

Impact of Criteria Air Pollutants on Respiratory Health: A Case Study of Kano Metropolis

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Abstract

Air pollution is a significant public health concern in urban environments worldwide. This paper investigates the relationship between Criteria Air Pollutants (CAPs) and respiratory health outcomes in the Kano metropolis. Using Aeroqual Portable Monitor S500 V6 ENV and HoldPeak Aerosol Mass Monitor, ambient concentrations of CAPs were measured at 34 randomly sampled locations monthly for 12 months. Additionally, medical records on lung cancer, asthma, upper respiratory tract infections (URTIs), pneumonia, and chronic obstructive pulmonary disease (COPD) were collected from the four public specialist hospitals in the study area. The data were analysed using a stepwise multiple regression model. Results revealed that the prevalence of asthma significantly correlated ($R^2=0.92$, $p<0.05$) with $PM_{2.5}$. The COPD was significantly influenced ($R^2=0.84$, $p<0.05$) by CO and O_3 , and the occurrence of pneumonia by NO_2 ($R^2=0.700$, $p<0.05$). Likewise, cases of URTIs were associated ($R^2=0.890$, $p<0.05$) with $PM_{2.5}$ and SO_2 and lung cancer was significantly linked ($R^2=0.967$, $p<0.05$) to $PM_{2.5}$. This underscores the critical need for air quality interventions in the Kano metropolis to mitigate the adverse health impacts of pollution. The paper advocates for the enactment of public health policy initiatives aimed at reducing pollutant levels to prevent respiratory illnesses and improve overall community health.

Key words: Air Pollutants, Public Health, Urban, Respiratory Diseases

INTRODUCTION

Over the past three decades, in a process known as urbanization, urban areas have developed more densely than rural ones (Zhong *et al.*, 2023). This progress is much faster in developing than in developed countries (Sakketa, 2023; Soubbotina and Sheram, 2000). Urbanization does not always mean improving situations but rather has increased the quantity and complexity of waste generated (Golzary *et al.*, 2024; Khatib, 2011), most especially of gasses and air pollutants emitted.

Rapid and largely unplanned urban growth has led to numerous economic, social, and environmental issues (Rashed, 2023). These encompass heightened resource demands; waste generation that infiltrates air, water, and land ecosystems; significant population shifts; rising population densities; and evolving habitats for all species, including humans. Estimates suggest that a city with one million residents consumes approximately 625,000 tonnes of water, 2,000 tonnes of food, and 9,500 tonnes of fuel daily, while producing 500,000 tonnes of wastewater, 2,000 tonnes of solid waste, and 950 tonnes of air pollutants (Tolba *et al.*, 1992; Sadik, 1991). In

essence, urban areas are experiencing population surges, leading to increased emissions of air pollutants due to diverse lifestyles, industries, and consumption habits (Humbal *et al.*, 2023).

Many cities worldwide, especially in developing nations, are undergoing rapid expansion but often without sufficient environmental policies and programs in place (Rentschler *et al.*, 2023; Luca *et al.*, 2023). This growth comes with significant and escalating economic and social costs. The increasing population, industrial activity, and number of vehicles contribute to worsening air pollution, presenting a serious environmental risk in many urban areas. The World Health Organization (WHO) and other global organizations have long recognized urban air pollution as a critical public health issue (Bikis, 2023; Schwela, 2012). In Africa, after decades of political struggles, including civil wars, many nations are now experiencing accelerated economic growth, which has spurred urbanization, a rise in automobiles, industrialization, and waste production. Currently, Africa's urban population growth rates are the highest globally, averaging about 50% annually, and are expected to climb even higher in the future (Sakketa, 2023;

UNESCAP, 2010). These changes frequently occur without regulations to prevent or control air pollutant emissions, leading to deteriorating air quality, particularly in urban settings (Sicar *et al.*, 2023; Schwela, 2012).

Many major cities in West Africa are currently grappling with a significant challenge of air pollution. It's not uncommon to witness a thick layer of smog enveloping the skies over these African urban areas, a result of the high population density and the widespread use of motor vehicles emitting large amounts of fumes (Boko, 2003). This stands in stark contrast to the situation in developed nations, where ongoing efforts to manage air quality have been successful in reducing the release of air pollutants from human activities into the atmosphere (EEA, 2007).

Air pollution, defined as the contamination of the atmosphere by harmful or toxic substances beyond the environment's natural capacity to disperse or neutralize them, can stem from direct emissions or the formation of secondary pollutants through atmospheric chemical reactions (Manisalidis *et al.*, 2020). These pollutants' levels in urban areas can occasionally be three times higher than the World Health Organization's (WHO) recommended values for air quality (Pai *et al.*, 2022; Peláez *et al.*, 2020; Wambebe, & Duan, 2020; WHO, 2005).

The release of air pollutants poses dangers to human health and ecosystems. The negative effects of air pollution are evident: it harms health in the short and long term, has adverse impacts on ecosystems, and causes damage and staining of materials, including those used in cultural artefacts. The rise in disease burden and deaths from ambient air pollution is alarming, as reported by the WHO in 2016. The WHO linked 3.7 million deaths worldwide to air pollution in 2012, 4.2 million in 2016, and a staggering 7.0 million in 2018, which surged to 8.8 in 2019 and 8.7 in 2021 (WHO, 2016; Lelieveld *et al.*, 2019; Lelieveld *et al.*, 2020; Vohra *et al.*, 2021; Vohra *et al.*, 2022). According to the United Nations Environment Programme (UNEP, 2023), air pollution is the biggest single environmental health risk globally (Rentschler & Leonova, 2023; Xu *et al.*, 2022). The reduction of air pollution has the potential to save millions of lives. Recent discoveries by the WHO highlight a stronger connection between exposure to indoor and outdoor air pollution and cardiovascular diseases,

such as strokes and heart disease, as well as the link between air pollution and cancer (de Bont *et al.*, 20224; Scimeca *et al.*, 2024; Konduracka, *et al.*, 2022).

Exposure to high levels of air pollutants regularly poses a challenge to sustainable development by increasing the burden of diseases and causing harm to the environment, thus reducing life expectancies and leading to significant economic losses (Chen *et al.*, 2024). Sustainable development can only be successful if it involves minimizing the negative impact of human activities on human health and the environment (Van Zanten and van Tulder, 2021). Additionally, the release of air pollutants into the environment and their absorption by plants and animals can lead to these chemicals entering the food chain or contaminating drinking water, resulting in additional sources of human exposure (Chaitanya *et al.*, 2024).

Furthermore, the structure and function of ecosystems, as well as their ability to self-regulate and overall quality of life can be influenced by the direct impact of air pollutants on plants, animals, and soil (Antwi *et al.*, 2021). Despite its effects on the environment, human health, and urban planning, air pollution in the Northern states of Nigeria has not received adequate attention from scholars or the government. This lack of attention prompted the need to investigate the impact of air pollution in the Kano metropolis of north-western Nigeria.

MATERIALS AND METHODS

Study Area

Kano Metropolis is situated in the central-western region of Kano State. It spans latitudes from 10°59'59.57" N to 12°02'39.57" N and longitudes from 8°03'19.69" E to 8°31'59.69" E (Figure 1). Its population, according to the 2006 census, is 2,828,861 (NPC, 2006). Using the Malthusian growth model of population projection given as:

$$P_t = P_0 x e^{rt}$$

Where:

P_t = the projected population

P_0 = the initial population size,

e = the exponential

r = the population growth rate,

t = time

The projected population of the Kano metropolis as at 2023 was 4,541,802.

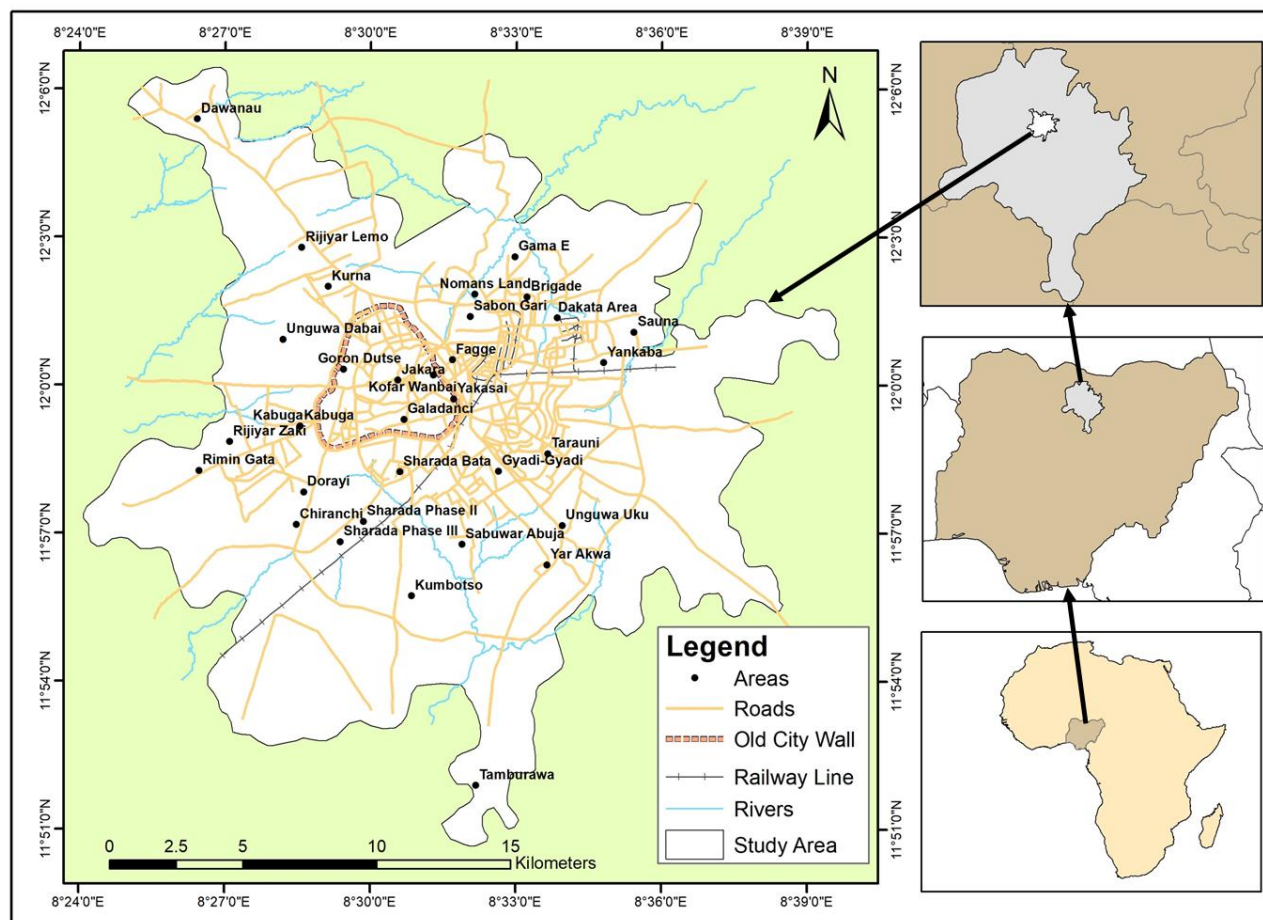


Figure 1: The Study Area

Methods

The four public Specialist Hospitals were purposively selected for the collection of hospital records on asthma, chronic obstructive pulmonary diseases (COPD), lung cancer, and acute lower respiratory infections in children which according to WHO (2018a) are the human diseases that are mostly caused by air pollution. Ethical clearance was obtained from the Kano State Ministry of Health (Appendix I) to this effect. These hospitals were:

- i. Murtala Muhammad Specialist Hospital, Kano
 - ii. Abdullahi Wase Specialist Hospital, Kano
 - iii. Sir Sanusi Specialist Hospital, Kano
 - iv. Hasiya Bayero Hospital, Kano
- Aeroqual Portable Monitor S500 V6 ENV were used to measure and monitor nitrogen dioxide (NO₂), sulphur dioxide (SO₂), carbon monoxide (CO) and ozone (O₃); and Aerosol mass monitor (HoldPeak Laser PM2.5-5800D Digital Meter) was

also used to measure particulate matter (PM_{2.5} and PM₁₀). These gases, along with the particulate matter, are the principal "criteria" pollutants that can injure health, harm the environment and cause property damage (USEPA, 2015). The data was collected from 34 sampled points within the metropolis over a twelve (12) calendar month period.

Methods of Data Analysis

The data was analysed using a stepwise multiple regression model to determine the contribution of each pollutant (as independent variables) on the prevalence of pollution-related diseases (dependent variables). The regression model is:

$$y = a + b_1x_1 + b_2x_2 + \dots b_6x_6$$

Where:

y = pollution-induced diseases (asthma, COPD, pneumonia, URTI, lung cancer)

a = constant

x_1 = Carbon monoxide

$x_2 = \text{Ozone}$
 $x_3 = \text{Sulphur dioxide}$
 $x_4 = \text{Nitrogen dioxide}$
 $x_5 = \text{PM}_{2.5}$
 $x_6 = \text{PM}_{10}$

Evidence from literature indicates that both short- and long-term exposure to criteria ambient air pollutants contribute to a wide range of human health challenges, and environmental and property damage. These health challenges may be as a result of the combined or singular presence of pollutants in the ambient air.

RESULTS AND DISCUSSION

Table 1: Regression Model Summary of CAPs with Asthma

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.940 ^a	.883	.871	34.449
2	.964 ^b	.929	.913	28.302

a. Predictors: (Constant), x_5 (PM_{2.5})

b. Predictors: (Constant), x_5 (PM_{2.5}), x_3 (SO₂)

The model summary of the regression between CAPs and Asthma (Table 1) reveals that only PM_{2.5} and SO₂ contributed to the prevalence of Asthma in the metropolis. Particulate matter (PM_{2.5}) or fine particles accounted for 88.3% ($R^2 = 0.883$) of Asthma. The combined contribution of PM_{2.5} and

SO₂ explained 92.9% ($R^2 = 0.929$) of the cases of Asthma attacks (Tsai *et al.*, 2024; Varghese *et al.*, 2024). Also, the results show that the two independent variables statistically and significantly predict the dependent variable, $F = 58.480$, $p < 0.05$, $R^2 = 0.929$ (Table 2).

Table 2: Regression ANOVA for CAPs and Asthma

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	94263.121	2	47131.561	58.840	.000 ^b
	Residual	7209.129	9	801.014		
	Total	101472.250	11			

a. Dependent Variable: Asthma

b. Predictors: (Constant), x_5 (PM_{2.5}), x_3 (SO₂)

This result agrees with the findings of Henning (2024), Lu *et al.* (2024), Li *et al.* (2023), Xu *et al.* (2023), Liwsrisakun *et al.* (2023) and Wei *et al.* (2023) who reported that ambient air pollution is the leading risk factor for both acute and chronic asthma and even short-term exposure to PM_{2.5} can trigger its attack. Also, Meo *et al.* (2024) and Ojima *et al.* (2024) discovered that air pollutants, most especially particulate matter and gases such as SO₂,

cause oxidative damage to the lungs and airways, leading to inflammation and increased threat of sensitisation. Khreis *et al.* (2019) attributed a substantial percentage of childhood asthma cases to ambient PM_{2.5} and NO₂ in Europe. The results obtained by Wu *et al.* (2019) in China suggest that exposure to both PM₁₀ and PM_{2.5} has significant short-term effects on childhood asthma exacerbation.

Table 3: Regression Model Summary of CAPs with COPD

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.865 ^a	.748	.722	18.509
2	.918 ^b	.843	.808	15.392

a. Predictors: (Constant), x_2 (O₃)

b. Predictors: (Constant), x_2 (O₃), x_1 CO

The results of the regression model summary (Table 3) indicated that it is O₃ and CO that contribute more to COPD. Ozone alone accounts for 74.8% ($R^2 = 0.748$) of the prevalence

of COPD. While the combined contribution of O₃ with CO amounted to 84.3% ($R^2 = 84.3$). The regression model is statistically significant $F = 24.145, p < 0.05, R^2 = 0.843$ (Table 4).

Table 4: Regression ANOVA for CAPs and COPD

Model		Sum of Squares	df	Mean Square	F	Sig.
2	Regression	11440.665	2	5720.332	24.145	.000 ^b
	Residual	2132.252	9	236.917		
	Total	13572.917	11			

a. Dependent Variable: COPD

b. Predictors: (Constant), x_2 (O₃), x_1 (CO)

The regression results are consistent with the findings of Li *et al.* (2016). The study identified CO and O₃ as significant pollutants to the occurrence of COPD in Hong Kong. Also, Khaniabadi *et al.* (2017) discovered that O₃ contributed as much as 88.8% of the burden of COPD in Iran. In a related study, Xiang *et al.* (2019)

identified O₃ as the leading cause of COPD-related mortality, where it caused 273,600 deaths in urban adults in mainland China. Also, Wang *et al.*, (2023) and Doiron *et al.* (2019) reported that higher concentrations of air pollutants were significantly associated with a high prevalence of COPD in the UK.

Table 5: Regression Model Summary of CAPs with Pneumonia

Model	R	R Square	Adjusted Square	RStd. Error of the Estimate
1	.836 ^a	.700	.670	48.182

a. Predictors: (Constant), x_4 (NO₂)

The results only associated NO₂ with the prevalence of pneumonia. Though stronger correlations exist between pneumonia and PM_{2.5}, its contribution to pneumonia occurrence was minimal. Nitrogen dioxide accounted for 70% of pneumonia

(Table 5). This means NO₂ alone is associated with 70% of pneumonia cases. This relationship was statistically significant $F = 23.290, p < 0.05, R^2=0.700$ (Table 6).

Table 5.6: Regression ANOVA for CAPs and pneumonia

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	54068.004	1	54068.004	23.290	.001 ^b
	Residual	23214.913	10	2321.491		
	Total	77282.917	11			

a. Dependent Variable: pneumonia

b. Predictors: (Constant), x_4 (NO₂)

Studies identified NO₂ and PM_{2.5} as the leading environmental causes of pneumonia (WHO, 2019). Nitrogen dioxide was associated with the death of 2,208 pneumonia adult patients aged 65 years and above in Hong Kong (Sun *et al.*, 2019). While NO₂ and SO₂ were linked to child mortality

from pneumonia in China (Wang *et al.*, 2019). Also, Pirozzi *et al.* (2018) found positive associations between pneumonia and NO₂, PM_{2.5} and O₃. While the effects of NO₂ were felt more in the colder months, O₃ was higher in the warmer months.

Table 7: Regression Model Summary of CAPs with URTI

Model	R	R Square	Adjusted Square	RStd. Error of the Estimate
1	.898 ^a	.806	.787	41.634
2	.943 ^b	.890	.866	33.082

a. Predictors: (Constant), x_5 (PM_{2.5})

b. Predictors: (Constant), x_5 (PM_{2.5}), x_3 (SO₂)

The regression results show that PM_{2.5} and SO₂ are the pollutants that are associated with the prevalence of URTI (Table 7). Particulate matter (PM_{2.5}) alone is associated with 80.6% of the cases of URTI coupled with SO₂, 89% of the cases are

explained in the model. It is worth noting that NO₂ also positively correlated with URTI. The regression model was statistically significant $F = 36.395$, $p < 0.05$, $R^2 = 0.890$ (Table 8).

Table 8: Regression ANOVA for CAPs and URTI

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	79664.359	2	39832.180	36.395	.000 ^b
	Residual	9849.891	9	1094.432		
	Total	89514.250	11			

a. Dependent Variable: URTI

b. Predictors: (Constant), x_5 (PM_{2.5}), x_3 (SO₂)

These results are similar to the findings of (Zhang *et al.*, 2019) and (Liu *et al.*, 2019), which associated the prevalence of URTI with PM_{2.5} in China. Also, (Rana *et al.*, 2019) discovered a strong significant relationship between solid fuel use and its consequent emission of PM_{2.5} with the incidence

of URTI in Pakistan. Likewise, (Croft *et al.*, 2019) reported strong correlations between URTIs with PM_{2.5} in the United States of America. However, NO₂ was also said to have played a significant role in the prevalence of URTIs in China (Li *et al.*, 2018).

Table 8: Regression Model Summary of CAPs with Lung cancer

Model	R	R Square	Adjusted Square	RStd. Error of the Estimate
1	.983 ^a	.967	.964	2.626

a. Predictors: (Constant), x_5 (PM_{2.5})

The regression result indicates that PM_{2.5} is highly accountable for the prevalence of lung cancer (Table 8). The pollutant is associated with 96.7% ($R^2 = 0.967$) of the cases of lung cancer in the study

area. The regression model shows that the independent variables statistically and significantly predict the dependent variable $F = 292.324$, $p < 0.05$, $R^2 = 0.967$ (Table 9).

Table 9: Regression ANOVA for CAPs and Lung Cancer

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2015.954	1	2015.954	292.324	.000 ^b
	Residual	68.963	10	6.896		
	Total	2084.917	11			

a. Dependent Variable: Lung Cancer

b. Predictors: (Constant), x_5 (PM_{2.5})

These findings are consistent with that of Tseng *et al.* (2019) which associated an increase in

PM_{2.5} with the rise in lung cancer among non-smokers in Taiwan. Also, the burden of lung cancer

was attributed to exposure to fine particulate matter which was linked to having led to an additional 1466 cases of the disease in France (Kulhánová *et al.*, 2018). Again, Myers *et al.* (2018) found an association between lung cancer and the outdoor PM_{2.5} among female non-smokers in British Columbia, Canada. However, bladder cancer was also associated with the concentration of PM_{2.5} (Turner *et al.*, 2019). Similarly, Zhu *et al.* (2019) reported significant associations between lung cancer and SO₂, while Nafstad *et al.* (2003) elucidated the contribution of NO_x and SO₂ to the disease.

CONCLUSION

The findings from this study underscore the significant health risks posed by Criteria Air Pollutants in the Kano metropolis. Our investigation reveals that exposure to elevated levels of carbon monoxide is linked to a heightened incidence of Chronic Obstructive Pulmonary Disease (COPD). At the same time, nitrogen dioxide (NO₂) contributes to increased rates of pneumonia. Additionally, ozone (O₃) exposure correlates with exacerbated outcomes of COPD. Conversely, sulphur dioxide (SO₂) and fine particulate matter (PM_{2.5}) emerge as significant risk factors for asthma, Upper Respiratory Tract Infections (URTIs), and lung cancer in the local population.

These results highlight the urgent need for targeted interventions to mitigate air pollution levels in Kano. Public health initiatives should prioritize reducing carbon monoxide, nitrogen dioxide, sulphur dioxide, and PM_{2.5} emissions to safeguard respiratory health and mitigate the burden of COPD, pneumonia, asthma, URTIs, and lung cancer. Furthermore, continued monitoring and research are essential to better understand air quality dynamics and health outcomes in this urban setting, ensuring evidence-based policies and interventions for improved public health.

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