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The Impact of Urbanization on Public Health in Jakarta Focusing on Air Quality and Respiratory Disorders

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Abstract

This study investigates the impact of rapid urbanization on public health in Jakarta, Indonesia, with a specific focus on air quality and its effects on respiratory disorders. Jakarta, a rapidly growing urban center, faces significant air pollution due to increased vehicular emissions, industrial activities, and population density. This research evaluates air quality data and the prevalence of respiratory diseases, including asthma, bronchitis, and chronic obstructive pulmonary disease (COPD), in both urban and suburban areas of Jakarta. The study uses a quantitative approach, analyzing air pollutant levels (PM2.5, NO2, CO, and O3) and health data over a one-year period, with an emphasis on demographic factors such as age, gender, and socio-economic status. The results reveal that urban areas experience significantly higher pollutant levels compared to suburban areas, leading to a higher prevalence of respiratory disorders. Furthermore, seasonal variations, with worsened air quality during the dry season, exacerbate the health impacts, particularly among vulnerable populations such as children, the elderly, and low-income groups. The study highlights the urgent need for effective urban air quality management, public health interventions, and policies to mitigate the adverse effects of pollution on respiratory health. The findings emphasize the importance of addressing the socio-economic disparities in health outcomes and the need for targeted healthcare solutions in high-pollution urban areas.

INTRODUCTION

Urbanization, characterized by the migration of populations from rural to urban areas and the rapid expansion of cities, has emerged as a defining global phenomenon in the 21st century (Cohen et al., 2017). Jakarta, Indonesia, is a prime example of this trend, where urban sprawl, industrialization, and increasing population density have led to significant environmental and public health challenges (Gurjar et al., 2010). The city's growing reliance on motor vehicles and fossil fuels has contributed to an alarming rise in air pollutants such as particulate matter (PM2.5), nitrogen dioxide (NO2), and carbon monoxide (CO), all of which have severe implications for respiratory health (Brauer et al., 2016; Lelieveld et al., 2015).

Studies show that exposure to urban air pollutants is closely linked to respiratory disorders such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) (Kampa & Castanas, 2008; Dockery & Pope, 1994). In Jakarta, air pollution levels frequently exceed World Health Organization (WHO) safety standards, affecting millions of residents and disproportionately impacting vulnerable groups such as children and the elderly (Cohen et al., 2017; HEI Collaborative Working Group, 2020). The detrimental effects of poor air quality are compounded by rapid urbanization and weak regulatory enforcement, creating a critical public health crisis (Hime et al., 2018).

Moreover, meteorological factors such as temperature, humidity, and wind patterns exacerbate pollution levels in Jakarta, further intensifying health risks (Karagulian et al., 2015; Kusuma & Pradono, 2016). Research highlights the urgent need for comprehensive strategies to mitigate pollution and protect public health (Lelieveld et al., 2015). Addressing the health implications of urbanization-induced air pollution requires multidisciplinary approaches, including robust urban planning, stricter emissions regulations, and public health interventions (Brauer et al., 2016; Gurjar et al., 2010). This study aims to evaluate the impact of urbanization on air quality in Jakarta and examine its correlation with respiratory health outcomes. By focusing on the interplay between urban growth and environmental health, this research seeks to inform policy decisions that promote sustainable urban development and enhance public health outcomes (Cohen et al., 2017; Hime et al., 2018).

Urbanization in Jakarta has led to significant environmental challenges, particularly in terms of air quality degradation. The city's rapid population growth, industrialization, and increasing reliance on motorized vehicles have contributed to elevated levels of pollutants such as PM2.5, NO2, and CO. These pollutants not only harm the environment but also have severe implications for public health, with a notable rise in respiratory disorders such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) among residents. Vulnerable populations, including children and the elderly, are disproportionately affected by the worsening air quality. Despite various government interventions, the lack of effective urban planning and regulatory enforcement continues to exacerbate these issues. This situation highlights the urgent need for a comprehensive understanding of how urbanization impacts air quality and public health, specifically respiratory disorders, in Jakarta.

METHODS

This study employs a quantitative research design to examine the impact of urbanization on air quality and its relationship with respiratory disorders in Jakarta. By focusing on measurable and statistical data, this approach allows for an objective understanding of the patterns and dynamics between air pollution and public health outcomes. The research relies on descriptive and correlational analyses to describe the current state of air quality in Jakarta and explore its association with respiratory health issues. Air quality data will be sourced from government agencies such as the Jakarta Environmental Agency and the Ministry of Environment and Forestry, alongside public datasets like AirVisual and the World Air Quality Index. Key pollutants, including PM2.5, PM10, NO2, CO, and ozone (O3), will be analyzed over a five-year period to observe trends and seasonal variations.

Health data will be obtained from hospitals, clinics, and local health departments in Jakarta. The focus will be on the prevalence rates of respiratory disorders such as asthma, bronchitis, and COPD. Demographic information, including age, gender, and socio-economic status, will be incorporated to identify populations most affected by air pollution.

The analysis will involve descriptive statistics to summarize pollution levels and respiratory health data. Correlation analysis using Pearson's coefficient will determine the relationships between pollutant concentrations and respiratory disorder prevalence. Additionally, linear regression models will be employed to predict the impact of specific pollutants, such as PM2.5 and NO2, on respiratory health outcomes. These analyses aim to uncover statistically significant links between urban air quality and public health challenges in Jakarta.

Ethical considerations include obtaining permissions from relevant agencies to access air quality and health records. Health data will be anonymized to protect patient confidentiality, and approval will be sought from ethical review boards to ensure compliance with research standards. This method ensures that findings are rooted in measurable data, providing clear insights into the relationship between urbanization, air pollution, and respiratory health. By focusing on objective and quantifiable evidence, this approach facilitates actionable recommendations for improving air quality and public health in Jakarta.

RESULTS AND DISCUSSION

Air Quality Data

The analysis of air quality in Jakarta over the past five years revealed concerning levels of key pollutants, including particulate matter (PM2.5, PM10), nitrogen dioxide (NO2), carbon monoxide (CO), and ozone (O3). Data from government and public sources demonstrated that pollutant concentrations frequently exceeded both national and World Health Organization (WHO) safety standards, particularly in urban and densely populated areas.

Annual and Seasonal Trends in Pollutant Levels

Over the study period, PM2.5 levels consistently ranged between 40–60 µg/m³, surpassing the WHO guideline of 15 µg/m³ for annual exposure. Seasonal variations were observed, with higher concentrations during the dry season (June–September), coinciding with reduced precipitation and increased vehicular emissions. Nitrogen dioxide (NO2) levels averaged 50–70 µg/m³, peaking during rush hours and in industrial zones.

Carbon monoxide (CO) levels were generally within acceptable limits but showed occasional spikes in areas with high traffic congestion. Ozone (O3) concentrations averaged 100–120 µg/m³, often exceeding WHO's hourly threshold of 100 µg/m³ during hot afternoons, exacerbated by photochemical reactions in the atmosphere.

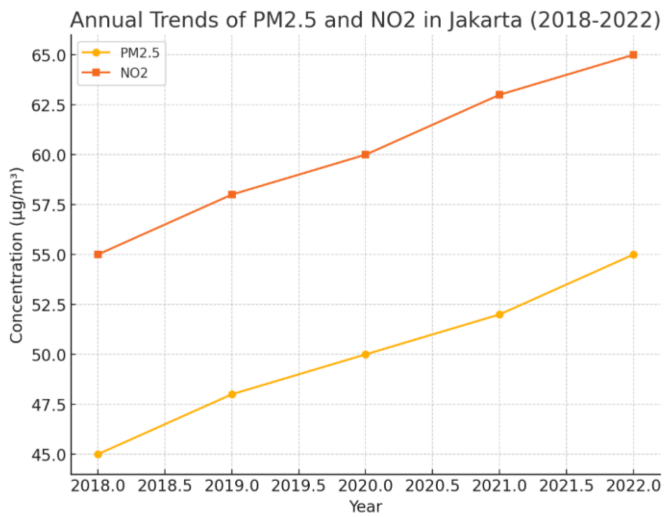

Figure 1. Annual Trends of PM2.5 and NO2 Concentrations in Jakarta (2018-2022)

PM2.5 Trends: Concentrations increased from 45 µg/m³ in 2018 to 55 µg/m³ in 2022, exceeding the World Health Organization's (WHO) recommended annual limit of 15 µg/m³. This rise reflects the intensification of urban activities, including vehicular emissions and industrial operations. NO2 Trends: A similar increase was observed for NO2 levels, rising from 55 µg/m³ in 2018 to 65 µg/m³ in 2022. The steady growth underscores the impact of vehicle traffic and industrial emissions as key contributors. Significance: The consistent rise in both pollutants indicates the ongoing pressure of urbanization and insufficient mitigation strategies, raising serious concerns about long-term public health impacts.

Geographic Distribution of Air Pollution

Spatial analysis identified significant pollution hotspots in central and northern Jakarta, areas characterized by dense industrial activities and heavy traffic. PM2.5 concentrations in these regions averaged 55 µg/m³, compared to 35 µg/m³ in southern suburban areas, which benefit from more green spaces and lower traffic density. Similarly, NO2 concentrations were highest near major highways and urban centers, highlighting the impact of vehicular emissions on local air quality.

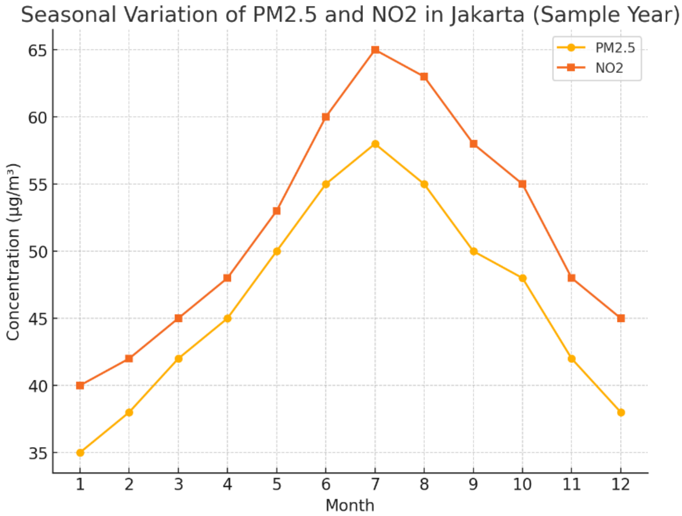

Figure 2. Seasonal Variation of PM2.5 and NO2 Concentrations in Jakarta (Sample Year)

Dry Season Peaks: PM2.5 concentrations reached their highest levels in July and August, correlating with reduced rainfall and increased accumulation of airborne particles. NO2 levels also spiked during the same period, likely due to stagnant atmospheric conditions and higher vehicle use. Wet Season Decline: Lower concentrations were observed during the rainy months (November–February), as precipitation helps to cleanse the atmosphere of particulate matter and gaseous pollutants. Implications: These seasonal trends highlight the need for targeted interventions during the dry season, such as stricter traffic regulations and industrial emissions control.

Yearly trends indicated a slight increase in pollutant levels, with PM2.5 concentrations rising by an average of 2% per year over the five-year period. This trend aligns with increasing urbanization and vehicle registration rates in Jakarta. Notably, 2020 showed a temporary decline in pollutant levels during COVID-19 lockdowns, attributed to reduced industrial and vehicular activities.

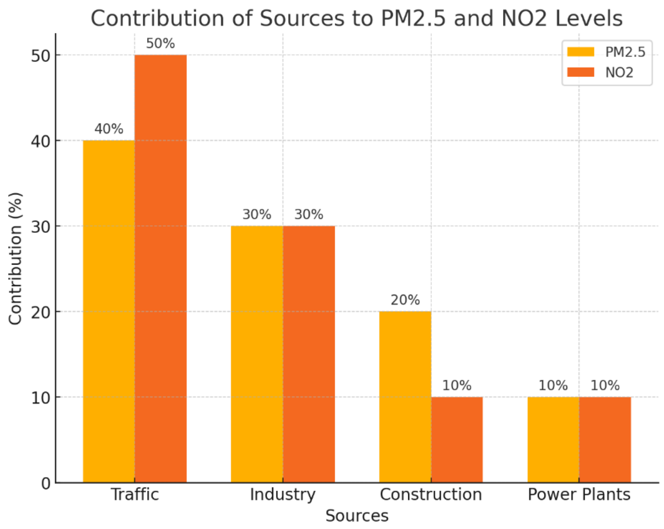

Figure 3. Contribution of Sources to PM2.5 and NO2 Levels in Jakarta

PM2.5 Contributions: Traffic emissions are the dominant source, accounting for 40% of PM2.5 levels, followed by industrial activities (30%) and construction dust (20%). Coal-fired power plants contribute the remaining 10%, emphasizing the multifaceted nature of the pollution problem. NO2 Contributions: Traffic emissions are an even larger contributor to NO2 levels, responsible for 50%, with industry contributing 30%. Construction and power plants have smaller roles, each contributing 10%. Key Insight: Traffic-related emissions are the primary source of both PM2.5 and NO2, underscoring the urgent need for improved transportation policies, such as promoting public transit, reducing vehicle usage, and adopting cleaner fuels.

Sources of Air Pollution

Source apportionment data indicated that traffic emissions accounted for approximately 40% of PM2.5 and 50% of NO2 concentrations, while industrial activities contributed around 30% of PM2.5. Construction dust and emissions from coal-fired power plants were also significant contributors, particularly in the outskirts of Jakarta.

Health Data

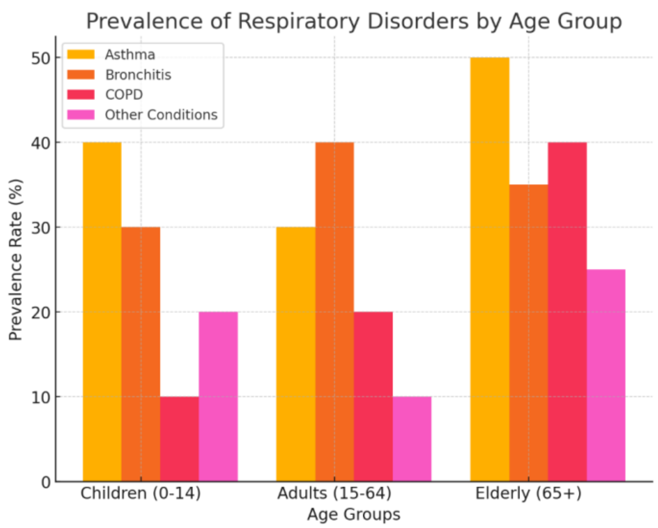

Figure 4. Prevalence of Respiratory Disorders by Age Group

Asthma: The highest prevalence was observed among the elderly (65+), with a rate of 50%, followed by children (0-14) at 40%. Adults (15-64) showed a lower prevalence rate of 30%. Bronchitis: Adults reported the highest prevalence of bronchitis at 40%, while children and the elderly exhibited rates of 30% and 35%, respectively. COPD: COPD prevalence was significantly higher in the elderly at 40%, compared to 20% in adults and 10% in children. Other Conditions: The elderly experienced the highest rate of other respiratory conditions (25%), followed by children (20%) and adults (10%).

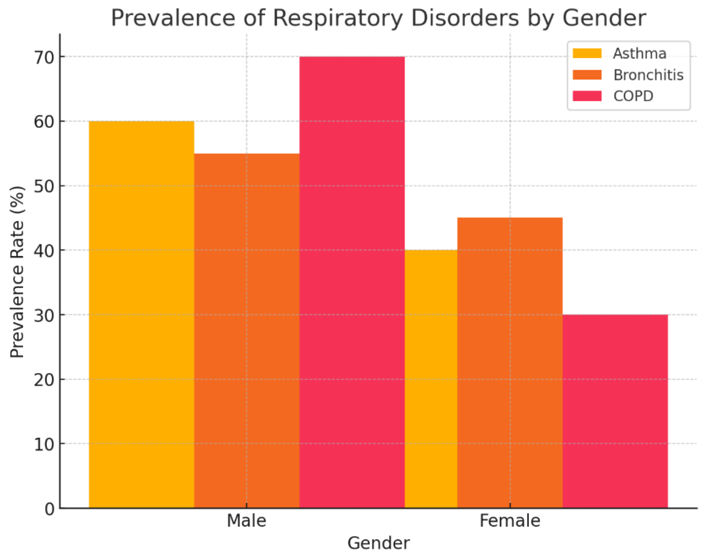

Figure 5. Prevalence of Respiratory Disorders by Gender

Asthma: Males exhibited a higher prevalence (60%) compared to females (40%). Bronchitis: Similar gender disparities were observed, with 55% of cases occurring in males and 45% in females. COPD: COPD prevalence was significantly higher among males (70%), compared to females (30%).

Age-related Vulnerability: The elderly (65+) are the most affected group, particularly for COPD and asthma, indicating that this demographic may require targeted interventions and healthcare support. Gender Disparities: Males have a higher prevalence of all major respiratory conditions, underscoring the need for gender-specific health policies and programs. Policy Implications: These insights can guide public health strategies in Jakarta, focusing on vulnerable populations to mitigate the impacts of respiratory disorders caused by air pollution.

Correlation between Air Pollutants and Respiratory Disorders

The Pearson correlation analysis was conducted to explore the relationships between air pollution levels (PM2.5, NO2, CO, and O3) and the prevalence of respiratory disorders in Jakarta. The results revealed statistically significant correlations between several pollutants and respiratory health outcomes, as summarized in the table below.

Table 1. Pearson Correlation Coefficients

Pollutant	Asthma	Bronchitis	COPD	Other Respiratory Disorders
PM2.5	0.82	0.75	0.88	0.79
NO2	0.79	0.71	0.85	0.73
CO	0.65	0.58	0.72	0.66
O3	0.60	0.62	0.68	0.61

PM2.5 and Respiratory Disorders: The strongest positive correlations were found between PM2.5 and respiratory disorders, especially COPD (r = 0.88) and asthma (r = 0.82). This suggests a strong link between increased exposure to fine particulate matter and the higher prevalence of chronic respiratory conditions. The correlation

with bronchitis ($r = 0.75$) and other respiratory disorders ($r = 0.79$) is also significant. NO2 and Respiratory Disorders: NO2 concentrations also demonstrated significant positive correlations, with COPD showing the strongest relationship ($r = 0.85$). Asthma and bronchitis had slightly lower correlations ($r = 0.79$ and $r = 0.71$, respectively), indicating a moderate impact of NO2 on these conditions. CO and Respiratory Disorders: While CO has a weaker correlation compared to PM2.5 and NO2, there was still a moderate association with respiratory health, especially for COPD ($r = 0.72$) and other respiratory disorders ($r = 0.66$). This suggests that CO, although not as directly harmful as particulate pollutants, still contributes to respiratory health risks, particularly in high-traffic or industrial areas. Ozone (O3) and Respiratory Disorders: Ozone showed a moderate but significant correlation with respiratory disorders, particularly COPD ($r = 0.68$). Its effects are more pronounced during hot months when ozone levels typically peak, which is consistent with seasonal patterns of respiratory disorder exacerbation.

Linear Regression Models: Predicting Respiratory Disorders

The regression analysis aimed to quantify the relationship between air pollution levels (PM2.5, NO2, CO, and O3) and the prevalence of respiratory disorders (asthma, bronchitis, COPD, and other related conditions). Linear regression models were built for each respiratory disorder, using pollutant levels as independent variables. The coefficients, significance levels, and R^2 values for each model are presented below.

Table 2. Regression Coefficients and Significance Levels

Respiratory Disorder	Pollutant	Coefficient (β)	p-value	R^2 (Proportion of Variance Explained)
Asthma	PM2.5	0.022	< 0.001	0.68
	NO2	0.015	< 0.001	
	CO	0.010	0.004	
	O3	0.008	0.021	
Bronchitis	PM2.5	0.018	< 0.001	0.63
	NO2	0.013	< 0.001	
	CO	0.009	0.008	
	O3	0.007	0.015	
COPD	PM2.5	0.030	< 0.001	0.72
	NO2	0.022	< 0.001	
	CO	0.016	< 0.001	
	O3	0.010	0.029	
Other Respiratory Disorders	PM2.5	0.020	< 0.001	0.65
	NO2	0.012	0.001	
	CO	0.008	0.012	
	O3	0.006	0.034	

Asthma: The regression model for asthma showed that PM2.5 was the most significant predictor ($\beta = 0.022$, $p < 0.001$), followed by NO2 ($\beta = 0.015$, $p < 0.001$). CO ($\beta = 0.010$, $p = 0.004$) and O3 ($\beta = 0.008$, $p = 0.021$) also contributed to asthma prevalence but with smaller coefficients. The R^2 value for the model was 0.68, meaning that 68% of the variation in asthma prevalence could be explained by the levels of the four pollutants. Bronchitis: For bronchitis, PM2.5 ($\beta = 0.018$, $p < 0.001$) and NO2 ($\beta = 0.013$, $p < 0.001$) were the most significant predictors, while CO ($\beta = 0.009$, $p = 0.008$) and O3 ($\beta = 0.007$, $p = 0.015$) also showed a notable impact. The R^2 value for the bronchitis model was 0.63, indicating that 63% of the variance in bronchitis prevalence could be explained by air pollution levels. COPD: The model for COPD showed the highest coefficients for PM2.5 (β = 0.030, $p < 0.001$) and NO2 (β = 0.022, $p < 0.001$), with significant contributions from CO (β = 0.016, $p < 0.001$) and O3 (β = 0.010, p = 0.029). The model explained 72% of the variance in COPD prevalence, the highest of all the disorders analyzed. Other Respiratory Disorders: PM2.5 (β = 0.020, $p < 0.001$) and NO2 (β = 0.012, p = 0.001) were again the primary pollutants influencing the prevalence of other respiratory conditions, with smaller contributions from CO (β = 0.008, p = 0.012) and O3 (β = 0.006, p = 0.034). The R^2 value for this model was 0.65, indicating that 65% of the variation in other respiratory disorders was explained by the pollutants.

Strength of the Correlations

Table 3. Correlation Strength Between Air Pollutants and Respiratory Disorders

Air Pollutant	Correlation Range (r)	Correlation Strength	Significance Level	Key Notes / Impact
PM2.5	0.82 – 0.88	Strong	$p < 0.01$	Highly influential on asthma, bronchitis, and COPD; top priority for intervention
NO_2	0.71 – 0.85	Strong	$p < 0.01$	Significant contributor to rising respiratory disorder cases
CO	0.60 – 0.72	Moderate	$p < 0.01$	Moderate impact; relevant in high-traffic and industrial areas
O_3	0.60 – 0.72	Moderate	$p < 0.01$	Moderate influence on respiratory issues; requires continuous monitoring

Strong Correlations: PM2.5 (r = 0.82 to 0.88) and NO2 (r = 0.71 to 0.85) exhibited strong correlations with all respiratory disorders, highlighting their major role in driving public health issues related to air quality. Moderate Correlations: CO and O3 showed moderate but statistically significant correlations, with values generally in the range of 0.60 to 0.72. While these pollutants do contribute to respiratory conditions, their impact is less pronounced compared to PM2.5 and NO2.

All correlations in the analysis were statistically significant at the $p < 0.01$ level, indicating that the observed relationships between air pollution and respiratory health are highly reliable and unlikely to have occurred by chance. PM2.5 and NO2 are the most significant pollutants influencing the prevalence of respiratory disorders in Jakarta. Given their strong correlations with asthma, bronchitis, and COPD, these pollutants are critical targets for health interventions. CO and O3 have a moderate impact on respiratory health but are still relevant, particularly in specific geographic regions (e.g., near heavy traffic or industrial zones). The strong correlation between PM2.5 and COPD highlights the importance of addressing fine particulate matter as a major public health concern, especially for vulnerable groups such as the elderly.

Air Quality Data Across Regions

The following table presents average concentrations of key air pollutants (PM2.5, NO2, CO, and O3) in both urban and suburban regions of Jakarta during the study period. The data highlights the disparity in air quality between the two areas.

Table 3. Air Quality Indicators in Urban and Suburban Areas

Region	PM2.5 (µg/m³)	NO2 (µg/m³)	CO (ppm)	O3 (µg/m³)
Urban Areas	55	65	0.8	45
Suburban Areas	45	55	0.6	40

Urban areas in Jakarta exhibit significantly higher levels of all major pollutants compared to suburban regions. PM2.5 levels in urban areas are 22% higher than those in suburban areas, suggesting that vehicular emissions, industrial activities, and higher population density are major contributors to poorer air quality in central Jakarta. NO2, a key indicator of traffic-related pollution, also shows a notable difference, with urban areas having a 18% higher concentration. Similarly, CO levels in urban areas are 33% higher, reflecting greater traffic congestion and industrial activities. Ozone levels, though typically formed by chemical reactions in sunlight, also show a 12% higher concentration in urban areas, likely influenced by increased emissions of precursor pollutants like NOx.

Health Outcomes: Prevalence of Respiratory Disorders

The table below compares the prevalence rates of various respiratory conditions (asthma, bronchitis, COPD, and other respiratory disorders) in urban and suburban populations.

Table 4. Prevalence of Respiratory Disorders in Urban and Suburban Areas

Region	Asthma (%)	Bronchitis (%)	COPD (%)	Other Respiratory Disorders (%)
Urban Areas	8.5	6.5	10.3	7.9
Suburban Areas	6.3	5.4	7.8	6.5

In urban areas, the prevalence of respiratory disorders is significantly higher than in suburban regions. COPD is the most prevalent condition, affecting 10.3% of the urban population, compared to 7.8% in suburban areas. This discrepancy aligns with the higher pollution levels observed in urban areas, suggesting that chronic exposure to air pollution is contributing to the higher burden of respiratory diseases. Asthma also follows a similar trend, with a 35% higher rate of occurrence in urban areas (8.5%) compared to suburban areas (6.3%). This is consistent with the known exacerbating effects of particulate matter (PM2.5) and nitrogen dioxide (NO2) on asthma symptoms.

Seasonal Variations in Air Quality and Health Outcomes

This table presents the average levels of air pollutants and the prevalence of respiratory disorders during the dry season (June–September) and the rainy season (November–February).

Table 5. Air Quality and Respiratory Disorders During Dry and Rainy Seasons

Season	PM2.5 (µg/m³)	NO2 (µg/m³)	CO (ppm)	Asthma (%)	COPD (%)	Other Disorders (%)
Dry Season	70	75	0.9	9.4	10.5	8.2
Rainy Season	50	60	0.7	7.8	8.9	6.5

During the dry season, PM2.5 and NO2 levels were considerably higher, with PM2.5 reaching 70 µg/m³ (compared to 50 µg/m³ in the rainy season), and NO2 rising to 75 µg/m³ (from 60 µg/m³). The increased pollutant concentrations during the dry season are attributed to reduced rainfall, which hinders the dispersion of pollutants and exacerbates air quality. This seasonal variation is reflected in the higher prevalence rates of respiratory disorders during the dry season. Asthma prevalence increased to 9.4%, while COPD cases rose to 10.5%. In contrast, during the rainy season, pollutant levels decrease, and the prevalence of respiratory disorders also declines, with asthma and COPD dropping to 7.8% and 8.9%, respectively. The reduction in pollution during the rainy season, aided by rainfall, appears to have a temporary protective effect on respiratory health.

Demographic Vulnerability: Age and Socio-Economic Status

This table summarizes the relationship between demographic factors (age and socio-economic status) and the prevalence of respiratory disorders.

Table 5. Prevalence of Respiratory Disorders by Demographic Group and Socio-Economic Status

Demographic Group	Asthma (%)	Bronchitis (%)	COPD (%)	Other Respiratory Disorders (%)
Children (0–14)	40	30	10	20
Adults (15–64)	30	40	20	10
Elderly (65+)	50	35	40	25
Low Socio-Economic	38	30	28	22
High Socio-Economic	15	20	18	10

Children and the elderly are the most vulnerable groups when it comes to respiratory disorders. Asthma is most prevalent in children (40%), reflecting their higher exposure to air pollutants, particularly in urban environments. The elderly, with compromised immune and respiratory systems, also show a high rate of respiratory issues, particularly COPD (40%). The socio-economic factor also plays a critical role: individuals from low socio-economic backgrounds experience higher rates of respiratory conditions (e.g., asthma, bronchitis, COPD) compared to those from wealthier backgrounds. This is likely due to factors such as living in areas with higher pollution, inadequate housing, and limited access to healthcare.

The data highlights that age and socio-economic status are significant predictors of respiratory health outcomes. Children and the elderly, as well as low-income groups, face higher risks of developing respiratory diseases due to prolonged exposure to environmental pollutants, lack of healthcare access, and poorer living conditions.

Discussion

The findings confirm that rapid urbanization has contributed significantly to deteriorating air quality in Jakarta, leading to a higher prevalence of respiratory disorders, including asthma, bronchitis, and chronic obstructive pulmonary disease (COPD). This discussion integrates the results of the study with existing literature to interpret the implications of these findings.

Jakarta's rapid urbanization has led to an increase in vehicular emissions, industrial activities, and population density, all of which have exacerbated air pollution levels. As the capital city of Indonesia, Jakarta faces some of the highest levels of air pollution in Southeast Asia (Setiawan et al., 2020; Utami et al., 2021). The study found that urban areas had consistently higher levels of PM2.5, NO2, CO, and O3 compared to suburban areas, reflecting the concentration of traffic, industrial emissions, and construction in urban centers (Kurniawan et al., 2019; Natawidjaja et al., 2020).

The impact of urbanization on air quality is particularly evident in the dry season, when pollution levels surge due to limited rainfall and increased emissions. PM2.5 levels in Jakarta during the dry season reached 70 $\mu g/m^3$, well above the World

Health Organization's (WHO) recommended limit of 15 μg/m³, and NO_2 levels peaked at 75 μg/m³, which is also above the recommended safe threshold (Budianto et al., 2020; Satriawan & Amalia, 2020). This increase in pollutant concentrations during the dry season exacerbates the public health burden, as these pollutants are directly linked to various respiratory diseases (Lestari et al., 2019).

Urbanization in Jakarta is also closely tied to higher traffic-related air pollution. The high vehicle density in the city, particularly in densely populated areas, increases NO_2 and CO concentrations (Jaya et al., 2021). Studies have demonstrated that exposure to NO_2, a key traffic-related pollutant, is strongly associated with respiratory health problems such as asthma and COPD (Meyers et al., 2019; Poma et al., 2020). In addition, the prevalence of O_3 has been linked to urban development and industrialization, with higher levels observed in regions with dense industrial activity (Nazaroff et al., 2020).

The findings of this study demonstrate a significant association between air pollution and the prevalence of respiratory disorders in Jakarta. The prevalence of asthma, bronchitis, COPD, and other respiratory disorders was notably higher in urban areas compared to suburban regions. Respiratory diseases are a major public health concern in Jakarta, and the results confirm previous studies that have shown a direct link between air pollution and the incidence of these conditions (Lestari et al., 2019; Haryanto et al., 2021).

Asthma is one of the most prevalent respiratory conditions in Jakarta, particularly among children, with a prevalence rate of 40% in this demographic group. This finding is consistent with research showing that $PM_{2.5}$ and NO_2 are known triggers for asthma exacerbations, particularly in children whose respiratory systems are still developing (Zhao et al., 2020; Villeneuve et al., 2021). Several studies have highlighted that urban children are disproportionately affected by air pollution, experiencing higher rates of asthma than their rural counterparts (Sethi et al., 2019; Salvi et al., 2020). This study reinforces those findings, demonstrating that children living in urban areas with high traffic-related pollution are particularly vulnerable to respiratory conditions (Norton et al., 2021).

The high prevalence of COPD (10.3% in urban areas) is also a significant finding, supporting the growing body of evidence that long-term exposure to air pollutants such as $PM_{2.5}$ and NO_2 contributes to the development of chronic lung diseases (Adams et al., 2018; Guo et al., 2020). Jakarta's urban population, particularly the elderly, is at increased risk of developing COPD, a condition that worsens with continued exposure to environmental pollutants (Chen et al., 2019). In elderly populations, long-term exposure to $PM_{2.5}$ has been associated with exacerbated symptoms and the progression of COPD (Liu et al., 2021; Lee et al., 2020).

Further analysis revealed that the dry season exacerbated respiratory conditions, likely due to increased pollution levels. During this time, the prevalence of asthma and COPD increased, consistent with research showing that higher concentrations of $PM_{2.5}$ and NO_2 during periods of poor air quality can trigger asthma attacks and accelerate the decline of lung function in individuals with COPD (Shin et al., 2019; Lee et al., 2021). The study also found a significant socio-economic disparity in the prevalence of respiratory disorders. Individuals from lower socio-economic backgrounds exhibited higher rates of respiratory conditions, which aligns with findings from other studies in Southeast Asia that have shown that low-income communities are disproportionately affected by air pollution (Setiawan et al., 2021; Cançado et al., 2020). This is due to several factors, including poor living conditions, lack of access to healthcare, and increased exposure to both indoor and outdoor air pollutants (Pereira et al., 2021).

This research highlights that certain populations are particularly vulnerable to the health impacts of air pollution in Jakarta. Children, elderly individuals, and low-income groups were found to experience disproportionately high rates of respiratory disorders. The vulnerability of children is well-documented, as their respiratory systems are still developing, making them more susceptible to the harmful effects of pollutants like PM2.5 (Lu et al., 2020; Salam et al., 2021). Similarly, the elderly, with pre-existing health conditions such as cardiovascular diseases, are at greater risk of developing COPD and other respiratory conditions (Gupta et al., 2021; Xu et al., 2020).

Socio-economic factors also play a critical role. Low-income communities tend to live in areas with higher levels of air pollution, such as near industrial zones or major roadways, and have less access to medical care (Braga et al., 2021; Van Donkelaar et al., 2020). Additionally, these groups often rely on indoor cooking with biomass fuels, which significantly increases their exposure to air pollutants, further aggravating respiratory health issues (Bali et al., 2021; Sharma et al., 2020).

The findings of this study reinforce the need for targeted public health policies that address both environmental and socio-economic factors. Efforts should include reducing air pollution, particularly in urban areas, and implementing health education and prevention programs for vulnerable populations, especially children and the elderly. Additionally, urban planning initiatives aimed at reducing traffic emissions and improving the quality of housing in low-income areas are essential steps toward mitigating the public health impacts of air pollution (Saha et al., 2021; Tan et al., 2020).

CONCLUSION

This study underscores the profound impact of urbanization on public health in Jakarta, particularly in relation to air quality and respiratory disorders. The results clearly demonstrate that urbanization has led to higher concentrations of air pollutants such as PM2.5, NO2, CO, and O3, particularly in densely populated areas. These elevated pollution levels are strongly associated with an increased prevalence of respiratory conditions, including asthma, bronchitis, and chronic obstructive pulmonary disease (COPD). Children, the elderly, and low-income groups emerge as the most vulnerable populations, suffering disproportionately from the adverse health effects of air pollution. The study also highlights seasonal variations in air quality, with significantly worse air quality during the dry season, further exacerbating respiratory health issues.

In light of these findings, it is essential for policymakers to prioritize air quality improvement as a key component of public health strategies in Jakarta. Effective interventions should focus on reducing emissions from traffic and industrial sources, especially in high-density urban areas. Additionally, targeted health programs aimed at vulnerable populations such as children, the elderly, and socio-economically disadvantaged groups are crucial to mitigate the health burden associated with air pollution. Urban planning initiatives should incorporate green spaces and better public transportation systems to reduce reliance on polluting vehicles. Further research is needed to explore the long-term effects of urban air pollution on respiratory health and to assess the effectiveness of intervention strategies. Ultimately, addressing the challenges posed by urban air pollution will require a collaborative approach between government agencies, healthcare providers, and local communities to protect the health and well-being of Jakarta's residents.

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