Health Risk of Particulate Matter on Primary School Students in West Jakarta

Lailatul Qomariyah[1], Bambang Wispriyono[2], Haryoto Kusnoputranto[3], Abdur Rahman[4], Meliana Sari[4]

Faculty of Public Health, Department of Environmental Health, Universitas Indonesia, Depok, Indonesia

Abstract

Background: Particulate matter (PM) is the most common air pollutant found in West Jakarta, with the main source being the increase of the motor vehicle used.

Methods: This study investigated the PM concentrations and the related health risk from PM exposure on primary school students in West Jakarta. The $PM_{2.5}$ concentration was measured using instrument HAZDUST, Model: SKC EPAM-5000, PA 15330.

Results: The highest mean concentration of $PM_{2.5}$ measured from three primary schools in West Jakarta was 129 μg/m^3.

Discussion: The health risk analysis of the students showed that the $PM_{2.5}$ intake was lower than the reference dose or safety limit.

Conclusions: The findings of this study showed that primary school students were not under the risk of exposure to $PM_{2.5}$ in the school environment.

Competing Interests: The authors declare no competing financial interests

Keywords: *Particulate matter, student, primary school, risk assessment.*

Introduction

The air quality in West Jakarta was considered as unhealthy and polluted according to the national air quality criteria (KEPMEN LH NOMOR: KEP-45/ MENLH/10/1997[(1)]. The data of air quality in West Jakarta is collected from the monitoring stations throughout Jakarta. According to the Jakarta province regulation number 2 year 2005, the government has done efforts on tackling air pollution and air quality recovery. Regardless, those efforts did not seem to succeed in lowering the level of air pollution[(2)].

One of the main sources of air pollution was the high number of motor vehicles in busy traffic. The motor vehicles released several gasses and particulate matter (PM). There are several categories of PM, i.e., PM_{10}, $PM_{2.5}$, and ultrafine PM with a diameter of 0.1 μm[(3)]. Smaller-sized PM caused a higher risk than the bigger-sized PM[(4)]. The most common pollutant from the incomplete fossil fuel combustion was $PM_{2.5}$, which has similar characteristics with gas molecules that can reach the gas exchange areas in the lungs, translocate the lungs, and reached the blood circulation system[(5)]. $PM_{2.5}$ can be easily inhaled into the respiratory system and kept in the lung's alveoli where toxic particles can cause lung damage and disrupt the lung functions[(4,6,7)] . The $PM_{2.5}$ also contributes to the steady increase of asthma prevalence in humans, especially in children[(8)].

Children spend most of their time in school. Therefore, the air quality in school was considered as an important factor which affects the health of children[(9)]. Children are more vulnerable to a higher amount of air pollution since their respiratory volume is higher compared to adults[(10)t]. In general, the children's organ is more vulnerable to toxic compounds since it is not fully developed[(11)]. Therefore, a proper approach to

Corresponding author:
Bambang Wispriyono
email: bwispri@ui.ac.id

calculating and predicting the health risk which called the risk analysis on environmental health is needed, which taken into account several steps, i.e., identification of uncertain factors, investigation on certain exposure, consideration on characteristics of concerning pollutant agent and the specific target. This study aims to estimate the risk of $PM_{2.5}$ on primary school students in West Jakarta.

Abbreviations	
RQ	Risk quotient
RFC	Reference concentration

Methods

The samples in this study were taken from three primary schools in West Jakarta which located near the highway. The samples were coded as follows: CT 05, CB 03, PS 06.

Sampling

The measurement of $PM_{2.5}$ concentration was taken from 3 points in the school area during the school hours. The sampling point was based on the most visited areas of students during school hours. The $PM_{2.5}$ concentration was measured with instrument HAZDUST (Model: SKC EPAM-5000, PA 15330) and was being done at the same time with the health survey.

Study Participants

Several inclusion criteria for sampled students used were students from fourth and fifth grade in a healthy condition and were willing to be respondents by signing the form of consent. Besides that, the bias in this study was minimized by ensuring that there were no friendship or sibling relations between the students as the study subject with the researcher.

Particulate Analysis

The results of $PM_{2.5}$ concentration measured was compared to the threshold value of the national threshold value (i.e., PermenLH, Permenkes), WHO, and EPA (see Table 1 for more details).

Health Risk Assessment

Parameters used to predict the health risk through various inhalation ways are described in Table 2. We calculated intake as the amount of risk agent concentration (mg) which enters the human body with a certain weight (kg) daily (Equation 1).

(Equation 1)

With:

I = daily intake (mg/kg/day)

C = risk agent concentration (mg/m^3)

R = inhalation rate (m^3/hour)

L = exposure time (hour/day)

Ef = frequency of exposure (day/year)

Ed = duration of exposure (year)

Bwt = weight (kg)

At = average daily period

We then compared the intake value with the reference dose (RfC), which resulted in the Risk Quotient (RQ) value (mg/m^3/day).

(Equation 2)

The reference dose (RfC) used was based on the value of the National Ambient Air Quality Standards (NAAQS) for the $PM_{2.5}$ (35 µg/ m^3). We did not use the national air quality value since the default value of the exposure factor was not known. The value of RfC used on determining the risk of $PM_{2.5}$ exposure was 0.005 mg/kg/day (16).

Results

Respondent characteristics

The total number of the respondent in this study is 103 primary school students from three public primary school in West Jakarta. The statistical descriptive of the respondents studied is shown in Table 3. In all three primary schools, respondents from the eleven-year age group have the highest percentage on every school compared with the other age groups.

Physical description of the study sites

The measurement of the physical environment of each school was done on different days. Besides the measurement of $PM_{2.5}$ concentration, we also measured the classrooms' temperature and relative humidity. The $PM_{2.5}$ concentration on each study site was measured from 9 points of sampling which were spread on each school for 6 hours. The lowest and highest value of $PM_{2.5}$ concentration found were both at primary school CB with the lowest being 30 μg/m^3 (fifth-grade classroom) and the highest being 197 μg/m^3 (fourth-grade classroom).

Analysis of environmental health risk

Anthropometry characteristics and respondents' activity pattern

We used the default value of exposure time and inhalation rate as described in the guidelines on the analysis of environmental health risk[12]. Other related variables, i.e., respondents' weight, exposure frequency, and exposure time were variables that depend on each respondent. The exposure frequency was calculated from the number of appointed school days or effective school days (209 days) subtracted by the number of students' absence days. We assumed that the exposure time is four years for the fourth-grade students and 5 years for the fifth-grade students. The students' weight was measured directly during the study.

The results showed that the respondents' weight was normally distributed (Table 5), except in the primary school CB. From the total of 103 respondents, the lowest weight recorded was 22.6 kg and the highest was 69.6 kg. Based on the calculation of estimated risk, the RQ value was ≤ 1, which indicated that the health exposure risk of $PM_{2.5}$ on the primary school students was considered safe during the moment of study. The risk management will only be done if the value of RQ exceeds 1.

Table 1. The threshold of $PM_{2.5}$ concentration (μg/m^3) for ambient and indoor air

Source of PM2.5 threshold regulations	Ambient air (μg/m3)		Indoor air (μg/m3)
	24 hours	1 year	24 jam
PermenLH No 12 Tahun 2010 (12)interconnected and stable flowing network of these natural fractures within the shale, without penetrating into water bearing zones below the shale. Shale wells capable of producing gas at several million scf/d, require development of a fracture pathway with shale face contact of an estimated five to ten million square feet (about one million square meters	65	15	
Permenkes No 1077 Tahun 2011 (13)			35
World Health Organization (WHO) year 2005 (14)	25	10	
Environmental Protection Agency (EPA) 2009 (15)1994; hereafter, the Inhalation Dosimetry Methodology	35	15	

Table 2. Standard value to count the PM exposure

Exposure Factors	Units	Values
Concentration (C)	mg/m3	-
Exposure frequency (Ef)	day/year	209
Inhalation rate (R)	m3/jam	0.5
Exposure duration (Ed)	year	6
Body weight (Bwt)	kg	-
Exposure time (Et)	h/day	6
Average time (At)	day	1,254

Table 3. The characteristics of the studied respondents

Characteristics	CT	(n = 46)	CB	(n = 36)	PS	(n = 21)
	Number	%	Number	%	Number	%
Sex						
Female	20	42.6	23	60.5	10	43.5
Male	26	55.3	13	34.2	11	47.8
Age (year)						
10	10	21.3	3	7.9	3	13.0
11	20	42.6	21	55.3	11	47.8
12	13	27.7	12	31.6	6	26.1
13	2	4.3	-	-	1	4.3
14	1	2.1	-	-	-	-
Duration of exposure (years)						
4	28	59.6	16	42.1	10	43.5
5	18	38.3	20	52.6	11	47.8

Table 4 Concentration of $PM_{2.5}$

Location	PM2.5 (µg/m3)			Temperature (0C)	Relative humidity (%)
	TWA	Min	Max		
CT					
4th grade	107	59	161	30.3	70
5th grade	67	47	108	29.6	73.1
Outdoor	84	43	136	33.1	63
CB					
4th grade	129	73	197	30.5	69.7
5th grade	37	30	49	31.6	66.9
Outdoor	114	74	191	30.8	68.1
PS					
4th grade	115	40	191	33.1	55.7
5th grade	79	56	121	33	56
Outdoor	78	43	157	31.3	70.1

Table 5. The anthropometry characteristics and activity pattern of respondents

Variable	Mean	Median	Min-Max	Distribution
Body weight (kg)				
CT	38.4	39.2	22.6 – 64.5	Normal
CB	35.7	33.4	22.7 – 69.6	Abnormal
PS	34.5	33.2	23.5 – 59.1	Normal
Exposure frequency (days/year)				
CT	895	832	776 – 1,045	Normal
CB	929	1,000	692 – 1,045	Normal
PS	904	960	720 – 1,030	Normal

Discussion

The results of indoor $PM_{2.5}$ concentration measurement in three primary schools in West Jakarta showed a higher value compared with the national threshold of the ambient air quality[13]. However, this result cannot conclude that the air quality in the studied areas being harmful to human health since the national air quality threshold[13, 14] require 24 hours of ambient air $PM_{2.5}$ measurements. Besides the ambient air, the indoor $PM_{2.5}$ concentration from three schools was higher than the national threshold (i.e., 35 μg/m^3) for offices for 8 hours. However, this value also cannot conclude that the indoor air quality from the studied schools being harmful to human health, since the threshold value is based on the office environment. A specific value designated for schools was not available yet. Meanwhile, our study only measured the $PM_{2.5}$ concentration during teaching activities. A relatively long period of measurement may reflect better the health risk caused by the $PM_{2.}5$ exposure since the effects of air pollutants were not only depending on the pollutants' concentration, but also the exposure time. The longer a person is being exposed to pollutants, the higher the chance of related health risks might appear.

Our study showed similar results with another study[15], where the ambient air $PM_{2.5}$ concentration was higher than the air quality standards. The safe intake (RfC) of $PM_{2.5}$ concentration for students was 0,031 mg/kg/day. Our $PM_{2.5}$ concentration value was higher compared with the ones recorded at a secondary school in Bandung (SMPN 16 Bandung), West Java, Indonesia[16]. The study on this secondary school showed a lower $PM_{2.5}$ concentration compared to the national air quality standards, but higher compared with the EPA standards. Another study in the industrial area (20) showed an overall higher value than the national air quality threshold and several points of sampling also showed a higher value compared to the EPA standards. The Indonesian national air quality standard is indeed being less restricted compared to other countries' air quality standards. Several related studies highlighted the need of special attention on the air quality; therefore, it is important for various groups working on the health and environment quality sectors (i.e., researcher, government, students, and related stakeholders) to know methods to measure the health risk, e.g., the analysis of environmental health risk.

Based on the calculation of the intake values, the lowest and the highest values were shown by the primary school PS. The possible explanation was due to the students' body weight; the lower body weight will result in a high intake value and the higher eight will result in a lower intake value. Another similar result was shown by other studies that explain that bodyweight is one of the determining factors of the intake value[16,17].

The health risk of $PM_{2.5}$ was only considered the value of RQ, this was due to the toxicity of $PM_{2.5}$[18,19] which was not allowing to further assess the carcinogenic health risk. The RQ value ≤ 1 found means that the students of primary school in West Jakarta was not under the risk at the moment of the study was conducted. This value can be interpreted as the inhalation exposure of $PM_{2.5}$ with the exposure time of 692-1,045 days and a duration of 4-6 years was considered safe to non-carcinogenic risk. This result was similar to another study(16), which also shown the $PM_{2.5}$ was not causing a health risk.

Conclusions

The lowest and the highest $PM_{2.5}$ concentration was found in fifth grade (35 ug/m^3) and fourth grade (129 ug/m^3) of primary school CB. The lowest and the highest intake was found in the primary school PS. The non-carcinogenic health risk from $PM_{2.5}$ exposure of the three primary schools has a value of RQ $\leq$ 1 which was considered safe in the time being.

Acknowledgment: This study was supported by the Publikasi Internasional Terindeks Tugas Akhir in Universitas Indonesia (Hibah PITTA) Universitas Indonesia, year 2019 (project number 217/ UN2.F10 / PPM.00.02/2019).

Ethical Clearance: This study was approved by the Research and Community Engagement Ethical Committe Faculty of Public Health Universitas Indonesia Number: Ket-285/UN2.F10/PPM.00.02/2019

Conflict of Interest: There is no conflict of interest inflicted in this study.

References

1. Indeks Standar Pencemar Udara (ISPU) di Provinsi DKI Jakarta Tahun 2019 - Indeks Standar Pencemar Udara di Provinsi DKI Jakarta Bulan Agustus Tahun 2019 - data.
2. Provinsi G, Khusus D, Jakarta I. 2005;
3. Brown JS, Gordon T, Price O, Asgharian B. Thoracic and respirable particle definitions for human health risk assessment. Part Fibre Toxicol [Internet]. 2013;10(1):1–12. Available at: http://www.particleandfibretoxicology.com/content/10/1/12
4. Li T, Hu R, Chen Z, Li Q, Huang S, Zhu Z, et al. Fine particulate matter (PM2.5): The culprit for chronic lung diseases in China. Chronic Dis Transl Med [Internet]. 2018;4(3):176–86. Available at: https://doi.org/10.1016/j.cdtm.2018.07.002
5. Kim KH, Kabir E, Kabir S. A review on the human health impact of airborne particulate matter [Internet]. Vol. 74, Environment International. Elsevier Ltd; 2015. hal. 136–43. Available at: http://dx.doi.org/10.1016/j.envint.2014.10.005
6. Laeremans M, Dons E, Avila-Palencia I, Carrasco-Turigas G, Orjuela JP, Anaya E, et al. Short-term effects of physical activity, air pollution and their interaction on the cardiovascular and respiratory system. Environ Int [Internet]. 2018;117(May):82–90. Available at: https://doi.org/10.1016/j.envint.2018.04.040
7. Atkinson RW, Kang S, Anderson HR, Mills IC, Walton HA. Epidemiological time series studies of PM2.5 and daily mortality and hospital admissions: A systematic review and meta-analysis. Vol. 69, Thorax. 2014. hal. 660–5.
8. Gowers AM, Cullinan P, Ayres JG, Anderson HR, Strachan DP, Holgate ST, et al. Does outdoor air pollution induce new cases of asthma? Biological plausibility and evidence; A review. Vol. 17, Respirology. 2012. hal. 887–98.
9. Madureira J, Paciência I, Pereira C, Teixeira JP, Fernandes E de O. Indoor air quality in Portuguese schools: levels and sources of pollutants. Vol. 26, Indoor Air. 2016. hal. 526–37.
10. Rovelli S, Cattaneo A, Nuzzi CP, Spinazzè A, Piazza S, Carrer P, et al. Airborne particulate matter in school classrooms of northern Italy. Int J Environ Res Public Health. 2014;11(2):1398–421.
11. Yu Y, Wang Q, Li L, Liu Z, Sun P, Zhang Y, et al. Particle-Associated Ambient Benzo[a]pyrene and Levels of Urinary 1-Hydroxypyrene in a Non-occupationally Exposed Population of Adults and Children in Lanzhou, China. Bull Environ Contam Toxicol. 2016;96(3):303–8.
12. Direktur Jendral PP dan PL Kementerian Kesehatan. Pedoman Analisis Risiko Kesehatan Lingkungan (ARKL). 2012.
13. KemenLH No.12. Peraturan Menteri Negara Lingkungan Hidup Nomor 12 Tahun 2010 Tentang Pelaksanaan Pengendalian Pencemaran Udara Di Daerah. Pelaksaan Pengedalian Pencemaran Udar Di Drh Menteri Negara Lingkung Hidup [Internet]. 2010;1–199. Available at: www.menlhk.go.id
14. Kemenkes. Peraturan Menteri Kesehatan No. 1077 tentang Pedoman Penyehatan Udara dalam Ruang Rumah. 2011;(1077):2011.
15. Bedah S, Latifah I. Risiko pajanan konsentrasi pm 10 dan pm 2,5 di kecamatan ciwandan, cilegon jawa barat tahun 2014. J Ilm Kesehat. 2017;9(1):93–102.

16. Rosalia O, Wispriyono B, Kusnoputranto H. Karakteristik Risiko Kesehatan Non Karsinogen Pada Remaja Siswa Akibat Pajanan Inhalasi Debu Particulate Matter <2,5 (PM2,5). Media Kesehat Masy Indones. 2018;14(1):26.
17. Atrisman, Abdurahman SW. Analisis dan manajemen risiko kesehatan pencemaran udara. Jurnal Ekologi kesehatan Vol 4. 2005. page. 270–89.
18. Lelieveld J, Evans JS, Fnais M, Giannadaki D, Pozzer A. The contribution of outdoor air pollution sources to premature mortality on a global scale. Nature. 2015;525(7569):367–71.
19. M. L. Toxicological and epidemiological studies of cardiovascular effects of ambient air fine particulate matter (PM2.5) and its chemical components: Coherence and public health implications [Internet]. Vol. 44, Critical Reviews in Toxicology. 2014. page. 299–347. Available in: http://www.embase.com/search/results?subaction=viewrecord&from=export& id=L372733161%0 Ahttp://dx.doi.org/10.3109/10408444.2013.861796