African Journal of Internal Medicine ISSN 2326-7283 Vol. 8 (10), pp. 001-007, October, 2020. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Toxic effect of naphta exposure on respiratory system among workers in the tyre industry

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Accepted 11 August, 2020

A cross-sectional study was carried out on workers in a tyre manufacturing industry in Malaysia to determine the effects of naphtha exposure on lung functions and respiratory symptoms. Sixty male workers exposed to naphtha and 42 unexposed workers were selected for this study. Personal air monitoring carried out using solid sorbent tubes and low flow pumps (Model: PAS-500 Personal Air Sampler). Personal air monitoring showed that the mean air naphtha concentration was 28.50 mg/m^3, the median was 28.47 mg/m^3 and the inter quartile range of 1.27 mg/m^3. The range was from 0.19 to 200.51 mg/m^3 (PEL is 400 mg/m ^{3}). The lung function tests showed in 2 groups for all the 3 parameters (FVC%, FEV$_1$% and FEV$_1$/FVC) were in exposed group 96.16, 85.23 and 0.791 respectively and in Unexposed group was 113.23, 116.28 and 0.903 respectively. The lung function tests showed that there were significant difference in the 2 groups for FVC% ($p < 0.001$), FEV$_1$% ($p < 0.001$) and FEV$_1$/FVC% ($p = 0.002$). Multiple linear regression test showed that monthly household income significantly influence the FVC% predicted ($b = 0.003$, $p < 0.001$) and FEV$_1$% predicted ($b = 0.006$, $p < 0.001$). In conclusion there was an inverse relationship between air naphtha concentrations and lung functions ability. Early impairment of the respiratory system is detected on the workers who are exposed to naphtha which made up of several chemicals.

Key words: Lung function, naphtha concentrations, tyre manufacturing process.

INTRODUCTION

Organic solvent is a chemical widely used in variety of industries. Exposure to organic solvents are common and have been known to cause toxicity to the nervous system, liver, kidney and skin, however, the effects of these organic solvents to the respiratory system are poorly investigated (Hanachi et al., 2008). The animal tests showed that exposure to these organic solvents can cause serious problem to the respiratory system (Cakmak et al., 2004).There are several organic solvents that can cause the effects and one of them is naphtha.

Naphtha-type solvent has been used in the manufacture of rubber tyres since the 1940s (Sullivan et al., 2001; Rosenberg, 1994). Its excellent lipid-soluble properties make it a highly used solvent (Saulsbury, 1984).

Almost all the epidemiological studies and published which have appeared since 1964 on the effects on human chronic exposure to naphtha have been concerned with occupational exposure to mixtures of substances containing n- hexane. A large proportion of the gasoline and naphtha intoxications described in the literature are primarily of n-hexane intoxications (Bradley, 1999). There are no well-documented reports of industrial injury resulting from the inhalation of naphtha. However, naphtha is expected to be an irritant to human skin, eyes and mucous membranes and also a central nervous system depressant (Hathaway, 1991).

According to the Occupational Safety and Health Administration (NIOSH,1991), naphtha solvent has several synonyms such as n-hexane, benzene B70, benzene pe-

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troleum, coal tar naphtha and high solvent naphtha. It is a mixture of several aromatic hydrocarbon included toluene, xylene, benzene and cumene (NIOSH, 1991) . The permissible exposure limit (PEL) for air naphtha was 100ppm (400mg/m^3) for 8 hours TWA (time-weighted average) (Rossol,1995; ATS, 1978).

All types of natural or synthetic solvent are toxic. Exposure to organic solvents whether through contact, inhalation of the vapor that is volatile in air can affect the health (Singh and Singhe, 1993). However, there were some limitations of this study because smoking was a confounder for the spirometer test carried out; therefore, matching in term of smoking was carried out in the unexposed group. For the time being, there is no specific study on the effects of air naphtha exposure on the respiratory system carried out although it is widely use in petroleum industries generally and specifically in the tyre manufacturing process. Hence, we conducted this study to investigate the toxic effects of naphtha exposure on lung functions and respiratory symptoms on workers in a tyre manufacturing industry.

METHODOLOGY

Subject recruiting

This study was made in a rubber tyre plant in Malaysia on 2006. The venue was selected on the assumption of the high level of solvent used during the manufacturing and processing of the rubber tyre.

To recruit the study subject, lists of names were obtained from the Human Resource Department in the factory. From the name listed, workers exposed to naphtha were recruited as the respondents. The other 42 workers, who fulfill the stated criteria and matched as a group, were recruited from the administrative sections as the unexposed group.

Study design

This is a cross-sectional comparative study between the exposed and unexposed group. The Making 10 A unit was made up of light truck and motorcycle tyre manufacturing section. However, the exposure was supposedly to be higher among workers that manufactured light truck tyres. This is because of its direct exposure to the respiratory system compared to the motorcycle manufacturing workers who only use small amount of naphtha.

Similarly, the Repair and Moulding Technical Section use naphtha to open the part of tyre that is damaged for reuse. The workers at the Solution House Section also work by dissolving raw naphtha at high concentrations. Therefore, it is the most hazardous section due to the high exposure to air naphtha. Workers at the Extruder Section carry-out semi-automatically work tasks with engineering control in this section. Thus, their exposure to air naphtha is moderate.

Compared to other sections, the workers at the Test House are only exposed to naphtha for a certain time. This is because of its operation in checking the tyres for quality assurance. Therefore, the naphtha concentration here is at the lowest level.

Questionnaires

A set of questionnaires will be used to get the demographic background, smoking and socio-economic of the respondents such as personal information, health status, educational status, income. Respiratory symptoms questions were based on the Medical Research Council Committee on Research into Chronic Bronchitis. The information needed include the worker's health status and symptoms of respiratory diseases such as chronic cough, cough with phlegm, chest tightness and shortness of breath.

Questionnaires contain information on the previous workplace, working history and also department of current work (administration, mechanical, operation, maintenance, etc) and also working background such as overtime, shift work schedule, duration of work per day, duration of work per week and the employment years at the industry. Respondents also will be asked on their use and exposure to naphtha at their work sections.

Lung function test

In this study, Chestgraph H-101 model spirometer was used to measure the lung functions among study workers. The use was referred to the methods by American Thoracic Society (1991). The main objective of using this instrument is to identify lung functions abnormalities at an earlier stage. Lung function test measured were Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1) and Forced Expiratory Volume in one second as a percentage of the Forced Vital Capacity (FEV_1/FVC). Three trials were carried out and the best value was taken as the true value for the lung function test result.

To identify the lung function abnormalities of respondents, the spirometer value was standardized with a prediction equation from a study on the Malaysian population in term of body weight, height, environment, altitude and lung functions (Singh and Singhe, 1993). The measurements were classified according to the standard percentage as carried out by (Miller et al., 1978).

Personal air sampling pump using solid sorbent tube

Personal air sampling pump with the solid sorbent tube as a sampler was used to sample the air naphtha from the individual breathing zone by attaching it to the shirt collar for an hour at the beginning and at the end of the 8 h shift.

Absorbed naphtha levels were determined by the method recommended by the NIOSH 1550 method, (1994). The sample was treated with 99:1, carbon disulfide: dimethylformamide. Analysis was conducted using gas chromatography with a flame ionization detector (GC/FID). The sample aliquot was injected manually using the solvent flush technique or with an auto sampler. The peak area could then be measured. The peak of the analysis was divided by the peak area of the internal standard on the same chromatogram. The calculation began by determining the mass, mg (corrected for DE) of naphtha found in the sample front (W_f) and back (W_b) sorbent section and in the average media blank front (B_f) and (B_b) Sorbent sections. The concentration, C, of naphtha in the air volume sampled, V (L) is calculated using this formula:

$$C = \frac{(W_f + W_b - B_f - B_b)}{V} 10^3 \text{ mg/m}^3$$

This method is described in the OSHA Computerized Information System (OSHA 1994) and NIOSH Method No. 1550 (NIOSH 1994). The study protocol was approved by the Scientific Advisory Committee and Ethical Committee of University Putra Malaysia.

Data analysis

All statistical analyses were performed with using SPSS 11.0 (Sta-

Table 1. Mean of anthropometric measurements and background information of respondents.

Variables	Exposed		Comparative		t/Z	p
	Mean (S.D)	Median (IQR)	Mean (S.D)	Median (IQR)		
Age (years)	34.09 (8.08)		35.6(8.48)		- 0.98[a]	0.33
Height (cm)	164.30 (6.10)		165.10(8.12)		- 0.60 [a]	0.55
Weight (kg)	65.82 (12.58)		68.55 (15.62)		- 1.05 [a]	0.30
BMI	24.35 (4.29)		25.02 (4.76)		- 0.80 [a]	0.42
Years of education		11.00 (0.00)		11.50 (2.00)	- 4.41[b]	< 0.001***
Monthly income (RM)		1000.00 (657.50)		2403.70(2004.50)	- 5.75 [b]	< 0.001***
Number of cigarettes per day		6.00 (10.00)		10.00 (14.00)	- 1.10 [b]	0.273
Years of smoking		6.50 (15.00)		5.50 (15.00)	- 0.301 [b]	0.750

***significant at p < 0.001, [a] t-test, [b] Mann-Whitney.

tistical Package for Social Science). Descriptive statistics including means and SDs for the outcome variables of interest were computed. The probability levels of significance reported were based on the 2-tailed t and Mann Whitney test. The statistical methods were used linear regression. Correlations test were used to determine the association between naphtha exposure on lung functions, respiratory symptoms on workers in a tyre manufacturing industry and the different variables.

RESULTS

The Malays workers made up the highest number of the exposed group (98.3%) as well as the unexposed group (100%). The majority of the respondents were married. The 2 groups were similar in their age, anthropometric measurements and smoking habits but significantly different in term of the educational years and household income (p < 0.001) (Table 1).

From the questionnaires response, majority of the respondents said that they were exposed to naphtha everyday and were exposed for more than 7 h for every shift (43.4%). Most respondents were exposed (55%) when they do their works manually with a distance of about 1-4 feet from the source of naphtha (Table 2).

All the unexposed group respondents had a normal lung function while impairments were seen in the ex-posed group. As shown in Table 3, there were significant differences in the lung function parameters between the 2 groups, FVC% predicted (F = 46.40, p < 0.001), FEV_1% predicted (F = 53.31, p < 0.001) and FEV_1/FVC% predicted (F = 10.12, p = 0.002) after adjusting for the confounding factors such as age, smoking habits and body mass index (BMI) . Many of the exposed group were classified as abnormal lung function (Table 4). However there were no significant differences in the respiratory symptoms between exposed and unexposed groups.

There were significant inverse correlation between FVC% predicted (r = - 0.258, p = 0.046) and FEV_1% predicted (r = - 0.301, p = 0.020) with the individual air naphtha concentrations (mg/m^3) but not for the FEV_1/FVC% predicted. For multiple regression statistics, the factors that significantly influenced the predicted FVC% and FEV_1% was household income per month and for FEV1/FVC% predicted was years of formal education of respondents (Tables 5 - 7).

DISCUSSIONS

Personal air data showed that the individual naphtha level were different according to work tasks and units. The highest exposure level was found among workers who make light truck tyre with the naphtha level of 200 mg/m^3. However, this exposure level is still below the permissible exposure level for naphtha (400 mg/m^3). Vapor concentrations above recommended exposure levels may be irritating to the eyes and the respiratory tract, may cause headaches and dizziness, could be anesthetic and may have other central nervous system effects.

Lung functions of respondents from both groups were normal with the parameters tested FVC% and FEV_1% predicted averaged over 80%. The FEV_1/FVC% predicted more than 75% showed normality of the lung function (Miller et al., 1978). However, statistics showed that the group exposed to naphtha significantly had a lower lung function for all parameters FVC%, FEV_1% and FEV_1/FVC% predicted after adjustment for the confounders. Solvent used in rubber based industries could cause varieties of lung function changes (Nutt, 1984).

Both groups showed the normal value of lung function for all 3 parameters with the exposed group had significantly lower lung function primarily on FVC% that indicate lung restrictive patterns. There were also obstruction problem reported by decreased in FEV_1% predicted among respondents exposed to air naphtha. It showed impairment in the lung functions among the exposed workers.

Lung restrictive can occur when there were damages and loss of lung tissues. It occurs when inspiration airflow is lower than normal caused by inhalation of dust or organic and inorganic fine particles. These phenomena also

Table 2. Information on occupational naphtha exposure in respondents.

Parameter	Exposed group	
	Number (n)	Percentage (%)
Exposed to naphtha		
Yes	60	(100)
Not	0	(0)
Frequencies		
Very frequently	40	(66.7)
Frequently	5	(8.3)
Always	3	(5.0)
Sometimes	10	(16.7)
Seldom	2	(3.3)
Duration of exposure		
More than 7 h/shift	26	(43.3)
4 - 7 h /shift	17	(28.3)
2 - 4 h/shift	2	(3.3)
1 - 2 h/shift	11	(18.3)
Less than 1 h/shift	4	(6.7)
Working methods		
Automatic	5	(8.3)
Semi-automatic	22	(36.7)
Manual	33	(55.0)

Data were expressed as mean, figures within parenthesis indicate percentage.

Table 3. Comparison of lung functions between two groups after adjusting confounders (n = 102).

Variables	Exposed (n = 60)	Unexposed(n = 42)	Mean difference	F (df, error)	P
	Mean ^{c}(S.E)	Mean ^{c} (S.E)	(95% C.I)		
FVC%	96.16 (1.81)	113.23 (2.10)	-17.07 (- 22.51, -11.64)	46.40(1, 97)	< 0.001***
FEV_1%	85.23 (2.82)	116.28 (3.26)	- 31.06 (- 39.50, -22.62)	53.31(1, 97)	< 0.001***
FEV_1/FVC	0.791 (0.23)	0.903 (0.27)	- 0.11 (- 0.813, -0.04)	10.12(1, 97)	0.002**

Data were expressed as mean. FVC (Forced Vital Capacity). FEV_1 (Forced Expiratory Volume in one second. FEV_1/FVC (Forced Expiratory Volume in one second as a percentage of the Forced Vital Capacity).
^{c}adjusted for age, smoking, duration of work. **significant at p < 0.01
***significant at p < 0.001.

Table 4. Classification of lung functions (N = 102).

Variable	Exposed n = 60		Comparative n = 42		^{2} (df)	P
	Normal freq (%)	Abnormal freq. (%)	Normal freq. (%)	Abnormal freq. (%)		
FVC% predicted	52 (92.2)	8 (13.3)	42 (100.0)	0 (0.0)	6.08(1)	0.020*
FEV_1% predicted	41(68.3)	19 (31.7)	42 (100.0)	0 (0.0)	16.34(1)	< 0.001***
FEV_1/FVC% predicted	46 (76.7)	14 (23.3)	42 (100.0)	0 (0.0)	11.36(1)	< 0.001***

Data were expressed as mean, Figures within parenthesis indicate percentage. Data were expressed as mean. FVC (Forced Vital Capacity). FEV_1 (Forced Expiratory Volume in one second. FEV_1/FVC (Forced Expiratory Volume in one second as a percentage of the Forced Vital Capacity).
Source: Miller et al., 1978
*significant at pn < 0.05
***significant at p < 0.001.

Table 5. Regression for the factors that influenced FVC% predicted.

Variables		SLR		MLR		
Dependent	Independent	b	P	Adj b	t	p
FVC%	Years of school	1.806	0.024*			
	Income per month	0.003	<0.001***	0.003	4.201	<0.001***
	Years of working	0.454	0.029*			
	Overtime	5.882	<0.001***			
	Number of cigarette per day	0.260	0.270			
	Age (Years)	0.591	0.001***			
	Air naphtha concentration (mg/m^3)	- 0.093	0.077			

FVC (Forced Vital Capacity).
*significant at $p < 0.05$
***significant at $p < 0.001$
Model: FVC% predicted = 97.275 + (1.806*years of school) + (0.003*monthly income) + (0.454*duration of work) + (5.882* overtime) + (0.591* age).

Table 6. Regression for the factors that influenced FEV_1% predicted.

Variables		SLR		MLR		
Dependant	Independent	b	p	Adj b	t	p
FEV_1%	Years of school	4.358	< 0.001***			
	Monthly income	0.006	< 0.001***	0.006	4.353	< 0.001***
	Years of employment	0.557	0.093			
	Overtime	9.524	< 0.001***			
	Number of cigarette per day	0.012	0.969			
	Age(year)	0.296	0.327			
	Air naphtha concentration (mg/m^3)	-0.131	0.087			

FEV_1 (Forced Expiratory Volume in one second).
***significant at $p < 0.001$
Model: FEV_1predicted = 48.985 + (4.358*years of school) + (0.006*monthly income) + (9.524*overtime).

Table 7. Regression for the factors that influenced the FEV_1/FVC% predicted.

Variables		SLR		MLR		
Dependent	Independent	B	p	Adj b	t	p
FEV_1/FVC%	Years of school	2.422	0.015*	4.358	3.612	< 0.001***
	Monthly income	0.002	0.076			
	Years of employment	0.093	0.725			
	Overtime	3.279	0.130			
	Number of cigarette per day	- 0.085	0.774			
	Age (years)	-0.202	0.396			
	Air naphtha concentration (mg/m^3)	0.003	0.967			

FEV_1/FVC (Forced Expiratory Volume in one second as a percentage of the Forced Vital Capacity).
*significant at $p < 0.005$
Model: FEV_1/FVC% predicted = 67.275 + (2.422*years of school).

associated with occupational exposures (Singh and Singhe, 1993). A previous study showed that lung obstructive like emphysema among rubber tyre manufacturing workers in Ohio as a main cause of working resignation (McMichel et al., 1976; Lender et al., 1977).

Statistic showed that there was no significant difference for all the 4 respiratory symptoms for both groups studied. Most of the respondents from the exposed group

(38.3%) and unexposed group (58.1%) had no respiratory symptoms. Less than 10% of the respondents had all four symptoms. Similar study reported increasing impairment in the respiratory systems among a rubber based factory workers (Fine et al., 1976).

It is shown that the respondents that are exposed had shown early stage of symptoms that they have tendency to have respiratory symptoms such as cough and cough with phlegm. However, some of the exposed respondents had already lung abnormalities with chest tightness and shortness of breath. This maybe because of their long exposure duration compared to the unexposed group.

There were significant inverse correlation between the exposure to air naphtha and lung function abilities for FVC% predicted dan FEV_1% predicted. Both lung restrictive and obstructive patterns were shown. However, there were no significant correlation between the air naphtha level with FEV_1/FVC% parameter.

A study (Trupin et al., 2004) showed that there was a significant association between the exposures to vapour at the workplace with lung obstructive problem after adjusting for the smoking habit (Blanc et al., 1999) that found there was no significant association between the smoking habits with the respiratory problem.

There was a correlation between naphtha exposure levels with the lung function impairment. However, exposure to air naphtha was not the only factor that contributes to this problem. So, Simple Linear Regression and Multiple Linear Regressions were run to identify the factor that mostly influenced the lung function.

The variable that significantly influence lung function problem include education, household income per month, overtime, shift works, duration of work in hours, duration of work in years, years of smoke and age. Using the Simple Linear Regression, it showed that these factors significantly related to the lung functions. However, Multiple Linear Regression showed that those factors that significantly influence the lung function was household income per month.

This showed that the concentration of air naphtha was not only the factor that influence the in lung function impairment of workers in this study, but household income per month was the confounding factor that significantly influence it. Same results were found by study Trupin et al. (2003) that found that workers with low household income per month more vulnerable to have lung problems.

Thus, it could be assumed that peoples with high household income per month have a good diet and health nutrition compared to the peoples with low income. This situation indirectly influenced lung function abilities to be better.

As conclusion, there were significant difference between lung functions of exposed workers and the unexposed group. Beside, there was an inverse relationship between air naphtha concentrations and lung functions ability. Early impairment of the respiratory system is detected on the workers who are exposed to naphtha which made up of several chemicals such as toluene, xylene and benzene.

ACKNOWLEDGEMENTS

The author would like to thank the following academic institutions for funding this study: the Faculty of Medicine and Health Sciences, University Putra Malaysia.

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