Original Research Article

Vehicular Volume and Spatial Variation of gaseous atmospheric pollutants and Particulate Matter at Selected Road Junctions in Port Harcourt, Nigeria

Abstract

The increase in industrial and vehicular activities has led to the proliferation of atmospheric pollutants in cities globally. The Niger Delta region is an industrial hub and serves as the nation's resource base by exploring crude oil. In this work, we postulated that there would be high pollutants and particulate matter at road junctions due to the multiplicity of several vehicles owned by the surging human population. We counted the number of vehicles at each junction. We used a multi-parameter gas monitor (A multi–RAE PLUS (PGM-50)) to collect air samples at different junctions ($n = 5$). We analyzed the concentration of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), particulate matter ($PM_{2.5}$, PM_{10}), temperature, relative humidity, and wind. The result revealed that the volume of the vehicles at road traffic junctions follows the order Rumuola>Mile 3/UST Roundabout>Choba Junction>Garrison>Lagos Bus Stop. Choba Junction had the highest concentration of pollutants. The highest concentration of vehicular pollutants was observed in the morning. Carbon monoxide (CO) had the highest concentration, followed by SO_2 and NO_2. While for particulate matter, $PM_{2.5}$ had a higher concentration than PM_{10}. The result implies that the number of vehicular traffic does not necessarily determine the concentration of pollutants because other anthropogenic activities are causing a spike in atmospheric pollutants within the city.

Keywords: air pollution, particulate matter, vehicles, junctions, health

Introduction

Vehicular emission has been identified to be caused by incomplete combustion of hydrocarbon fuels. In many developing countries, such as Nigeria, the rapid increase in vehicular volume has negatively affected the air quality of the environment. More worrisome is that the appropriate environmental authorities adjugated with the responsibility of mitigating the adverse effects of increased vehicular volume and deteriorating air quality have been comatose (Han & Naeher, 2006).

It is reported that motor vehicles account for 51% of carbon monoxide emissions annually, 34% of nitrogen dioxide, and 10% of particulate matter released in the United States (USEPA, 2006). On a regional level, Naude et al., (2000) revealed that road transportation significantly contributed to the elevated levels of carbon dioxide in the atmosphere in South Africa.

In Nigeria, exhaust emissions have significantly increased by over 54% from 1980 to 2005. This steady rise in carbon exhaust emissions could be attributed to increased vehicular volume and importation of old and used vehicles, as Abam & Unachukwu (2005) reported. Moreso, the study of Enemari (2001) revealed a progressive increase in vehicle registration from 38,000 to 1.6 million between 1950 and 1992.

The elevated level of carbon emissions into the atmosphere can also be attributed to traffic congestion occasioned by bad roads, low-quality petroleum products motorists use, and inadequate automobile engine maintenance. The rapid growth of the Port Harcourt metropolis has further exacerbated air quality within the city. The increase in industrial and commercial

activities within the city has resulted in the frequent use of automobiles and other transport systems, which release harmful toxic substances into the atmosphere when not regularly serviced.
Anjaneyulu (2005) defines air pollution as limited to situations in which the outer ambient atmosphere contains materials in concentrations that are harmful to man and his environment. Air quality degradation is not new, but the environmental concern is growing. The earliest pollutant noted in the atmosphere was of natural origin. Ash, fumes, smoke and forest fires, sand, and dust from windstorms in arid regions, and dews during the dry season were part of our environment long before humans; however, the industrialization of society, the explosion of the human population, and the introduction of vehicles have cause exponential growth not just to goods but also air pollution (USEPA, 1993).
According to the World Health Organization (2000), motor vehicle has been identified as one of the significant causes of air pollution in most cities worldwide.

According to Ajayi & Dosunmu (2002), the exhaust, the crankcase, the fuel tank, and the carburetor are the sources of unburned hydrocarbon (HC). However, the proportion of these pollutants attributable to the transport sector varies significantly across different cities. One of the major pollutants that humans are exposed to its harmful effect is carbon monoxide (CO). It is a colorless, odorless, non-irritant, and tasteless poisonous gas. It is a product of the incomplete combustion of hydrocarbons (such as oil, gasoline, natural gas, and coal). It occurs when carbon in the fuel is partially oxidized rather than fully oxidized to carbon dioxide (Chichkova & Prockop, 2007).

Johnson & Gerhold (2001) pointed out that carbon monoxide's worst levels of pollution are seen in such urban cities as are densely populated. Carbon monoxide is present in small amounts in the atmosphere, chiefly as a product of volcanic activities but also from natural and artificial fires (such as forest and bushfires, burning of crop residues, and sugarcane fire-cleaning). Outdoor concentrations of carbon monoxide vary depending on how, where, and when the gas is produced. For example, in urban areas, carbon monoxide levels are most significant in downtown areas where motor vehicle density is high, during peak commuting times, and in the passenger compartments of motor vehicles. Unfortunately, carbon monoxide presents an important environmental hazard, Carbon monoxide poisoning is the most common type of fatal air poisoning in many countries (Walker & Hay, 1999).

According to Ayoola (2012), if one breathes in air containing carbon monoxide (CO), this will lead to the replacement of the Oxygen (O2) present in Oxy-hemoglobin (HbO2) and becomes carboxy-hemoglobin (HbCO) which is poisonous. It reduces the flow of oxygen in the bloodstream and is particularly dangerous, is ineffective for delivering oxygen to bodily tissues, termed anoxemia (Omaye, 2002).

The health effects of carbon monoxide poisoning are enormous, ranging from impaired mental alertness and performance, headaches, nausea, fatigue, and dizziness to coma and death. Long-term (chronic) exposure includes damage to the nervous system and death. Exposure of pregnant women to CO may cause low birth weight and nervous system damage to the offspring (Henry et al., 2006).

Carbon monoxide concentrations are both short-lived in the atmosphere and spatially variable. Apart from the health implication of CO, it is also a major culprit associated with global warming, which generates ground-level ozone (Ukpebor et al., 2010).

Sulfur dioxide is another recognized pollutant because it forms cold-time smog (Hermann, 1991). It is an acidic, irritant gas formed when sulfur is exposed to oxygen at high temperatures during fossil fuel combustion, oil refining, or metal smelting. SO_2 is toxic at high concentrations, but its principal air pollution effects are associated with the formation of acid rain and aerosols which in high concentrations can cause difficulties (Purnendu, 1991).

Motor pollutants include carbon dioxide, carbon monoxide, sulfur oxide, nitrogen oxide, particulate matter, hydrocarbons, and lead (Corbitt, 1999). It is feared that, if these pollutants are unchecked, they may alter the environment to endanger even human existence on the planet. Moreso, air pollutants travel long distances, chemically reacting in the atmosphere to produce secondary pollutants such as ozone and other greenhouse gases (Enemari, 2001). The objectives of the study are: (1) to determine the spatial variation of vehicular pollutants around junctions in Port Harcourt, (2) to determine the spatial variation of suspended particulate matter around junctions in Port Harcourt, and (3) to assess the vehicular volume at selected junctions around Port Harcourt.

Materials and Methods

Research Design

The cross-sectional research was adopted as the research design of this study. The choice of this research design is premised on the fact that the study seeks to unravel the cause–effect relationship between vehicular volume and carbon exhaust emissions.

Description of Study Area

Port Harcourt is the capital of Rivers State. It is the main city in the state and has one of the largest seaports in the Niger Delta region of Nigeria. It is the hub of the state's industrial, commercial, administration, and other activities. The city lies between latitude 04^0 43’ and 04^0 57’ North of the Equator and between 06^0 53’ and 07^0 08’ East of the Greenwich Meridian. The city is surrounded by patches of islands and creeks of the Niger Delta, such as Dockyard Creek, Bonny River, and Amadi Creek, at a height of about 12m above sea level. It is approximately 60km from the crest upstream of the Bonny River and covers an estimated 1811.6 square kilometers (Obafemi, 2006). The map of Rivers State showing the Port Harcourt metropolis and the map of Port Harcourt metropolis is represented in Figures 1 and 2, respectively.

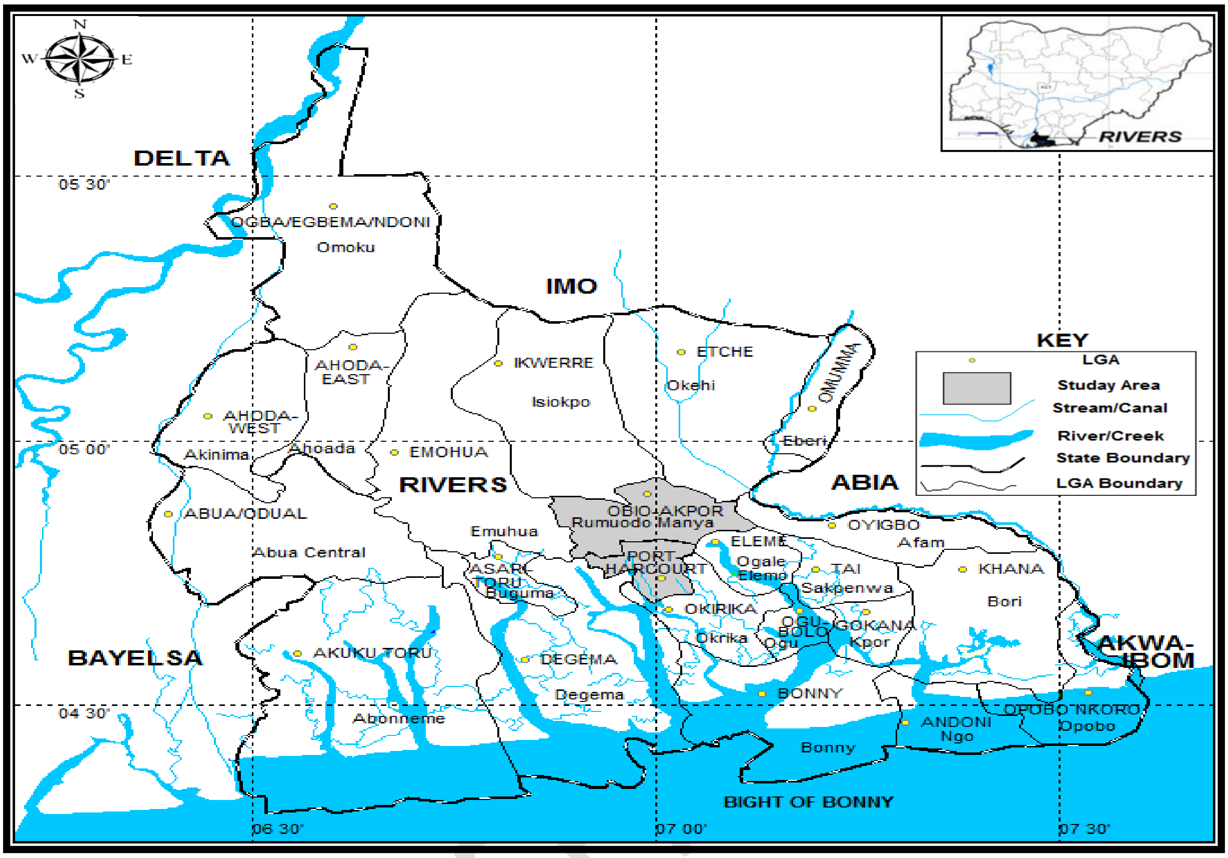

Figure 1. Map of Rivers State Showing Port Harcourt Metropolis
(Source: Cartography/GIS Laboratory, Department of Geography and Environmental Management, University of Port Harcourt, Choba).

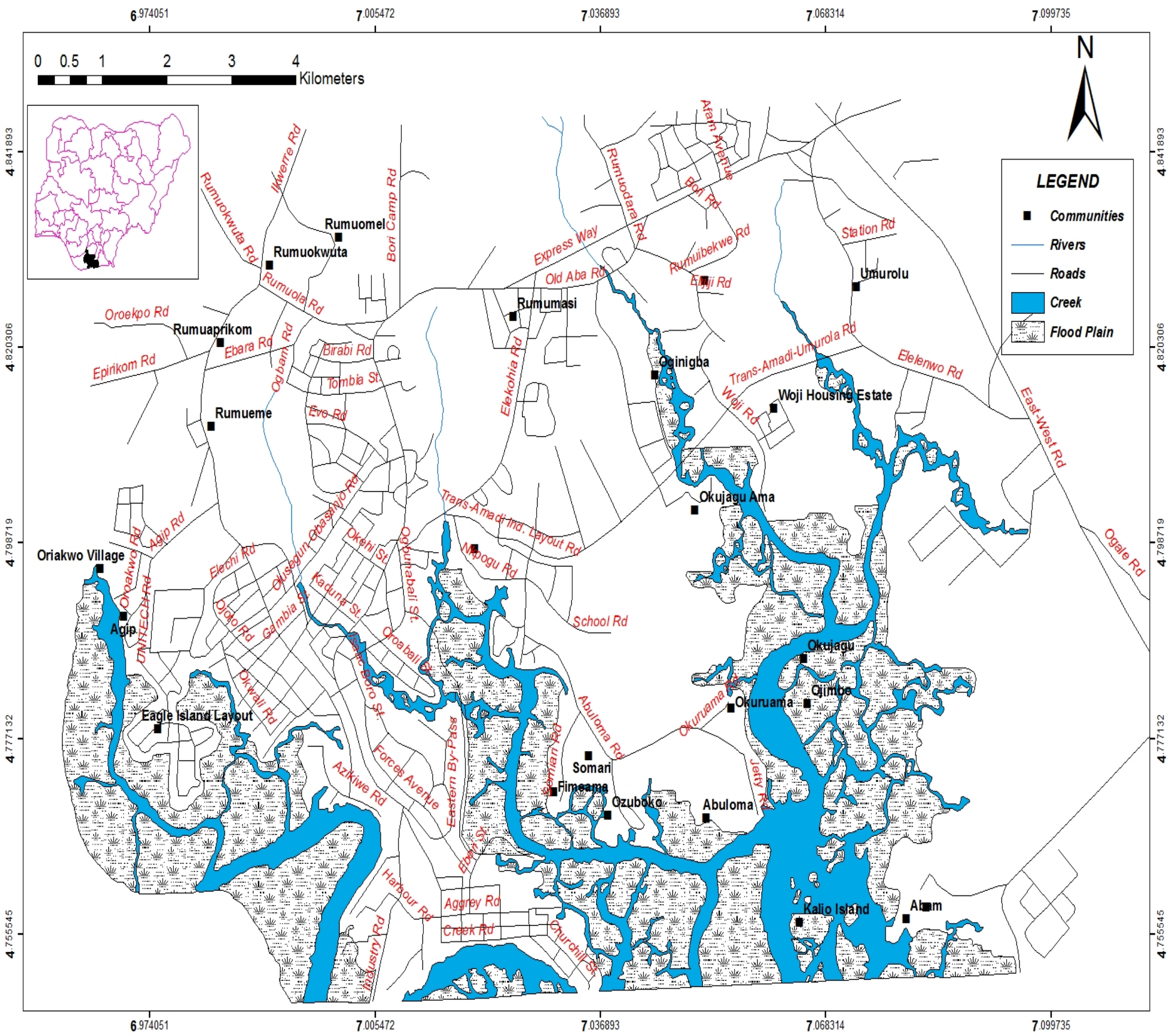

Figure 2. Map of Port Harcourt Metropolis, Nigeria
(Source: Cartography/GIS Laboratory, Department of Geography and Environmental Management, University of Port Harcourt, Choba).

Port Harcourt enjoys the tropical hot monsoon climate because of its latitudinal position. Heavy rainfall and high temperature all year round is one of the unique characteristics of the tropical monsoon climate. The excessive temperature is accounted for by its latitudinal position of just 4^0 North of the equator. Similarly, its geographical contiguity to the Atlantic Ocean is one of the reasons for the heavy rainfall witnessed within the region (Osuiwu & Ologunorisa, 1999). The mean annual rainfall ranges from 2000mm to over 4000mm. The rainy season which starts from April through October has double maxima characteristics. It has rainfall peaks in July and September with a little August break. However, this August break period has been fluctuating recently due to the ever-changing climate (Mmom, 2003). The relative humidity is enormously high throughout the year, while the diurnal temperature ranges between 25^0C and 30^0C (Ashton, 1998). The region's climate is prompted by two principal air masses viz; the tropical maritime and tropical continental air masses. The tropical maritime is a moisture-laden air mass that originates from the Atlantic Ocean and blows onshore. The high equatorial temperature causes the air mass to evaporate moisture from the surface of the Atlantic Ocean. As the moisture rises, it is carried by the Southwest monsoon wind into the Delta. Alternatively, the

tropical continental air mass is a dry wind that blows offshore from the hinterland, bringing the dry season between late November and March. It is accompanied by a dry, dusty wind (Harmattan) (Mmom, 2003).
The city has a top soil layer of soft mud about 6m thick, having high organic materials in the delta area and a relatively high water table. An upper soil layer of silt and sand of identical thickness is found in the dry land area. Because the soil type of Port Harcourt is a mix of silty clays and sand, it can be categorized geologically under the Benin formation. The superficial soils of the region consist of reddish-brown sand clay loam; brown sandy soil; light gray, slightly organic fine sand soils; silty clay, and dark organic clay soils (Obafemi, 2006). The soil of the area includes various forms of superficial deposits overlying thick tertiary sandy and clayey deposits, which are over 100 m thick in places. The continuously high rainfall and temperature of the area encourage excessive chemical weathering of the rocks, which results in the formation of ubiquitous clay minerals in the area (Wizor, 2012).

Sample and Sampling Techniques

The sample size includes five locations selected within Port Harcourt. The selected locations include Choba Junction, Rumuokoro Junction, Garrison Junction, Mile 3/UST roundabout, and Lagos Bus Stop. The purposive sampling technique was deployed to select the five road traffic junctions within the city. The selection criterion is that each sampling site must be a high-traffic density road junction. The parameters that were measured include air temperature, relative humidity, wind speed, nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and suspended particulate matter (SPM).

Air Quality

Sampling and measurements of the chemical constituents of atmospheric pollutants were carried out in situ with hand-held air quality monitors. A multi–RAE PLUS (PGM-50), a programmable multi-gas monitor with an electrochemical sensor, was used to detect NO_2 and SO_2. The range of detection is between 0-20ppm with a resolution of 0.0lppm. The alarm set point (low/high) was set at 2 and 10 ppm, respectively. Measurements were taken by holding the sensor to a height of about 1.5 meters in the direction of the prevailing wind, and readings were recorded at stability.

An ELE Analox Sensor Gas Monitor Model GC 401 was used to detect CO. The equipment detects CO via an electrochemical sensor that generates a signal linearly proportional to the concentration of the gas. The detection range is between 0-500ppm, and the detection limit is ppm. Measurements were taken by holding the sensor to a height of about 1.5 meters in the direction of the prevailing wind, and readings were recorded at stability.

Suspended Particulate Matter (SPM)

A Met One Instrument, Inc Aerosol Mass Monitor was used to measure suspended Particulate matter (SPM). This ambient particulate monitor with recorder collects and records "real-time" information on airborne particulate concentration and provides continuous particle monitoring. A laser optical sensor for detecting and measuring particulate concentration up to 1 milligram per cubic meter is included. Measurements were collected at each selected location for the morning peak (7:00-9:00 am) and an evening peak (5:00-7:00 pm) daily for five days. The traffic flow pattern is uninterrupted; hence the measurements were taken at the road's median for a double carriageway and at the side of the road for a single carriageway. All measurements were taken at 1.5 meters above ground level, the average height of a person exposed to pollution from traffic sources. A five-minute manual count of the passing vehicles shall be undertaken to ascertain the vehicular volume.

The air quality gas monitors and sampling devices were calibrated and operated according to specifications. They were reset and allowed to stabilize before and after every reading. The batteries were inspected periodically to ensure they were in perfect working condition and were replaced when they became weak. While the measurements were going on, there arose the need to adjust the height of the equipment between one (1) and two (2) meters above the ground to ensure that the values were exact representations of pollution from traffic sources.

Statistical analysis

The study utilized quantitative techniques in data presentation and analysis. Mean values for the selected road junctions were computed and presented in tables. Hypothesis 1, stated for the study, was tested using the One-way ANOVA. The variations in different parameters studied were computed to determine the spatial variation of each parameter across the selected road junctions in the study area. Hypothesis 2 stated for the study was tested using the Pearson Product Moment Correlation (PPMC) Statistics. This was performed in order to show the relationship between meteorological conditions and atmospheric pollutants observed at the selected road junctions. The computer software used for the statistical analysis is Statistical Package for Social Sciences (SPSS), version 21.

Results

The concentration of vehicular pollutants

Table 1 below reveals the mean concentration levels of vehicular pollutants at selected road junctions during the morning and evening peak periods. The results showed that the mean concentration of carbon monoxide ranged from a lowest of 13ppm at Lagos Bus Stop in the morning to a highest of 27.2ppm at Rumuola Bus Stop in the morning. Sulfur dioxide concentration was below the detection limit at Lagos Bus Stop, while the highest concentration was observed at Choba junction with a concentration of 0.6 ppm. Nitrogen oxide concentration was below the detection limit at all the selected road traffic junctions except for Choba Junction, which recorded a mean concentration of 0.02 ppm. Generally, the concentration of vehicular pollutants was higher in the morning than in the evening except for the carbon monoxide concentrations of Mile 3/ UST Roundabout and Lagos Bus Stop.

Table 1. Mean Concentration of Vehicular Pollutants around some junctions in Port Harcourt, Nigeria.

Study Locations	Time	Carbon Monoxide (ppm)	Sulfur dioxide (ppm)	Nitrogen oxides (ppm)
Choba	Morning	24.8	0.6	0.02
Junction	Evening	17.2	0.2	0.00
Rumuola	Morning	27.2	0.2	0.00
Bus Stop	Evening	17	0.2	0.00
Garrison	Morning	19.8	0.0	0.00
Bus Stop	Evening	15.8	0.4	0.00
Mile 3/ UST	Morning	21.6	0.25	0.00
Roundabout	Evening	22.8	0.2	0.00
Lagos	Morning	13	0.0	0.00
Bus Stop	Evening	17.8	0.0	0.00

Table 2 below reveals the mean concentration of particulate matter at selected road junctions during the morning and evening peak periods. The results showed that the mean concentration of $PM_{2.5}$ ranged from a lowest of 71.4µg/m3 at the garrison bus stop in the evening to a highest of 162.6µg/m3 at the Choba junction in the morning. The results also showed that the mean concentration of PM_{10} ranged from a lowest of 78.2µg/m3 at the Garrison bus stop in the evening to a highest of 174.4µg/m3 at the Choba junction in the morning. Generally, the concentration levels of the particulate matter were higher in the morning peak periods than in the evening peak periods.

Table 2. Mean Concentration of Particulate Matter around some junctions in Port Harcourt, River State, Nigeria

Study Locations	Time	PM2.5 (µg/m3)	PM10 (µg/m3)
Choba	Morning	162.6	174.4
Junction	Evening	76.4	91.8
Rumuola	Morning	116.6	138
Bus Stop	Evening	75	87.6
Garrison	Morning	122.4	129.4
Bus Stop	Evening	71.4	78.2
Mile 3/ UST	Morning	98.7	115.4
Roundabout	Evening	88.2	102.4
Lagos Bus	Morning	90.8	101
Stop	Evening	77.4	86.4

Spatial Variation of Vehicular Pollutants and Suspended Particulate Matter

The analysis of the spatial variation of carbon monoxide is revealed in Figure 3 below, which reveals that the mean concentration of carbon monoxide was highest at Mile 3/ UST roundabout and Rumuola bus stop, while the least concentration of carbon monoxide was recorded at Lagos bus stop.

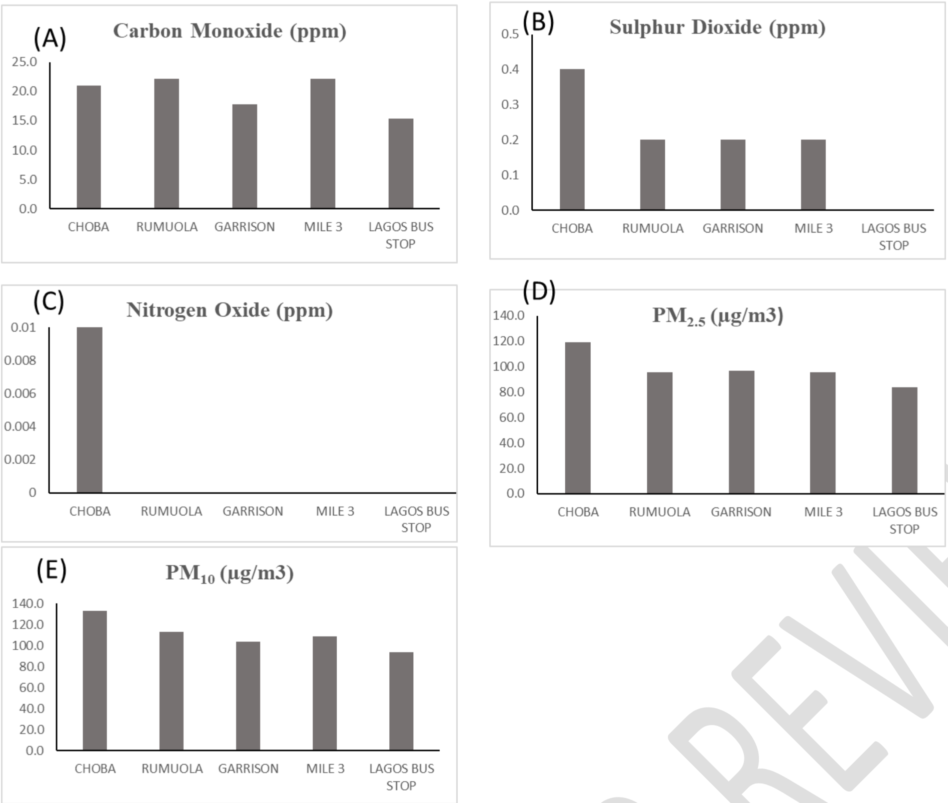

Figure 3. Spatial Variation (concentrations) of (A) Carbon Monoxide, (B) Sulphur Dioxide, (C) Nitrogen Oxide. (D) $PM_{2.5}$, and (E) PM_{10}. The mean concentration of gaseous pollutants is highest in Choba.

Assessment of Vehicular Volume at Selected Road Junctions

Table 3 below reveals the vehicular volume at selected road traffic junctions. The results showed that day 3 recorded the highest volume of vehicular traffic while day 2 witnessed the least.

Table 3. Vehicular Volume at Selected Road Traffic Junctions in Port Harcourt, Rivers, Nigeria

Days	Choba Junction	Rumuola	Garrison	Mile 3/ UST R/About	Lagos Bus Stop	Daily Total
Day 1	357	416	308	342	234	1657
Day 2	304	356	218	355	196	1429
Day 3	367	396	326	417	201	1707
Day 4	337	381	301	350	190	1559
Day 5	347	402	281	375	228	1633
Total	1712	1951	1434	1839	1049	7985

For the five days under study, the Rumuola bus stop recorded the highest volume of vehicular traffic with a value of 1951 automobiles**,** while the least volume of vehicular traffic was witnessed in the Lagos bus stop with a value of 1049 automobiles, as shown in Figure 4 below.

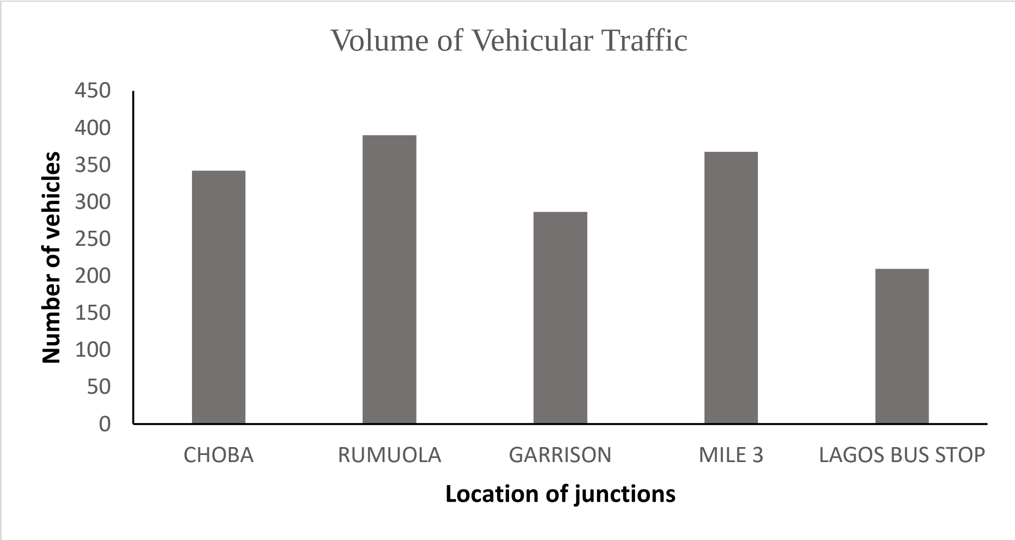

Figure 4. The volume of vehicular traffic around some junctions in Port Harcourt, Nigeria

The ANOVA result revealed no significant difference in carbon monoxide, temperature, relative humidity, wind speed, $PM_{2.5,}$ and PM_{10} across the selected road junctions in Port Harcourt ($F_{7, 3241}$, 0.814, P=0.575). Similarly, the second hypothesis reveals that there was no significant difference between the concentration levels of carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxide (NO_2), and particulate matter at selected road junctions in Port Harcourt (P>0.05).

Table 4 below reveals the Pearson product-moment correlation computed for hypothesis 2. The correlation table revealed that there is no statistically significant relationship between vehicular count and the concentration levels of carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen oxide (NO_2), as their p-values were greater than the critical value of α=0.05.

Table 4. Pearson Product Moment Correlation Computed for Hypothesis 2

		Carbon monoxide	Sulfur dioxide	Nitrogen Oxide	Temp.	Relative Humidity	Wind Speed	$PM_{2.5}$	PM_{10}
Carbon monoxide	Pearson Correlation	1	.409	.409	.562	.432	-.169	.663*	.739*
	Sig.(2tailed)		.240	.241	.091	.213	.641	.036	.015
	N	10	10	10	10	10	10	10	10
Sulfur dioxide	Pearson Correlation	.409	1	.733*	.394	.204	-.239	.435	.442
	Sig.(2tailed)	.240		.016	.259	.572	.506	.209	.200
	N	10	10	10	10	10	10	10	10
Nitrogen Oxide	Pearson Correlation	.409	.733*	1	-.623	.468	-.596	.793**	.760*
	Sig.(2tailed)	.241	.016		.054	.172	.069	.006	.011
	N	10	10	10	10	10	10	10	10
Temp	Pearson Correlation	-.562	-.394	-.623	1	-.958**	.380	-.856**	-.891**
	Sig. (2-tailed)	.091	.259	.054		.000	.279	**.002**	**.001**
	N	10	10	10	10	10	10	10	10
Relative Humidity	Pearson Correlation	.432	.204	.468	.958**	1	-.223	.799**	.820**
	Sig. (2-tailed)	.213	.572	.172	.000		.536	**.006**	**.004**
	N	10	10	10	10	10	10	10	10
Wind Speed	Pearson Correlation	-.169	-.239	-.596	.380	-.223	1	-.377	-.380
	Sig. (2-tailed)	.641	.506	.069	.279	.536		.283	.279
	N	10	10	10	10	10	10	10	10
$PM_{2.5}$	Pearson Correlation	.663*	.435	.793**	-.856**	.799**	-.377	1	.988**
	Sig. (2-tailed)	.036	.209	.006	.002	.006	.283		.000
	N	10	10	10	10	10	10	10	10
PM_{10}	Pearson Correlation	.739*	.442	.760*	-.891**	.820**	-.380	.988**	1
	Sig. (2-tailed)	.015	.200	.011	.001	.004	.279	.000	
	N	10	10	10	10	10	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5 below shows the Pearson product-moment correlation computed for hypothesis 3. The correlation table revealed a p-value of 0.047 for the relationship between carbon monoxide and vehicular count. Since the p-value of 0.047 is less than the critical value of 0.05, the alternate hypothesis, which states that there is a statistically significant relationship between carbon monoxide concentration levels and vehicular count, is upheld. However, it was also discovered that the relationship between nitrogen oxide, sulfur dioxide, and the vehicular count was not statistically significant, as its p-values were greater than the critical value of $\alpha=0.05$, which implies that the null hypothesis is upheld. Therefore, the research revealed no statistically significant relationship between nitrogen oxide, sulfur dioxide concentration levels, and vehicular count.

Table 5. Pearson Product Moment Correlation for atmospheric pollutants and vehicular counts

		Carbon monoxide	**Sulfur dioxide**	**Nitrogen Oxide**	**Vehicular Count**
Carbon monoxide	Pearson Correlation	1	.409	.409	.637*
	Sig. (2-tailed)		.240	.241	**.047**
	N	10	10	10	10
Sulfur dioxide	Pearson Correlation	.409	1	.733*	.621
	Sig. (2-tailed)	.240		.016	.055
	N	10	10	10	10
Nitrogen Oxide	Pearson Correlation	.409	.733*	1	.261
	Sig. (2-tailed)	.241	.016		.466
	N	10	10	10	10
Vehicular Count	Pearson Correlation	.637*	.621	.261	1
	Sig. (2-tailed)	.047	.055	.466	
	N	10	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed).

Discussion

This research revealed a slight variation in the mean concentration levels of carbon monoxide and particulate matter across the selected study locations. The finding of this study is in line with the study of Iwuala & Oriaku (2019), who revealed in their separate study of the spatiotemporal emissions from road transport that the arithmetic mean of the different study locations varied slightly. This could be attributed to each junction's characteristics and traffic flow in each study location.

This study revealed slight variations in vehicular volume across the selected study locations. It was also revealed that vehicular volume was higher during the morning peak period than in the evening peak period. This study's finding agrees with the previous research findings of Obadina & Akinyemi (2018), whose study revealed that the volume of vehicular traffic (VVT) was higher in the morning than evening.

On the contrary, studies have revealed that temperature and relative humidity had a statistically significant relationship with the concentrations of $PM_{2.5}$ and PM_{10}. The finding of this study agrees with the findings of Giri et al., (2008), who observed that variations in PM_{10} concentrations are partly attributed to changes in the meteorological conditions.

The finding of this research reveals no statistically significant relationship between the concentration of nitrogen oxide, sulfur dioxide, and vehicular count. However, the research revealed a statistically significant relationship between the concentration of carbon monoxide and vehicular count. The finding of this study agrees with the earlier findings of Emenike &

Orjinmo (2017), who observed a strong correlation between total vehicle count and carbon monoxide. The high concentration of carbon monoxide around the junction in Port Harcourt is a result of the incomplete combustion of faulty and old second-handed cars that have flooded the streets in recent times. In addition to vehicular movement, human activities such as cooking, frying, burning waste, etc., contribute to increased atmospheric pollutants, especially carbon monoxide. Industrial activities are also common within and around Port Harcourt.

This research revealed that the mean nitrogen oxide concentration did not exceed the National Ambient Air Quality Standards (NAAQS) stipulated limit of 0.06 ppm. However, the study revealed that the mean concentration of sulfur dioxide exceeded the National Ambient Air Quality Standards (NAAQS) stipulated limit of 0.1ppm in all the selected locations except the Lagos bus stop, which was below the detection limit. In the same vein, the mean concentration of carbon monoxide exceeded the National Ambient Air Quality Standards (NAAQS) stipulated limit of 20 ppm in all the selected locations except the Garrison bus stop and Lagos bus stop. However, the concentration of particulate matter in all the selected locations did not exceed the National Ambient Air Quality Standards (NAAQS) stipulated limit of 250µg/m^3. The findings of this research agree with the findings of Asin et al., (2016), who revealed that the mean concentrations of CO, SO_2, and NO_x pollutants were much higher than the Federal Ministry of Environment limit.

Conclusion

The study also ascertained the temporal variation of vehicular traffic, which revealed that the volume of vehicular traffic was higher in the morning than in the evening peak period. This research reveals no statistically significant difference between the nitrogen oxide concentration, sulfur dioxide, and vehicular count. However, the research revealed a statistically significant difference between carbon monoxide concentration levels and vehicular count. This study has shown that vehicles are among the significant contributors to air pollution along road transport routes. The rising number of vehicle owners has led to high traffic volume in urban areas and city centers. The problem is that older vehicles associated with higher emission rates of vehicular pollutants still ply our transport routes. Furthermore, the lack of maintenance and periodic servicing of vehicle engines has further exacerbated the emission of these pollutants into the environment. The study has shown that carbon monoxide and sulfur dioxide at the road transport routes exceeded the National Ambient Air Quality Standards (NAAQS) stipulated limits. Therefore, It is important to note that this can pose a significant health hazard to commuters and passers-by, especially those who spend long periods along these road transport routes.

References

Abam, F.I., & Unachukwu., G.O. (2009). Vehicular Emissions and Air Quality Standards in Nigeria. *European Journal of Scientific Research*, 34, 550-552.

Ajayi, A., & Dosunmu, O. (2002). Environmental Hazards of Importing Used Vehicles into Nigeria. Proceedings of International Symposium on Environmental Pollution Control and Waste Management. Retrieved from http://www.geocities.jp/epcowmjp/EPCOWM2002/521-532ajayi.pdf.

Anjaneyulu, Y. (2005). *Introduction to Environmental Science*. India: BS Publications Hyderabad.

Ashton-Jones N. (1998). *The Human Ecology of the Niger Delta*.An Era Handbook. Benin City: Environmental Right Action Group.

Ayoola T.J (2012) Gas Flaring and its Implication for Environmental Accounting. *Journal of Sustainable Development Nigeria,* 4(5), 123-145.

Chichkova, R.I., & Prockop, L.D. (2007). Carbon Monoxide Intoxication: An Updated Review. *Journal of the Neurological Sciences*, 262(1-2), 122–130.

Corbitt, R. A. (1999). *Standard Handbook of Environmental Engineering* (2nd Ed). New York: McGraw-Hill.

Emenike, G. C. & Orjinmo, C. (2017) Vehicular Emissions around Bus Stops in Port Harcourt Metropolis, Rivers State, Nigeria. *European Journal of Research in Social Sciences*, 5(3), 19-36.

Enemari, J. J. (2001). 'Vehicular Emissions, the Environment and Health Implication'. Retrieved from: http://www. airinpacts.org/document/local/articides – 36255-5pdf.pdf-

Giri D., Murthy, K.V., & Adhikary, P.R. (2008). The Influence of Meteorological Conditions on PM_{10} Concentrations in Kathmandu Valley. *Int. J. Environ. Res,* 2, 49-60.

Han, X., & Naeher, L. (2006). A Review of Traffic-Related Air Pollution Exposure Assessment Studies in the Developing World. Environment International Conference, 2006 January, 30.

Henry, C.R., Satran, D., Lindgren, B., Adkinson, C., Nicholson, C.I., & Henry, T.D. (2006). Myocardial Injury and Long-term Mortality Following Moderate to Severe Carbon Monoxide Poisoning. *JAMA,* 295(4), 398- 402. DOI:10.1001/jama.295.4.398.

Iwuala, I.S., & Oriaku, T. O. (2019). Assessment of Vehicular Carbon Dioxide Emission at Major Road Intersections in Benin City, Edo State Nigeria. Paper presented at the SPE Nigeria Annual International Conference and Exhibition, Lagos, Nigeria, August 2019. doi https://doi.org/10.2118/198780-MS.

Johnson, A.D. & Gerhold, H.D (2001). Carbon Storage by Utility-Compatible Trees. J.Arboricult.,27, 57-68.

Mon, P.C. (2003). The Niger Delta; A Spatial Perspective to Its Development. Zelon Enterprises, Portharcourt.

Naude, C.M., Meyer, A., Coovadia, T. & Pretorius, J. (2000). Unpublished. Mitigating Options: Transport Sector Report. Prepared for the SA Country Studies Programme.

Obadina, E.O. & Akinyemi, C. Y. (2018). Analysis of Traffic Congestion on Lagos/Abeokuta Expressway-Agege Motorway in Lagos Metropolis. *Journal of Environment and Earth Science,* 8(1), 7-17.

Obafemi, A. A. (2006) *Spatio Temporal Analysis of Noise Pollution in Port Harcourt Metropolis.* Ph.D. Dissertation, Department of Geography and Environmental Management, University of Port Harcourt, Choba, Rivers State.

Omaye, S.T. (2002). Metabolic Modulation of Carbon Monoxide Toxicity. *Toxicology*, 180(2), 139–50. doi:10.1016/S0300-483X(02)00387-6. PMID

Osuiwu, B.O and Ologunorisa, T.E.,(1999) "Weather and Climate", In Oyegun, C.U & Adeyemo, A.(Ed): Port Harcourt Region, Paragraphics Port Harcourt

Punaendu, K.D. (1991). Fluorometric Determination of Atmospheric Sulphur Dioxide without Tetrachloromercurate (II). *Anal. Chem*., 53, 2084-2087.

Ukpebor, E. Ukpebor, E.J., Eromomene, F., Odiase, J.I., & Okoro, D. (2010). Spatial and diurnal variations of carbon monoxide (CO) Promotion from Motor Vehicles in an urban center. *Polish Journal of Environmental Studies*, 19 (4), 817-823

USEPA (2006). United States Environmental Protection Agency. 'National Air Quality and Emissions Trends Report, Technical Support Division, US Environmental Protection Agency, Office of Air and Radiation, Office of Air Quality Planning and EPA-450/490- 011.

USEPA, (1993). Guide to Environmental Issues, Doc. No. 520/B-94-01 United States Environmental Protection Agency, Washington, DC, USA.

Walker, E., & Hay, A. (1999). Carbon Monoxide Poisoning. *BMJ*, 319, 1082-1089.

Wizor, C. H. (2012). *Analysis of the Developmental Trends of Single-Family Housing Estates in Port Harcourt Metropolitan Fringe Areas*. Ph.D. Dissertation, Department of Geography and Environmental Management, University of Port Harcourt, Choba, Rivers State.

World Health Organization (2000). Air Quality Guidelines for Europe, World Health Organization Regional Office for Europe, Copenhagen.