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Research Article

Roadside Air Pollution Assessment in Port-Harcourt, Nigeria

Zagha O and *Nwaogazie Ify L

Centre for Occupational Health Safety and Environment, University of Port Harcourt, Nigeria

*Corresponding Author Email: ifynwaogazie@yahoo.com, ify.nwaogazie@cohseuniport.com

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Abstract

In this study, the level of air pollution along roadsides at selected locations in Port-Harcourt metropolis was assessed. The ambient air quality survey was done with respect to Carbon monoxide, Sulphur dioxide, Oxides of nitrogen and Particulate matter (PM10) and monitored in the study area at four locations. Three junctions (Mile One Junction, Rumuola Junction and Artillery Junction) along the Port-Harcourt Aba Expressway were monitored because of their high traffic density and the presence of roadside vendors while Bodo Street in the New GRA was used as the control. The air pollution measurements were carried out using direct reading, automatic in-situ gas monitors; HAZDUST Particulate Air Monitoring Equipment for PM10, VRAE Multi Gas Monitor for SOx and NOx and AEROQUAL Gas Detector for CO. Sampling was carried out for six consecutive days; three days for each location. The measured parameters were found to be in the following ranges for hourly readings: CO (0-60.24ppm), NOx (0-1.5ppm), SOx (0-0.75ppm) and PM10 (26-199µg/m^3). Air Quality Index values in the study varied between a maximum of 267.17 and a minimum of 14.71 showing that the health of people who spend long hours along roadsides are at risk.

Keywords: Air quality, PM10, carbon monoxide, sulphur dioxide. Oxides of nitrogen, roadsides, traffic density, AQI

INTRODUCTION

Air pollution may be taken as the contamination of air by discharge of harmful substances, which can cause health problems including burning eyes and nose, itchy irritated throat and breathing problems (USEPA, 1994). Air pollution is a major part of the overall atmospheric pollution and the motor vehicle emissions usually constitute the most significant source of ultrafine particles in an urban environment (Zhu and others, 2002). Important chemical pollutants emitted by land vehicles are Carbon monoxide (CO), Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2) and Total Suspended Particles (TSP) (Najeeba and Saleem, 1997).

Ambient air is one of the environments that human beings have to live in throughout their lives. The quality of the environment is therefore very important to the quality of life. It seems fitting and proper to examine the problem of air pollution from the view point of public health. An average man breathes 22,000 times each day. The air is the main link to life. It far exceeds one's consumption of food and water. Hence, there is a general interest in air pollution studies (Subramani, 2012). In recent years many African countries have experienced significant economic growth leading to increased urbanization, motorization and energy use. Air pollution generated by motor vehicular exhaust has become a major cause of public concern worldwide. The rapid and the marked increase in motor vehicular traffic and its associated gaseous pollutants in the urban areas have caused a sharp increase in the prevalence of respiratory allergies (Polosa and Salvi, 1999). The net effect of this increase in population and cars is the drastic increase in environmental pollution including air pollution (Jackson, 2005).

Salami (2007) noted that vehicular emission has become one of the most complicated environmental challenges. In effect, cities which rely on a large number of automobiles for the bulk of daily transportation, and offering few efficient public mass transportation modes, may suffer from effects of automobile emission. It should be noted that perfectly operating motor engines would produce only water (H_2O) and carbon dioxide (CO_2) in the process of fuel combustion. However, with the problems of old and worn out engines, improper fuel grades, lack of regular maintenance, physical ageing of engines, intensive use of vehicles and misuse of lubricants (especially motor cycles), all these factors combine to produce a constraint on perfect fuel combustion. The ultimate effect is the emission of CO, Hydrocarbons (HCs), NO_2 and SO_2 from the exhaust system and engine parts of motor vehicles.

As a result, poor air quality has emerged as a major environmental concern due to a lack of effective control measures. With modern activities for development, contamination of the atmosphere by gases, smoke, dusts and other suspended substances constantly takes place thus, making the air people breathe in, a source of hazard to their lives (Othman, 2010). The United Nations estimated that over six hundred (600) million people in urban areas worldwide were exposed to dangerous levels of traffic-generated air pollutants (Cacciola et al., 2002). Recently, in developing countries, enormous environmental problems due to inadequate environmental planning and monitoring have emanated. In such places, environmental problems like air pollution due to increased volume of traffic on ill-planned roads are aggravating already serious problems (Arokodare, 1976). In Nigeria, much attention is given to general industrial pollution and pollution in oil industries, with little reference to pollution caused by automobiles. It is claimed that Nigeria's carbon dioxide emissions from industrial processes, estimated at 96513 million metric tons in 1992, was the highest in sub-Saharan Africa, excluding South Africa. The emission from flared gas alone accounted for more than one half of this figure (Ukemenam, 2014). Pollution from mobile transportation is on the rise due to increase in per capital vehicle ownership, thus, resulting in high congestion on Nigerian roads and increase in the concentration of pollutants in the air, thus, increasing health risks for human population.

In comparison with the large volume and varieties of studies carried out in the developed world, exposure studies carried out in Nigeria are relatively scarce (Okunola et al., 2012). Vehicular growth has not been checked properly by environmental regulating authorities leading to increased levels of pollution (Han and Naeher, 2006). Only a few studies have been conducted in Nigeria so far for the assessment of pollution levels prevalent in relation to the ever increasing roadside automobile traffic. Roadside vendors generally spend 8-10 hours on the margins of the road and are continuously exposed to the vehicular emissions as well as fugitive dust (Mani et al., 2013). Many market places, shops, business centres are in close proximity to roadsides thereby exposing these people to harmful pollutants which may have no serious effects now but in the long term could lead to respiratory diseases and possibly death. The basic objectives of this study are to assess the level of roadside air pollution in the Port-Harcourt metropolis and determine the air quality index for the sampling locations.

MATERIALS AND METHOD

Study Area

Port – Harcourt (4.46^{o}N; 7.01^{o}E) is the capital of Rivers State, Nigeria. It lies along the Bonny River (an eastern distributary of the Niger River, 66km upstream from the Gulf of Guinea. According to the 2006 Nigerian census, Port-Harcourt has a population of 1,382,592. Port-Harcourt features a tropical monsoon climate with lengthy and heavy rainy seasons and very short dry seasons. Only the months of December and January truly qualifies as dry season months in the city. The harmattan, which climatically influences many cities in West Africa, is less pronounced in Port-Harcourt. Port-Harcourt's highest precipitation occurs during September with an average of 367mm of rain. December on average is the driest month of the year, with an average rainfall of 20mm.

Temperatures throughout the city are relatively constant, showing little variation throughout the course of the year. Average temperatures are typically between 25^{o}C-28^{o}C in the city. The chosen sampling locations are located along the Port-Harcourt-Aba Expressway, a major road in Port-Harcourt and were selected because of the high traffic density usually observed at these junctions with the exception of Bodo Street in the New GRA which served as control location.

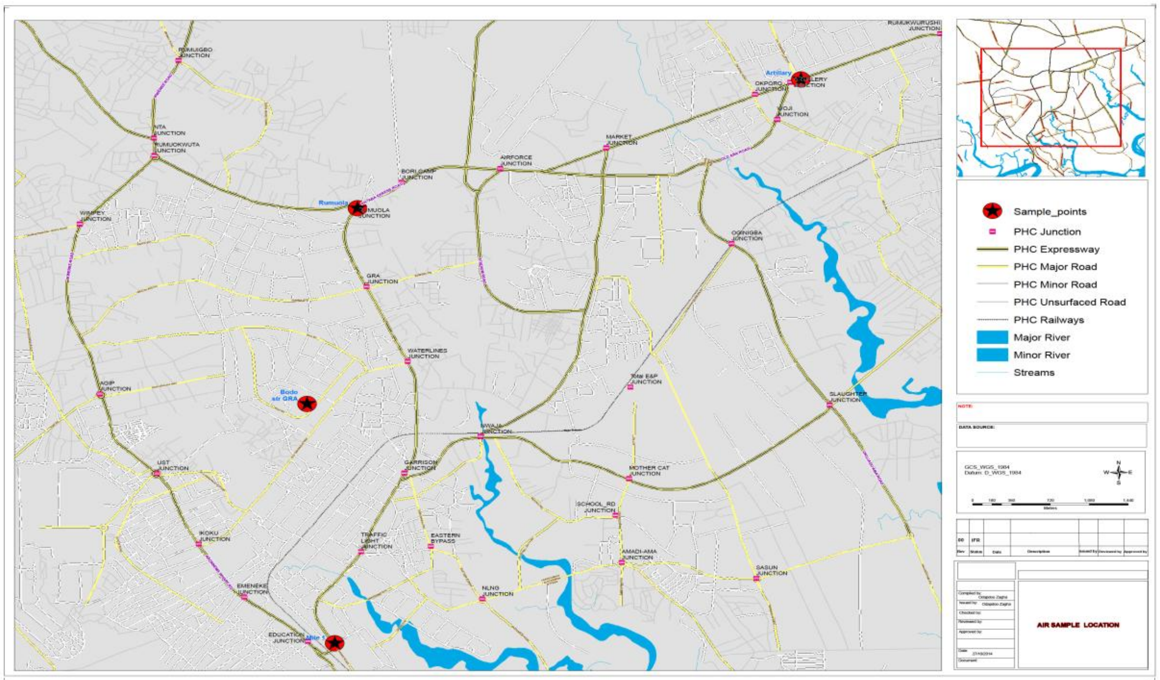

Figure 1. Map of the Study Area showing Air pollution sampling points along Port Harcourt Aba express road

Sampling Design

The sampling design used for choosing the sampling locations and points was the Purposive Sampling Method. Purposive sampling is a type of non-probability sampling technique which relies on the judgment of the researcher when it comes to selecting the units (e.g., people, cases/organizations, events, pieces of data) that are to be studied (Nwaogazie, 2011). The main goal of purposive sampling is to focus on particular characteristics of a population that are of interest, which will best enable the researcher answer his research questions. Through careful observations, sampling sites or stations in the metropolis were identified prior to the dates of fieldwork. These sampling sites are areas of high traffic density in the metropolis. The three roadside sites along the Port-Harcourt – Aba Expressway were purposely selected as sampling locations and Bodo Street in the New Government Residential Area (GRA) was chosen as the air sampling station to indicate background air quality away from major roads (Control). The background study location was chosen because of its relatively low traffic level. However, the three roadsides used as sampling locations were selected using the following criteria:

i. Presence of street vendors, shopping centres or kiosks with substantial presence of pedestrians.
ii. Presence of adequate traffic density in order to characterize the significant air pollutants along the roadsides.
iii. Absence of physical barriers that could impair the air sampling process.
iv. Locating the sampling site in an industry free zone. This is used to exclude the industrial sources of pollution.

MATERIALS

For this research work, the air pollution measurements were carried out using direct reading, automatic *in situ* gas monitors. The instrument used for the measurement of SOx and NOx was the VRAE Multi Gas Monitor and the unit was in ppm. Aeroqual Gas Detector for measurement of CO in ppm while HAZ-DUST Particulate Air Monitoring Equipment was used for measurement of particulate matter. The particulate monitoring equipment was a continuous reading device in addition to being an automatic direct reading and *in situ* measuring meter.

DATA COLLECTION

Sampling was done on six days of the week (that is, Monday to Saturday) between the 8th and 13th of September 2014. All sampling locations were sampled at different times of the day (morning, afternoon and evening). Morning readings were taken between 8am-11am, afternoon readings between 12pm-3pm and evening readings were taken between 4pm-7pm. Sampling involved open air sampling on the pavements in closest proximity to the roads and at a height of 1m. Measurements were taken after steadying the equipment for at least 15 minutes before readings were taken in order to provide real time reading of parameters of interest.

DATA ANALYSIS

Mean values for concentration of each of the parameters were calculated using the Microsoft Excel Spreadsheet computer program for repeated measurements and as well as to obtain a representative discrete value. Bar graphs were generated with the data and used to compare side by side, the concentrations of the different parameters for the four sampling locations on the various sampling days.

The Air Quality Index (AQI) was calculated for all sampling locations using the daily average concentration of the measured parameters. Local air quality affects how we live and breathe. Like the weather, it can change from day to day or even hour to hour. The AQI is an index for reporting daily air quality. It tells us how clean or polluted the air is, and corresponding health effects. The EPA calculates the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particle pollution, carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect public health. The AQI scale is divided into six categories and a specific colour assigned to each to appreciate at first glance whether air pollutants are reaching unhealthy levels in the area or not (See Table 1).

Table 1. Air Quality Index Values, Health Concerns and Colour Codes ±

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

± Source: www.airnow.gov

The AQI was computed by using the pollutant concentration data and the linear interpolation equation (Equation 1):

$$I_p = \frac{I_H - I_L}{BP_H - BP_L}(C_p - BP_L) + I_L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where: I_p = the index of pollutant, p;
C_p = the rounded concentration of pollutant p;
BP_H= the breakpoint that is greater than or equal to C_p (upper limit);
BP_L= the breakpoint that is less than or equal to C_p (lower limit);
I_H= the AQI value corresponding to BP_H; and
I_L= the AQI value corresponding to BP_L.

For better understanding of the Equation 1, (See Table 2).

Table 2. Breakpoints for the AQI ±

BREAKPOINTS FOR THE AQI							
CATEGORY	GOOD	MODERATE	UNHEALTHY FOR SENSITIVE GROUPS	UNHEALTHY	VERY UNHEALTHY	HAZARDOUS	
AQI	0-50	51-100	101-150	151-200	201-300	301-400	401-500
Pollutant	Breakpoint						
CO (ppm)	0-4.4	4.5-9.4	9.5-12.4	12.5-15.4	15.5-30.4	30.5-40.4	40-50.4
NO_2 (ppm)					0.65-1.24	1.25-1.64	1.65-2.04
O_3 1-hour (ppm)			0.125-0.164	0.165-0.204	0.205-0.404	0.405-0.504	0.505-0.604
PM 2.5	0-15.4	15.5-40.4	40.5-65.4	65.5-150.4	150.5-250.4	250.5-350.4	350.5-500.4
PM 10	0-54	55-154	155-254	255-354	355-424	425-504	505-604
SO_2 (ppm)	0-0.034	0.035-0.144	0.145-0.224	0.225-0.304	0.305-0.604	0.605-0.804	0.805-1.004

± Source: Fernando (2012)

RESULTS AND DISCUSSION

Average concentrations of Carbon monoxide, Nitrogen dioxide, Sulphur dioxide and Particulate matter (PM10) obtained at Bodo Street, Mile One Junction, Rumuola Junction and Artillery Junction are as shown in Figures 2-9. The results of air quality monitoring indicate high variability at different sampling locations depending on the density of mobile and stationary air pollution sources. All measured pollutants were within permissible limits at Bodo Street in the New GRA. This could be attributed to the low traffic density in the area and also the presence of trees and shrubs planted along the street which serve as carbon sink.

The concentrations of carbon monoxide in the study area are varied between a minimum of 0-60.24ppm. The maximum value was observed at Rumuola junction and it exceeds prescribed hourly standards by the United States Environmental Protection Agency (USEPA} and Department of Petroleum Resources (DPR) Nigerian standards which are 35ppm and 0.26ppm, respectively. This could be as a result of the high traffic density at this location, absence of trees planted along roadsides and the very slow movement of vehicles (traffic congestion). Highest sulphur dioxide concentration was also observed at Rumuola junction at 0.75ppm exceeding USEPA hourly standard of 0.075ppm, however within the limit set by the DPR at 1.34ppm. Also, particulate matter was within the limits set by the DPR at all locations between 150 and 230 $\mu g/m^3$.

Although most values looked relatively low or within limits at the sampling locations, when converted to AQI, it was observed that all locations with the exception of Bodo Street in New GRA, posed serious health risks to individuals who spent long hours at these locations. Sensitive groups such as asthmatics, children and the elderly, people with heart or lung diseases were at highest risk. The Air Quality Index values in the study area varied between a maximum of 267.17 and a minimum of 14.71 (See Table 3).

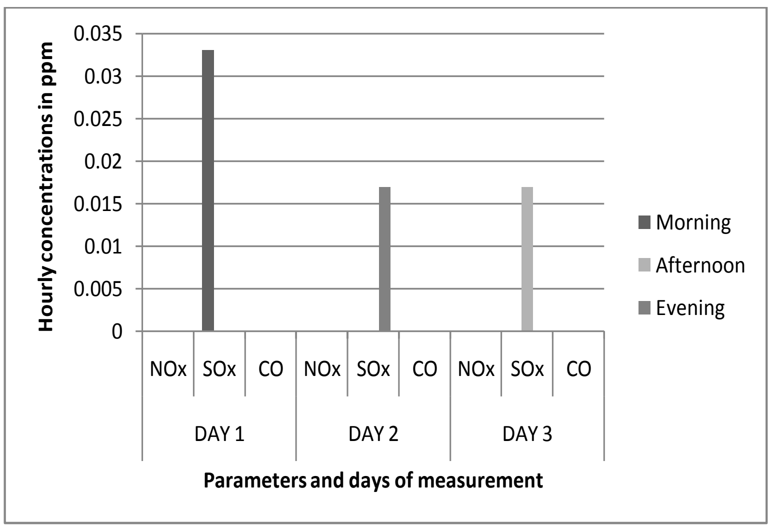

Figure 2. Hourly concentrations of NOx, SOx and CO at Bodo Street in New GRA

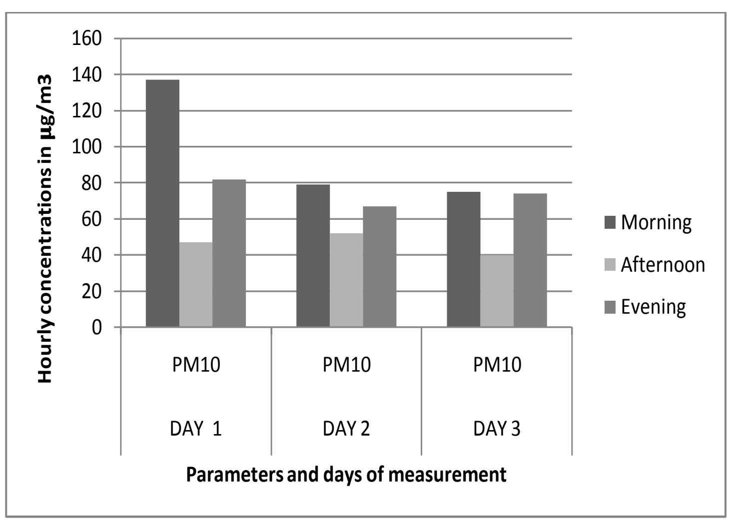

Figure 3. Hourly concentrations of PM10 at Bodo Street in New GRA

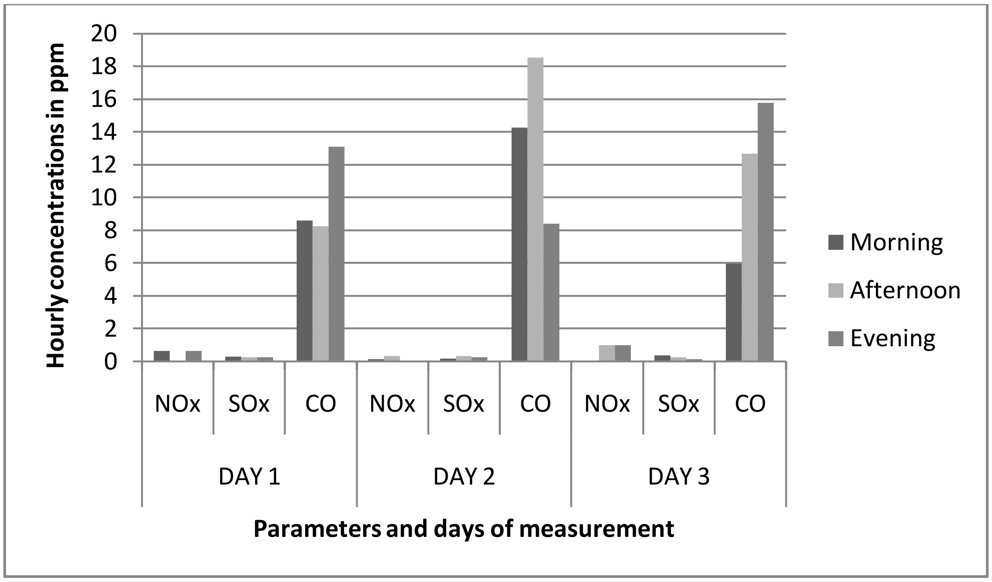

Figure 4. Hourly concentrations of NOx, SOx and CO at Mile One Junction

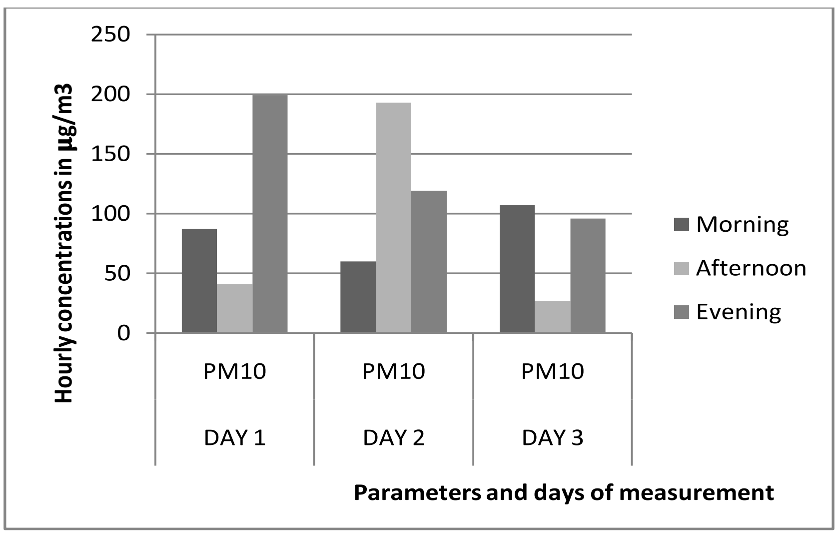

Figure 5. Hourly concentrations of PM10 at Mile One Junction

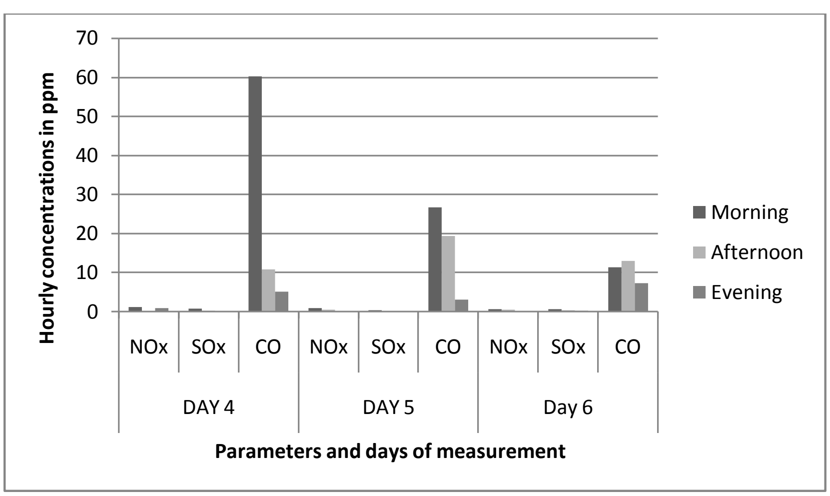

Figure 6. Hourly concentrations of NOx, SOx and CO at Rumuola Junction

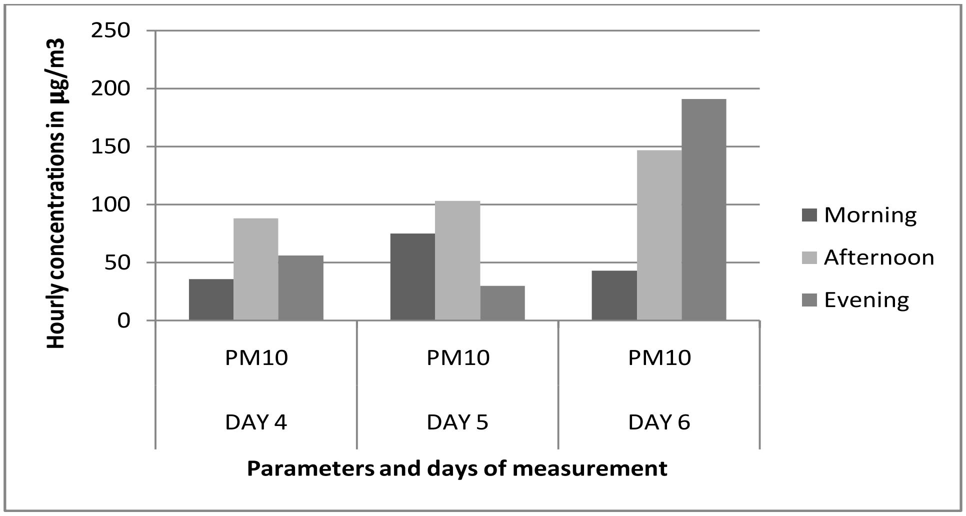

Figure 7. Hourly concentrations of PM10 at Rumuola Junction

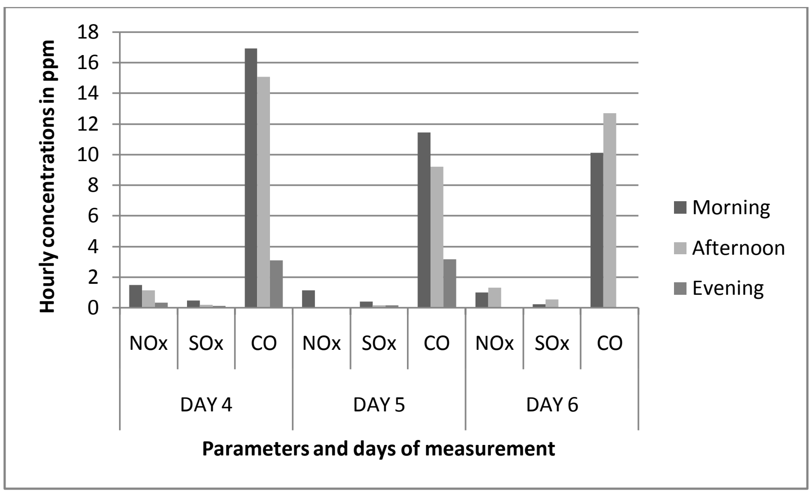

Figure 8. Hourly concentrations of NOx, SOx and CO at Artillery Junction

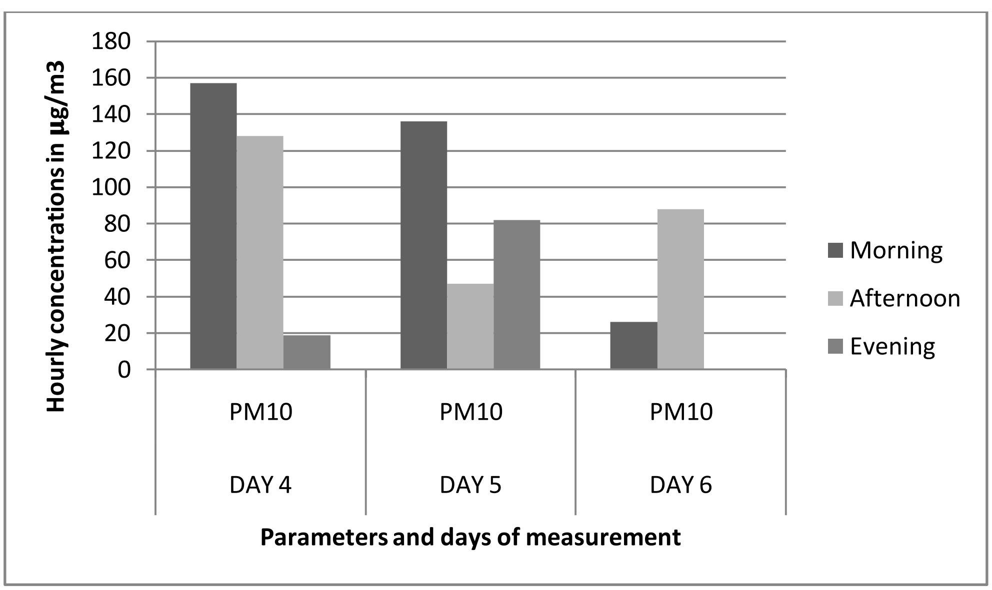

Figure 9. Hourly concentrations of PM10 at Artillery Junction

Table 3. Air quality index (AQI) values and colour codes of all sampling locations

DAY	LOCATION	POLLUTANTS				AQI FOR THE DAY	POLLUTANT THAT CHARACTERIZE THE AIR QUALITY	COLOU R CODE	CATEGORY
		NOx	SOx	CO	PM10				
DAY 1	BODO STREET, GRA	NIL	16.18	NIL	67.66	67.66	PM 10	YELLOW	MODERATE
DAY 2	BODO STREET, GRA	NIL	14.71	NIL	56.44	56.44	PM 10	YELLOW	MODERATE
DAY 3	BODO STREET, GRA	NIL	14.71	NIL	54.96	54.96	PM 10	YELLOW	MODERATE
DAY 1	MILE ONE	NIL	190.69	109	78.27	190.69	SOx	RED	UNHEALTHY
DAY 2	MILE ONE	NIL	176.43	171.86	85.15	176.43	SOx	RED	UNHEALTHY
DAY 3	MILE ONE	203.85	183.87	134.11	61.72	203.85	NOx	PURPLE	VERY UNHEALTHY
DAY 4	RUMUOLA	213.08	230.46	267.17	53.47	267.17	CO	PURPLE	VERY UNHEALTHY
DAY 5	RUMUOLA	NIL	170.23	206.85	58.09	206.85	CO	PURPLE	VERY UNHEALTHY
DAY 6	RUMUOLA	NIL	249.01	119.74	86.64	249.01	SOx	PURPLE	VERY UNHEALTHY
DAY 4	ARTILLERY	259.73	183.87	138.12	73.93	259.73	NOx	PURPLE	VERY UNHEALTHY
DAY 5	ARTILLERY	NIL	173.33	85.37	67.5	173.33	SOx	RED	UNHEALTHY
DAY 6	ARTILLERY	NO SAMPLING							

CONCLUSION

Results of this study have confirmed that the dwellers or passers-by along the Rumuola, Artillery and Mile One Junctions were being exposed to high levels of the air pollutants (NO_2, SO_2, CO and SPM). Persons at the Bodo Street in New GRA, away from high traffic density, were safer and enjoy a much healthier environment. The pollutant concentrations in this study were above established ambient air quality standards for some parameters on some days. It is reasonable to assume that certain road corridors will likely exceed these reported values in future especially during the dry season and given the continued increase of vehicles in the city. The majority of public transport vehicles in Port-Harcourt are not air-conditioned and it is very likely that commuters are exposed to very high levels of pollution. A large number of people commute by two or three wheelers and thus they will have the highest exposure. The present road system in Port-Harcourt cannot cater for the need of the growing number of automobiles and the problem is being aggravated by an aging vehicle fleet, in poor mechanical conditions and low levels of fuel efficiency. The present study revealed that there is a dire need to focus on air quality management in urban areas to safeguard the public health and the environment.

RECOMMENDTIONS

The following are some of the recommendations to ensure that clean air quality is achieved in Port-Harcourt.

i. There should be an improved traffic control management in Port-Harcourt city.
ii. Introduction of an efficient mass transit system in Port-Harcourt city (train system and good ferries) to help reduce air pollution from motor vehicles with faulty and worn out engines. Also, metro and bus services should be introduced to encourage private vehicle users to switch to mass transportation.
iii. Extensive plantation (trees) to remove a significant amount of pollution from the atmosphere as part of their normal functioning. Trees normally increase the quality of the air in the city and its surroundings and should be considered an integral part of any comprehensive plan aimed at improving overall air quality.
iv. More awareness, collective preventive measures and campaigns against air pollution is needed.
v. The protocol for the checking of vehicles fitness should be strictly implemented and enforcement of laws banning old second-hand cars on the streets to be observed.
vi. Promoting the use of environment friendly alternative clean fuels.
vii. Compliance with all applicable regulations will help in reducing the menace of pollution in Port-Harcourt city and Nigeria.
viii. Air pollution monitoring stations should be put in place in Port-Harcourt city.

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