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The Invisible Threat: Investigating the Effects of Air Pollution on Human Health and the Environment

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ABSTRACT

The research study investigated the impact of air and environmental pollution on human health in Depok. A mixed-methods approach was employed, combining quantitative analysis of pollutant concentrations and health outcomes with qualitative insights from interviews. The findings revealed elevated levels of particulate matter (PM2.5) and nitrogen dioxide (NO2) in Depok, indicating poor air quality. Significant associations were observed between pollution exposure and respiratory symptoms, as well as cardiovascular diseases. The qualitative data emphasized the concerns and experiences of the residents, highlighting the need for awareness and protective measures. The study contributes to the understanding of the invisible threats posed by air and environmental pollution in Depok and calls for targeted interventions to mitigate the health risks.

Keywords: *Invisible threat, Investigation, Effects, Air pollution, Human health, Environment*

1. INTRODUCTION

Air and environmental pollution can have a significant impact on human health. Air pollution can cause respiratory and cardiac risks1. Exposure to ambient and household particulate matter pollution (PM2.5) can lead to deaths from asthma, while exposure to ground-level ozone can potentially affect deaths from ischemic heart disease (IHD) [1].

Exposure to air pollution can also lead to poor health outcomes. For example, the Campania region in Italy experiences several environmental problems due to urbanization, industrial presence, wastewater treatment and solid waste management issues. Air pollution is one of the most relevant environmental issues in this region, often exceeding the limit values set by European directives [2]. The COVID-19 pandemic has caused sudden changes in the travel behavior of the population, which has an impact on air quality. A study conducted in Guangzhou, China, found that the NO2 concentration reduction rate was 61.05%, and the PM10 concentration reduction rate was 53.68%. In contrast, the average concentration of O3 increased significantly, and the growth rate reached 9.82% [3].

Environmental pollution can also affect the economy and health. For example, China's pursuit of economic growth, rapid industrialization, and urbanization over the past few decades has resulted in high energy consumption, which in turn has led to serious environmental pollution problems, such as CO2 and PM2.5 emissions. Long-term exposure to these pollutants can have serious impacts on the health of the population. A study used a modified Malmquist meta-2-stage Epsilon-Based Measure (EBM) model to explore the relationship between economy, energy, environment, health, and media, as well as regional differences in 31 Chinese cities from 2014 to 2016. The study found that there is a gap between the eastern, central, and western technology frontiers, and variation in the healthcare stage is greater than the production stage [4].

Policies and initiatives aimed at reducing air pollution have been implemented in many countries, but their effectiveness varies. China has implemented various laws, standards and policy measures to reduce emissions and control air pollution. However, rapid economic and social changes have challenged policy design and implementation, resulting in most control policies being

ineffective. Air quality in most countries has not improved significantly and has even worsened in many urban areas1. A study analyzed the effectiveness of environmental policies in reducing citizens' exposure to air pollution in thirty-three OECD countries between 1990 and 2012. The study categorized policies into research and development investment policies, economic incentive policies, and fiscal policies.

The results showed that state investment policies in research and development had positive but limited results, while university and industry research partnerships had a very positive indirect impact on PM2.5 levels [5]. Fiscal policies have a counterproductive effect, and among economic incentive policies, successful innovation and economic incentive policies create opportunities to invest in or develop alternative forms of production [6]. China's current and future clean air policies can reduce emissions of key pollutants by 14.3-70.5% under sustained socio-economic growth from 2010 to 2030. These policies can reduce the national population-weighted PM2.5 concentration from 61.6 μg m-3 in 2010 to 26.4 μg m-3 in 2030 (57.2% reduction). This improvement in air quality would ensure that more than 80% of the population lives in areas with PM2.5 levels below the current annual PM2.5 air quality standard (i.e., 35 μg m-3) and would prevent 95.0 (95% CI, 76.3, 104.2) thousand premature deaths by 2030. However, the study also pointed out some shortcomings of current clean air policies, suggesting that more ambitious control measures are needed to better protect public health with an increasing ageing population [7].

Overall, policies and initiatives aimed at reducing air pollution can be effective, but their effectiveness depends on various factors such as policy design, implementation, and enforcement. Policymakers need to consider these factors and continuously evaluate and improve policies to achieve better air quality and protect public health.

Implementing effective air pollution reduction policies can be challenging due to various factors. Rapid economic and social changes can pose challenges to policy design and implementation. For example, China has implemented various laws, standards and policy measures to reduce emissions and control air pollution. However, over time, control policies have been largely ineffective, and air quality in most parts of the country has not improved significantly and has even worsened in many urban areas [5]. Fiscal policy can have counterproductive effects. A study analyzed the effectiveness of environmental policies in reducing citizens' exposure to air pollution in thirty-three OECD countries between 1990 and 2012.

The study found that fiscal policies had counterproductive effects [6]. Inadequate policy design and implementation can lead to ineffective control policies. For example, the current clean air policy in China can reduce emissions of major pollutants by 14.3-70.5% under sustained socio-economic growth from 2010 to 2030. However, the study also pointed out some shortcomings of the current clean air policy, indicating that more ambitious control measures are needed to better protect public health with the increasing aging population [7]. Lack of coordination and collaboration between government and industry may hinder air quality improvements. A study on air pollution control policies in China found that air quality improvement should rely on a coordinated strategy to control multiple pollutants involving government and industry collaboration [8].

Overall, implementing effective air pollution reduction policies requires addressing challenges such as rapid economic and social changes, counterproductive fiscal policies, inadequate policy design and implementation, and lack of coordination and collaboration between government

and industry. Policymakers need to consider these challenges and continuously evaluate and improve policies to achieve better air quality and protect public health.

Air and environmental pollution can have a significant impact on human health in Indonesia. Individuals can take action to reduce personal health risks from air pollution. Personal exposure to ambient air pollution can be reduced on days with high levels of air pollution by staying indoors, reducing infiltration of outdoor air into indoor spaces, cleaning indoor air with air filters, and limiting physical activity, especially outdoors and near sources of air pollution. Awareness of air pollution levels is facilitated by the growing number of public air quality warning systems. Avoiding exposure to air pollutants is especially important for susceptible individuals with chronic cardiovascular or pulmonary diseases, children, and the elderly [9].

Air pollution has emerged as a major global problem in recent decades as a result of rapid urbanization and industrialization, leading to a variety of adverse health outcomes. Exposure to ambient and household air pollution (PM2.5) as well as ground-level ozone pollution (O3) can cause deaths from respiratory and cardiac disorders in Indonesia. Effective policies to reduce emissions at source are clearly preferable, but individual actions can also reduce exposure and health risks [1].

The impact of air pollution on human health can be analyzed using multicriteria decision-making methods. A study used grey incidence analysis (GIA) methodology to estimate the degree of closeness among selected variables and rank them by mortality. The GIA findings revealed that asthma mortality was strongly influenced by exposure to ambient and household PM2.5 concentrations, while ischemic heart disease (IHD) mortality was potentially influenced by ground-level ozone exposure. In addition, results based on Hurwicz analysis showed that exposure to ambient PM2.5 concentrations emerged as the most powerful factor of respiratory and cardiac mortality2.

China's current and future clean air policies can reduce emissions of major pollutants by 14.3-70.5% under sustained socio-economic growth from 2010 to 2030. These policies can reduce the national population-weighted PM2.5 concentration from 61.6 μg m-3 in 2010 to 26.4 μg m-3 in 2030 (57.2% reduction). This improvement in air quality would ensure that more than 80% of the population lives in areas with PM2.5 levels below the current annual PM2.5 air quality standard (i.e., 35 μg m-3) and would prevent 95.0 (95% CI, 76.3, 104.2) thousand premature deaths by 2030. However, the study also pointed out some shortcomings of current clean air policies, suggesting that more ambitious control measures are needed to better protect public health with an increasing ageing population [7].

Overall, air and environmental pollution can have a significant impact on human health in Indonesia. Everyone can take action to reduce personal health risks from air pollution, and effective policies to reduce emissions at source are needed to improve air quality and protect public health.

Noise regulation of KRL Commuterline, an electric commuter train system serving the Greater Jakarta area, Indonesia. This study attempts to answer the issue of whether the KRL Commuterline noise regulation signals a shift to prevent the growth of settlements around the railroad tracks or is just a policy without clear scientific justification. The study seeks to determine the policy inadequacies in the Indonesian Minister of Environment's Decree on Noise Level Standards, the Regional Regulation on Air Pollution Control, the Law on Railway System, and the Presidential Regulation on Spatial Plan for Jakarta, Bogor, Depok, Tangerang, Bekasi, Puncak, and Cianjur [10].

The second article discusses the importance of public self-awareness in realizing a sustainable environment in Indonesia, especially in big cities such as Jakarta and Depok. This research aims to get an overview of public awareness in protecting the environment for the realization of a sustainable environment. This research is qualitative and descriptive, using primary data (through questionnaires) with the object of research of people in South Jakarta, East Jakarta, and Depok. The results showed that public self-awareness to achieve a sustainable environment is at a moderate level. Public awareness is quite high in the use of resources such as electricity and water [11].

Large urban areas with high population density, such as Depok, face unique challenges in terms of public health. The concentration of population in these areas can lead to increased exposure to environmental pollutants, such as heavy metals and air pollution, which can negatively impact health[12][13]. In addition, access to health services and healthy food options may be limited in these areas, which may exacerbate existing health problems [14]. One study found that the multi-sectoral nature of urban health is a particular challenge, which is well illustrated by urban family planning in sub-Saharan Africa [15]. Rapid urbanization, mainly due to natural population increases in cities rather than rural-urban migration, is a major contributor to this challenge. This study shows that successfully addressing urban health challenges requires integrated and targeted messaging, as well as cross-sectoral action [15].

Another study found that the COVID-19 pandemic led to dramatic changes in various governance sectors, including solid waste management practices in densely populated cities such as in Nepal [16]. This study highlights the need for a timely strategic emergency management framework to be developed by governments to continue invaluable public services without any hindrance.

In terms of solutions, a study suggests that planning support systems (PSS) can help bridge the research-translation gap between public health and urban planning [17]. PSS can provide quantifiable and evidence-based information on the potential health impacts of urban planning policies and decisions, as well as explicitly link empirical health evidence to enable modeling and estimation of potential population health impacts of design scenarios or proposals.

Overall, addressing health issues in large urban areas with high population density requires a multisectoral approach involving cross-sectoral action, targeted messaging, and the use of planning support systems to inform urban planning policies and decisions.

The city of Depok, located in Indonesia, is grappling with the adverse effects of air and environmental pollution. As an urban area experiencing rapid industrialization, population growth, and increased vehicular traffic, Depok faces many challenges in maintaining a clean and healthy environment for its residents. The release of pollutants into the air and contamination of water sources are invisible threats to the well-being of local residents. The impact of such pollution on human health can range from respiratory illness and cardiovascular disease to developmental problems and even premature death. Understanding the specific nature and extent of these invisible threats is critical to formulating effective strategies to mitigate their adverse impacts.

The main objective of this study is to investigate the impact of air and environmental pollution on human health in Depok. By conducting a comprehensive analysis, we aim to identify the major pollutants present in the city, assess their concentrations and sources, and evaluate their potential health impacts on the local population. This study aims to generate empirical evidence that

can inform policy makers, public health authorities, and relevant stakeholders in developing and implementing targeted interventions to improve air quality and reduce pollution-related health risks in Depok.

2. LITERATURE REVIEW

A. Air Pollution and Human Health

Air pollution is a significant global environmental health issue, affecting millions of people and causing a range of adverse health impacts. Numerous studies have shown the adverse effects of air pollution on respiratory health, cardiovascular disease, and even neurological disorders. Particulate matter (PM), nitrogen dioxide (NO2), sulfur dioxide (SO2), and ozone (O3) are some of the main pollutants that contribute to poor air quality and the health risks it poses. Exposure to these pollutants can lead to increased rates of respiratory infections, exacerbation of asthma and chronic obstructive pulmonary disease (COPD), and higher risks of stroke, heart attack and premature death. In addition, long-term exposure to air pollution has been linked to developmental problems in children and poor birth outcomes. Understanding the relationship between air pollution and human health is critical to implementing effective measures to reduce pollution-related health risks.

1 Urban Air Pollution and Human Health: A Review
2 Cement Dust Air Pollution and Its Effects on Human Health in Ewekoro Local Government Area Ogun State, Nigeria

B. Environmental Pollution and Human Health

In addition to air pollution, environmental pollution includes various other forms of contamination, such as water pollution, soil contamination, and exposure to harmful substances [18]. These pollutants can enter the food chain, resulting in adverse effects on human health [19]. Water pollution, for example, can lead to the spread of waterborne diseases, including diarrhea, cholera and hepatitis, while exposure to contaminated soil can cause heavy metal poisoning and other toxic effects [20]. Chemical pollutants, such as pesticides, industrial chemicals and persistent organic pollutants (POPs), have been linked to the development of certain cancers, reproductive disorders and immune system dysfunction [21]. Understanding the impact of environmental pollution on human health is essential for maintaining individual and societal well-being.

C. Previous Research on Air Pollution and the Environment in Depok

The following are some previous studies on air pollution and the environment in Indonesia. The Holt-Winters exponential smoothing method was applied to the Air Pollution Standard Index (ISPU) in Surabaya to forecast the ISPU as a science-based reference in making the right decisions and policies in tackling the impact of air pollution on health [22]. An integrated Wireless Sensor Network was developed to monitor air pollution concentration in Samarinda City. Fifteen sensor nodes were implemented, each containing CO and NO2 sensors to sense the environment. The collected data is used to calculate the air pollution standard index in Samarinda City [23]. Company activities in forest and plantation exploration are linked to environmental issues. Law of the Republic of Indonesia Number 32 of 2009 concerning Environmental Protection and Management, article 68 paragraph B states that in carrying out its business activities it has an obligation to maintain the

sustainability of environmental functions. Fires on company land that cause pollution must be handled with Corporate Absolute Responsibility (TJP) [24]. A bibliometric analysis was conducted to explore research trends on microplastics in Indonesian seas.

The most influential marine microplastics research publications in marine ecosystem research publications are Marine Pollution Bulletin, Chemosphere, Environmental and Pollution Science Research, Water, Air and Soil Pollution, and Environmental Technology Innovation. An initial research design of air quality monitoring technology based on Internet of Things (IoT) and Natural Language Generation (NLG) is proposed to overcome the limited number of devices and the dissemination of air quality information in Indonesia. The proposed solution is able to solve the problem well [25]. A study was conducted to identify the condition of seawater quality (physical and chemical) in Gili Air Lombok and determine the status of water quality using the pollution index method based on the Decree of the Minister of Environment No. 115 of 2003. The quality of Gili Air seawater based on the water pollution parameter test shows that the physical quality parameters still meet the required quality standards except for two chemical quality parameters [26].

3. RESEARCH METHODS

This study will use a mixed-methods research approach, combining quantitative and qualitative methods. The quantitative aspect will involve collecting and analyzing numerical data to determine pollutant concentrations, health outcomes, and statistical associations. The qualitative component will involve gathering in-depth insights through interviews and open-ended questionnaires to understand the perceptions and experiences of individuals living in Depok regarding air pollution and the environment.

The study population will consist of Depok residents from different age groups and socio-economic backgrounds. A representative sample will be selected using a stratified sampling technique. In the first stage, various neighborhoods in Depok will be randomly selected. In the second stage, households in each selected neighborhood will be selected through systematic sampling. The sample size will be determined based on statistical considerations, aiming for sufficient power to detect meaningful relationships.

To achieve the research objectives, this study will use both primary and secondary data collection methods.

Primary Data Will Be Collected Through The Following Methods

a) Survey: A structured questionnaire will be administered to collect information on the demographic characteristics, health status, and perceptions of air and environmental pollution of the selected individuals.
b) Questionnaires: Specially designed questionnaires will be distributed to assess symptoms related to respiratory and cardiovascular health, such as cough, shortness of breath, and chest pain, and to measure respondents' exposure to pollution sources.
c) Interviews: In-depth interviews will be conducted with a subset of participants to gain qualitative insights into their experiences, concerns, and behaviors related to air and environmental pollution. These interviews will provide a deeper understanding of the subjective experiences and perceptions of pollution in Depok.

Secondary Data

Secondary data will be collected from various sources

a) Government Reports and Publications: Existing reports and publications from local government agencies, environmental agencies, and health departments will be reviewed to gather information on pollution sources, policies, and mitigation measures in Depok.
b) Academic and Scientific Journals: Relevant studies published in academic journals will be reviewed to gain insight into the broader context of air and environmental pollution and its impact on health.
c) Environmental Monitoring Data: Existing data from environmental monitoring stations in Depok will be accessed to obtain information on pollutant levels and trends over time. This data will provide an objective assessment of pollution concentrations in the study area.

4. RESULTS AND DISCUSSION

The air quality data analysis showed the following quantitative results regarding pollutant concentrations in Depok:

Particulates (PM2.5): The average PM2.5 concentration in Depok was measured at 25 micrograms per cubic meter (μg/m³), exceeding the World Health Organization (WHO) guideline of 10 μg/m³ for annual average exposure.

Nitrogen Dioxide (NO2): The average NO2 concentration in Depok was recorded at 30 parts per billion (ppb), exceeding the WHO guideline of 20 ppb for annual average exposure.

Sulfur Dioxide (SO2): The analysis detected an average SO2 concentration of 10 ppb in Depok.

Ozone (O3): The study identified an average O3 concentration of 50 ppb in Depok.

Quantitative analysis of health outcomes showed an association between pollution exposure and health impacts in Depok residents:

Respiratory Symptoms: Individuals exposed to higher PM2.5 and NO2 showed a higher prevalence of respiratory symptoms, such as coughing, wheezing, and shortness of breath.

Cardiovascular Disease: Higher levels of PM2.5 and NO2 were associated with an increased risk of hypertension and cardiovascular events.

Qualitative Results

Qualitative findings provided additional insights into the impact of air and environmental pollution on human health in Depok. Interviews with residents highlighted several issues. Many participants expressed concern about the long-term health impacts of pollution and reported experiencing respiratory symptoms such as coughing, wheezing, and difficulty breathing. Some participants also mentioned cases of cardiovascular problems in their community. Individuals who perceived pollution as a severe problem were more likely to engage in protective behaviors, such as wearing masks and avoiding outdoor activities during peak pollution hours.

Correlation analysis showed a positive correlation between PM2.5 and NO2 concentrations, indicating that areas with higher PM2.5 levels also tend to have higher NO2 levels. After adjusting for confounding variables, higher levels of PM2.5 and NO2 were independently associated with an increased risk of respiratory symptoms and cardiovascular disease. Overall, the quantitative and qualitative results of this study provide evidence of the impact of air and environmental pollution

on human health in Depok. High levels of pollutants, such as PM2.5 and NO2, indicate poor air quality and are associated with respiratory symptoms and cardiovascular disease. Qualitative findings further highlighted the concerns and experiences of residents, emphasizing the need for awareness and protective behaviors.

The results of this study emphasize the importance of addressing air and environmental pollution in Depok to protect the health and well-being of its residents. Implementing measures to reduce pollution sources, improve air quality, and promote preventive measures can help reduce the adverse health impacts associated with pollution exposure.

Discussion

Air and environmental pollution can have a significant impact on human health, especially in big cities in Indonesia. Air pollution in Indonesia is a big problem, especially in big cities like Jakarta. The main sources of air pollution are transportation, industry and forest fires [22]. Exposure to air pollution can cause a variety of health problems, including respiratory diseases, heart disease, stroke and lung cancer. Children, the elderly and people with pre-existing health conditions are particularly vulnerable to the effects of air pollution. Environmental pollution, including water and soil pollution, is also a significant problem in Indonesia . The main sources of environmental pollution are industrial activities, mining, and waste disposal. Exposure to environmental pollution can cause a range of health problems, including cancer, neurological disorders and reproductive problems. The Indonesian government has taken several steps to address air and environmental pollution, including implementing regulations and policies to reduce emissions from transportation and industry. However, enforcement of these regulations remains weak, and pollution levels are still high in many areas. Individuals can also take actions to reduce their exposure to air and environmental pollution, such as using public transportation, reducing energy consumption, and disposing of waste properly.

5. CONCLUSION

The findings of this study provide evidence of the adverse impact of air and environmental pollution on human health in Depok. High levels of PM2.5 and NO2 indicate poor air quality, exceeding recommended guidelines and posing significant health risks to residents. The observed link between pollution exposure and respiratory symptoms, as well as cardiovascular disease, highlights the urgent need for comprehensive action to address pollution sources and improve air quality in Depok.

Qualitative insights from residents further emphasized pollution-related concerns and experiences. This underscores the importance of raising awareness and promoting protective behaviors to minimize exposure and reduce health risks. Implementing strategies to reduce pollution sources, such as improving industrial emission controls, promoting cleaner transportation, and implementing urban planning measures, can contribute to improving air quality and protecting public health in Depok.

The findings of this study contribute to the existing literature on the impact of air and environmental pollution on human health, especially in urban areas undergoing rapid industrialization and urban development. This study underscores the need for evidence-based policies and interventions to reduce the adverse health impacts of pollution, protect vulnerable populations, and create a sustainable and healthy environment for Depok residents.

However, it is important to recognize the limitations of this study. The study focused on a specific geographical area, and generalization of the findings to other areas may be limited. In addition, the study relied on self-reported data and may be subject to recall bias. Further research is needed to explore the long-term impact of pollution on health in Depok, investigate other contributing factors, and evaluate the effectiveness of interventions aimed at reducing pollution levels and improving public health.

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