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EXPOSURE TO INDOOR PARTICULATE MATTER 2.5 ($PM_{2.5}$) AND VOLATILE ORGANIC COMPOUNDS (VOCS) AMONG PRESCHOOL CHILDREN AT AN INDUSTRIAL AREA IN PETALING JAYA, SELANGOR

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ABSTRACT

This study was conducted to determine the exposure of ($PM_{2.5}$) and Volatile Organic Compounds (VOCs) and their association towards respiratory health among preschool children in an industrial area. 100 preschool children aged between 5-6 years old were involved in this cross sectional study with the exposed group consisting of 50 children who live near the industrial area, while the comparative group consisting of 50 children who live far from industrial area. The questionnaires adapted from American Thoracic Society questionnaire were filled by their parents. Lung function test was done using MM-SPOO4 Tabletop Portable Spirometer. Gillian Air Pump and Pbbrae Portable VOC Monitor (Pbbrae 3000) were used to measure the amount of $PM_{2.5}$and Volatile Organic Compounds (VOCs) respectively. There was a significant difference between exposed and comparative group for lung function test and lung function abnormality. Besides that, there was also a significant difference for prevalence of reported between studied and comparative groups for cough, phlegm and wheezing with 3 times more likelihood of getting cough for studied group (PR= 3.451, 95% CI =1.22-9.76). There was a correlation between $PM_{2.5}$ with FEV_1/FVC of all respondents involved in this study. Exposed group has an increased risk for respiratory symptoms and reduction of lung function from exposure to indoor $PM_{2.5}$ andVOCs but not statistically significant. The findings conclude that there was a significant difference between exposedand comparative group for lung function test. Plus, respondents living near an industrial have a risk of getting lung function abnormality and respiratory problem.

KEYWORDS: Indoor Air Pollutants, Particulate Matter $_{2.5}$, VOCs, Respiratory Health, Industrial Area

INTRODUCTION

Air pollution is the mixture of natural and man-made substances. Substances like fine particles, ground level ozone and noxious gas such as sulfur dioxide, nitrogen dioxide, carbon monoxide and chemical vapors, are components that makes up air. Many health effects due to air pollution have been reported in various research studies over the past 30 years (Noor Hisyam and Juliana, 2014; Yahaya and Jalaludin, 2014; Ayuni et al., 2014., J Jalaludin et al., 2014). Air pollution can trigger new cases of asthma and provoke development of lung illnesses such as lung cancer and emphysema. Other than that, air pollution can also interrupt the development of normal lung function, especially on individuals of younger age as they are exposed to these factors at the earlier stages of body development.

A few common indoor air pollutants can aggregate the health of the person staying in a particular environment. These pollutants include biological contaminants, VOCsand respirable suspended particles, $PM_{2.5}$ and PM_{10}. According to

World Health Organization, $PM_{2.5}$particles are particles that have an aerodynamic diameter smaller than 2.5µm (WHO, 2012). $PM_{2.5}$has a greater probability of reaching the small airways and the alveoli of the lungs than larger particles. In 1997, the US National Ambient Air Quality Standard for airborne particulate matter was revised, maintaining the previous indicator of particulate matter of less than or equal to 10 µm in aerodynamic diameter (PM_{10}) and creating a new indicator for fine particulate matter of less than or equal to 2.5 µm in aerodynamic diameter ($PM_{2.5}$). Almost 10 years later there continues to be a lack of $PM_{2.5}$ related health effects studies in the literature, particularly multi-year and multi-community based (Francesca *et. al*, 2006).

VOCs include a variety of chemicals, some of which may have short and long-term adverse health effects. VOCs can originate from a variety of household products including paints, aerosol sprays, disinfections, moth repellents as well as indoor combustion source (USEPA, 2013). Concentrations in new buildings are much greater, often by an order of magnitude or more, and appeared to arise from construction materials and building contents. It is believed that indoor air pollution, one way or another, may cause indoor air complaints. The reported symptom rates of, in particular, eye and upper airway irritation cannot generally be explained by our present knowledge of common, chemically non-reactive VOCs measured indoors (Rohr *et al*., 2002 ;Chua, P.C., and J. Jalaludin, 2015.).

Children are more vulnerable to diseases related to indoor air pollutants at home because they spend more time at home compared to working adults, who spend most of their time working outside. In addition, children have immature immune systems, greater food intake and inhaled breath per unit mass as well as rapid growth that makes them more susceptible to diseases due to indoor air quality (USEPA, 2012).

METHODOLOGY

Study Background

A cross sectional comparative study design was selected to study the exposure of $PM_{2.5}$ and VOCs towards preschoolers living near industrial areas and to compare their respiratory symptoms with preschoolers who live in non-industrial areas. Purposive sampling method was used in this study with a sampling frame that consisted of preschoolers aged between 5-6 years old and lived within 5km from the industrial area for the exposed group, whereas comparative group was those who lived outside the 5km radius from industrial area.

The respondents were selected based on the students' name list given out by the preschools' teachers. Selected preschoolers who fulfilled the inclusion criteria obtained permission from their parents. Several exclusion criteria were set up to avoid bias, which include children with existing respiratory illness' to ensure that their current respiratory symptoms are due to the exposure to$PM_{2.5}$and VOCs from nearby industries. Furthermore, only respondents who have been living in the same house since birth were selected. To maintainracial homogeneity of the participants, only Malay respondents were chosen in this study. Approval from Ethics Committee of Universiti Putra Malaysia was obtained prior to data collection. The research was conducted at an industrial area near Petaling Jaya as well as in a non-industrial area near Hulu Langat. Both locations are in Selangor. The data collections was done among selective respondents of preschool children.

Measurement of Indoor $PM_{2.5}$ and Volatile Organic Compounds

Air Sampling Pump was used to measure $PM_{2.5}$ concentrations in the respondents' houses. Fully charged sampling pumps were placed at common areas where the respondents spend most of their time within the house. These devices include the portable air sampling pump, a cyclone, a cassette with specified filter membrane and rechargeable batteries.

The cyclone is the most important part as it is responsible for separating the $PM_{2.5}$ from particulate matters of other sizes. The ambient air was collected at 1.7 liter/minute for 24 hours and fine particles were trapped in the filter membrane. Filter membrane used was Cellulose Nitrate Membrane with a diameter of 47mm and 0.45µm air pore size.

PbbRAE Portable VOC Monitor (PbbRAE 3000) was used to assess the presence of Volatile Organic Compounds in the respondents' houses. This device was placed at the same location as the Gillian Air Sampling Pump. It was placed at least 1 meter away from the wall, 0.6 meters above the floor, as well as away from the windows, doors, a minimum 0.5 meters away from bookshelves and other potentially stagnant areas. Moreover, the device located away from obvious sources of potential contaminants and unreachable by children.

Respiratory Health Symptoms Data

Questionnaire used was adapted from American Thoracic Society Questionnaire ATS-DLD-78-C WHO (1984). Function of the distributed questionnaire was to gather all required information regarding respondents' demographic information, respiratory symptoms, home environment exposures as well as asthma and allergy information.

Spirometry/Lung Function Test

Lung function was measured using Spirolab II Model. Spirometry measurements include forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC) and FEV_1/FVC%. Weight and height of each respondents were measured prior the lung function test. A demonstration and training was given to the respondents, which include the exact way to seal their lips around the mouthpiece tightly. It was also done to ensure the respondents exhaled as forcefully as possible and maintained their expiration until the indicator reached the end of the tracing. At least three spirometry tests were conducted whereby the best spirogram with the highest sum of FVC and FEV_1 were chosen for further analysis.

Statistical Analysis

Statistical Packages for Social Science (SPSS) Version 22.0 was used in order to analyze statistical data gained from the questionnaire as well as the measurements of indoor $PM_{2.5}$ and VOCs in the respondents' houses. All the variables were analyzed using both univariate and bivariate analysis. T-test was used for parametric data, whereas Mann-Whitney test was used for non-parametric data.

RESULTS

To Identify the Socio-Demographic Data of the Respondents

The study was conducted at an industrial area in Petaling Jaya, Selangor and a non-industrial area in Hulu Langat, Selangor. There were 52 girls and 48 boys with 50 respondents from an industrial area and the other 50 respondents were from a non-industrial area. However, only 30 respondents from each group were selected for measurements of indoor $PM_{2.5}$ and VOCs in their houses and for lung function test. There was no significant difference for age, body weight, height and gender between two groups with $p>0.05$ as shown in Table 1. There was no significant difference between both groups for total household income.

Table 1: Comparison of Socio-Demographic Data among Respondent in Industrial and Non-Industrial Area

Variables	Industrial(N=50)	Non-Industrial (N=50)	Z-Value	P value
	Median (IQR)			
Age	6(0)	6(1)	-1.441	0.150
Body Weight	19(0.25)	16.50(7.25)	-1.434	0.151
Height (cm)	92(14.25)	98(18)	-2.415	0.160

As shown in table 2, majority of the respondents from the non-industrial area lived far away from the main roads (>1000m from road), whereas majority of the respondents from industrial area lived within 100m to 1000m from main roads. There was a significant difference between both groups at $p<0.001$. On the other hand, majority of the respondents from industrial area were less than 1000m away from factories. For non-industrial area, all of the respondents lived more than 5km away from factories. There was also a significant difference at $p<0.001$for distance from factory for both areas.

Table 2: Distribution of the Outdoor Information between Exposed and Comparative Group

Variables	Industrial (N=50)	Non-Industrial (N=50)	χ^2	p value
	Number (%)			
Distance From Main Road				
<100m From Road	3(6)	0(0)	96.078[a]	0.001*
100-1000m From Road	46(92)	0(0)		
>1000m From Road	1(2)	50(100)		
Distance From Factory				
<1km From Factory	30(60)	0(0)	100.00[a]	0.001*
1-5km From Factory	20(40)	0(0)		
>5km From Factory	0(0)	50(100)		

a=Mann Whitney Test, *Significant level at $p<0.001$

To Compare the Concentration of Indoor $PM_{2.5}$ and Volatile Organic Compounds (VOCs) at the Homes of the Exposed and Comparative Group

Normality test (Shapiro-Wilk) was performed in order to evaluate the data distribution of indoor pollutant concentrations. Results show that all the data were normally distributed and parametric test was conducted to compare the indoor $PM_{2.5}$ between industrial and non-industrial area. Table 3 shows the comparison of exposed and comparative group for indoor $PM_{2.5}$ concentration. The mean and standard deviation of $PM_{2.5}$ concentration for industrial area were higher than non-industrial area, but they were not statistically significant. Indoor $PM_{2.5}$ concentration inside respondents' houses was not significantly different between exposed and comparative group. Parametric analysis revealed that the distribution of VOCs concentrations were slightly higher in industrial area compared to non-industrial area but it was not statistically significant at $p>0.05$.

Table 3: Comparison of Exposed and Comparative Group of Indoor $PM_{2.5}$ and VOC Scon centration

Variables	Industrial (n=30)		Non-Industrial (n = 30)		t-Value	p-value
	Mean±SD	Range	Mean±SD	Range		
$PM_{2.5}$(μg/m^3)	17.7453 ± 7.550	5.90 -35.30	15.3629± 5.354	5.90 -23.80	1.417	0.162
VOCs(ppm)	0.5163 ± 0.1726	0.23– 0.88	0.4739 ± 0.13805	0.18-0.65	1.063	0.292

To Compare the Lung Functions among Exposed Group and Comparative Group

Comparison of lung function among both groups was done to compare the values of FVC, FEV_1, FEV_1/FVC,

FVC%, FEV_1% and FEV_1/FVC%. Mann-Whitney test was used and there were significant differences between the two groups for FVC, FEV_1, FEV_1% and FEV_1/FVC% at p=0.001. However, there were no significant differences between groups for FEV_1/FVC and FVC%. Table 4 shows the comparison between both the exposed and comparative group based on lung function test.

Table 4: Comparison between Exposed and Comparative Group Based on Lung Function Test (N=60)

Variables	Industrial (n=30)	Non-Industrial (n=30)	Z/t	P -Value
	Mean(SD)/Median(IQR)			
FVC (liter)[a]	0.415(0.20)	0.695(0.10)	-5.629	0.001*
FEV_1 (liter)[a]	0.400(0.144)	0.805(0.147)	-6.191	0.001*
FEV_1/FVC (liter)[a]	0.995(0.020)	0.974(0.130)	-0.775	0.438
FVC% [a]	69.19(12.09)	73.00(13.381)	-0.267	0.790
FEV_1% [a]	72.760(11.87)	104.3(15.59)	-5.914	0.001*
FEV_1/FVC% [a]	105.22(5.95)	138.5(28.39)	-5.757	0.001*

a=Mann Whitney Test, *Significant level at $p<0.01$

Lung function test was conducted among children and was based on American Thoracic Society (1991) to test the normality of lung function. Table 5 shows the comparison between the exposed and comparative group of lung function percentage of abnormality for FVC%, FEV_1% and FEV_1/FVC%. There were significant differences for FVC% and FEV_1% between both groups. However, FEV_1/FVC% between both groups was not significantly different with $p>0.05$.

Table 5: Comparison between Exposed and Comparative Group of Lung Function Abnormality (N=60)

Lung Function	Industrial (n=30)		Non-Industrial (n=30)		χ^2	p-value	OR	95% CI	OR
	Abnormal n (%)	Normal n (%)	Abnormal n (%)	Normal n (%)					
FVC%	16(53.33%)	14(46.67)	8(26.67)	22(73.33)	4.444	0.035*	0.32	0.11-0.94	0.67
FEV_1%	13(43.33)	17(56.67)	0(0)	30(100)	16.60	0.001*	0.57	0.41-0.78	0.28
FEV_1/FVC%	1(3)	29(97)	0(0)	30(100)	1.017	0.313	0.97	0.90-1.03	0.02

To Compare the Respiratory Symptoms among Exposed Group and Comparative Group

Table 6 shows the respiratory symptoms studied, which were cough, phlegm, chest tightness and wheezing.

Table 6: Comparison between Exposed Group and Comparative Group of Respondents' Respiratory Symptoms

Variables	Industrial n (%)	Non-Industrial n (%)	χ^2 Value	p-Value	PR	95% CI	PR[a]
Cough			5.828	0.016	3.451	1.22-9.76*	3.54
Yes	14(32)	6(12)					
No	34(68)	44(88)					
Phlegm			10.509	0.001	3.930	1.69-9.15*	1.38
Yes	29(58)	12(26)					
No	21(42)	37(64)					
Chest tightness			3.326[a]	0.068	2.347	0.93-5.49	2.85
Yes	17(34)	9(18)					
No	33(66)	41(82)					
Wheezing			7.294[a]	0.007	4.235	1.41-12.70*	3.76
Yes	16(32)	5(10)					
No	34(68)	45(90)					

N=100, *significant level at $p<0.05$, a= adjusted prevalence ratio for smoking and total household income

To Determine the Association between Indoor $PM_{2.5}$ and VOCs Concentrations and Lung Functions among Exposed Group Living near the Industrial Area

Table 7 shows result from Pearson and Spearman correlation that revealed no correlation between FVC, FEV_1, FVC%, FEV_1% and FEV_1/FVC% with indoor $PM_{2.5}$ concentration among children in both industrial and non-industrial area. There was a significant correlation between $PM_{2.5}$ and lung function for all respondents for FEV_1/FVC%. This is the same with VOCs asPearson and Spearman correlation revealed that there were no correlation between FVC, FEV_1, FVC%, FEV_1% and FEV_1/FVC% with indoor VOCs concentration among children in both industrial and non-industrial area as well as for all respondents.

Table 7: Correlation of Individual $PM_{2.5}$ and VOCs Level with Lung Function among Exposed Group (N=60)

Variables	Industrial		Non Industrial		All	
	r	p	R	P	r	p
$PM_{2.5}$						
FVC (liter)[a]	0.062	0.745	-0.313	0.092	-0.153	0.243
FEV_1 (liter)[a]	0.060	0.751	0.225	0.233	-0.60	0.650
FEV_1/FVC (liter)[b]	-0.025	0.897	-0.036	0.851	-0.012	0.926
FVC% [b]	0.112	0.554	0.291	0.118	0.169	0.196
FEV_1 % [b]	0.163	0.389	-0.015	0.937	-0.030	0.818
FEV_1/FVC%[b]	-0.210	0.265	-0.323	0.081	-0.272	0.036*
VOCs						
FVC (liter)[a]	0.170	0.368	-0.143	0.450	-0.068	0.603
FEV_1 (liter)[a]	0.181	0.339	0.110	0.563	-0.036	0.785
FEV_1/FVC (liter)[b]	0.213	0.258	0.090	0.635	0.128	0.328
FVC% [b]	-0.122	0.521	0.119	0.530	-0.038	0.771
FEV_1 % [b]	-0.123	0.519	-0.129	0.495	-0.176	0.178
FEV_1/FVC%[b]	-0.97	0.610	-0.194	0.306	-0.222	0.088

a= Pearson test, b= Spearman Rho test, *significant level at $p<0.05$

Table 8 shows the association of $PM_{2.5}$ concentration and VOCs concentration with FVC% and FEV_1% of exposed group. It reveals that they were not significant for both $PM_{2.5}$ and VOCs concentrations with FVC% abnormality for respondents living in industrial area, but there was an increased risk.

Table 8: Association of Indoor $PM_{2.5}$ Concentration and VOCs Concentration with FVC% and FEV_1% Abnormality among Exposed Group

Variables	Abnormal Number (%)	Normal Number (%)	χ^2	p value	PR	95% CI
Lung Function (FVC%)						
$PM_{2.5}$			0.000	1.000	1.00	0.24-4.2
High	8(27)	7(23)				
Low	8(27)	7(23)				
VOCs			0.117	0.732	0.78	0.18-3.28
High	9(30)	7(23)				
Low	7(23)	7(23)				
Lung Function FEV_1%						
$PM_{2.5}$			0.136	0.713	1.31	0.30-5.58
High	9(30)	6(20)				
Low	8(27)	7(23)				
VOCs			0.002	0.961	0.96	0.23-4.10
High	7(23)	9(30)				
Low	6(20)	8(27)				

To Determine the Association between Indoorpm$_{2.5}$ and VOCs Concentrations and the Respiratory Health Symptoms among Exposed Group Living Near the Industrial Area

As shown in table 9, cough, phlegm, chest tightness and wheezing did not show any significance with concentration of PM$_{2.5}$ among exposed group. Nevertheless, children who were exposed to high indoor PM$_{2.5}$ concentration have increased risk (PR >1) contracting cough and chest tightness, which was not statistically significant. Meanwhile, the respiratory symptoms did not show any significant difference with concentration of VOCs among exposed group but risk of getting phlegm and wheezing is high.

Table 9: The Association of Exposure between Indoor PM$_{2.5}$ and VOCs with Respiratory Symptoms among Preschool Children in Exposed Group

Variables	High Number (%)	Low Number (%)	χ^2	p value	PR	95% CI
PM$_{2.5}$						
Cough			2.400	0.121	3.50	0.69-17.71
Yes	7(46)	3(20)				
No	8(54)	12(80)				
Phlegm			0.133	0.715	0.77	0.18-2.24
Yes	7(46)	8(54)				
No	8(54)	7(46)				
Wheezing			0.159	0.690	0.73	0.15-3.49
Yes	4(27)	5(33)				
No	11(73)	10(67)				
Chest tightness			2.400	0.121	3.50	0.69-17.71
Yes	7(46)	3(20)				
No	8(54)	12(80)				
VOCs						
Cough			1.071	0.301	0.44	0.94-2.09
Yes	4(25)	6(43)				
No	12(75)	8(57)				
Phlegm			0.000	1.000	1.00	0.24-4.20
Yes	8(50)	7(50)				
No	8(50)	7(50)				
Wheezing			0.026	0.873	1.14	0.24-5.46
Yes	5(31)	4(29)				
No	11(69)	10(71)				
Chest tightness			1.071	0.301	0.44	0.09-2.09
Yes	4(25)	6(43)				
No	12(75)	8(57)				

DISCUSSIONS

Children are believed to be more susceptible to respiratory diseases due to differences in ventilation rate, and upper and lower respiratory tract structure and size. The mean and standard deviation of PM$_{2.5}$ and VOC sconcentration for houses in industrial area were higher than the non-industrial area. However, PM$_{2.5}$(t=1.417, p=0.162) and VOCs concentrations (t=1.063, p=0.292)inside respondents' houses were not significantly different probably due to the limitation of the study design itself. The sample size of this study is too small (N=60) and measurement of both pollutants were made one time only as this is a cross sectional study.

Comparison of lung function between both groups were done to compare the value of FVC, FEV$_1$, FEV$_1$/FVC, FVC%, FEV$_1$% and FEV$_1$/FVC%. There were significant differences between exposed and comparative groups for FVC,

FEV_1, FEV% and FEV/FVC% at p=0.001. There were significant differences for FVC% and FEV_1% between both groups. This result was supported by previous studies done by Nurul Anis Sofiah and Juliana (2013), as well as Yahaya and Jalaludin (2014), in which results show significant lung function abnormality among children who lived near busy roads, compared to the comparative group. From here, we can conclude that respondents who live in industrial areas have poor lung function status than the ones who live in non-industrial areas whereby air pollution in the industrial areas is a risk factor in the prevalence of respiratory system symptoms and this is consistent with the results of other authors (Diapouli *et. al*., 2007; Noor Hisyam and Juliana, 2014; Ayuni *et al*., 2014).

Some of the respiratory symptoms studied were cough, phlegm, chest tightness and wheezing. With an observed prevalence of 3.451(95% CI, 1.22-9.76), respondents who live in industrial area were 3 times more likely to get cough compared to the ones who live in non-industrial area, which is in line with a local study by Noor Hisyam and Juliana, 2014. The prevalence ratio for cough increased to 3.545 after it was adjusted for smoking and total household income. A study conducted among residents of a heavy-industry province also showed the same result where cough is one of respiratory symptoms with high prevalence ratio together with symptoms of phlegm and wheeze (Wilson *et al*., 2008). This points out that the respiratory health status of preschool children in the non-industrial area is better than those in the industrial area.

There was a significant correlation between $PM_{2.5}$ and lung function for all respondents in this study for FEV_1/FVC% with $p<0.05$. However, there was no significant association between indoor $PM_{2.5}$ and VOCs concentration and lung functions among exposed group living near industrial area. It concludes that high indoor $PM_{2.5}$concentration has a risk of reducing lung function of preschool children. Meanwhile, there was no significant association between indoor $PM_{2.5}$ and VOCs concentration with respiratory health symptoms among exposed group. The children who were exposed to high indoor $PM_{2.5}$ concentration have increased risk of getting cough and chest tightness as well as increased risk of getting phlegm and wheezing for high indoor VOCs concentration, which was not statistically significant. This result was consistent with a study by Nurul Anis Sofiah and Juliana (2013), where children living near busy road have significantly higher indoor $PM_{2.5}$ concentration than those living near less busy road, which puts them at a higher risk of getting respiratory illnesses.

CONCLUSIONS

The study suggested that there was a significant difference between exposed and comparative group for lung function test. Besides that, there was a significant difference for prevalence of reported respiratory symptoms between groups for cough, phlegm and wheezing with the exposed group being 3 times more likely to get cough for exposed group. Study also found that there was a significant correlation between $PM_{2.5}$ and lung function for all respondents in this study for FEV_1/FVC%. Indoor $PM_{2.5}$ and VOCs concentration increases risk of reduction lung function and respiratory symptoms among respondents who live near an industrial area but it was not statistically significant.

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