



Original Article

Effect of Exposure to 2.5 μm Indoor Particulate Matter on Adult Lung Function in Jakarta

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ABSTRACT

Article history:

Received: November 5, 2018

Revised: February 7, 2019

Accepted: February 25, 2019

Keywords:

indoor air pollution,
lung function test,
particulate matter

Objectives: Lung function impairment due to exposure to indoor air pollution of particulate matter size 2.5 micrometers ($\text{PM}_{2.5}$) is not well documented in Jakarta.

Methods: To assess whether there is an association between indoor $\text{PM}_{2.5}$ concentration and lung function impairment among the adult population, a cross-sectional design was implemented. There were 109 adults selected aged between 20 years and 65 years from the Pulo Gadung industrial area, East Jakarta. Association and logistic regression analysis were implemented for statistical analysis of the data.

Results: The average exposure to indoor $\text{PM}_{2.5}$ was $308 \mu\text{g}/\text{m}^3$. There were 38.5% of participants that had lung function impairment. $\text{PM}_{2.5}$ concentration was found to be associated with lung function impairment among the adult population living in Pulo Gadung industrial area after controlling for gender, duration of exposure, ventilation, smoking status, and humidity.

Conclusion: The results of this study suggest that $\text{PM}_{2.5}$ concentrations in the Pulo Gadung industrial area may be the main contributor to the impairment of lung function for adults living in the surrounding residential area.

<https://doi.org/10.24171/j.phrp.2019.10.2.02>
pISSN 2210-9099 eISSN 2233-6052

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Introduction

The impact of air pollution on human health is the main driver toward implementing air quality regulations, yet the mechanisms linking increased air pollution in Southeast Asia with the impact on health is poorly understood. It has been recognized through epidemiological investigations, that particulate matter (PM) in the air contributes to the progression and exacerbation of respiratory diseases such as asthma, and leads to an increase in morbidity and mortality from respiratory and cardiac conditions [1].

In the developing countries of Southeast Asia, PM pollution particularly in urban areas, is routinely above the daily average standard (daily average national ambient air quality standards

for PM_{10} and $\text{PM}_{2.5}$ are $100 \mu\text{g}/\text{m}^3$ and $60 \mu\text{g}/\text{m}^3$, respectively) and the conditional pollutant for calculating the Air Quality Index for health, impacts assessments. This is important as PM has a significant correlation with adverse effects on human health, especially for PM with a diameter of less than $10 \mu\text{m}$ (PM_{10}) and less than $2.5 \mu\text{m}$ ($\text{PM}_{2.5}$). These PM are small enough to penetrate the thoracic region of the respiratory system to cause disease [2].

$\text{PM}_{2.5}$ has potentially the most significant adverse effects on health compared to other pollutants, and has become a new indicator for “major problem pollution” in the world during the last 3 decades. The World Health Organization (WHO) in 2015, reported the annual average of exceeded $\text{PM}_{2.5}$ concentration was 8.6% in USA, 0.01% in Canada, 99.9% in Mexico, 83.4% in

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Europe, and 88.9% in Indonesia [3].

Some health studies [4-6] have shown a significant association between PM_{2.5} and lung function. A mechanism of lung injury can be described as the ability of PM_{2.5} to induce oxidative stress. The oxidative stress mediated by the particles may arise from direct generation of reactive oxygen species from the surface of particles, or from soluble compounds such as transition metals or organic compounds (poly-aromatic hydrocarbons). Oxidative stress may upregulate redox sensitive transcription factors (via nuclear factor kappa B, NF-κB) in airway epithelial cells, thus increasing the synthesis of proinflammatory cytokines resulting in cell and tissue injury [4]. This condition can cause the decline of lung function which in turn is an indicator used to determine chronic respiratory disorders [7]. WHO reported that there were 4.2 million deaths due to chronic respiratory disease [8]. A study performed in Rome showed the association of exposure to high concentrations of PM_{2.5} and declining lung function. It has been reported that the metallic content of PM_{2.5} may be important given the negative effects of Zn, Fe and Ni concentrations on lung function indices [4]. Wegesser et al [9] in 2009 reported that in mice, PM_{2.5} caused lung injury, especially in alveoli.

Jakarta is one of the most polluted cities in the world. Air pollution in Jakarta exceeds the safe limit specified by the WHO [10]. This current study was conducted in Pulo Gadung, an industrial area located in Rawa Terate Village of Cakung sub-district, in East Jakarta. The Jakarta Environmental Office reported that the average concentration of total suspended particulates in the area was far above the safe limit (296 µg/m³ in 2009, 301.9 µg/m³ in 2010, and 248.8 µg/m³ in 2011) [11]. The objective of this study was to assess the association between indoor PM_{2.5} concentrations and lung function impairment in an adult population.

Materials and Methods

A cross-sectional study design was implemented that included 109 adults aged 20 to 65 years old, who had been living in Rawa Terate village for 5 years or more, who were not seriously ill (including respiratory infection), and who had agreed to participate in this study. The participants were drawn from 6 of the smallest community groups (Rukun Tetangga) of Rawa Terate village, with 6 community level areas of the village (Rukun Warga) identified using a stratified random sampling method. Data collection was conducted on March to May 2012.

The lung function was measured using the spirometry test and vital capacity, forced vital capacity (FVC), the first second of forced expiration (FEV₁), and FEV₁ / FVC were recorded. The indoor PM_{2.5} concentration was measurement by real-time DustTrak TSI equipment over 60 minutes (every 10 seconds

data was recorded) for every single point source in the house. A total of 42 houses had points of measurement selected. The points of measurement were based on the family's most frequently occupied areas which were mostly the living room, and the bedroom where typically 6-12 hours per day would be spent. Trak Pro Version 3.41 software was used for downloading indoor PM_{2.5} data.

The data of the participants' characteristic demographics such as gender, smoking status, nutritional status, age, length of stay in the area, the duration of exposure, and living environmental data (type of floor, residential density, house ventilation, fuel for cooking, mosquito coil, temperature, and humidity) were obtained from individual interviews and observations made using modifications of a questionnaire adopted from a standard questionnaire used in similar studies previously.

Results

Indoor PM_{2.5} measurements were successfully obtained from 42 (100%) of 42 houses. Lung function measurements were obtained from 109 (97%) of 112 participants. The concentration range of indoor PM_{2.5} was from 80 µg/m³ to 1,240 µg/m³, with an average concentration of 308 µg/m³ +/- 213 µg/m³ (95% CI: 267.6 - 348.5 µg/m³). This showed that the concentration of PM_{2.5} in Rawa Terate village exceeded the safe limit of 35 µg/m³ specified by Peraturan Menteri Kesehatan Republic of Indonesia Number: 1077/2011. Univariate analysis of adults' lung function showed that 42 out of 109 samples suffered lung function impairment.

The participants' characteristics in the Pulo Gadung area were predominantly female (71%) and non-smokers (70%). More than half of the participants (51%) had a malnutrition (Table 1). The average participants' age was 43 years, and the

Table 1. Participants' characteristics (N = 109).

Variable	n (%)	n (%)
Gender		
Male	32	(29.4)
Female	77	(70.6)
Smoking status		
Yes	33	(30.3)
No	76	(69.7)
Nutritional status		
Abnormal	56	(51.4)
Normal	53	(48.6)

average length of time lived in the area was 33 years. The exposure time to indoor PM_{2.5} averaged at 17 hours per day (Table 2).

Most of participants lived in a house which was made from tiles or ceramics (98%), with an adequate residential occupancy for that space (≥ 3.5 m²/people), and used gas/electric for cooking. However, 75% of the houses did not have appropriate ventilation. Lung function impairment was observed in 38.5%

of the participants. The indoor PM_{2.5} concentration was found to be statistically significantly associated with adult lung function impairment [$p < 0.01$, with a crude Odds Ratio (cOR) = 3.31 (1.46-7.48), and length of exposure (cOR) = 3.56; (1.57-8.08)]. Meanwhile, age and length of stay in the area had no association with lung function impairment (cOR = 0.99; 0.97-1.03 and cOR = 0.99; 0.97-1.02 respectively). Gender and smoking status were however associated with lung function impairment which was a higher risk for males than females (cOR = 2.8) and among smokers (cOR = 2.6). The nutritional status was not associated with lung function impairment (Table 3).

The environmental risk factors tested for an association with adult lung function impairment included house ventilation, use of mosquito coils, temperature and humidity. Adequate house ventilation and room humidity outside the ideal range of 40%-70% was associated with lung function impairment ($p < 0.05$). The cOR was 3.4 for inadequate ventilation and 3.1 humidity outside the ideal range of 40% - 70% (Table 4).

Table 2. The distribution of age, length of stay in the area, and length of daily exposure to indoor PM_{2.5}.

Variable	Mean	SD	Range	95% CI
Age (y)	43	13	20 – 65	40 - 45
Length of stay (y)	33	18	5 – 65	30 - 37
Length of exposure (h)	17	5	6 – 24	16 – 18

SD=standard deviation; CI=confidence interval

Table 3. Association of adult lung function impairment with gender, smoking status, and nutritional status.

Variable	Adult lung function Impairment (n = 109)				cOR	p
	Yes		No			
	n	%	n	%		
Gender						
Male	18	56.2	14	43.8	2.8	0.03
Female	24	31.2	53	68.8		
Smoking status						
Yes	18	54.5	15	45.5	2.6	0.04
No	24	31.6	52	68.4		
Nutritional status						
Abnormal	19	33.9	37	66.1	0.7	0.41
Normal	23	43.4	30	56.6		

cOR=crude Odds Ratio

Table 4. Environmental factors associated with adult lung function impairment.

Variable	Adult lung function impairment (n = 109)				cOR	p
	Yes		No			
	n	%	n	%		
House ventilation						
Inadequate	36	45.6	43	54.4	3.4	0.03
Adequate	6	20.0	24	80.0		
Mosquito coil						
Yes	7	50.0	7	50.0	1.7	0.52
No	35	36.8	60	63.2		
Temperature						
Not ideal (< 18 °C, > 30 °C)	15	37.5	25	62.5	0.9	1.00
Ideal (18 °C - 30 °C)	27	29.1	42	60.9		
Humidity						
Not ideal (< 40%, > 70%)	18	58.1	13	41.9	3.1	0.02
Ideal (40% - 70%)	24	30.8	54	69.2		

cOR=crude Odds Ratio

Discussion

In 1983 Spengler and Sexton reported that indoor air pollution was dependent on outdoor air pollution and the activities of household occupants [12]. This study showed that indoor $PM_{2.5}$ concentration in the surroundings areas of Pulo Gadung was above the safe limits as specified by the Environmental Protection Agency 2006 [13]. The average indoor $PM_{2.5}$ concentration in this study was 9 times higher than the air quality standard, probably resulting from the industrial business area in East Jakarta. Another study found that an increase in air pollution by $1 \mu\text{g}/\text{m}^3$ $PM_{2.5}$ in the outdoor environment, may increase indoor pollution by $0.58 \mu\text{g}/\text{m}^3$ $PM_{2.5}$ [14].

This study indicates that adults who are exposed to a higher than acceptable indoor $PM_{2.5}$ concentration, have a risk of lung function impairment. This result is consistent with a previous study that found a correlation between $PM_{2.5}$ concentration and impaired lung function [5]. In addition, another study reported that the $PM_{2.5}$ contained 8 types of metals, Iron (Fe), Zinc (Zn), Lead (Pb), Platinum (Pt), Cadmium (Cd), Chromium, and Nickel (Ni) [4]. Exposure of mice to high levels of $PM_{2.5}$ was shown to damage lung structure and function, especially in the alveoli. Furthermore, this was in a dose-dependent manner with higher doses of $PM_{2.5}$ having a worsening effect than lower doses of $PM_{2.5}$ [9].

When inhaled $PM_{2.5}$ reaches the alveoli, with particulate and oxygen metabolites interacting to produce reactive oxygen species which oxidize guanine to 8-oxoguanin resulting in oxidative stress in the body [4]. Oxidative stress occurs when the number of free radicals in the body exceeds the capacity to neutralize them, in turn causing inflammation in the lung and limiting lung expansion which decreases lung function [15].

This study showed that gender, smoking status, and the daily duration of exposure were statistically significantly associated with the decline of adult lung function. Using cross sections of the upper respiratory tract Kim and Hu explained that females have a higher risk for deposition than males because their lungs are smaller. Peak expiratory flow is affected by lung volume, the elasticity of the lungs, lung strength, and coordination of respiratory muscles. In general, males produce higher alveolar pressure than females. Therefore, males can have a higher value of peak expiratory flow than females so that the inhaled air in males is greater [16].

Indonesia has the third largest number of smokers in the world after China and India [17]. Basic Health Research 2007 reported that males consume more cigarettes than females [18]. Previous studies have found that males who smoked 1 pack of 20 cigarettes per day reduce their average FEV_1 by 12.6 mL per year. Meanwhile, females who smoked the equivalent number of cigarettes reduce their average FEV_1 by

7.2 mL per year. Therefore, cigarette smoking carries a higher risk of lung function decline for males than females [19]. A previous study showed that occupant smoking in the home can increase indoor $PM_{2.5}$ concentration by $0.42 \mu\text{g}/\text{m}^3$ [13]. One study reported that females are more at risk of lung function impairment than males due to cigarette smoke [20]. The years of exposure duration to indoor $PM_{2.5}$ is also associated with adult lung function impairment. A previous study showed that lung function impairment occurred after 5-6 years of indoor exposure to $PM_{2.5}$ [21].

House ventilation, mosquito coils, temperature, and humidity are environmental variables assessed during this study. The results showed that ventilation and humidity were statistically significantly related to adult lung function impairment. A previous study in Nunavut, Canada showed that reduced house ventilation can adversely influence respiratory tract disorder in children [22]. The function of ventilation is to exchange air from inside to outside. Increasing ventilation has been shown to reduce indoor pollutants [23]. A study performed in Nigeria showed that ventilation in the kitchen reduced pollutants arising from cooking such as $PM_{2.5}$ aliphatic hydrocarbons, and polycyclic aromatic hydrocarbons [6].

Humidity is the compounding variable in this study which directly influences the association between $PM_{2.5}$ and adult lung function impairment. A previous study has showed that the impact of air pollution will worsen human health if it is supported by high humidity [24].

The limitation of this study was that it was not carried out in both an industrial and a non-industrial area. Therefore, it was not possible to confirm that the risk of adult lung function impairment was due to the surrounding industrial area of Pulo Gadung.

Conclusion

The average concentration of $PM_{2.5}$ inside homes in Pulo Gadung area was 9 times higher than air quality standard specified by EPA (2006) and the prevalence of lung function impairment was 38.5%. The average indoor $PM_{2.5}$ concentration was significantly associated with lung function impairment in the population living in the area after controlling for gender, daily duration of exposure, ventilation, smoking status, and humidity. Industry may be the main contributor to $PM_{2.5}$ concentrations in the surrounding area causing adult lung function impairment. Air pollution control needs to be implemented and strictly enforced for industries to reduce $PM_{2.5}$ concentrations in the surrounding residential areas.

Conflicts of Interest

The authors declare no competing financial interests.

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