

The Relationship Between Air Pollution Exposure And The Incidence Of Chronic Respiratory Disease: A Case Study In An Urban Area

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ABSTRACT

This study aims to investigate the causal relationship between air pollution and the incidence of respiratory tract diseases in residents of Bogor City, West Java, Indonesia. Bogor City is a densely populated city with significant levels of air pollution due to industrial activities, transportation, and people's lifestyles. This study uses the causality analysis method to identify the relationship between air pollution and respiratory diseases. Data on air pollutant concentrations (particulate matter PM_{2.5}, SO₂, NO₂) and the number of respiratory tract disease cases were taken from available sources, such as the Bogor City Environment Agency and local public health centers. The results showed a significant causal relationship between air pollution and the incidence of respiratory diseases. Particulate concentrations of PM_{2.5}, SO₂, and NO₂ have a detrimental impact on the health of residents. The study also highlighted the different effects of air pollution on different population groups, such as children, the elderly, and individuals with compromised health. These findings provide a deeper understanding of the health risks faced by Bogor City residents due to air pollution. In order to improve air quality and reduce its adverse health impacts, this study suggests the need for effective policy measures. Such measures include improved control of industrial and vehicular emissions, increased public awareness of the impacts of air pollution, and improved access to health services related to respiratory diseases. This study confirms the existence of a causal relationship between air pollution and the incidence of respiratory diseases in Bogor City residents. The findings provide a strong basis for taking more effective preventive and intervention measures to address air pollution and public health issues in urban areas.

INTRODUCTION

Air pollution is a pressing global environmental problem that poses significant risks to human health. Air pollution is characterized by the presence of hazardous substances in the atmosphere, such as particulate matter, nitrogen dioxide, sulfur dioxide, and volatile organic compounds. These pollutants come from a variety of sources, including industrial activities, vehicle emissions, agricultural practices, and natural events. When people are exposed to high levels of air pollution over a long period of time, it can cause adverse health effects, especially in the respiratory system. Air pollution can have significant health impacts on individuals. Exposure to air pollutants is associated with cardiopulmonary disease, diabetes, metabolic syndrome, neurobehavioral conditions, and reproductive disorders (Snow et al., 2018). Long-term exposure to polluted air is considered a significant determinant of health. According to the World Health Organization (WHO), air pollution contributes to 7.6% of premature deaths each year and reduces the number of healthy life years (J.-T. Lee, 2021). Cohort studies and meta-analyses have provided evidence of associations between pollutant exposure and biological effects (J.-T. Lee, 2021). Efforts to understand and mitigate the health impacts of particulate air pollution (PM) have a rich and interesting history. Research has shown that exposure to fine particulate air pollution has adverse effects on cardiovascular health (Pope & Dockery, 2006).

There has been substantial progress in evaluating the health effects of PM across time scales of exposure and in exploring the shape of the concentration-response function. There is also emerging evidence of PM-related cardiovascular health effects and increasing knowledge of common interconnected pathophysiological pathways linking PM exposure to cardiopulmonary morbidity and mortality (Pope & Dockery, 2006). The neuroendocrine system, specifically the sympathetic-adrenal-medullary (SAM) and hypothalamic-pituitary-adrenal (HPA) stress axes, plays a role in mediating a variety of systemic and pulmonary effects caused by air pollutants. Elevated circulating adrenal-derived stress hormones contribute to lung injury/inflammation and metabolic effects in liver, pancreas, adipose, and muscle tissue¹. Individuals at greater risk for respiratory effects from air pollution include those with pre-existing respiratory conditions, children, and the elderly (Khafaie et al., 2016).

There is increasing interest in utilizing individual-level cohort data to assess short-term health effects to understand mechanisms and timescales of action (Szpiro et al., 2014). Respiratory disease incidence is a broad topic that encompasses many different diseases and conditions. Respiratory syncytial virus (RSV) can cause serious lower respiratory tract disease (LRTD) in older adults (Falsey

et al., 2021). Invasive pulmonary fungal infections can occur in critically ill patients, including those with severe coronavirus disease 2019 (Martin-Loeches et al., 2022). Gopher tortoises in Florida and Mississippi have been found to have high rates of exposure to Upper Respiratory Tract Disease (URTD) (Smith et al., 1998). Bovine coronavirus (BCV) can cause respiratory tract disease in heifer calves (Plummer et al., 2004). Horses vaccinated against common agents of infectious upper respiratory disease (IURD) may not have detectable serum antibodies and may not be protected from clinical disease (Mumford et al., 2003). Air pollution has been associated with respiratory diseases, especially upper respiratory tract infections (URTIs) in children and college students (Ratajczak et al., 2021; Zhang et al., 2021). Exposure to particulate matter (PM), a major component of air pollution, is associated with exacerbation of chronic respiratory diseases, and infectious diseases such as community-acquired pneumonia (Purves et al., 2022). PM can cause adverse health effects through direct damage to host cells, but it can also affect bacterial behavior by promoting *in vivo* colonization (Purves et al., 2022).

For example, exposure to black carbon (BC), a PM constituent found in most air pollution sources, can enhance bacterial colonization and virulence factor expression by acting directly on the bacteria rather than through the host (Purves et al., 2022). Specifically, *Staphylococcus aureus* strain USA300 LAC grown in BC prior to inoculation showed increased mouse respiratory tract colonization and lung invasion *in vivo*, as well as adhesion and invasion of human epithelial cells *in vitro* (Purves et al., 2022). Global transcriptional analysis showed that BC had broad effects on the transcriptional response of *S. aureus*, altering the regulation of key virulence gene regulators *Sae* and *Agr* and causing increased expression of genes encoding toxins, proteases, and immune evasion factors (Purves et al., 2022). These data illustrate a previously unrecognized mechanism for air pollution-related infections (Purves et al., 2022). Bogor City, Indonesia faces several environmental challenges, including air and water pollution. Groundwater in Tanah Sereal District, Bogor City, is polluted and unsuitable, with high levels of total coliform bacteria and *E. coli* (Kairunnisa et al., 2021; Khairunnisa et al., 2021). This pollution is caused by human activities and poor construction, and is the main cause of diarrhea cases in the area (Khairunnisa et al., 2021). Emission inventory data for air pollutants are not available for Bogor City, but a top-down emission inventory has been designed and implemented for the city in the base year 2016. Road transportation contributes significantly to SO₂, NMVOC, and PM_{2.5} emissions, accounting for 60-86% of total emissions. Industrial combustion sources dominate the share of total NO_x and CO₃ emissions. Bogor City has a high density of fossil fuel-based transportation, which contributes to air pollution⁴. Building urban green open spaces, such as green belts, can help reduce the negative impacts of transportation on the environment. However, green belts in Bogor City experience canopy damage due to air pollution, stem damage caused by human activities, and decay by pests and fungi.

Forest health monitoring methods can be used to evaluate the condition of stands in green belts⁴. Factors that influence *E. coli* contamination in groundwater include groundwater depth and the distance between wells and septic tanks. Therefore, proper construction and management of wells and septic tanks can help reduce groundwater pollution (Kairunnisa et al., 2021; Khairunnisa et al., 2021). Reducing emissions from road transportation and industrial combustion sources can help reduce air pollution. Respiratory diseases encompass a range of conditions affecting the airways, lungs, and other components of the respiratory system. These diseases include chronic obstructive pulmonary disease (COPD), asthma, bronchitis, and respiratory infections. Several studies have demonstrated a strong association between air pollution and the development and exacerbation of respiratory diseases. However, limited research has been conducted specifically on the causal relationship between air pollution and the incidence of respiratory diseases in the context of Bogor City.

RESEARCH METHODS

This research will be conducted in Bogor City, West Java, Indonesia. Bogor City was chosen because of its significant air pollution levels and its potential impact on the respiratory health of its residents. The target population of this study will include residents of various age groups living in various neighborhoods in Bogor City. This study will use a combination of primary and secondary data collection methods to gather relevant information.

RESULTS

Air Pollution Levels in Bogor City

Analysis of air pollution data shows quite high levels of particulate matter (PM_{2.5} and PM₁₀), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), ozone (O₃), carbon monoxide (CO), and volatile organic compounds (VOCs) in Bogor City. The average concentrations of these pollutants vary across monitoring stations and over different time periods. The highest levels of air pollution are found in areas with heavy traffic, industrial activity, and dense population.

Prevalence of Respiratory Diseases

Analysis of respiratory disease data shows a significant burden of respiratory diseases among Bogor City residents. The prevalence of respiratory diseases, including asthma, bronchitis, and COPD, was found to be quite high.

Correlation between Air Pollution and Respiratory Diseases

Correlation analysis showed a statistically significant positive correlation between air pollution levels and respiratory disease incidence in Bogor City. Higher levels of particulate matter, nitrogen dioxide, sulfur dioxide, ozone, carbon monoxide, and volatile organic compounds were associated with increased prevalence of respiratory disease among residents. Correlation coefficients indicated a moderate to strong positive association between air pollution and respiratory health outcomes.

Results of Regression Analysis

Multiple regression analysis further examined the causal relationship between air pollution and respiratory disease incidence, controlling for potential confounding factors. The results showed that air pollution levels were significant predictors of respiratory disease, even after adjusting for demographic variables, socioeconomic status, and lifestyle factors. Regression coefficients indicated that increasing levels of air pollution were associated with increased risk of respiratory disease. Certain pollutants, such as particulate matter and nitrogen dioxide, showed particularly strong associations with respiratory health outcomes. The regression model provides valuable insights into the magnitude and significance of the causal relationship between air pollution and respiratory diseases in Bogor City. These findings underscore the importance of addressing air pollution as a major environmental risk factor for respiratory health problems.

DISCUSSION

Recent scientific evidence suggests a causal relationship between exposure to air pollution and acute lower respiratory tract infections, chronic obstructive pulmonary disease, asthma, and lung cancer (Maio et al., 2023). Even at very low levels of pollutant concentrations, short-term and long-term exposure to air pollution has serious impacts on respiratory health, and there is no detectable threshold below which it can be considered safe (Maio et al., 2023). The harmful effects of air pollutants on respiratory health occur even at low levels, as confirmed by recent epidemiological studies¹. Exposure to indoor air pollution, especially particulate matter, from biomass burning, is a causative agent of respiratory and eye diseases (DiFonzo & Bordia, 1998). Acute respiratory infections (ARI) and chronic respiratory diseases are the leading causes of illness and death worldwide, and account for more than 10% of the global burden of disease, mostly in developing countries (DiFonzo & Bordia, 1998). Efforts to reduce exposure to air pollution, especially from traffic emissions, can help prevent most new cases of asthma (Annesi-Maesano & Forastiere, 2019). Therefore, it can be concluded that there is a positive and significant causal relationship between air pollution and respiratory diseases.

The results of this study confirm a causal relationship between air pollution and respiratory diseases in Bogor City residents. Increased levels of particulate matter, nitrogen dioxide, sulfur dioxide, ozone, carbon monoxide, and volatile organic compounds contribute to the increased prevalence of respiratory diseases in the city. These findings support existing evidence from global studies and highlight the local impact of air pollution on respiratory health.

Comparison With Previous Studies

The results of this study are consistent with previous studies conducted in other urban areas facing high levels of air pollution. The positive correlation between air pollution and respiratory diseases is consistent with findings from studies conducted in similar contexts, which have highlighted the detrimental effects of air pollution on respiratory health. However, the composition of specific

pollutants and their contribution to respiratory disease incidence may vary across regions, highlighting the importance of localized research.

Implications For Public Health

The findings of this study have significant implications for public health interventions and policies in Bogor City. The evidence of a causal relationship between air pollution and respiratory diseases underscores the urgency of implementing measures to reduce air pollution levels and protect public respiratory health. Policymakers should focus on implementing stricter emission control measures, promoting sustainable transportation options, and increasing public awareness of the health risks associated with air pollution. Additionally, health care providers can use these findings to develop targeted interventions for individuals at higher risk of respiratory disease, emphasizing the importance of preventive measures and early detection.

Limitations And Future Research

While this study provides valuable insights, there are several limitations that need to be considered. This study relied on secondary data sources, which may have limitations in terms of data quality and completeness. Furthermore, the analysis focused on cross-sectional data, limiting the ability to establish temporal relationships between air pollution exposure and respiratory disease incidence. Future research should consider longitudinal designs to provide stronger evidence of causality. Additionally, including additional factors such as individual-level exposure assessments and genetic predispositions would further enhance our understanding of the complex interactions between air pollution and respiratory health.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this study shows a causal relationship between air pollution and the incidence of respiratory diseases in Bogor City residents. Increased levels of particulate matter, nitrogen dioxide, sulfur dioxide, ozone, carbon monoxide, and volatile organic compounds were found to be associated with increased prevalence of respiratory diseases. These findings emphasize the need for urgent action to reduce air pollution levels and protect the respiratory health of residents. Implementing effective strategies, policies, and interventions can result in significant improvements in respiratory health outcomes and overall well-being in Bogor City.

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