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AIR POLLUTION LOAD ASSESSMENT IN THE RESIDENTIAL LAND-USE TYPES IN ASABA, DELTA STATE, NIGERIA

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Abstract

Air pollution continues to be a challenge in the world and the consequences of it are more in developing countries, due to the use of fossil fuels, generators, bad domestic fuel sources and infrequent pollution monitoring. This study investigated the pollutant load across different residential areas in Asaba, Delta State, Nigeria. A longitudinal research design was deployed for the study. Multi-gas detectors were used to collect pollutant readings at a height of 4 feet above ground level across the study area. The data was collected daily for 12 months from January to December 2023. The stated hypothesis "there is no significant spatial variation in atmospheric pollutants in Asaba", was tested using the Analysis of Variance (ANOVA). The study found that the pollutants increased from the low-density to the high-density areas. There was also a seasonal difference in pollutants amount across the residential areas. The computations of ANOVA models showed that there were statistically significant differences in the means of CO ppm P<0.05 (F=12.3123, sig = 0.00); NO2 P<0.05(F=15.1223, sig=0.03); O3 P<0.05(F=10.1021, sig = 0.05); PM2.5 P<0.05 (F=10.5231, sig = 0.04) and PM10 P<0.05 (F=6.4331 sig = 0.05). However, there was no significant difference in SO2 P>0.05(F=1.3001, sig = 0.10) in the residential areas. Investment in renewable energy and planting of trees and green spaces were among the recommendations of the study.

Keywords: Air pollution, Load assessment, Particulate matter, Residential land use

INTRODUCTION

Air pollution is a pervasive environmental matter that affects human health, ecosystems, and the climate (Manisalidis et al., 2020). Urbanization, industrialization, and increased vehicular traffic are the primary drivers of air pollution, especially in residential areas (Maji et al., 2023). Assessing air pollution across different residential density types - high, medium, and low - is critical to understanding the distribution and impact of pollutants, which is essential for developing effective mitigation strategies (Lu et al., 2021). Generally, air pollution refers to the presence of harmful substances (gases) in the atmosphere, which emanate from either natural sources, anthropogenic activities or both (Ukaogo et al., 2020). Pollutants such as particulate matter (PM 2.5 or 10), sulfur dioxide (SO_2), and carbon monoxide (CO) can cause many health problems, from respiratory and cardiovascular diseases to cancers of diverse dimensions, and can also lead to environmental issues such as acid rain, eutrophication, and global warming (Singh & Kumar, 2022).

There have been strong links between landuse type (functions) and the pollutant loads prevalence (Zhang et al., 2021). Residential areas can be classified based on population density or the structure of the city, into high, medium, and low density (Angel et al., 2021). Each type of land use has distinct characteristics that influence the levels and sources of air pollution (Liang & Gong, 2020). The sources of air pollution vary across high, medium, and low-density residential areas, impacting the type and concentration of pollutants (Ozabor & Obaro, 2016). In high-density areas, the significant number of vehicles leads to elevated levels of CO and PM from exhaust emissions and tyre wear amongst other activities (such as construction and road repairs) (Harrison et al., 2021). Additionally, closeness to industrial zones contributes to SO_2, VOCs, and heavy metals in the atmosphere of high-density residential environments (Ahmed et al., 2021). Also, using fossil fuels for various activities increases emissions of PM and CO (Echendu et al., 2020). In medium-density residential areas, pollution comes from mixed sources (Yang et al., 2020), so pollution can happen from either transportation, or residential activities (cooking, generating sets, etc), and these sources are similar to pollutant sources in high-density areas. However, studies adduce that pollution rates in medium-density areas are generally lower than in high-density areas. Light industrial and commercial activities contribute to VOCs and PM (Liang & Gong, 2020; Gan et al., 2020). Also, suburban traffic volumes arising from increased use of private vehicles lead to higher per capita emissions of NOx and CO (Böhm et al., 2022). In low-density areas, agricultural activities release ammonia (NH_3), which can contribute to secondary PM formation (Tang et al., 2021). Also, using wood and other biomass for cooking leads to emissions of PM and CO in the atmosphere (Godspower et al., 2023). Pollutants from urban areas can be transported to low-density residential areas and impact air quality (Angelevska et al., 2021).

Health effects arising from air pollutants (pollution) have been documented in the literature (Brumberg et al., 2021; Tainio et al., 2021). Short-term exposure to air pollution can cause respiratory symptoms, asthma exacerbation, and cardiovascular problems (Tiotiu et al., 2020), while long-term exposure is linked to chronic respiratory diseases, lung cancer, and reduced life expectancy (Sierra-Vargas et al., 2023). Children, the elderly, and those with pre-existing health conditions are particularly vulnerable (Tran et al., 2023). PM (2.5 and 10) can penetrate deep into the respiratory tract, causing inflammation, exacerbating asthma, and contributing to cardiovascular diseases. Nitrogen Oxides (NOx) can irritate the airways, reduce lung function, and increase susceptibility to respiratory infections. It also contributes to the formation of ground-level ozone, a harmful pollutant (Ćurić et al., 2022). Additionally, Sulfur Dioxide (SO2) has been noted to particularly cause respiratory problems, especially in people with asthma, and can form fine particulate matter (sulfates), which have additional health effects and could even lead to dizziness or death (Grzywa-Celińska et al., 2020). Carbon Monoxide (CO) impairs oxygen delivery in the body, leading to cardiovascular and neurological effects, especially in individuals with existing heart conditions (Kleinman, 2020).

Beyond health, air pollution has significant environmental and economic consequences (Ozabor & Nwagbara, 2018). Acid rain can damage forests, soils, and aquatic ecosystems. Also, air pollutants can harm wildlife, reduce biodiversity, and affect crop yields. Certain pollutants, such as black carbon (a component of PM) and ozone, have warming effects, contributing to global climate change (Sharma & Mishra, 2022). There are economic consequences that cascade from air pollution as well. Increased incidence of diseases due to air pollution leads to higher healthcare costs both for the government and individuals (Liao et al., 2021). Health problems related to air pollution can result in lost workdays and reduced productivity (Wang et al., 2022). Pollution can reduce crop yields and affect food security (Guo et al., 2020) a crisis which Nigeria currently faces.

Understanding the spatial and temporal distribution of air pollution in different residential density areas is essential for several reasons (Fan et al., 2020). Identifying pollution hotspots enables targeted measures to reduce emissions and protect public health and awareness (Filippelli et al., 2020). Additionally, data-driven insights support the formulation of effective air quality regulations and urban planning strategies (Bibri & Krogstie, 2020). Detailed assessments help quantify the health risks associated with exposure to different pollutants, guiding healthcare responses and preventive measures (Hassan Bhat et al., 2021).

In the Asaba region, many activities could lead to air pollution. These activities range from construction (building, roads and factory fabrication work), generators, and vehicular emissions, to cooking fuels. Measuring pollution in the region is a bit convoluted due, in part, to the interwoven nature of the land uses (Zheng et al., 2021). And so, there is a thin line of distinction between the land uses, and by implication the pollution rates that exist inherently. This means that there is a continuous need to investigate the pollution rates in the different land uses, to enlighten the policymakers of the dangers ahead for locals. However, despite extensive research on urban air pollution, significant gaps remain in understanding the differential impacts of air pollution across high, medium, and low-density residential areas, especially, in complexly knit areas (Yu et al., 2022). Existing studies often focus on high-density urban centres, neglecting the unique pollution dynamics in medium, and low-density, areas (Badach et al., 2023). Moreover, there is a lack of comprehensive, comparative studies that integrate temporal variations and seasonal differentials in the residential land uses. This gap limits the development of targeted mitigation strategies and hinders effective policy formulation to address air quality issues in Asaba.

MATERIALS AND METHODS

This study was carried out in Asaba, which is the capital city of Delta State. Asaba is located on Latitudes 6° 09ˈ 35ˈˈN to 6° 13ˈ 48ˈˈN and longitude 6° 40ˈ 56ˈˈE to 6° 44ˈ 17ˈˈE (Ozabor & Ajukwu, 2023) as shown in Figure 1. The area is a nodal town that connects the eastern and western states of the country, Nigeria. This makes vehicular emissions very high due to the volume of vehicular traffic that traverses the area daily (Ojiako et al., 2018). That status makes that area attract a pool of social and economic activities. These activities are sometimes done without any environmental precautions (Ozabor & Ajukwu, 2023).

Consequently, these activities led to environmental pollution. To put in proper perspective the economic activities mostly carried out in the area include but are not limited to, transportation business, banking, trade and services, printing and general fabrications. There are also block moulding and other construction activities in the area. Albeit, the area receives about 6 hours of power supply daily; which mostly comes at night. Therefore, during the day, businesses; both small and medium scales, rely heavily on the use of generators. These generators are scarcely environmentally friendly. Thus increasing the pollutants in the environment (Rahman et al., 2022).

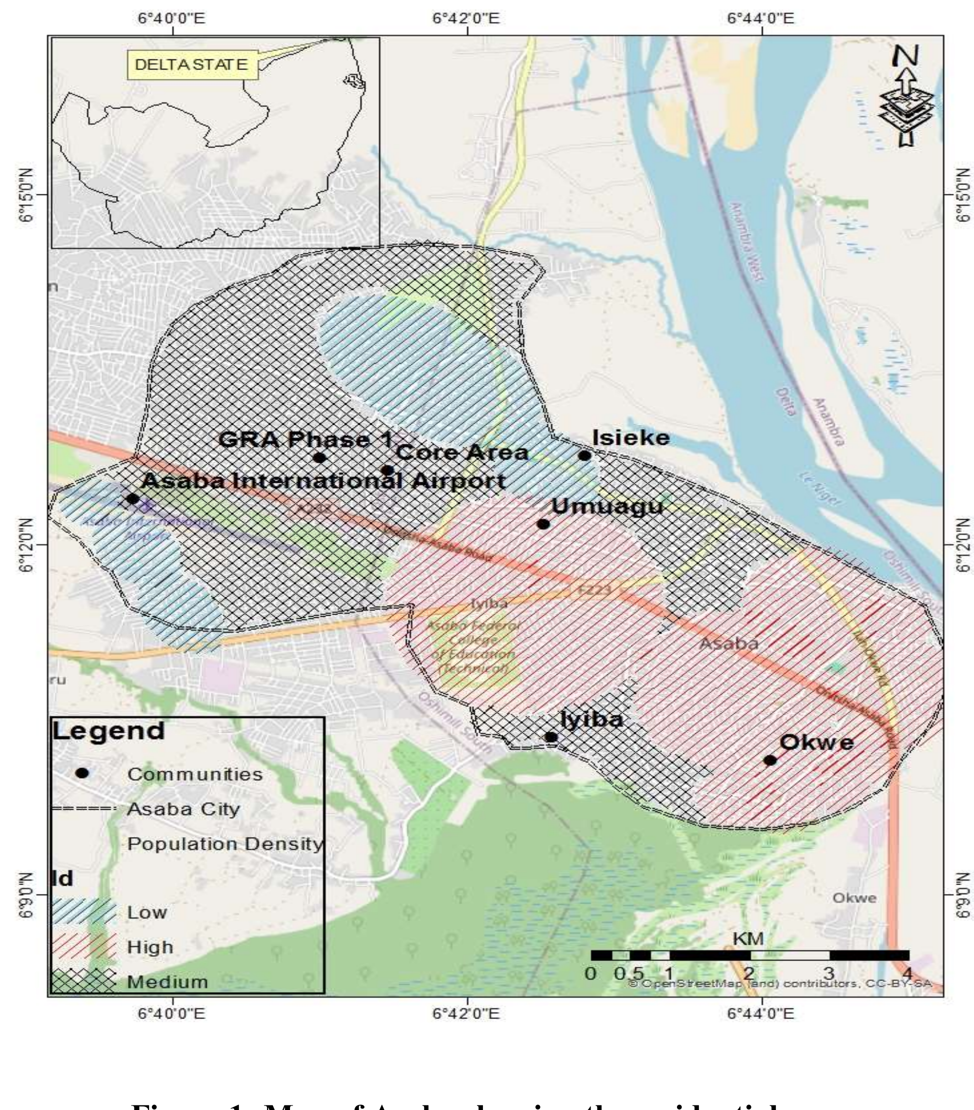

Figure 1: Map of Asaba showing the residential areas

Source: Adapted from Ozabor and Ajukwu (2023)

High-Density Residential Areas hereafter referred to as HDRA, are typically urban centres with high population densities, characterized by tall buildings, heavy traffic, and significant commercial activities. The concentration of people and activities leads to high emissions of pollutants, primarily from vehicles, industrial activities, and residential heating (Ribeiro et al., 2021). In Asaba, the HDRA are Ezenei, Okwe, and Nnebuisi. The Medium-Density Residential Areas hereafter referred to as MDRA are suburban areas with moderate population densities and a mix of residential, commercial, and light industrial activities (Conteddu et al., 2023). Pollution levels in these areas are influenced by both urban and suburban sources, including transportation, domestic fuel use, and nearby industrial emissions. The MDRA in Asaba includes Cable, Urhobo Camp, Federal College of Education, Direct Labour Road (DLA), Federal Medical Centre (FMC) and Summit. The Low-Density Residential Areas hereafter referred to as LDRA are often rural or peri-urban areas with low population densities, characterized by dispersed housing, limited commercial activities, and significant green spaces (Wolff et al., 2021). Pollution levels are generally lower but can still be affected by specific local sources, such as agriculture, and by long-range transport of pollutants from urban areas (Bodor et al., 2020). In Asaba, Umuonaje, Asaba International Airport Area, and Government Reservation Area (GRA) Phase 1, all fall within the LDRA.

The study deployed the longitudinal research design. Multi-gas detector (Sensit® Ramp) (Liu et al., 2020), was placed fitted to a platform of 4 feet above ground level across the study area. This was done to eliminate any biases from the data. The data was collected daily, and for 12 months (January-December, 2023). This is because the researchers intended to show the seasonal variation in the pollutant load over the area (Weli & Famous, 2018). A description of the machine is presented below. The Sensit® Ramp is a wide-ranging air quality monitoring instrument used for monitoring and management of air quality at affordable costs. Additionally, it can monitor multiple gases and pollutants cum particulate matter simultaneously (see Plate 1).

Plate 1: The SENSIT ® RAMP multi gas detector

Source: Bonilla et al. (2023)

The machine weighs about 3.4kgs which makes it easy to mount on platforms for air quality monitoring. The machine is rechargeable and has a backup battery which can last up to 3-15 days depending on the usage and the age of the battery. The operational temperature of the machine ranges from -20°C to 50°C. The data collected is logged and can be extracted using a USB adapter or card. This makes data collection less stressful. More details of the machine's detection methods and accuracy standards are presented in Table 1.

Table 1: SENSIT® RAMP machine detection methods and accuracy standards

Sensors	CO	NO_2	O_3	SO_2	$PM_{2.5}$	PM_{10}
Detection method	Electrochemical	Electrochemical	Electrochemical	Electrochemical	Laser Scattering	Laser Scattering
Range (standard)	20ppb-25ppm	20ppb-25ppm	20ppb-25ppm	20ppb-25ppm	1-1000 µg/m3	1-1000 µg/m3
Accuracy (standard)	±20ppb min or 50%	±20ppb min or 50%	±20ppb min or 50%	±20ppb min or 50%	± 10 µg min or 50%	± 10 µg min or 50%
Response time (standard)	60-90 sec	60-90 sec	60-90 sec	60-90 sec	12-30 sec	12-30 sec
Range (high)	1-l000ppm	1-l000ppm	1-l000ppm	1-l000ppm	1-1000 µg/m3	1-1000 µg/m3
Accuracy (high)	±2 ppm min or 10%	±2 ppm min or 10%	±2 ppm min or 10%	±2 ppm min or 10%	± 10 µg min or 50%	± 10 µg min or 50%
Response time (high)	30 sec	< 30 sec	< 30 sec	< 30 sec	15-30 sec	15-30 sec

When the data had been collected, they were presented in tables and statistical diagrams. The hypothesis - there is no significant spatial variation in atmospheric pollutants in Asaba, was tested using the Analysis of Variance (ANOVA). The researchers deployed ANOVA because of the technique's ability to decipher the variation in the means of three or more independent samples (Bolt et al., 2021; Weli et al., 2017). The analysis was done in a statistical package for the social sciences (IBM/SPSS, version 25).

RESULTS

The mean air pollutants load of Asaba is presented in Table 2. The data from Table 2 showed variations in the monthly distribution of CO, NO_2, O_3, SO_3 $PM_{2.5}$ and PM_{10}. September recorded a very high concentration of O_3 (204.2ppm). September is the peak of the rainy season in Asaba when rainfall is very frequent, intense, and with high relative humidity, due to evapotranspiration from the urban ecology. The case is different for NO_2 in which the month of January recorded 207.2ppm. January is a dry month (dry season) in Asaba. It is the period where the tropical continental air mass prevails in dusty environments and increases the retention of $PM_{2.5}$ and PM_{10} in the atmosphere.

Table 2: Mean monthly distribution of pollutants across Asaba

Months	CO (PPM)	NO_2 (PPM)	O_3 (PPM)	SO_2 (PPM)	$PM_{2.5}$ (µg/m3)	PM_{10} (µg/m3)
	Air pollutants					
January	263.4	207.3	187.3	0.1	113.9	121.9
February	237.4	206.3	186.2	0.1	108.2	116.2
March	208.1	218.1	182.0	0.2	107.1	115.1
April	174.4	168.4	167.2	0.1	94.8	102.8
May	179.1	178.9	188.2	0.1	107.8	115.8
June	189.5	91.3	199.2	0.3	76.8	84.8
July	207.3	83.2	203.8	0.1	75.2	83.2
August	202.4	81.3	201.8	0.1	84.8	92.8
September	189	71.3	204.2	0.1	83.8	91.8
October	187.4	104.1	192.0	0.2	90.1	98.1
November	230	156.3	179.2	0.1	109.2	117.2
December	266	192.3	187.8	0.1	112.2	120.2
Mean	211.2	146.6	189.9	0.1	97.0	105.0

The distribution of SO_2 is relatively uniform with a mean of 0.1ppm, and a departure from the distribution was observed in March (0.2), October (0.2) and June (0.3). The high concentration of carbon monoxide (CO) in Asaba reveals the nature of the urban land use. For instance, the months of January, February and March recorded 263.4, 237.4 and 208.1 respectively. August recorded 202.3 ppm. It is inferred that more vehicular movement and commercial activities are recorded in these months. However, the emissions from household use of generators are constant all through the year due to a limited supply of electricity.

The high concentration of pollutants in core areas where population density is high is expected. The High Density, residential areas of Asaba (Table 3) are the beehive of commercial, industrial, construction activities, and very high vehicular movement. Given the poor investment in mass transit, the number of automobiles in the city has increased tremendously in recent years. The implication is that emissions from transportation have also increased. December recorded a very high concentration of CO in the core part of Asaba with 281.1ppm which is slightly different from January with 279.5ppm. A cursory look at the distribution of pollutants across all the months shows that the rainy season has less pollutant loads in the atmosphere which could be attributed to the influence of climatic parameters such as rainfall, wind speed and temperature. Previous studies have reported that rainfall influences the pollutant loads in the atmosphere (Ouyang et al., 2015; Emekwuru & Ejohwomu, 2023). The variation in economic activities between the rainy and dry seasons is documented in the literature (He et al., 2023), and also reflected in the data in Table 3; wherein more of the pollutants are deposited during the rainy season, while more are retained in the atmosphere during the dry season in Asaba. The concentration of SO_2 showed relative uniformity given that virtually all the months had 0.1ppm with November, June, May and March as exceptions.

Table 3: Pollutant concentration in the high-density residential area of Asaba

Months	Air pollutants

	CO (PPM)	NO_2 (PPM)	O_3 (PPM)	SO_2 (PPM)	$PM_{2.5}$ (µg/m3)	PM_{10} (µg/m3)
January	279.5	224	198.6	0.1	119.1	128.6
February	253.5	223	197.5	0.1	113.4	122.9
March	224.2	234.8	193.3	0.2	112.3	121.8
April	190.5	185.1	178.5	0.1	100	109.5
May	195.2	195.6	199.5	0.15	113	122.5
June	205.6	108	210.5	0.31	82	91.5
July	223.4	99.9	215.1	0.1	80.4	89.9
August	218.5	98	213.1	0.1	90	99.5
September	205.1	88	215.5	0.13	89	98.5
October	203.5	121	203.3	0.2	95.3	104.8
November	246.1	173	190.5	0.13	114.4	123.9
December	282.1	209	199.1	0.1	117.4	126.9
Mean	227.3	163.3	201.2	0.1	102.2	111.7

The data presented in Table 4 (medium-density residential areas) show a significant reduction in the monthly distribution of pollutant loads in the atmosphere; when compared to the High Density Residential Areas. It is inferred that the reduction can be attributed to reduced commercial activities, construction works, informal sector activities, manufacturing and vehicular movement in the urban fringe of the town. While it is true that the town is expanding rapidly, the difference in economic activities between the urban fringe and the core is noticeable.

Table 4: Pollutant concentration in the medium-density residential area of Asaba

	Air pollutants					
Months	**CO (PPM)**	**NO_2 (PPM)**	**O_3 (PPM)**	**SO_2 (PPM)**	**$PM_{2.5}$ (µg/m3)**	**PM_{10} (µg/m3)**
January	264.2	210	186.3	0.1	112.9	118.4
February	238.2	209	185.2	0.1	107.2	112.7
March	208.9	220.8	181	0.2	106.1	111.6
April	175.2	171.1	166.2	0.1	93.8	99.3
May	179.9	181.6	187.2	0.15	106.8	112.3
June	190.3	94	198.2	0.31	75.8	81.3
July	208.1	85.9	202.8	0.1	74.2	79.7
August	203.2	84	200.8	0.1	83.8	89.3
September	189.8	74	203.2	0.13	82.8	88.3
October	188.2	107	191	0.2	89.1	94.6
November	230.8	159	178.2	0.13	108.2	113.7
December	266.8	195	186.8	0.1	111.2	116.7
Mean	212.0	149.3	188.9	0.1	96.0	101.5

However, the urban fringe is also replete with open dump sites not approved by the local authorities, urban farming, and minimal construction works, household use of generators that equally emit different gases into the atmosphere. The dry months also recorded higher pollutant loads in the urban fringe, for instance, CO for the months of January, February, March, November and December recorded 246.5ppm, 220.5 ppm, 191.2 ppm, 213.1 ppm and 249.1 ppm respectively (Table 5). The case is the same for SO_2, NO_2, O_3, $PM_{2.5}$ and PM_{10} which recorded more concentration of pollutant loads during the dry months.

Table 5: Pollutant concentration in the low-density residential area of Asaba

	Air pollutants					
Months	**CO (PPM)**	**NO_2 (PPM)**	**O_3 (PPM)**	**SO_2 (PPM)**	**$PM_{2.5}$ (µg/m3)**	**PM_{10} (µg/m3)**
January	246.5	188	177.1	0.10	109.6	118.8
February	220.5	187	176	0.06	103.9	113.1
March	191.2	198.8	171.8	0.16	102.8	112
April	157.5	149.1	157	0.10	90.5	99.7
May	162.2	159.6	178	0.15	103.5	112.7
June	172.6	72	189	0.20	72.5	81.7
July	190.4	63.9	193.6	0.10	70.9	80.1
August	185.5	62	191.6	0.10	80.5	89.7
September	172.1	52	194	0.10	79.5	88.7
October	170.5	85	181.8	0.15	85.8	95
November	213.1	137	169	0.13	104.9	114.1
December	249.1	173	177.6	0.10	107.9	117.1
Mean	194.3	127.3	179.7	0.1	92.7	101.9

Data in Figure 2 show the seasonal distribution of pollutants in the different residential areas of Asaba. Given that Asaba is in the southern part of Nigeria, the weather is influenced by two air masses, which are the tropical maritime and tropical continental air masses. Additionally is the influence of the equatorial easterlies. The concentration of carbon monoxide in Asaba is higher during the dry season than in the wet season. The case is the same NO_2. But the inverse is the case for O_3 and SO_2 which recorded higher loads during the wet season.

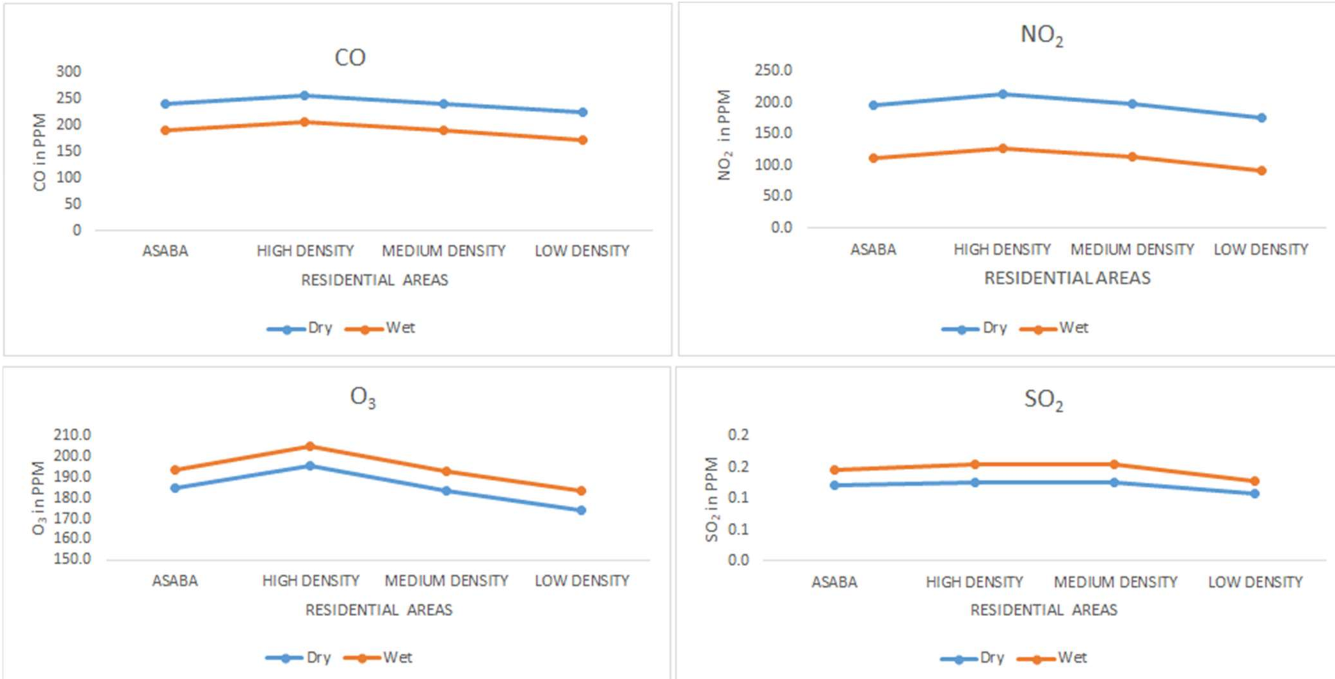

Figure 2: Seasonal distribution of pollutants (Gases) in the different residential areas of Asaba

The seasonal variation in the dispersion and concentration of $PM_{2.5}$ and PM_{10} is presented in Figure 3. It is inferred that the pollutant loads of particulate matter in the dry season are higher than what is recorded in the wet season in the town. $PM_{2.5}$ during the months of the dry season was an average of more than 100µg/m^3. The case is also the same for PM_{10}. But curiously, $PM_{2.5}$ and PM_{10} recorded less than 100 µg/m^3 in all the months in the wet season in Asaba.

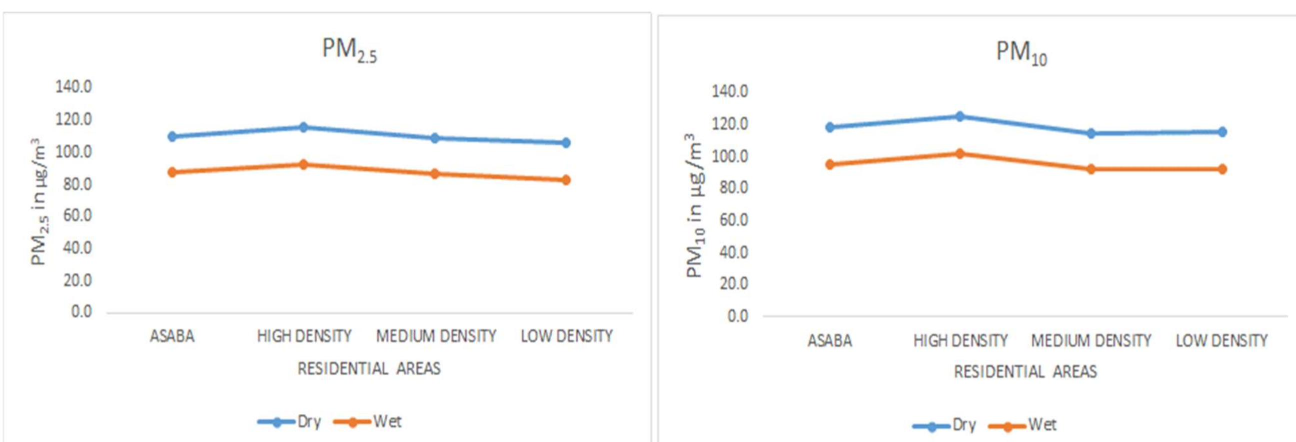

Figure 3: Seasonal distribution of pollutants (particulate matters) in the different residential areas of Asaba

Analysis of variance was carried out to ascertain the spatial variation in air quality in the residential areas of Asaba in Delta State. The core intention is to find out if differences in pollutant load in the high, medium and low-density residential areas in Asaba were significant. The results are presented in Table 6. While some gases showed spatial variability, others reflected relative uniformity in dispersion from sources. Analysis of variance showed that the mean difference for CO ppm in the three zones (high density, medium and low density) is significant at the $P<0.05$ (F=12.3123, sig = 0.00). Since the significant value is 0.00 which is below 0.05(*p*-value), it indicates that there is a statistically significant difference in the spatial distribution of CO across the three land-use zones in Asaba. Analysis of variance also showed that the mean difference for NO_2 ppm in the three zones (high density, medium and low density) is significant at the $P<0.05$(F=15.1223, sig = 0.03). Since the significant value is 0.03 and it is below 0.05(*p*-value), it indicates that there is a statistically significant difference in the spatial variation in NO_2 across the three zones in Asaba.

Table 6: ANOVA summaries of the spatial variation in air quality in the residential areas of Asaba in Delta State

	Mean values				
Parameters	**High density**	**Medium density**	**Low density**	**F-values**	**Sig**
CO (PPM)	227.3001	212.1121	194.3001	12.3123	*0.00
NO_2 (PPM)	163.3010	149.3101	127.3122	15.1223	*0.03
O_3 (PPM)	201.2120	188.9111	179.7123	10.1021	*0.05
SO_2 (PPM)	0.1021	0.11022	0.1201	1.3001	0.10
$PM_{2.5}$ (µg/m^3)	102.2102	96.0132	92.7112	10.5231	*0.04
PM_{10} (µg/m^3)	111.7112	101.5122	101.9230	6.4331	*0.05

*significant at 5% alpha level

Analysis of variance showed that the mean difference for O_3 ppm in the three zones (high density, medium and low density) is significant at the $P<0.05$(F=10.1021, sig = 0.05). Since the significant value is 0.05 which is equal to 0.05(*p*-value), it indicates that there is no statistically significant difference in the spatial variation in 0_3 across the three zones in Asaba. Also, ANOVA showed that the mean difference for SO_2 ppm in the three zones (high density, medium and low density) is not significant at the $P>0.05$(F=1.3001, sig = 0.10). Since the significant value is 0.05 which is above 0.05(*p* value), it indicates that there is no statistically significant difference in the spatial variation in SO_2 across the three zones in Asaba. ANOVA showed that the mean difference for $PM_{2.5}$ (µg/m^3) in the three zones (high density, medium and low density) is significant at the $P<0.05$ (F=10.5231, sig = 0.04). Since the significant value is 0.04 which is below 0.05(*p*-value), it indicates that there is a statistically significant difference in the spatial variation in $PM_{2.5}$ (µg/m^3) across the three zones in Asaba. Finally, ANOVA showed that the mean difference for PM_{10} (µg/m^3) in the three zones (high density, medium and low density) is significant at the $P<0.05$ (F=6.4331 sig = 0.05). Since the significant value is 0.05 which is equal to 0.05 (p-value), it indicates a statistically significant difference in the spatial variation in PM_{10} µg/m^3) across the three zones in Asaba.

DISCUSSION

The rapid structural development, population growth and spatial expansion of Asaba are characterized by a high concentration of pollutant loads. Though air pollution represents a major public health concern, documentation on the nexus between urban land use and the increasing pollutant load across the different residential quarters is scant. There is also more focus on the air pollution in the bigger cities. The growth of Asaba has increased construction works, transportation, urban agriculture, waste generation, commercial activities and manufacturing given the heavy reliance on fossil fuels. The implication is that incomplete combustion from fossil fuels is rife and highly pervasive given the enormous emission of harmful gases into the atmosphere. Urban land use in Asaba is poorly regulated and has contributed to a high level of environmental deterioration given the analysis of the pollutant loads in the different residential areas just conducted. However, there is spatial variation in the concentration of pollutant loads across the high, medium and low density areas in the city.

The high-density residential areas where more vehicular movement is recorded, with a high concentration of informal and commercial activities, construction works, waste generation, and use of diesel engines recorded high loads of ozone, carbon monoxide, sulphur oxide and particulate matter. The implication is that residents in high-density areas are more exposed to health problems such as cardiovascular diseases and respiratory ailments (Marchetti et al., 2023). The medium and low-density residential areas recorded lower concentrations of pollutants due to the gradual reduction of transportation, commercial and construction works. However, the level of concentration is sufficient to cause different public health concerns (Maji et al., 2023). As also corroborated by Chu et al., (2023). It needs to be further investigated whether there is a spatial variation in exposure and cases of health problems related to the spatial differences in the distribution of pollutants in the atmosphere. This is an area outside the scope of the current study. This is because it cannot be straightforwardly concluded that the residents in the high-density areas, where pollutant loads are very high, are suffering more health related problems. Many of the residents in the low-density areas have their business workplaces, religious centres, hospitals, schools and markets located in high-density areas, and they are also exposed to pollutant loads, this has been situated within the concept of occupational exposure to hazards in previous studies (Liu et al., 2023; Gastineau et al., 2023).

Virtually, all the household in Nigeria uses electricity-generating sets. The case of Asaba is very worrisome due to the limited power supply to high, medium and low residential areas. Ogbuewu and Nnaji (2023) implicated the use of an electricity generator as a major emitter of carbon monoxide. The author's reports are consistent with the case of Asaba when they contend that generator is a silent and rampant epidemic due to its chemical constituents which are known to be toxic and highly carcinogenic to humans. The World Health Organization (WHO) estimated in 2012 that 11.6% of the deaths in the world were attributed to intake of outdoor and indoor air pollutants. The WHO reported that 3 million deaths are attributed to air pollution annually, 88% of these deaths occured in low and medium-income countries of the world in 2016. Similarly, the Organization of Economic Co-operation and Development (OECD) Centre declared that 700,000 untimely deaths have been linked to air pollution in 2013 in Africa. This connotes that more deaths have been recorded due to air pollution than drinking unsafe water and malnutrition in Africa. However, air pollution is not receiving the needed attention due to its asymptomatic manifestation in public health at the early stages. The case of Asaba requires urgent intervention given that residents are exposed to inhaling and ingesting toxins. The work of Abam and Unachukwu, (2009) recognized industries, oil and gas processing, trade and transportation as major emitters of air toxins in Nigeria which is very consistent with the case in Asaba except for oil and gas mining and processing. The authors contend that the implication of these activities is the emission of oxides of nitrogen, polycyclic aromatic hydrocarbon (PAH) and carbon monoxide. They are toxic and carcinogenic when inhaled and ingested. Symptoms include difficulty in breathing, respiratory illness, alteration of pulmonary defence and aggravation of cardiovascular diseases. Other symptoms include headache, vomiting, dizziness, nausea and weakness of the body. The fetus of expecting mothers could be affected by prolonged exposure. A similar study by Hemba et al. (2020) reported poor ambient air quality in the vicinity of waste dumps in Wadata and the North bank in Markudi which is similar to the cases of open and unapproved waste dumps in the fringes of Asaba. The study conducted by Abam and Unachukwu, (2009) reported that CO, NO_2, SO_2 and PM_{10} from vehicular movement in Nigeria portends serious public health concerns for urban residents. The study projected that with increasing vehicle ownership in Nigeria and poor investment in affordable urban transit and renewable energy; residents in urban areas would be exposed to more air quality-related illnesses.

The case of Asaba is similar to the study conducted in Dhaka that reported that air pollution is a major environmental malady that is aggravating the public health burden in many large cities globally (Kane et al., 2023). The study in Dhaka also reported a significant positive correlation between short-term daily and seasonal air pollution from particulate matter ($PM_{2\cdot5}$, PM_{10}), sulfur dioxide (SO_2), and ozone (O_3) concentrations and hospitalizations with cardiovascular and respiratory illness were reported in China, Iran, Taiwan, Pakistan, Nepal, Myanmar, Turkey, and several European cities (Kane et al., 2023). The work of Arole et al. (2023) reported that the use of diesel generators is unsafe as incomplete combustion could increase occupational hazards for operators. The authors contend that a typical diesel generator exhaust includes more than 40 toxic contaminants which include carcinogenic compounds such as benzene, arsenic, formaldehyde and oxide of nitrogen. The banks, and factories where bread and other consumables are produced in Asaba rely heavily on diesel-powered engines due to the limited supply of electricity in the town. Many of the households also rely on personal generating sets that use premium motor spirit (PMS) and diesel with enormous emissions of carbon monoxide. The implication is that residents could develop respiratory diseases and cardiovascular ailments. Given this backdrop, this study canvassed the urgent need to invest in urban mass transit to reduce the emissions from transportation which is reported in previous studies as a major contributor to the carbon footprint in urban areas globally.

CONCLUSION AND RECOMMENDATIONS

This study assessed the air quality status in the different land uses in Asaba. The study deployed the longitudinal research design. Multi-gas detectors were fitted to platforms, 4 feet above ground level, across the study area. This was done to eliminate any biases from the data. The data was collected daily and for 12 months in 2023. This was to help the researchers unravel the seasonal variations in the pollutant's characteristics. The analysis of variance (ANOVA) was deployed to find the spatial variation in the pollutant load across the different land uses in Asaba. The study found that the pollutants decreased from the high density residential areas to the low-density areas. Also, there was a seasonal variation in the pollutant distribution especially for $PM_{2.5}$ and $_{10}$.

The spate of pollutants was seen to be high across all the land uses and thus the study concludes, that there is a need to further evaluate the consequences of the pollutants on the locals in the area.

However, the study recommends investment in renewable energy such as solar power, which could reduce the heavy reliance on fossil fuel. To reduce the carbon footprint in the city, the use of green roofs, planting of trees and green spaces should be encouraged to increase the carbon sink in the city. Improved waste management would reduce the uncontrolled incineration of waste that contributes to the carbon footprint in the town. This would require more investment in waste management and residential and commercial places. Legislation against open dumps where methane and other harmful gases are emitted is sacrosanct to reducing air pollution. Agricultural waste should be disposed of properly in the urban fringe to reduce emissions, and cycling and shot foot walk should be encouraged to reduce emissions from transportation. Improved supply of electricity to banks, factories and telecommunications masts in the high-density places would reduce incomplete combustion and emission of black soot in the town. Regular medical examinations should be encouraged for proactive action on medical cases related to air pollution. Redistribution of land use and decongestion of high density areas would reduce the exposure of residents in the high density places in the town to harmful gases. Air monitoring networks for periodic assessment of air samples would make far reaching impacts to reducing the vulnerability of locals to air pollutants.

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