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AMBIENT AIR QUALITY ASSESSMENT FOR THREE CRITERIA AIR POLLUTANTS (NO_2, SO_2, AND PM_{10}) UNDER VARIOUS LAND USES IN GWAGWALADA, FCT

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ABSTRACT
Air pollution and its detrimental health impacts have become a major global environmental and health concern. The aim of this study is to assess air quality under different land uses and determine the variation in air quality between urban and rural areas of Gwagwalada Area Council, Federal Capital Territory (FCT). The concentrations of three criteria pollutants - nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and particulate matter (PM_{10}) were measured across four identified land uses - market, motor parks, residential and roadside in both urban and rural areas. The average concentration of ambient air pollutants from these different land uses were compared to the standard limits for outdoor concentration established by World Health Organization (WHO), United States Environmental Protection Agency (USEPA) and Federal Ministry of Environment (FMEnv). Among the criteria pollutants, NO_2 was not detected across the entire land use types in both urban and rural areas except for urban markets. Average SO_2 concentration across the different land uses for urban areas exceeded the limits of WHO and FMEnv. PM_{10} concentrations varied across land use types but were within the FMEnv and USEPA limits. PM_{10}, and SO_2 were the main pollutants in both urban and rural areas. The Analysis of Variance (ANOVA) result showed that there was no substantial difference in the average concentration of pollutants across urban and rural areas of Gwagwalada Area Council. The study concludes that air quality monitoring should be considered a priority for both urban and rural areas.

Keywords: ambient air quality, pollutants, land use, rural, urban

INTRODUCTION

Air pollution and its detrimental health impacts have become a major global environmental and health concern, and the mitigation of air pollution is a primary focus of policymakers. Many air pollutants are extremely detrimental to health. Rapid population growth, increase in vehicular traffic, urban expansion and the burning of solid biomass fuel are considered some of the main factors contributing to poor air quality in Africa (Amegah & Agyei-Mensah, 2017; Abera et al., 2021). Ambient air pollution is a major contributor to mortality and morbidity especially in vulnerable people such as children and the elderly. The World Health Organization (WHO) identified four pollutants for which there is strong evidence of health effects on humans: particulate matter (PM), ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) (WHO, 2006). In West Africa, air pollution was responsible for about 80,000 premature deaths in 2017 (Heft-Neal et al., 2018). The concentration of air pollutants and their magnitude vary across different areas and depend upon the types of industrial and other activities in the area. Land use patterns and changes can create tremendous stress on the local, regional and global environment (Xu et al., 2016; Yan et al., 2016)

The spatiotemporal and seasonal variations in air quality in response to various land uses have been the subject of numerous studies. These studies examined the spatial changes in air quality in rural and urban areas, as well as in business and residential areas, roads, and areas of human activities (Sahu & Gurjar, 2020; Kumar & Dash, 2018, Syafei et al., 2014). The effect of particulate matter on air quality has also been studied (Weli & Ayoade 2014), as it is especially harmful to human health. Some other studies assessed ambient air quality in a single land use such as abattoirs (Salama & Berekaa, 2016); sawmill industry (Adelagun et al., 2012); high traffic areas, agricultural zones and oil mills (Ohimain et al., 2013). The literature shows there are numerous studies on urban ambient air quality, but shortage of studies on air quality across varied land uses with diverse human activities taking place. This study seeks to address this gap using air quality assessment equipment and GIS technology to empirically compare air quality on different land uses in both urban and rural communities. The specific objectives are to identify the major urban and rural land uses in the study area, determine the ‘urban and rural variation in ambient air quality across the various land uses within both urban and rural areas, and produce interpolation map showing areas of poor air quality in the study area.

Study Area

Gwagwalada Area Council lies between latitude $08^0 55'$N and $09^0 15'$N and longitude $06^0 53'$E and $07^0 05'$E as shown in Figure 1. Gwagwalada township region has a total landmass of about 6,500 hectares. Gwagwalada Area Council consists of the older traditional and new planned sections (Balogun, 2001) encompassing the old and the pre-1976 section, and new section arising from the development of the Federal Capital Development in line with its planned role in the spatial development of the Federal Capital Territory (FCT).

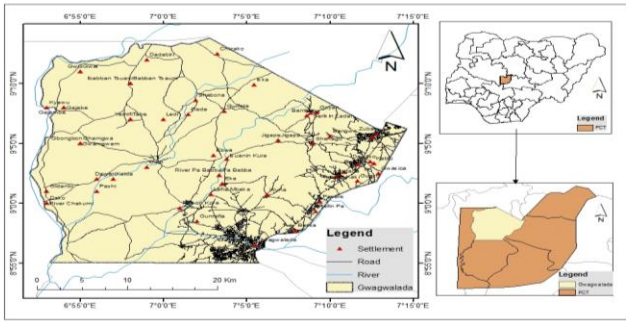

Figure 1: The Study Area
Source: Adapted from the administrative map of Abuja, 2019

MATERIALS AND METHODS

Data Collection

Data was first collected and collated in a reconnaissance survey and was used to delineate sampling points in each of the land uses. The land uses identified were: motor parks, markets, road sides, and residential. The geographic points of each sampling units were duly referenced. Primary data collected include data on diurnal variation in air pollutants (NO_2, SO_2, CO and PM_{10}) across rural and urban land uses (motor parks, markets, road sides, farmlands, and residential). The pollutant concentrations were randomly sampled at five sampling points each for the rural areas (Dobi village) and the urban area (Gwagwalada town). The instruments used were GasAlert for NO2 and SO2, and PM Meter for PM_{10}.The ambient air pollutant measurements were taken at a minimum of 1.5m height at noon time. Handheld GPS device was used to take the coordinates of every point where the device for monitoring pollutants was used. Table 1 shows the coordinates of the various land use in urban and rural areas.

Table 1: Sampling points

S/N	Land Use	Urban		Rural	
		Latitude	Longitude	Latitude	Longitude
I	Market	8°56'23.93"N	7° 4'39.35"E	9° 3'33.15"N	6°59'36.93"E
Ii	Motor Park	8°56'37.92"N	7° 4'50.64"E	9° 3'26.86"N	6°59'43.62"E
iii	Roadside	8°56'19.72"N	7° 5'25.83"E	9° 3'1.19"N	6°59'51.97"E
Iv	Residential	8°57'30.42"N	8°57'30.42"N	9° 3'40.95"N	6°59'47.24"E

Source: Authors' Fieldwork, 2019**.**

Data Analysis

The spatial variation in atmospheric pollutants concentration was evaluated by analyzing the actively sampled pollution data from the different land uses. Both descriptive and inferential statistical tools were used to give meaningful explanations to the data obtained from the processes explained above. The descriptive statistics involved graphs, while the inferential statistics involved the use of Analysis of Variance for comparing group mean of pollutant between the different land use types. For the spatial interpolation, the measurement of the pollutants were taken as attributes and collated on an excel worksheet, and then converted into Comma Separated Values (CSV). They were then imported in to a GIS environment using the ARCGIS software (10.5) and interpolated. The inverse distance weight (IDW) model within the ArcGIS spatial analysis module (Version 10.5) was used to interpolate the air pollutants mapping. The pollutant data were further subjected to the Air Quality Index Rating.

Assessment of Pollution Index

The Air Quality Index (AQI) is an index for reporting daily air quality (Tan et al., 2021). It tells how clean or unhealthy the air is, and what associated health effects might be a concern. The AQI converts different air pollutants concentrations to a single number of an area. This AQI is divided into six categories indicating increasing levels of health concern. The results from the AQI computation are further subjected to the air quality-rating table to determine the condition of the air as presented in Table 2. The AQI is based on the five "criteria" pollutants - PM, carbon monoxide, sulphur dioxide, and nitrogen dioxide and ozone. Ambient air quality standards are presented in Table 3.

Table 2: Air Quality Rating Table

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Source: USEPA, 2017

Table 3: Ambient Air Quality Standards for the Selected Pollutants

Pollutants	Time of Average	Nigeria standard	USEPA standard	WHO Guideline
Particulates PM 5 PM10	Daily average of daily values 1 hour.	250 μg/m³ *600 μg/m³	150 μg/m³	50 μg/m³
Sulphur oxides (Sulphur dioxide)	Daily average of hourly values 1 hour	0.01 ppm (26 μg/m³ 0.1 ppm (26 μg/m³	0.5ppm 0.075ppm	20 μg/m³
Nitrogen oxides (Nitrogen dioxide)	Daily average of hourly values (range)	0.04 ppm- 0.06 ppm (75.0 μg/m³- 113 μg/m³)	0.053ppm	0.02 μg/m³

Source: Adapted from USEPA, 2017

i. **Good -** AQI (0-50), satisfactory air with little or no health risk.
ii. **Moderate -** AQI (51-100), acceptable air with moderate health concern for a very small number of individuals while people who are unusually sensitive to ozone or particle pollution may experience respiratory symptoms.
iii. **Unhealthy for Sensitive Groups -** AQI (101-150), members of sensitive groups may experience health effects but the general public is unlikely to be affected.
iv. **Unhealthy - e**veryone may begin to experience health effects, AQI (151-200). Members of sensitive groups may experience more serious health effects.
v. **Very Unhealthy –** AQI (201-300), triggers a health alert, meaning everyone may experience more serious health effects.
vi. **Hazardous -** AQI (>300), triggers health warnings of emergency conditions. The entire population is even more likely to be affected by serious health effects.

RESULTS AND DISCUSSION

Concentration of Pollutants

Ambient concentrations of Sulphur Dioxide, Nitrogen Dioxide, and Particulate Matter were recorded from five locations across Gwagwalada Town and Dobi Village, which constitutes the urban and rural areas respectively. The results for ambient concentrations of the pollutants are presented in graphical format.

Nitrogen Dioxide (NO_2)

The average concentrations of nitrogen dioxide across the different land-use backgrounds in both urban and rural areas are presented in Figure 2.

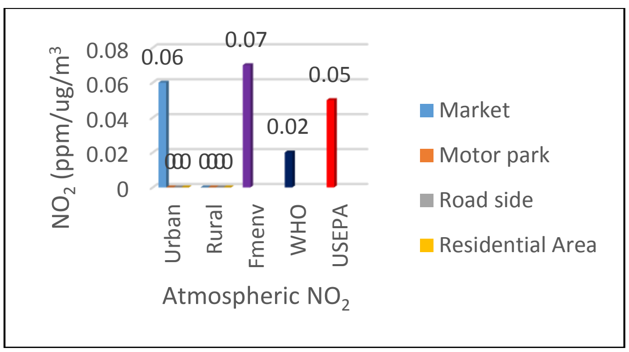

Figure 2: Average concentration of NO_2 in urban and rural land use
Source: Authors Analysis, 2019.

Surprisingly, the ambient concentration of NO_2 across the different land-use backgrounds in urban and rural areas were not detected and thus, are all within the standard limits of atmospheric NO_2 concentration recommended by WHO, USEPA and FMevn. The only exception was the market centre in urban area, where NO_2 concentration of 0.06 ± 0.08ppm was recorded. This value falls above the standard limit set by WHO (0.02ppm) and the USEPA (0.05pmm), however, it is within the limits for outdoor concentration of NO_2 set by Federal Ministry of Environment. The result of this study implies that in general, the complex environment of market centres encompasses activities such as buying and selling to burning of accumulated waste from unwanted products and roasting of animals within the market confinement. Motor and motorcycle parks within the market centres are also sources of the release of NO_2. However it is surprising that it was not detected at all by the roadside and motor park, where there is a concentration of vehicles. A study by Njee et al., (2016) also found where NO_2 to be within the recommenmded standard across urban background in Dar es Salaam city of Tanzania.

Nitrogen Dioxide (NO_2) Inverse Distance Weight (IDW).

Figures 3 and 4 show urban and rural area nitrogen dioxide Inverse Distance Weight (IDW). The spatial air pollutants mapping clearly showed the dispersion of nitrogen dioxide pollutants in the urban area (Figure 3) which is higher by the roadside, market and motor parks with value of nitrogen dioxide ranging between 0.054 - 019998 (ppm/μg/m^3) and 0.0385-0.0544 (ppm/μg/m^3). The lowest concentration of nitrogen dioxide is dominant around the residential areas and urban fringes with values of 0.0 - 0.0223 (ppm/μg/m^3). The rural area (Figure 8) depicts no concentration of nitrogen dioxide.

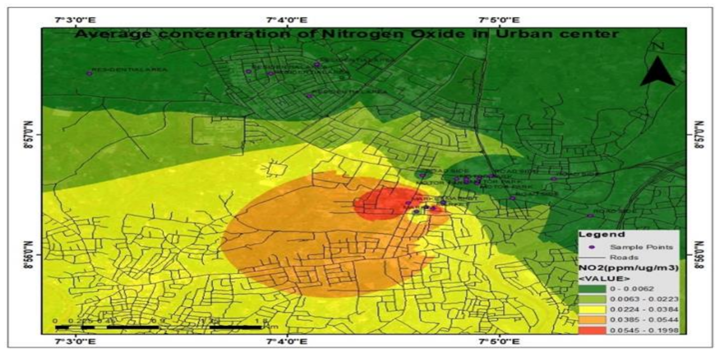

Figure 3: Average urban concentration of NO_2
Source: Authors Analysis, 2019

Figure 4: Average rural concentration of NO2
Source: Authors Analysis, 2019

Sulphur Dioxide (SO_2)

The average concentration of SO2 across the different land-use varies considerably in both urban and rural areas as presented in Figure 5.

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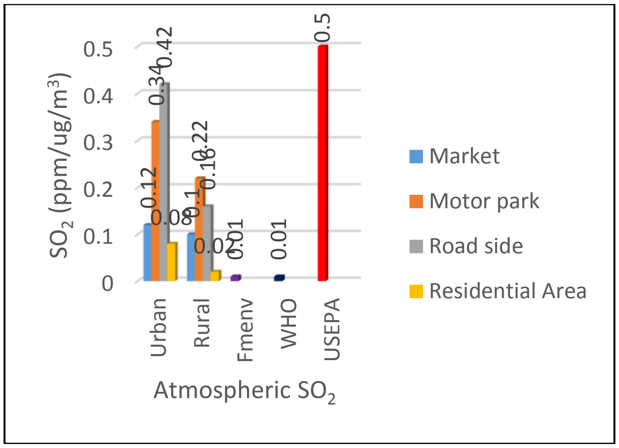

Figure 5: Average concentration of Sulphur dioxide in urban and rural land use
Source: Authors Analysis, 2019**.**

Daily human activities in different land use areas (market, motor parks, road side and residential) are the point sources of SO_2 emission in both urban and rural with motor parks and road sides are main point sources of SO_2 sources of emission. This result is in consonance with the findings of Mohammed et al., (2013), where SO_2 was detected in some selected traffic areas of Kaduna metropolis. The concentrations exceeded the FMEnv and WHO permissible limits but fall within the USEPA standards for criteria pollutants.

Sulphur Dioxide (SO_2) Inverse Distance Weight (IDW).
The IDW of SO_2 is shown in Figure 6 and 7 respectively. The spatial SO_2 mapping showed the concentration of SO_2 pollutants in the urban area is higher by the roadside, motor parks and market while the highest concentration of SO_2 in the rural area is in areas dominated with economic activities (roadsides, motor parks and markets). The lowest concentration of SO_2 is around the well planned residential areas and urban fringes. It is obvious that the concentration of SO_2 is relatively higher in the urban area.

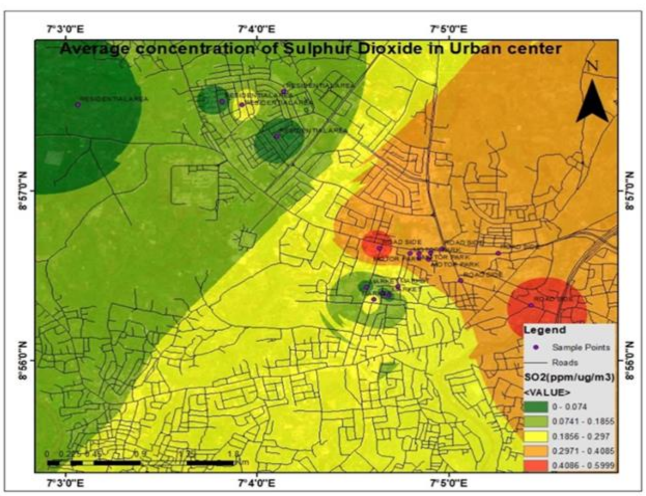

Figure 6: Average Urban concentration of SO2
Source: Authors Analysis, 2019

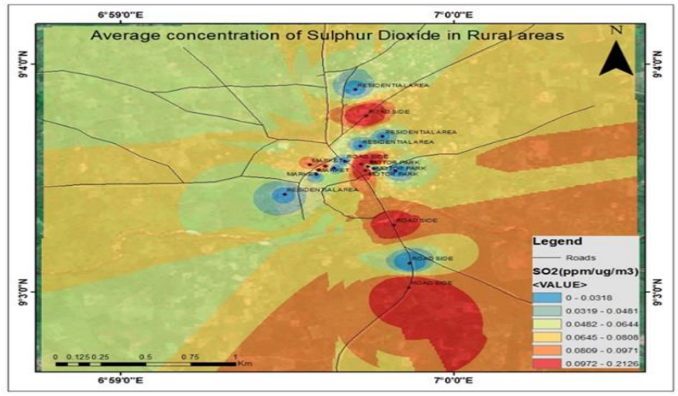

Figure 7: Average rural concentration of SO2
Source: Author Analysis, 2019

Particulate Matter (PM_{10})
Particulate matter is one of the most dangerous air pollutants. The average concentration of PM_{10} across the different urban and rural land uses is presented in Figure 8.

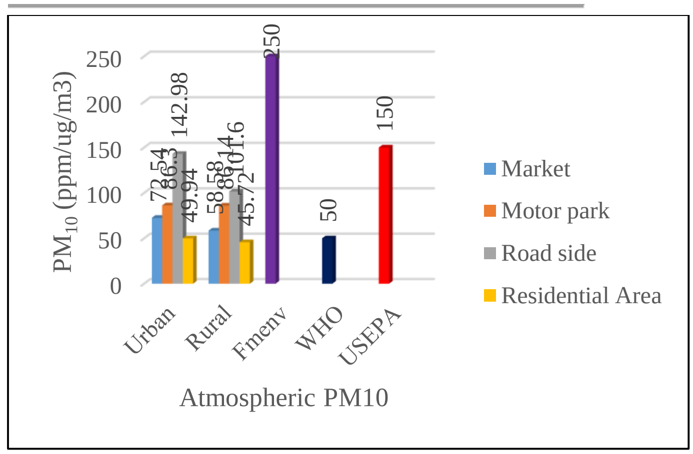

Figure 8: Average concentration of particulate matter in urban and rural land use
Source: Source: Author Analysis, 2019

Average concentration of PM_{10} varies across land use type in both rural and urban areas respectively. The result shows that roadsides have the highest mean concentration of PM_{10} in both urban and rural areas which could be predetermined by vehicular/motorcycle emmision. The result was in consonance with the permissible limit for outdoor concentration of PM_{10} established by FMEnv and USEPA in all land use areas in both urban and rural background. With the exception of residential areas, all land use types in both urban and rural areas have high concentrations of PM_{10} above the WHO standards. This result corresponds with Enotoriuwaet al. (2016) in Rivers State and Zheng et al., (2017) in China, where PM_{10} concentrastion was found vary across different urban areas.

Particulate Matter IDW
Figures 9 & 10 show the IDW of PM_{10} in urban and rural areas. The spatial mapping shows that the concentration of the pollutant in the

urban area is higher along the Gwagwalada-Giri highway where road construction and rehabilitation was going on at the time of the study, while the highest concentration of particulate matter was mostly around abandoned road construction project sites. The lowest concentration of PM_{10} was found in green areas. The figures show that the concentration of particulate matter was relatively different in urban and rural area.

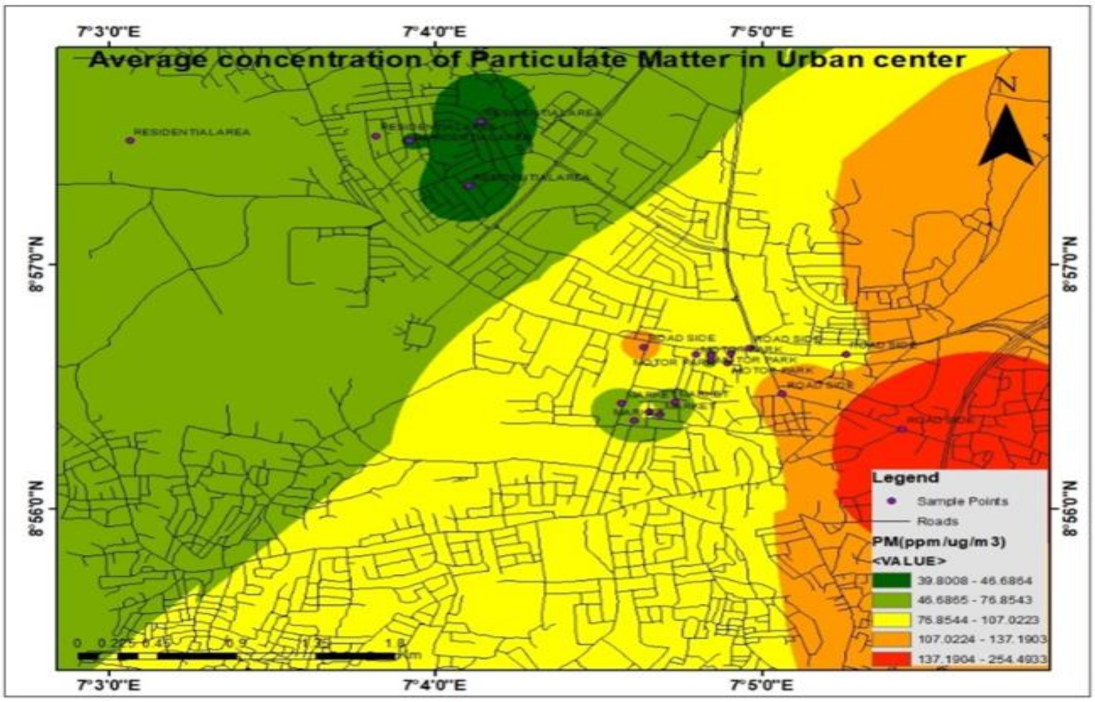

Figure 9: Average Concentration of Particulate Matter in Urban Area
Source: Author Analysis, 2019

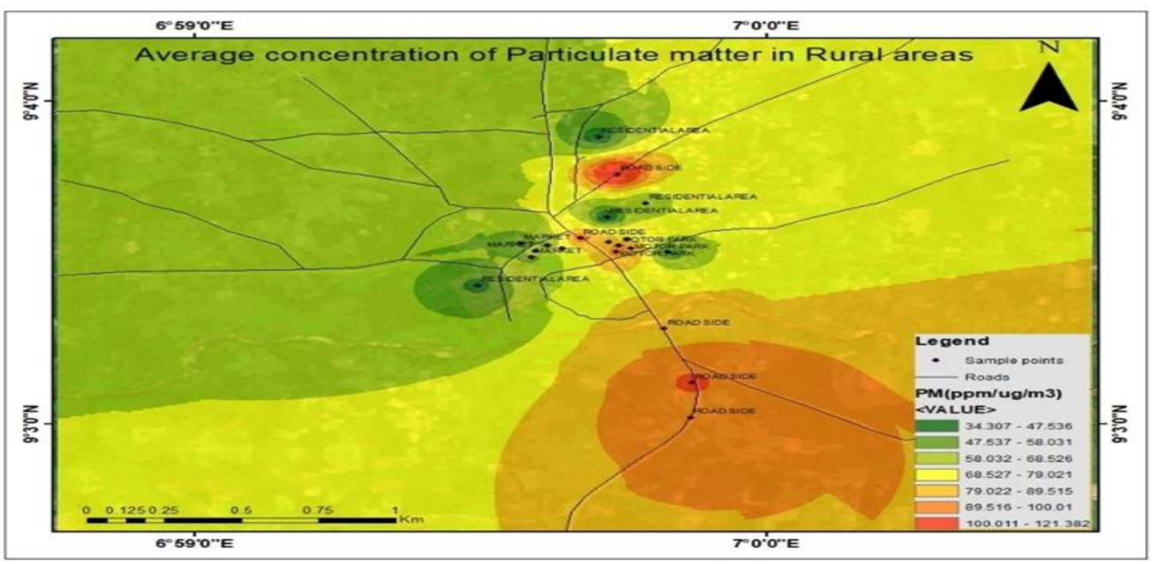

Figure 10: Average Concentration of Particulate Matter in Rural Area
Source: Author Analysis, 2019

Air Quality Index

Using the USEPA index for calculating Air Quality Index (AQI), the average concentration of the three criteria pollutants (NO_2, SO_2 PM10) were converted into the air quality index. The AQI and rating for the three pollutants is presented in table 4 and table 5 respectively.

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Table 4: Air Quality Index of Pollutants urban area

Location	NO_2	AQI	SO_2	AQI	PM	AQI
Market	0.06	300	0.12	1200	72.5	145.1
Motor Park	0.0	0	0.34	3400	86.3	172.6
Roadside	0.0	0	0.42	4200	142.9	286
Residential	0.0	0	0.08	800	49.94	99.9

Source: Author Analysis, 2019

Table 5: Air Quality Index of Pollutants in rural area

Location	NO_2	AQI	SO_2	AQI	PM	AQI
Market	0.0	0	0.1	1000	58.58	118.2
Motor Park	0.0	0	0.22	2200	86.14	172.3
Roadside	0.0	0	0.16	1600	101.6	203.2
Residential	0.0	0	0.22	2200	45.72	91.4

Source: Author Analysis, 2019

Table 6: Air Quality Index Interpretation Keys

Good	Moderate	Unhealthy for sensitive group	Unhealthy	Very unhealthy	Hazardous
0-50	51-100	101-150	151-200	201-300	301-500

Air quality index rating as presented in Tables 5 and 6 was calculated based on the WHO standard for the concentrations of atmospheric pollutants. The AQI for NO_2 are within the rating of good for all land use type in both rural and urban areas, with the exception of market center in the urban environment with a rating of very unhealthy. For SO_2, the concentration rating was hazardous in all land use types in urban and rural areas. In accordance with the index rating, SO_2 is expected to pose high health risk in all land use types in both urban and rural areas of Gwagwalada, while for NO_2; risk is only expected in market center in urban areas. The AQI for PM_{10} shows that with the exception of residential areas, all other land use type have a high concentration of PM_{10}.
Results of the AQI depict poor air quality in the study area, with considerable atmospheric air pollutants far above standards or human health. Major pollutants of concern include SO_2, and PM_{10}. Both SO_2 and PM_{10} were found to be the chief air pollutants in both urban and rural areas in Gwagwalada Area Council. Human health is expected to be affected by these pollutants across the different land use types in both rural and urban areas as indicated by the AQI. This is in line with the research of Enotoriuwa et al., (2016), where PM were found to be above the standard of WHO across hospitals, roads, markets in Obigbo urban area of Rivers state. Similarly, findings of the current study correspond with the study of Ola et al. (2013) where there were unhealthy levels of CO, H_2S and PM as compared to AQI in Jos Metropolis.

Test of Hypothesis

The hypothesis of the study was that level of air pollutants does not vary significantly across different land uses in both urban and rural area, and this was tested. The three pollutants were measured in the same scale unit and the hypothesis was tested for each of the pollutants across the different urban and rural land-uses using two-way ANOVA to examine the significant differences in their mean score. Results of the analysis as well as their significance are presented in Table 7.
Decision rule**:** null hypothesis is rejected where the P value is $\leq$ 0.05.

Table 7: Two-way analysis of Variance (Anova)

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Sample	84.64141	1	84.64141	0.069883	0.792864	4.084746
Between	1058.627	3	352.8755	0.291348	0.831382	2.838745
Within	48447.27	40	1211.182	0.027626	0.993706	2.838745
Interaction	100.3786	3	33.45954			
Total	49690.92	47				

Source: Author Analysis, 2019

The analysis shows that with p-value (0.83), df (3) and F-critical (2.84), there is no substantial difference in the average concentration of pollutants across urban and rural areas of Gwagwalada as depicted by the between groups. Likewise, the within group also depict no significant difference in the pollutant across land uses in both urban and rural areas of Gwagwalada (p-value '0.99,' df '40,' f-critical '2.84').

Conclusion and Recommendations

The findings of the study reveal that there is no considerable

difference in air quality between the urban and rural locations, and variations in air quality are mainly determined by the land use. The low concentrations of NO_2 in motor parks and roadsides is also worthy of note, and requires further investigation.
Among the various land uses, the residential areas have the lowest concentration of air pollutants, and this is to be expected as most are devoid of commercial activities and heavy vehicular movement. The non-detection of NO_2 in the roadside and motor park is worthy of note and calls for further study, as this could be an anomaly. There is a higher concentration of SO_2 and PM_{10} in the motor parks and roadside, and this could be attributed to vehicular traffic, and also commercial activities which necessitate the burning of solid fuels, such as street food preparation in these areas.
Based on the air quality findings, the following are recommended. Firstly, cleaner energy sources must be considered a priority to replace the use of solid biomass such as wood and charcoal, as they emit large amounts of criteria pollutants such as CO, SO_2 and PM. Secondly, the road network at the hinterland of Gwagwalada should not only be expanded to allow free movement of vehicles most importantly during traffic peak periods, but effort should be made to rehabilitate the road to forestall cases of traffic gridlock, which is a major factor in poor air quality. Finally, air quality monitoring should be considered an important part of safeguarding public health in both rural and urban areas.

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