AIR QUALITY ASSESSMENT AND PARTICULATE MATTER LEVELS IN SELECTED LOCATIONS OF JOS-SOUTH LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

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ABSTRACT

Air quality is a critical aspect of environmental health, as it directly impacts human well-being and the ecosystem. Monitoring and assessments of air quality levels, particularly the particulate matter ($PM_{2.5}$ and PM_{10}), are therefore absolutely essential. In this study, the levels of $PM_{2.5}$ and PM_{10} were analyzed in some selected areas of Jos-South area using a portable CW-HAT 200 Dust Particles Counter. The finding of the study revealed that 70 % of $PM_{2.5}$ and 100 % of PM_{10} in all the sampling sites exceeded the World Health Organization (WHO)'s threshold limit, with the highest level of $PM_{2.5}$ of 1.014 mg/m³ recorded at Old Airport Roundabout YG Way and the lowest level of 0.007 mg/m³ was observed at D.B. Zang Roundabout in comparison with the control. For PM_{10}, the highest concentration of 0.039 mg/m³ was recorded at Old Airport Roundabout YG Way, while the lowest concentration of 0.012 mg/m³ was observed at Old Airport Roundabout Anguldi when compared with the control. There was a temporal variation in PM levels during the morning and afternoon, but the variations were not significant as confirmed by the independent t-test results ($p = 0.05$). Air Quality Index (AQI) analysis results indicated that the PM contributes to high pollution levels and significant human health concerns, particularly the $PM_{2.5}$, which require urgent remediation strategies to safeguard public health and the environment.

Key words: Air quality, Air Quality Index, Jos-South, Particulate matter, $PM_{2.5}$, PM_{10}

INTRODUCTION

Air quality is an important part of environmental health since it directly affects human well-being and ecology [1, 2]. Approximately 91 % of the world's population lives in areas where air quality exceeds the World Health Organization (WHO) with annual deaths of 9-12 million globally [3, 4]. Particulate matters ($PM_{2.5}$ and PM_{10}) are a major source of concern for air quality because of its ubiquitous prevalence and negative health impacts. PM_{10} (particles with diameters ≤ 10 microns) and $PM_{2.5}$ (particles with diameters ≤ 2.5 microns) are mixtures of solid particles and liquid droplets floating in the air [5, 6]. They are primarily produced by various forms of combustion, including power plants, motor cars, home wood burning, and some industrial activities [7]. These tiny fragments can go deep into the respiratory system, causing major health hazards such as lung cancer and cardiovascular disease as well as ecosystem damage [8, 9]. Among the negative consequences of particulate matters is that, in addition to being pollutants themselves, they may also serve as transporters of other harmful pollutants like heavy metals and other

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contaminants [10, 11]. Therefore, monitoring and assessing the levels of particulate matters is critical towards public health protection and the management of the environment. In Nigeria, rapid urbanization, industrial activities, vehicular emissions, biomass burning and laxity of laws governing the regulations of air pollution are major contributors in increasing levels of air pollution [11, 12]. The Health Effects Institute's recent annual status of the global air study ranked Nigeria fourth in the world, with 150 fatalities per 100,000 Nigerians, and first in Africa [13]. As a progressively urbanizing region, Jos-South is seeing an increase in human activity, which is expected to add to air pollution [14]. Despite the obvious risk of air quality deterioration in this region, there is a scarcity of empirical data on particulate matter levels and their consequences for public health and environmental sustainability [15]. This study is aimed at assessing particulate matter concentrations and air quality in selected areas of Jos-South LGA, Plateau State, Nigeria, with a view to evaluating the potential health implications to residents. The study will provide useful baseline data to policymakers raise public awareness and guide interventions to reduce air pollution and its health consequences.

MATERIAL AND METHODS

Description of the Study Area

Jos South Local Government Area (LGA), located between Latitude 9º 35'00"N and 9º 55'00"N and Longitude 8º 37'00"E and 9º 57'00"E (Figure 1), is one of the seventeen LGAs in Plateau State, located in the Northwestern part of the State. It is headquartered in Bukuru and is surrounded by Jos North, Jos East, Bassa, Riyom and Barkin Ladi LGAs [16]. The LGA comprises of four districts: Vwang, Du, Gyel and Kuru. It covers an area of 1,037 km² and experiences a mean annual temperature of 14°C to 27°C and annual rainfall of 1000 mm to 1650 mm [17].

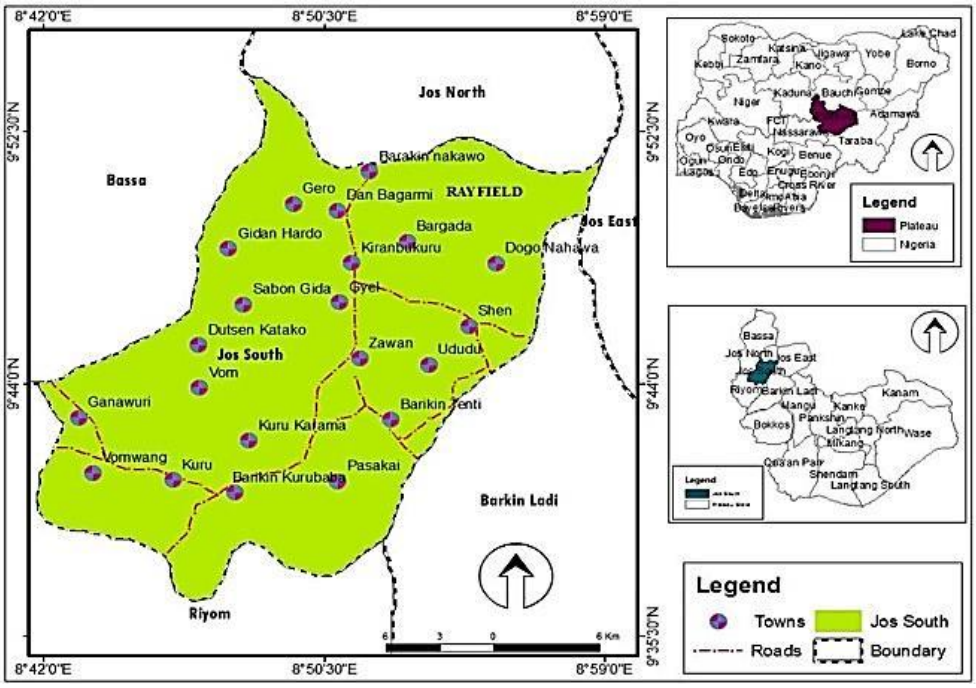

Figure 1: Map of Jos South Local Government Areas [14]

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Sampling and Samples Collection

The sampling locations were randomly selected within the Southern part of Jos. A total of six (6) sampling sites were selected to suit the purpose and objectives of this research, with one site serving as the control. These sites are both commercial and residential areas. In these areas or sites, there are full of activities that can cause high traffic flow except for the control (Kwang Boundary), where those activities are noticed to be low. The sampling sites include Old Airport Roundabout YG way, Zarmaganda-Rayfield Roundabout, Total Bukuru Roundabout, D.B Zang Roundabout, Old Airport Roundabout Anguldi, and Dilimi village (Kwang Boundary) as control. The research was carried out for a period of four months from March to June 2021 in the Jos-South areas. The areas were selected because they experienced daily high traffic density of vehicular movement.

Determination of the Particulate Matter ($PM_{2.5}$ and PM_{10}) Concentrations

A portable CW-HAT 200 dust particle counter was used to measure the concentrations of $PM_{2.5}$ and PM_{10} in the samples. The CW-HAT 200 was designed for real-time monitoring of $PM_{2.5}$ and PM_{10} in the range of 0-500 µg/m³ and has a detection sensitivity of 0.001 mg at every location. The CW-HAT 200 offers a user-friendly and efficient method for monitoring PM levels, making it a valuable tool for environmental assessments, air quality research, and public health studies [18, 19]. It operates using light-scattering technology, which measures the concentration and size distribution of airborne particles [20]. The device was turned on by pressing the power button and held for 3 seconds to allow it boot and get set for reading to be recorded. After initialization, the levels of $PM_{2.5}$ and PM_{10} were subsequently measured. The device was allowed to display automatically in each of the sampling locations. Each measurement took sixty seconds to ensure sample representation as close as possible to the average value of the surrounding air. The air quality was monitored during the morning and afternoon hours in each locations of the study area [18].

Determination of Air Quality Index (AQI)

The air quality index (AQI) was used for describing ambient air quality. The mean concentrations of $PM_{2.5}$ and PM_{10} were computed and compared with the World Health Organization guideline [21], where the annual mean for $PM_{2.5}$ is 10 µg/m³, while that of PM_{10} is 20 µg/m³. These mean values were used to calculate the air quality index (AQI). The indices for each pollutant (average of the total sum from each sampling location) were derived using the mathematical formula as shown in equation 1 [4].

$$AQI_{PM} = \frac{Observed\ Concentrations\ of\ PM}{WHO\ Standard} \text{ x } 100 \quad (1)$$

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Where AQI_{PM} is the air quality index of the particulate matter ($PM_{2.5}$ and PM_{10}), concentrations of PM are the analyzed concentrations of $PM_{2.5}$ and PM_{10} in µg/m³ and WHO standard is the World Health Organization's permissible concentrations of $PM_{2.5}$ and PM_{10} in µg/m³ [4]. The classifications of AQI based on air pollution level and level of health concerns are presented in Table 1.

Table 1: Classification of the Air Pollutants for the Air Quality Index (AQI) Value Ratings

AQI Value Rating (µg/m³)	Air Pollution Level	Level of Health Concern	Color of AQI Indicator
0 – 50	1	Good	Green
51-100	2	Moderate	Yellow
101 – 150	3	Unhealthy for sensitive groups	Orange
151 – 200	4	Unhealthy	Red
201-300	5	Very unhealthy	Purple
≥ 300	6	Hazardous	Maroon

Quality Control and Statistical Analysis

The CW-HAT 200 Dust Particle Counter device was properly cleaned and calibrated according to the manufacturer's instructions to guarantee accurate readings. The analyses were replicated ten (10) times and results obtained were expressed as mean ± standard deviation of ten replicates. The student t-test was used to establish a significant difference between the morning and afternoon PM monitoring periods.

RESULTS AND DISCUSSION

Levels of Particulate Matter ($PM_{2.5}$ and PM_{10})

The concentrations of $PM_{2.5}$ and PM_{10} in the analyzed samples from Jos-South LGA areas are presented in Tables 2 and 3.

Table 2: Concentrations of $PM_{2.5}$ in Jos South LGA

Sampling Locations	Concentration of $PM_{2.5}$ (mg/m³)	
	Morning	Afternoon
A	1.014 ± 0.569	0.009 ± 0.004
B	0.015 ± 0.007	0.006 ± 0.003
C	0.065 ± 0.047	0.055 ± 0.038
D	0.007 ± 0.062	0.012 ± 0.101
E	0.046 ± 0.003	0.010 ± 0.010
F	0.003 ± 0.001	0.010 ± 0.001

Values are Mean ± Standard Deviation (n = 10)
A = Old Airport Roundabout YG way, B = Zarmaganda-Rayfield Roundabout, C = Total Bukuru Roundabout, D = D.B Zang Roundabout, E = Old Airport Roundabout Anguldi, F = Dilimi village, Kwang Boundary (Control Site)

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Table 3: Concentrations of PM_{10} in Jos South LGA

Sampling Locations	Concentration of PM_{10} (mg/m^3)	
	Morning	Afternoon
A	0.039 ± 0.025	0.018 ± 0.008
B	0.032 ± 0.019	0.014 ± 0.008
C	0.015 ± 0.144	0.015 ± 0.207
D	0.015 ± 0.017	0.024 ± 0.028
E	0.012 ± 0.008	0.019 ± 0.014
F	0.002 ± 0.001	0.009 ± 0.002

Values are Mean ± Standard Deviation (n = 10)
A = Old Airport Roundabout YG way, B = Zarmaganda-Rayfield Roundabout, C = Total Bukuru Round about, D = D.B Zang Roundabout, E = Old Airport Roundabout Anguldi, F = Dilimi village, Kwang Boundary (Control Site)

The levels of $PM_{2.5}$ in Old Airport Roundabout YG Way, Zarmaganda-Rayfield Roundabout, Total Bukuru Roundabout, D.B. Zang Roundabout and Old Airport Roundabout Anguldi ranged from 0.445 to 1.583, 0.008 to 0.022, 0.018 to 0.112, 0.055 to 0.069 and 0.043 to 0.049 mg/m^3 respectively during the morning period. The highest level of $PM_{2.5}$ (1.014 mg/m^3) was recorded at Old Airport Roundabout YG Way, while the lowest concentration (0.007 mg/m^3) was observed at D.B. Zang Roundabout. The concentration of $PM_{2.5}$ in all the sampling locations except D.B. Zang Roundabout is above the World Health Organization's standard of 0.01 mg/m^3. This indicates high levels of $PM_{2.5}$ contamination and air quality deterioration in the area. In the afternoon, the concentrations varied from 0.005 to 0.013, 0.003 to 0.009, 0.017 to 0.093, 0.089 to 0.113 and 0.00 to 0.020 mg/m^3 at Old Airport Roundabout YG Way, Zarmaganda-Rayfield Roundabout, Total Bukuru Roundabout, D.B. Zang Roundabout and Old Airport Roundabout Anguldi respectively. The highest mean concentration of 0.055 mg/m^3 was obtained at Total Bukuru Roundabout, while the lowest (0.006 mg/m^3) was recorded at Zarmaganda-Rayfield Roundabout. Comparable highest mean value of 0.069 mg/m^3 was obtained by Abulude *et al*. [11], who assessed the levels of $PM_{2.5}$ in Lagos State, Nigeria. Except for Old Airport Roundabout YG Way and Zarmaganda-Rayfield Roundabout sampling sites, the concentration of $PM_{2.5}$ exceeded the World Health Organization's standard of 0.01 mg/m^3, which signifies high levels of $PM_{2.5}$ contamination. The concentration of $PM_{2.5}$ in the morning is generally higher than in the afternoon, except for the B Zang Roundabout, where it was lower in the morning. Statistically, however, there was no significant difference between $PM_{2.5}$ concentrations in the morning and afternoon. Cholianawati *et al*. [22] reported similar variations when they analyzed the $PM_{2.5}$ levels in Indonesia. The concentrations of $PM_{2.5}$ in Old Airport Roundabout constitute approximately 88 % of all the sampling locations. This is followed by Total Bukuru Roundabout (6 %), Total Bukuru Roundabout (4 %),while Zarmaganda-Rayfield Roundabout and D.B Zang Roundabout had lowest percentage contribution (approximately 1 %

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each). The concentrations of PM_{10} (mg/m³) in Old Airport Roundabout YG Way, Zarmaganda-Rayfield Roundabout, Total Bukuru Roundabout, D.B. Zang Roundabout and Old Airport Roundabout Anguldi ranged from 0.014 to 0.064, 0.013 to 0.051, 0.129 to 159, 0.002 to 0.032 and 0.004 to 0.02 respectively during the morning period. The highest concentration of PM_{10} (0.039 mg/m³) was recorded at Old Airport Roundabout YG Way, while the lowest concentration (0.012 mg/m³) was observed at Old Airport Roundabout Anguldi when compared with the control. In the afternoon, the concentrations varied from 0.01 to 0.026, 0.006 to 0.022, 0.192 to 0.222, 0.004 to 0.052 and 0.005 to 0.033 at Old Airport Roundabout YG Way, Zarmaganda-Rayfield Roundabout, Total Bukuru Roundabout, D.B. Zang Roundabout and Old Airport Roundabout Anguldi respectively. Abulude *et al*. [23] reported comparable results when they evaluated the concentrations of PM_{10} in Akure, South-West, Nigeria. The concentrations of PM_{10} in all the sampling locations during both morning and afternoon periods were above the World Health Organization's standard of 0.01 mg/m³. Similar PM_{10} concentrations above the WHO standard were also reported by Wambebe and Duan [4] when they assessed the PM_{10} around Abuja Metropolis, Nigeria. Based on this finding, the people, including residents, businessmen, and women, as well as the regular motorists residing around the study area are at higher risk of being exposed to PM_{10}-induced pollution, which is of significant health concern. The concentration of PM_{10} in the morning, contrary to $PM_{2.5}$, was lower than that of the afternoon, but the differences are not statistically significant as established by independent t-test ($p = 0.05$). The concentrations of PM_{10} in Total Bukuru Roundabout had the highest contribution, with approximately 60 % of the contributions. This is followed by D.B. Zang Roundabout (13 %), Old Airport Roundabout Anguldi (11 %), Old Airport Roundabout YG Way (10 %), while Zarmaganda-Rayfield Roundabout had the lowest contribution of 6 %.

Air Quality Index (AQI)

Air quality index of $PM_{2.5}$ and PM_{10} are usually computed by dividing the observed concentrations of $PM_{2.5}$ and PM_{10} (µg/m³) by World Health Organization (WHO) standard values (µg/m³). In this study, the AQI of $PM_{2.5}$ depicted in Table 5 ranged from the 2nd to the 6th levels of air pollution, which signifies moderate to potentially hazardous health effects. About 40 % of $PM_{2.5}$ analyzed had the potential to cause unhealthy and hazardous effects (Fig 2). This demonstrates that the study area is highly polluted by $PM_{2.5}$. Akinfolarin *et al*. [24] reported similar, significantly high $PM_{2.5}$ levels when they assessed particulate matter-based air quality index in Port Harcourt, Nigeria. The congestion of vehicle traffic observed at the entire selected roundabout and junctions were the major cause of air pollutants in the area due to the incomplete combustion of fossil fuels from the vehicles exhausts [25].

The AQI values of PM_{10} as presented in Table 6 varied from 2nd to 4th levels of air pollution. This demonstrates a moderate to unhealthy

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health concern. The study area is found to be moderately polluted with PM_{10} accounting for 70 % of moderate health concern (Figure 2), which suggests that PM_{10} has the potential to cause adverse health effects on the people around the study area.

Table 5: Air Quality Index (AQI) values of $PM_{2.5}$

Sampling Locations	Air Quality Index of $PM_{2.5}$	
	Morning	Afternoon
A	10140	90
B	150	60
C	650	550
D	70	120
E	460	100
F	30	100

Table 6: Air Quality Index (AQI) values of PM_{10}

Sampling Locations	Air Quality Index of PM_{10}	
	Morning	Afternoon
A	195	90
B	160	70
C	75	75
D	75	120
E	60	95
F	10	45

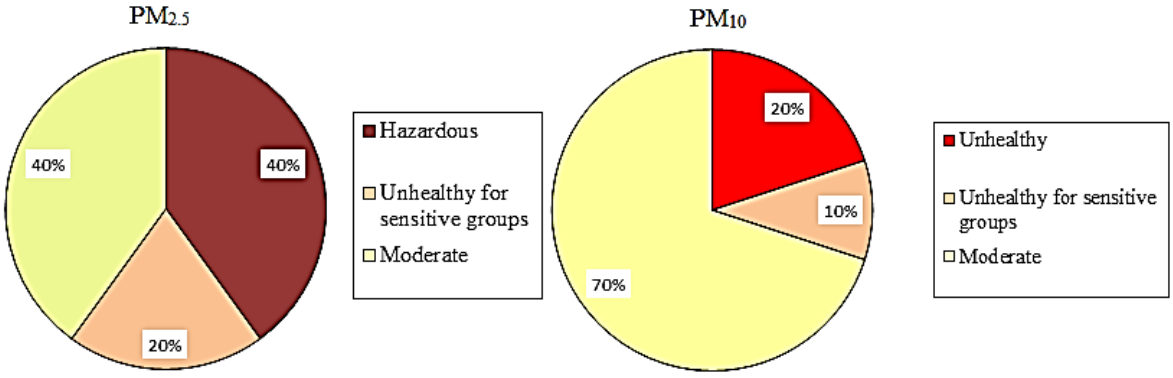

Figure 2: Percentage Contribution of $PM_{2.5}$ and PM_{10} to Human Health Concern

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Generally, $PM_{2.5}$ has the potential to cause more significant air pollution and adverse health effects than PM_{10}. This may be attributed to the smaller $PM_{2.5}$, which could pass through the human respiratory system easily than PM_{10} [4, 26].

CONCLUSION

The findings of this study revealed that the PM levels in the study area are generally higher than the acceptable standard, which demonstrates significant air quality deterioration. The PM contributes to high pollution levels and significant human health concerns, particularly the $PM_{2.5}$. Proper monitoring, assessments, and remediation strategies are therefore urgently needed in the study area to safeguard public health and the environment.

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