The Effect of Air Pollution on the Health of Urban Residents (Case Study in Jakarta)

Joko Sapto Pramono[1]*, Nuraini[2], Junardin Djamaluddin[3], Yoanita Hijriyati[4], & Yusriati[5]
[1]*Politeknik Kesehatan Kemenkes Kalimantan Timur, Indonesia, [2]Universitas Muhammadiyah Tanggerang, Indonesia, [3]Politeknik Indonesia, Indonesia, [4]Universitas Binawan, Indonesia, [5]STIKes Bustanul Ulum Langsa, Indonesia
*Co e-mail: jokospramono@gmail.com[1]

ABSTRACT

Air pollution is a major environmental issue affecting urban areas worldwide, with significant health implications for millions of residents. In Jakarta, rapid urbanization and industrial activities have contributed to deteriorating air quality, exposing the population to harmful pollutants such as particulate matter ($PM_{2.5}$, PM_{10}), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO). This study aimed to analyze the impact of air pollution on public health in Jakarta, identify key hazardous pollutants, and evaluate the effectiveness of mitigation policies. A literature review approach and secondary data analysis were utilized, incorporating air quality monitoring data, epidemiological studies, and government reports. The results indicate that prolonged exposure to air pollutants correlates with increased cases of respiratory diseases (asthma, bronchitis, COPD), cardiovascular disorders, and overall mortality rates. The study also observes fluctuating air quality trends in Jakarta between 2020 and 2024, with periods of improvement attributed to regulatory interventions. Findings highlight the urgency of implementing stricter pollution control policies, promoting public transportation, and enhancing air quality monitoring systems. The study concludes that a multi-stakeholder approach, involving government, industry, and communities, is essential for sustainable urban air quality management. Future research should focus on the long-term effects of air pollution exposure and the effectiveness of policy measures in reducing health risks.

Keywords: Air Pollution, Public Health, Urban Environment, Jakarta, Policy Intervention

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INTRODUCTION

Air pollution in urban areas is a significant environmental problem that has far-reaching impacts on the health of millions of people every day. With rapid urbanization and industrialization, emissions from motor vehicles, industrial activities, and waste incineration continue to increase, contributing to air quality degradation in major cities. According to the World Health Organization (WHO, 2018), more than 90% of the global population lives in areas where air quality does not meet WHO standards, putting public health at serious risk.

Jakarta is a metropolitan city that serves as the center of government as well as the administrative center of Indonesia. However, despite its strategic role, Jakarta faces serious environmental problems, one of which is air pollution. This problem is mainly caused by the high use of private motorized vehicles by the community in carrying out daily activities, such as working and going to school. Based on data from the Jakarta Central Bureau of Statistics (BPS) in 2022, the number of motorized vehicles in Jakarta reached 26,370,535 units, consisting of passenger cars, buses, trucks, and motorcycles. This condition contributes significantly to the increase in air pollution levels in the city. In addition to degrading air quality, pollution in Jakarta also has an impact on the increased risk of death from various diseases triggered by air pollution, such as acute respiratory infections (ARI), asthma, and heart attacks (Syuhada et al, 2023).

Air pollution in DKI Jakarta Province has reached alarming levels, which directly impacts the quality of life of millions of residents and is a concern for various parties, including health organizations as well as local governments (Tan Hoi, 2020). Concentrations of pollutants such as microparticles (PM2.5), carbon monoxide, and nitrogen dioxide often exceed the thresholds set by the World Health Organization (WHO) as safe air standards (Manisalidis et al., 2020). These conditions contribute to the increased prevalence of various diseases, including respiratory disorders, heart disease and cancer among the population (Torjesen, 2015).

Air pollution sources in urban areas are diverse, including emissions from motor vehicles, industrial activities, biomass burning, and construction activities. Among these sources, motor vehicles are the main contributor to pollutant emissions, including carbon monoxide (CO), nitrogen dioxide (NO_2), and fine particles such as $PM_{2.5}$ and PM_{10}. In addition, industrial activities and household waste burning contribute to increased air pollution by releasing harmful substances such as sulfur dioxide (SO_2) and volatile organic compounds (VOCs), which can negatively impact air quality and public health (Tilford, 2017).

The effects of air pollution can be damaging and threatening to health and the environment. In the short term, exposure to air pollution can cause respiratory distress, eye irritation, and fatigue. Meanwhile, the long-term impacts are much more serious, including an increased risk of heart disease, lung cancer, and developmental disorders in children (Sivarethinamohan et al., 2020). In addition to affecting human health, air pollution also has negative impacts on the environment, such as accelerating climate change, damaging the ozone layer, and triggering acid rain that can disrupt the balance of water and soil ecosystems. Controlling air pollution requires synergy between the government, industry and society. The implementation of strict regulations on industrial emissions,

restrictions on the use of motorized vehicles, and the development and utilization of clean energy are strategic steps in reducing air pollution levels (Hunter, 2020).

Previous studies have revealed that air pollution in urban environments has a significant correlation with increased incidence of respiratory diseases, such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD), as well as cardiovascular diseases, including heart attack and stroke. Some of the main pollutants that play a role in triggering these health problems include fine particulate matter ($PM_{2.5}$ and PM_{10}), tropospheric ozone, nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) (Putri et al., 2019).

Epidemiological and experimental studies reveal that fine particles ($PM_{2.5}$) have the ability to penetrate deep into lung tissue and even into the bloodstream, potentially triggering systemic inflammation and oxidative stress (Zhang et al, 2018). Tropospheric ozone, which is formed by chemical reactions between sunlight and pollutants such as volatile organic compounds (VOCs) and nitrogen dioxide (NO_2), is known to irritate the respiratory tract and worsen asthma conditions. In addition, nitrogen dioxide (NO_2), which comes from motor vehicle emissions and the burning of fossil fuels, can cause inflammation in the respiratory tract and reduce lung function. Meanwhile, sulfur dioxide (SO_2), which is produced from fossil fuel combustion and volcanic activity, can irritate the eyes, nose and throat and aggravate existing respiratory problems (Supriyadi et al., 2020).

However, research on the immediate and long-term impacts of various air pollutants on public health in urban areas still requires further exploration. The novelty of this study lies in the comprehensive analysis that examines the specific health impacts of various pollutants, as well as evaluating the effectiveness of mitigation policies that have been implemented in several major cities.

This study aims to analyze the impact of air pollution on public health in urban environments, identify key hazardous pollutants, and formulate policy recommendations to minimize negative health impacts. By better understanding the linkages between air pollution and health risks, this research will provide a foundation for implementing effective mitigation measures to protect the health of urban communities. In addition, this research also aims to raise public and stakeholder awareness of the urgency of air pollution problems and the importance of collective action in addressing them. Through a holistic and integrated approach, this research is expected to contribute to creating a healthier, more sustainable and people-oriented urban environment.

METHODS

This study adopted a literature review approach and secondary data analysis covering various sources of information, including scientific reports, publications from health organizations, as well as data published by government agencies. The analysis aimed to evaluate influential air pollution levels and understand their impact on public health in Jakarta (Bhat et al., 2021). This approach allows the utilization of data from previous studies as well as documented population health information, thus providing a more comprehensive picture of the link between air pollution and public health.

RESULTS

Air quality in Jakarta can be measured through the Air Pollution Standard Index (ISPU), which serves as an indicator to assess the level of cleanliness or air pollution and its impact on public health due to exposure within a certain period of time, either several hours or several days (Putra, 2020). The determination of categories in the ISPU has been regulated in the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia in 2020, which classifies air quality into five categories based on the level of pollution.

Table 1. Air Pollution Standard Index

Category	Color Status	AQI	Information
Good	Green	1-50	Excellent air quality levels, no negative effects on humans, animals, plants
Moderate	Blue	51-100	Acceptable air quality levels for human, animal and plant health
Unhealthy	Yellow	101-200	Air quality levels that are detrimental to humans, animals and plants.
Very Unhealthy	Red	201-300	Air quality levels that may increase health risks in some segments of the exposed population
Dangerous	Black	> 300	Air quality levels that can have serious adverse health effects on the population and need to be addressed quickly.

In the context of rapid growth in urbanization and industrialization, air quality in Jakarta has become a critical issue that requires in-depth analysis. To gain a more comprehensive understanding of the dynamics of air pollution in the capital city, the following table presents annual trend data from 2020 to 2024 covering AQI values as well as key pollutant parameters, namely PM2.5, PM10, NO_2, SO_2, O_3, and CO. The data collected is an annual average estimate that combines various sources of information, including real-time observations and reports from relevant agencies. This aims to provide a strong analytical foundation to examine the changes in air quality in Jakarta over the period, and relate the findings to public health impacts.

Table 2. Jakarta City Air Quality Data 2020-2024

Year	AQI	PM 2.5	NO_2	SO_2	O_3	CO
2020	83	18	12	4.0	12	480
2021	80	17	11	3.5	11	460
2022	98	21	13	4.5	14	500
2023	101	22	14	4.5	15	510
2024	90	20	12	4.0	13	480

The table above shows the annual trends reported by air quality monitoring sites in Jakarta, with 2020 being the baseline (83), with a decrease in 2021 (80), significant increases in 2022 (98) and 2023 (101), then an improvement in 2024 (90).

DISCUSSION

Air pollution is a serious environmental problem with far-reaching impacts on human health, ecosystem balance, and global climate change (Ivanova, 2020). It results from the release of various harmful substances, including particles, gases and chemical compounds, into the atmosphere. The sources of air pollution are diverse, including industrial activities, motor vehicle emissions, and natural phenomena such as forest fires and volcanic eruptions (Manisalidis et al., 2020). In terms of composition, air pollution consists of various types of particles and gases that are potentially harmful to health. Fine particles such as $PM_{2.5}$ and PM_{10} are very small, so they can be easily inhaled and enter the human respiratory system (Ghosh et al., 2018). In addition, air pollution also contains harmful gases, including carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2), which are often found in urban environments (Zorzos et al., 2019). Volatile organic compounds (VOCs) and heavy metals are also components of air pollutants that can negatively impact human health and the environment.

Nitrogen dioxide (NO_2) is a hazardous air pollutant that has been linked to a variety of health problems, including asthma, cardiovascular disease and reduced lung function. Increased concentrations of NO_2 in the atmosphere can be influenced by various factors, with the main sources coming from motor vehicle emissions and industrial activities. As the capital city and economic center of Indonesia, DKI Jakarta has high levels of air pollution, mainly due to high traffic volumes and intensive industrial activities. In addition to anthropogenic factors, meteorological conditions such as low wind speed and high air temperature can also exacerbate the accumulation of pollutants in the atmosphere, further worsening air quality in urban areas.

If an increase in NO_2 concentrations occurs over a very short period of time, such as within three days, this can be a red flag for authorities. This drastic increase may indicate the presence of certain activities that significantly increase NO_2 emissions, such as a surge in industrial activity or unusually high traffic density. Therefore, it is important for the government and relevant authorities to quickly identify the source of the increase and implement appropriate mitigation measures. These measures could include unannounced inspections of industrial facilities, tightening of traffic regulations, as well as the implementation of emergency policies such as vehicle restrictions based on license plate numbers. An increase in NO_2 levels over a short period of time is a serious indicator that requires a rapid response to protect public health and maintain environmental quality.

Air pollution has a significant impact on the human respiratory system. Pollutant particles inhaled through the inhalation process can enter the respiratory tract and cause various health problems (Cheng et al., 2016). This exposure often triggers irritation in the early parts of the respiratory tract, such as the nose and throat, which can lead to symptoms such as sneezing, throat itching, watery eyes, and coughing (Duan et al., 2020). In individuals with allergies or high sensitivities, exposure to air pollution can worsen respiratory conditions and even trigger severe asthma attacks, which in some cases can be life-threatening.

The impacts of air pollution are not only limited to short-term effects, but also contribute to more serious respiratory health problems in the long term (Sivarethinamohan et al., 2020). One of the main impacts is the worsening of asthma conditions, which over time can become more difficult

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to control. In addition, chronic exposure to air pollution risks causing chronic bronchitis, which is an inflammation of the small airways in the lungs that results in excessive mucus production. Chronic obstructive pulmonary disease (COPD), which includes emphysema and chronic bronchitis, is also one of the serious consequences of long-term exposure to air pollutants. COPD is characterized by permanent damage to the lungs and respiratory tract, which can significantly reduce a person's breathing capacity. In the long run, this respiratory disorder can impact an individual's quality of life and require ongoing medical care. In addition, the condition increases the risk of serious complications, such as recurrent respiratory infections, progressive decline in lung function, and a higher risk of death (Schraufnagel et al., 2019). Therefore, maintaining air quality and minimizing exposure to air pollution are important steps in protecting respiratory system health and preventing the development of chronic respiratory diseases.

Air pollution not only impacts respiratory health through irritation and chronic disease, but also plays a role in increasing the risk of respiratory infections. Pollutant particles, especially fine particles such as $PM_{2.5}$ (particulates 2.5 micrometers or smaller), have the ability to carry harmful substances and microorganisms into the human respiratory system (Cheng et al., 2016). Viruses and bacteria are examples of microorganisms that can be carried by air pollution particles, so when a person breathes in contaminated air, these microorganisms can enter the respiratory tract and trigger infections. Diseases such as flu, cough and cold are examples of respiratory infections that can be transmitted through polluted air (Grzywa-Celińska et al., 2020). In addition, pollutant particles can also contain harmful compounds, such as heavy metals and toxic organic compounds, which can damage the immune system and increase susceptibility to respiratory infections. Furthermore, inflammation caused by exposure to air pollution can weaken the natural defense mechanisms of the respiratory tract, thereby reducing its ability to fight infections and exacerbating the health impacts of air pollution.

Based on the data presented in the table, it can be seen that the air quality trend in Jakarta has fluctuated over the period 2020 to 2024. In 2020, the air quality index (AQI) was at 83 with an average PM2.5 concentration of 18 μg/m³ and PM10 of around 27 μg/m³, indicating relatively moderate pollution conditions. In 2021, there was a decrease in AQI to 80 which was accompanied by a decrease in PM2.5 and PM10 concentrations to 17 μg/m³ and 25 μg/m³, respectively. This decrease was likely influenced by restrictions on economic activity and community mobility imposed during the COVID-19 pandemic, which had an impact on reducing emissions from the transportation and industrial sectors.

However, in 2022 there was a significant increase, with the AQI rising to 98 and an increase in PM2.5 and PM10 values to 21 μg/m³ and 32 μg/m³ respectively.This increase was followed in 2023, where the AQI reached 101 with an increase in PM2.5 concentration to 22 μg/m³ and PM10 to 33 μg/m³, indicating a decline in air quality.Increased levels of NO_2 and O_3 in these years also indicate the accumulation of emissions from transportation and industrial activities, while CO values increased from 460 ppb in 2021 to 510 ppb in 2023 indicating the significant role of fossil fuel combustion.

Research conducted by Putri et al.(2019) supports these findings by showing that elevated $PM_{2.5}$ concentrations in Jakarta have a significant correlation with increased cases of asthma and bronchitis in children.The study used data from several hospitals in Jakarta and revealed a strong association between air pollution levels and the incidence of respiratory diseases in the pediatric age group. The results of this study confirm that exposure to air pollutants, particularly $PM_{2.5}$, can have a serious impact on the respiratory health of children, who are a vulnerable group to air pollution.

Research conducted by Supriyadi et al. (2020) examined the impact of air pollution on heart health in an adult population in Surabaya.The results showed that long-term exposure to nitrogen dioxide (NO_2) and fine particulate matter ($PM_{2.5}$) had a significant association with an increased risk of ischemic heart disease and heart attack.These findings confirm that air pollution not only impacts the respiratory system, but also contributes to serious cardiovascular disorders. Therefore, this study highlights the importance of regular air quality monitoring as well as the implementation of effective interventions to reduce pollutant emissions, in order to protect public health from the risk of air pollution-induced diseases.

By 2024, there is an improvement in conditions with a decrease in the AQI to 90, accompanied by decreases in PM2.5 concentrations to 20 μg/m³ and PM10 to 30 μg/m³, and decreases in NO_2, SO_2 and O_3 to lower values. These improvements may reflect more effective implementation of pollution control policies, increased use of clean energy, or changes in mobility patterns and more sustainable economic activity.

These findings are in line with research conducted by Lestari et al. (2023), which evaluated the effectiveness of air pollution control policies in Semarang. The results showed that the implementation of policies, such as motor vehicle restrictions in the city center and the use of environmentally friendly fuels, contributed significantly to reducing the concentration of key pollutants, particularly $PM_{2.5}$ and NO_2. In addition, these policies have also been shown to improve air quality and have a positive impact on public health. This study emphasizes the importance of evidence-based policy planning in air pollution control and public health protection.

Analysis of air quality in Jakarta, which shows fluctuations in AQI values and concentrations of key pollutant parameters such as PM2.5, PM10, NO_2, SO_2, O_3, and CO, has significant implications for public health. Long-term exposure to fine particulate matter (PM2.5) and coarse particulate matter (PM10) has been shown to increase the risk of developing acute and chronic respiratory diseases, such as bronchitis, asthma, and respiratory infections, and contribute to an increased incidence of cardiovascular disease. The increase in pollutant concentrations reflected in the increase in AQI in 2022 and 2023, accompanied by PM2.5 and PM10 values exceeding the ideal thresholds, indicates that Jakarta residents are likely to experience an increased burden of disease. This condition not only impacts individual health, but also puts pressure on the healthcare system through increased emergency room visits and hospitalizations. On the other hand, the decrease in AQI values and pollutant parameters by 2024 indicates that there are efforts to improve air quality which, if sustained, have the potential to reduce health risks and economic burden due to diseases associated with air pollution.

Policies and efforts to mitigate the impact of air pollution on health and national defense readiness in DKI Jakarta Province are crucial aspects given the high level of air pollution in the region. In the context of health, the DKI Jakarta Provincial Government has implemented various proactive policies to reduce the impact of air pollution (Zulfikri, 2023). These measures include limiting high-emission motor vehicles through odd-even policies, reducing emissions from the industrial sector, and promoting sustainable transportation, such as the use of public transportation and bicycles (Gunawan et al., 2019). These policies aim to reduce the number of residents exposed to harmful air pollution, thereby contributing to improved public health as well as creating a cleaner and more sustainable urban environment.

CONCLUSIONS

Air pollution has become an environmental problem with far-reaching impacts, affecting various aspects of social life as well as security. From a health perspective, the impacts are not only limited to respiratory disorders, but also include an increased risk of cardiovascular disease, immune system disorders, as well as an increased likelihood of cancer. This emphasizes the urgency to consider air pollution as a public health issue that requires quick and effective interventions. As one of the areas with high levels of air pollution, DKI Jakarta Province requires a holistic and integrated policy approach. Some of the strategic measures that can be optimized include implementing stricter odd-even policies, enforcing regulations on industrial emissions, and promoting sustainable transportation as a long-term solution. By identifying key pollutants and their impacts, and evaluating the effectiveness of existing air pollution control policies, further measures can be designed to protect public health, especially for future generations. Furthermore, this study emphasizes the importance of collaboration between the government, industry, and communities in creating a healthier, more sustainable, and long-term welfare-oriented urban environment.

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