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Occupational xylene exposure and respiratory impairment of paint manufacturing workers

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A cross-sectional study was conducted among paint workers to determine the association between xylene exposures with respiratory health. Sixty-four exposed workers working with xylene and 47 unexposed administrative workers were selected. Air xylene (AX) were analyzed using the Gas Chromatography while urinary methyl hippuric acid (MHA) were analyzed using High Performance Liquid Chromatography. Lung functions were measured using Chestgraph HI-701 spirometer. The AX for the exposed was significantly higher than the unexposed workers (p<0.001). The urinary MHA of the exposed was higher than the unexposed workers (p<0.001). Among the exposed, more respiratory symptoms, higher lung functions abnormality and significantly lower FEV1% predicted and FVC% predicted were found. Findings showed significant correlations between AX and urinary MHA. AX significantly influenced the lung functions. Smoking years and education influenced the respiratory symptoms. Those exposed have early signs of lung impairment and respiratory symptoms. Smokers faced the risk of developing chronic irreversible respiratory diseases.

Key words: Solvent, xylene, methyl hippuric acid, lung functions, paint manufacturing industries.

INTRODUCTION

Solvent also defined as an organic substance that is liquid at room temperature, and under standard atmospheric conditions is able to dissolve a wide range of organic compound. Organic solvents are used for extraction of fats and oils, degreasing, dry cleaning, and the manufacturing of a wide range of products including paints, adhesives, plastics, textiles, electronics and semiconductors. Although solvents have many useful properties that make them ubiquitous in human activities, they have, however, many potential adverse health effects (Schenker and Jacobs, 1994).

Solvent made up of mixtures of chemicals such as xylene, produced in very large quantities and is extensively employed in a broad spectrum of applications, primarily as a solvent for which its use is increasing as a "safe" replacement for benzene, and in gasoline as part of the BTX (benzene-toluene-xylene) component. There is a broad potential for exposure both to industrial workers in the production and use of the xylenes, and to the general public via vehicle exhausts, consumer products,

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consumer products, and others (Fishbein, 1984). Technical (industrial) xylene is a mixture of the isomers plus ethylbenzene (6 - 15%) and occasionally toluene, trimethyl benzene and other trace components. Xylene is widely used as thinner for paints and varnishes, often in combination with other organic compounds and as a solvent in glues and printing inks (International Programme on Chemical Safety – IPCS, 1992).

Xylene exposure has been associated with effects in a number of organ systems including the lungs, skin and eyes, neurological system; heart and gastrointestinal system; kidney; and possibly the reproductive system. High levels of xylene exposure for short periods are associated with irritation of the skin, eyes, nose and throat (Agency for Toxic Substances and Disease Registry – ATSDR, 1992).

The general objective of the study was to determine if there is a significant relationship between xylene exposures with respiratory problems among the paint manufacturing workers.

SUBJECTS AND METHODS

This is a cross-sectional comparative study in a paint manufacturing factory. This factory is made up of two plants namely the Industrial Used Plant and the Trade Used Plant. The Industrial Used Plant produces paints for industrial purposes while the Trade Used Plant produces paints for home use. Both plants had the same work process and use xylene as solvent.

Thousands of chemical compounds are used in paint products as pigments, extenders, binders, solvents and additives. Painters are commonly exposed by inhalation to solvents and other volatile paint components; inhalation of less volatile and nonvolatile components is also common during spray painting. Painters are commonly exposed to solvents, mainly the petroleum solvents, toluene, xylene, ketones, alcohols, esters and glycol ethers. In this factory, the paint is made up of mixtures with thinner containing up to 30 - 40% xylene.

The sampling frame for exposed group was the list of name of workers obtained from the Human Resource Section. Those who work with solvent as the raw material in the manufacturing process were randomly selected. The unexposed group was made up of workers from other sections where they were not exposed. Majority of the workers were males, therefore, only male were selected as respondents for both the exposed and unexposed group in order to match the two groups. Matching was also on the basis of age, ethnicity, educational level and smoking habit. Statistical test were carried out to determine if the differences in these variables were significant.

Questionnaires were used to gather the demographic and socioeconomic background, educational level, work history, current work activities and other relevant information from the respondents. The questionnaires were pretested to ensure quality of the data collected. This pre-test involved 10% of the sample size among other working population that have similar characteristics with the study sample.

Spirometer was used to determine any early stage abnormalities to lung functions. Before the test, each worker was instructed on how the tests would be carried out. Measurements were made by recording the volume of air that a worker can forcibly blow out from the lungs after a full inspiration. A flow-volume curve generated and thus several values were derived from this maneuver, where the best value will be taken after three trials. The percentage of predicted value for each spirometric value was calculated according to the worker's age, sex, weight and height. The spirometer used was according to the recommended method by American Thoracic Society (1991). The instrument was calibrated by using the method. The personal air sampling pump was calibrated each time before the measurement. The calibrations and measurements were carried by using NIOSH Analytical Method 1501.

For individual air sampling, portable air sampling pump PAS-500 model with solid sorbent tube containing coconut shell charcoal were used. The sampling was carried out during the 8-h shift at 2 h interval with four tubes. The sampling pump with flexible tubing was calibrated at an accurately known flow rate of 0.2 L/min for a total sample size of 0.25 to 12 L.

Urine samples were collected to determine the methyl hippuric acid (MHA) as the metabolite of xylene, measured using High Performance Liquid Chromatography (HPLC), according to NIOSH Manual of Analytical Method - NMAM 8301 (2003). The samples were collected at the end of the weekly work shift on alternate days for 1 work week. The urine was stored in 250-ml polyethylene bottle containing a few crystals of thymol. For storage, urine samples were bagged and refrigerated at a temperature of 4°C in which they were stable for a month.

RESULTS

The socio-demographic status of respondents, such as sex, marital status, educational level and ethnic background are shown in Table 1.

From Table 1, majority of the exposed workers were from Mixing and Canning Processing Sections. Both of these processes use solvents for mixing all of the chemials into a big container while the canning process ensures all of the finished products were canned properly. Beside these, the workers in the Color Match Section were also exposed to the solvent. For the process workers, their task were to make sure all of the solvents and chemicals were mixed well, the ingredients balanced and to ensure the final product fulfill the company's criteria by comparing the final product's color with the standard. For other paint work processes, workers were also exposed to the xylene because of their work tasks as well as the work environment.

For the unexposed group, most of the workers were forklift drivers and storage workers who did not use xylene or other solvent in their work tasks. However, they were exposed to dust which can be a confounder in this study (Table 1).

There was no significant difference in the height and weight between the exposed and unexposed group. The comparison between the two groups on the number of children, total years of formal education, employment years and the total household income, did not show any significant difference. However, there was a significant difference in age ($p=0.010$), whereby, the unexposed group was made up of older workers. As much as possible, the two groups were matched (Table 2).

The main confounder in this study was their smoking habit. The majority of the exposed workers was smokers and, was matched with the unexposed workers. No significant difference was observed in the number of cigarette

Table 1. The background information of respondents.

Variable	Exposed group {n=64; Frequency (%)}	Unexposed group {n=47; Frequency (%)}
Marital status		
Single	18 (28.1)	8 (17.0)
Married	46 (71.9)	39 (83.0)
Educational level		
Primary	3 (4.7)	4 (8.5)
SRP/PMR	12 (18.8)	7 (14.9)
SPM	49 (76.6)	31 (66.0)
STPM/Diploma	0 (0)	4 (8.5)
Degree	0 (0)	1 (2.1)
Ethnicity		
Malay	57 (89.1)	41 (87.2)
Chinese	3 (4.7)	2 (4.3)
Indian	2 (3.1)	4 (8.5)
Smokers	46 (71.9)	30 (63.8)
Consume carbonate drink	39 (60.9)	19 (40.4)
Drink alcohol	0 (0)	0 (0)
Consume seafood	37 (57.8)	25 (53.2)
Take medication	12 (18.8)	11 (23.4)
Job classification		
Mixing workers	17 (26.6)	
Canning workers	17 (26.6)	
Color matcher	9 (14.1)	
Grinder	3 (4.7)	
Packer	1 (1.6)	
Quality controller	5 (7.8)	
Paint work processors	10 (15.6)	
Supervisor in exposed sections	2 (3.1)	
Managers		3 (6.4)
Forklift driver		15 (31.9)
Lorry driver		1 (2.1)
Security guard		3 (6.4)
Product distributor		8 (17)
Maintenance personnel		1 (2.1)
Picking cans worker		1 (2.1)
Supervisors of unexposed section		1 (2.1)
Storage workers		12 (25.5)
Transportation personnel		2 (4.2)

N=111, PMR=Lower Certificate of Education, SPM= Malaysian Certificate of Education, STPM=Higher School Certificate.

cigarette smoked daily and the years of smoking between the exposed and unexposed group (Table 2). Spirometric test were conducted for a few parameters such as FVC% predicted, FEV_1% predicted and FEV_1/FVC% predicted. The lung functions were classified into normal, mild, oderate, severe and very severe based on a previous study (NIOSH Manual of Analytical Methods - NMAM, 2003).

Table 3 shows the classification of lung functions of the two groups. From Table 3, the exposed group showed a higher number of respiratory symptoms than the un-xposed group. The four main symptoms observed were cough, phlegm, chest tightness and shortness of breath.

Table 2. Comparison of socio-economic variables

Variable	Exposed group (n=64)	Unexposed group (n=47)	Statistical test		
	Mean[a] (SD) /Median (IQR)	Mean[a] (SD) /Median (IQR)	t	z	p
Age (log_{10})	1.50[a] (0.11)	1.56[a] (0.11)	-2.58		0.010**
No. of children	1.00 (3.0)	2.00 (3.0)		-0.930	0.353
Total years of education	11.00 (0)	11.00 (0)		-0.845	0.398
Total employment years	11.50 (10.8)	13.00 (11.00)		-1.456	0.145
Total income	1800.00 (1400.5)	1870.00 (1100.00)		-0.836	0.403

N=111, ** Significance at $p \leq 0.01$, t = t-test, z = Mann-Whitney U test.

Table 3. Classification of lung functions between the groups.

Abnormality of the lungs	Exposed {n=64; Frequency (%)}	Unexposed {n=47; Frequency (%)}
FVC% predicted		
Normal	55(85.9)	43(91.5)
Mild	4(6.3)	3(6.4)
Moderate	5(7.8)	1(2.1)
Severe	0	0
Very severe	0	0
FEV_1% predicted		
Normal	55(85.9)	46(97.9)
Mild	8(12.5)	1(2.1)
Moderate	1(1.6)	0
Severe	0	0
Very severe	0	0
FEV_1/FVC% predicted		
Normal	64(100)	47(100)
Mild	0	0
Moderate	0	0
Severe	0	0
Very severe	0	0
Respiratory symptom		
Cough	10 (15.6)	7 (14.9)
Cough with phlegm	25 (39.1)	14 (29.8)
Chest tightness	13 (20.3)	11 (23.4)
Shortness of breath	6 (9.4)	3 (6.4)

There was no significant correlation between all parameters for lung functions and respiratory symptoms such as cough, phlegm, chest tightness and shortness of breath with the air xylene concentrations. However, the correlation between urinary MHA and air xylene was significant (Table 4).

The lung functions values for FVC% predicted and FEV_1% predicted of the exposed group were significantly lower than unexposed group, while for the urinary MHA and personal air xylene, the exposed group was significantly higher than the unexposed group. However, for the FEV_1/FVC% predicted, there was no significant difference between the groups (Table 5).

General Linear Model was used to determine which of the variable significantly influenced the lung functions. All the related variables such as smoking, age, total income, frequency of exposure, air xylene exposure, daily work duration, overtime hours, hours of handling and exposure

Table 4. Correlation between lung functions, air xylene concentrations and respiratory symptoms with urinary MHA per creatinine (g/g) among the exposed group.

Variable	Concentration of urinary MHA (g/g creatinine)		
	r	χ^2	p
FVC% predicted	-0.123		0.333
FEV_1% predicted	-0.176		0.165
FEV_1/FVC% predicted	-0.016		0.900
Air xylene conc. (ppm) [a]	0.387		0.009**
Cough		0.166	0.920
Cough with phlegm		1.003	0.606
Chest tightness		0.709	0.701
Shortness of breath		1.124	0.570

N = 64, r = Spearman Rho correlation test, χ2= Chi square test, ** Significance level of p≤ 0.01, [a] N = 45.

Table 5. Comparison of lung functions, urinary MHA and air xylene concentrations between two groups.

Variable	Exposed (n=64)	Unexposed (n=47)	t	Z	p
FEV1% predicted	98.03 (14.58)	105.40(13.90)	-2.70		0.008**
FVC% predicted	92.79(14.59)	98.22(13.01)	-2.06		0.040*
FEV1/FVC% predicted	95.38(9.76)	96.95*(11.15)		-0.687	0.492
MHA per creatinine (g/g)	$7.4x10^{-3}$(0.019)	$1.5\ x10^{-4}$*(0.0004)		-4.695	0.001***
Air xylene conc.[a]	0.25 (0.32)	-0.15 (0.02)	8.199		0.001***

N=111, *Significance level of p≤ 0.05, z = Mann-Whitney U test, [a] n exposed = 45, unexposed = 3, t = student t test, **, *** Significance level of p≤ 0.01 and p≤ 0.001, respectively.

Table 6. Variables that influenced the lung functions and respiratory symptoms of the exposed group.

Independent variable	FEV% predicted			FVC% predicted			Cough		
	Mean square	F	p	Mean square	F	p	Mean square	F	p
Solvent exposure (h)	263.6	9.7	0.029*	218.2	2.9	0.164	-	-	-
Income (RM)	1180.5	43.5	0.003*	1253.2	16.8	0.015*	-	-	-
Weight (kg)	246.4	9.1	0.039*	541.4	7.3	0.054	-	-	-
Smoking (yr)	-	-	-	-	-	-	1.482	10.241	0.015*

N=64, General linear model significance at p≤0.05.

to solvent, number of cigarettes smoked daily, years of smoking, height, weight, urinary MHA concentrations, and air xylene concentrations were included. The results in Table 6 shows that the hours of handling and exposure to solvent during work, total income, and weight were the most significant variables influencing the FEV% predicted. While the FVC% predicted was influenced only by the total income.

The variables that significantly influenced the respiratory symptoms were the total years of smoking (Table 6).

DISCUSSION

This study was an attempt to minimize the influence of confounding factors by using matched controls who were also smokers but not exposed to solvent in their daily work tasks. Majority of the exposed (71.9%) as well as the unexposed group (63.8%) were smokers. The two groups were quite comparable. Results showed that for the FVC% predicted, 6.4% of both the exposed and unexposed group have mild lung functions, and 7.8 and 2.1% of the exposed and unexposed group have moderate classification respectively.

As for the FEV_1%, 12.1% of the exposed group and only 2.1% of the unexposed group had mild classifications while all respondents were normal for the FEV1/FVC% predicted. Therefore, the exposed workers are experiencing obstructive airways as indicated by the reduction in the FEV_1% predicted. Traditionally, the severity of chronic obstructive pulmonary disease is graded by FEV_1% predicted rather than the FEV_1/FVC ratio

(Jakeways et al., 2002).

Meo et al. (2008) conducted a study on 20 workers exposed to crude oil spill in sea water, have significant reduction in FVC and FEV_1 compared to their matched controls. Crude oil is a complex of mixtures of para-phenol and aromatic hydrocarbon such as benzene, toluene and xylene as well as polycyclic hydrocarbon. Petrol pump workers exposed to gasoline also experienced reduced mechanical properties of breathing. In this study, the exposed group also experienced more respiratory symptoms such as cough, cough with phlegm, chest tightness and shortness of breath (Table 5).

There was no significant correlation between air xylene concentrations with all parameters of lung functions and the respiratory symptoms. The air xylene in the individual breathing zone sampled, were very low and therefore, the association between these parameters were not seen. There were limitations in sampling the individual air since the sampling duration was short and the samples stored for about 2 - 3 weeks before analysis of xylene tend to vaporize. These low results may also be due to the effectiveness of the workplace ventilation. The employer seems to be concerned about the safety and health of the workers. However, there was a significant direct correlation between the air xylene and the urinary MHA. This result was supported by Kawai et al. (1991) study in which 121 male workers engaged in dip-coating of metal parts who were predominantly exposed to 3 xylene isomers that were o-, p- and m-xylene. Findings showed that there was a linear relationship between the exposure concentrations to xylene with the urinary metabolite MHA.

Results showed no significant correlation between urinary MHA per creatinine (g/g) with lung functions and respiratory symptoms among respondents. Probably urinary metabolite MHA is the product of acute exposure while lung function impairment and respiratory symptoms were usually chronic health outcome which would not be seen immediately after exposure. Inoue et al. (1993) found that smoking habit could also decrease the urinary excretion of MHA. This study groups were made up of healthy young males; very few of them had respiratory symptoms, however, majority of the exposed workers smoked.

No significant association between respiratory symptoms with lung functions was found. Jakeways et al. (2003) study conclude that FEV_1% predicted appears to be the measure of airflow impairment most closely associated with chronic respiratory symptoms in the general population. Jedrychowski and Krzyzanowski (1990) study conducted on the respiratory symptoms in men with normal lung functions, showed associations with a lower FEV_1%. Based on another study by Jakeways et al. (2003), there was a significant relationship between FEV_1 declines with respiratory diseases. In this study, the lung function in men decreased steeply after pneumonia infection. The acceleration of FEV_1 decline due to pneumonia was greater than in normal population.

In another study by Inoue et al. (1993), among 175 Chinese workers who had been predominantly exposed to xylene, there were correlations between exposure to three xylene isomers and the resulting urinary excretion of MHA isomers. Non-exposed controls (281 men and women) were also studied to determine the background level of urinary MHA. From the study, the concentration of each MHA isomer correlated significantly with the time weighted average intensity of exposure to the corresponding xylene isomer.

There was a significant difference in the air xylene concentrations between the two groups with a higher mean among the exposed. Table 5 also shows there are significant differences for FVC% prediction and FEV_1% prediction between exposed and unexposed, with the exposed group having lower values than unexposed group. However, for the FEV_1/FVC% predicted, there was no significant difference because both groups are normal.

Results from Shin et al. (2005) study proved that exposure to organic solvents such as xylene can reduce the lung function and induce asthma related symptoms or attacks. For income and weight, Cakmak et al. (2004) study supported the results in which with good income, the lung growth and functions improved with good nutritional intake. Weight also affected the lung function whereby lung function would decrease with obesity (Eagan et al., 2004). For other variables, no significant relation was found. Smoking can induce a decline in pulmonary functions (Miller et al., 2005) as well as aggravate throat irritation which usually gives rise to severe dry cough (Table 6).

Conclusion

From the results, the mean urinary MHA concentrations and air xylene for exposed workers was significantly higher and they also have significantly lower FEV% predicted and FVC% predicted compared to the unexposed group. Significant correlations between air xylene and urinary MHA found. The exposure to the solvent vapors during work, and confounders such as total income, and weight significantly influenced the FEV_1% predicted and FVC% predicted while the confounding factors such as total years of smoking and years of education significantly increased coughing among the exposed workers. The exposed workers should quit smoking because exposure to tobacco smoke together with the solvent will further impair the lung functions and elevate respiratory symptoms such as coughing among them.

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