Journal of Sustainability Science and Management
Volume 16 Number 6, August 2021: 165-179
eISSN: 2672-7226

ASSOCIATIONS OF EXPOSURE TO PM_{10} AND $PM_{2.5}$ WITH RESPIRATORY HEALTH SYMPTOMS AND LUNG FUNCTION STATUS AMONG CHILDREN LIVING NEAR PALM OIL ACTIVITY IN SEMENYIH, SELANGOR

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Submitted final draft: 21 November 2020 *Accepted: 29 November 2020* http://doi.org/10.46754/jssm.2021.08.015

Abstract: The use of biomass fuels in palm oil boilers produces pollutants into the air, such as particulate matter (PM). PM has been linked to many respiratory health symptoms in humans, especially children. This study aims to determine the exposure of PM_{10} and $PM_{2.5}$ in the air and its association with respiratory symptoms and lung function implications among children in Semenyih, Selangor. A cross-sectional study was carried out among primary school children in Hulu Langat and Semenyih, Selangor. Eighty-six children from two primary schools in Hulu Langat were selected for the comparative group, while 50 children from two primary schools in Semenyih were selected for the study group. 30 and 32 houses were selected as study and comparative sites. A validated questionnaire from American Thoracic Society (ATS-DLD-78-C) was used to determine respondents' background, previous illnesses and respiratory symptoms. PM_{10} and $PM_{2.5}$ were measured in schools and houses using the TSI DustTrak DRX Aerosol Monitor Model 8534 and Escort LC Personal Sampling Pump. A spirometer was used to obtain lung function status among children. Analysis showed high levels of PM_{10} and $PM_{2.5}$ recorded in schools and houses of the study areas at $p<0.05$. The highest concentrations of PM_{10} (mean: 117.13 $\mu g/m^3$) and $PM_{2.5}$ (mean: 76.22 117.13 $\mu g/m^3$) in a school were detected in S2, located 650m from the palm oil plant. High levels of PM_{10} (PR=14.24, 95% CI=4.17-48.53) and $PM_{2.5}$ (PR=30.0, 95% CI=5.936-151.62) were found in houses in the study area ($p<0.05$). Significant levels of all respiratory health symptoms in schools were recorded at $p<0.05$ for cough (PR=2.90, 95% CI=1.24-6.80), phlegm (PR=9.72, 95% CI=2.61-36.16), wheezing (PR=6.30, 95% CI=2.11-18.81) and chest tightness (PR=8.74, 95% CI=2.33-32.77). High levels of PM_{10} were significantly associated with cough (p=0.013, PR=4.72, 95% CI=1.43-15.59) and wheezing (p=0.029, PR=4.83, 95% CI=1.18-19.80) in houses. Cough (p=0.02, PR=6.43, 95% CI=1.26-32.83) and phlegm (p=0.049, PR=7.75, 95% CI=0.87-68.77) symptoms were associated with the high exposure to $PM_{2.5}$ in houses. Significant lung function abnormalities of FVC, FEV_1 and FEV_1/FVC were found among children in the study group ($p<0.05$). PM_{10} had significant inverse relationship with FVC% (p=0.018, r=-0.332) and FEV_1% (p=0.001, r=-0.438) parameters, while $PM_{2.5}$ had a significant inverse correlation with FEV_1% (p=0.049, r=-0.042). Concentration of PM_{10} has been identified as a factor influencing the FVC (p=0.028, PR=1.02, 95% CI=1.002-1.038) and FEV_1 (p=0.023, PR=1.018, 95% CI=1.002-1.035) lung function status after controlling all confounders. This study concludes that palm oil plants release large amounts of PM_{10} and $PM_{2.5}$ into the air and have increased the risk of lung function abnormalities and respiratory illnesses among children who live near this industrial site.

Keywords: Children, lung function status, PM_{10}, $PM_{2.5}$, respiratory health symptoms

Abbreviations: PM_{10}: Particulate matter size with 10 aerodynamic in diameter; $PM_{2.5}$: Particulate matter size with 2.5 aerodynamic in diameter; FVC: forced vital capacity; FEV_1: forced expiratory volume in 1 second; S1, S2: studied schools; S3, S4: comparative schools

Introduction

Palm oil is one of the major industries in Malaysia and one of the main pillars of Malaysia's economy. Kun and Abdullah (2013) stated that the use of biomass fuels in boilers create another serious threat to human health. Rashid *et al.* (2013) stated that the combustion of biomass fuels releases a huge amount of particulate matter (PM). The large emission of PM affects the air quality in the surrounding area, thus increasing the prevalence of disease among the community. The particulate emission from the palm oil mill can be classified into two types of particulates. The fine mode of particles ($PM_{2.5}$) are caused by the burning process that undergoes growth and coagulation processes of particles. The coarse mode of particles (PM_{10}) are caused by unburnt biomass fuels due to incomplete combustion in the boiler (Hussin & Jalaludin, 2016).

According to Goldizen *et al.* (2016), the smaller respiratory tract of young children compared with adults causes them to be uniquely affected by air pollutants. Lim *et al.* (2018) stated that children are the most vulnerable group to be exposed to air pollutants, as the physiological air intake characteristic of children was larger compared to an adult. PM is one of the air pollutants of concern that can affect children's health. A study conducted by Othman *et al.* (2019) found that exposure to PM10 and PM2.5 increased the risk of respiratory health symptoms and chances of inducing micronuclei formation among children who lived near palm oil plants.

Lung function test is used to evaluate any respiratory and lung abnormality through the quantification of lung volume with its diffusing capacities and spirometry test. The key parameters that are measured in this test are the forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1). Culver *et al.* (2017) classified respiratory disorder into two main categories: restrictive disorder and obstructive disorder. Restrictive disorder is when the effort of breathing is increased due to the restriction of the lung's expansion. According to Mithani (2013), patients that develop obstructive disorder have a reduction of airflow limits. This is because airways in the respiratory pathway are obstructed.

The objective of the study is to determine the associations of exposure to PM_{10} and $PM_{2.5}$ with respiratory health symptoms and lung function status among primary school children who live near a palm oil plant in Semenyih, Selangor.

Materials and Methods

Study Design and Location

A comparative cross-sectional study was conducted that focussed on the association of exposure to $PM_{2.5}$ and PM_{10} with respiratory health symptoms and lung function among male and female primary schoolchildren living near palm oil plant in Semenyih. The parameters involved were exposure to PM_{10}, $PM_{2.5,}$ FVC, FEV_1 and FEV_1/FVC. The studied schools S1 and S2 (Figure 1) were within 5 kilometres to the nearest palm oil plant. S1 and S2 were 3.6 kilometres and 650 metres from the palm oil plant, respectively. Meanwhile the comparative schools S3 and S4 (Figure 2) were within 40-kilometre radius from the palm oil plant.

Study Sample

A total of 136 Malay primary schoolchildren were selected in this study. Eighty-six children were randomly selected from two primary schools in Hulu Langat to be in the comparative group, while 50 children from two primary schools in Semenyih were in the study group. There were several inclusion criteria that were included in this study. The first inclusion criteria was that the respondents must be among primary schoolchildren who have been enrolled in the same school since Year 1 and lived in the residential area since birth. The respondents must be Malaysian citizens between 7 and 11 years old and studying in selected schools registered under the Ministry of Education. The children selected must include male and female pupils and must be free from any

Figure 1: Study locations (S1) and (S2) within 5 kilometres from palm oil plant

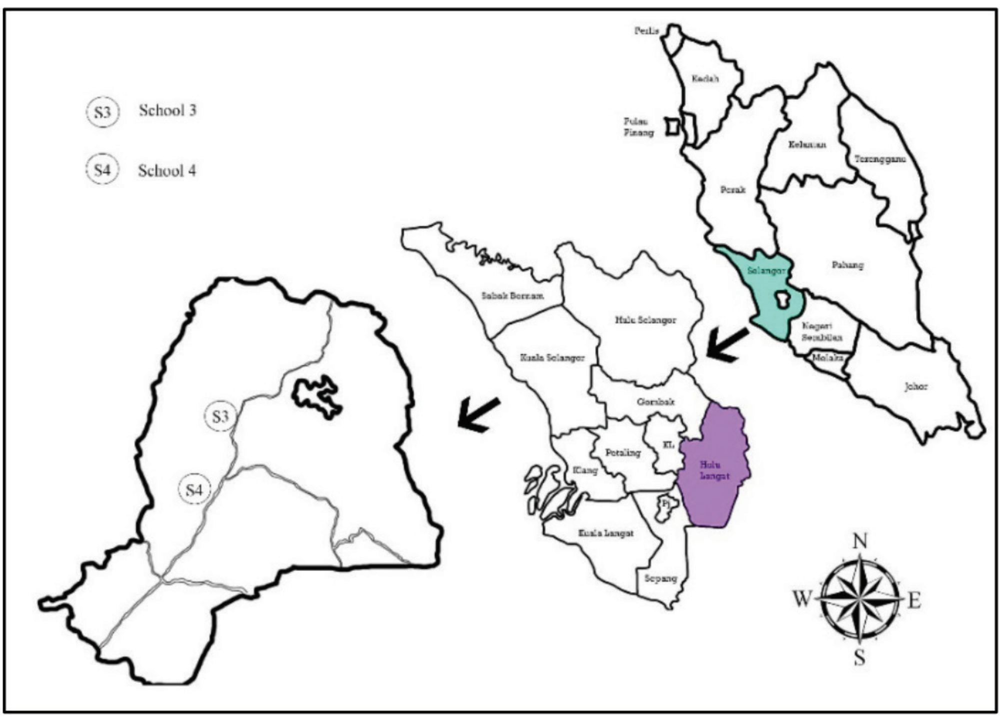

Figure 2: Study locations (S3) and (S4) located within 40 kilometres from palm oil plant

respiratory disease. Approval from the Ministry of Education was obtained before conducting measurements in the selected schools (Ref. No: KPM.600-3/2/3-eras(2643)). Children who did not have consent from their parents or guardians and who have a history of medical problems and respiratory diseases were excluded from this study (Hussin & Jalaludin, 2016).

Measurements of $PM_{2.5}$ and PM_{10} Concentrations in Schools

PM_{10} and $PM_{2.5}$ concentrations at schools were measured outside and inside the classrooms of the respondents. The sampling for $PM_{2.5}$ and PM_{10} were taken on weekdays (Monday to Friday) for a duration of 6 hours in the presence of the students in their classrooms starting from 7.00 am until 1.00 pm to ensure the timing of measurement was equivalent to the exposure of the children in the school (Hussin & Jalaludin, 2016). The measurements were done in triplicate and averaged. Three classrooms per school were chosen, which gave a total of 12 classrooms involved in this study. $PM_{2.5}$ and PM_{10} concentrations were measured using the TSI DustTrak DRX Aerosol Monitor Model 8534 and instruments were placed in the breathing zone of the children (1.0 metre above the floor) and 1.5 metres from the windows. This to ensure that the dust collected represented the dust inhaled by the children. The sampling points were selected to ensure no disruption of movement and attraction from the children.

Measurements of PM_{10} and $PM_{2.5}$ Concentrations in Respondents' Houses

The selection of respondents' houses in this study was based on the consent of the parents/guardian of the children. A total of 30 and 32 houses in the studied and comparative areas were selected. PM_{10} and $PM_{2.5}$ concentrations in respondents' houses were measured using a personal sampling pump, which was operated for 24 hours. The pumps were placed in the respondent's living room and in the children's bedroom. The sampling points were selected based on where the children spent most of their time in the house. The filter papers used to measure $PM_{2.5}$ were Mixed Cellulose Ester Membrane (MCE) with a pore size of 5µm, while the filter papers used to measure PM_{10} were Poly Vinyl Chloride (PVC) with a pore size of 5µm. Prior to sampling, the filter papers were weighed in a control environment area and then were assembled into cassettes before closing them firmly to avoid any openings for environmental contamination. The interior of the cyclone was cleaned to prevent any contamination from the re-entrainment of large particles. The alignment of filter holder and cyclone in the sampling head were assembled and checked to prevent any leakages. Before sampling, the cassette was equilibrated for 2 hours in a control environment. The sampling's flow rate was standardized at 1.7 L/min according to the NIOSH Manual of Analytical Methods (NMAM) 0600: Particulates Not Otherwise Regulated, Respirable.

Sociodemographic Data

This study used an internationally validated questionnaire based on the American Thoracic Society (Questionnaire ATS-DLD-78-C). The children's parents/guardians were asked to fill in the questionnaire that consisted of sociodemographic data, history of respiratory symptoms and disorder and the physical activity of their children. The questionnaire also included questions on the daily activities of the occupants, such as frequency of cooking, cleaning and smoking, that occur in the house. Each questionnaire was attached with a consent letter to roughly explain to the parents the methodology used throughout this study. The questionnaires were collected one week after being distributed to the children. A quick interview with the respondents was done to ensure the questionnaires were fully filled by the children's parents/guardians.

Measurement of Lung Function Parameters

The primary schoolchildren were required to undergo a lung function test using a spirometer (Culver *et al*., 2017). The Chestgraph HI-101 Spirometer used in this test was calibrated by injecting air into the spirometer using a 3L syringe. Before the assessment, the researcher demonstrated anthropometric measurement in the presence of a medical assistant. Respondents were asked to breathe through a mouthpiece attached to the spirometer and inhale as deep as possible before exhalation. The test took only 3 seconds and children were required to perform for 3 times to test the reproducibility of the best value. The measurements in schools were taken in the early morning before recess the same day air samples were taken. Assessment of lung function was done based on American Thoracic Society (1991) standard method.

Statistical Analysis

All the data were analysed using SPSS Version 22.0 by IBM SPSS Inc. Independent t-test and Mann-Whitney U Test were used to compare the concentrations of PM_{10} and $PM_{2.5}$ and to compare the lung function test results between exposed and comparative schools. Chi-square test was used to compare the respiratory health symptoms of the children. Meanwhile, Pearson Correlation and Spearman Rho tests were used to determine the association between concentrations of PM_{10} and $PM_{2.5}$ with lung function status and respiratory health symptoms among children.

Results and Discussion

A total of 136 Malay primary schoolchildren were enrolled in this study. Twenty-two boys (44.00%) and 28 girls (56.00%) agreed to participate in the study group. Meanwhile, 33 boys (38.37%) and 53 girls (61.63%) agreed to participate in the comparative group.

Concentrations of PM_{10} and $PM_{2.5}$

Table 1 shows the concentrations of PM_{10} and $PM_{2.5}$ measured in the schools and houses of the study and comparative groups. The mean concentration of PM_{10} in the stud schools was higher (105.21 μg/m^3) than in the comparative schools (53.92 μg/m^3). The results were similar in the respondents' houses. The mean concentration of PM_{10} in the study houses was higher (104.29 μg/m^3) than in comparative houses (32.14 μg/m^3). The mean concentration of $PM_{2.5}$ in the study schools was also higher (68.83 μg/m^3) than in the comparative schools (13.03 μg/m^3). The results showed a similar trend in the study houses (74.29 μg/m^3) and in the comparative houses (22.86 μg/m^3). The concentrations of PM_{10} and $PM_{2.5}$ in houses were high. This was expected because occupants' daily activities listed in the questionnaire, such as cooking, use of cars or motorcycles, gardening and even open burning might affect the concentrations of PM_{10} and $PM_{2.5}$. Even though the levels of PM_{10} and $PM_{2.5}$ in both study and comparative areas in schools and houses were below the concentration limit recommended by the Malaysian Ambient Air Quality Standard (PM_{10}: 150 μg/m^3; $PM_{2.5}$: 75 μg/m^3), the readings were considered as high and exceeded the World Health Organization Guidelines, which had listed 20 μg/m^3 (annual mean) and 50 μg/m^3 (24-hour mean) for PM_{10}; 10 μg/m^3 (annual mean) and 25 μg/m^3 (24-hour mean) for $PM_{2.5}$ (WHO, 2005).

Table 1: Concentrations of PM_{10} and $PM_{2.5}$ at study and comparative schools and houses

Variable	[1]Study schools N=2	[1]Comparative schools N=2	t-value	p-value	[2]Studied houses N=30	[2]Comparative houses N=32	t-value	p-value
	Mean ± SD				Mean ± SD			
PM_{10} (μg/m^3)	105.21 ± 46.11	53.92 ± 12.37	3.323	**0.014**	104.29 ± 58.70	32.14 ± 58.70	3.16	**0.017***
$PM_{2.5}$ (μg/m^3)	68.83 ± 13.03	13.03 ± 17.45	2.287	**0.040**	74.29 ± 42.57	22.86 ± 36.73	2.42	**0.032***

1Independent sample T-test, 2 Sampling measurement for 24 hours, *Significant at p<0.05

Table 2 shows the comparison of concentrations PM_{10} and $PM_{2.5}$ according to the study sites. This study found that studied schools (S1, S2) recorded higher levels of PM_{10} than the comparative schools. S2 showed the highest PM_{10} mean concentration, at 117.13 µg/m^3 followed by S1 at 93.30 µg/m^3. This was due to the location of S2 within 650 metres of a palm oil plant as compared with S1 (3.6 kilometres). S3 and S4 recorded mean values of 71.32 µg/m^3 and 69.00 µg/m^3 of PM_{10} due to their distance from the palm oil plant (40 km) and main federal roads. These findings were supported by Hussin and Jalaludin (2016), where they identified activities from the palm oil plant as significantly increasing the concentrations of PM_{10} and $PM_{2.5}$ in studied areas as compared with comparative areas.

Other than palm oil plants, there were other industrial activities that actively operated within a 20-kilometre radius from the studied schools, which included a road construction company, cranes and heavy machinery company, spices and food seasoning processing factory and also electrical and transformer manufacturing factory. Although they were far from the studied radius, factors such as air dispersion and weather enabled mix pollution to occur. Mixed pollution from a multi-point source polluter contributed towards the increased concentrations of PM_{10} and $PM_{2.5}$ (Gao *et al.*, 2015).

Table 3 shows the association between concentrations of PM_{10} and $PM_{2.5}$ between studied and comparative houses. The concentration level was determined according to the Malaysian Ambient Air Quality Standard, where they classify PM_{10} with value of 150 µg/m^3 and above as high, and $PM_{2.5}$ with value of 75 µg/m^3 and above as high. From the studied group, 23 (76.67%) houses were exposed to

Table 2: Comparison of PM_{10} and $PM_{2.5}$ concentrations according to schools

Variable	**Study School**		**Comparative School**	
	S1	**S2**	**S3**	**S4**
	Mean		**Mean**	
[1]PM_{10} (µg/m^3)	93.30	117.13	71.32	69.00
[1]$PM_{2.5}$ (µg/m^3)	61.44	76.22	57.32	59.10

1Independent sample t-test

Table 3: Exposure to PM_{10} and $PM_{2.5}$ between studied and comparative groups in respondents' house

Variables	**Studied area N=30**	**Comparative area N=32**	χ^2	**P-value**	**PR**	**95% CI**
	Total (%)					
PM_{10}						
[1]High (≥150 µg/m^3)	23 (76.67)	6 (18.75)	20.86	**<0.001**	**14.24**	**4.17-48.53**
[1]Low (<150 µg/m^3)	7 (23.33)	26 (81.25)				
$PM_{2.5}$						
[1]High (≥75 µg/m^3)	20 (66.67)	2 (6.25)	24.69	**<0.001**	**30.00**	**5.936-151.62**
[1]Low (<75 µg/m^3)	10 (33.33)	30 (93.75)				

1Pearson Chi-square, 24-hour measurement, *significant at p<0.05

high concentrations of PM_{10} and 6 (18.75%) houses in the comparative group were exposed to high concentrations of PM_{10}. The children who lived in the studied area were 14 times more likely to be exposed to high concentrations of PM_{10} than children in the comparative area. The exposure by the palm oil plant located within 5 km of the studied area significantly affected the concentration of PM_{10} in the air. This was supported by Hussin and Jalaludin (2016), where they had identified that the palm oil plant had significantly increased the concentrations of PM_{10} and $PM_{2.5}$.

Meanwhile, in the studied area, 20 (66.7%) houses were exposed to high concentrations of $PM_{2.5}$ while only 2 (6.25%) houses in the comparative area were similarly exposed. The children who lived in the studied area were 30 times more likely to be exposed with the high concentration of $PM_{2.5}$. The use of biomass fuels for the boilers in the palm oil plant released high concentrations of dust containing PM_{10} and $PM_{2.5}$ into the air (Kun & Abdullah, 2013). The dust would disperse in a large area as it is released from the chimney of the palm oil plant. Ghanbari and Rezazadeh (2018) stated that PM discharged from the boilers through the chimney duct will affect the surrounding air quality. Huda *et al.* (2014) supported this claim, as dust produced by agricultural waste released high volumes of PM_{10} and $PM_{2.5}$ if not managed properly.

Based on the data in Table 3, 76.67% of the respondents' houses were exposed to high concentration of PM_{10} and 66.67% of the houses were exposed to high concentration of $PM_{2.5}$. However, by referring to the PR value for $PM_{2.5}$, respondents in the studied group were 30 times more likely to be exposed to high concentrations of $PM_{2.5}$ (PR=30.00, 95% CI=5.936-151.62) compared to the comparative group. With high levels of $PM_{2.5}$ in the air, the smaller sized particle can easily enter deeper into the respiratory system and cause harm to the humans (Hussin & Jalaludin, 2016). Exposure to high concentrations of $PM_{2.5}$ also increases the risk of developing respiratory illnesses. This claim was supported by Luong *et al.* (2017) where higher incidences of respiratory illnesses can be found in higher average concentrations of $PM_{2.5}$ (108 $\mu g/m^3$) than in lower average concentrations of $PM_{2.5}$ (74 $\mu g/m^3$). Meanwhile, respondents in the studied group were 14 times more likely to be exposed to the high level of PM_{10} (PR=14.24, 95% CI=4.17-48.53). Due to the high number of houses exposed to large amounts of particulate matter, the risk of developing respiratory illnesses among occupants, especially those in the vulnerable groups, such as children and elderly, may also increase. This was supported by Rodopoulou *et al.* (2014), where the risk of developing respiratory illnesses was estimated to be 3.2% to 3.9% for every increment of 10 $\mu g/m^3$ of PM10 concentrations. Therefore, this study shows that the exposure to high concentrations of PM_{10} and $PM_{2.5}$ in the studied group had strong associations with development of respiratory illnesses.

Respiratory Health Symptoms of the Respondents

Table 4 shows the associations between reported respiratory health symptoms between studied and comparative groups. The reported respiratory symptoms were cough, phlegm, wheezing and chest tightness. Based on the questionnaire, the number of children who had experienced respiratory symptoms in the studied group are as follows: 16 children (32.0%) developed cough, 13 children (26.0%) developed phlegm, 14 children (28.0%) developed wheezing and 12 children (24.0%) developed chest tightness. Meanwhile, in the comparative group, 12 children (14.0%) developed cough, 3 children (3.5%) had phlegm, wheezing was observed in 5 children (5.8%) and 3 children (3.5%) with chest tightness. All respiratory symptoms showed significant results at $p<0.05$ with significant risk.

Based on the prevalence ratio (PR) obtained in this study, the children in the studied group were 2 times more likely to develop cough, 9 times more likely to have phlegm, 6 times more likely to experience wheezing and 8 times more likely to have chest tightness when

Table 4: Reported respiratory symptoms between studied and comparative groups at schools

Variables	Studied group N=50	Comparative group N=86	x^2	p-value	PR	95% CI
	Total (%)					
[1]Cough						
Yes	16 (32.0)	12 (14.0)	6.30	**0.012***	2.90	1.24-6.80
No	34 (68.0)	74 (86.0)				
[1]Phlegm						
Yes	13 (26.0)	3 (3.5)	15.44	**<0.0001***	9.72	2.61-36.16
No	37 (74.0)	83 (96.5)				
[1]Wheezing						
Yes	14 (28.0)	5 (5.8)	12.95	**<0.0003***	6.30	2.11-18.81
No	36 (72.0)	81 (94.2)				
[1]Chest tightness						
Yes	12 (24.0)	3 (3.5)	13.56	**<0.0002***	8.74	2.33-32.77
No	38 (76.0)	83 (96.5)				

1Pearson's chi square, *significant at p<0.05

exposed to air pollutants. These results were supported by a study conducted in schools near to the petrochemical industry area in Kerteh, Terengganu by Ayuni and Juliana (2014), which reported significant respiratory health symptoms at p<0.05 for cough (PR=5.09, 95% CI=2.23-11.65), 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) in exposed group. Another study performed by Kamaruddin *et al.* (2016) at primary schools located near to the industrial area in Kemaman, Terengganu also found significant prevalence of respiratory illnesses among children in the exposed area. Most of the respondents were reported with cough (p=0.035, PR=1.712, 95% CI=1.04-2.83), phlegm (p=0.029, PR=2.216, 95% CI=1.07-4.23) and wheezing (p=0.041, PR=2.193, 95% CI=1.02-4.72). However, no significant difference in chest tightness symptoms for both exposed and comparative groups.

Table 5 shows the associations and prevalence ratios of the respiratory health symptoms of the respondents with differences in the levels of PM_{10} in their house. There was significant association between exposure to high levels of PM_{10} with cough and wheezing symptoms at p<0.05, where 14 (30.0%) respondents reported cough (p=0.013) with the likelihood of it occurring at 4 times higher. Meanwhile, wheezing was reported among 10 (33.3%) respondents (p=0.029) with 4 times likelihood. However, there was no significant association between exposures to PM_{10} with phlegm and chest tightness symptoms.

The findings were in line with previous studies which linked the exposure to PM_{10} with respiratory illnesses. Hussin and Jalaludin (2016) recorded significant relationships on exposure to high level of PM_{10} with the symptoms of cough (p=0.032, PR=3.289, 95% CI=1.074-10.072) and wheezing (p=0.032, PR=5.220, 95% CI=1.030-26.453) among children in the exposed group. A study by Othman *et al.* (2019) found significant association between exposure to high concentration of PM_{10} and coughing (p=0.005, PR=13.286, 95% CI=1.565-112.803) in children living near palm oil factories. Kamaruddin *et al.* (2016) reported significant relationships between concentrations of $PM_{10 \text{ and}}$ respiratory symptoms among children attending schools near industrial sites, such as for cough (p=0.010, PR=2.33, 95% CI=1.21-4.94) and

Table 5: Reported respiratory health symptoms related to the level of PM_{10} exposures at respondents' house

	High PM_{10} N=30	Low PM_{10} N=32	x^2	P-value	PR	95% CI
	Total (%)					
[1]Cough						
Yes	14 (30.0)	5 (15.6)	7.02	**0.013***	4.72	1.43-15.59
No	16 (70.0)	27 (84.4)				
[1]Phlegm						
Yes	5 (16.7)	1 (3.1)	3.248	0.099	6.200	0.680-56.56
No	25 (83.3)	31 (96.9)				
[1]Wheezing						
Yes	10 (33.3)	3 (9.4)	5.36	**0.029***	4.83	1.18-19.80
No	20 (66.7)	29 (90.6)				
[1]Chest tightness						
Yes	5 (16.7)	2 (6.3)	1.677	0.25	3.000	0.54-16.81
No	25 (83.3)	30 (93.8)				

1 Fisher exact test; * Significant at p<0.05

wheezing (p=0.019, PR=3.345, 95% CI=1.17-9.58). The current findings prove that the exposure to a high level of PM_{10} could worsen the symptoms of respiratory health of children due to air pollution.

Table 6 shows the relationships between exposure to the different $PM_{2.5}$ levels in a residential area and the respiratory health symptoms among respondents. Exposure to high levels of $PM_{2.5}$ caused significant incidences of cough and phlegm among respondents. Nine (30.0%) children developed cough symptoms at p=0.02, <0.05 when exposed to high concentration of $PM_{2.5}$. This symptom is

Table 6: Reported respiratory health symptoms related to the level of $PM_{2.5}$ exposure at the respondents' house

	High $PM_{2.5}$ N=30	Low $PM_{2.5}$ N=32	x^2	P-value	PR	95% CI
	Total (%)					
[1]Cough						
Yes	9 (30.0)	2 (6.3)	5.984	**0.020***	6.43	1.26-32.83
No	21 (70.0)	30 (93.8)				
[1]Phlegm						
Yes	6 (20.0)	1 (3.1)	4.402	**0.049***	7.75	0.87-68.77
No	24 (80.0)	31 (96.9)				
[1]Wheezing						
Yes	5 (16.7)	2 (6.3)	1.677	0.249	3.20	0.57-17.89
No	25 (83.3)	30 (93.8)				
[1]Chest tightness						
Yes	6 (20.0)	2 (6.3)	4.402	0.141	3.75	0.69-20.28
No	24 (80.0)	30 (93.8)				

1 Fisher exact test; *Significant at p<0.05

6 times more likely to occur among children living in the area with high $PM_{2.5}$ content, based on the PR value of 6.43 (95% CI=1.26-32.83). Similar incidences of phlegm were found, where 6 (20.0%) children had this symptom when exposed to high levels of $PM_{2.5}$ for 24-hour monitoring at p=0.049, <0.05. Phlegm was found to be 7 times more likely to occur among children exposed to high $PM_{2.5}$, based on PR=7.75 at 95% CI=0.87-68.77. However, there was no significant relationship between exposure to $PM_{2.5}$ and wheezing and chest tightness.

Several studies had linked the exposure to high levels of $PM_{2.5}$ in residential areas near an industrial site with respiratory illnesses among children. Othman *et al.* (2019) reported a significant relation between exposure to high $PM_{2.5}$ with coughing (p=0.02) among children living in industrial areas. They found the symptom was 6 times more likely to occur in the exposed group with PR=6.429 at 95% CI= 1.259-32.827. Another study conducted in an industrial area in Petaling Jaya, Selangor, by Jalaludin and Mawar (2015) found that incidences of cough, phlegm, wheezing and chest tightness did not significantly increase with high levels of $PM_{2.5}$ exposure. However, they reported that children who were exposed to high $PM_{2.5}$ concentration had increased risk (PR>1) of contracting cough (PR=3.5) and chest tightness (PR=3.5), even though it was not statistically significant. The present findings prove that children exposed to $PM_{2.5}$ also have an increased risk of developing wheezing and chest tightness based on their PR value more than 1.

Lung Function Status of the Respondents

From Table 7, data analysis showed significant relationships for all lung function parameters between studied and comparative groups at p<0.05. Twenty-six (52.0%) out of 50 children from the studied group had an abnormal FVC while 20 (23.3%) from the 86 children in the comparative group showed similar results. A significant difference between the two groups of respondents and the abnormality of FVC was detected at p=0.001. The children were 3.58 times more likely to have an abnormal FVC parameter (PR=3.58, 95% CI=1.964-7.546) when exposed to particulate matter. As for the FEV_1 parameter, 31 (62.0%) and 16 (18.6%) of the children from the studied and comparative groups developed abnormal readings. A significant difference of this parameter was observed at p<0.001 where the children in the studied group were 7 times more likely to have this abnormality (PR=7.14, 95% CI=3.246-15.698) when exposed to air pollutants. Next, 24 (48.0%) children from the studied group and 11 (12.8%) children from the comparative group

Table 7: Comparison of lung function parameters between studied and comparative groups

Variables	Studied group N=50	Comparative group N=86	x^2	p-value	PR	95% CI
	Total (%)					
[1]FVC						
Abnormal	26 (52.0)	20 (23.3)	11.67	**0.001***	**3.58**	**1.964-7.546**
Normal	24 (48.0)	66 (76.7)				
[1]FEV_1						
Abnormal	31 (62.0)	16 (18.6)	26.33	**<0.001***	**7.14**	**3.246-15.698**
Normal	19 (38.0)	70 (81.4)				
[1]FEV_1/ FVC	24 (48.0)	11 (12.8)	20.51	**<0.001***	**6.30**	**2.713-14.602**
Abnormal	26 (52.0)	75 (87.2)				
Normal						

1Pearson's chi square, *significant at p<0.05

had abnormal lung function reading of FEV_1/FVC at p<0.001. These children were 6 times more likely to have an abnormal FEV_1/FVC parameter due to the PM exposure (PR=6.30, 95% CI=2.713-14.602).

The abnormal readings of the lung function parameters in the studied group were due to the exposure to high concentration of air pollutants in the school and residential areas. A few studies conducted on the determination of lung function status among children who live near industrial and heavy traffic areas found significant correlation between both variables. Hussin and Jalaludin (2016) found a significant relationship between exposure to air pollutants at industrial sites and lung function parameters. The study recorded abnormal FVC, FEV_1 and FEV_1/FVC among the studied group at p<0.05 with the PR value at 3.60, 5.62 and 5.81, respectively. A study conducted among children in urban preschools located near heavy traffic areas found significant results on FVC and FEV_1 in the exposed group, both at p<0.05 (Asrul & Juliana, 2017). Another study carried out in preschools and residential areas near heavy traffic in Selangor showed significant differences in FVC and FEV_1 abnormalities when exposed to PM_{10} among children after being monitored for 24 hours in their house (Yahaya & Jalaludin, 2014). Guarnieri & Balmes (2014) also supported the claim that there were associations between the exposure of $PM_{2.5}$, lung function status and the prevalence of reported asthma among children. Hence, it is clearly shown that exposure to particulate matter in the air affects the lung function parameters in humans.

Meanwhile, children who study and live in the comparative area have prolonged exposure to air pollutants, which may have affected the performance of their lungs. Even though the concentrations of PM_{10} and $PM_{2.5}$ in the comparative area were lower than the studied area, the concentrations of these pollutants were still considered as high as they exceeded the limit recommended by the WHO (2005). Since the children lived in those areas from birth, prolonged exposure to PM_{10} and $PM_{2.5}$ were significantly associated with the higher odds of developing respiratory illnesses, such as restrictive lung function, as claimed by Navaneethan *et al.* (2016). The findings of this previous study may explain the number of respondents in the comparative group with abnormal lung function parameters. At worse, longer exposure and decreased lung function parameters could lead to more chronic diseases, such as pulmonary cavitation and excessive inflammation of the lungs (Kesten *et al.*, 2011).

Table 8 above shows the relationship between PM_{10} and $PM_{2.5}$ concentrations, and the lung function status of the respondents. There were significant correlations between exposure to PM_{10} with FVC% (r=-0.332, p=0.018) and FEV_1% (r=-0.438, p=0.001) in the studied group. Inverse relationships were obtained for the exposure to PM_{10} with FVC% and FEV_1%. This means that as the concentration of PM_{10} increases, the FVC% and FEV_1% decrease. However, there was insignificant correlation between exposure to PM_{10} and FEV_1/FVC% (r=0.191, p=0.184). For the $PM_{2.5}$ exposure in the studied group, a significant inverse correlation was observed for FEV_1% parameter

Table 8: Relationship between PM_{10} and $PM_{2.5}$ concentrations and respondents' lung function

PM_{10} / $PM_{2.5}$ (µg/m³)	**Studied group N= 50**		**Comparative group N= 86**	
	r	**p**	**r**	**p**
[1]FVC%	-0.332/-0.012	**0.018***/0.932	0.150/-0.117	0.297/0.906
[1]FEV_1%	-0.438/-0.042	**0.001*/0.049***	0.180/0.269	0.212/0.773
[1]FEV_1/FVC%	0.191/-0.090	0.184/0.532	-0.048/-0.015	0.743/0.916

1Pearson's Correlation Test, *significant at p<0.05

(r=-0.042, p=0.049). This indicates a decrease of FEV_1% with increased $PM_{2.5}$ in the air. On the other hand, insignificant inverse relationships were recorded for the exposure to $PM_{2.5}$ with FVC% (r=-0.012, p=0.932) and FEV_1/FVC% (r=-0.090, p=0.532).

A study conducted by Asrul and Juliana (2017) showed significant correlation between PM_{10} and $PM_{2.5}$ exposures, and FVC% and FEV_1% parameters. This study indicated that high levels of PM_{10} and $PM_{2.5}$ had impacted the lung function status of the children in the studied group. These findings were consistent with the local studies by Choo *et al.* (2015) and Nur Azwani *et al.* (2014) among preschool children in urban areas with heavy traffic, where significant associations were found between indoor PM_{10} and $PM_{2.5}$ in respondents' houses, and lower-lung function status. $PM_{2.5}$ has been linked with reduced lung function parameters due to the small size of $PM_{2.5}$ which allows it to invade deeper into the lower respiratory region (Hussin & Jalaludin, 2016). Palm oil activity has been identified as the major source of high concentrations of PM_{10} and $PM_{2.5}$ in the studied area. Moreover, possibilities of mix pollution from wind dispersion and the current weather condition might affect the transmission of air pollutants in the area (Gao *et al.*, 2015) and eventually cause health impacts on children.

Meanwhile, indoor concentrations of PM_{10} and $PM_{2.5}$ might have been influenced by the outdoor concentrations of these pollutants. This could be because dust residue on the children's shoes and clothing may have been transferred inside the classroom and increased indoor concentrations as they moved in and out of the classroom. This finding was supported by a recent study conducted in Finland where the researchers concluded that taking shoes off when entering the school building can enhance indoor air quality by reducing the particle mass concentrations from PM_{10} and $PM_{2.5}$ (Leppänen *et al.*, 2020). Apart from that, the classrooms selected in this study used open ventilation to regulate indoor air. There was no proper air filtration method to prevent outdoor dust from entering the classroom. This study also found that the studied houses also used open ventilation. Other than outdoor dust, based on the information from the questionnaire, occupant activities in the houses, such as cooking, released particulate matter and reduced indoor air quality. Guarnieri & Balmes (2014) supports the claim that domestic cooking also influences lung function decrement among indoor occupants. Previous studies also showed similar results, as increased concentrations of $PM_{2.5}$ and PM_{10}, led to decreased FEV_1 values among children that have respiratory disease (Isiugo *et al.*, 2019).

Table 9 shows the factors that influence abnormalFVC among children in the studied area after controlling all the confounders. There was a significant regression at p<0.05 between the concentration of PM_{10} and abnormality of FVC. This study shows that the concentration of PM_{10} was the main confounder in the development of abnormal FVC among the exposed children after controlling all the confounders. Children exposed to PM10 concentrations were one time more likely to develop abnormal lung function (PR=1.020, 95% CI=1.002-1.038). This claim is supported by Zwozdziak *et al.* (2016) where there was a significant reduction in FVC among studied schoolchildren aged from 13 to 14 years

Table 9: Factors influenced the abnormality of FVC among the studied children

Independent Variables	B	S.E	p-value	PR	95% CI
Constant	0.164	1.307	0.900		
Concentration of PM_{10}	0.020	0.009	**0.028***	**1.020**	**1.002-1.038**
Father's educational level	-1.329	1.961	0.498	0.265	0.006-12.357
Mother's educational level	-1.234	1.879	0.511	0.291	0.007-11.569
Total salary	0.000	0.000	0.423	1.000	1.000-1.00

B=Regression Coefficient, S.E= Standard Error, Nagelkerke R square = 0.313 *Significant at p<0.05

old with exposure to PM. The study denied the socioeconomic factors as major influences on the abnormal FVC at $p>0.05$. Although a study by Polak *et al.* (2019) found that socioeconomic status was one of the predictors of pulmonary health, it varied according to the income status of the household. To control this confounder, this study selected respondents either both parents or one of them contributed an income to the family. This was to mitigate immune-deficiency due to poverty as a factor.

Table 10 shows the factors that influence abnormal FEV_1 among children in the studied area after controlling all confounders. There was a significant regression at $p<0.05$ between the concentration of PM_{10} and abnormality of FEV_1. The study showed that the concentration of PM_{10} was the main confounder in the development of abnormal FEV_1 among the exposed children. Based on Table 10, children who were exposed to significant concentrations of PM_{10} were one time likely to have lung function abnormality compared to the comparative group (PR=1.018, 95% CI=1.002-1.035). Previous studies showed that exposure to high concentrations of PM significantly decreased the FEV_1 parameter after 5 to 7 days (Weiden *et al.*, 2015). This indicated that short-term exposure also causes reduction in lung function status. Another study also agreed that increased concentrations of $PM_{2.5}$ and PM_{10} had caused the FEV_1 value to decrease among children who have respiratory disease (Isiugo *et al.*, 2019).

Conclusion

Findings from this study prove that the studied group has a higher exposure to PM_{10} and $PM_{2.5}$ at schools and in residential areas near to the palm oil plant. This study indicated that exposure to high levels of PM_{10} and $PM_{2.5}$ is a contributing factor to the respiratory health symptoms and reduction of lung function among schoolchildren living in the studied area. Thus, it can be concluded that exposure to high concentrations of PM_{10} and $PM_{2.5}$ which are released into the air through biomass fuel burning can affect the health of children living near to a palm oil plant. Therefore, this study suggests a re-evaluation of the effectiveness of the control measurements by the palm oil company management to ensure more complete combustion of biomass and to lower the particulate emission into the air.

Acknowledgements

Highest gratitude and appreciation to all personnel that directly and indirectly contributed to this study. Special thanks to all respondents, parents and guardians, teachers, staff and lecturers of the Faculty of Medicine and Health Sciences of UPM for being supportive in completing the study. Last but not least, to the Ministry of Education for granting permission to enter school premises to conduct the study.

References

Asrul, S., & Juliana, J. (2017). Indoor air quality and its association with respiratory health among preschool children in urban and suburban area. *Malays J Public Health Med, 1*, 78-88.

Ayuni, N., & Juliana, J. (2014). Exposure to PM10 and NO2 and association with respiratory health among primary school

Table 10: Factors influencing abnormal FEV1 among the studied children

Independent Variables	B	S.E	p-value	PR	95% CI
Constant	-0.645	1.237	0.602		
Concentration of PM_{10}	0.018	0.008	**0.023***	**1.018**	**1.002-1.035**
Father's educational level	0.236	1.881	0.900	1.266	0.032-50.545
Mother's educational level	-2.397	2.217	0.281	0.092	0.001-7.054
Total salary	0.000	0.000	0.304	1.000	1.000

B=Regression Coefficient, S.E= Standard Error, Nagelkerke R square = 0.243 *Significant at $p<0.05$

children living near petrochemical industry area at Kertih, Terengganu. *Journal of Medical and Bioengineering, 3*(4).

https://doi:10.12720/jomb.3.4.282-287.

Culver, B. H., Graham, B. L., Coates, A. L., Wanger, J., Berry, C. E., Clarke, P. K., … Rosenfeld, M. (2017). American Thoracic Society Recommendations for a Standardized Pulmonary Function Report An Official American Thoracic Society Technical Statement, *196*, 1463-1472. https://doi.org/10.1164/rccm.201710-1981ST.

Gao, J., Tian, H., Cheng, K., Lu, L., Zheng, M., Wang, S., … Wang, Y. (2015). The variation of chemical characteristics of PM 2 . 5 and PM 10 and formation causes during two haze pollution events in urban Beijing , China. *Atmospheric Environment*, *107*, 1-8. https://doi.org/10.1016/j.atmosenv.2015.02.022.

Ghanbari, M., & Rezazadeh, G. (2018). Giant chimney for air ventilation of metropolises. *Atmospheric Pollution Research*, (May), 0-1. https://doi.org/10.1016/j.apr.2018.09.010.

Goldizen, F. C., Sly, P. D., & Knibbs, L. D. (2016). Respiratory effects of air pollution on children. *Pediatric Pulmonology*, *51*(1), 94-108. https://doi.org/10.1002/ppul.23262.

Guarnieri, M., & Balmes, J. R. (2014). Asthma 1 Outdoor air pollution and asthma. *The Lancet*, *383*(9928), 1581 -1592. https://doi.org/10.1016/S0140-6736(14)60617-6.

Huda, N., Rashid, M., & Hasfalina, C. M. (2014). Particulate emission from agricultural waste fired boiler, *8*(3), 1265-1295.

Hussin, F. S., & Jalaludin, J. (2016). Association of PM10 and PM2.5 exposure with respiratory health of the children living near Palm Oil Mill, Dengkil, *16* (January), Original Article 20-26.

Isiugo, K., Jandarov, R., Cox, J., Ryan, P., Newman, N., Grinshpun, S. A., … Reponen, T. (2019). Science of the Total Environment Indoor particulate matter and lung function in children. *Science of the Total Environment*, *663*, 408-417. https://doi.org/10.1016/j.scitotenv.2019.01.309.

Jalaludin, J., & Mawar, N. J. (2015). Exposure to Indoor Particulate Matter 2.5 (Pm2. 5) and Volatile Organic Compounds (VOCS) among preschool children at an industrial area in Petaling Jaya, Selangor. *International Journal of Applied and Natural Sciences (IJANS), 6*(6), 41-50.

Kamaruddin, A. S., Jalaludin, J., & Hamedon, T. (2016). Exposure to industrial air pollutants and respiratory health school and home exposure among primary school children in Kemaman, Terengganu. *International Journal of Applied Chemistry, 12*(1), 45-40.

Kun, Y. C., & Abdullah, A. M. H. (2013). Simulation of total dust emission from palm oil mills in Malaysia using biomass fuel composition and dust collector efficiency models. *International Journal of Energy and Environmental Engineering*, *4*(1), 1-13. https://doi.org/10.1186/2251-6832-4-19.

Leppänen, M., Peräniemi, S., Koponen, H., Sippula, O., & Pasanen, P. (2020). The effect of the shoeless course on particle concentrations and dust composition in schools. *Science of the Total Environment, 710*, 136272. https://doi.org/10.1016/j.scitotenv.2019.136272

Lim, C. C., Hayes, R. B., Ahn, J., Shao, Y., Silverman, D. T., Jones, R. R., … Thurston, G. D. (2018). Association between long-term exposure to ambient air pollution and diabetes mortality in the US. *Environmental Research*, *165*(February), 330 -336. https://doi.org/10.1016/j.envres.2018.04.011.

Liu, A. G., Xiao, M., Zhang, X., Gal, C., Chen, X., Liu, L., … Clements-croome, D. (2017). A review of air filtration technologies for sustainable and healthy building ventilation. *Sustainable Cities and Society*. https://doi.org/10.1016/j.scs.2017.04.011.

Luong, L. M. T., Phung, D., Sly, P. D., Morawska, L., & Thai, P. K. (2017). The between particulate air pollution and respiratory admissions among young children in Hanoi, Vietnam. *Science of the Total Environment*, *578*, 249 -255. https://doi.org/10.1016/j.scitotenv.2016.08.012.

Maryam, Z., Hazrin, A., Hizrri, A., Norhidayah, A., Samsuddin, N., & Mohd Shukri, M. (2018). Association of Particulate Matter (PM) with respiratory symptoms among children in selected primary schools in Pahang. *Journal CleanWAS, 2*(1), 11-15.

Mithani, A. (2013). Lung function. In M. Gellman & J. Turner (Eds.), *Encyclopedia of Behavioral Medicine* (Vol. 251). New York: Springer. https://doi.org/10.1007/978-1-4419-1005-9.

Mohd Nor Rawi, N. A., Jalaludin, J., & Chua, P. C. (2015). Indoor air quality and respiratory health among Malay preschool children in Selangor. *BioMed research international, 2015*. https://doi.org/10.1155/2015/248178.

Navaneethan, S. D., Mandayam, S., Arrigain, S., Rahman, M., Winkelmayer, W. C., & Schold, J. D. (2016). Obstructive and restrictive lung function measures and CKD: National Health and Nutrition Examination Survey (NHANES) 2007-2012. *American Journal of Kidney Diseases*, 2007 -2012. https://doi.org/10.1053/j.ajkd.2016.03.415.

Othman, S. F., Jalaludin, J., Hisamuddin, N. H., & Widajati, N. (2019). Association of exposure to PM2.5 and PM10 with DNA damage in Exfoliated Buccal Mucosa Cells among primary school children living nearby palm oil activity at Semenyih, Selangor.

Polak, M., Szafraniec, K., Kozela, M., Wolfshaut-wolak, R., Bobak, M., & Paj, A. (2019). Socioeconomic status and pulmonary function, transition from childhood to adulthood : Cross-sectional results from the polish part of the HAPIEE study, 1-9. https://doi.org/10.1136/bmjopen-2018-022638.

Rashid, M., Chong, W. C., Ramli, M., Zainura, Z. N., & Norruwaida, J. (2013). Evaluation of particulate emission from a palm oil mill boiler. *Sains Malaysiana*, *42*(9), 1289-1292.

Rodopoulou, S., Chalbot, M., Samoli, E., Dubois, D. W., San, B. D., & Kavouras, I. G. (2014). Air pollution and hospital emergency room and admissions for cardiovascular and respiratory diseases in Doña Ana County, New Mexico. *Environmental Research*, *129*, 39-46. https://doi.org/10.1016/j.envres.2013.12.006.

Weiden, M. D., Kwon, S., Caraher, E., Berger, K. I., Reibman, J., Rom, W. N., Prezant, D. J., & Nolan, A. (2015, June). Biomarkers of World Trade Center particulate matter exposure: Physiology of distal airway and blood biomarkers that predict FEV1 decline. In *Seminars in respiratory and critical care medicine* (Vol. 36, No. 03, pp. 323-333). Thieme Medical Publishers.

WHO. (2005). WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide. Global Update 2005. Summary of Risk Assessment. World Health Organization; WHO/SDE/PHE/OEH/06.02.

Yahaya, N. A., & Jalaludin, J. (2014). Exposure to indoor PM 10 and volatile organic compounds and its association with respiratory health among preschool children from urban and rural areas in Selangor. In *From Sources to Solution* (pp. 13-16). Springer. DOI: 10.1007/978-981-4560-70-2_3.

Zwozdziak, A., Sówka, I., Willak-Janc, E., Zwozdziak, J., Kwiecińska, K., & Balińska-Miśkiewicz, W. (2016). Influence of PM1and PM2.5on lung function parameters in healthy schoolchildren—a panel study. *Environmental Science and Pollution Research*, *23*(23), 23892 -23901. https://doi.org/10.1007/s11356-016-7605-1.