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RESEARCH ARTICLE

Indoor Air Pollution and Respiratory Function on Primary School Students in West Jakarta, Indonesia

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Abstract:

Background:

This study aimed to investigate the relationship between air pollutant exposure, *i.e.,* Particulate Matter ($PM_{2,5}$), and the numbers of airborne bacterial colonies inside the classroom to the respiratory symptoms of three primary school children in West Jakarta.

Methods:

We did a quantitative study with a cross-sectional design using variables, *i.e.*, age, sex, physical activity, nutritional status, students' density, ventilation, classroom temperature, and classroom humidity. We used Haz-Dust EPAM 5000 to measure $PM_{2,5}$,MAS 100 NT to calculate the total bacterial colony, spirometry to measure the respiratory capacity, and questionnaire to measure other related variables.

Results:

We found a significant relationship between $PM_{2,5}$concentration with respiratory symptoms, however, there was no significant relationship between the total number of airborne bacterial colonies with respiratory symptoms.

Conclusion:

Based on our results, we conclude that there was a significant relationship between the $PM_{2,5}$ concentration and obstructive pulmonary symptoms and there was no significant relationship between the numbers of the bacterial colonies with pulmonary symptoms.

Keywords: Children, $PM_{2,5}$, Airborne bacterial colony, Respiratory function, Primary school, West Jakarta.

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1. INTRODUCTION

Polluted air is a condition where the air composition changes from the normal state due to the presence of a certain quantity of foreign substances during a certain period which mainly caused by the increase of human activity [1]. Humans spend most of their time in an indoor environment, *i.e.*, house and school [1, 2]. Children are more vulnerable to the effects of air pollution because their epithelial tissue in their respiratory tract is more permeable to pollutants [3]. Children's educationalactivities are mainly done inside the school, the classroom as the main area for study. The health of students and their school environment are crucial factors that support the education process. Poor air quality caused by several pollutants, such as airborne microorganisms (*e.g.*, bacteria, fungi) and particulate matter (*e.g.*, $PM_{2,5}$) could disrupt the education process, especially if the maintenance and cleanliness of schools were not done properly [4 - 6].

In general, the source of classroom pollutants was cigarette fume, incomplete combustion of fuel from the traffic and industry, and aircontaminatedwith microorganisms [7]. The main source of indoor microorganisms, or bioaerosol, is contaminated air from the outside environment. Bioaerosol can be a specific bacterium that enters indoor or fungi from decayed organisms [8]. Bioaerosols from dust particles are potentially causing the respiratory symptoms in humans [9]. Particulate Matter (PM) is one of the air pollutants which mainly consist of a complex mixture of solid and suspended liquid particles. Small-sized PM ($PM_{2,5}$) has 2.5 μm diameter which can penetrate thorax in the respiratory system and could

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cause several health symptoms, *e.g.*, asthma, respiratory tract infection, even death [10].

The ambient and indoor air pollution exposure could affect lung development of children, which can reduce lung function in the future [11, 12].The diseases (*e.g.*, asthma, lung cancer, pneumonia) and deaths caused by indoor air pollution mostly affected children and women, especially those who were coming from low-income households [13]. Air polluted by airborne microorganisms, *i.e.,* hundreds of species of bacteria and fungi which grow indoors when the air is humid may cause several health issues, such as allergy and asthma [14]. Asthma is a chronic inflammation of the respiratory tract which caused bronchus hyperactivity to several stimuli, *e.g.*, air pollution [15, 16].

Several types of research have reported the relationship between the occurrence of health symptoms to poor air quality, which were indicated by $PM_{2,5}$concentrationand airborne microorganisms. Study of air quality from 20 schools in Porto, Portugal reported a significant relationship between $PM_{2,5}$concentrationand the bacterial and fungi count with several health symptoms on children [2]. Asrul and Juliana [5] reported a significant relationship between $PM_{2,5}$concentration, fungi, bacterial count, and gram-negative bacteria with the lung function (%FVC and %FEV) on preschool children. Other research in East Jakarta on 2013 [17] reported poor air quality with $PM_{2,5}$concentrationof 10-168 μg/$m^3$with a mean value of 33.056±25.26 μg/m^3 with bacterial count between 92-1,828 CFU/$m^3$and mean 405.18±275.39 CFU/m^3. Based on data in the year 2018 taken from the air quality monitoring station in Jakarta, the poorest air quality appeared in West Jakarta [18]. From 183 measured days between March 2018 and October 2018, 164 days were categorized as unhealthy and 19 days was extremely unhealthy. The West Jakarta area has a highway located nearby primary schools. Seventy percent of air pollution in big Indonesian cities were coming from a high traffic activity, with the increase in the number of vehicles is being one of the primary causes [19]. People who spend most of their time at a distance of 200 m from the highway were more exposed to traffic air pollutants [20]. This research aimed to analyze the relationship of the classroom $PM_{2,5}$concentration and the number of bacterial colonies to the lung function on primary school children.

2. METHODS

2.1. Study Design

This study used a cross-sectional design with randomly assigned three primary school locations. We did the study from April 2019 to May 2019 with 100 students from grades 4 and 5 (10 and 11 years) as the samples. Sample size in this study is determined with estimated proportion formula by Lemenshow *et al*. (1990) in Notoatmodjo , resulting in minimum sample size of 69 respondents.To avoid missing respondents, the number of research samples was added by 20% so that the number of samples increased by 83 samples, eventually rounded up to 100 samples. Then, we use the probability proportional to size method to count the total number of each respondent (students) in each school. Probability proportional to size method is chosen so that the sample size will adjust and be even with the number of students in each school. Respondents were randomly assigned based on their willingness to participate after their guardians permitted and several other inclusion criteria. The inclusion criteria in this study were respondents who were in good health, were willing to become respondents by first signing the informed consent that was approved by parents/guardians, and were at the location of the study throughout the study. Respondents filled out the questionnaire, an incomplete questionnaire or a questionnaire from a respondent without their guardian's permission was excluded from the study.

2.2. Indoor Air Pollution Measurement

We measured the $PM_{2,5}$concentration using Haz-Dust EPAM 5000 positioned 1 meter above the ground and distant to walls and doors (*i.e.*, representing the actual children's respiration zone). We used one point of measurement in each classroom and one point outside the classroom. The measurement was done in six hours (7 am - 1 pm).

We measured the indoor airborne bacterial colony using Microbiological Air Sampler (MAS) 100 NT on six points in the classroom for 3.5 minutes positioned 1 meter above the ground anddistant to walls and doors (*i.e.*, representing the actual children's respiration zone).Inhaled air sample was flowed through the impinger pipe and then captured with 85% physiological solution in the impinger. Physiological solutions containing air samples would be planted in a medium, incubated, then observed for growing colonies. The total plate count methodwas used to measurethe number of colonies used. The number of colonies formed at each stage was recorded and counted again after 72 hours which was then used as a result of airborne microbial sampling. However, if after five days the microorganisms did not grow, the sample was declared negative. The number of colonies that grew was expressed in units ofCFU/m^3 (colony forming units per m^3volume of room air that is sucked).

2.3. Lung Function, Classroom Condition, and Physical Activity Measurement

We measured the lung function on students using a spirometer . We did the anthropometry test on respondents (*i.e.*, height, weight, sex, and age). In addition to that, we also measured the classroom's physical conditions (*i.e.*, temperature and humidity) and observed the classroom situation.The study data was collected on the characteristics of respondents using a questionnaire. Physical activity data was obtained using *Physical Activity Questionnaire for Older Children (PAQ-C)* questionnaire .

2.4. Statistical Analysis

All data were analyzed using statistical software. We used descriptive analysis to calculate mean, median, standard deviation, maximum value, and minimum value. Skewness and histogram of the data were observed to test the normality of data. Besides that, we also conducted a correlation testand students' t-test to understand the differences and relationship between $PM_{2,5}$concentration and the number of indoor airborne

bacteria colonies to respondents' lung function. Before the correlation test is performed, the normality test data is done first. Based on the results of the normality test data, if it is known that the lung function data is normally distributed and the PM2.5 concentration is not normally distributed, the Spearman non parametric correlation test is then performed. In addition, when the total air bacterial colonies tend to be normally distributed the Pearson correlation test is then performed.We used $p<0.05$ as the significant value on our bivariate analysis.

3. RESULTS

From the overall study location, the indoor and outdoor $PM_{2,5}$concentration did not differ significantly, with the minimum indoor concentration of 37.2 $\mu g/m^3$ and a median of 77.2 $\mu g/m^3$. The mean total number of indoor and outdoor bacterial colonies was 112.01 CFU/m^3, with a median of 113 CFU/m^3, and a standard deviation of 19.2CFU/m^3. The highest number of the bacterial colonies was 140 $CFU/m^3$and the lowest was 79 CFU/m^3. The environmental characteristic factor which affected the school's air quality was outdoor $PM_{2,5}$(measured in the schoolyard, nearby the gate), with the highest concentration 75.8 $\mu g/m^3$ and the lowest 84.7 $\mu g/m^3$(Table **1**).

Table 1. Descriptive distribution of the air quality measurement in study sites (n=100).

Variable	Mean	Median	Standard Deviation	Range
$PM_{2,5}$ indoor($\mu g/m^3$)	83.17	77.2	34.87	37.2 – 153.8
$PM_{2,5}$ outdoor($\mu g/m^3$)	83.1	84.5	3.22	75.8 – 84.7
Total airborne bacterial colony (CFU/m^3)	112.01	113	19.02	79 – 140

The age proportion on study sites with the age group of above 11 years was 55% (Table **2**). In general, there were no significant differencesin the number of respondents between age groups 10 and 11, or between female (49%) and male (51%). There were 53% of respondents with a normal nutritional condition and 47% with an abnormal nutritional condition. There was also no significant difference between respondents with sufficient physical activity (51%) and respondents with a lackof physical activity (49%). We found that each school has a different temperature and humidity level. Most schools have indoor classroom temperature of 30C (86%), indoor humidity of 60%Rh (93%), a proper ventilation system (84%), and a proper However, we suspected that thisstudents density (84%).

We found that our respiratory function data and the total number of airborne bacterial colonies were normally distributed.The$PM_{2,5}$concentration data were not normally distributed, therefore, we proceeded with the non-parametric Spearman correlation test. We found a weak correlation between the lung function and $PM_{2,5}$concentration (Spearman correlation r=0.230), but a significant relationship (p=0,018). We found a weak correlation (Pearson correlation r=-0.178) and no significant relationship (p=0.070) between $PM_{2,5}$concentration and the total number of airborne bacterial colonies (Table **3**).

We found no significant differences in the lung function between the female and male respondents sex group (p=0.149, Table **4**). The lung function differed significantly between the age group in our study (p=0.008). The lung function also did not differ significantly between the respondents' nutritional status (p=0.521) and physical activity (p=0.326). Several environmental factors inside the classroom also did not affect the respondents' lung function, *i.e.*, students' density (p=0.777), ventilation (p=0.482), and humidity (p=0.909). However, we found that the respondents' lung function significantly differed between the classroom temperature (p=0.001).

Table 2. Frequency distribution of individual characteristics and environmental factors.

Variable	Frequency Distribution (n=100)	
	Number	%
Age		
≥11 years	55	55
10 years	45	45
Sex		
Female	49	49
Male	51	51
Nutritional status		
Abnormal	47	47
Normal	53	53
Physical activity		
Lack	49	49
Sufficient	51	51
Temperature		
<18or>30C	86	86
18-30C	14	14
Humidity		
<40%Rh and>60%Rh	93	93
40-60% Rh	7	7
Ventilation		
Proper	16	16
Improper	84	84
Students' density		
Proper	16	16
Improper	84	84

Table 3. Pearson product-moment correlation analysis between respondents' lung function with $PM_{2,5}$ concentration and total bacterial colony on primary school students in West Jakarta.

Variable	r-value	p-value
$PM_{2,5}$concentration	0.236	0.018
Total bacterial colony	-0.178	0.070

4. DISCUSSION

In this study, the respiration symptom was identified by comparing the respondents' lung function measurement results

(FEV1/FVC%) with the national predicted value. The national predicted value that we used was based on the normal lung function value issued by *Pneumobile Project Indonesia* and specifically calculated by using our respondents' age, sex, and height. We then interpreted the results based on the lung function symptoms category, *i.e.*, the value of FEV_1/FVCless than 70% showed lung function symptom [21, 22]. Based on our analysis, the mean lung function (FEV1/FVC) of our primary school children was 89,4% with a median of 90,40%,a minimum value of 67,1%, a maximum value of 100%, and standard deviation of 7.2%. There was only one student with pulmonary symptoms (67%). However, we suspected that this was due to the student'ssmoking habit. The pulmonary function of the primary school students that we studied was relatively normal. A similar result was also shownin a study of lung function on primary school children in Porto, Portugal by Madureira *et al*. [2]. Madureira *et al*. [2] study also showed normal pulmonary function in primary school children and although there were some statistical differences, there were no relevant differences according to the levels of indoor air parameter tested.

Table 4. Analysis results of relationship between environmental characteristics with respondents' lung condition on primary school students in West Jakarta.

Variable	Mean	SD	p-value
Sex Female Male	90.45 88.37	6.65 7.62	0.149
Age ≥11 years 10 yers	87.20 91.18	7.80 6.18	0.008
Nutritional status Abnormal Normal	89.88 88.95	6.90 7.50	0.521
Physical activity Abnormal Normal	89.94 88.86	7.58 6.86	0.326
Students' density High Low	89.64 89.13	7.04 7.42	0.777
Ventilation Improper Proper	90.56 89.17	7.39 7.19	0.482
Temperature Abnormal Normal	90.32 83.66	6.75 7.48	0.001
Humidity Abormal Normal	89.32 90.28	7.33 5.62	0.909

The indoor $PM_{2,5}$concentration was more affected by the outdoor infiltration compared to the indoor source related to the presence of children and their indoor activities [23, 24]. There were several factors related to the outdoor source of $PM_{2,5}$, *i.e.*, location, weather condition, humidity, chemical and physical characteristics of pollutants, building characteristics, frequency of window opening, building inhabitants, and human activities [25, 26]. We found that the $PM_{2,5}$indoor concentration was higher than 35 μg/m^3, exceeding the Indonesian national air quality threshold in three schools [27]. We also found that most of the outdoor $PM_{2,5}$concentration in those schools was higher than 65 μg/m^3, also exceeding the Indonesian national air quality threshold [28]. Other studies also showed a high indoor $PM_{2,5}$concentration compared with the WHO air quality threshold or their national air quality threshold, *i.e*., (1) Study by Madureira [2] in 73 classrooms in Porto showed a $PM_{2,5}$concentration of 39-244 μg/m^3; (2) Study by Asrul and Juliana [5] in 120 preschool classroom in Puchong and Hulu Langat, Malaysia showed the indoor $PM_{2,5}$concentration of 48-67 μg/m^3; (3) Study by Khamal *et al.* [29]. in daycare classroom in DistrikSeremban, Negeri Sembilan, Malaysia showed the indoor $PM_{2,5}$concentration of 69.35 μg/m^3. It was observed thatmost of the outdoor source of $PM_{2,5}$in schools located near the highway was incomplete fuel combustion from the vehicles. Besides that, dust from asphalt road which entered through the ventilation and students' activity can also contribute to the indoor $PM_{2,5}$concentration. This study supports the hypothesis of a relationship between the $PM_{2,5}$ concentration and obstructive pulmonary symptoms on students from three primary schools in West Jakarta. However, our results must be cautiously interpreted since the $PM_{2,5}$concentration that we have measured was the present indoor exposure, not the individual exposure of each school children. Further research to measure the amount of individual exposure on every child can be done by using a personal dust sampler and measuring the lung function twice (*i.e*., before and after school) to observe the changes in FEV_1/FVC% ratio during school activities.In addition, the limitation of this study is the existence of information bias because respondents were asked to remember the habits of their physical activities during the week. This depended on the ability of respondents to remember and honesty in answering questions.

Our results on the classroom quality, which were obtained by the total number of bacterial colony showed a lower value (13-286 CFU/m^3) compared with the national threshold by the Ministry of Health (<700 CFU/m^3). Our results also showed lower value compared with another study in DistrikSeremban, Negeri Sembilan, Malaysia, which showed the total bacterial colony of 566,63 CFU/m^3 [29]. Our results also showed that the bacterial colony was not related to the pulmonary function. A possible explanation for our low number of bacterial colonies was due to the fact that the study was done during the dry season period, where the condition was not favorable for bacterial growth. Several researches showed that even a healthy lung was not free from the risk of airborne bacterial exposure, however, the total bacterial colony exposure inside a healthy human lung was tending to be constant and temporary [30]. Besides that, the inconsistent relationship between indoor bacterial exposure with health conditions can also be affected by the variation and design of the research, sampling method, analysis method, seasonal variation during the sampling, areas of sampling, and indoor activities [2]. The indoor bacterial colonies' concentration count can only reflect a short term of the actual concentration since inhabitants and their indoor activities can rapidly affect the indoor microorganism concentration [2]. In this study, we found a significant relationship between the total microorganism colony with the classroom temperature (p=0.0001, r=-0.812) and humidity

(p=0.0001, r=0.452). The indoor temperature negatively affects the number of microorganisms' colony, implying that the lower the classroom temperature, higher the bacterial colonies count. The humidity also negatively affects the bacterial colonies: the more humid the classroom, more bacterial colony growth and replicate. The negative effect of the indoor air temperature was also reported by other studies [31, 32]. Inside the room, several groups of people, *i.e*., children, elderly, and people who suffer from respiratory symptoms, allergy, and pulmonary diseases, were more vulnerable to diseases caused by microbiological pollutants [33 - 36]. Indoor microorganisms (*i.e*., fungi, mold, yeast, house dust mites) can trigger asthma. For instance, Woolcock and Kothen (1990) showed the prevalence of asthma in children in Bali with bronchus hyperactivity was 2.4% and pulmonary symptoms of 0.7% [21]. Asthma is one of the respiratory tract symptoms due to the chronic inflammation which caused bronchus hyperactivity to several stimuli, such as air pollution [15, 16].

In further research, it is recommended to measure $PM_{2.5}$ concentration and total concentration of bacterial colonies in a room with lung function using a cohort study to determine the decline in lung function of elementary school students. In primary schools, healthy school programs can be improved, one of which is to work closely with environmental agencies related to air pollution control in schools by measuring air pollution to determine the level of risk of exposure generated in the school area. Our data also can be used as the baseline scientific information for updating the regulation in air pollution and heath implication in a big city such as in Jakarta.

CONCLUSION

Based on our results, we conclude that there was a significant relationship between the $PM_{2.5}$concentration and obstructive pulmonary symptoms and there was no significant relationship between the numbers of the bacterial colonies with pulmonary symptoms.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

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

HUMAN AND ANIMAL RIGHTS

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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