ORIGINAL ARTICLE

School Indoor Air Quality and Health Risk on the Junior High Schools Students in Depok, Indonesia

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ABSTRACT

Introduction: School environment represents an important microenvironment for students who spend 6-8 hours in classrooms. Indoor air quality is linked to several respiratory diseases in the school age group. This research aims to study indoor air quality of schools at different environmental characteristic and assess its health risks to students. **Methods:** This research measured air quality ($PM_{2.5}$, PM_{10}, CO_2, and HCHO) in three junior high schools and followed by health risk assessment. **Results:** This research found that the mean or median level of indoor $PM_{2.5}$ and PM_{10} in all three schools exceeded the standard value with health risks (HQ> 1) for $PM_{2.5}$ in all three schools and PM_{10} in two schools. Whereas carbon dioxide and formaldehyde concentrations were still safe and did not inflict health risks (HQ < 1). The scenario for managing the health risk of $PM_{2.5}$ and PM_{10} exposure was to control the exposure at a safe threshold of $PM_{2.5}$ 0.035 mg/m^3; 0.043 mg/m^3 and PM_{10} 0.144 mg/m^3 for most of the population at normal school time. **Conclusion:** It was concluded that the level of indoor particulate matters indicates poor indoor air quality in all three schools at different environmental characteristic and inflicts health risk on students so that the health risk management is required.

Keywords: $PM_{2.5}$, PM_{10}, carbon dioxide, Formaldehyde, School health

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INTRODUCTION

School is an important microenvironment because school children spend about 6 – 8 hours per day inside school building during weekdays (1,2). Classrooms in school have unique characteristics such as higher density than office room, diversity of student activities, and variety of ventilation systems that affect its indoor air quality (3). In addition, the indoor air quality is also determined by school environmental characteristic such as position to pollutant source and neighborhood activity (4,5). Several studies reported that traffic, industrial activity and biomass burning emit air pollutants to outdoor air that come in through infiltration and inadequate ventilation system and affect indoor air quality of classroom (1,4,6).

Some reports have estimated indoor exposures for children and adults, finding that children are at greater risk from pollutants that accumulate indoors due to higher respiratory frequency, higher physical activity, and the development of their respiratory system (7–9). In adolescent males, lung and thoracic development occurs until the end of puberty. Conversely, in adolescent females, lung development is almost finished following menarche (10). Indoor air quality of classroom has been associated to several diseases such as asthma, rhinitis and rhino conjunctivitis (4,11,12). Moreover, exposure to air pollutants in the school environment has been linked to the performance of students (13,14).

Indoor air pollutants that became the focus of this research were particulate matters (PM_{10} and $PM_{2.5}$), carbon dioxide (CO2), and formaldehyde (HCHO). Exposure to particulate matters, carbon dioxide, and formaldehyde inhaled is associated with symptoms of respiratory diseases such as asthma, wheeze, bronchitis, and lower respiratory tract infection (15–18). In addition, particulate matter is also reported to affect lung development while high carbon dioxide concentration is associated with drowsiness, lethargy, fug and even decrease in learning ability (13,18–20). Formaldehyde is a common indoor air pollutant, works as carcinogen for humans as proved in animal studies. In addition, acute and chronic formaldehyde exposure is related to non-cancer health effects such irritation of the eyes, nose, and throat (21,22).

Student health is important in academic achievement so that the Indonesian government runs a school health program but air quality has not obtained significant concern in this program. This research aims to study indoor air quality of schools with different environmental settings and assess its health risks to students. The health risk management would be advised if health risk is estimated in this study. The result of this study may be useful to improve school health program such as conducting air quality monitoring and controlling or improving school's environmental features.

MATERIALS AND METHODS

Location and Sampling

The location of air quality measurement was ten classrooms and three fields from three junior high schools located in sub-districts with different environmental characteristics namely Cimanggis (school A), Tapos (school B), and Beji (school C) as shown in Fig. I. School A is on the roadside and surrounded by office, stores and housing complex. School B is in the residential area. School C is located in the city center near busy main road, public transportation terminal and business area. The three schools had characteristics as shown in table I. The classrooms of each school were selected randomly.

Measurement of air quality parameters ($PM_{2.5}$, PM_{10}, CO_2 and HCHO) was conducted in May 2018 using several air quality monitoring instruments , namely DustTrak ™ II Aerosol Monitor 8532 ($PM_{2.5}$, PM_{10}), VelociCalc/ Q-Trak 7565 (CO_2, CO, temperature, humidity), and Formal Demeter HtV (HCHO). The instruments installed in the middle front of the classroom, at height parallel to student seating position. Each instrument was calibrated on measured point before running a measurement episode (23,24). The measurement was conducted on school hours with each parameter measured for one hour per point (classroom and field) unless formaldehyde that was only measured for 30 minutes per classroom point. The measurement of $PM_{2.5}$ and PM_{10} were not conducted simultaneously due to limited instrument availability. Indoor and outdoor air quality measurements were not conducted simultaneously due to the limited instrument availability. Formaldehyde was measured indoor only. The size of the floor (C) and ventilation (V) of the classroom was also measured using measuring tape. The ventilation size was the opening area of windows during air quality monitoring (25). Closed windows were not measured.

The minimum sample size was calculated using sample size formula for simple random sampling (26). The exposure of poor air quality is associated with abnormal lung function so that be used to approach the proportion of risk group. The proportion of abnormal lung function was based on a study by Kamaruddin (23). The sample size formula was as followed, with 95% confidence, the proportion of risk group (p) was 0.65 and absolute precision (d) was 0.05. Therefore, the minimum sample size (n) in this study was 350. The number of participated students from ten classrooms was 357, met the minimum sample size.

$$n = \frac{Z_{1-\alpha}{}^{2} p\,(1-p)}{d^{2}}$$

A survey was conducted on 357 students from randomly selected ten classrooms of each school to obtain data on body weight, height, and activity patterns that describe the population of junior high school students in Depok. The measurement of weight and height used digital scale and microtoise, while data on activity patterns were collected through questionnaires filled directly by the students.

Data Analysis

Air quality data, anthropometry, and activity patterns were analyzed descriptively to determine mean, median, and normal distribution of data using statistical analysis software. The used median size was in the form of mean or median based on data distribution. Furthermore, the non-parametric Mann Whitney test was used to compare the air quality inside and outside the classroom because not all data were normally distributed even though the data were transformed. Statistical analysis was carried out using SPSS version 22.0.

Health Risk Assessment

Quantitative risk assessment was conducted by referring to the Risk Assessment and Management Handbook 1996. Classrooms air quality data, anthropometric data, and students' activity data were used to estimate daily intake of $PM_{2.5}$, PM_{10} and carbon dioxide as non-carcinogenic agent; and formaldehyde as carcinogenic agent (27,28). The formula used is as follows:

$$CDI\ or\ LADD = \frac{C\ x\ R\ x\ t_E\ x\ f_E x\ D_E}{W_b\ x\ t_{avg}}$$

Calculation of the non-carcinogenic and carcinogenic daily intake (CDI or LADD, mg/kg/day) using mean or median pollutant concentrations (C, mg/m3) depending on the data distribution. For the daily intake of carbon dioxide and formaldehyde, the concentration value of ppm is converted to mg/m3 with the ideal gas equation at a measured temperature. While the rate of inhalation (R) uses the inhalation rate value of 11-16 years old, which are 15.7 m3/day (29). Junior high schools in Depok apply school time (tE, hour/day) 6 hours/day, 5 days/week. Based on the 2017/2018 academic calendar set by the West Java Provincial Education Board are obtained 218 days/year of school days including the exam days which is then deducted by the average of absence day according to the survey of student activity patterns so that the frequency of exposure (fE, day/ year) is obtained. In addition, students also conducted extracurricular activities after the normal 6 school-hours so then the calculation of the daily intake was also conducted based on the average time and frequency of extracurricular activities in the classroom. Duration of exposure (was based on the compulsory junior high school education for three years. Subsequently, it was divided by the value of student weight (Wb, kg) and the average daily period of carcinogenic exposure (DE x 365 day/year). Therefore, the daily intake value is the amount of normal daily intake (CDIn or LADDn) and additional daily intake (CDIt or LADDt).

Daily intake value of $PM_{2.5}$, PM_{10} and carbon dioxide would be used to calculate the risk level of non-carcinogenic (HQ) exposures. Daily intake value of formaldehyde was used to calculate the risk level of carcinogenic (ECR) exposures. The risk level was calculated using following formula:
Non-carcinogenic risk:

$$HQ = \frac{CDI}{RfC}$$

Carcinogenic risk:

$$ECR = LADD \ x \ IUR$$

The risk level (HQ) calculation of non-carcinogenic health impact through the inhalation pathway was carried out on the exposure to $PM_{2.5}$, PM_{10}, carbon dioxide, and formaldehyde by comparing the daily intake to the estimated value of exposure that did not provide health impact. For the inhalation pathway, this value was called reference concentration (Rfc), which could be obtained from NOAEL, LOAEL, or benchmark concentration along with uncertainty factor. The RfC value for $PM_{2.5}$, PM_{10}, carbon dioxide and formaldehyde were not available in the IRIS list. The researchers used annual guideline value that was derived based on the default value of exposure factors for adult individual recommended by U.S. EPA in 2014 and Exposure Factors Handbook 2001 to obtain a safe reference for daily intake. The guideline value used is the annual (long term) guideline value of $PM_{2.5}$ (primary guideline 0.012 mg/m^3, secondary 0.015 mg/m^3) and PM10 (0.05 mg/m^3) based on National Ambient Air Quality Guidelines (NAAQS) U.S. EPA in 1997 and 2012, carbon dioxide (1000 ppm) from American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Guideline 62.1-2016 recommendation, and 30 minutes formaldehyde guideline value (0.08 ppm) based on World Health Organization (WHO) in 2010 (30). The reference value of the safe intake used was $PM_{2.5}$ 0.002 mg/kg/day and 0.003 mg/kg/day, PM_{10} 0.009 mg/kg/day, carbon dioxide 338.51 mg/kg/day, and formaldehyde 0.019 mg/kg/day. The risk level of carcinogenic exposure (ECR) is calculated for formaldehyde exposure using the value of Inhalation Unit Risk (IUR) was 1.3 x 10-8 mg/m^3 (31).

If the HQ exceeded one, it is estimated that the level of $PM_{2.5}$, PM_{10}, carbon dioxide, and formaldehyde exposure inflict non-cancer effects to the students. Similarly, if the ECR exceeded one, it is estimated that the level of formaldehyde exposure inflict cancer effects to the students.

This research was approved by the ethic board of Universitas Indonesia, Faculty of Public Health, Universitas Indonesia (No.: 458/UN2.F10/PPM.00.02/2018) and the respondent's parents by signing the informed consent sheet.

RESULTS

Indoor Air Quality

The three schools have characteristics as shown in table I and Fig 1 with the highest percentage of ventilation to the size of classroom (% V/C) in school C. According to Regulation of Health Minister of Republic of Indonesia No. 1429/2006 on Guidelines of Health School Environment (Permenkes RI No. 1429/2006), the percentage of ventilation opening to room area should be 20%. The result of air quality measurement in table II shows the concentration of exposures at each school. The highest value of $PM_{2.5}$ was in school B with a median of 0.119 mg/m^3 for indoor air and a mean of 0.144 mg/m^3 for outdoor air. The lowest was at school C with a median of 0.056 mg/m3 for indoor air. While the PM_{10} indoor and outdoor was found to be highest at school C with a mean of 0.229 mg/m^3 and median of 0.218 mg/m^3, respectively. The lowest concentration of indoor PM_{10} was measured at school B with a median of 0.071 mg/m^3 and outdoor PM_{10} at school A with a mean of 0.065 mg/m^3. The highest value of carbon dioxide concentration indoor and outdoor was found in school B (556 ppm indoor, 270 ppm outdoor) followed

Table I: School and Classroom Characteristics

School	Mean V/C (%)	Guideline: Regulation of Minister of Health RI (Permenk-es RI) No. 1077/2011	Environmental Characteristics	Classroom Equipment
A	14.39	20%	On the roadside. A combination of business and residential area. Cemented floor and field, with some not cement-ed courtyard.	Fan, wooden table, wooden chair, white-board, and marker.
B	14.50		In the middle of residential area. Cemented floors and field and paved courtyard.	Fan, wooden table, wooden chair, white-board, and marker.
C	29.65		On the side of the busy main road. A business area in the city center. Cemented floors and courtyard.	Fan, wooden table, wooden chair, white-board, and marker. One class with carpet.

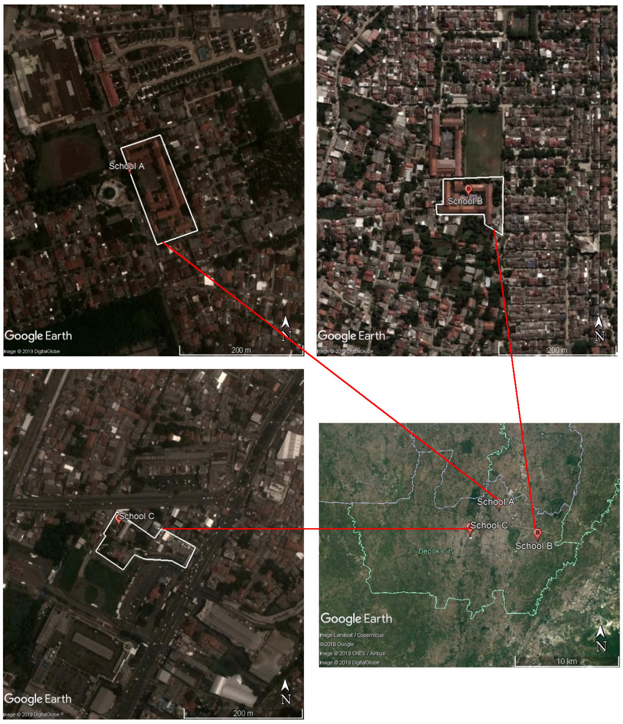

Fig. 1: The junior high school A, B, and C were located in in sub-districts of Depok, with different environmental characteristics. School A (Cimanggis) was on the roadside, surrounded by offices, stores and houses. School B (Tapos) was in the residential area. School C (Beji) was in the city center, adjacent to busy main road and business district. Source: Google Earth, accessed on Mar 2, 2019

by A and C. The formaldehyde central tendency was substantially the same between the three schools. The highest formaldehyde value of 0.025 ppm was found in school C. The mean of indoor temperature at school A (30.67 0C) was slightly higher than school B, and C. While the highest mean of indoor humidity was at school B (73.09% Rh). In table II, the measured parameters is compared against several guidelines i.e. National Ambient Air Quality Guidelines (NAAQS) U.S. EPA, WHO air quality guidelines, Government Regulation of Republic of Indonesia No.41/1999 on Environmental Management (PP RI No. 41/1999), Regulation of Health Minister of Republic of Indonesia No. 1077/2011 on Guidelines Air Sanitation in House (Permenkes RI No. 1077/2011).

Measurement of indoor and outdoor air quality was conducted in different hours but the same day, so it was assumed to represent the outdoor air quality along the measurement of the same day. The value of I/O ratio > 1 in table III shows that certain parameters were found to be higher at indoor. The value $PM_{2.5}$, PM_{10}, and CO_2 indoor concentration ratio to the outdoor was found more than one at school A (I/O $PM_{2.5}$ 2.13; PM_{10} 2.89; CO_2 1.64) and was statistically and significantly different. The ratio of indoor $PM_{2.5}$ and PM_{10} concentration to outdoor at school B and C was not more than one, not statistically and significantly for school C. The value of indoor carbon dioxide ratio to the outdoor in all schools

Table II: Indoor Air Quality of School A, B and C

Parameter & Location	School A	School B	School C	Guidelines	
	Mean (±SD)/ Median (IQR)	Mean (±SD)/ Median (IQR)	Mean (±SD)/ Median (IQR)	a)NAAQS U.S. EPA 1997, b)NAAQS U.S. EPA 2012, c)WHO, 2006 d)WHO, 2010	e)Government Regulation of Republic of Indonesia (PP RI) No.41/1999, f)Regulation of Minister of Health RI (Permenkes RI) No. 1077/2011
Temperature(^{0}C)					
Indoor	30.76 ± 1.43	29.54 ± 1.25	29.98 ± 0.46		e)18-30
Outdoor	37.03 ± 1.31	33.53 ± 0.36	36.43 ± 0.88		
Humidity (% Rh)					
Indoor	68.83 ± 8.07	73.09 ± 6.16	69.31 ± 4.23		e)40-60
Outdoor	39.81 ± 5.58	52.71 ± 1.17	44.63 ± 3.45		
$PM_{2.5}$ (mg/m^3)					
Indoor	**0.113 ± 0.015**	**0.119(0.120)**	**0.056(0.020)**		e)0.035, 24 hours
Outdoor	0.053 ± 0.003	0.144 ± 0.012	0.057 ± 0.009	b)0.012 - 0.015, 1 year b)0.035, 24 hours c) 0.010, 1 year c) 0.025, 24 hours	d)0.065, 24 hours d)0.015, 1 year
PM_{10} (mg/m^3)					
Indoor	**0.188(0.127)**	**0.071(0.017)**	**0.229 ± 0.058**		e)0.070, 24 hours
Outdoor	0.065 ± 0.003	0.087(0.030)	0.218(0.023)	b)0.15, 24 hours a)0.05, 1 year c)0.05, 24 hours c)0.02, 1 year	d)0.15, 24 hours
CO_2 (ppm)					
Indoor	408.741 ± 75.276	572.446 ± 170.169	368.0(40)		
Outdoor	250.813 ± 20.961	268.0(4)	250.0(11)		
CO (ppm)					
Indoor	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)		e)9.00, 8 hours
Outdoor				d)25, 1 hour	
Formaldehyde (ppm)					
Indoor	0.020(0.010)	0.020(0.010)	0.025(0.030)	d)0.08, 30 minutes	f)0.10, 30 minutes

Table III: Ratio of Indoor to Outdoor Air Quality

Parameter	School A		School B		School C	
	I/O	p value[a)]	I/O	p value [a)]	I/O	p value [a)]
$PM_{2.5}$	2.13	0.000[b)]	0.83	0.001 [b)]	0.98	0.593
PM_{10}	2.89	0.000 [b)]	0.82	0.000 [b)]	1.05	0.089
CO_2	1.63	0.000 [b)]	2.14	0.000 [b)]	1.47	0.000 [b)]

Mann-Whitney Test Indoor and outdoor air significantly different at $p < 0.05$

was more than one and statistically and significantly different.

Assessment of Non-Carcinogenic and Carcinogenic Health Risks

The risk assessment was conducted for three academic years of exposure to the junior high schools' students therefore the calculation of daily intake values based on anthropometric data and activity patterns of the respective group. The daily intake (CDI or LADD) was calculated by adding up normal daily intake (CDIn or LADDn) and additional daily intake (CDIe or LADDe), as shown in table IV. Normal daily intake describes intake during normal school hours while additional daily intake describes intake during extracurricular activities after normal school hours. The normal and additional daily intake used anthropometric data according to the results of survey by 357 students as respondents consisted of 157 males (44%) and 200 females (56%) with weight median of 46 kg, age 10-17 years from grade seven to nine of junior high school. Inhalation rate of the students is 15.7 m^3/ day, based on the inhalation rate of children aged 11-16 years old (29).

Based on the survey, a median of absence day was 2 days/year that reduce the number of normal school days (218 days/year), so that the frequency of exposure (fEn) was 216 days. The duration of exposure (DE) was three years according to the academic period of junior secondary. The extracurricular activity in the classroom took a median of 0.75 hour/ day (tEe), 1 day/week. It was assumed that students carry out activities for 30 weeks/year outside the exam weeks so that they can get 30 days/year of extracurricular activity (fEt).

The calculation of non-carcinogenic risk health of $PM_{2.5}$

Table IV: Daily Intake of Non-Carcinogenic and Carcinogenic Exposures in Three Years

Effect & Exposure	School A	School B	School C
Non-carcinogenic			
$PM_{2.5}$	0.006	0.006	0.003
PM_{10}	0.010	0.004	0.012
CO_2	0.011	0.004	0.013
Formaldehyde	3.705E+01	5.056E+01	3.345E+01
Carcinogenic			
Formaldehyde	1.175E-03	1.242E-03	1.736E-03

was HQ > 1 in all three schools, and PM_{10} was HQ > 1 in two schools, so that the exposure of particulate matters was estimated to have non cancer health effects on junior high school students (Table V). Risk management was then conducted by establishing a safe threshold value as shown in table VI.

Table V. Risk of Non-Carcinogenic and Carcinogenic Exposure

Effect & Exposure	Rfc or IUR	HQ		
		School A	School B	School C
Non-carcinogenic				
$PM_{2.5}$ [a)]	0.002	2.57	2.71	1.27
$PM_{2.5}$ [b)]	0.003	2.06	2.17	1.02
PM_{10}	0.009	1.03	0.39	1.25
CO_2	338.51	0.11	0.15	0.11
Formaldehyde	3.39E+02	1.11E-01	1.49E-01	9.88E-02
Carcinogenic				
Formaldehyde	1.30E-08	6.89E-13	6.92E-13	8.64E-13

a) The primary guideline value is 0.012 mg / m^3
b) The secondary guideline value is 0.015 mg/m^3

Table VI: Safe Threshold of $PM_{2.5}$ and PM_{10} Exposure

Exposure (mg/ m^3)	Students Characteristics			
	Normal School Hours		Normal & Extracurricular Hours	
	Wb = 46kg	Wb = 35.5kg[c)]	Wb = 46kg	Wb = 35.5kg[c)]
$PM_{2.5}$ [a)]	0.045	0.035	0.044	0.034
$PM_{2.5}$ [b)]	0.056	0.043	0.055	0.042
PM_{10}	0.186	0.144	0.183	0.141

a) The primary guideline value is 0.012 mg/m^3
b) The secondary guideline value is 0,015 mg/m^3
c) 10th percentile of student bodyweight to protect 90% of students.

DISCUSSION

Indoor Air Quality

Indoor $PM_{2.5}$ and PM_{10} in school A were considerably high and exceeded the guideline of 24-hours and annual of WHO, NAAQS U.S. EPA, PP RI No. 41/1999, and Permenkes RI No. 1077/2011. By considering the environmental characteristics of school A, indoor $PM_{2.5}$ and PM_{10} might be sourced from outdoor such as traffic emission, not cemented school yard, or particulate matters attached to students (32,33). However, school A had the lowest concentration of outdoor $PM_{2.5}$ and PM_{10} among all schools. The low outdoor $PM_{2.5}$ and PM_{10} might be caused by rain that occurred a day before the measurement at school A, so that it was expected to dissolve mainly outdoor $PM_{2.5}$ and PM_{10} but not much affect indoor air. In addition, it is reported that high indoor concentration of $PM_{2.5}$ and PM_{10} were associated with less or inefficient deposited particles removal or room cleaning and inadequate ventilation causing accumulation of the particulate matters (34). The average V/C % of school A was found below the guideline value of 20% according to Permenkes RI No. 1077/2011. The particulate matters might be trapped in the classroom, not much affected by the rain on previous day. Resulting in, school A had highest I/O ratio for $PM_{2.5}$ and PM_{10} among all schools This research did not record meteorological condition but several studies reported that meteorological conditions such as the wind and rain could reduce the concentration of particulate matters (9,35). However, the level of outdoor $PM_{2.5}$ exceeded the guideline of 24-hours and annual of WHO, NAAQS U.S. EPA, and annual of PP RI No. 41/1999. The level of outdoor PM_{10} exceeded the guideline of 24-hours and annual of WHO. Government Regulation of Republic of Indonesia and was U.S. EPA are more loose on the guideline of annual level of PM_{10} than WHO.

The measurement of particulate matters level in school B, which was located in the residential area, showed high indoor and outdoor $PM_{2.5}$. The level of indoor and outdoor $PM_{2.5}$ was the highest among three schools. Meanwhile, indoor and outdoor PM_{10} of school B was relatively low. Biomass burning and cooking are the main source of $PM_{2.5}$ pollutants in the residential areas (6,33). Besides that, soil particles from not cemented yard around the school leads to a high concentration of indoor $PM_{2.5}$ in school located in the residential area (6,34). The indoor concentration of $PM_{2.5}$ and PM_{10} at school B was lower than outdoor leaded to lower I/O ratio than school A and C. This might indicate modest source of indoor particulate mattes or good classroom cleanliness despite inadequate ventilation. The average V/C % of school B was found below the guideline value of 20% according to Permenkes RI No. 1077/2011. However, the level of indoor and outdoor $PM_{2.5}$ in school B exceeded the value guideline of 24-hours and annual of WHO, NAAQS U.S. EPA, PP RI No. 41/1999, and Permenkes RI No. 1077/2011. The level of outdoor PM_{10} exceeded the guideline of 24-hours and annual of WHO.

The level of indoor $PM_{2.5}$ and PM_{10} in school C exceeded the guideline of 24-hours and annual of WHO, NAAQS U.S. EPA, PP RI No. 41/1999, and Permenkes RI No. 1077/2011. Similar to the school A, the measurements at school C was performed after a rainy day but with different result. The rain was estimated to dissolve $PM_{2.5}$ so that it was measured low but still left high PM_{10}. The level of indoor and outdoor PM10 was the highest among three schools and exceeded the guideline of 24-hours and annual of WHO, NAAQS U.S. EPA, PP RI No. 41/1999, and Permenkes RI No. 1077/2011. However the level of outdoor $PM_{2.5}$ and PM_{10} was statistically not different to indoor and exceeded the compared guidelines. The location of school C was on the side of the main highway in the city center. High particulate matters could be sourced from heavy traffic that infiltrates school building. Traffic activity becomes one of the sources of indoor and outdoor PM10 due to fuel burning from motorized vehicles (32,33). A research on indoor PM_{10} reported that highway dust was a major component and associated with the high level of indoor PM_{10} (32). The chemical components of particulate matters could be analyzed further so that it can indicate the source of indoor and outdoor PM_{10} (4,32).

EPA studies indicate that indoor levels of pollutants may be two to five times higher than outdoor levels (3). Other study in Poland reported I/O ratio of particulate matters was 0.8 to 5.6 in school during day time with the level of particulate matters exceeded the WHO air quality guidelines (2). Whereas a study in tropical schools found I/O ratio of PM_{10} was above one and its level also exceeded the WHO air quality guidelines (32). The I/O ratio above one indicates higher indoor particulate matters. In this study, the I/O ratio of $PM_{2.5}$ and PM_{10} was 0.82 to 2.89 and the level of $PM_{2.5}$ and PM_{10} exceeded various guidelines. These studies showed that air quality in school environment requires significant attention since school age children spend about 6-8 hours per day in this microenvironment.

The median of indoor and outdoor carbon dioxide all schools did not exceed the guideline of Permenkes RI No. 1077/2011 and ASHRAE Guideline 62.1-2016. The level of carbon dioxide concentration in school A and B was higher than school C. The high carbon dioxide in the might be due to the ventilation factor. The average V/C % of school A and B was below the guideline value of 20% according to Permenkes RI No. 1077/2011. Indoor carbon dioxide concentration is related to several factors, i.e. occupant activity, room density, and length of occupancy. In addition, the size, number, position and type of ventilation affect the concentration of carbon dioxide in the classroom air using natural ventilation (36,37). The 30-minutes concentration of formaldehyde in all schools did not exceed the guideline value of WHO and Permenkes RI No. 1077/2011. Formaldehyde in classrooms might be sourced from markers, furniture tables and wooden chairs, or painted wall which are observed at the time of measurement.

Assessment of Non-Carcinogenic and Carcinogenic Health Risk

This research estimated that the exposure of $PM_{2.5}$ in classroom led to non-cancer health problems to the students. $PM_{2.5}$ exposure is considered more dangerous risk factor than PM_{10} because of the smaller particle size that enters the lungs and consist more toxic materials. Short-term exposure to $PM_{2.5}$ is associated with a number of respiratory health effects such as development of chronic respiratory diseases; reduced lung function; increased hospital visits and emergencies for respiratory diseases such as asthma, coughing, wheezing and shortness of breath and development of cardiovascular disease (17,38). Short term exposure might be reversible but long term exposure associated with greater health effect such as chronically reduced lung growth and function, cardiopulmonary and lung cancer mortality (17,18,39). Long term exposure to $PM_{2.5}$ is stronger risk factor of mortality than PM_{10} (17) . Studies reported the exposure of $PM_{2.5}$ at school environment was associated with asthma or asthma-like symptoms and airway inflammation on students (1,12).

The assessment of the exposure of PM_{10} in this research estimated non cancer health risk to the students. Short-term exposure to PM_{10} may be related to respiratory health and hospital visits and emergency units for cardiopulmonary related diseases. A study in Brazil showed that daily respiratory hospital admissions for children and adolescents in Sao Paulo increased with PM_{10} level (40). Whereas, studies at school environment found the exposure of PM_{10} at was associated with asthma-like symptoms and lung function disorder on students (1,12). Various long-term exposure toxicology studies indicate that PM_{10} is contaminated with heavy metals and other pollutants such as polycyclic aromatic hydrocarbons (PAHs) that can directly enter the body through inhalation, skin and oral contact so as to increase the risk of cardiovascular and respiratory diseases, and lung cancer (4,32,41). Furthermore, health risk could be assessed based on the chemical composition of particulate matters.

Level of $PM_{2.5}$ and PM_{10} concentration that exceeds the guideline values may lead to health risk (HQ > 1) and requires risk management. The most possible control scenario is to control the concentration of $PM_{2.5}$ and PM_{10} so that the daily intake value is lower than the RfC. School hour and academic year are associated to the quality of education and student achievement, not to be modified. Based on the tenth percentile of student body weight, 35.5 kg and the normal school hour without additional activities, a safe threshold of $PM_{2.5}$ is 0.035 mg/m^3; 0.043 mg/m^3 and PM_{10} 0.144 mg/m^3. This concentration is higher than the set guideline value and safe for 90% of the population only during normal school hours. Controlling the concentration of particulate matters can be performed by regular room cleaning to reduce the accumulation of particulate matters, regulating ventilation opening to the class area to meet the guideline, the use air purifier in the classroom, and school location should not adjacent to pollutant sources such as roads or industries.

Risk studies on the exposure of indoor carbon dioxide estimated no health effect to the students. In addition, 1000 pm recommendation value is related to the formation of body odor that disrupts the comfort of room occupants and does not have a serious effect on health (2,34). A research in Portugal using a 984 ppm reference value reported that high CO_2 exposure is statistically related to the student concentration (36).

Low formaldehyde exposure in all schools was estimated to not provide non-carcinogenic and carcinogenic health effect. The exposure of 0.1 to 0.5 ppm formaldehyde through the inhalation pathway causes irritating effect on the eyes and nasal passages, neurological effects, and an increased risk of asthma or allergies (21). Meanwhile, carcinogenic health effect on humans, ATSDR 1989 classified formaldehyde as group B1 or possibly carcinogen because of limited evidence for the incidence of human cancer.

CONCLUSION

The pattern of particulate matters among the three schools was different which might be related to each school environmental characteristic and meterological condition. However, the level of $PM_{2.5}$ and PM_{10} at three schools located in different environmental settings exceeded various short-term and long-term guidelines which indicates indoor poor air quality and inflicts a risk level of HQ > 1 for junior high school students. While the concentration of carbon dioxide and formaldehyde exposure was still in accordance with the applicable guideline values. The risk management scenario of $PM_{2.5}$ and PM_{10} exposure is required by controlling the concentration level of $PM_{2.5}$ and PM_{10} throughout school hour. Controlling the particulate matters could be done by regular room cleaning to reduce the accumulation of particulate material, the provision of air purifier, periodic air quality monitoring, regulating ventilation opening to classroom area to fit guideline values, and improving school locations or environmental settings by not being close to pollutant sources such as roads or industries. Furthermore, this research could be improved by conducting longer and simultaneous air quality monitoring and advanced health assessment method, counting in meteorological condition and epidemiological study to find the association between exposure levels and student health status.

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