that the risk of skin itchiness was significantly higher among the exposed group that handled the soluble oil (OR 7.48, 95% CI 1.97-28.38), followed by stamping oil (OR 5.10, 95% CI 1.33-19.61) and straight oil (OR 1.28, 95% CI 0.13-12.30) compared with the MWFs unexposed group. Based on types of operations, a significant increased risk of skin itchiness among stamping workers (OR 5.25, 95% CI 1.24-22.19), followed by machining workers (OR 4.62, 95% CI 1.28-16.62).

Metalworking fluids can cause irritant and allergic contact dermatitis.[10] Production workers are potentially exposed to MWFs through skin contact when handling metal parts, tools or equipment contaminated with MWFs and exposure to splashes or aerosols during the misting or flooding of MWFs onto machine tools or metal parts.[17] Although workers can be exposed to MWFs through the inhalation of aerosols, reports of occupational skin diseases were higher than allergic respiratory diseases among machinists. Mirer[18] also reported frequent skin disorders, such as skin irritation, eczema, rashes and oil acne, followed by eye, nose and throat irritation, and respiratory symptoms (cough, chest tightness and asthma). Similarly, our study showed exposure to MWF was significantly associated with an increase in skin itchiness (OR 4.82, 95% CI 1.54-15.16) compared with the unexposed group. There was a significantly higher increase in skin itchiness in the MWF exposed group (OR 5.77) than for the unexposed group that did not use any chemical at work. In terms of operation, production workers presented significantly higher skin itchiness than the administrative workers (OR 4.82). When we investigate the association between the risk of skin itchiness and types of MWFs, it showed an elevated risk of skin itchiness in the exposed group that used soluble and stamping oils. This could be explained by a study using skin patch test with chemical components of soluble MWF which showed the highest positive reaction to monoethanolamine (MEA) (11%) and diethanolamine (DEA (2%).[19] According to the Material Safety Data Sheet (MSDS), stamping oil is mainly composed of mineral oil and paraffinic hydrocarbon, which are potentially a skin irritant. The soluble oil used was made up of triethanolamine (TEA) 5% to 20% or DEA with less than 15%, which varies depending on MWF manufacturers. Based on the report of Broding,[20] alkanolamines, which are

grouped into TEA, DEA and MEA, used in MWFs to stabilize the pH or inhibit corrosion. DEA is a potential carcinogen.[21] MEA, which has been reported to be a causative agent for allergic contact dermatitis, is especially used in soluble MWFs. DEA is used in straight MWFs but, today, the rate of usage is reduced.[22] Further investigation into the hazardous content of MWFs could be carried out to determine which chemical ingredient in the MWFs and microbial effect caused skin itchiness.

The method of applying MWFs onto metal parts or machine tools might influence skin itchiness. It was observed through the workplace inspection that straight oil was used at fully automated machines where straight oil was sprayed onto metal parts automatically. However, a number of workers need to apply stamping oil onto metal parts manually during the stamping process. The machines that used soluble oil were mainly for the grinding process through which the operators were potentially exposed to the splashes of soluble oil during the process. Hence, further analysis of the engineering control measures and frequency of manual handling were needed to identify the source and cause of skin itchiness in the MWF exposed group.

High total IgE

The findings showed that the unexposed group that use other types of chemical at work reported a significantly higher total IgE (OR 2.83, 95% CI 1.24-6.43) than the MWFs unexposed group that do not use any chemical at work, followed by the MWFs exposed group (OR 2.03, 95% CI 1.09-3.76). Our study showed the exposure to MWFs and other chemicals at work were significantly associated with the increased risk of high total IgE. This suggests the need for further analysis into sensitive allergens that contain other types of chemical used by the assembly workers. Hence, the effects of other types of chemical besides MWF, which also contributed to high total IgE among assembly workers, could be determined.

Analysis based on the types of MWFs,showed no significant associations between straight oil, stamping oil and soluble oil with high total IgE. We did not find any studies in the literature to support association between the risk of high total IgE with the types of MWFs. Such a lack of epidemiologic studies might be because skin tests, such as the IgE test are not available from commercial laboratories for MWFs or their components.[1] An occupational rhinitis case study by Graff[23] found allergic reaction mediated through IgE test to tolyltriazole was negative on a machining industry worker who encountered such problem

after 4 years work. This suggested the allergic reaction might not be mediated through an IgE test but through a patch test using 2% benzotriazole for cases of occupational dermatitis with a positive reaction in among workers exposed to industrial oils or greases which contained benzotriazole. Hence, the exact immunologic mechanism was not found and an allergic reaction could not be concluded.

Cross-shift lung function decrements (incidence of 5% cross-shift decrement in FEV_1)

Table 3 shows that there was no significant association between the MWFs exposure and the decrease of lung function capacity (cross-shift 5% FEV_1 decrement). Exposure to MWFs were significantly associated with respiratory disease, such as asthma and hypersensitivity pneumonitis.[5, 7, 24] The incidence of 5% cross-shift decrement in FEV_1 was significantly lower in the MWF exposed group (OR 0.54, 95% CI 0.29-0.99) and unexposed group that used other types of chemical at work (OR 0.25, 95% CI 0.09-0.70) when compared with the unexposed group who did not use any chemical. This finding contradicted our expectation. However, a similar trend was reported in the study of Kriebel et al.[7] in that the incidence of a 5% cross-shift decrement in FEV_1 was lower among machinists than non-machinists due to more MWF sensitive workers being transferred from the MWF exposed environment. Although synthetic MWFs are known to cause asthma in an exposed population, the prevalence of asthma was lower among the exposed workers than the unexposed workers in a cross-sectional study of autoworkers.[4] Furthermore, we were unable exclude healthy worker effect that was not investigated in detail whether the exposed workers might have been transferred from stamping or machining operation due to intolerant to MWF exposure or health-related reason.

The incidence of a 5% cross-shift decrement in FEV_1 was significantly lower in the MWF exposed group and unexposed group that used other types of chemical at work, which suggested those MWFs and other types of chemical did not affect the short term decrement in lung function over a day's work. There was some evidence that health effects may differ across different MWFs. The exposed group that used soluble oil reported a significantly lower risk of incidence in 5% cross-shift decrement in FEV_1 (OR 0.42, 95% CI 0.18-0.99) than those who did not use MWFs. This was in line with Eisen et al.,[25] who found that exposure to straight oil aerosols was associated with a decrease in forced expiratory volume in one second (FEV_1) in the lung function testing, which was not observed for exposure to soluble oils. This finding also in line with our findings in this study that the risk of cough

symptom was significant associated with the use of straight oil (OR 4.82, 95% CI 1.97-11.81).

CONCLUSION

This study showed the workers in the machining industry reported significant associations between respiratory and allergy symptoms with different types of MWFs. The risk of cough symptoms was significantly associated with the use of straight oil and also among the machining workers.The risk of skin itchiness was significantly associated with the use of soluble oils and stamping oils This suggests that the company shall look into selection of appropriate MWFs based on chemical compositions and control the concentrations of MWFs (straight oil and soluble oil) in order to minimize the hazard of exposure. Straight oils produce smoke with submicron in sizes, whereas the soluble oil produce mist with larger droplet sizes. Full automation of higher speed machines or processes using straight oil would generate larger amount of MWF smokes. This suggests reviewing current mist minimiser and the need for installation of dust and smoke collector to capture the mist, dust and smoke at the source of generation. The main allergy found was skin itchiness, which suggests the need for the use of proper protective clothing, gloves and lubrication method to minimize direct exposure. Clinical skin examination by dermatitis or physician could be carried out by the company to evaluate changes in the skin disease and pattern. This program would trigger early detection and diagnosis of workers who encounter allergic disease.

STUDY LIMITATION

MWFs are complex mixture of chemical that the responsible agents for adverse health effects is difficult to confirm. This cross sectional study in which the measurement was taken at one time only and hence not able to confirm the causal and temporal relationship of the exposures and respiratory health effects. A more comprehensive longitudinal study which examines the effects of PPE, presence of ventilation, effectiveness of the engineering control measures and frequency of manual handling which may be significantly related to the exposure of MWFs is recommended.

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