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ORIGINAL ARTICLE

Indoor Air Quality and Respiratory Health Implication Among Malay Preschool Children in Puchong and Hulu Langat Selangor, Malaysia

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ABSTRACT

Introduction: Indoor air pollutant has caused a greater impact on the health of occupants' especially preschool age who are still growing. Objective: To determine the association between indoor air pollutants (Particulate Matter ($PM_{2.5}$, PM_{10}), Volatile Organic Compounds (VOCs), mould) and respiratory implications among preschool children in Selangor. **Methods:** A cross-sectional comparative study was conducted on 270 preschool children in Puchong (study area) and Hulu Langat (comparative area). Respiratory symptoms were assessed using a questionnaire adapted from the American Thoracic Society (ATS). DustTrak Aerosol monitor was used to assess $PM_{2.5}$ and PM_{10}; PbbRAE for measuring VOCs; Q-Trak Monitor for temperature and relative humidity; VelociCalc for air velocity; Pbi DuoSAS Super 360 for mould; Chestgraph HI-101 spirometer for lung function test (Forced Expiratory Volume in 1 second/ Forced Vital Capacity (FEV_1/FVC%) and FEV_1%**. Results:** Indoor $PM_{2.5}$, PM_{10} and mould in the study area was significantly higher (p=0.001). There was a significant difference in FEV_1/FVC%, and FEV_1% predicted in the study and comparative group ($p<0.05$). There was a significant association between $PM_{2.5}$ and PM_{10} with cough ($p<0.005$). Indoor PM10 and VOCs were significantly associated with FVC% ($p<0.05$). VOCs was significantly associated with FEV_1% ($p<0.001$). Logistics regression analysis showed that the risk of FEV_1% abnormality increased significantly with increase in PM_{10} (OR=2.1, 95% CI=2.509-8.221), VOCs (OR=5.3, 95% CI=1.912-14.835) and RH (OR=14.3, 95% CI= 1.451-14.306). **Conclusion:** High exposure to indoor air pollutants increases respiratory symptoms and reduce lung function among children. The moisture-damaged building materials need to be replaced to avoid mould growth.

Keywords: Preschool children, Indoor air quality, Mold, Respiratory symptom

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INTRODUCTION

Indoor air quality (IAQ) refers to the nature of air circulating throughout the space where we live. That is the air human breathe during most indoor times. Indoor air is made up of physical, biological, and chemical components. Indoor air quality is not only for the comfort of occupants affected by temperature and humidity; it comprises harmful biological contaminants and chemicals found in the indoor environment. The biological components of an indoor environment, such as bacteria and mould, have also been shown to contribute to poor indoor air quality. Indoor air quality also comprises the characteristics of the indoor air, including temperature, relative humidity, and how it affects occupants (1,2).

Indoor air quality has become a concern due to the increase in health problems related to the air quality of an indoor environment. People spend more time indoors; hence they are more exposed to indoor air pollutants than outdoor. The rate of ventilation in an indoor environment can significantly affect the level of indoor air pollutants. High ventilation in an indoor environment reduces the spread of communicable diseases (3). The level of microbial pollutants indoors is higher outdoor due to the high ventilation rate. Several studies conducted on microbial air quality of schools have reported an extremely high level of indoor pollution than outdoor pollution (4,5,6,7).

Indoor air pollutant level is more than outdoor pollutant level (2). In recent years, there has been an increase in the prevalence of asthma and allergy among children in Malaysia (8). Indoor environments can be protective. At the same time, they can become toxic when they are contaminated with harmful particles, causing more severe risks than outdoor pollutants (9¬-11¬¬). When the concentration of indoor air pollutants exceeds the recommended maximum limits, it poses many health risks to occupants. Researchers now concentrate on school environments as a second source of exposure besides children's home environments (12-14).

Indoor air monitoring has been conducted in recent studies. These studies measured the indoor level of particulate matter, bacteria, mould, relative humidity, and occupants' thermal comfort (15-18). Indoor air quality can be significantly influenced by environmental factors such as temperature, relative humidity, moisture content of building materials, air density and geographical location (industrial, urban-suburban and rural) (19,20).

Studies conducted in indoor school environments have shown a consistent association between prolonged exposure to indoor air pollutants and a significant increase in respiratory symptoms such as cough, wheeze, asthma, phlegm, shortness of breath, communicable and non-communicable diseases. Studies have also found the association between respiratory health symptoms and the physible mould growth resulting from the accumulation of water and moisture damage on school building materials (14,21-25). The health effects associated with indoor air pollution are more prevalent among children, making them more susceptible than adults. Their immune system is not fully developed. They spend most of their time indoors, including homes and schools, causing prolonged exposure to air pollutants (24-25).

This study compares exposure to indoor air pollutants and the respiratory health implications between children in highly exposed areas (Puchong) and less exposed areas (Hulu Langat).

MATERIALS AND METHODS

Study location

This study involves preschool children in an industrial area in Puchong and a suburban area in Hulu Langat, Selangor, Malaysia. A total of 12 preschools were selected using the purposive sampling method for both the study and comparative area, respectively. Preschools in industrial areas in Puchong represented the exposed area with higher exposure to air pollutants. In comparison, those in Hulu Langat represented the sub-urban area with less exposure to air pollutants. Several inclusion criteria were considered before selecting schools for exposed and comparative areas. The schools in the exposed area are located in the high-density traffic areas, with more than or equal to 18,000 vehicles, located within five kilometres range to highways and industries. The comparative schools are those with an average of 2,800 vehicles and more than five kilometres away from highways and industries (26).

Study design

This study is a cross-sectional comparative study involving assessing IAQ and preschool children's respiratory symptoms. Indoor air quality monitoring was done daily for 4 hours, from 8 am to 12 pm. A sampling of preschools and lung function tests was assessed simultaneously within four months (18th August to 17th December 2017). The respiratory symptoms from the exposure to indoor air pollutants were determined using a questionnaire related to respiratory health symptoms.

Study ethics

Before the commencement of this study, ethical approval was obtained from the Ethics Committee in Universiti Putra Malaysia (UPM) (UPM/TNCPI/RMC/1.4.18.1 (JKEUPM)/F2 for research involving human subjects. Written permission was obtained from preschool management, and consequently, the teachers were briefed on the purpose of the study. An informed consent form was issued to the parents or guardians of the preschool children who participated in this research. The children whose parents or guardians signed the consent form were allowed to participate in this research. The information obtained in this study were kept confidential and used only for academic purpose.

Study population

In this study, a total of 270 preschool children aged between 4-6 years old were randomly selected for this study. The total preschools in the study and comparative areas were 34 and 29, respectively. The preschool children in this study were selected based on certain criteria: healthy children, aged between 4-6 years old, studied in the preschool for at least six months, and children who had a history of doctor-diagnosed respiratory illness were excluded in this study.

Measurement of indoor air pollutants in homes and schools

Indoor air quality assessment in preschools and homes of respondents was conducted by measuring the indoor level of particulate matter, temperature, relative humidity, VOCs, air velocity and mould. The assessment of these parameters in schools and homes was performed from 8 am to 12 pm daily. Air quality measurements in schools were taken throughout the school learning period and break time. Instruments that were used for measurement of indoor air quality in this study includes DustTrak DRX Aerosol Monitor for the measurement of PM_{10}, $PM_{2.5}$; PbbRAE portable VOC Monitor (pbbRAE 3000) for the measurement of VOCs; Q-Trak plus

Model 8554 Monitor for measurement of temperature and relative humidity, TSI Velocicale Plus Model 8386 for air velocity. Duo SAS super 360 microbiological air sampler was used for mould sampling. Air samples were taken using a bioaerosol sampler into petri dishes containing Sabouraud Dextrose Agar (SDA) to enumerate and identify mould. Periodical measurements (1 hour) were taken in all the classes and rooms in the preschools and homes of respondents. This step was done to ensure consistency in the temperature of the building and even distribution of air. The instruments used for air quality assessment was placed one meter from the ground in the classrooms, away from windows, doors, physical disturbances and disruption. Calibration of equipment was carried out before indoor sampling to ensure the accuracy of the results.

Assessment of respiratory health symptoms

A validated questionnaire related to a child's respiratory health adapted from the American Thoracic Society (ATS) (27) was utilised to access the respiratory health symptoms in this study. This questionnaire contained information such as address, age, sex, education, demographic characteristics of respondents' homes, kindergarten distance from school, house distance to major roads, household equipment, smoking habit in the family and respiratory symptoms for the last six months.

Lung function test

A lung function test was conducted using MM-SP004 Tabletop Portable Spirometer. This equipment helps detect how well the lungs can receive, hold, and use the air (oxygen) it receives. The children were required to inhale into a disposable mouthpiece connected to a spirometer recording device. A new disposable mouthpiece was used for each participant, and three readings were taken for each respondent for more accuracy. The data were collected continuously during the learning period and break time. The result obtained was compared with the standard and predicted value obtained from a study by Azizi and Henry (28). The sampling locations are free from any form of disturbances from people, away from windows, doors and a safe place for the children.

Data Analysis

All the collected data were analysed using Statistical Package for Social Science (SPSS) Version 21.0. This software was used to analyse the association and the difference between indoor air quality and the respiratory health implications of preschool children. Descriptive tests (Univariate analysis), which include mean, median, mode and standard deviation, were used to analyse the background of respondents; bivariate analysis, including Student t-test, Mann-Whitney U test and chi-square tests, were used to test the differences and association between study variables, multivariate analysis was performed using multiple logistics regression test to determine the main variables that can cause an influence in the respiratory health of study respondents. The level of significance in this study was set at $p< 0.5$.

Quality control

The calibration of the equipment was done according to the manufacturer's standard to ensure the accuracy of the results. Standards operational and sampling procedures were followed to avoid alteration of results. A new disposable mouthpiece was used for each respondent in this study.

RESULTS

This study was carried out to determine the association between exposure to indoor air pollution and respiratory health implications among Malay preschool children in selected areas in Selangor. A total of 135 children were selected from each location (Puchong and Hulu Langat). The respondents were randomly selected based on those who fulfilled the inclusion criteria.

Indoor air pollutants level in schools and homes

Table I shows the distribution of IAQ parameters in schools and homes. The result shows that preschools in the study area recorded significantly higher values for PM2.5 and PM10 (Z= -2.085, p= 0.037), (Z= -2.085, p=0.037) respectively while comparative schools recorded significantly higher relative humidity (Z= -2.236, p=0.049). Exposure to indoor air pollutants in homes is also shown in table 1. The result of analysis showed a significant difference in the level of .PM2.5, PM10, VOCs and relative humidity in both location (Z= -6.248, p=<0.001), (Z= -6.028, p =<0.001), (Z = -3.222, p =0.001), (Z= -2.489, p=0.013).

Table I. Indoor air quality parameters in study and comparative group (n=270), schools (n=12) and homes (n=60)

Location	IAQ Parameter	Mean ± SD / Median (IQR)		Statistics	
		Study Group	Comparative Group	t / Z	*p*-value
School	$PM_{2.5}$(μg/m³)	61.00 (54.00)	43.00 (21.00)	-2.085[b]	0.037*
	PM_{10}(μg/m³)	104.0 (86.00)	77.00 (22.00)	-2.085[b]	0.037*
	VOC (ppm)	0.04 (1.210)	0.003(0.202)	-0.382[b]	0.702
	Velocity(m/s)	0.308 (0.150)	0.242 (0.090)	-0.646[b]	0.518
	Mold (CFU/m³)	403.0 (250.0)	262.0 (125.0)	-5.783	<0.001**
	Temperature(°C)	30.35± 2.17	30.07 ± 0.68	0.293 [a]	0.776
	Relative Humidity (%)	66.88 ± 4.80	71.73 ± 2.30	-2.236[a]	0.049*

CONTINUE

Table I. Indoor air quality parameters in study and comparative group (n=270), schools (n=12) and homes (n=60) (CONT.)

Location	IAQ Parameter	Mean ± SD / Median (IQR)		Statistics	
Home	$PM_{2.5}$($\mu g/m^3$)	63.0 (47.0)	25.6 (14.0)	-6.248^b	<0.001**
	PM_{10}($\mu g/m^3$)	95.0 (44.0)	31.1 (5.0)	-6.028^b	<0.001**
	VOC (ppm)	0.002 (0.019)	0.001 (0.001)	-3.222^b	0.001*
	Velocity(m/s)	0.28 (0.10)	0.28 (0.10)	-0.524^b	0.601
	Mold (CFU/m^3)	285.0 (236.0)	248.5 (74.0)	-2.189^b	0.028*
	Temperature(°C)	30.2 ± 1.8	28.9 ± 1.6	3.011^a	0.004*
	Relative Humidity (%)	66.9 (10.1)	70.0 (4.7)	-2.489^b	0.013*

** Significant at $p = 0.001$; *Significant p value at 0.05; [a] Independent Sample t test; [b] Mann-Whitney U test.

Lung Function Test among respondents

Table II shows the Lung function of school children, which were assessed based on FVC% predicted, FEV% predicted, and FEV_1/ FVC% predicted. Based on Table II, the mean ± SD or median (IQR) for FVC (litre), FEV_1 (litre), FVC% predicted, FEV_1% predicted, and FEV1/ FVC% predicted are higher among comparative group children. The difference was only significant for FEV_1/ FVC% predicted (p=0.001).

Table II. Lung function test among preschool children (n=270)

Lung Function	Mean±SD / Median (IQR)		t/Z	*p*-value
	Study Group (n=135)	Comparative Group (n=135)		
FVC (litre)	0.90 (0.23)	0.92(0.27)	-0.698^b	0.485
FEV_1(litre)	0.85 (0.20)	0.87 (0.24)	-0.695^b	0.487
FVC% predicted	82.56 ± 23.42	83.74 ± 18.60	-0.485^a	0.647
FEV_1% predicted	83.94 ± 24.62	87.12 ± 18.48	-1.199^a	0.231
FEV_1/ FVC% predicted	105.32 (7.59)	106.68 (2.97)	-3.243^b	0.001*

* Significant p value at 0.05; [a] Independent Sample t-test; [b] Mann-Whitney U test

Lung Function Status and Abnormality among respondents

The evaluation of the lung function test in this study was done by comparing the values obtained with normal values (standard value). The predicted value was calculated based on the study conducted by Azizi and Henry (28) in Malaysia using the values below for boys and girls. Boy: FVC ($4.1120 \times 10^{-6} H^{2.6421}$), FEV_1 ($6.2523 \times 10^{-6} H^{2.5388}$)

Girl: FVC ($6.0777 \times 10^{7} H^{3.00112}$), FEV_1 ($5.7588 \times 10^{7} H^{3.0067}$)

Where:
H =Height
FVC= Forced Vital Capacity
FEV_1= Forced Expiratory Volume in 1 second
FVC% Predicted = (FVC Measured/FVC Predicted)x100
FEV_1% Predicted= (FEV_1 Measured/FEV_1 Predicted) x100

Abnormalities and lung patterns of the respondents were ascertained based on the standard category of lung function in this study. Evaluation of lung function (FVC% Predicted and FEV_1% Predicted) was calculated using the values based on the American Thoracic Society (ATS) (29).

Obstructive diseases (% Predicted FEV1) and Restrictive disease (% Predicted FVC)

Normal -	≥ 80
Mild-	70-79
Severe-	60 – 69
Very severe-	< 60

Table III shows the lung function status and abnormality among respondents. Results show more children with normal lung function parameters (FVC, FEV_1 and FEV_1/ FVC) and lung function status in the comparative group than the study group for all parameters. However, the analysis showed that only FEV_1% status; (χ^2 = 6.943, p=0.008) was significant.

Table III. Lung function status and abnormality among children (n=270)

Lung Function	N (%)		χ^2	p-value
	Study Group (n=135)	**Comparative Group (n=135)**		
FVC% Status				
Abnormal	44 (32.6)	31 (23.0)	3.120	0.077
Normal	91 (67.4)	104 (77.0)		
FEV_1% Status				
Abnormal	39 (28.9)	21 (15.6)	6.943	0.008*
Normal	96 (71.1)	114 (84.4)		
FEV1/ FVC% Status				
Abnormal	3 (2.2)	1 (0.7)	1.015^a	0.622
Normal	132 (97.8)	134 (99.3)		

* Significant *p* value at 0.05; [a]Fisher's Exact test

The Association between IAQ Parameters and the prevalence of cough

The association between indoor air pollutants and the prevalence of cough were computed based on two different categories of exposure levels (highly exposed and less exposed).

Table IV shows the association between IAQ parameters and the prevalence of cough. The analysis showed a significant association between the levels of $PM_{2.5}$ with cough. (OR=4.144, 95% CI = 1.939-8.855, p<0.001). The prevalence of cough was higher among those who resided in locations with high relative humidity, mould spores and high $PM_{2.5}$.

Table IV. Association between IAQ Parameters and the prevalence of cough among study respondents (n=270)

	N (%)		χ²	p-value	OR	95% CI
	Yes (n=41)	No (n=229)				
$PM_{2.5}$ (μg/m³)						
High (> 33.0)	31 (75.6)	98 (42.8)	15.008	<0.001*	4.144	1.939-8.855
Low (≤ 33.0)	10 (24.4)	131 (57.2)				
PM_{10} (μg/m³)						
High (> 39.0)	7 (17.1)	95 (41.5)	8.816	0.003	0.290	1.124-3.683
Low (≤ 39.0)	34 (82.9)	134 (58.5)				
VOC (ppm)						
High (> 0.001)	16 (39.0)	58 (25.3)	3.729	0.070	1.887	0.942-3.779
Low (≤ 0.001)	25 (61.0)	171 (74.7)				
Velocity (m/s)						
High (> 0.50)	0	0	Na	Na	Na	Na
Low (0.15 - 0.50)	82 (100)	188 (100)				
Mold (CFU/m³)						
High (> 403 CFU/m³)	24 (63.9)	20 (49.6)	1.48	0.241	0.150	0.91-3.61
Low (< 403 CFU/m³)	15 (36.1)	23 (50.4)				
Temperature (°C)						
High (> 26.0)	82 (100)	188 (100)	Na	Na	Na	Na
Low (23.0 - 26.0)	0	0				
Relative Humidity (%)						
High (> 65.0)	34 (82.9)	195 (85.2)	0.134	0.715	0.847	0.347-2.065
Low (300 - 65.0)	7 (17.1)	34 (14.8)				

*p value significant at 0.05; na = Not available

The Association between IAQ parameters and FVC% predicted status

Table V shows the association between IAQ parameters and FVC% predicted status. The analysis showed a significant association between FVC% status and VOCs level. High VOCs level significantly increases the risk of FVC% abnormality by 2.7 times (χ^2 =12.153, p= <0.001, OR=2.711, 95% CI = 1.532-4.798).

Table V. Association between IAQ parameters and FVC% predicted status

	N (%)		χ²	*p*-value	Crude OR	95% CI
	Abnormal (n=75)	Normal (n=195)				
$PM_{0.1}$ (pt/cc)						
High (> 0.03)	44 (58.7)	91(46.7)	3.120	0.077	1.622	0.946-2.780
Low (≤ 0.03)	31 (41.3)	104 (53.3)				
$PM_{2.5(}$μg/m³)						
High (> 33.0)	33 (44.0)	96(49.2)	0.008[a]	1.000	0.810	0.474-1.384
Low (≤ 33.0)	42 (56.0)	99(50.8)				
PM_{10}(μg/m³)						
High (> 39.0)	19 (25.3)	83(42.6)	6.842	0.009*	0.458	0.253-0.828
Low (≤ 39.0)	56 (74.7)	112 (57.4)				
VOC(ppm)						
High (> 0.001)	32 (42.7	42(21.5)	12.153	<0.001**	2.711	1.532-4.798
Low (≤ 0.001)	43 (57.3)	153(78.5)				

CONTINUE

Table V. Association between IAQ parameters and FVC% predicted status (cont.)

	N (%)		χ^2	*p*-value	Crude OR	95% CI
	Abnormal (n=75)	**Normal (n=195)**				
Velocity(m/s)						
High (> 0.50)	0	0	na	Na	na	Na
Low (0.15 - 0.50)	82 (100)	188 (100)				
Mold (CFU/m³)	28 (69.1)	23 (58.6)	18.142	0.632	2.621	0.321-1.421
High (>402 CFU/m³)	18 (30.9)	16 (51.4)				
Low (< 402 CFU/m³)						
Temperature(°C)						
High (> 26.0)	82 (100)	188 (100)	na	Na	Na	Na
Low (23.0 - 26.0)	0	0				
Relative Humidity (%)						
High (> 65.0)	61 (81.3)	168(86.2)	0.977	0.323	0.700	0.345-1.423
Low (30.0 - 65.0)	14 (18.7)	27(13.8)				

** Significant at *p* = 0.001; *p*-value significant at <0.05; na= Not available.

The Association between IAQ parameters and FEV_1% predicted Status

Table VI shows the association between IAQ parameters and FEV_1% predicted status among study respondents. There was a significant association between FVC% status and level of VOCs. High VOCs significantly increase the risk of FEV_1% predicted abnormality by 1.7 times.

Table VI Association between IAQ Parameters and FEV_1% Predicted Status among study respondents

	N (%)		χ^2	p-value	Crude OR	95% CI
	Abnormal (n=60)	**Normal (n=210)**				
$PM_{0.1}$ (pt/cc)						
High (> 0.03)	39 (65.0)	96 (45.7)	6.943	0.008*	2.205	1.215-4.002
Low (≤ 0.03)	21 (35.0)	114 (54.3)				
$PM_{2.5}$(µg/m³)						
High (> 33.0)	30 (50.0)	99 (47.1)	0.153	0.696	1.121	0.632-1.991
Low (≤ 33.0)	30 (50.0)	111 (52.9)				
PM_{10}(µg/m³)						
High (> 39.0)	18 (30.0)	84 (40.0)	1.985	0.159	0.643	0.347-1.192
Low (≤ 39.0)	42 (70.0)	126 (60.0)				
VOC(ppm)						
High (> 0.001)	28 (46.7)	46 (21.9)	14.382	<0.001**	3.120	1.706-5.704
Low (≤ 0.001)	32 (53.3)	164 (78.1)				
Velocity(m/s)						
High (> 0.50)	0	0	na	Na	na	Na
Low (0.15 - 0.50)	188 (100)	82 (100)				
Mold (CFU/m³)	19 (31.9)	18 (23.0)	6.641	0.615	0.543	1.18 -5.32
High (>402 CFU/m³)	21 (68.1)					
Low(< 402 CFU/m³)		24 (77.0)				
Temperature (°C)						
High (> 26.0)	188 (100)	82 (100)	Na	Na	Na	Na
Low (23.0 - 26.0)	0	0				
Relative Humidity (%)						
High (> 65.0)	48 (80.0)	181 (86.2)	1.389	0.239	0.641	0.304-1.349
Low (30.0 - 65.0)	12 (20.0)	29 (13.8)				

** Significant at p = 0.001; p value significant at 0.05; na= Not available

Factors that influenced the abnormality of lung function (FEV_1% predicted) among respondents

Table VIIa shows the significant factors that influenced the abnormality of lung function (FEV_1% predicted) among respondents in this study. Statistical analysis shows that the risk of FEV_1% abnormality increased significantly among children whose school had PM10 (AOR=2.1), VOCs (AOR= 5.3) and RH (AOR=14.3). Houses that were extremely dusty (AOR=2.7) and located about 100-500m from the main road (AOR=3.3) are more likely to cause FEV_1% predicted abnormality threat. The model explained 25.9% of the variance in FEV_1% predicted abnormalities and correctly classified 80.0% of cases.

Factors that influenced cough symptoms among the respondents after controlling all confounders

Table VIIb shows the significant factors that influenced cough symptoms among the respondents after controlling all confounders in this study. Logistics regression was used to assess the factors that could influence the respiratory symptoms in this study after all confounders were controlled. The risk of getting cough increased significantly among children whose school had a higher level of $PM_{2.5}$ (AOR=5.4). On the other hand, the risk was also higher among children who live in sub-city (AOR=6.9) and whose houses were located less than one kilometre from a factory (AOR=3.3). The model explained 16.7% of the variance in cough symptoms and correctly classified 85.2% of cases.

Table VII. Factors that Influence the Lung Function ($^aFEV_1$%) abnormality and Respiratory symptom (^{b}Cough) among study respondents after controlling all confounders

$^aFEV_1$%	B	S.E	p-value	AOR	95% CI
$PM_{0.1}$ (pt/cc)					
High (> 0.03)	0.910	0.461	0.048*	2.485	1.006-6.135
Low (≤ 0.03)					
PM_{10}(μg/m³)					
High (> 39.0)	3.063	1.093	0.005*	21.382	2.509-182.218
Low (≤ 39.0)					
VOC (ppm)					
High (> 0.001)	1.672	0.523	0.001*	5.325	1.912-14.835
Low (≤ 0.001)					
Relative Humidity (%)					
High (> 65.0)	2.658	1.166	0.023*	14.266	1.451-14.306
Low (30.0 - 65.0)					
Mold (CFU/m³)					
High (>402 CFU/m³) Low (< 402 CFU/m³)	0.431	0.660	0.513	0.621	0.171-2.372
Temperature					
	-1.158	0.384	0.003*	0.314	0.148-0.667
House Environment					
Less Dusty					
Moderate Dusty	0.649	0.375	0.084	1.914	0.917-3.992
Very Dusty	1.000	0.486	0.040*	2.717	1.048-7.041
Distance from Main Road					
< 100 meters	0.121	0.511	0.813	1.129	0.415-3.072
> 100 – 500 meters	1.191	0.491	0.015*	3.292	1.259-8.609
> 500 – 1000 meter	0.162	0.517	0.754	1.176	0.427-3.241
> 1000 meter					
^{b}Cough					
$PM_{2.5}$ (μg/m³)					
High (> 33.0)	0.936	0.460	<0.001**	5.385	2.365-14.391
Low (≤ 33.0)					
Velocity (m/s)	-8.484	3.259	0.009*	0.003	0.000-0.123
Duration Living in the Area					
≤ 1 year					
> 1 year	0.919	0.415	0.027*	2.507	1.112-5.652
Nature of Area					
Rural					
Sub-city	1.942	0.791	0.014*	6.970	1.480-32.839
City	1.170	0.808	0.148	3.221	0.661-15.686
Distance from Factory					
< 1 kilometre	1.180	0.580	0.042*	3.253	1.043-10.145
> 1 – 1.5 kilometre	0.595	0.508	0.241	1.812	0.670-4.902
> 1.5 – 3 kilometre	-0.130	0.524	0.804	0.878	0.314-2.451
> 3 kilometre					

Adjusted factors: Study group, Gender, Age, Fathers Education, Mothers Education, Monthly Household Income, Weight, Height; **p value significant at 0.001; *p value significant at 0.05;

AOR=Adjusted Odds Ratio; Nagelkerke FEV1 $^aR_2$ = 25.9%. Cough $^bR^2$ = 16.7%.

Discussion

A clean preschool environment provides a healthy and comfortable environment for learning activities among school children. IAQ parameters were measured for each location in all the classes. These include $PM_{2.5}$, PM_{10}, Volatile Organic Compound (VOCs), temperature, relative humidity, air velocity and presence of mould. This study reported a higher level of indoor pollutants in the study area for schools and homes.

Table I shows the level of indoor air pollutants and physical parameters in the study and comparative preschools and homes of respondents. The schools in the study area recorded a significantly higher level of $PM_{2.5}$, PM_{10}. In contrast, the schools in the comparative area recorded higher relative humidity. The result also shows the indoor pollutants level in the respondent's homes. The mean ± SD and median (IQR) values for $PM_{2.5}$, PM_{10}, VOCs, mould spores and the temperature was reported higher in the study area compared to the comparative area. At the same time, relative humidity was slightly higher in the comparative area.

This study recorded a higher indoor concentration of PM_{10} 104.0(86.00) μg/m^3 in the study area than the comparative area PM_{10} 77.00(22.00) μg/m3. The level of PM_{10} in this study was compared with other international and local standards, recommended for indoor exposure to PM_{10} for 8 hours exposure, which includes U.S Environmental Protection Agency (USEPA), Department of Environment and Department of Occupational Safety and Health (DOSH) Malaysia which is 150 μg/m^3. Therefore, the result obtained in this study did not exceed the recommended standard (30-32). The ambient standard was used in comparison for particulate matter in this study to ensure that the level is within the permissible limit and protect occupants' health.

The concentrations of particulates can be influenced by different sources, such as cooking activities in preschools. Most preschools had a kitchen where meals were prepared for the children. During cooking (especially during frying), particles are emitted into the building environment. Particulate matter can also be found in places with higher traffic density. The emissions of fine particles from vehicle fossil fuel can reduce the quality of air inside the classrooms (33). Buildings located close to the main roads in developed areas are more exposed to high particles, especially during morning rush hours (34-36). A local study conducted by Arifuddin et al. (37) found higher concentrations of $PM_{10,}$ $PM_{2.5}$ and VOCs in schools located in high traffic areas (Kajang) compared to schools located in lower-traffic areas (Hulu Langat) in Malaysia.

The high level of particles recorded in the study area can be attributed to outdoor sources such as particles from major roads, industries and indoor activities. The chemicals used for cleaning purposes and cooking gas could be a source of exposure to indoor pollutants. Most schools had kitchens where meals were prepared for the children. While cooking, gas and vapour are emitted into the classrooms where children take their classes. A similar result was seen in a study conducted by Supu et al. (14) which found a significant difference in the level of $PM_{2.5}$, PM_{10}, and mold in homes of study and comparative area (Z= -2.883, p= 0.004), (Z= -3.149, p= 0.002) and (Z= -2.198, p= 0.028) respectively.

Schools in the exposed area reported a higher level of particulates due to higher exposure to pollutants from outdoor sources such as dust from roads. The emission of particles is more during the morning hours when the roads are very busy (38-40). Previous local studies conducted in urban areas also found that indoor levels of $PM_{2.5,}$ PM_{10}, VOCs, mold and bacteria were higher in the studied area compared to the comparative area. This was attributed to the location of schools (41,42).

Similarly, a study by Hisamuddin et al. (9) also found a higher median (interquartile range) concentration of $PM_{2.5}$ (246.67(11.55) μg/m^3) and PM_{10} (193.33(11.55) μg/m^3) for urban areas and PM2.5 (40.00(20.00) μg/m3), PM10 (66.67(5.77) μg/m^3) for rural area respectively. Another study by Ismail et al. (6) also found a significant difference between exposed and comparative group for $PM_{2.5}$ (Z= -2.323, p =0.020) and PM_{10} (Z= -2.323, p =0.020).

This study found that the indoor level of VOCs (ppm) was higher at 0.04 (1.210) in the study area compared to the level in the comparative area was 0.003 (0.202). However, the result was not statistically significant for the VOCs levels in the study and comparative preschools (Z=-0.382, p = 0.702). The result did not exceed the recommended value (3ppm), compared with the Department of Safety and Health (DOSH) Malaysia.

A study by Suhaimi et al. (2) also found a significant difference ($p<0.05$) between indoor VOCs levels in urban and suburban areas, respectively (0.257 ppm and 0.003 ppm). Their study concluded that the level of VOCs may be due to the materials used inside the preschools.

Indoor sources of VOCs could be generated from high VOCs emitting materials like furniture, house paints, and carpet and cleaning agents. The distance of the preschool to the main road and factories can also increase indoor sources of VOCs. All chairs, tables and bookshelves found in the schools were made of pressed woods that emit formaldehyde gases (40,1). The most common types of VOCs found in schools are benzene, xylene, limonene, ethylbenzene, and toluene.

The chemicals used in homes for cleaning purposes could be a source of exposure to indoor VOCs. The use of cooking gas in homes could also expose children to pollutants. The analysis in this study shows that most of the parents used cooking gas, and cooking was done as often as 1-2 times daily. A higher percentage of parents in the study area also reported mosquito-killing agents as often as four times a week. The mosquito repellents were mostly placed in the bedroom and the living room. The presence of pets in homes could also be a source of exposure to pet allergen. The location of houses could also be a source of exposure to outdoor pollutants. Houses in the study area were located close to the main roads, where vehicles' emissions are usually high throughout the day (38). This study shows that preschool children in the study area are more exposed to home pollutants than those in the comparative homes, which could be attributed to reduced lung function among respondents.

This study found a significantly higher concentration of mould colonies of 403.0(250.0) CFU/m^3 in the study area compared to the comparative area, which was 262.0(125.0) CFU/m^3, where (Z= -5.783, p < 0.001). The result obtained in this study was compared with WHO (43) guidelines for eight hours of exposure to mould colonies (500CFU/m^3). Analysis shows that the result obtained in this study did not exceed the recommended level. The higher concentration of indoor mould observed in the industrial area could result from a high level of indoor air pollutants, low humidity, and ventilation rate. From observation in this study, building materials used in some preschools located in the industrial area had physible moisture problems and mould growth on them. This could be a source of exposure to mould-related symptoms such as cough, wheeze, headache, allergy and others.

A local study was conducted by Supu et al. (14) among preschool children in industrial and suburban areas. This study found a significant difference in the indoor level of mould between preschools in studied and comparative areas (Z= -5.793, p <0.001). The median (IQR) mould concentration level was 402.0 (260.0) and 252.0 (135.0) in the study and comparative area, which is in line with this study. This study found a higher report of respiratory symptoms among preschool children in the exposed area.

The indoor level for relative humidity (RH) obtained in this study show a significant difference for the study and comparative areas. The mean (SD) for the study area is 66.88 ± 4.4.80, while the comparative area is 71.73 ± 2.30 area. The range for relative humidity (RH) in this study exceeded the recommended range set by the American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE), 30-65%.

The main factor that could influence indoor humidity level is the thermal condition from the outdoor school environment. A high humidity rate increases the growth of microorganisms. A study conducted by Supu et al. (14) found an indoor level of relative humidity with the percentage of 70.5(4.6) % and 76.3(3.5) % in Puchong and Hulu Langat day-care centres, respectively. The level of indoor air pollutants at home could be attributed to indoor activities.

The thermal condition of an indoor environment can be influenced by the thermal condition of the outdoor environment. When the rate of humidity in an indoor environment is high, it increases the growth and multiplication of microbial particles. The high humidity rate could also be attributed to the use of air conditioning in the schools. In this study, the result for air velocity value shows that the difference is not statistically significant (p >0.05). This study also found a slightly higher relative humidity in the study and comparative group 60.80-86.00% and 62.00-87.00%, respectively. The recommended range for air movement is between 0.15-0.50m/s. A well-ventilated preschool reduces the risk of getting respiratory symptoms. Proper ventilation is essential to reduce mould growth in preschools (44).

The Department of Occupational Safety and Health (DOSH) Malaysia (45) has set standards for indoor temperature between 23-260C. The mean (SD) in this study has exceeded the recommended range of 30.35 ± 2.170C for the study area and 30.07 ± 0.680C for the comparative area. However, the result was not significant. The high temperature could be a result of improper ventilation. Most schools close their doors during school hours, therefore not letting enough ventilation into the classrooms.

A study by Supu et al. (14) found the average indoor temperature higher in the urban area (31.19 (3.0)0C compared to the suburban area (30.64 (2.3). The indoor temperature in this study was not statistically significant (p= 0.018). American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) has set an acceptable range for indoor humidity standards between 30–65% for the welfare and comfort of occupants. An independent sample t-test was used to compare the humidity level in both locations. The mean (SD) value for relative humidity recorded in this study is shown in Table 4.11. The result shows that the value exceeded the recommended range of 66.88 ±4.80 for the study area and 71.73 ± 2.30 for the comparative area. The result also shows a significant difference for both locations.

Table II shows the result of the lung function of respondents in the study and comparative area. The value of FEV1 and FVC were higher in the comparative area than in the study area. However, the result was statistically significant for both locations. Exposure to indoor air pollutants can cause a decrease in the lung function of occupants in the study and comparative group.

The previous study by Supu et al. (14) has also shown a similar result for lung function status of children. The found the mean value for FVC (litres) to be 0.61 ± 0.20 and 0.75 ± 0.19 for study and comparative areas, while the value of FEV1 (litres) was 0.59 ± 0.19 and 0.74 ± 0.19 for study and comparative area, respectively. This study found that the value of FVC (litres) and FEV1 (litres) were significantly lower in the study group when compared to the comparative group ($t = -3.710$, $p<0.001$) and ($t = -4.027$, $p<0.001$). The value for FVC% predicted and FEV_1% predicted in this study were also found to be significantly lower ($t= -4.811$, $p<0.001$) in the study area compared to the comparative area ($t=-4.577$, $p<0.001$).

Table III shows the lung function status and abnormality among respondents. A significant difference was found in the respondents' FEV_1% ($\chi^2 = 6.943$, $p=0.008$) status. Furthermore, there were more children with normal lung function parameters (FVC, FEV_1 and lung function status) in the comparative group than the study group for all parameters. This could be attributed to the level of exposure to pollutants in the study area, causing a decrease in the lung function of occupants. When there is an obstruction and restriction in the lung, it causes an abnormality in the lung function.

A local study by Supu et al. (14) in preschool also found a significant difference in FEV_1% status of respondents between study ($\chi^2 =20.979$, $p<0.001$) and comparative area children ($\chi^2= 23.177$, $p=0.001$). This study found that PM10 influenced the FEV_1 status in preschool children ($p=0.036$).

Table IV shows the association between IAQ parameters and the prevalence of cough among study respondents. This study shows that the prevalence of cough was reported higher in locations with higher mould spores and relative humidity and places with low $PM_{2.5}$, PM_{10} and VOCs. Increased risk of cough was seen in locations that recorded high $PM_{2.5}$ (OR = 4.144). $PM_{2.5}$ significantly increases the risk of cough.

The same result was obtained in a study conducted by Siwarom et al. (46) among exposed preschool children compared to the comparative group. Exposure to indoor pollutants increases the prevalence of respiratory symptoms among exposed while an increased ventilation rate reduces the spread of infections in an indoor environment (8)

Table V shows a significant association between FVC% predicted status and VOCs level, which significantly increases the risk of FVC% predicted abnormality by 2.7 times ($\chi^2= 14.382$, $p= <0.001$, OR=2.711, 95% CI = 1.532-4.798). There was a significant association between FVC% status and level of VOCs in this study, which shows that the preschool location and the nature of the area where schools are located can contribute to an increase in lung function abnormalities among preschool children.

A study conducted by Arifuddin et al. (3) found a higher prevalence of abnormality in FVC% predicted and FEV_1% predicted among the exposed group. Pollutants from traffic are associated with adverse health effects and reduction in FVC and FEV_1 status among respondents.

Table VI shows the association between IAQ parameters and FEV1% predicted status among study respondents. A higher prevalence of abnormal FEV1% was reported in high relative humidity locations and low PM_{10}, mould and VOCs. High VOCs level significantly increases the risk of FEV_1% predicted abnormality by 3.1 times ($\chi^2= 14.382$, $p= <0.001$, OR=3.120, 95% CI = 1.706-5.704).

A similar result was also seen in a study by Jung et al. (47), which recorded a significant association between indoor PM_{10} ($p=0.003$) and abnormality of FEV_1 predicted status among study respondents. The size of particles determines where they are deposited when they are inhaled into the respiratory system. PM_{10} can cause health problems when they are inhaled into the respiratory tract.

A study by Supu et al. (14) in Puchong and Hulu Langat area in Malaysia also found a significant association between FEV_1% predicted abnormality and indoor level of $PM_{2.5}$ ($p=0.013$, PR=2.66, 95% CI= 1.22-5.79), PM_{10} ($p=0.013$, PR=2.66, 95% CI=1.22-5.79), VOCs ($p=0.001$, PR=3.67, 95% CI=1.66-8.13). This study also found that high VOCs (ppm) significantly increase the risk of abnormality of FEV_1 status by 3.67 times.

Table VII shows the factors that influence the lung function (FEV_1) abnormality and respiratory symptom (cough) among study respondents after all confounders in this study were controlled. The confounders controlled in this study include the house environment and distance from the house from the main road. High risk was found among children with high PM_{10}, VOCs and relative humidity. Children who reside in houses located 100-500km from high way had a higher risk of having FEV_1 abnormality (AOR= 3.3). The model explained about 25.9% of the variance in FEV_1% predicted abnormality and correctly classified 80.0% of cases.

In this study, the risk of getting a cough increased significantly with an increased indoor concentration of $PM_{2.5}$ (AOR=5.385). At the same time, increased air velocity reduces the risk of cough (AOR=O.003). The result shows that the location of preschools and residential areas of preschool children could affect the respiratory health of children by causing respiratory health symptoms and deterioration in children's lung function. The nature of the area where children live can be due to their socioeconomic status. Those who live in a good and clean environment are less exposed to pollutants (44). Relative humidity and air velocity could also reduce the spread of respiratory symptoms among preschool children. When there is proper ventilation in preschools, it allows for the exchange of air in preschools, thereby reducing the spread of airborne diseases and reducing the growth of microorganisms, especially mould. Low temperature and humidity create a suitable environment for the growth of fungi and bacteria.

Studies among secondary school children in suburban and urban areas in Hulu Langat, Selangor, also found a significant difference ($p<0.001$) in the indoor level of relative humidity, PM_{10}, $PM_{2.5}$, VOCs (Formaldehyde) and temperature. These indoor air pollutants increase the risk of respiratory symptoms. Relative humidity and air velocity could also reduce the spread of respiratory symptoms among preschool children. When there is proper ventilation in preschools, it allows for the exchange of air in preschools, thereby reducing the spread of airborne diseases and reducing the growth of microorganisms, especially mould. Low temperature and humidity create a suitable environment for the growth of fungi and bacteria. (11,48,49).

CONCLUSION

This study found a higher exposure to indoor air pollutants ($PM_{2.5}$, PM_{10}, VOCs, mould), temperature and relative humidity among children in exposed areas, which may have increased the respiratory symptoms and caused reduced lung function among preschool children. The result obtained in this study shows a significant difference in the level of indoor air pollutants in the exposed area compared to the comparative area. It is recommended that the location of preschools should be done in places that are less exposed to outdoor sources of pollutants. Outdoor activities should be minimised for schools located close to sources of pollutants.

This study found that exposure to indoor air pollutants significantly increases the risk of respiratory symptoms such as cough, phlegm and wheezing and reduced lung function. An increase in respiratory symptoms could be linked to improper ventilation, which increases the spread of communicable infections. Adequate ventilation and indoor air quality assessment is necessary to ascertain the level of indoor air pollutants to ensure they are within the permissible value.

Mould can grow on surfaces that have been damaged by water. This study found that most preschools had visible water damage in the classrooms where the children had their classes both in the study and comparative areas. The water damages may create a favourable environment for the growth and multiplication of indoor mould. School teachers, the public and parents should be aware of the health risk of exposing preschool children to indoor air pollutants.

The use of moisture-damaged building materials in schools should be avoided to prevent mould growth. In conclusion, preschools should not be located close to main roads or sources of indoor pollutants. Water damaged ceiling and walls should be remediated to avoid further growth and multiplication of mould. High VOCs emitting materials should not be used in schools to minimise the level of VOCs in classrooms. School teachers, the public and parents should be aware of the health risks of exposing preschool children to indoor air pollutants.

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