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Comparative Study on Monthly Variations of Traffic-Related Ozone and Its Precursors in High and Low Vehicular Emission Areas: Education Perspective

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ABSTRACT

Emissions from vehicular traffic reduce air quality and increase the concentrations of precursor pollutants (NO_2, CO, and VOCs), thus influencing the variation of ground-level O_3 in the air. This study compares the monthly variations in concentrations of traffic-related O_3 and its precursors in high and low vehicular emission areas, carried out *in situ* using AeroQUAL 500 portable air analyzer across the three traffic periods [morning peak, off-peak (afternoon), and evening peak] for twelve months. Information on traffic flow was obtained by direct counting. Monthly concentrations of pollutants compared with the Nigerian Ambient Air Quality Standard (NAAQS) limits showed that maximum concentration for NO_2 (0.090 ppm), VOCs (1.927 ppm), and O_3 (0.063 ppm) were higher than the NAAQS limits of 0.04 – 0.06 ppm, 0.050 ppm and 0.060 ppm for NO_2, VOCs and O_3 respectively, informing the need to educate people in this area.

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1. INTRODUCTION

Emissions from road transport vehicles have been on the increase and in turn have increased the concentration of traffic-related pollutants such as nitrogen dioxide (NO_2), carbon monoxide (CO), and volatile organic compounds (VOCs) in the atmosphere (Okon *et al*., 2021a). These primary pollutants from vehicular emissions have been found to show a significant correlation with traffic flow and tropospheric ozone (O_3) (Ekwumemgbo *et al*., 2016). The concentration of these pollutants in the atmosphere could be influenced by vehicular traffic composition, for instance, the highest concentration of 0.045 ± 0.002 ppm for NO_2 was found at Kwangila Fly-Over during the evening peak traffic period resulting from a high number of heavy-duty vehicles in traffic composition, as heavy-duty vehicles emit more NO_2 than light vehicles naturally (Ekwumemgbo *et al*., 2015). Monthly variations of these vehicular emission pollutants can also be influenced by seasonal changes, Okon *et al*. (2021b) observed higher levels of these pollutants (NO_2, CO, VOCs, O_3) in the dry season compared to the rainy season ($p \leq 0.05$).

NO_2, CO, and VOCs as precursors to O_3 are emitted directly from the fuel combustion process, this is not so for O_3 as it is formed photochemically from these precursor pollutants released during the combustion (Sharma *et al*., 2017; Wałaszek *et al*., 2018). Photochemical formation of O_3 depends on the amount and availability of precursors, which are primarily NO_2, CO, and VOCs and it is subjected to levels of meteorological factors including wind speed, temperature, and humidity (Nidhi *et al*., 2015; Sharma *et al*., 2017; Warmiński and Bęś, 2018). During the complete combustion of pure fuel in auto-engines, carbon (IV) dioxide (CO_2) and water (HO_2) are formed according to the simple general expression in Equation 1.

$$\mathrm{Fuel} + O_2 \rightarrow CO_2 + H_2O \qquad (1)$$

When there is incomplete combustion of some molecules of the fuel, CO, and HCs (hydrocarbons otherwise known as volatile organic compounds, VOCs) are produced in addition to the CO_2 and HO_2. Okonkwo *et al*. (2014) in the study of automobile-induced pollution in Port-Harcourt expressed this incomplete combustion as shown in Equation 2.

$$3HC\,[\mathrm{Fuel}] + 2O_2 \rightarrow CO_2 + H_2O + CO + HCs \qquad (2)$$

However, due to the presence of impurities like sulfur in fuel and the presence of a high amount of nitrogen in the burning air, other products like SO_2 and NO_2 are also formed as products. For instance, in the fuel combustion process given in https://cefrc.princeton.edu/sites/g/files/toruqf1071/files/reitz_princeton-day1-hour12018.pdf as expressed in Equation 3, the nitrogen molecule formed from fuel combustion can combine with oxygen to form NO_2 and other NOx as products from fuel combustion in auto-engines.

$$C_8H_{18} + 12.5(O_2 + 3.76N_2) \rightarrow 8CO_2 + 9H_2O + 47N_2 \qquad (3)$$

These primary Pollutants (NO_2, CO, and VOCs) from vehicular emissions resulting from fuel combustion can form O_3, which is a secondary pollutant through photochemical reactions as simply presented in Equations 4, 5, and 6.

$$NO_2 + \mathrm{uv\ light} \rightarrow O + NO \qquad (4a)$$

$$O + O_2 \rightarrow O_3 \qquad (4b)$$

$$CO + 2O_2 \rightarrow CO_2 + O_3 \qquad (5)$$

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$$RH + 2O_2 + uv \xrightarrow{NOx,\ OH^{\cdot}} \rightarrow\rightarrow RCHO + H_2O + 2O_3 \quad (6)$$

O_3 is a greenhouse gas, which can create an impact on climate (Melkonyan and Wagner, 2013). Tropospheric ozone causes ill health to both plants and humans (Karthik *et al*., 2017). its precursors mainly NO_2, VOCs, and CO cause asthma aggravation, cancer, and carboxyhemoglobin in the blood of humans respectively (Wen-Tien, 2016; Jason *et al*., 2017). This paper, therefore, compares the monthly variation of traffic-related ozone and its precursor pollutants in high and low vehicular emissions areas of Port Harcourt, Nigeria.

2. METHOD

2.1. Study Area

Port Harcourt city in Nigeria was the study area; Port Harcourt is located along the coastal region of the southern part of Nigeria. In terms of geographical location, it is located in latitudes between 4°44' 58.8''N and 4°56' 4.6''N and longitudes between 6°52' 7.2''E and 7°7' 37.7''E (Robert, 2015; Emenike and Orjinmo, 2017). The city area is about 664 square kilometers with a metropolitan area of 934 square kilometers and is open to the outside world by land, sea, and air (Igbokwe *et al*., 2016). The study was conducted in the high and low vehicular-traffic areas of the city. The high vehicular-traffic area contains three major roads namely: Port Harcourt- Aba Express Road, East-West Road, and the Ikwerre Road. This area of Port Harcourt is of very high vehicular traffic resulting from the fact that the three main roads connect to feeder roads that lead to virtually all parts of the city (Kio-Lawson and Dekor, 2014). The low vehicular-traffic area of the city was the old Government Reservation Area (GRA). **Figure 1** shows a map of the study area (Port Harcourt in Nigeria).

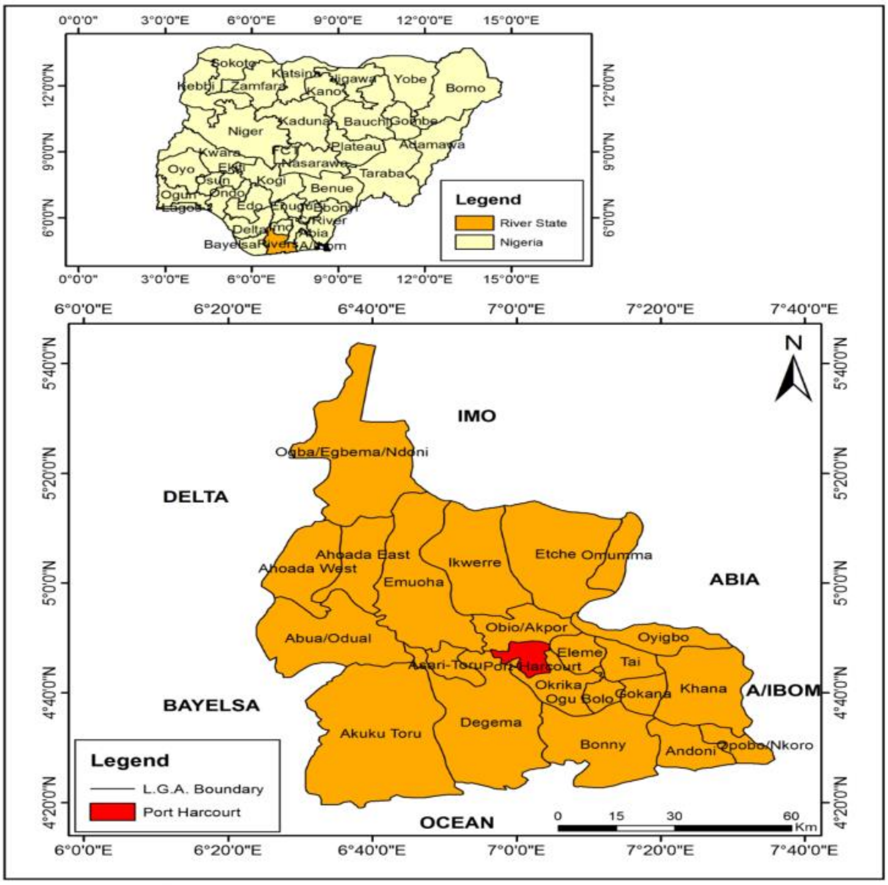

Figure 1. Map of study area.

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2.2. Sampling Sites

Ten junctions were used as sampling sites; this comprised eight high vehicular traffic junctions located along the three major roads. The eight Junctions are Water Lines, Air Force, Rumukwurushi, Eliogbolo, Rumuokoro, Nkpolu, Rumukwuta, and Rumuola. The remaining two (2) junctions, which are Odi and Opukuma along Force Avenue, are located in the low vehicular-traffic area of the city. **Figure 2** sampling shows the sampling sites.

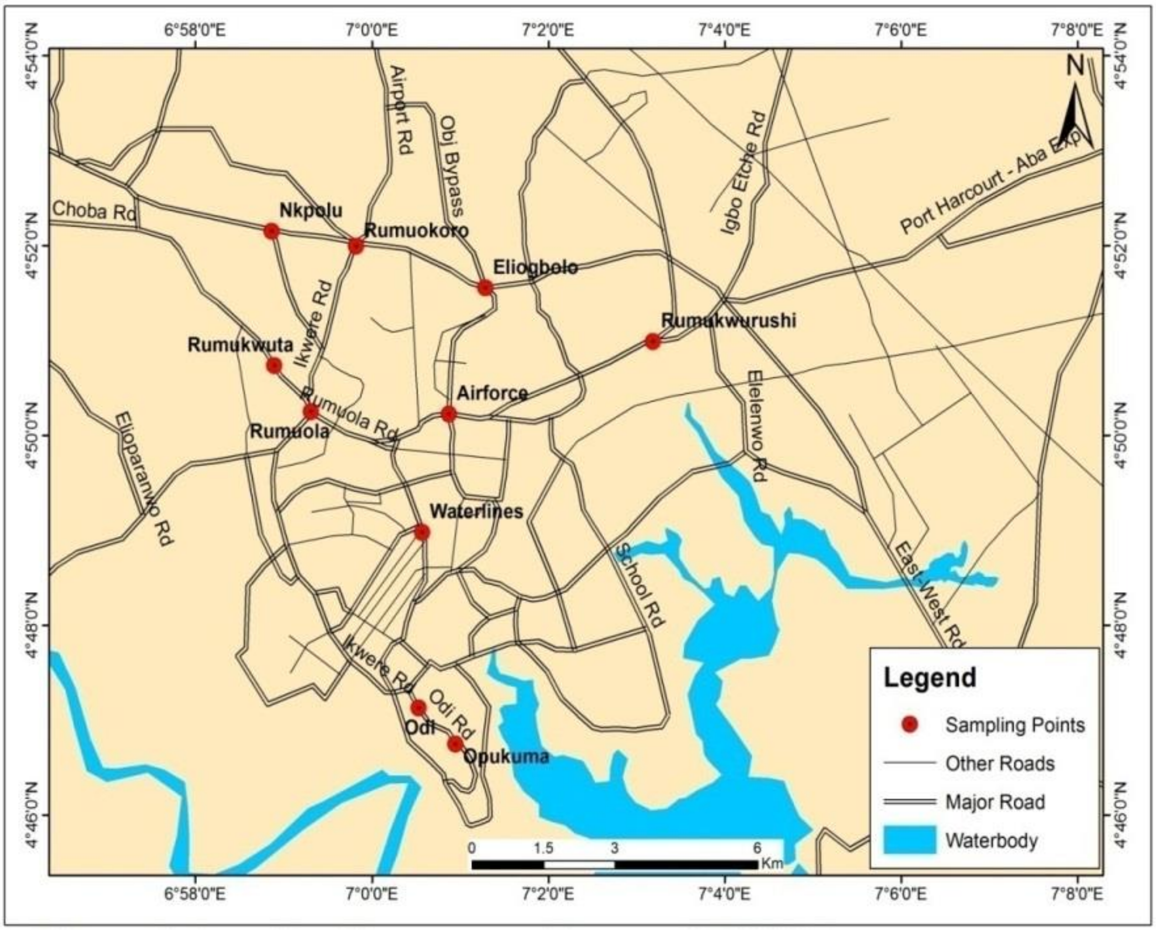

Figure 2. Sampling sites. Source: Okon *et al*. (2021a).

2.3. Data Collection and Statistical Data Analyses

Data were collected from December 2017 to November 2018. Data on levels of O_3 and its precursor pollutants (NO_2, CO, and VOCs) and vehicular traffic density were collected. The concentrations of O_3, NO_2, CO, and VOCs were measured monthly using the air autosampler (AeroQUAL 500 series portable ambient air analyzer) while traffic flow data was obtained through the tally sheet method. Data from the low vehicular-traffic area of Port Harcourt were collected according to the method contained in Okon *et al*. (2021a). Data from the high vehicular-traffic area are from Ekwumemgbo and Okon (2023). Data were presented in Tables and graphs, descriptive statistics were used for analysis.

2.4. Quality Assurance and Quality Control of Data Collected

2.4.1. Zero calibration of the AeroQual gas analyzer sensors used

For quality assurance and quality control of data collected, zero calibration of the AeroQual analyzer sensors used were carried out by delivering a certified clean air known as zero air (air that does not contain the analyte gas) to the sensor head and monitoring the response.

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In carrying out zero calibration for each sensor, the sensor was on and warmed up for three minutes, after which its air inlet was inserted into the air outlet of the calibration apparatus. Zero air was made to flow from the calibration apparatus into the sensor through the inlet of the sensor for ten minutes. The sensor was monitored to make sure it gives a zero reading. For a non-zero reading, an adjustment was made so that the monitor reports zero concentration of the analyte gas which the sensor is to measure. Zero calibration of the analyzer sensors was carried out once in six months. This was done for quality assurance of the data obtained from measurement using the analyzer.

2.4.2. Bump test on the AeroQual gas analyzer sensors used

Further on quality assurance, each of the air sensors was subjected to an accuracy test before carrying out measurements by subjecting the sensor to a bump test. The bump test was carried out by exposing the sensor to a known concentration of the gas to be measured and making sure the monitor reading corresponds with that concentration. A bump test was conducted on the sensors before measuring for each month during the study.

3. RESULTS AND DISCUSSION

3.1. Monthly Variation in Levels of Pollutants

The Monthly variation in concentrations (ppm) of O_3 and its precursor pollutants (NO_2, CO, and VOCs) across high vehicular-traffic areas (AHVA) and across low vehicular-traffic areas (ALVA) are presented in **Figures 3 – 7**.

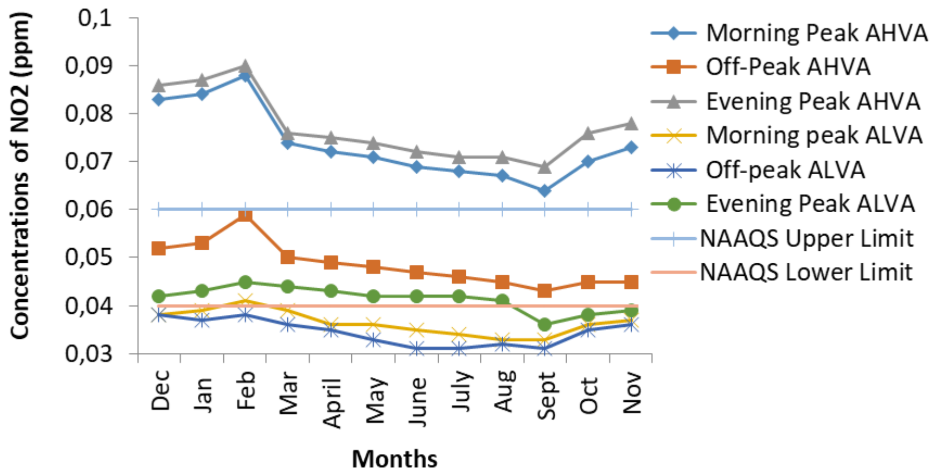

Figure 3. Monthly Concentrations of NO_2.

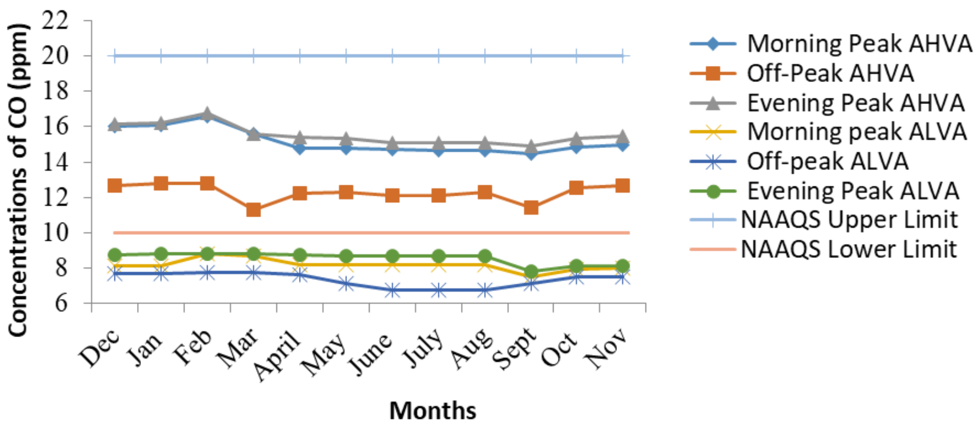

Figure 4. Monthly concentration of CO.

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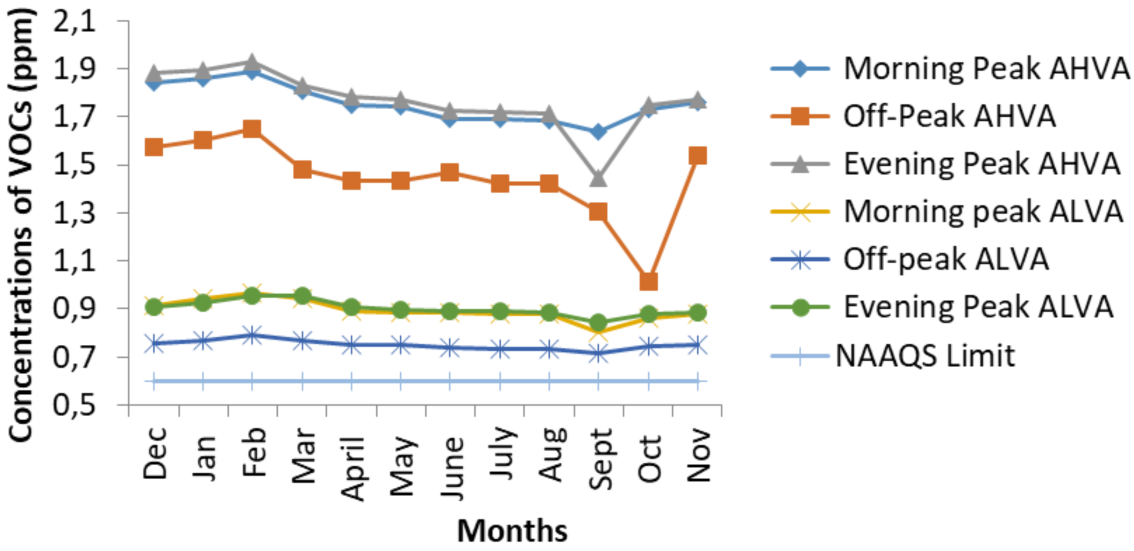

Figure 5. Monthly concentration of VOCs.

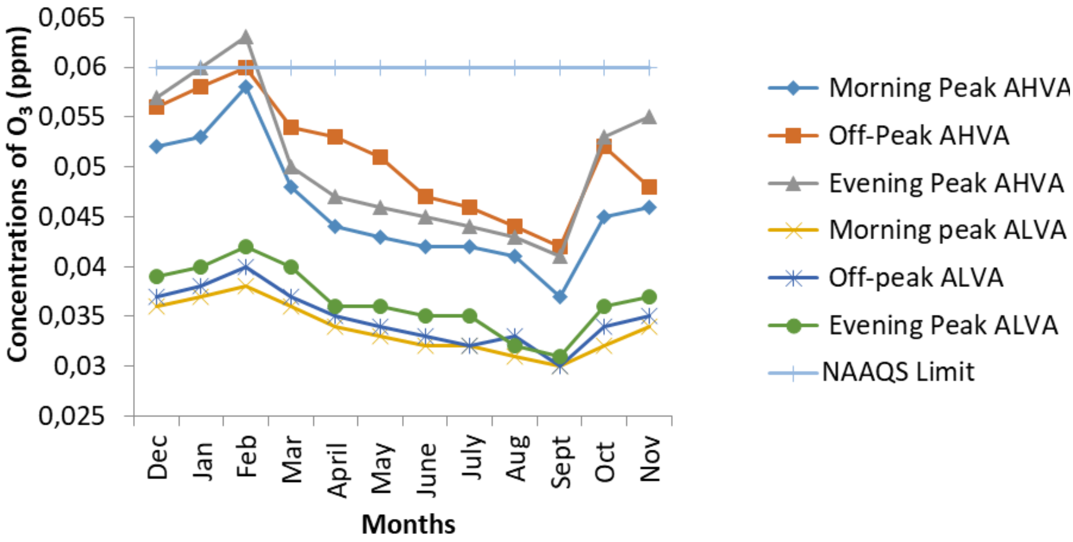

Figure 6. Monthly concentration of O_3.

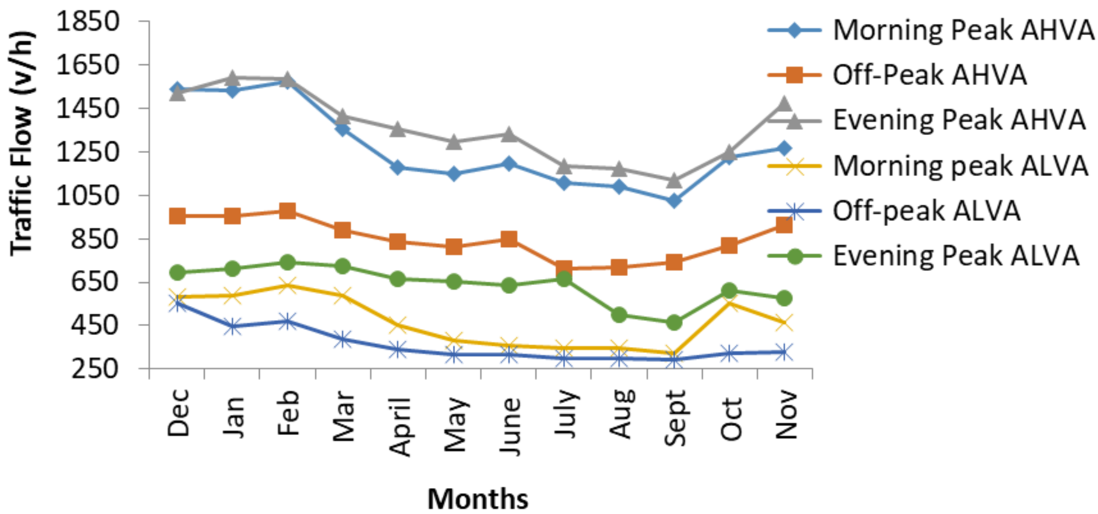

Figure 7. Monthly levels of traffic flow.

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3.2. Monthly Variations in Concentrations of NO_2

The monthly variations in concentration (ppm) of NO_2 across the high vehicular-traffic area ranged from 0.043 ± 0.002 – 0.090 ± 0.004 across traffic periods, while across the low vehicular-traffic area, the variations ranged from 0.031± 0.001 – 0.045 ± 0.001 as presented in **Figure 3**. The higher range of concentration for NO_2 in the high vehicular-traffic area shows that vehicular emissions had contributed to higher levels of NO_2 in the air of the area as a result of the higher volume of vehicular traffic as shown in **Figure 7**. Across the high vehicular-traffic area, the maximum monthly concentration (0.090 ± 0.004 ppm) was observed in February at the evening peak period, while the minimum value (0.043 ± 0.002 ppm) was observed at off-peak in September. This could be attributed to more vehicles in February and at evening peak leading to more NO_2 (Sawyer, 2010) and the lower number of vehicles observed at off-peak in September (Weli and Ayoade, 2014).

This maximum concentration value (0.090 ± 0.004 ppm) is tallied with the value obtained by Okonkwo *et al*. (2014) in their study on the assessment of automobile-induced pollution in Port-Harcourt City. However, this maximum concentration (0.090 ± 0.004 ppm) was lower than the 1.65 ppm, the study of comparative analysis of vehicular emissions in urban and rural milieus where Port Harcourt and Etche in Rivers State, Nigeria were used as a case study. The lower concentration of NO_2 reported in this study compared to that of Ucheje and Chidozie could be due to fewer heavy vehicles in traffic composition during the time of study as heavy vehicles contribute more to the concentration of NO_2 (Enroth *et al*., 2016).

The NO_2 concentration range of 0.043 ± 0.002 – 0.059 ± 0.006 ppm at off-peak was within the FEPA (1991) Nigerian Ambient Air Quality Standard (NAAQS) limit range (0.04 - 0.06 ppm). The range of 0.064 – 0.088 ppm and 0.069 – 0.090 ppm for morning and evening peaks respectively were higher than the NAAQS limit (0.04 - 0.06 ppm). This exceedance of NO_2 concentrations from the standard limit in the morning and evening is an indication of NO_2 pollution in the air of the city.

Across the low vehicular-traffic area, the maximum variation in the level of NO_2 (0.045 ± 0.001 ppm) was also observed in February at the evening peak. The minimum value (0.031 ± 0.001 ppm) was observed at off-peak in June, July, and September. There was no pollution in the low vehicular-traffic area at NO_2 concentrations (ppm) range of 0.033 – 0.041 (morning peak traffic period), 0.031 – 0.038 ppm (off-peak traffic period), and 0.036 – 0.045 ppm (evening peak traffic period) as presented in **Figure 3**. The concentration ranges were all within the NAAQS limit of 0.04 - 0.06 ppm. NO_2 pollution in the high traffic area could be linked to high transportation demand because of heavy commercial activities, and this resulted to increase in the concentrations of NO_2 and other pollutants in the air.

3.3. Monthly Variations in Concentrations of CO

For variation in levels of CO, concentrations varied in the ranges of 11.292 ± 0.061 - 16.756 ± 0.205 ppm and 6.752 ± 0.128 - 8.835 ± 0.007 ppm across the high vehicular-traffic area and low vehicular-traffic area respectively (**Figure 4**). Hence, monthly CO concentrations across the high-traffic area were higher than that of the low-traffic area, this could be due difference in traffic between the two areas. Across the high-traffic area, the highest level of CO (16.756 ± 0.205 ppm) was observed in February during the evening peak period; this could be attributed to more vehicles in February and evening (**Figure 7**). This maximum monthly concentration of 16.756 ± 0.205 ppm observed for CO was far lower than the 46.00 ± 0.00 ppm obtained by Okonkwo *et al*. (2014). The obtained maximum value (16.756 ± 0.205 ppm) was also lower than the 36.07 ± 2.60 ppm obtained by Robert (2015) in the study where CO concentrations in Port Harcourt were compared with set standards. The lower value

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compared to that of Robert (2015) and Okonkwo *et al*. (2014) could have resulted from less traffic hold-up, less traffic flow, or more complete combustion in vehicle engines at the time of this study. These factors can reduce the amount of ambient CO from vehicular emissions (Kimbrough *et al*., 2011; Agbozu *et al*.2015). The economic situation could also affect traffic flow at the time of this study leading to reduced vehicular movement and subsequently volume of emission, hence, the lesser concentration of traffic-related pollutants including CO.

The lowest monthly value for CO (11.292 ± 0.061 ppm) across study sites was observed at off-peak in September; this could come from lower traffic flow observed during the off-peak and rainy season which September belongs (Weli and Ayoade 2014). Across the high traffic area, the range of diurnal concentrations (ppm) for CO: 14.500 ± 0.358 – 16.559 ± 0.184 ppm (at morning peak), 11.292 ± 0.061 – 12.810 ± 0.177 ppm (at off-peak) and 14.917 ± 0.210 – 16.756 ± 0.205 (at evening peak) as presented in **Figure 4**, were all within the Nigerian Ambient Air Quality Standard (NAAQS) limit range of 10 – 20 ppm.

In low vehicular-traffic areas, the maximum concentration of 8.835 ± 0.007 ppm for CO was observed in February at the evening peak. The minimum value (6.752 ± 0.128 ppm) was observed at off-peak in July and August. This low concentration range (6.752 ± 0.128 - 8.835 ± 0.007 ppm) for CO in the low vehicular-traffic area could be due to scanty emissions due to less traffic flow (Agbozu *et al*., 2015).

3.4. Monthly Variations in Concentrations of VOCs

Monthly variations in levels of VOCs are explained in **(Figure 5).** Across the high vehicular-traffic area, VOCs also showed the same trend of maximum concentration (1.927 ± 0.069 ppm) in February at evening peak traffic period, but minimum concentration (1.010 ± 0.074 ppm) was observed in October at off-peak traffic period. There were lower concentrations in the low vehicular-traffic area; the highest monthly concentration for VOCs in the low-traffic area was 0.956 ± 0.008 ppm while the lowest was 0.713 ± 0.012 ppm. The maximum concentration (1.927 ± 0.069 ppm) observed across the high vehicular-traffic area for VOCs, was far lower than the values reported by some other researchers.

For instance, the maximum value (1.927 ± 0.069 ppm) obtained was far lower than the 7.00 ppm reported by Gobo *et al*. (2012) in the study of assessment of air quality and noise around Okrika communities, Rivers State, Nigeria. The maximum value was also lower than the 4.200 ppm obtained by Ideriah *et al*. (2012) in the study of the correlation between selected ambient air pollutants and total hydrocarbon content in plant leaves along roadsides in an industrialized city in Niger Delta, Nigeria. This scenario could have resulted from the differences in vehicle traffic composition (light-duty and heavy-duty vehicles), fuel quality and fuel type (gasoline and diesel) (Deng *et al*., 2018), and rate of vehicular evaporation emissions (VEEs) (Liu *et al*., 2017). The range of concentrations for VOCs (0.713 ± 0.012 ppm - 1.927 ± 0.069 ppm) was higher than the NAAQS limit of 0.6 ppm given by Adeyanju (2018), and this was an indication of pollution from VOCs. This very high level of VOCs in the air of the city is a serious issue and calls for austere environmental measures.

3.5. Monthly Variations in Concentrations of O_3

As presented in **Figure 6,** the maximum monthly concentrations of O_3 across the high vehicular-traffic area and low vehicular-traffic area were 0.063 ± 0.004 ppm and 0.042 ± 0.004 ppm respectively, and these were observed in February at evening peak. The result reveals that O_3 levels were higher in the high-traffic area than in the low-traffic area. The minimum monthly concentrations were 0.037 ± 0.004 ppm and 0.030 ± 0.001 ppm for high-traffic areas and low-traffic areas respectively, and these were observed in September during the morning

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peak traffic period. This was in contrast to the diurnal variation of other pollutants (NO_2, CO, and VOCs) where the minimum levels were all observed at off-peak. It could have been caused by the low temperature that prevails in the morning as this affects the ozone formation potential (OFP) of the precursor pollutants and is consistent with the report of Marzuki *et al.* (2016). The range of concentrations (0.030 – 0.063m ppm) observed was greater than the range (0.021 – 0.026 ppm) reported by Emenike and Orjinmo (2017) when vehicular emissions around bus stops in the Port Harcourt metropolis were studied. It was also higher than the 0.00 – 0.04 ppm range of concentration obtained by Augustine (2012) in the study of the impact of air pollution on the environment in Port Harcourt.

The higher level of O_3 observed in this study compared with Emenike and Orjinmo (2017) and Augustine (2012) could have emanated from a higher NO_2/NO ratio (Marzuki, 2016), more abundance of precursor pollutants (Sharma *et al*., 2017), favorable meteorological conditions (Warmiński and Bęś, 2018) and a greater number of diesel engine vehicles (Aneri 2018) at the time of this study. All monthly concentrations of O_3 obtained were lower than the FEPA (1991) Nigerian Ambient Air Quality Standard (NAAQS) limit of 0.060 ppm except 0.060 ± 0.004 ppm observed in February at off-peak, which equals the standard limit, and the 0.063 ± 0.004 ppm observed also in February at evening peak, which was higher than the standard limit. The 0.063 ± 0.004 ppm variability in O_3 observed in February is an indication of occasional O_3 pollution in the city.

3.6. Average Variation in Concentrations of Pollutants

Across the high vehicular-traffic area, the average levels (ppm) of pollutants at the morning peak were 0.074 ± 0.007, 15.186 ± 0.694, 1.756 ± 0.078, and 0.046 ± 0.006 for NO_2, CO, VOCs, and O_3 respectively. At off-peak, the levels (ppm) were 0.049 ± 0.004, 12.272 ± 0.492, 1.444 ± 0.166 and 0.051 ± 0.006. Average concentration (ppm) at the evening peak were 0.077 ± 0.007, 15.544 ± 0.556, 1.767 ± 0.124, and 0.050 ± 0.007 for NO_2, CO, VOCs, and O_3 respectively. Across the low vehicular-traffic area, the average variations (ppm) of pollutants were 0.036 ± 0.003, 8.179 ± 0.337, 0.894 ± 0.044, and 0.034 ± 0.003 for NO_2, CO, VOCs, and O_3 respectively at morning peak. At off-peak, the variations (ppm) were 0.034 ± 0.003, 7.343 ± 0.414, 0.749 ± 0.021, and 0.035 ± 0.003, while for the evening peak, the average variations (ppm) were 0.041 ± 0.003, 8.505 ± 0.339, 0.901 ± 0.032 and 0.037 ± 0.003. Average concentrations for each of the pollutants were in the order CO > VOCs > NO_2 > O_3 across traffic periods except at off-peak, where O_3 average concentrations were higher than that of NO_2. In the high vehicular traffic area, the average level for O_3 (0.051 ± 0.006 ppm) was higher than that of NO_2 (0.049 ± 0.004 ppm) during the off-peak period. This could be because NO_2 contributes more to O_3 formation during the photochemical reaction and in some cases decreases as O_3 increases (Nazatul *et al*., 2014).

The highest average concentration among the pollutants was observed for CO (15.544 ppm), and this was conspicuously high when compared to the maximum concentration for NO_2 (0.077 ppm), VOCs (1.767 ppm), and O_3 (0.051 ppm). This could be attributed to the fact that it is the predominant pollutant emitted by vehicles, especially gasoline-engine vehicles (Aneri, 2018). Average diurnal concentrations for all the pollutants in the high vehicular traffic are in the order- evening > morning > afternoon, except for O_3 where the afternoon value (0.051 ppm) was greater than that of the morning (0.046 ppm) and evening (0.050 ppm) values.

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3.7. Monthly Traffic Flow

Monthly Traffic flows are presented in **Figure 7**. Across the high vehicular-traffic area, the range of traffic flow was 711 ± 95 – 1591± 17 v/h while in the low-traffic area, the range was 295 ± 14 – 744 ± 66 v/h. This resulted from the fact that the high-traffic area is the busy part of the city where there were heavy commercial activities, which in any case could attract more vehicles (Ugbebor and Longjohn, 2018). Maximum traffic flow (1591 ± 17 v/h) was observed in January at evening peak while the lowest flow (295 ± 14 v/h) was in September at off-peak. In both traffic areas, the traffic flow was in the order: - evening peak > morning peak > off-peak. This higher volume of vehicular traffic obtained at evening peak could be attributed to the shorter travel time that led to higher traffic intensity on the road and is in line with what was observed by Attah (2015) in the study of the impact of vehicular traffic emissions on ambient air quality in Kaduna metropolis.

3.8. Average Traffic Flow

The overall average for vehicular traffic flow (v/h) across the high vehicular-traffic area was 1270±189, 847 ± 92, and 1364 ± 169 for the morning peak traffic period, off-peak traffic period, and evening peak traffic period respectively. Across the low vehicular traffic area, the average vehicular flow (v/h) was 468±116, 365±83, and 638±86 for the morning peak traffic period, off-peak traffic period, and evening peak traffic period respectively. Therefore, the range for average vehicular traffic flow across high vehicular traffic areas (847 – 1364 v/h) was no doubt greater than that of low vehicular traffic areas (365 – 638 v/h).

3.9. Comparison Between the Average Level of Parameters Across High Vehicular-Traffic Areas with Those of Low Vehicular-Traffic Area

As illustrated in **Figures 3 – 7**, there were differences in the average levels of parameters between the high vehicular-traffic area and the low vehicular-traffic area, to test for the significance of these differences, a t-test ($p \leq 0.05$) was deployed. **Table 1** shows the values for t-calculated (t- statistics) when levels of parameters in the high vehicular-traffic area were compared to those of the low vehicular-traffic area. For all the pollutants, the t- calculated ranged from 10.37 – 87.90 which was far above the t- critical (2.20). For the traffic flow, the t- calculated ranged from 21.82 – 30.71 which was also higher than the t- critical (2.20). From the t-test, the average concentrations for each of the pollutants (NO_2, CO, VOCs, and O_3) at all traffic periods in the high vehicular-traffic area were significantly higher ($p \leq 0.05$) than those of the low vehicular-traffic area as the t-calculated were all above the t-critical value of 2.20.

This could have emanated from the difference in the volume of vehicular emissions between high and low vehicular traffic. The significant variation in levels of pollutants between the high vehicular-traffic area and the low vehicular-traffic area was similar to what was observed by Trinya and Ideriah (2015) when levels of air pollutants around roadside gardens in the Port Harcourt metropolis were studied. It was also in line with a documented report by Asin *et al*. (2016) in the study where vehicular emissions in Uyo capital city, of Nigeria were investigated. Furthermore, it agreed with the findings of Lähde *et al*. (2014) when mobile particle mass ($PM_{2.5}$), black carbon (BC), as well as gaseous pollutants: NO, NO_2, NOx, CO, and CO_2 at Helsinki downtown, Finland were compared at different traffic flow areas.

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Table 1. T-Test values for comparing average level of parameters across the high vehicular-traffic area with the high vehicular-traffic area (Two tail; $p \leq 0.05$).

Air Parameters	Morning Peak		Off Peak		Evening Peak	
	t cal.	t crit.	t cal.	t crit.	t cal.	t crit.
NO_2	23.66	2.20	15.80	2.20	20.52	2.20
CO	43.58	,,	31.12	,,	40.95	,,
VOCs	87.90	,,	15.49	,,	30.30	,,
O_3	11.74	,,	17.71	,,	10.37	,,
Traffic Flow	28.51	,,	30.71	,,	21.82	,,

t cal. = t calculated; t crit. = t critical

4. CONCLUSION

The comparative study on the monthly variation of traffic-related ozone and its precursor pollutants (NO_2, CO, VOC) in high and low vehicular emissions areas of Port Harcourt showed that traffic density can increase the level of these precursor pollutants as the concentrations of pollutants in the high vehicular-traffic area was significantly higher ($p \leq 0.05$) than those of the low vehicular-traffic area. There was pollution from NO_2, VOCs as their levels were higher than the Nigerian Ambient Air Quality Standard (NAAQS) limit. O_3 level was higher than the NAAQS limit only in February. Variation in levels of pollutants across traffic periods was in the order evening traffic period > morning traffic period > afternoon traffic period (off-peak) except for O_3 whose average concentration at off-peak was higher than at morning.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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