Exposure to PM_{10} and NO_2 and Association with Respiratory Health among Primary School Children Living Near Petrochemical Industry Area at Kertih, Terengganu

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***Abstract*—This study was carried out to determine the level of exposure to PM_{10} and NO_2 and its relation to respiratory health among primary school children living near petrochemical industry area at Kertih, Terengganu. This cross sectional comparative study was conducted among 60 children from studied group and 60 children from comparative group. The respondents were selected based on inclusive criteria's for this study. Level of exposure of PM_{10} was measured using DustTrak Aerosol Monitor while level of exposure of NO_2 was measured using LaMotte Air Sampling Pump. Questionnaire was used to collect information on respondent's socio-demography background and respiratory symptoms. Lung function test was performed using Spirometer. Results showed that the mean concentration of PM_{10} (79 μg/m^3) and NO_2 (3.73 ppm) for studied group was higher compared to comparative group, PM_{10} (49 μg/m^3) and NO_2 (0.14 ppm). As overall, reported respiratory symptoms were significantly higher among studied group compare to comparative group. Significant reduction value of FEV_1/FVC% showed that there was airways obstruction for studied group. Findings from this study indicated that exposure to indoor PM_{10} and NO_2 concentrations may increase risk of getting respiratory symptoms and reduction of lung function among primary school children living near petrochemical industry area.**

***Index Terms*—PM_{10}, NO_2, respiratory symptoms, lung function, primary school children**

I. Introduction

There is growing concern about indoor air quality especially in the classroom [1]. School that is situated near to industry area has been the most concern due to prolong exposure to air pollutants that may cause health effect to children. One of the major industry sectors that produce air pollutants is petrochemical industries [2]. Child's respiratory system is the primary target for air pollutants such as PM_{10} and NO_2 [3]. Compared to adults, children are one of the most sensitive population subgroups since they may receive an increased dose of particulate matter to their lungs. In previous study carried out in China [2], it was demonstrated that school children that living near petrochemical industrial area have significantly more respiratory symptoms compared to control area. This great concern of pollutant emitted by petrochemical industries recently triggered local researchers to conduct preliminary air pollution simulation at this research site [4]. Further exercises focusing on NO_2 emitted by point source emission revealed that the maximum yearly out door concentration of NO_2 range from 6.91 to 8.49 ug/m^3 for a 5 years period from 2004 to 2008 [5]. Though the result obtained comparatively below the WHO guideline which is at 40ug/m^3, it is an intended of this paper to further explore the exposure of indoor air condition in related to respiratory health as the indoor air is well influenced by the outdoor air condition.

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II. Methodology

A. Study Background

This cross sectional comparative study was conducted among 120 primary school children and the entire respondents were Malay. Total of 60 school children from Sekolah Kebangsaan Paka III, Kertih were selected as a studied group and total of 60 school children from Sekolah Kebangsaan Serdang, Dungun were selected as a comparative group. Random sampling method was used to select the respondents based on inclusive criteria's such as aged between 10 to 12 years old, boys and girls and living near, which was 1 km from petrochemical industry area for studied group and living far, which was 10 km from petrochemical industry area for comparative group.

B. Questionnaire Form

Questionnaire was given based on standard questionnaire by American Thoracic Society for children.

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It focused on respiratory symptoms, home environment exposures, history of lung disease and socio-demographic information.

C. Monitoring in School

Measurement of the indoor air pollutant (PM_{10} and NO_2) inside the classroom of schools were performed for 5 hours during school hours by using Dust Track Aerosol Monitor to measure the concentrations of PM_{10} and LaMotte Air Sampling Pump to measure the concentrations of NO_2 that were placed 1.5m (same level of breathing zone of children) above floor level [1] at the back of the classroom. The area was selected to avoid any disruption of sound from instruments during learning session and avoid attraction from children.

D. Lung Function Test

Based on standardized procedure by American Thoracic Society, researcher explained and demonstrated to school children and asked them to inhale deeply in standing position and blew rapidly and completely into calibrated spirometer. The abnormalities are categorized according to American Thoracic Society Standard.

E. Statistical Analysis

Data collected in this study was analyzed using Statistical Packages for Social Sciences (SPSS, version 13). Anthropometric data were analyzed by using Mann-Whitney U and Independent T-Test. Mann-Whitney U was used to make comparison of lung function and indoor PM_{10} concentrations. Independent T-Test was also used to compare and to determine association between categorical variables. Results of the associations were also expressed as prevalence ratio (PR) and 95% confidence interval. Continuous variables were presented as mean and standard deviation (SD).

III. Results

A. Background and Selection of Respondent

This study was conducted to determine the relationship of exposure to PM_{10} and NO_2 with respiratory health among primary school children living near petrochemical industry area at Kertih, Terengganu. There were 45% boys ad 55% girls from the studied group while there were 46.67% boys and 53.33% girls from the comparative group who participated in this study.

B. Concentration of Indoor PM_{10} and NO_2

Table I illustrates the mean of indoor PM_{10} and NO_2 concentrations for the studied and comparative group. From statistical analysis, average of indoor PM_{10} concentration in the studied group was higher than the comparative group. The average value of indoor PM_{10} concentration for the studied group was $79\,\mu g/m^3$, whereas the average value of indoor PM_{10} concentration for the comparative group was $49\,\mu g/m^3$. Therefore, indoor PM_{10} concentration between studied and comparative groups were significantly different ($z = -10.91$, $p<0.001$). The average value of indoor NO_2 concentration for the studied group was 3.73 ppm, whereas the average value of indoor NO_2 concentration for the comparative group was 0.14 ppm. Therefore, indoor NO_2 concentrations between studied and comparative groups were significantly different ($t = 1.93$. $p<0.001$).

TABLE I. Comparison of Indoor PM_{10} and NO_2 Concentrations between Two Study Groups.

Paramaters	Studied (n = 60)	Comparative (n = 60)	z-value	p-value
	Mean	Mean		
PM_{10} ($\mu g/m^3$)	79	49	-10.91	0.001*
NO_2 (ppm)	3.73	0.14	1.93	<0.001*

N = 120
**significant at p<0.001

C. Lung Function Test

Lung function status among children was evaluated on FEV_1% predicted, FVC% predicted and FEV_1/FVC% predicted parameters. FEV_1% predicted and FVC% predicted were obtained based on normal value by Azizi and Henry [6]. Table II demonstrates the comparison of lung function between studied and comparative groups.

Therefore, mean of FEV_1% predicted was 76.25 ± 25.51 and 78.12 ± 18.06 for studied and comparative groups respectively. Mean for FVC% predicted was 77.56 ± 20.9 for studied group and 73.48 ± 16.47 for comparative group while mean of FEV_1/FVC% predicted for studied group was 98.79 ± 18.99 and 106.58 ± 9.96 for comparative group respectively. Mann-Whitney U test was performed to compare the values of FVC (litre/s), FEV_1 (litre/s), FEV_1% predicted, FVC% predicted and FEV_1/FVC% predicted between studied and comparative group. The statistical analysis proved that only FEV_1/FVC% predicted was significantly different between studied and comparative group ($z = -2.02$, $p = 0.04$).

TABLE II. Comparison of Lung Function Level between Two Study Groups

Variables	Exposed group (n= 60)	Comparative group (n= 60)	z-value	p-value
FVC% predicted	77.56 ± 20.9	73.48 ± 16.47	-0.49	0.62
FEV_1% predicted	76.25 ± 25.51	78.12 ± 18.06	-1.19	0.24
FEV_1/ FVC% predicted	98.79 ± 18.99	106.58 ± 9.96	-2.02	0.04*

Mann U Whitney Test
*significant at p<0.05

D. Respiratory Health Symptoms

Questionnaire was based on standard questionnaire by American Thoracic Society and used to determine the symptoms of respiratory disease among respondents in the two study groups. Respiratory symptoms included cough, phlegm, chest tightness, and wheezing. Reported respiratory symptoms between the two studies groups were presented in Table III. Results showed that 32 (53.33%) for studied group and 11 (18.33%) for comparative group were having cough. In addition, about 15 (25%) and 2 (3.33%) for studied and comparative groups were having phlegm. Chest tightness among children is 8 (13.33%) for studied group and 1 (1.67%) for comparative group. Lastly, for wheezing which was about 16 (26.67%) for studied group and only 3 (5%) for comparative group. Symptoms experienced the most by the respondents were cough, followed by phlegm, wheezing and chest tightness. As overall, reported respiratory health symptoms among studied group were higher than comparative group.

Results from statistical analysis by using Chi-Square test revealed that reported respiratory health symptoms were significantly higher among studied children which were 5 times likely to get cough (PR = 5.09, 95% CI = 2.23-11.65), and 9 times likely to get phlegm (PR = 9.66, 95% CI = 2.10-44.46), chest tightness (PR = 9.08, 95% CI =1.09-75.0) and wheezing (PR = 9.07, 95% CI =1.89-25.2) compared to comparative group.

TABLE III. PREVALENCE OF RESPIRATORY SYMPTOMS BETWEEN TWO STUDY GROUPS

Variables	Studied group (%) Total=60	Comparative group (%) Total=60	p-value	Prevalence ratio (PR)	95% CI
Cough					
Yes	32 (53.33)	11 (18.33)	<0.001*	5.09	2.23-11.65
No	28 (46.67)	49 (81.67)			
Phlegm					
Yes	15 (25)	2 (3.33)	0.001*	9.66	2.10-44.46
No	45 (75)	58 (96.67)			
Chest tightness					
Yes	8 (13.33)	1 (1.67)	0.015*	9.08	1.09-75.0
No	52 (86.67)	59 (98.33)			
Wheezing					
Yes	16 (26.67)	3 (5)	0.001*	9.07	1.89-25.2
No	44 (73.33)	57 (95)			

N=120
**significant at p<0.001

E. Association between Indoor PM_{10} and NO_2 Concentrations and Lung Functions among Studied Group.

Results from Table IV and V, the results showed that there were significant associations between levels of PM_{10} and NO_2 and lung functions. Children among studied group were categorized into normal and abnormal for lung functions.

TABLE IV. ASSOCIATION BETWEEN INDOOR PM_{10} CONCENTRATIONS AND LUNG FUNCTIONS AMONG STUDIED GROUP

Lung function	High PM_{10} level (>79 μg/m^3) Total (%)	Low PM_{10} level (<79 μg/m^3) Total (%)	p-value
Abnormal**	9 (15)	0 (0)	0.002*
Normal	22 (36.67)	29 (48.33)	

N = 60
Studied group = exposed
*significant at p<0.05
**Fisher exact test for value <5

F. Association between Indoor PM_{10} and NO_2 Concentrations and Respiratory Health Symptoms among Studied Group

As shown in Table VI, there was significant association between indoor PM_{10} concentrations and respiratory health symptoms among studied group which were, cough, phlegm, chest tightness and also wheezing. All the symptoms showed increased risk from exposure of indoor PM_{10} concentrations which were cough (PR= 4.64, 95% CI= 1.56-13.81), phlegm (PR=9.75, 95% CI= 1.96 – 48.47), chest tightness (PR= 3.43, 95% CI= 1.87 – 15.23) and wheezing (PR= 3.95, 95% CI= 1.09 – 3.95). The p-value obtained for cough (p= 0.005), phlegm (p= 0.002), chest tightness (p= 0.003), and wheezing (p= 0.03).

TABLE V. ASSOCIATION BETWEEN INDOOR NO_2 CONCENTRATIONS AND LUNG FUNCTIONS AMONG STUDIED GROUP

Lung function	High NO_2 level (> 3.73 ppm) Total (%)	Low NO_2 level (< 3.73 ppm) Total (%)	p-value
Abnormal**	9 (15)	0 (0)	0.024*
Normal	32 (53.33)	19 (31.67)	

N = 60
Studied group = exposed
*significant at p<0.05
**Fisher exact test for value <5

As shown in Table VII, there were also significant associations between indoor NO_2 concentrations and respiratory health symptoms among studied group which includes cough, phlegm, and chest tightness even all the symptoms show increased risk from exposure of indoor NO_2 concentrations which were cough (PR= 2.93, 95% CI= 1.02 – 8.45), phlegm (PR=7.43, 95% CI=1.50 – 36.79), chest tightness (PR= 5.86, 95% CI= 6.49 – 16.32) and wheezing (PR= 3.00, 95% CI=0.84 – 10.75). The p-

value obtained for cough (p= 0.043), phlegm (p= 0.007), and chest tightness (p= 0.008).

G. *Logistic Regression for Association between Indoor PM_{10} and NO_2 and FEV_1/FVC% predicted after controlling the Confounders.*

Logistic regression was conducted to determine the association between PM_{10} and NO_2 and FEV_1/ FVC% predicted among two study groups after controlling the confounders in the study. Table VIII showed main variables, PM_{10} and NO_2 that influenced FEV_1/ FVC% predicted among students after controlling the confounders (p=0.03).

TABLE VI. ASSOCIATION BETWEEN INDOOR PM_{10} CONCENTRATIONS AND RESPIRATORY HEALTH SYMPTOMS AMONG STUDIED GROUPS.

Variables	High PM_{10} level (> 64 µg/m3) Total (%)	Low PM_{10} level (< 64 µg/m3) Total (%)	p-value	PR (95% CI)
Cough				
Yes	22 (36.67)	10 (16.67)	0.005**	4.64
No	9 (15)	19 (31.67)		(1.56-13.81)
Phlegm				
Yes	13 (21.67)	2 (3.33)	0.002**	9.75
No	18 (30)	27 (45)		(1.00-48.47)
Chest tightness				
Yes	8 (13.34)	2 (3.33)	0.003**	3.43
No	23 (38.33)	27 (45)		(1.87-15.23)
Wheezing				
Yes	12 (20)	4 (6.67)	0.03**	3.95
No	19 (31.67)	25 (41.67)		(1.09-3.95)

N = 60
Studied group = exposed
**significant at p<0.05

TABLE VII. ASSOCIATION BETWEEN INDOOR NO_2 CONCENTRATIONS AND RESPIRATORY HEALTH SYMPTOMS AMONG STUDIED GROUP.

Variables	**High NO_2 level (> 3.52 ppm) Total (%)**	**Low NO_2 level (< 3.52 ppm) Total (%)**	**p-value**	**PR (95% CI)**
Cough				
Yes	22 (36.67)	10 (16.67)	0.043**	2.93
No	12 (20)	16 (26.67)		(1.02-8.45)
Phlegm				
Yes	13 (21.67)	2 (3.33)	0.007**	7.43
No	21 (35)	24 (40)		(1.50-36.79)
Chest tightness				
Yes				
No	8 (13.33)	1 (1.67)	0.008**	5.86
	25 (41.67)	26 (43.33)		(6.9-16.32)
Wheezing				
Yes	12 (20)	4 (6.67)	0.084	3.00
No	22 (36.67)	22 (36.67)		(0.84-10.75)

N = 60
Studied group = exposed
**significant at p<0.05

TABLE VIII. LOGISTIC REGRESSION FOR ASSOCIATION BETWEEN INDOOR PM_{10} AND NO_2 AND ABNORMALITY OF FEV_1/FVC% PREDICTED AFTER CONTROLLING THE CONFOUNDERS

Variables	B	S.E	p-value	OR	95% CI
PM_{10}	0.08	0.04	0.03*	1.08	1.01-1.16
NO_2	0.65	0.30	0.03*	1.92	1.07-3.45
Total Income	-0.00	0.00	0.19	1.00	1.00-1.00
Mosquito Coil	-0.87	0.82	0.29	0.42	0.08-2.07
Smoking	1.31	0.81	0.10	3.72	0.76-18.31

N=120
95% CI =95% Confident Interval
B = Regression Coefficient
S.E = Standard Error
Nagelkerke R Square = 0.147
*Significant at p<0.05

IV. DISCUSSION

There were significant differences of indoor PM_{10} and NO_2 concentrations among primary school children who lives near petrochemical industry area compared to those who lives far from petrochemical industry area. PM_{10} concentration in ambient air in Malaysia are monitored based on Recommended Malaysian Guidelines, RMG at a threshold of 150 µg/m^3 for 24 hours average and an annual means of 50 µg/m^3 whereas NO_2 concentrations, at a threshold for 24 hours average is 0.04 ppm and an annual means of 0.17 ppm^3 [7]. A significant difference of indoor PM_{10} and NO_2 concentrations might be influenced by the petrochemical industry that released air pollutants to community nearby. According to study by Ismail *et al.*, [8], the significant differences of indoor concentrations between selected schools in Terengganu

showed that pollutants has been released, influenced by surrounding human activities.

Statistical analysis proved that only FEV_1/FVC% predicted was significantly different between studied and comparative group (Z = -2.02. p = 0.04). Significant value for FEV_1/FVC% predicted showed that there was airways obstruction for lung function among studied group compare to comparative group. Airway obstruction is a blockage of respiration in the airway and may affect children's lung function. This finding was supported by a study in California that lung function growth in children is reduced in areas with high exposure of PM_{10} [9]. There were also linking association by this study that, both PM_{10} and NO_2 have been associated with increases in the frequency of asthma symptoms and also with lung function reduction in children on a daily scale [10].

Symptoms that most experienced by the respondents were cough (53.33%), followed by wheezing (26.67%), phlegm (25%), and chest tightness (13.33%). As overall, reported respiratory symptoms were significantly higher among studied group compared to comparative group. This finding was also supported by another research by Abdul *et al.* [11] who concluded that PM_{10} affected exposed children's respiratory system in terms of lung functions abnormality and also increased their respiratory symptoms. Another study showed that short-term exposures to the irritant gas which is NO_2 may cause airway responsiveness and lung function injury. Whereas, for long-term exposure it may reduced immunity of body and lead to respiratory infection involving more than 25 million inhabitants including children in Europe [12]. A study done by Nazariah *et al.* [13] also showed a significant association between indoor PM_{10} and reported respiratory symptoms in urban area for cough (OR=1.81, CI 95%=1.18-2.79), phlegm (OR=2.45, CI 95%=1.42-4.24) and wheezing (OR=5.43, CI 95%=2.21-13.37).

Association between indoor PM_{10} and NO_2 concentrations and lung functions were analyzed among studied group in order to know how the level of indoor PM_{10} and NO_2 concentrations may influenced the exposed group that living near petrochemical industry. Based on median value, the level of indoor PM_{10} concentrations were categorized into two groups, which were high PM_{10} level (>64 μg/m3) and low PM_{10} level (<64 μg/m3) and for indoor NO_2 concentrations, high NO_2 level (>3.52 ppm) and low NO_2 level (<3.52 ppm). For lung functions, it was categorized into normal and abnormal functions and associated with exposure of indoor air among studied group. The result from Table 4 and 5, from Fisher's Exact test, p-value obtained that there were significant associations between levels of PM_{10} and NO_2 and lung functions, which were for PM_{10} ($x^2 = 9.91$, p = 0.002) and NO_2 ($x^2 = 4.91$, p = 0.024).

This findings were also supported by study of Timonen *et al*. [14] that showed the result of 33 children who participated in the PEACE study in Kupio that performed repeated lung function tests with maximum five times, related with increased levels of PM_{10} and NO_2 were associated with impairment of lung functions among children.

The association between indoor PM_{10} and NO_2 concentrations and respiratory health symptoms were analyzed among studied group in order to know how the level of indoor PM_{10} and NO_2 concentrations may influenced the exposed group that live near petrochemical industry. Median value was used to categorize the concentrations of indoor PM_{10} and NO_2. As shown in Table VI and VII, there were also significant associations between indoor PM_{10} and NO_2 concentrations and respiratory health symptoms among studied group.

Yang et al. [2] also claimed that the subjects living in exposed area had higher rates of selected respiratory symptoms (cough, phlegm, wheezing, and chronic bronchitis) but had a lower rate of dyspnea. The differences in phlegm production and dyspnea were significant ($p<0.05$). Besides, this study also demonstrated that schoolchildren living in exposed area near petrochemical industry area have significantly more respiratory symptoms compared in a control area.

Table VIII showed after controlling the confounders in the study, PM_{10} and NO_2 is the main factors influenced FEV_1/FVC predicted. There are few observations of an association between exposures to high pollution with reduced lung functions in all ages. Besides respiratory illness, it was proven that lung function be a good indicator of the health impacts of exposure to air pollutants [15].

V. Conclusion

In summary, this study indicated that the exposure to indoor PM_{10} and NO_2 concentrations might increase the risk of getting respiratory symptoms among primary school children living near petrochemical industry. Besides that, children living near to petrochemical industry area might have reduction of lung function impairment due to chronic exposure of PM_{10} and NO_2 concentrations. On balance, responsibility of petrochemical management can come out with more effective control measures in order to minimize the exposure from petrochemical area to community surrounding.

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