ORIGINAL ARTICLE

Respiratory Health of Children Exposed to PM_{10}: Consequence of Construction Waste Open Dumping

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ABSTRACT

Introduction: Due to rapid urbanization, Malaysia is currently undergoing extensive amount of construction activities and significant rise in the construction waste. Improper construction wastes management practices have led to rise in the waste open dumping sites which may significantly affect the environment and public health. This study was undertaken to assess air pollution in such a site and the impact to the respiratory health of children studying in a nearby school. **Methods:** A comparative cross-sectional study was conducted in Sungai Buloh (exposed) and Kuala Selangor (comparative). Concentration of PM_{10} was monitored at the open dumping site (n=15), a nearby primary school (n=45) and a comparative primary school (n=12). Parents who gave consent (n=229) answered a questionnaire related to child's respiratory health whereas their children participated in lung function assessment. **Results:** Concentration of PM_{10} at the dumping site, exposed school and comparative school was 0.245±0.048mg/m^3, 0.270±0.020mg/m^3 and 0.051±0.016mg/m^3 respectively, with the first two significantly exceeded the 24-hour Malaysian Air Quality Standard (MAQS) for PM_{10} (0.150mg/m^3). Besides, PM_{10} concentration in the exposed school was similar to the dumping site ($p>0.05$) and many folds higher than the comparative school ($p<0.001$). There was a significant risk of cough (PR=1.55), phlegm (PR=1.70), wheezing (PR=1.55) and obstructive pattern of lung function defect (PR male = 4.36; PR female = 3.65) among the exposed group children than their comparative counterpart. **Conclusion:** Open dumping of construction waste would release substantial amount of PM_{10} into ambient air and ultimately affect the respiratory health of community, especially children.

Keywords: Construction waste; Open dumping; PM_{10}; Respiratory Symptoms; Lung Function

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INTRODUCTION

For the past few decades, construction activities have been gradually increasing worldwide in respond to rapid developments and urbanization (1). Malaysia too currently is experiencing rapid urbanization which contribute to extensive amount of construction activities and significant rise in the construction waste (2). Construction wastes are waste that created by construction activities such as scrap, damaged or spoiled materials, temporary and expendable construction materials, and aids that are not included in the finished project, packaging materials, as well as the waste generated by the workforce (3). Solid Waste and Public Cleansing Management Corporation confirmed that approximately 8 million tons of construction wastes are generated each year from construction projects in Malaysia (4). Due to this reason, and insufficient waste management practices in construction projects (2, 5), construction wastes open dumping sites are emerging in Malaysia (6).

Poorly managed construction wastes are associated with serious environmental issues (1). Top in the list is air pollution, due to broadcasts of dusts and gases, either as primary particles cleared directly in the atmosphere or secondary particles that are formed in the atmosphere following chemical transformation (7, 8). Construction wastes' dust is classified as particulate matters with diameters 10µm and smaller (PM_{10}), and wide-reaching over an extensive stretch of time (9, 10). Exposure to PM_{10} can cause adverse effects on human's respiratory health such as damaging the lung tissues, decreasing the lung function and increasing the prevalence of respiratory symptoms such as chronic cough, asthma, and chronic airway diseases (11).

Recently, community of a region in Sungai Buloh, Selangor are worn out dealing with the pollution arise at their residency due to open dumping of construction waste and immense transportation, especially lorries, believed to be associated with construction works. These often generate dusty cloud along the road, which may lead to respiratory illness among the residents. To make it worse, the dumping site is situated in a close proximity to a primary school in the locality. In fact, children are more susceptible to the health effects of air pollution as they breath in more air relative to their weight and lung surface compared to adults, beside their immune system as well as organs which are still maturing (12, 13). Therefore, this study was undertaken as an initiative to address the extent of air pollution due to open dumping of construction waste in the region in Sungai Buloh and its impact to the lung function as well as respiratory symptoms among the primary school children.

MATERIALS AND METHODS

Ethics statement

The study was approved by Human Ethics Committee under the Research Management Centre (RMC) of Management and Science University (MSU-RMC-02/FR01/08L2/083). Approvals was obtained from the schools prior to data collection.

Study design and location

This was a comparative cross-sectional study conducted among primary school children in Sungai Buloh of Petaling district (exposed group) and Kuala Selangor (comparative group), between June to December 2018. While the exposed school is located 640m radius away from the open construction waste dumping site, the comparative school is located in a district which is a rural area and recorded 'good' air quality in 97.7% of the air quality monitoring station in 2017, as reported by the Selangor Department of Environment (Fig. 1).

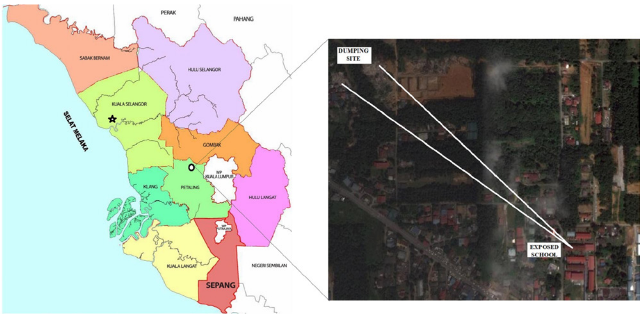

Figure 1: Left – Selangor map pointing the study locations, Right – satellite view of the dumping site and exposed school. ❍ location of dumping site and exposed school; ☆location of the comparative school. The exposed school is approximately 600m radius away from the dumping site (Adapted from UPI - Unique Parcel Identifier. (n.d.)., 2018 and *Google Map*)

Samples

Sample size was estimated using formula for group-comparison analytical study (Formula 1); $Z_{1-\alpha/2} = 1.96$, $Z_{1-\beta} = 1.282$ (14).

$$n = \frac{\{Z_{1-\frac{\alpha}{2}}\sqrt{2\bar{P}(1-\bar{P})} + Z_{1-\beta}\sqrt{P_1(1-P_1)+P_2(1-P_2)}\}^2}{(P_1-P_2)^2}$$

In a study to asses respiratory health of children living near palm oil mill, 42.7% of the exposed and 11.4% of the unexposed children had abnormal lung function (12). Hence, P1= 0.427, P2=0.114 and $\bar{P}$ = average of P1 and P2 = 0.271. Replacing these values in Formula 1 gave an initial sample size of 40. Adjusting to hypothesis testing (2 groups), design effect (2.0), response rate (70%) and eligibility (80%) gave a sample size of 286 (143 children in each group). A total of 290 students were randomly selected in both schools (145 for each school). Both male and female children studying in the school for at least one year were included. Students who were reported (by parents) with history of doctor diagnosed respiratory disease like asthma at the time of data collection were excluded.

Instruments and Data Collection

Survey:

Questionnaire (ATS-DLD-78-C) related to child's respiratory health based on the recommendations by the American Thoracic Society (15) was used. Questionnaire consists of information about socio-demographic characteristics, house location, lung disease history and respiratory symptoms in the past 6 months (cough, chronic cough, phlegm, chronic phlegm and chest tightness, wheezing). Questionnaire together with information sheet and parents' informed consent form were distributed to the selected students to be given to their parents or guardian. Parents or guardian who have read the information sheet and agreed to participate, signed the consent form and answered the survey questions. Children returned the consent form and questionnaires within 2 days and were identified for lung function assessment.

Particulate Matter (PM_{10}):

Air sampling was performed using DUSTTRAK II Aerosol Monitor 8532. Monitoring was done at the waste dumping site and the exposed as well as the comparative school. Layout plan of these sampling site were divided into smaller grids of equal size; 15 at dumping site, 45 at exposed school and 12 at comparative school. In each grid, monitoring device was placed 0.6m – 1.5m off the ground, approximately at children's breathing zone, during school hours.

Lung Function:

Digital spirometer (Spirobank II, MIR) was used to conduct lung function assessment. Children were asked to breath into a disposable mouth piece. The values recorded were forced vital capacity (FVC), forced expiratory volume in 1s (FEV1) and FEV1/FVC ratio. The quality of lung function was evaluated by comparing the obtained value with the predicted value calculated based on Azizi and Henry (1994) (16) (Table I) and

Table I: Predictive Equation for Lung Function Assessment

Lung Function Test	Male Children	Female Children
FVC	$4.1120 \times 10^{-6} H^{2.6421}$	$6.0777 \times 10^{-7} H^{3.0112}$
FEV1	$6.2523 \times 10^{-6} H^{2.5388}$	$5.7588 \times 10^{-7} H^{3.0067}$

Source: Azizi and Henry (1994) H=Height in cm classified as normal (> 75%) or abnormal (having an obstructive pattern of lung function defect) lung function based on Miller et al. (1988) (17).

Data analysis

Data was analysed using SPSS Statistical Package version 23.0. Normality assumption test was done on all continuous data. Comparison of PM_{10} level with standard value was done using one-sample t-test. Comparison of all other variables (sociodemographic, PM_{10} level, lung function and respiratory symptoms) between the exposed and comparative group was done using independent sample t-test and chi-square measure of association. Prevalence ratio was computed to estimate the risk among exposed group. Statistical significance was considered at p-value of less than 0.05.

RESULTS

Respondent's Background

Of the 290 parents, only 229 gave consent to conduct lung function assessment among their children and answered the survey; 94 from exposed and 135 from comparative group. As many parents are not aware of the risk, they failed to give consent for their child to be assessed. This gave a response rate of 65% (94/145) for the former group, 93% (135/145) for the latter group and 79% overall. As given in Table II, all of the respondents were Malays. They were 115 male and 114 female children with an average age of 9.7 years old (SD=1.8) and a normal body mass index (BMI) (23.6 ± 4.7). Statistical analysis showed that the children from both the schools were similar for their socio-demographic characteristics (p>0.05).

Particulate Matter (PM_{10}) Concentration at Dumping Site and the Schools

Concentration of PM_{10} at the waste dumping site, exposed school and comparative school was 0.245 ± 0.048mg/m^3, 0.270 ± 0.020mg/m^3 and 0.051 ± 0.016mg/m^3 respectively. The concentrations were compared to the recommended 24-hour Malaysian Air Quality Standard (MAQS) value for PM_{10} (0.150mg/m^3) (Fig. 2). One-sample t-tests showed that the dumping site (t(14) = 10.125) and exposed school (t(44) = 49.702) had PM_{10} concentration significantly higher than the MAQS permitted level whereas the comparative school ((t(11) = 14.927) had levels significantly lower, p<0.001. A one-way ANOVA showed that the PM_{10} concentrations were significantly different between the sampling points. Dunnett T3 post-hoc test further revealed that the ambient air of comparative school recorded PM_{10} concentration significantly lower than waste dumping site and exposed school while the exposed school had levels similar to the dumping site (p>0.05) and many folds higher than the comparative school (p<0.001).

Table II: Socio-demographic characteristics of the children

	Exposed Group (n=94)	Compara-tive group (n=135)	Overall (n=229)	t / χ2	p-value
Age, mean ± SD	9.4 ± 1.9	9.8 ± 1.7	9.7 ± 1.8	1.586[a]	0.114
Gender, n (%)					
Male	41 (43.6)	74 (54.8)	115 (50.2)	2.779[b]	0.095
Female	53 (56.4)	61 (45.2)	114 (49.8)		
Race, n (%)					
Malay	135 (100)	135 (100)	229 (100)	na	na
Others	0	0	0		
Height, mean ± SD	139.3 ± 10.7	142.2 ± 12.3	141.0 ± 11.7	1.850[a]	0.072
Weight, mean ± SD	46.0 ± 10.9	47.6 ± 10.6	46.9 ± 10.7	1.151[a]	0.251
BMI, mean ± SD	23.5 ± 4.3	23.6 ± 4.9	23.6 ± 4.7	0.134[a]	0.893

[a] Independent sample t-test
[b] Chi-square measure of association
na = No statistic was computed

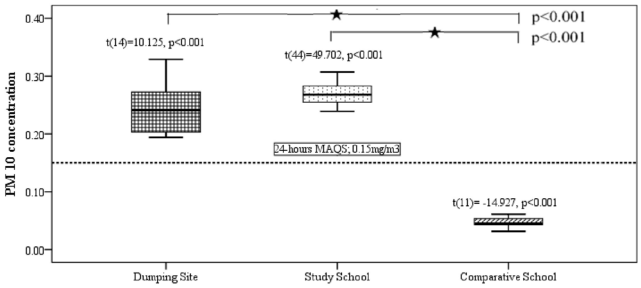

Figure 2: Comparison of PM10 concentration (mg/m^3) with the 24-hour Malaysian Air Quality Standard (MAQS) for PM_{10} (0.150mg/m^3) and between the sampling sites. Mean concentration at each site were compared to the standard value using one-sample t-tests. Mean concentration between the sampling sites were compared using a one-way ANOVA and Dunnett T3 post-hoc test. (★indicate significant difference between the sampling site)

Risk of Respiratory Symptoms among the Exposed Children

Table III shows the prevalence of respiratory symptoms among the exposed and comparative school children. Overall, a higher proportion of children studying in the exposed school reported to have had cough (43.6%), phlegm (27.7%), wheezing (30.9%) and chest tightness (7.4%) compared to the comparative group, 28.1%, 16.3%, 15.6% and 3.0% respectively. Chi-square test showed a significant association for the prevalence of cough, phlegm and wheezing between the exposed and comparative group (p<0.05) whereby children in the exposed group are at increased risk to encounter cough (PR=1.55, 95% CI=1.09 – 2.21), phlegm (PR=1.70, 95% CI=1.03 – 2.81), and wheezing (PR=1.98, 95% CI=1.21 – 3.26). There were neither any significant differences for the prevalence nor risk of chest tightness between the study groups.

Risk of Lung Function Defect among the Exposed Children

Table IV shows that children in the exposed group had some signs of lung function complication. From the predictive formula suggested by Azizi and Henry (1994) (16), FVC% predicted, FEV1% predicted and the subsequent FEV1/FVC% predicted were determined.

Table III: Prevalence of respiratory symptoms among the school students (N = 229)

Symptoms	Prevalence, n(%)		χ^2	p-value	PR (95% CI)
	Exposed Group (n=94)	Comparative group (n=135)			
Cough					
Yes	41 (43.6)	38 (28.1)	5.868	0.015[b]	**1.550 (1.087 – 2.208)**
No	53 (56.4)	97 (71.9)			
Phlegm					
Yes	26 (27.7)	22 (16.3)	4.319	0.038[b]	**1.697 (1.026 – 2.807)**
No	68 (72.3)	113 (83.7)			
Wheezing					
Yes	29 (30.9)	21 (15.6)	7.596	0.006[a]	**1.983 (1.208 – 3.257)**
No	65 (69.1)	114 (84.4)			
Chest Tightness					
Yes	7 (7.4)	4 (3.0)	2.436	0.130[c]	2.513 (0.757– 8.344)
No	87 (92.6)	131 (97.0)			

[a] Significant at p-value 0.01
[b] Significant at p-value 0.05
[c] Fisher's Exact Test

Overall, children in the comparative school had a significantly better FVC% predicted (male = 66.60 ± 4.71 / female = 63.99 ± 7.65) and FEV1/FVC% predicted (male = 102.91 ± 0.89 / female = 100.31 ± 0.51) compared to the exposed school students (FVC% predicted: male = 50.05 ± 8.86 / female = 46.18 ± 8.57; FEV1/FVC% predicted: male = 83.96 ± 8.49 / female = 79.17 ± 9.14). Based on the classification suggested by Miller et al. (1988) (17), all of the children in the comparative school had a normal lung function. In contrast, 53.7% of male and 43.4% of female children in the exposed school had abnormal or obstructive pattern of lung function defect (p<0.001). The children in the exposed group were almost three to four times at risk of getting abnormal lung function (male: PR=4.36, 95% CI= 3.02 – 6.70 / female: PR=3.65, 95% CI=2.58 – 5.17) then their comparative counterpart.

DISCUSSION

One of the benefits of construction industry is to overcome the housing problems faced by the developing countries. However, lately the industry had caused numerous new issues, waste management among others. Poor waste management may contribute to elevation in pollution that will greatly affect the health and quality of life of people living closely. In this research, we measured air pollution (PM_{10} concentration) at an open construction waste dumping site and a nearby school in Sungai Buloh, and compared it to a school in rural area, along with the school children's respiratory symptoms and lung function.

The PM_{10} concentration in the dumping site was found to be similar to that of exposed school. This gives a strong indication that PM_{10} pollution in the exposed school vicinity could have emerged from the open construction waste dumping site. The values were many folds higher than the unexposed school and exceeded the 24-hour MAQS for PM_{10}. Besides, the concentrations were also much higher than the PM_{10} values reported for urban environment in Klang Valley (0.080mg/m^3) (7), for several schools located near to palm oil mill, Dengkil (0.069mg/m^3) (12), Kuala Lumpur and Putrajaya (0.080mg/m^3) (18) and in Putrajaya and Bangi (0.034mg/m^3) (19). On the other hand, the PM_{10} concentration were similar to the rural sites in Northern part of India (0.283mg/m^3) which was attributed to pollution from road construction activities nearby (10). Construction procedures such as site clearance, unearthing, construction, refurbishment,

Table IV: Comparison of lung function parameters between the school students (N = 229)

Male	Exposed group, (n=41)	Comparative group, (n=74)	t / χ^2	p-value	PR (95% CI)
FVC, %	50.05 ± 8.86	66.60 ± 4.71	5.204[b]	<0.001[a]	
FEV1, %	51.44 ± 8.72	54.71 ± 1.67	0.927[b]	0.359	
% FEV1/FVC Predicted	83.96 ± 8.49	102.91 ± 0.89	6.559[b]	<0.001 [a]	
Lung Function Status, n (%)					
Normal	22(53.7)	74 (100)	41.080[c]	<0.001[a]	**4.364 (3.024 – 6.698)**
Abnormal	19 (46.3)	0			
Female	**Exposed group, (n=53)**	**Comparative group, (n=61)**	**t / χ^2**	**p-value**	**PR (95% CI)**
FVC, %	46.18 ± 8.57	63.99 ± 7.65	4.504[b]	<0.001[a]	
FEV1, %	46.32 ± 8.58	48.96 ± 0.16	0.886[b]	0.379	
% FEV1/FVC	79.17 ± 9.14	100.31 ± 0.51	8.041[b]	<0.00 1[a]	
Lung Function Status, n (%)					
Normal	23 (43.4)	61 (100)	46.860[c]	<0.001[a]	**3.652 (2.578 – 5.174)**
Abnormal	30 (56.6)	0			

[a] Significant at p-value 0.01; [b] Independent Sample t-test; [c] Chi square measure of association

renovation, demolition and road works can produce waste that releases high level of particulate matters (20). Hence, it is likely that open dumping of construction waste significantly increased the PM_{10} concentration and contribute to air pollution in the neighbourhood and the exposed school vicinity. In addition to construction waste itself, transportation used for the construction activities that are extensively passing by the village would probably be another source.

We found a significant risk of respiratory symptoms; cough, phlegm and wheezing among the children exposed to PM_{10}, similar to other epidemiological studies. Jang (2012) reported that children showed threefold increase in non-specific respiratory symptoms such as cough, phlegm and wheezing upon exposure to particulate matters (11) while Nazariah and colleagues found significant associations between PM_{10} exposure and 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) (7). In another study, children exposed to PM_{10} from palm oil mill were more prone to get cough (PR=2.7), phlegm (PR=5.9), and wheezing (PR=6.3) (12). Not only that, Swiss children in areas most polluted with PM_{10} had a significant risk of bronchitis (OR=2.17) (21) whereas in Delhi, children had almost two times risk of respiratory symptoms which correlated well with the level of PM_{10} in ambient air (22). Ambient annual PM_{10} concentration was also associated with the frequency of common cold among children in China (23). Due to the size, PM_{10} can travel pass the nasopharyngeal region to reach the tracheobronchial region and the lung and triggered significant threat to airways in children which can cause respiratory symptoms and to a certain extent, respiratory deaths (24, 25).

Lastly, our statistical analysis also showed that children exposed to PM_{10} from the dumping site had a higher risk of getting obstructive pattern of lung function defect. Hussin and Jalaludin (2016) and Kamaruddin, Jalaludin & Choo (2015) also found that children exposed to high level of PM_{10} had higher risk of getting abnormal lung function (12,26). Hashim and colleagues have reported that rise in the PM_{10} concentration in ambient air had increased the hospital admissions for chronic obstructive pulmonary disease (COPD) cases and respiratory deaths in Klang Valley (25). Deposition and accumulation of particles in the airways are related to lung anatomy and particle size (27). Particulate matters released from construction activities and the waste generated are largely in the coarse fraction and of ultrafine particles which can penetrate the periphery of the lungs and settle deeper enough to deteriorate the pulmonary function (28). Exposure duration or dose is another critical factor. In reality, students spend a substantial part of their time in school amid weekdays which leave them unprotected from the pollutants in the ambient air (27). While the exposed school in our study is situated just 640m radius away from the open dumping site, most of the children in the school also reside in the same locality. Hence, the children are anticipated to be exposed to the air pollutants throughout the day and are at higher risk of getting abnormal lung function.

CONCLUSION

Finding from this study demonstrates that the construction waste open dumping site released substantial amount of PM_{10} into ambient air of the area. Not only that, children studying in the school closer to the dumping site had higher exposure level to PM_{10} than their comparative counterparts which lead to respiratory symptoms and decrement of lung function. Certainly, continuing the open dumping will continuously increase the particulate matter in air and worsen health of the children. This warns action by authority to initiate site clearance and enforce a stringent regulation and guidelines for developers with poor waste management practices.

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