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The impact of $PM_{2.5}$ air pollutant exposure on human respiratory health: A literature review

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Abstract

Exposure to air pollutant serves as an important indicator Global Burden of Disease. Most of the total mass of particles in the air consists of fine particles measuring between 0.1 and 2.5 μm or what commonly known as $PM_{2.5}$. The common sources of $PM_{2.5}$ exposure are motor vehicles, cooking activities (using wood fuel or charcoal briquettes), mining industry activities, and smoking. $PM_{2.5}$ is the main component of air pollutant that causes respiratory disease because it can penetrate lung alveoli and enter the bloodstream, causing inflammation of the respiratory tract. This study aims to examine $PM_{2.5}$ exposure to human respiratory disease based on previous studies which are summarized into one environmental health-based study. The design of this study is literature review using the PubMed and Google Scholar databases published in 2018-2023. From the screening process and conformity with the inclusion criteria, 9 reference articles were obtained in this study. From the 9 studies reviewed, there were 4 studies which stated that there was a significant relationship between $PM_{2.5}$ exposure and asthma, while 5 other studies stated that there was a significant relationship between $PM_{2.5}$ exposure and decrease in lung function that refers to COPD. So it can be concluded that exposure to $PM_{2.5}$ causes human respiratory disease, especially asthma and COPD.

Keywords: $PM_{2.5}$; Asthma; COPD; Air Pollution; Environmental Health

1. Introduction

Air pollution is a form of environmental contamination by chemical, physical or biological substances that occurs both indoors and outdoors. Nearly the entire population in lower-middle-income countries has inhaled air pollutants that exceed the limits allowed by WHO, that cause nearly 90% of deaths (1). In fact, in 2020, air pollution is the cause of 3.2 million deaths, including more 237,000 deaths of children under 5 (2). Exposure to air pollutants, including particulate matter (PM), serves as one of the main indicators of the cause of Global Burden of Disease (3). Particulate Matter (PM) is one of the most common types of air pollutant. PM can be classified as coarse, fine, or very fine (PM_{10}, $PM_{2.5}$ and UFP) according to their size. Most of the total mass of particles in the air consists of fine particles with a size range of 0.1 to 2.5 μm or commonly known as $PM_{2.5}$ (4). Industrial activities, motorized vehicles, cooking activities (such as using wood fuel or charcoal briquettes), wild fires, and smoking can be the main sources of high concentrations of $PM_{2.5}$ (5,6). Meteorological conditions including average temperature, wind speed, and relative humidity during the time of research can also play an important role in increasing the concentration of $PM_{2.5}$ in the air (7,8).

Based on the Air Quality Guidelines (AQGs) published by WHO in 2021, the threshold value for exposure to $PM_{2.5}$ is 25 μgram/m^3 (9). High concentrations of PM in a room can be caused by the formation of PM in the room itself accompanied by the entry of PM from outdoor. Indoor occupant activities can generate and resuspend PM, which turn can increase PM concentrations both indoors and outdoors (10). The elderly with chronic heart or lung disease, children, and people with asthma are the groups most likely to experience adverse health effects from exposure to $PM_{2.5}$ (11). The elderly are

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more susceptible than young adults and have a higher risk of living with chronic diseases due to exposure to $PM_{2.5}$ (12). While children in exposure to $PM_{2.5}$ can cause significant blockages and interfere with lung function development (13).

$PM_{2.5}$ is referred to as the main component of air pollutants that cause respiratory problems (3,14,15). The Health Effect Institute states in its book "State of Global Air 2020" that during 2019, long-term exposure to $PM_{2.5}$ contributed to more than 4 million deaths and accounted for 62% of all deaths from air pollution in the world (16). People exposed to $PM_{2.5}$ with high concentrations and long duration, has a risk of decreased lung function, chronic obstructive pulmonary disease, asthma (COPD), and the immune response of the lung organs which tends to be low (17,18). Several studies have shown that $PM_{2.5}$ increases the risk of respiratory morbidity, hospital admissions and visits to the emergency department for respiratory disorders, exacerbates chronic respiratory conditions, and decreases lung function (19,20).

Like other components of air pollution, $PM_{2.5}$ contains toxic substances and carries them into the respiratory tract. $PM_{2.5}$ particles can penetrate the alveoli of the responsive lung and enter the bloodstream, causing adverse health effects (21). $PM_{2.5}$ is easily inhaled into the respiratory tract and penetrates the alveoli of the lungs, where these toxic particles will cause structural damage and decreased lung function (21). A small portion of $PM_{2.5}$ penetrates the deepest parts of the airways to impair the pulmonary immune response. This causes inflammation of the airways and makes them susceptible to various respiratory infections (11).

The effects of $PM_{2.5}$ exposure can cause negative effects on the health of the respiratory system, especially for populations that are vulnerable and sensitive to dust particles (22,23). Some populations that are susceptible to $PM_{2.5}$ exposure include children under 18 years, pregnant women, and the elderly people (24). Meanwhile, the level of sensitivity to $PM_{2.5}$ is associated with physiological differences between men and women. Specifically, it is known that males and females differ in lung size, airway diameter, air absorption, and cardiovascular response. Toxicokinetic differences in $PM_{2.5}$ absorption and metabolism may influence acceptable dose-related pollutants for men and women. This difference can affect the dose of $PM_{2.5}$ inhalation, which ultimately leads to different health risks (25).

Chronic exposure to $PM_{2.5}$ can cause COPD and asthma (11,26). $PM_{2.5}$ contributes to the increased prevalence and severity of symptoms in children and adults with asthma. Air pollutants with high levels of $PM_{2.5}$ can affect the development and morbidity of asthma (27,28). PM exposure can cause oxidative stress, airway remodeling, inflammatory pathways and immunological responses, which can then exacerbate allergic respiratory sensitization to aeroallergens (29). Inflammatory or inflammatory responses that occur are considered as predisposition and exacerbation of the asthma response to inhaled allergens, giving rise to asthma symptoms (30).

Air pollutants, including $PM_{2.5}$, can cause COPD exacerbations. COPD exacerbations (increased symptoms of cough, dyspnea, and periodic sputum production) are the main contributors to decreased lung function and decreased quality of human life (31). The lungs, the initial site of $PM_{2.5}$ deposition in the airways, are one of the main targets of $PM_{2.5}$ toxicity. High $PM_{2.5}$ exposure can interfere with the normal immune response through two mechanisms. First, by damaging the bronchial mucociliary system which functions as a cleaning agent. Second, by disrupting the cytokine network, it can cause death of lung epithelial cells and fibroblasts, as well as increase the permeability of the epithelial barrier and impair its function as a physical barrier for the innate immunity of the lung organs. (11).

Interestingly, exposure to $PM_{2.5}$ is up to 4 to 5 times higher in developing countries than in developed countries (32). Thus, in recent years, more research has been conducted regarding the impact of Particulate Matter pollution on public health because PM is still a one of the issues related to environmental health, especially dangerous air pollution in developing countries (3,33,34). Therefore, the researcher wrote a literature review which aims to examine $PM_{2.5}$ exposure to respiratory problems due to exposure to $PM_{2.5}$ air pollution based on previous research which was summarized into one study based on environmental health.

2. Material and methods

This type of research is a literature review which is carried out by summarizing and concluding some of the research results that have been published in the form of journal articles. Article searches use the PubMed and Google Scholar databases based on the 2018-2023 range. The keywords used when searching for articles in the database are "$PM_{2.5}$" and "human respiratory health". The inclusion criteria in this study were: articles from original research studies, articles published in international journals, the dependent variable is respiratory disorders or diseases related to human respiratory, and research published in the year 2018-2023. After screening based on inclusion criteria, 9 relevant articles were obtained and further analysis will be carried out in this study.

3. Results and discussion

Table 1 Summary of 9 Articles Used as Literature Review References

Author	Research Method	Dependent Variable	Result	Conclusion
(Sak et al., 2018)	*Cross sectional*	Asthma (wheezing and asphyxiation)	$PM_{2.5}$ exposure is associated with wheezing and shortness of breath in people in the cotton plantation area of Urfa City, Turkey with p-values of 0.015 and 0.012 respectively. An increase in $PM_{2.5}$ levels is associated with a 2.1-fold increased risk of wheezing and a 2.2-fold increased risk of asphyxiation in the cotton plantation area of Urfa City, Turkey	There is a significant relationship between increased levels of $PM_{2.5}$ and asthma among people in the cotton plantation area of Urfa City, Turkey
(Khamal et al., 2019)	*Cross sectional*	Asthma (wheezing)	$PM_{2.5}$ exposure is associated with wheezing in toddlers at daycare in Seremban, Malaysia with p-value 0.020	There is a significant relationship between exposure to $PM_{2.5}$ and asthma in toddlers at daycare in Seremban, Malaysia.
(Johnson et al., 2019)	*Cross sectional*	Asthma (wheezing and chronic cough)	The peak of $PM_{2.5}$ exposure is associated with chronic cough and wheezing in the Morwell mine area, Australia with p-values 0.021 and 0.004 respectively	There is a significant relationship between exposure to $PM_{2.5}$ and asthma in people in the mine fire area in Morwell, Australia
(Leon-Kabamba et al., 2018)	*Case control*	Asthma (wheezing and asphyxiation)	All respiratory distress were more common in the case population (coltan miners) than in the control group. $PM_{2.5}$ exposure resulted in a 4.67-fold increase in the risk of wheezing and a 4-fold increase in the risk of shortness of breath in coltan miners in Malemba-Nkulu, Africa	There is a significant relationship between exposure to $PM_{2.5}$ and asthma in coltan mining workers in Malemba-Nkulu, Africa
(Syahira et al., 2020)	*Cross sectional*	Decreased lung function	Lung function tends to work abnormally (FEV1 and FVC) due to exposure to high concentrations of PM2.5 with p-values of 0.002 and 0.003 respectively	There is a significant relationship between exposure to $PM_{2.5}$ pollutants and decreased lung function in Kuala Lumpur and Johor Bahru traffic police, Malaysia
(Li et al., 2020)	*Cross sectional*	Decreased lung function	Increased exposure to $PM_{2.5}$ is associated with two main indicators of decreased lung function (FEV1 and FVC) in school children aged 7-12 years	There is a significant relationship between long-term exposure to $PM_{2.5}$ and decreased lung function in school

			in Lanzhou, China with p-value <0.0001	children in Lanzhou, China
(Arifuddin, Jalaludin and Hisamuddin, 2019)	*Cross sectional*	Decreased lung function	Exposure to air pollutant $PM_{2.5}$ increases the risk of decreased lung function up to 3 times for school children exposed to $PM_{2.5}$ due to traffic vehicle pollution in Kajang, Malaysia	There is a significant relationship between exposure to $PM_{2.5}$ and decreased lung function in school children exposed to $PM_{2.5}$ due to traffic vehicle pollution in Kajang, Malaysia
(Guo et al., 2018)	*Cohort study*	COPD and decreased lung function	Each 5 μg/m^3 increase in PM2.5 was associated with a 1.18% decrease in Forced Vital Capacity (FVC) and 1.46% in Forced Expiratory Volume in 1 second (FEV1). The risk of COPD was higher in participants who were older, had a lower body mass index (BMI), and had smoking status	Long-term exposure to $PM_{2.5}$ is associated with reduced lung function and an increased risk of COPD
(Doiron et al., 2019)	*Cohort study*	COPD and decreased lung function	COPD prevalence is associated with higher concentrations of $PM_{2.5}$ (OR 1.52, 95% CI 1.42–1.62, per 5 μg/m^3)	Long-term exposure to $PM_{2.5}$ is associated with decreased lung function and risk of COPD

Based on the analysis of collected articles, the following findings were found:

3.1. Relationship $PM_{2.5}$ and Asthma

Asthma is an inflammation of the airways that causes narrowing and difficulty breathing in individuals suffering from exposure to allergens. People with asthma generally experience hyperresponsiveness or had response very strongly to stimuli, either directly or indirectly. Symptoms of asthma include wheezing, shortness of breath, chest tightness, and chronic cough along with variable expiratory airflow limitation (35).

Environmental factors which contain various harmful pollutants, play an important role in the emergence of asthma (36). Exposure to air pollutants such as $PM_{2.5}$ has been shown influence the increasing prevalence and worsening of symptoms in asthma (37). The mechanism of $PM_{2.5}$ causing asthma is by causing pulmonary oxidative stress and increase the inflammatory response to trigger inflammation in the respiratory tract. $PM_{2.5}$ interacts with the innate immune system and produces free radicals and cytokines that can damage lung tissue, exacerbate asthma symptoms, and increase the risk of respiratory tract infections (38).

There are 4 articles that discuss the relationship between $PM_{2.5}$ exposure and asthma. Based on the results of research conducted by Sak, et. al., 2018 (39) which showed that there was a relationship between exposure to $PM_{2.5}$ and wheezing and shortness of breath of people in the cotton plantation area of Urfa City, Turkey with p-values of 0.015 and 0.012 respectively. An increase in $PM_{2.5}$ exposure resulted in a 2.1-fold increase in the risk of wheezing and a 2.2-fold increase in the risk of shortness of breath in people exposed to pesticides in the cotton plantation area of Urfa City, Turkey. This is reinforced by the results of research by Khamal et. al., 2019 (40) which showed that there was a significant relationship between $PM_{2.5}$ exposure and wheezing in toddlers at the daycare Seremban, Malaysia with p-value 0.02. From several air quality parameters measured in the study, it was found that $PM_{2.5}$ and total number of bacteria were associated with wheezing in 90 toddlers at 10 daycare observed in the Seremban area, Malaysia. About 7 out of 10 daycare observed were private residential buildings with kitchens inside. Cooking activities carried out by caregivers can cause high concentrations of $PM_{2.5}$ in daycare. In addition, toddler activities in the daycare such as playing, coughing or talking allow airborne bacteria which can then trigger allergic reactions, including asthma (41).

Another similar study, research conducted by Johnson, et. al., 2019 (42) showed that there was a relationship between $PM_{2.5}$ exposure and chronic coughing and wheezing in people living in mining fire areas in Morwell, Australia with p-values of 0.021 and 0.004 respectively. The mine fire in Morwell, Australia that occurred in 2014 still causes health impacts caused by long-term exposure to mine smoke containing $PM_{2.5}$ on the chronic cough and wheezing of the local community of Morwell, Australia. This was also reinforced by the results of research by Leon-Kabamba et al., 2018 (43) which stated that there was a significant relationship between $PM_{2.5}$ exposure and wheezing and shortness of breath in coltan mining workers in Malemba-Nkulu, Africa with a p-value of <0.05. Exposure to $PM_{2.5}$ resulted in a 4.67-fold increase in the risk of wheezing and a 4-fold increase in the risk of shortness of breath in coltan miners in Malemba-Nkulu, Africa. Areas where there are mining activities within, have a higher potential for $PM_{2.5}$ exposure because mining activities are carried out in open spaces, with bare hands, and do not use appropriate mining equipment. In addition, miners often do not have good access to reduce ambient air pollution such as ventilation and masks (44).

3.2. Relationship $PM_{2.5}$ and Chronic Obstructive Pulmonary Disease (COPD)

Chronic obstructive pulmonary disease (COPD) is a common lung disease that causes restricted airway and difficulty breathing. Airway obstruction that occurs in COPD sufferers mostly occurs in the small airways in the periphery of the lung and makes the lungs damaged or blocked by phlegm. Symptoms include coughing, sometimes with phlegm, difficulty breathing, wheezing and fatigue. People with COPD are more susceptible of other health problems (45).

Airway obstruction in COPD patients usually progresses slowly with age. One feature of COPD is the accelerated decline in lung function, as measured using spirometry. The diagnosis of COPD shows reduction in the FEV1/FVC ratio to a value that is usually <70%. People with COPD experience a relatively rapid annual decline in lung function and symptom progression increases when FEV1 falls below about 60% of normal. Symptoms increase as the airway obstruction increases from reduced physical activity, to shortness of breath on exertion and finally to shortness of breath at rest followed by respiratory failure (46).

Air pollution is a major cause of COPD (45). The impact of environmental exposure such as ambient air pollution on COPD has received more attention recently. Previous research has shown that the prevalence of COPD is associated with $PM_{2.5}$ concentrations (47). Chemical compounds contained in $PM_{2.5}$ such as heavy metals and organic compounds that can react with oxygen can cause oxidative stress and stimulate inflammation in the lungs. This inflammation causes a decrease in lung function and causes COPD (48,49).

There are 5 articles regarding the relationship between $PM_{2.5}$ exposure and decreased lung function. Based on the results of research conducted by Syahira et al., 2020 (50) showed that there was a significant relationship between $PM_{2.5}$ pollutant exposure and decreased lung function (FEV1 and FVC) in the Kuala Lumpur and Johor Bahru traffic police, Malaysia with p-values of 0.002 and 0.003 respectively. Research conducted by Li et al., 2020 (51) also showed that there was a relationship between long-term exposure of $PM_{2.5}$ and decreased lung function (FEV1 and FVC) in school children in Lanzhou, China with p-value <0.0001. This was reinforced by the results of Arifuddin, Jalaludin and Hisamuddin, 2019 (52) which showed that exposure to air pollutant $PM_{2.5}$ increased the risk of decreased lung function by up to 3 times for school children due to traffic vehicle pollution in Kajang, Malaysia. The lungs tend to work abnormally due to the exposure of high concentrations $PM_{2.5}$. An increase in $PM_{2.5}$ exposure is associated with a decrease in the two main indicators related to decreased lung function, namely FVC and FEV1 for vulnerable populations such as traffic police in Kuala Lumpur and Johor Bahru, Malaysia and children who attend school in dense traffic areas in the Lanzhou area, China and Kajang, Malaysia. This finding is supported by Chen et. al., 2015 which states that children who live near highways or in urban areas and are exposed to traffic-related pollutants experience decreased lung function (53).

Another cohort study, namely a study conducted by Guo et al., 2018 (54) and Doiron et al., 2019 (55) showed that long-term exposure to $PM_{2.5}$ was associated with decreased lung function and an increased risk of COPD in Taiwan and UK. Each 5 $\mu g/m^3$ increase in $PM_{2.5}$ was associated with a 1.18% decrease in forced vital capacity (FVC) and 1.46% in forced expiratory volume in 1 second (FEV1) with OR of 1.52. Respondents were defined as having COPD if they had a history of COPD diagnosed by a doctor or an FEV1/FVC ratio of less than 70% based on the Global Initiative for COPD (56). In addition to exposure of $PM_{2.5}$ pollutants, the risk factors for COPD shown in the two cohort studies were cigarette smoke. Further research is needed to discuss the impact of exposure to cigarette smoke on COPD risk.

4. Conclusion

Based on the results of a review for 9 articles, it was concluded that $PM_{2.5}$ exposure has a negative impact on human respiratory health, in particular it can cause asthma and decreased lung function which refers to COPD. From the 9 articles reviewed, there were 4 research which stated that there was a significant relationship between $PM_{2.5}$ exposure and asthma, while 5 other research stated that there was a significant relationship between $PM_{2.5}$ exposure and decreased lung function, namely the risk of COPD. The most common sources of $PM_{2.5}$ exposure are motorized vehicles, cooking activities (such as using wood fuel or charcoal briquettes), mining industry activities, and smoking. Several attempts to reduce $PM_{2.5}$ exposure are using public transportation, not smoking, and using protective equipment or personal protective equipment (PPE) if there is a risk of $PM_{2.5}$ exposure.

Compliance with ethical standards

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