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Assessment of Air Pollution Trends in Jos Metropolis Using Ground Observations

Adamu Muhammad Kamaludeen[1*], Izham Bin Mohamad Yusoff[2], Suleiman Mohammed Gidado[3]

[*1]Geography Section, School of Distance Education, Universiti Sains Malaysia.
Orcid 0000-0002-2168-2181
[2] Geography Section, Transdisciplinary Research on Environmental Science, Occupational Safety and Health Section, School of Distance Education, Universiti Sains Malaysia.
Orcid 0000-0003-0805-804X, Email ID: izham@usm.my
[3]American University of Nigeria, Yola Nigeria.
Email ID: suleiman.gidado@gmail.com
[*]**Corresponding author:**
Adamu Muhammad Kamaludeen
Email ID: mkamaludeen@student.usm.my

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ABSTRACT
This study examines air pollution in Jos Metropolis, Plateau State, Nigeria, focusing on PM_{10}, $PM_{2.5}$, SO_2, and CO levels from September to December in 2023 and 2024. Data from six monitoring stations reveal significant diurnal and seasonal variations, with higher pollutant concentrations in the morning due to peak vehicular and industrial activities.

Findings indicate a rise in $PM_{2.5}$ and CO levels in 2024, particularly in Jos North, linked to urbanization, increased vehicle emissions, and biomass combustion. CO levels surged from 11.82 ppm in 2023 to 27.48 ppm in 2024, emphasizing worsening air quality. The study underscores the contribution of human activities, including fuel combustion, industrial processes, and inadequate waste management, to air pollution trends in the region.

To mitigate pollution, strategic interventions such as enforcing stricter emissions regulations, promoting cleaner energy alternatives, and improving public transport systems are recommended. Public awareness campaigns on air pollution and sustainable waste management should also be encouraged. Without effective measures, deteriorating air quality could lead to severe health implications for residents. This study provides critical insights into air pollution trends in Jos Metropolis, serving as a foundation for further research and policy development aimed at improving urban air quality in Nigeria.

Keywords: *Air Pollution, GIS, Geo-Spatial, Metropolis,* PM_{10}

1. INTRODUCTION

LITERATURE REVIEW

Urban canters, particularly densely populated metropolises, are significantly affected by air pollution due to various anthropogenic activities. Common contributors include vehicular emissions, improper waste management systems, and inadequate sewage disposal practices (Nicholas et al., 2019). The health impacts of air pollution in these areas are profound, often leading to respiratory, cardiovascular, and optical ailments (Reu-Junquiera et al., 2023). Vulnerable groups, particularly children in underdeveloped regions such as Africa, are disproportionately affected by air pollution. This vulnerability is primarily due to limited access to air monitoring technologies and reliance on solid fuels for cooking and heating (Tan et al., 2021). In 2019, the United Nations Department of Economic and Social Affairs reported that over 350 million Africans resided in homes utilizing solid fuels, significantly contributing to indoor air pollution. Notably, in 2017, air pollution-related deaths in Africa exceeded 400,000 (Nicholas et al., 2019).

Recent studies underscore the severe health implications of air pollution. Afifa et al. (2024) and Totolici et al. (2022) emphasized that urban areas, particularly in developing nations such as Nigeria, experience heightened health risks from pollution. Cities like Jos Metropolis exemplify the growing urbanization challenges that exacerbate air quality issues, leading to a significant increase in pollutants in the atmosphere. Scholars have identified several factors responsible for the global rise in air pollution. Afifa et al. (2024) linked the phenomenon to climate change and global warming, noting that these environmental changes accelerate pollution levels. Shivanna (2022) highlighted that global warming has caused biodiversity loss, sea-level rise, and increased human-induced pollution levels. This trend is evident in Jos, Nigeria, where air pollution has historical roots dating back to the colonial era. During this period, industrial and mining activities were rampant, significantly contributing to air contamination. Furthermore, the city's rapid population growth fuelled by high birth rates and migration has intensified urbanization and its accompanying pollution challenges.

Advancements in geo-spatial technologies and GIS have proven instrumental in addressing air pollution challenges. These tools enable policymakers to identify pollution hotspots, analyse pollutant types, and propose targeted solutions (Mac Lenna et al., 2023). For example, GIS methods, including overlay analysis and interpolation, provide accurate data on pollutant concentrations and their spatial distribution, aiding in environmental management (Hiba & Bijay, 2023). These technologies have been successfully applied in industrial regions to monitor and manage pollutants such as PM2.5, PM10, and sulphur dioxide.

The World Health Organization (WHO, 2019) defines air pollution as the contamination of indoor or outdoor air with harmful gases or particulate matter, such as PM2.5, PM10, carbon monoxide, and sulphur dioxide that alter the air's natural properties. Reu-Junquiera et al. (2023) described air pollution as the presence of foreign substances in concentrations detrimental to human health. These substances may originate from activities such as cooking, smoking, vehicular emissions, and industrial processes. Hussain et al. (2023) further established the link between air pollution and climate change, attributing the rise in pollution to industrial activities and the presence of climate pollutants like carbon dioxide.

Air pollution remains a pressing global challenge, profoundly impacting human societies, especially in densely populated regions. Mousavi and Wu (2021) emphasize that the adverse effects of air pollution are most pronounced in congested urban areas. Cities such as Beijing, California, and Delhi experience alarmingly high levels of air pollution due to factors such as industrialization, traffic emissions, and population density (Lu, 2021). Notably, during the COVID-19 pandemic, the highest infection rates were observed in these metropolitan areas, a phenomenon partly linked to poor air quality and its impact on respiratory health. Effective use of technology, including functional ground monitoring facilities and Geographic Information Systems (GIS), has been shown to mitigate the adverse effects of air pollution (Mac Lenna et al., 2023). This underscores the disparity in air pollution management between developed cities and underdeveloped areas, where technological interventions are often lacking. Scholars unanimously agree that both human activities and natural causes contribute to air pollution, although anthropogenic sources are responsible for more immediate and severe impacts (Sturiale et al., 2023).

Bignan (2022) conducted an in-depth analysis of air pollution in Beijing, identifying both natural and anthropogenic sources as key contributors. The study highlighted the severe public health implications of air pollution, including reduced quality of life and heightened health risks. However, the research did not extensively discuss the role of GIS and geo-spatial technology in addressing air pollution challenges in Beijing. This gap indicates the need for further exploration of how technological tools can enhance pollution monitoring and mitigation efforts in megacities. Several GIS methods have been identified as effective in measuring air pollution, including overlay analysis and interpolation techniques (Trivedi and Bergi, 2022). These methods facilitate the accurate assessment of pollutant concentrations and spatial distribution, enabling targeted interventions.

Air pollutant and their emission sources Keswani et al., 2022)

Pollutant	Major sources
PM	Vehicular emissions, fire smoke which are secondary formation of particles from precursors (NOx, Sox, VOCs)) which transformed to inhalable (PM_{10}) dust in the environment.
O_3	It is mostly gotten from secondary formation through the chemical reaction of (NOx, VOCs) through sunlight.
NO_2	Fuel combustion from transportation, electricity, and other industrial activities. Natural emissions from soil.
SO_2	Combustion of fossil fuel for power generation, industrial boilers, coal combustion and oil.

Sources of primary and secondary pollutant along with their major precursor gases and sources (EEP and agency 2022)

Air pollutant	Category	Major precursor gases	Sources
Particulate Matter (PM)	Primary	-	Combustion (fossil fuels, biomass,

			biogas/biofuel) industrial combustion and dust from windblown sources.
Particulate Matter (PM_{10})	Secondary	Sulfur dioxide (SO2)	Gas to particle conversion particulate matter (PM)
Sulfur oxide (SO_2)	Primary	-	Burning of fossil fuels (coal and oil) for electricity generation.
Nitrogen oxide (NOx)	Primary	-	Fuel combustion (industrial and transport) Biomass burning.
Ozone O_3	Secondary	Nitrogen oxide (NOx), Carbon monoxide (CO) non-methane VOCs, methane (CH_4)	Gas to particle conversion fuel combustion (industrial and transport biomass burning.

2. MATERIALS AND METHOD

2.1 The Study Area: Jos Metropolis

Jos metropolis is the most urbanized area in Plateau State. The geographical area encompasses urban settlements of Jos North and Jos South that's including the central township. The area is a hide of human activities. Jos metropolis is an area that developed out of the former mining settlements that had been established since the colonial period. Human population in Jos metropolis is estimated at 5 million people with Tudun Wada, Angwan Rogo, Gada and Bukuru among the most populated settlements. Human activities in our study area such as sewage disposal, burning of fuel, bush burning as well as the cooking energy waste: Charcoal and firewood as well as fumes from cars and industries and major agents of population.

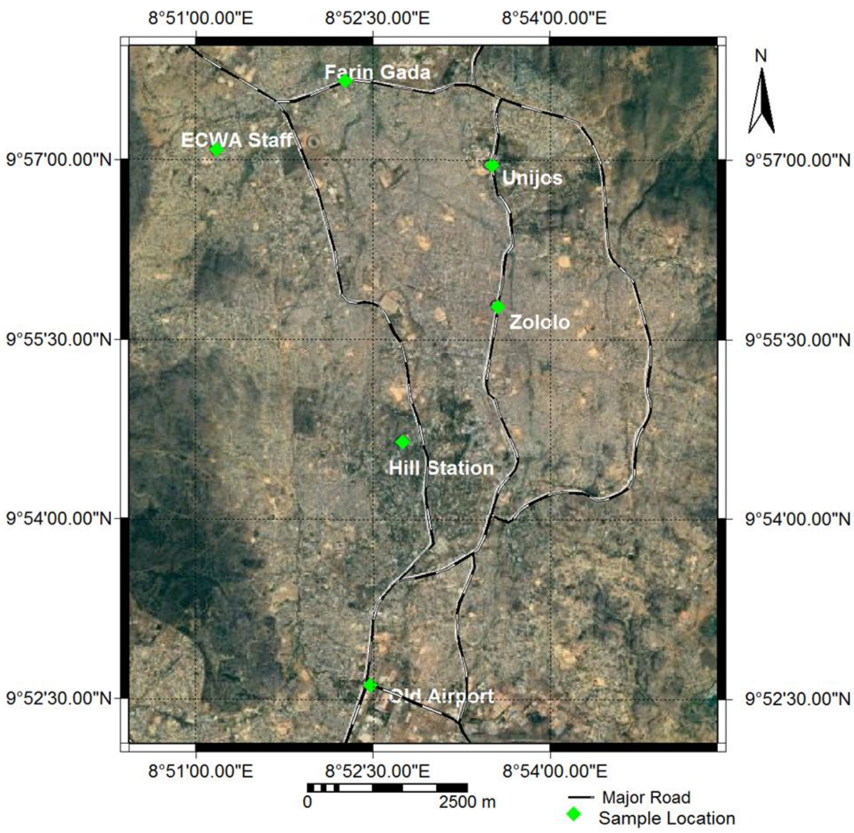

FIG 1

2.2 Data

The Ground stations pollutant that will be used includes PM_{10}, NO_2, O_3 and SO_2 being recorded hourly. Ground stations' data will be obtained from the Centre for Atmospheric Research of the Nigerian Space. The data of 6 monitoring stations were used to measure the concentration of the pollutant.

Table 1: Mean Concentration of PM_{10}, $PM_{2.5}$, SO_2, CO for SEPTEMBER

LOCATION	POLLUTANTS							
	PM10		PM2.5		SO2		CO	
	2023	2024	2023	2024	2023	2024	2023	2024
Farin Gada	21.87	17.56	11.71	6.87	0.008	0.146	12.02	18.01
Hill Station	16.76	18.67	4.59	6.03	0	0.084	6.09	15.78
Old Airport	8.52	11.78	2.96	4.94	0.009	0.235	7.28	26.15
Uni Jos	10.08	10.94	7.18	8.83	0.011	0.06	10.21	15.44
Zololo Junc.	9.89	14.86	7.09	7.89	0.012	0.093	12.4	17.45
ECWA Staff	7.04	19.09	3.99	11.98	0.001	0.014	5.1	16
Mean	12.36	15.48	7.99	6.09	0.006	0.105	8.85	18.13

Table 2: Mean Concentration of PM_{10}, $PM_{2.5}$, SO_2, CO for OCTOBER

LOCATION	POLLUTANTS							
	PM10		PM2.5		SO2		CO	
	2023	2024	2023	2024	2023	2024	2023	2024
Farin Gada	29.97	23.96	7.06	8.65	0.447	0.044	11.97	24.07
Hill Station	18.81	21.56	6.43	8.13	0.002	0.399	7.53	101.25
Old Airport	13.49	16.63	3.12	9.76	0.119	0.298	10.01	55.61
Uni Jos	16.28	17.87	8.18	9.53	0.21	0.029	22.09	11.87
Zololo Junc.	12.37	18.76	8.9	9.04	0.012	0.021	37.37	12.09
ECWA Staff	14.82	26.23	7.89	16.99	0.025	0.017	3.06	13.09
Mean	17.62	20.83	6.93	10.35	0.205	0.134	15.33	36.33

Table 3: Mean Concentration of PM_{10}, $PM_{2.5}$, SO_2, CO for NOVEMBER

LOCATION	POLLUTANTS							
	PM10		PM2.5		SO2		CO	
	2023	2024	2023	2024	2023	2024	2023	2024
Farin Gada	21.87	17.56	11.71	6.87	0.008	0.146	12.02	18.01
Hill Station	16.76	18.67	4.59	6.03	0	0.084	6.09	15.78
Old Airport	8.52	11.78	2.96	4.94	0.009	0.235	7.28	26.15
Uni Jos	10.08	10.94	7.18	8.83	0.011	0.06	10.21	15.44
Zololo Junc.	9.89	14.86	7.09	7.89	0.012	0.093	12.4	17.45

ECWA Staff	7.04	19.09	3.99	11.98	0.001	0.014	5.1	16
Mean	12.36	15.48	7.99	6.09	0.006	0.105	8.85	18.13

Table 4: Mean Concentration of PM_{10}, $PM_{2.5}$, SO_2, CO for DECEMBER

LOCATIONS	POLLUTANTS							
	PM10		PM2.5		SO2		CO	
	2023	2024	2023	2024	2023	2024	2023	2024
Farin Gada	20.65	13.06	5.12	6.95	0.125	0.204	9.167	44.88
Hill Station	12.76	16.56	5.99	7	0.023	0	11.231	22.053
Old Airport	10	14.21	1.92	7.89	0.047	0.013	10.8	32.13
Uni Jos	14.09	15.23	6.34	7.531	0.006	0.018	8.125	5.364
Zololo Junc.	11.07	17.89	9.91	10.76	0.031	0.013	9.438	19.533
ECWA Staff	9.824	18.87	5.09	14.69	0.067	0.004	12.161	29.04
Mean	13.06	15.97	5.72	9.17	0.049	0.042	10.15	25.5

Table 5: Overall Mean of the Impurities

MONTHS	POLLUTANTS							
	PM10		PM2.5		SO2		CO	
	2023	2024	2023	2024	2023	2024	2023	2024
SEPTEMBER	11.9	15.15	4.73	7.48	0.044	0.158	12.97	29.98
OCTOBER	12.36	15.48	7.99	6.09	0.006	0.105	8.85	18.13
NOVEMBER	17.62	20.83	6.93	10.35	0.205	0.134	15.33	36.33
DECEMBER	13.06	15.97	5.72	9.17	0.049	0.042	10.15	25.5
Mean	13.73	16.85	6.34	8.27	0.076	0.109	11.82	27.48

DISCUSSION

Analysis of Air Pollutant Concentrations in Jos North Local Government

The findings from the research, as presented in Table 1, clearly indicate the mean concentrations of various air pollutants across six selected areas within Jos North Local Government Area. These pollutants—PM_{10}, $PM_{2.5}$, Sulfur Dioxide (SO_2), and Carbon Monoxide (CO) were closely monitored to assess air quality patterns in both the years 2023 and 2024.

3.1 Concentration Patterns of pollutant (Table 1)

In 2024, the mean concentration of PM10 was recorded at 15.51 µg/m³ in the morning and 11.90 µg/m³ in the evening. This suggests that human activities, particularly economic and vehicular movements, are more intense in the early hours, leading to higher particulate emissions. This pattern is consistent with the findings of Abdulkareem et al. (2020), who observed peak pollutant levels during morning rush hours in Nigerian urban centres due to increased vehicular traffic and industrial operations.

The concentration ranges for other pollutants are as follows: $PM_{2.5}$: 7.46 µg/m³ in 2024 and 4.73 µg/m³ in 2023 as for SO_2: 0.158 ppm in 2024 and 0.044 ppm in 2023. Furthermore, CO: 29.98 ppm in the morning and 12.97 ppm in the evening.

These results underscore the elevated pollution levels during morning hours, primarily driven by transportation and industrial emissions, aligning with studies by Okonkwo et al. (2021), who reported higher morning pollutant concentrations in Northern Nigerian cities.

3.2 Annual Comparative Analysis (Table 2)

The pollutants were tracked in both 2023 and 2024, with notable differences in concentrations: PM_{10}: Decreased from 15.48 µg/m³ in 2024 to 12.36 µg/m³ in 2023, and $PM_{2.5}$: Increased from 6.09 µg/m³ in 2024 to 7.99 µg/m³ in 2023. Meanwhile, SO_2: Averaged 0.105 ppm in 2024 and dropped to 0.006 ppm in 2023 and CO: Rose from 18.13 ppm in 2024 to 8.85 ppm in 2023.

This data suggests a slight improvement in air quality between 2023 and 2024, potentially due to environmental regulations or reduced industrial activities, supporting findings by Lawal et al. (2022), who emphasized the role of policy in lowering pollutant emissions in Nigerian cities.

3.3 Diurnal Variation in Pollutants (Table 3)

Further analysis revealed substantial diurnal variation in pollutant levels: PM_{10}: 20.83 µg/m³ in the morning, dropping to 17.62 µg/m³ in the evening. Meanwhile, $PM_{2.5}$: 10.35 µg/m³ in the morning, reducing to 6.93 µg/m³ in the evening and SO_2: Increased from 0.134 ppm to 0.205 ppm over the day. CO: Rose sharply from 15.33 ppm in the evening to 36.33 ppm in the morning.

The sharp rise in CO and PM_{10} concentrations in the morning correlates with increased traffic congestion and industrial activity, consistent with findings by Ukoje and Babatunde (2020), who identified morning and evening rush hours as critical periods for air pollution in urban Nigerian settings.

3.4 Pollution Trends Across Years (Table 4)

In-depth monitoring across the two years revealed the following pollutant levels: PM_{10}: 15.97 µg/m³ in 2024 and 13.06 µg/m³ in 2023 and $PM_{2.5}$: 9.17 µg/m³ in 2024 and 5.72 µg/m³ in 2023 meanwhile, SO_2: 0.042 ppm in 2024 and 0.049 ppm in 2023. And CO: 25.13 ppm in 2024 and 10.15 ppm in 2023. The persistent increase in $PM_{2.5}$ and CO levels in 2024 indicates escalating emissions, likely due to expanding urbanization and vehicular growth in Jos North, aligning with the conclusions drawn by Ezeh et al. (2019) regarding urban pollution trends in Sub-Saharan Africa.

Overall Mean Concentration of Pollutants (Table 5)

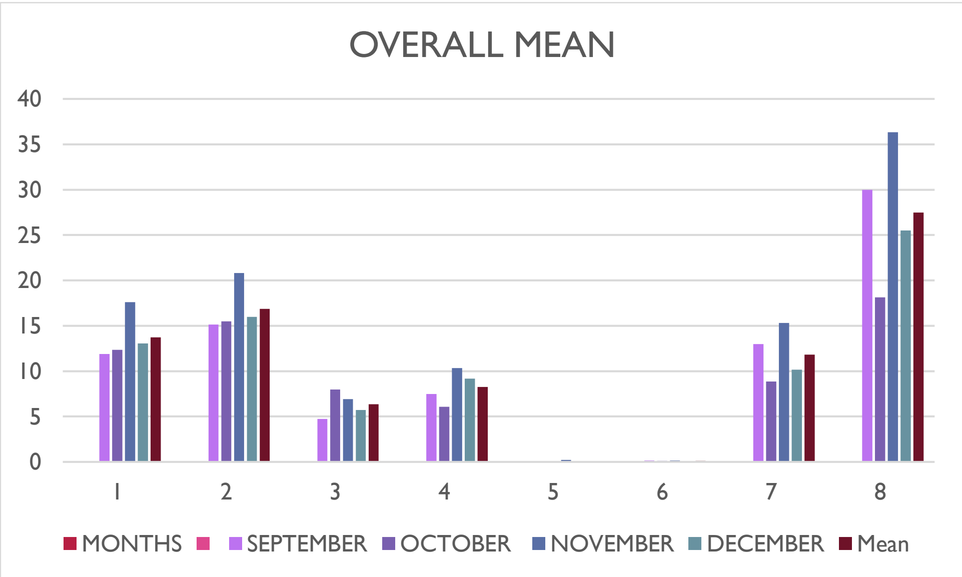

FIG 2

To standardize the analysis, fig 2 analyse the average concentrations of all pollutants over four months were computed: PM10: 16.85 µg/m³ in 2024 and 13.73 µg/m³ in 2023 and PM2.5: 8.27 µg/m³ in the morning and 6.34 µg/m³ in the evening and SO_2: 0.109 ppm in 2024 and 0.076 ppm in 2023 and CO: 27.48 ppm in 2024 and 11.82 ppm in 2023.

The higher averages in 2024 imply a progressive deterioration in air quality, particularly in particulate matter and carbon monoxide levels, reflecting findings by World Health Organization (2021), which emphasized that urban air pollution is intensifying in rapidly growing cities in developing countries. The observed pollution patterns can be attributed to various anthropogenic activities. The significantly higher PM_{10} and CO levels in the morning can be linked to increased vehicular traffic, industrial emissions, and residential fuel combustion. Studies by Akpan et al. (2021) highlight that Nigeria's heavy reliance on fossil fuels and inefficient energy use contribute substantially to urban air pollution. Moreover, the increase in

PM2.5 levels in 2024 reflects intensified construction activities and agricultural burning, as corroborated by Osuntogun and Koku (2020). The slightly higher SO_2 concentrations are indicative of emissions from fuel combustion and industrial processes. The seasonal variation in pollutant levels suggests that climatic factors such as wind speed, humidity, and temperature inversions could significantly influence pollutant dispersion and concentration, aligning with Ngele et al. (2019), who reported seasonal influences on air quality in Nigeria's urban centres.

3. CONCLUSION

The comprehensive analysis across various tables reveals:

- Morning periods consistently experience higher pollution due to intensified human activities.
- Annual trends indicate rising levels of $PM_{2.5}$ and CO, reflecting growing urban emissions.
- Seasonal and diurnal variations highlight the role of human activity and climatic factors in air quality dynamics.

Addressing these air quality concerns requires implementing sustainable urban policies, improving public transport systems, and enforcing stricter emission controls, aligning with WHO (2021) guidelines on urban air quality management.

In view of all the work and effort concerning the topic at hand, it was observed that the high rate of Human activities in our study area such as sewage disposal, burning of fuel, bush burning as well as the cooking energy waste: Charcoal and firewood as well as fumes from cars and industries and major agents of population contribute badly to the contamination of the environment and hence reduces the quality of air. The outcome of this investigation clearly denotes that fumes from cars, human activities and burning of charcoal and firewood is important and as such, there is a need for it to be studied and examined. As the city grows, the value of air will continue to deteriorate and will further lead to health issues. Most residence of Jos who live or carry out business where burning of charcoal and fumes from cars are inevitable, such persons are prone to having health challenges.

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