ORIGINAL ARTICLE

ASSOCIATION OF PM_{10} AND $PM_{2.5}$ EXPOSURE WITH RESPIRATORY HEALTH OF THE CHILDREN LIVING NEAR PALM OIL MILL, DENGKIL

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ABSTRACT

Waste and by-products form palm oil trees are versatile and can be used as biomass fuel, but the processes of producing electricity by using low pressure boilers are causing air pollution. The objective of this study is to determine the association between PM_{10} and $PM_{2.5}$ exposure with respiratory symptoms and lung function among children living near to palm oil mill. A cross- Sectional comparative study was carried out among school children at Dengkil and Kerling. Questionnaires adopted from ATS-DLD-78-C were distributed to the respondents' parents. PM_{10} and $PM_{2.5}$ was measured. Lung function of the respondents was evaluated by using Chest Graph Spirometer; results were compared with standards of lung function, by ATS (1991). There was a significant difference for Mean±SD PM_{10} and $PM_{2.5}$ in studied and comparative area, ($p<0.05$). There were significant association between PM_{10} with wheezing and cough (PR=5.220, CI%=1.030-26.453) and (PR=3.289 CI%=1.074-10.072). The study indicates that the lung function of; FEV_1 % (t=-4.54, p=0.001) and FEV_1/FVC % (t=-7.00, p=0.001) were lower among studied group compared to the comparative group. Results also showed that there is a significant inverse correlation between $PM_{2.5}$ and FVC% (r=-0.352, p=0.0226). The need for palm oil mill management to evaluate the effectiveness of their implemented control measure seems to be very important, as black soot emitted from boilers stack is believed to contain high level of. The high efficiency biomass boiler and the used of fabric filters should be considered if the implemented control measure is not functioning effectively.

***Keywords**: PM_{10}, $PM_{2.5}$, children, respiratory symptoms and lung function*

INTRODUCTION

The development of palm oil mill in Malaysia has been remarkable. As compared to the number of mills in 2005, there are additions of more than 30 new mills that are put into operation. The palm oil mill generates large quantities of waste and by-products. Example of waste and by-products produced are oil palm trunks (OPT), empty fruit bunches (EFB), oil palm fronds (OPF), palm shell, and palm pressed fibre (PPF). Palm oil trees are very versatile, the waste and by-products can used as biomass fuel. However, the processes of producing electricity by using low pressure boilers are causing air pollution.

Sources of air pollution can be found during the extraction process of crude palm oil, air pollution produced in a palm oil mill will usually come from combustion process that takes place in the boilers and incinerators. Due to incomplete combustion of solid waste materials (fibres, shells and potash ash), smoke and dusts that could cause adverse health effects are the main outcomes. The smoke and other particulates in the air that are emitted from palm oil mills can be a serious source of public complaint when the mills are closely located in residential areas and when the emissions are unabated. PM_{10} and $PM_{2.5}$ are small enough to penetrate the thoracic region of the respiratory system. Particularly, elderly people, susceptible groups with pre-existing lung or heart diseases, as well as children are vulnerable to be affected with PM_{10} and $PM_{2.5}$. Children are vulnerable during their growth and are more susceptible to the health effects of air pollution than adults because of their physical constitution and breathing pattern[1]. Since children spend most of their time outdoors compared to adults, children are believed to be a vulnerable population. Due to their unique physiological and behavioral characteristics, they are prone to get diseases that are related to the respiratory system; this is because immune system and the developing organs of the children are not mature yet. Children breathe more air relative to their weight and lung surface than what the adults do.

METHODS

The cross sectional comparative type of study was carried out among male and female school children who attended the selected primary schools in Dengkil near to palm oil mill (studied group). While the population for the comparative group were among male and female who attended the selected schools in Kerling which far from palm oil mill and industrial area.

The questionnaire used was based on the recommendations by the American Thoracic Society, (1978)[2]Questionnaire(ATS-DLD-78-C). Questionnaire was pre-tested on 10% of the sample size. At schools, the ambient measurementwas performed during school hours. DustTrak Aerosol Monitor Model 8520 was used to measure PM_{10}, while DustTrak DRX Aerosol Monitor Model 8534 was used to measure $PM_{2.5}$. Both of these DustTrak were placed with the same level of children's breathing zone. On the other hands, measurement of PM_{10} and $PM_{2.5}$ at the respondent's home was taken by using Aircheck 52 personal sampling pump and gravimetric technique was used in this measurement. The pump operated for 24 hours and it was placed at the same level of children's breathing zone. Chestgraph spirometer was used to conduct a lung function test among the respondents. Steps for lung function test were referred to American Thoracic Society, 1978[2].The evaluation of lung function test was performed by comparing the obtained value with the standard normal value and the predicted value was calculated based on Aziziand Henry, 1994[3].

RESULTSAND DISCUSSION

As being illustrated in Table 1, it was found that theMean±SD concentration of PM_{10} in studied area was higher (72.35±11.87μg/m^3) comparedto the comparative area (46.14±13.99μg/m^3). Based on T-test, there is a significant difference in PM_{10} concentration level between studied and comparative group, (t=-8.14, p=<0.001). A local study by Nazirahet al.[4]showed that PM_{10} concentration is significantly higher in urban area compared to rural area, and international study (Athens, Greece) by Grivas et al.[5]showed that the mean concentration of PM_{10} at studiedarea was around 73.8μg/m^3. Based on Table 1 also, result from Mann-Whitney U test showed that there is a significant difference in $PM_{2.5}$ concentration level between studied and comparative group, (z=-4.54, p=0.001). This study is supported by Salami et al.[6]who prove that the concentration level of $PM_{2.5}$ at industrial area was 3 times higher than those found in reference location.

Table 1 - PM_{10} and $PM_{2.5}$ concentration level at studied and comparative respondents' house

Variable	Studied group (n =31)	Comparative group (n=34)	t/z-value	p-value
	Mean±SD/Median±IQR			
PM_{10} (μg/m^3)^a	72.45±11.87	46.14±13.99	-8.14	**<0.001***
$PM_{2.5}$ (μg/m^3)^b	41.26±18.79	23.54±6.88	-4.54	**<0.001***

According to the results obtained (Table 2), the Mean±SD concentration of PM_{10} at studied schools (68.52±13.37μg/m^3) was higher compared to the comparative schools (44.52±11.69μg/m^3). While mean concentration of $PM_{2.5}$ at studied schools and comparative schools is 41.33μg/m^3 and 23.04μg/m^3. Based on the T-test, statistical analysis showed that there were significant differences in PM_{10} and $PM_{2.5}$ concentration level between studied and comparative schools, (t=-6.28, p=<0.001) and (t=-13.42, p=<0.011). Previous study by VadanaTyagiet al.[7]and Amos et al.[8] revealed some similarity when it was proven that schools which are located near to the mill area (within 0-5km) have demonstrated a high concentration level of PM_{10} and $PM_{2.5}$.

Table 2 - PM_{10} and $PM_{2.5}$ concentration level at studied and comparative schools

Variable	Studied schools n=82	Comparative schools n=88	t-value	p-value
	Mean±SD			
PM_{10} (μg/m^3)	68.52±13.37	44.52±11.69	-6.28	**<0.001***
$PM_{2.5}$ (μg/m^3)	41.33±15.14	23.04±13.58	-13.42	**<0.001***

Table 3 shows the respiratory symptoms among studied and comparative group, basically it was reported that most of the children at studied group were having respiratory symptoms. For cough (%), phlegm (%), wheezing (%) and chest tightness (%), the findings showed that majority of the studied group reported that they have these symptoms, 31(66%), 10(83.3%), 19(82.6) and 9(81.8) compared to the comparative group 16(34%), 2(16.7%), 4(17.4%) and 2(18.2). Statistical analysis (chi-square) result revealed that there were significant differences in prevalence of cough, phlegm, wheezing and chest tightness between studied and comparative group, (PR=2.73, 95% CI=1.36-5.52), (PR=5.97, 95% CI=1.27-28.14), (PR=6.33, 95% CI=2.05-19.54) and (PR=5.30, 95% CI=1.11-25.32). Through local study by Rafiaet al.[9] the total number of acute respiratory infection cases among children exposed to high level of PM_{10} has increased from about 6000 to more than 30000 during the same period in Malaysia. While, a study in Eastern Finland by Tiitanen et al.[10] support that PM_{10} and $PM_{2.5}$ were significantly associated with increased risk of respiratory symptoms among children.

For respondents that ambient air measurement was taken at their home, according to chi square test (Table 4), results for prevalence of wheezing and coughing were significantly associated with the concentration level of PM_{10}, (PR=5.220, 95%CI=1.030-26.453) and (PR=3.289 95% CI=1.074-10.72). However, results from the chi square test also showed that the prevalence of phlegm and chest tightness were not significantly associated with the concentration level of PM_{10} (PR=3.107, 95% CI=0.578-16.712) and (PR=4.000, 95% CI=0.422-37.912). A recent study by Azwaniet al.[11] and Anis et al.[12]found that there was a significant association between wheezing and PM_{10} (OR=5.31, 95% CI= 1.07-6.97), and children who are exposed to high level of PM_{10} was 5 times more likely to get a cough. Besides that a study in Hong Kong by Gao et al.[13]has confirmed that PM_{10} is the most relevant pollutant with adverse effect on wheezing among children at urbanized area.

Table 3 - Respiratory symptoms among studied and comparative group

Variables	Studied group n=82	Comparative group n=88	x^2	p-value	PR	95% CI
	Total (%)					
Cough						
Yes	31 (66.0)	16 (34.0)	**8.17**	**0.004***	**2.73**	**1.36-5.52**
No	51 (41.5)	72 (58.8)				
Phlegm						
Yes	10 (83.3)	2 (16.7)	**6.37**	**0.012***	**5.97**	**1.27-28.14**
No	72 (45.6)	86 (54.4)				
Wheezing						
Yes	19 (82.6)	4 (17.4)	**12.59**	**<0.001***	**6.33**	**2.05-19.54**
No	63 (42.9)	84 (57.1)				
Chest tightness						
Yes	9 (81.8)	2 (18.2)	**5.31**	**0.021***	**5.30**	**1.11-25.32**
No	73 (45.9)	86 (54.1)				

Table 4 - Association between PM_{10} concentration levels with respiratory symptoms

	High PM_{10} n=34	Low PM_{10} n=31	x^2	P-value	PR	95% CI
	Total (%)					
Cough						
Yes	15 (44.1%)	6 (19.4%)	**4.547**	**0.032***	**3.289**	**1.074-10.072**
No	14 (55.9%)	25 (80.6%)				
Phlegm						
Yes	6 (17.6%)	2 (6.5%)	1.883	0.170	3.107	0.578-16.712
No	28 (82.4%)	29 (93.5%)				
Wheezing						
Yes	9 (26.5%)	2 (6.5%)	**4.622**	**0.032***	**5.220**	**1.030-26.453**
No	25 (73.5%)	29 (93.5%)				
Chest tightness						
Yes						
No	4 (11.8%)	1 (3.2%)	1.665	0.197	4.000	0.422-37.912
	30 (88.2%)	30 (96.8%)				

Based on Table 5, children at studied group have shown some indication that they are having lung function implication. Number of respondents that having abnormal FVC (%), abnormal FEV_1 (%) and abnormal FEV_1/FVC (%) were among children in studied group (75%), (78%) and (77.8%) were higher compared to the comparative group (25%), (22%) and (62.4%). This was strengthened by the result in Aniset al.[12]study that revealed the abnormalities of lung function for FVC (%), FEV_1 (%) and FEV_1/FVC (%) were higher among the exposed group (62%), (76%) and (2%) compared to the comparative group

(38%), (34%) and (0%). A study by Hwang et al.[14]in Taipei, Taiwan also providesevidence that children who livein urban area may have a detrimental effect on the development of lung function in children due to the exposure to fine particulate matter.

Table 5 - Comparison of lung function between two study groups

Variables	Studied group n=82	Comparative group n=88	x^2	p-value	PR	95% CI
	Total (%)					
FVC						
Abnormal	12(75.0)	4 (25.0)	**5.07**	**0.024***	**3.60**	**2.47-12.76**
Normal	70 (45.5)	84 (54.4)				
FEV_1						
Abnormal	32 (78.0)	9 (22.0)	**19.23**	**<0.001***	**5.62**	**1.11-11.66**
Normal	50 (38.5)	79 (61.2)				
FEV_1/ FVC						
Abnormal	35 (77.8)	10 (22.2)	**21.39**	**<0.001***	**5.81**	**2.64-12.81**
Normal	47 (37.6)	78 (62.4)				

Table 6, the Mean±SD for FVC% were (94.80±16.52) and (95.35±15.09) for the studied and comparative group respectively. Mean±SDfor FEV_1 %, among studied and comparative group were (73.87±22.58) and (96.35±17.23). Whereas, Mean±SD obtained for FEV_1/FVC % were (73.85±16.32) for studied group and (102.68±16.14) for comparative group. Meanwhile, based on T-test, it can be said that there were significant differences between FEV_1% and FEV_1/FVC % of the studied group and comparative group, (t=-4.54, p=<0.001) and (t=-7.00, p=<0.001). In a different study by Chua et al.[15] the result for mean FVC%, FEV_1% and FEV_1/ FVC% were lower among children in urban area (75.04 ± 28.41), (75.83 ± 29.35) and (97.10 ± 10.32) compared to children in rural area (85.14 ± 23.81), (83.17 ± 24.53) and (97.55 ± 10.25). Furthermore, according to Mankowski[16], results obtained showed that the mean and standard deviation of FEV_1 and FVC among children in industrial region were significantly lower with p<0.05, with older subjects showed alarger deficit.

By referring to Table 7, the correlation test shows that there were insignificant inverse correlations between exposure level of PM_{10} with FEV_1% (r=-0.036, p=0.849) and FEV_1/FVC% of the studied group, (r=-0.022, p=0.904). However, there is a significant inverse correlation between $PM_{2.5}$ and FVC% of the studied group, (r=-0.352, p=0.0226). As the concentration level of $PM_{2.5}$ increased, the FVC% decrease, this can be due to the characteristic of $PM_{2.5}$ which is small in size that allows it to invade deeper into the lower respiratory region. Based on study by Ayuniet al.[17], the result clearly showed that there is a significant inverse correlation between exposure to $PM_{2.5}$ with lung function of FVC% (r=-0.404, p=0.027). In addition, Hwang et al., (2015)[14], also support that FVC were associated with increased exposure to $PM_{2.5}$, as greater exposure to $PM_{2.5}$ (IQR, 17.92μg/m^3) was associated with an annual deficit in FVC growth of 75 ml in boys and 61 ml in girls.

Table 6 - FVC%, FEV_1% and FEV_1/FVC% among studied and comparative group

Variables	Studied group n=31	Comparative group n=34	t value	p-value
	Mean ± SD			
FVC %	94.80±16.52	95.35±15.09	-0.147	0.884
FEV_1 %	73.87±22.58	96.35±17.23	-4.54	**<0.001***
FEV_1/FVC %	73.85±16.32	102.68±16.14	-7.00	**<0.001***

Table 7 - Relationship between PM_{10} and $PM_{2.5}$ concentration with respondents' lung function

PM_{10} ($PM_{2.5}$) µg/m^3	Studied group n=31		Comparative group n=34	
	r	p	r	p
FVC%	0.168(-0.352)	0.365(**0.026***)	-0.134(0.034)	0.449(0.850)
FEV_1%	-0.036(0.025)	0.849(0.894)	0.013(-0.221)	0.942(0.209)
FEV_1/FVC%	-0.022(-0.206)	0.904(0.267)	0.096(-0.327)	0.588(0.057)

After controlling all the confounders, such as father's educational level, mother's educational level, total salary and smoking activity of family members. Table 9 shows that there is a significant regression between $PM_{2.5}$ with FVC among studied group (p=0.033, OR=13.74, 95% CI=4.95-20.03). To strengthen this study, by referring to Chua et al.[15], the results are comparable as Chua at al.[15]prove that FVC% were significantly lower among children in urban area as they were exposed to high level of $PM_{2.5}$ compared to children from rural area.

Table 8: Factors influenced the abnormality of FVC among studied group after control all the confounder in the study

Independent variables	B	S.E	p-value	OR	95% CI
Constant	-1.403	0.743	0.089		
Concentration of PM_{10}	1.534	0.798	0.056	1.245	0.62-1.66
Concentration of $PM_{2.5}$	1.365	0.644	**0.033***	**13.74**	**4.95-20.3**
Father's educational level	0.563	0.725	0.229	8.362	0.26-2.84
Mother's educational level	0.669	0.633	0.191	4.055	1.00-3.67
Total salary	0.464	0.138	0.563	1.736	2.37-4.27
Smoking activity	0.282	0.372	0.379	2.842	2.19-5.83

n=82
Nagelkerke R Square= 0.450

CONCLUSION

Finding from this study proves that the studied group has a higher exposure to PM_{10} and $PM_{2.5}$ either at home or school. This study indicates that exposure to high level of PM_{10} and $PM_{2.5}$ is a factor that may become contributing factors for respiratory symptoms and reduction of lung function among school children living near palm oil mill. The results of this study prove that, children among the studied group are more prone to get cough, phlegm, wheezing and chest tightness compared to the comparative group. The study also indicates that the lung function of; FEV_1 % and FEV_1/FVC % were lower among studied group compared to the comparative group. In addition, through Pearson's correlation analysis, there is a significant inverse correlation between $PM_{2.5}$ and FVC% among studied group. Thus, it can be concluded that more childrenin the studied group demonstrate decrement of lung function compared tothe comparative group. As the source of air pollutant is believed to be mainly from palm oil mill, the need for palm oil mill management to evaluate the effectiveness of their implemented control measure seems to be very important, as black soot emitted from boilers stack is believed to contain high level of PM_{10}, $PM_{2.5}$ and other types of air pollutants. Selecting a high efficiency biomass boiler to better regulate oxygen flow in order to optimize combustion, thereby ensuring a more complete burn and lower the particulate emission rate. The use of fabric filters (baghouses) may help in controlling the emission. Depending on the design and choice of fabric, particulate control efficiency of more than 99% of total particulate matter can be achievedwith fabric filters.

REFERENCES

1. Chua, P.C. &Jalaludin, J. An overview of indoor air quality and its impact on respiratory health among Malaysian school-aged children. *Rev Environ Health*2015;30(1): 9-18.

2. American Thoracic Society. Lung function testing: Selection of reference values and interpretive strategies. *American Review of Respiratory Disease*1978;85: 762- 768.

3. Azizi, B.H and Henry, R.L. Ethnic differences in normal spirometric lung function of Malaysian children.*Respiratory Medicine*1994;88: 349-356.

4. Nazariah, S.S., Juliana,J. and Abdah,M.A. Interleukin-6 via Sputum Induction as Biomarker of Inflammation for Indoor Particulate Matter among Primary School Children in Klang Valley, Malaysia. *Glob J Health Sci*2013;5(4): 93-105.

5. Grivas, G., Chaloulakou, A., Samara, C., & Spyrellis, N. Spatial and Temporal Variation of Pm10 Mass Concentrations within the Greater Area of Athens, Greece. *Kluwer Academic Publishers*2004;158(87):357–371.

6. Salami, Indah R. S., & As, Zulfikar A., M. M. & D. R. Respiratory health risk assessment of children living close to industrial areas in Indonesia. *Environmental Health*2004;29(2): 139–142.

7. Vandana Tyagi, B.R. Gurjar, Namita Joshi, P. K. PM10 and heavy metals in sub-urban and rural atmospheric environments of Northern India. *ASCE Journal of Hazardous, Toxic and Radioactive Waste*2012;9(16): 175–182.

8. Amos, B. B., Musa, I., Abashiya, M., & Abaje, I. B. Impacts of Cement Dust Emissions on Soils within 10km Radius in Ashaka Area, Gombe State, Nigeria. *Canadian Center of Science and Education*2015;4(1): 29–36.

9. Rafia, R., N.H. Mohd and I.N. Akma. Review of air pollution and health impacts in Malaysia. *Environment Res*2003;9(2): 71-77.

10. Tiitanen, P., Timonen, K. L., Ruskanen, J. J., Mirme, A., & Pekkanen, J. Fine particulate air pollution , resuspended road dust and respiratory health among symptomatic children. *European Respiratory Journal*1999;13(1): 266–273.

11. Azwani. N., Nor, M., J. Jalauludin., & Chua. P. C. Indoor Air Quality and Respiratory Health among Malay Preschool Children in Selangor. *BioMed Research International*2015;1:1-8.

12. Anis S. K., J. Juliana & Chua P. C. Indoor Air Quality and Its Association with Respiratory Health among Malay. *Advances in Environmental Biology*2015;9(9): 17–26.

13. Gao, Y., Chan, E. Y. Y., Li, L., Lau, P. W. C., & Wong, T. W. Chronic effects of ambient air pollution on respiratory morbidities among Chinese children : a cross-sectional study in Hong Kong. *BMC Public Health* 2014;14(1): 105-114.

14. Hwang, B., Chen, Y., Lin, Y., Wu, X., & Leo, Y. Relationship between exposure to fine particulates and ozone and reduced lung function in children. *Environmental Research*2015;137(19): 382–390.

15. Chua P.C., J. Juliana, Titi R. H. &Nor Mariah A. Indoor Air Quality Assessment and Lung Functions Among Children in Preschool at Selangor, Malaysia. *Advance in Environmental Biology*2015;9(9): 1-9.

16. Mankowski, R. Effects Of Long-Term Exposure to Air Pollution on Respiratory Function and Physical Efficiency of Pre-Adolescent Children. *European Journal of Medical Research* 2010;15(2): 224–228.

17. Ayuni B., J. Juliana &Sarva M. P. Exposure to $PM_{2.5}$, Ultrafine Fine Particle and Lung Function Among Photocopy Workers in Selangor. *Springer Singapore*2014;1(1): 191-195.