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Traffic air pollution and urban sustainability: an assessment of strategic road intersections in Owerri urban, Nigeria

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Abstract

An assessment of the ambient air quality in selected road intersections in Owerri Urban, Southeastern Nigeria was carried out. Random sampling of 5 air pollutant species: NO_2, CO, SO_2, and PM $_{2.5}$ and PM $_{10}$, from 4 major points coded SP1 to SP4 were carried out daily, morning, afternoon and evening sections for 14 days in the dry season. The levels of each air pollutant species were determined in-situ using standard sampling devices. The coordinates of the sampled locations were recorded using GPS equipment. The results obtained revealed elevated levels of pollutants in all the selected intersections. NO_2 ranged between 0.055-0.089 ppm, CO ranged between 0.70-12.70 ppm, SO_2 ranged between 0.47-0.86 ppm, PM $_{2.5}$ ranged between 0.008-0.027 ppm whereas PM $_{10}$ ranged between 0.019 - 0.067 ppm in all the locations. SO_2 level at SP1 (0.47±0.15), SP2 (0.86±0.21), SP3 (0.71±0.06), and SP4 (0.74±0.13) were found to be above the National Ambient Air Quality Standard (NAAQS) and Federal Ministry of Environment (FMEnv) limits. PM (2.5 & 10) was concentrated in SP4 whereas elevated levels of CO and SO $_2$ were observed at SP3 and SP2. SP3 was observed to have elevated levels of NO_2. Changes could be attributed to high density of vehicles observed during peak hours and the presence of building clusters. The selected road intersections may not be safe due to cumulative impacts to various socio-economic and health effects triggered by prolonged exposures. Greening approach towards low-carbon cities and urban sustainability becomes essential.

Keywords: *Air Quality, Road Intersection, Owerri Urban, Southeastern Nigeria*

Introduction

Atmospheric pollution has continued to attract a lot of attention from researchers, policy makers and concerned citizens in the world due to its negative impacts on the environment and man's well-being (Njoku *et al.,* 2016; Xie *et al.,* 2017). According to (World Bank, 2016), air pollution is now the world's fourth leading fatal health risk which caused one in ten deaths in 2013. Decades of toxicological, clinical, and epidemiological research demonstrate significant associations between exposure to ambient air pollution and deleterious human health effects, including respiratory disease, cardiovascular disease, and premature death (Anenberg *et al.*, 2016).

Today, there is no doubt that the world has increasingly become urban (Aliyu *et al.*, 2017) and human exposure to air pollutants is unavoidable in an urban environment (Njoku *et al.,* 2016). Owerri, the capital city of Imo State is a fast growing metropolitan in the South East of Nigeria (AC-Chukwuocha *et al*, 2016; Okonkwo and Mbajiorgu,

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2010). It is an epicenter of economic, social and political development, and a center of industry and commerce (Njoku *et al.,* 2016; Nyhan, 2015). Consequently, there has been an influx of people into the city of Owerri in search for greener pastures (Omenikolo *et al*., 2017). With rising incomes, this human influx combined with an increasing propensity for personal mobility and travel has led to a pronounced increase in automobile ownership and bus transportation (Faiz *et al*., 1990). Thus, an attendant increase in the number of motor vehicles on the major roads in the city of Owerri (Zagha and Nwaogazie, 2015) which cumulatively could degrade the air due to the emission of exhaust gases from these motor vehicles (Muralikrishnan *et al*., 2014).

(Krzyzanowski *et al*., 2005) stated that transport is a vital part of modern life and according to (Faiz *et al*., 1990), motorization is inextricably linked to urbanization. In Nigeria, more than 95% of urban transports are by road (Aliyu *et al*., 2017) and cars are objects of desire and pride in many societies (Krzyzanowski *et al*., 2005).

Over the years, commercial transportation within the city of Owerri has undergone several transitions; from the use of motorcycles to tricycles popularly known as "Keke Napep" and recently, the use of mini buses for commercial transport within the city (Achonu, 2017; Alozie, 2017; David, 2017). Currently, there is an abundance of these mini buses within the city of Owerri in addition to privately owned cars, commercial vehicles, utility Lorries and heavy duty trucks.

According to (Moran and Morgan, 1989) the single most important human related source of air pollutants is the internal combustion engine that propels most motor vehicles. In the process of combustion, a number of gaseous materials and impurities are generated (Omenikolo *et al*., 2017). These combustion by-products are emitted into the atmospheric environment as exhaust gases (Omenikolo *et al*., 2017) and these gases are potentially toxic to humans and the environment. (Faiz *et al*., 1990) also, opines that motor vehicles cause more air pollution than any other single human activity.

Consequently, in urban areas, vehicular emissions are one of the largest contributing factors to air degradation. In addition, a multitude of air contaminants of varying toxicity comes from road transport (Krzyzanowski *et al*., 2005). According to (Saville, 1993), pollution due to road traffic constitutes 80-90% of nitrogen oxides (NO_x), hydrocarbons (HCs), particulate matter (PM) and 90-95% of the ambient carbon monoxide (CO) levels. Studies around the world have indicated that carbon monoxide is the most abundant pollutant per annum with practically 70% of all carbon monoxide gas produced solely by motor transport vehicles (Kiely, 1997).

(Fu, 2001) and (Goyal, 2006) submitted that traffic emissions contributes about 50-80% of nitrogen dioxide (NO_2) and carbon monoxide (CO) concentrations in developing countries. Moreover, combustion of hydrocarbon (HC) fuels has the potential to producing oxides of sulphur (SO_x) and oxides of nitrogen (NO_x), which can combine with water in the atmosphere to form acids (Ojo and Awokola, 2012). High concentration of lead (Pb) released into the atmosphere of an urban environment comes from the internal combustion engines of motor vehicles and its integral parts (Dziubak and Dziubak, 2022).

Ambient air is one of the environments that human beings have to live in throughout their lives, and therefore, the quality of the environment is of utmost concern to the quality of life (Zagha and Nwaogazie, 2015).

Owing to the gradual increase in population accompanied with the steady increase in the number of commercial and privately owned vehicles, the city of Owerri has continually experienced high volume of vehicular traffic at some of its major road intersections. Air pollution concentrations near road intersections are usually higher than at roadway links due to vehicles spending longer periods of time near intersections in driving modes (deceleration, queuing and acceleration) which generate a lot of pollutants (Tippichai *et al*., 2005).

Materials and Methods

The Study Area

Owerri is a rapid growing urban city with a population density of 937,042 people (AC-Chukwuocha *et al*, 2016; NPC, 2006). It is the capital of Imo State, South Eastern Nigeria (AC-Chukwuocha *et al*, 2016). The study area, Owerri Urban, lies in the central business district of Owerri in Imo State and is located between longitude 6°55'E and 7°08'E, and latitude 5°20'N and 5°34'N (Omeni-

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kolo *et al.*, 2017). The area is drained mainly by River Nworie and River Otamiri and their tributaries (Nwachukwu *et al.*, 2018). It is bordered on its south by Otamiri River and on its west by Nworie River (Omenikolo *et al.*, 2017).

Owerri consists of three local government areas namely; Owerri Municipal, Owerri North and Owerri West. Owerri Urban is within the Owerri Municipal and covers a total landmass of 24.88 km (Omenikolo *et al.*, 2017). Owerri has a tropical climate with a mean temperature range between 24°C to 34°C and a relative humidity of 70% in dry months and 90% in wet months (Emeribeole, 2015). An annual mean rainfall of about 2000 mm to 2500 mm is experienced in the study area (Okonkwo and Mbajiorgu, 2010). Owerri has two distinctive seasons, the dry and rainy seasons. The rainy season ranges from April to November with its peak in July and September, and a short break in August (Nwachukwu *et al.*, 2018). The dry season ranges from December to February with the influence of Harmattan felt between the months of December and January (Nwachukwu *et al.*, 2018). Owerri has significant rainfall most months of the year, with a short dry season. Vegetation ranges from light rainforest to Savannah with high trees particularly oil bean and palm trees around stream banks and swamps (Nwachukwu *et al.*, 2018). In terms of relief, Imo state is characterized by high, medium and low areas and Owerri urban falls within the low areas (Nwachukwu *et al.*, 2018). The general topography of Owerri is fairly flat (Ezemonye and Emeribe, 2012). Owerri Urban is characterized by influx of people and high density of vehicular flows in and out of the city (Omenikolo *et al.*, 2107). Owerri Municipal has one large central market, the Eke Ukwu Market (Onyemauwa *et al.*, 2008). This is a daily market and destination point of most agro and agro-based products within and outside the state (Onyemauwa *et al.*, 2008).

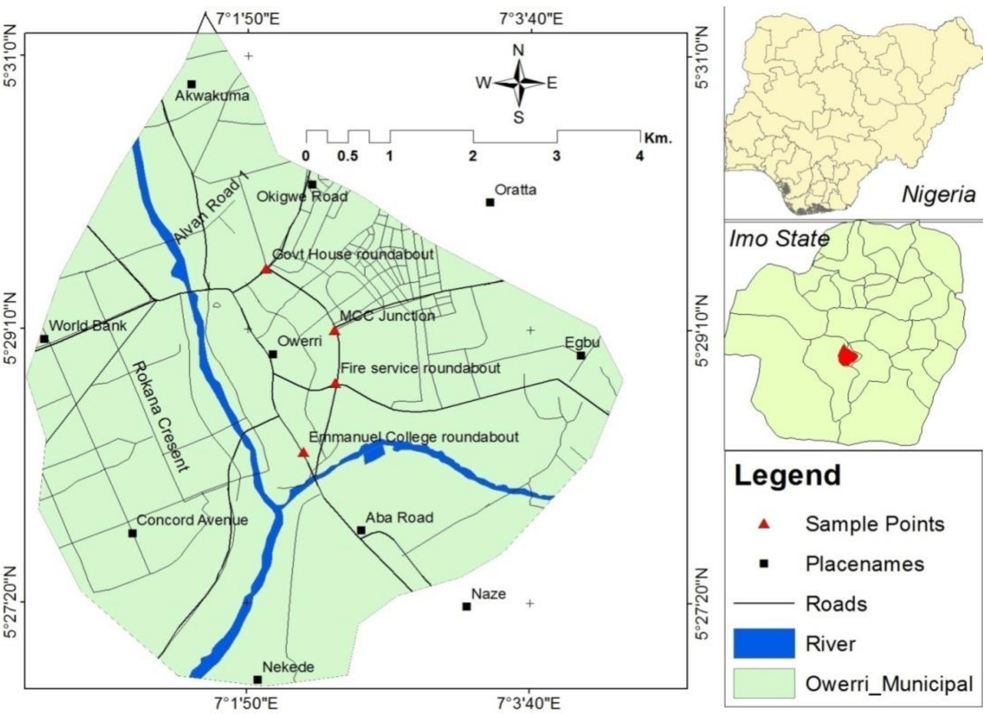

Figure 1. The study area showing the various sampling points.

Sampling Design

For the purpose of this study, the randomized method of sampling was adopted. Four road intersections in Owerri Urban coded SP1 to SP4 were monitored. Air samples collected were analyzed for five air quality parameters during the morning hours (8 - 10 am), the afternoon hours (2 - 4 pm) and evening hours (6 - 8 pm). There were a total of 60 experimental runs for the five air pollution indices in the four locations monitored. The parameters monitored are NO_2, CO, SO_2, $PM_{2.5}$ and PM_{10}.

Sampling Location

A total of four road intersections in Owerri, Imo State were selected for the study. Designated SP1 -

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SP4, these road intersections are:
SP1:Government House/Okigwe Road Roundabout
SP2: MCC Junction
SP3: Fire Service Roundabout and
SP4: Emmanuel College Roundabout
All the selected sampling locations are characterized by high density of vehicular movement, presence of offices, residential buildings, and human activities.

Field Sampling Instruments

Aeroqual series 500 handheld air quality and gas monitor with interchangeable sensor heads; used for ambient air quality monitoring. Sensor heads used include: NO_2, CO, SO_2, PM ($PM_{2.5}$ and PM_{10}).
The Series 500 air quality and gas sensor enables accurate real-time surveying of air pollutants species, all in an ultra-portable handheld monitor. The monitoring device can be used for: wide area air quality surveys; checking pollution hotspots; personal exposure monitoring; and short term fixed monitoring networks. Sensors are housed within an interchangeable cartridge (head) that is attached to the monitor base. The sensor head can be removed and replaced in seconds, allowing users to measure as many gases as possible in one device. The sensor heads features active fan sampling which ensures a representative sample is taken and therefore increases measurement accuracy.
Garmin Gpsmap 76; was used for the determination of coordinates of the selected road Intersections in Owerri, Imo State. Gas monitoring and evaluation/sampling is a spatial phenomenon, thus it is very essential to determine the accurate geographical coordinates for the sampling points using a global positioning system (GPS)
Safety helmet and high visibility jacket; used for precautionary safety purposes owing to the fact that the field work was going to be on busy roads.

GIS Spatial analysis

ArcMap 10.4: was used to develop the spatial interpolation maps of the air quality parameters (NO_2, CO, SO_2, $PM_{2.5}$, and PM_{10}). The tool used in the software is the interpolation analyst tool which has an inverse distance weighted model for spatial distribution and geo-statistics. MS Excel 2016: was used for the data conversion and analysis before transferring the data to ArcMap for further geospatial data processing. This data were processed in the excel spreadsheet and imported into an ArcMap 10.4 version and Splotted to display the Longitude and Latitude (XY) in spatial relation to the air quality parameters average concentration (Z) dataset. The parameters were individually plotted into a map using the inverse distance weighted (IDW) model of the ArcGIS version 10 Interpolation tool in Spatial Analysis tool of the software. The tool uses the values of the parameter as the Z value and the area extent of the spatial interpolation analysis as the area boundary of the study area which was generated from the local study area map shown in the description of the study area.

<u>Results and Discussion</u>

The Tables 1 and 2 presents the summarized pollutants concentrations measured at the four (SP1, SP2, SP3 and SP4) strategic and the mean concentration compared to regulatory standards (FMEnv and NAAQS) respectively.

Table 1. *Selected air pollutants concentrations and the associated mean sampled at strategic locations (SP1, SP2, SP3 and SP4) measured at reasonable intervals of Morning (MH), Afternoon (AH) and Evening (EH) hours of the day*

Air pollutants	Pollutant concentration (ppm)															
	SP1 (GHR)				SP2 (MCC)				SP3 (FSR)				SP4 (ECR)			
	MH (8-10AM)	AH (2-4PM)	EH (6-8PM)	MC	MH (8-10AM)	AH (2-4PM)	EH6-8PM)	MC	MH (8-10AM)	AH (2-4PM)	EH (6-8PM)	MC	MH (8-10AM)	AH (2-4PM)	EH (6-8PM)	MC
NO_2	0.03	0.07	0.07	0.06	0.05	0.08	0.07	0.07	0.10	0.08	0.09	0.09	0.08	0.07	0.09	0.08
CO	0.00	0.30	2.20	0.80	2.70	7.80	6.60	5.70	5.60	2.60	29.8	12.7	0.00	0,00	2.20	0.70
SO_2	0.77	0.33	0.31	0.47	1.27	0.72	0.58	0.86	0.77	0.77	0.58	0.71	0.57	1,00	0.65	0.74
$PM_{2.5}$	0.02	0.00	0.00	0.01	0.01	0.01	0.04	0.02	0.04	0.01	0.01	0.02	0.02	0.03	0.04	0.03
PM_{10}	0.05	0.01	0.01	0.1	0.03	0.05	0.04	0.03	0.04	0.08	0.02	0.05	0.15	0.02	0.03	0.07

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Table 2 *Calculated mean of selected pollutants at strategic locations (SP1, SP2, SP3 and SP4) compared with regulatory standards.*

Air pollutants	Mean concentration SP1	SP2	SP3	SP4	FMEnv limit	AH	NAAQS	AH
	ppm				ppm	hours	ppm or μg/m^3	hours
NO_2	0.055	0.006	0.089	0.08	0.04 - 0.06	1	0.100 ppm	1
CO	0.8	5.7	12.7	0.7	10 - 20	8	9 ppm	8
SO_2	0.47	0.86	0.71	0.74	0.01 - 0.1	1	0.14 ppm	24
$PM_{2.5}$	0.008	0.017	0.017	0.027	-	-	35 μg/m^3	24
PM_{10}	0.019	0.029	0.047	0.067	-	-	150 μg/m^3	24

AH: Averaging Hour

Spatial distribution of NO_2 in the study locations

From the results shown in Figure 2a, b, it can be observed that the trends show that to the north of SP1, NO_2 appears to be lower in concentration ranging between 0.055 to 0.069 ppm. At the SP2, lower concentration of NO_2 was equally observed.
To the South of SP1, NO_2 level increased gradually and was observed to be high, particularly at the SP3. The NO_2 level in this part of the city was observed to be between the ranges of 0.076 to 0.089 ppm. NO_2 level was highly concentrated at the SP3 owing to the presence of high density of vehicular movement at the road intersection in the afternoon and evening hours in addition to traffic congestion around the road intersection.. Furthermore, vehicles queued for several minutes in the road intersection which might have caused the increase in NO_2 concentration. The SP4 recorded a similar trend as the SP1 with concentration ranging between 0.076 to 0.082 ppm. To the West of the SP3, there appears to be a lower concentration of NO_2 in that area. This could be attributed to the windy nature of this area which encouraged the dispersion. However, lower concentration observed could be alluded to sequence of photochemical reactions NO_2 undergoes in the presence of solar radiation and the regeneration of O_3 cyclically (Han *et al.*, 2011).

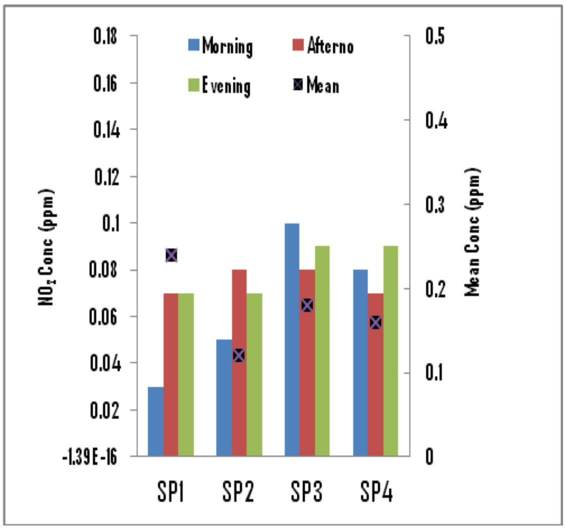

Figure 2a. *Mean concentration across spatiotemporal distribution of NO_2 pollutants in the study area*

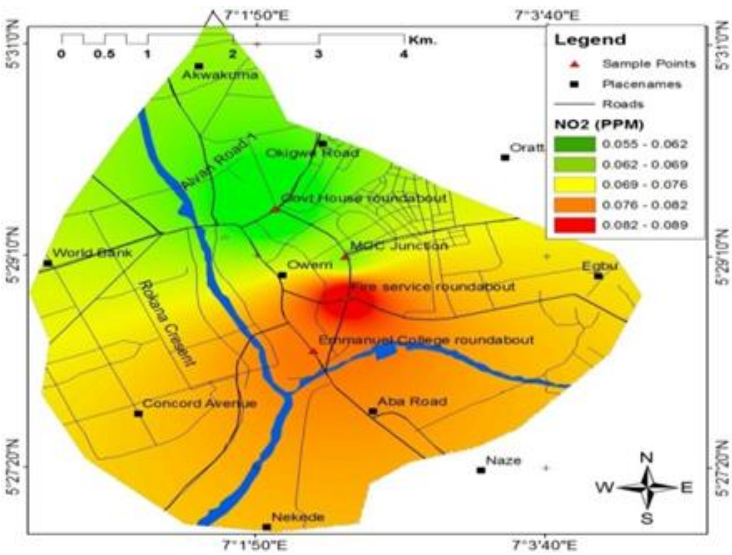

Figure 2b. *Spatial distribution of NO_2 in the study location*

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Spatial distribution of CO in the study locations

The CO results obtained and displayed in Figures 3a, b shows that SP3 and the surrounding areas had the highest level of CO in the studied locations with a range of 7.9 to 12.7 ppm.

These values are by far higher than the NAAQS and Federal Ministry of Environment limits of 9 ppm and 10 - 20 ppm respectively. SP1 and the SP4 was observed to have comparatively. low concentration of CO and this could be as a result of meteorological conditions such as high windy condition prevalent at those locations. There was a sharp deviation in CO level from that observed at SP3 in the afternoon hours at the SP4 and can be attributed to a down pour at this location during the air sampling exercise. This condition may have affected the concentration of CO in the location. Furthermore, the traffic congestion experienced in this sampling location is less compared to that of SP3 and SP2. However, higher CO levels observed maybe due to greater automobile traffic peculiar to the location (Jaffe, 2017). The GIS spatial interpolation analysis shown in Figure 4.2 presents the spatial distribution pattern of CO in the study location and further reveals distant surrounding locations like World Bank, Concord Avenue and Akwakuma. It has been predicted that CO concentration can be elevated above the air quality regulatory standards following expected growth in vehicle numbers likely to occur in developing countries (Adepoju *et al.*, 2018), except emission control and management programs are institutionally enforced.

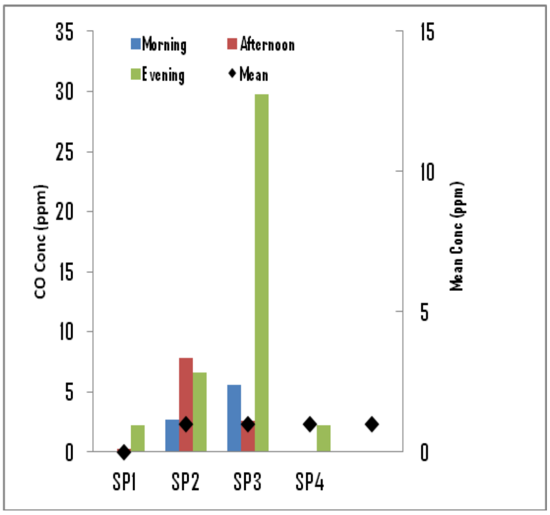

Figure 3a. *Mean concentration across spatiotemporal distribution of CO pollutants in the study area*

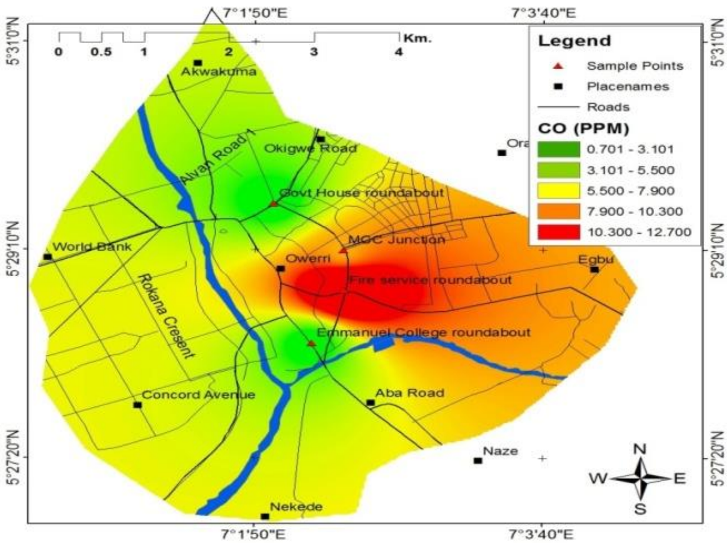

Figure 3b. *Spatial distribution of CO in the study location*

Spatial distribution of SO_2 in the study locations

For SO_2 the level was quite high in SP2 with a range of 0.781 to 0.858 ppm as depicted in Figures 4a, b. Heavy traffic congestion was observed during the sampling hours within the MCC Junction leading to high vehicular emission of SO_2 in the area. This is possibly the reason for high SO_2 value recorded in this location. SO_2 concentration ranged from 0.703 to 0.781 ppm in the southern part of SP2. However, the SP1 and the adjoining surrounding areas such as Alvan and Works-Layout were observed to be lower in SO_2 concentration ranging between 0.47 to 0.55 ppm. Though comparatively, these locations have lower SO_2 concentration compared to other locations of the study area. These concentrations were above the Federal Ministry of Environment limits of 0.01 to 0.1 ppm. The GIS spatial map illustrated in Fig 4a, b shows the distribution of SO_2 in the study locations.

Spatial distribution of particulate matter ($PM_{2.5}$ and PM_{10}) in the study locations

Elevated level of $PM_{2.5}$ is observed at the SP4 with a range of 0.023 to 0.027 ppm as depicted in Figures 5a, b. The observed elevated level of $PM_{2.5}$ at the SP3 can be linked to the several movements of heavy duty trucks at that location. To the north of SP3, the level of $PM_{2.5}$ was observed to decrease exponentially from 0.019 to 0.008 ppm partly due to the presence of pot holes on the roads, thereby

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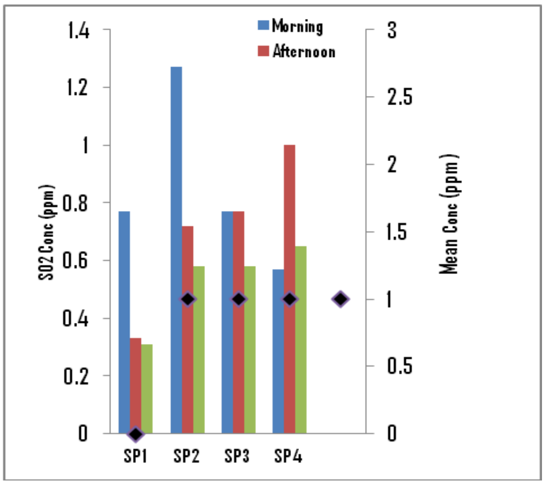

Figure 4a. *Mean concentration across spatiotemporal distribution of SO_2 pollutants in the study area*

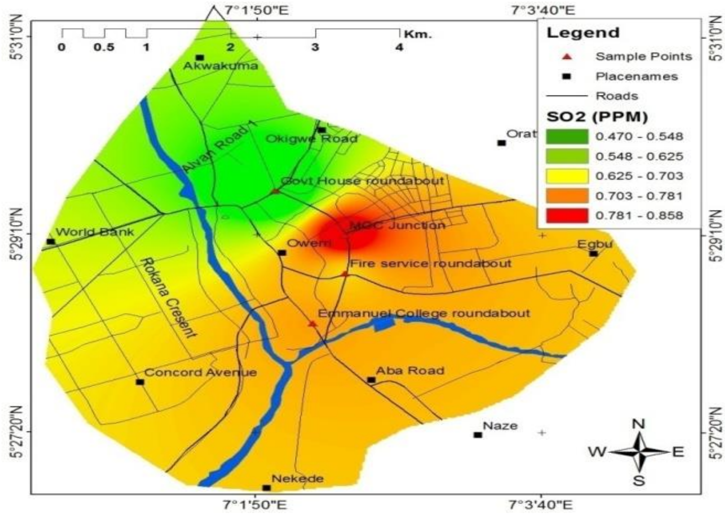

Figure 4b. *Spatial distribution of SO_2 in the study location*

compelling vehicles to momentarily slow down before accelerating. This situation can lead to higher vehicular emissions than on smoother roads. South of SP3 also shows a significant level of $PM_{2.5}$ ranging between 0.019 to 0.023 ppm. Suffice to say, the dense commercial activities in the location can be a contributor to the increase in $PM_{2.5}$ concentration.

Elevated level of PM_{10} was observed within SP4. This observed elevated level could be attributed to the commercial activities going on in the location where the use of power generators is prevalent (Esen *et al.*, 2017). Though, to the North of the location, the concentration of PM_{10} decreased from a range of 0.038 to 0.019 ppm. Convincingly, it was observed that both $PM_{2.5}$ and PM_{10} were quite high in SP4 as seen in the geospatial map (Fig. 6a,b). These two results were also observed to be geospatially significant in the distribution pattern.

Generally, from the results of the study, all the air pollutants studied were detected in all the selected road intersections in Owerri Urban. In SP1, mean concentrations of NO_2 and CO were within the permissible limits of the two regulatory standards used for comparison. However, SO_2 was above the permissible limits at SP1.

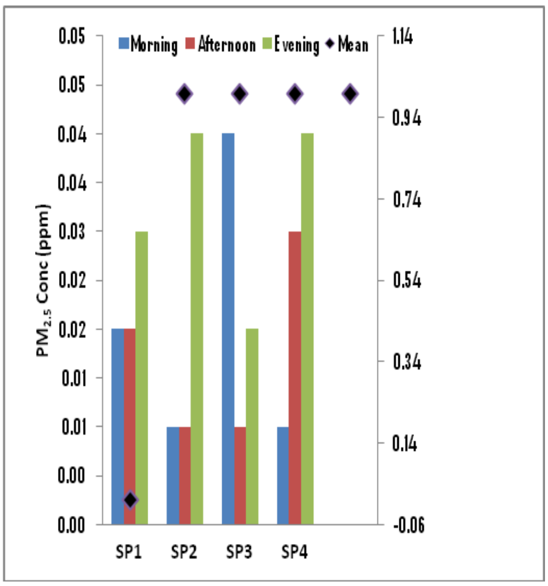

Figure 5a. *Mean concentration across spatiotemporal distribution of $PM_{2.5}$ pollutants in the study area*

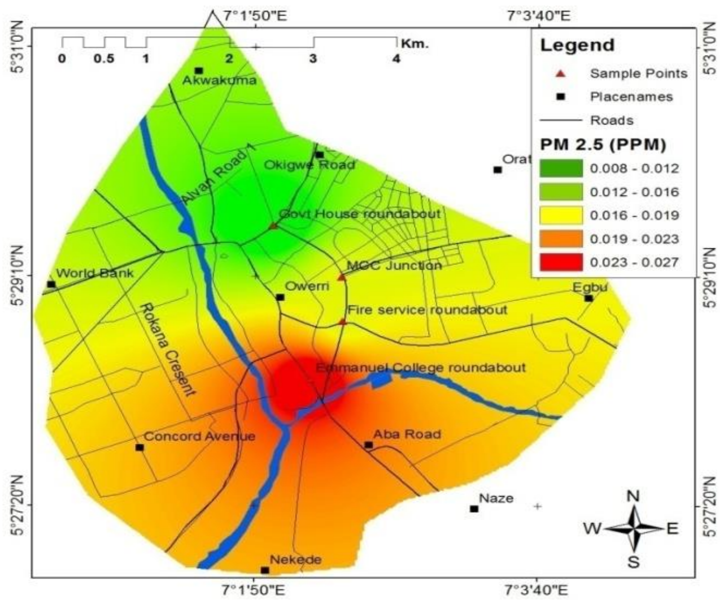

Figure 5b. *Spatial distribution of $PM_{2.5}$ in the study location*

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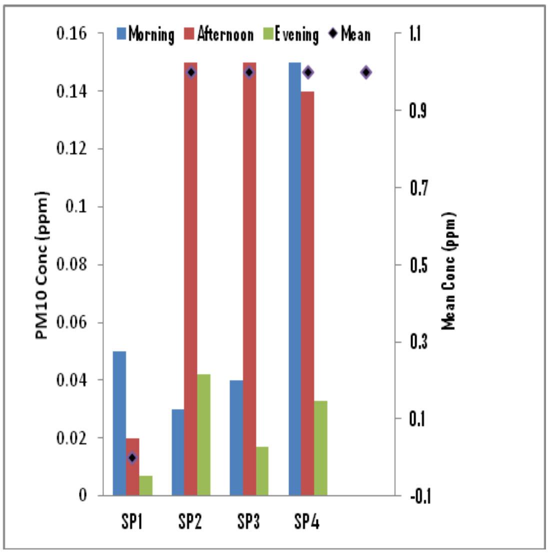

Figure 6a. *Mean concentration across spatiotemporal distribution of PM_{10} pollutants in the study area*

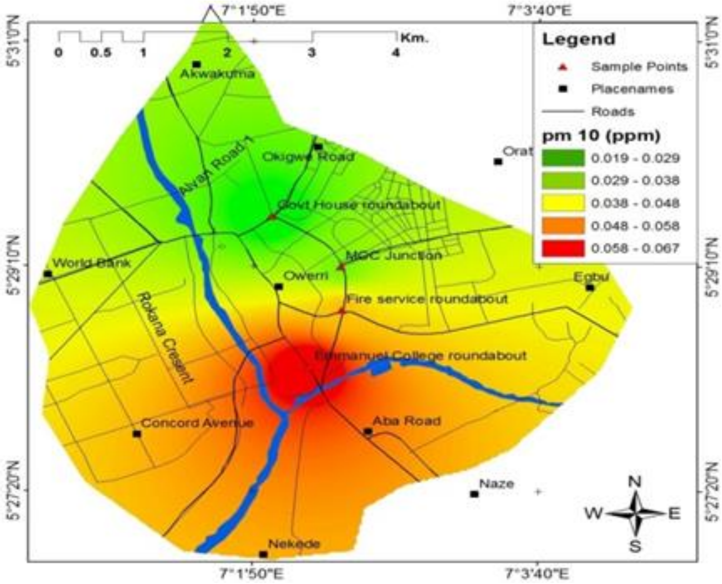

Figure 6b. *Spatial distribution of PM_{10} in the study location*

NO_2 and SO_2 mean concentrations at SP2 were also above the permissible limits whereas mean concentration of CO was lower than the permissible limits in this location. The mean concentrations of NO_2, CO, and SO_2 were equally above the regulatory limits at the SP3. Similarly, mean concentration levels of NO_2 and SO_2 were higher than the permissible limits at the SP4. However, in order to compare the influence of the four sampling locations (SP1, SP2, SP3 and SP4), the data presented a graphical data summary, including the median, quartiles, mean concentration as well as skweness of distribution (Figure 7). The data were averaged across the sampling locations. It is observed that the four locations exhibited similar and comparable trend in their skweness pattern to the left though with significant variations in their mean values.The difference in mean variations shows the influence of vehicular emission being prominent in some locations compared to others.

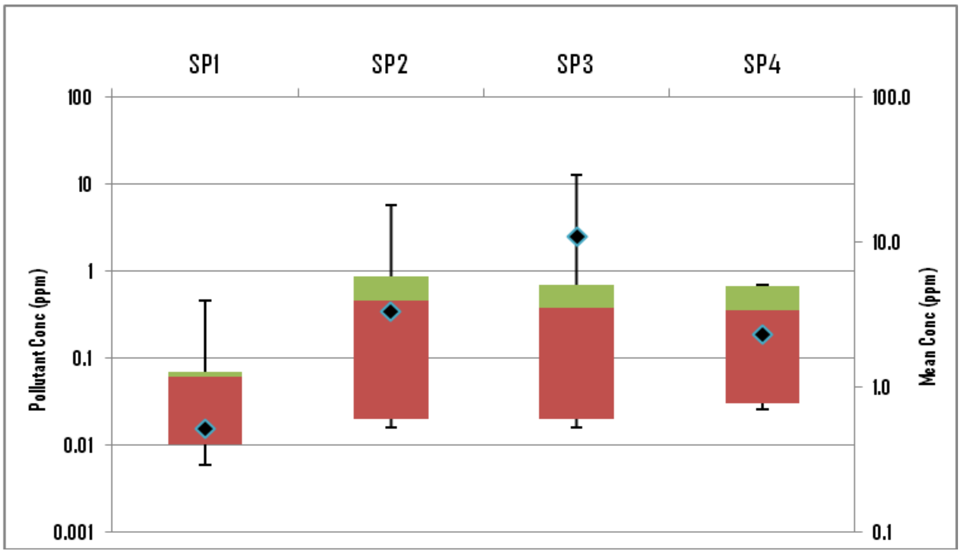

Figure 7

Box plot comparing Mean concentrations of the different strategic locations (SP1, SP2, SP3 and SP4) using the mean calculated across the five pollutants. The lines inside the boxes represent the median values; the black dots represents the mean values; and the lower and upper boundaries of the box represent 25^{th} and 75^{th} percentiles of the sample size (n = 5).

Conclusion

The present study reveals that urban road traffic around the metropolis played a significant role in increasing the background concentrations of criteria air pollutants (CAPs) in NOx, SOx, CO and $PM_{(10,2.5)}$. The presence of elevated concentrations of CAP above the regulatory threshold indicates

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possible air pollution resulting from vehicular emission and other related sources. The spatial distribution maps clearly showed concentration levels with colour codes depicting low and high concentrations and therefore, more reliable in conveying the extent of air pollutant coverage within a given location. The results correlate with the fact that vehicular emission is one of the degrading factors of ambient air quality in the metropolis with attendant impairment on urban environmental aesthetics.

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