Chapter

Atmospheric Air Pollution in Nigeria: A Correlation between Vehicular Traffic and Criteria Pollutant Levels

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Abstract

In Nigeria, the rising levels of used/poorly maintained vehicles are contributing to most urban air pollution with possible repercussion on the general public health. This study evaluates the inferences of vehicular traffic surge on outdoor pollutant measurement using Zaria, northern Nigeria, as a case study. The study collected a 1-year time-series dataset for the vehicular count and the respective outdoor criteria pollutant measurements over 19 study sites. The vehicular traffic was categorized into motorcycles (2-W), tricycles (3-W), cars, buses, light-duty vehicles (LDV) and heavy-duty vehicles (HDV). The outdoor pollutants that were measured include carbon monoxide (CO), sulfur dioxide (SO2) and particulate matter (PM2.5/PM10). We utilized validated portable monitors (CW-HAT200 particulate counter and the MSA Altair 5x multigas sensor) for the outdoor measurements during December 2015–November 2016. The observed measurements for the validation procedure were normally distributed [kurtosis (0.301); skewness (−0.334)] and coefficient of determination (R2 ≥ 0.808). The time-series analysis of particulate matter (PM) measurements displayed alarming concentrations levels. Combined vehicular traffic density analysis revealed significant contribution (R2 ≥ 0.619) to the population exposed outdoor pollutant measurements. The 2-W (motorcycle) was found to be the vehicular category that attributed the most significant relationship with observed outdoor pollutant measurements.

Keywords: urban air quality, vehicular traffic, portable sensors, criteria pollutants, Zaria-Nigeria

1. Introduction

In most developing countries, atmospheric pollution continues to affect exposed population health [1–3]. In Africa, air quality studies are devising alternative and reliable means to obtain pollutant measurements for research. The approach
includes reliable validation of sampling techniques that contribute to the up-to-date understanding of criteria pollutants, maintenance outflow and technical know-how [4].

Nigeria’s rising population is escalating anthropogenic activities within its territory without any reliable information on its air quality [5]. The atmospheric air quality of most of its urban cities continues to remain exposed to the growing, poorly managed vehicular traffic from ineffective fuel combustion [6]. The situation is familiar, however, the motivation to address it lingers ambiguously.

The rising levels of used/poorly managed vehicular operations remains an unnoticed contributor to urban atmospheric air pollution. While the literature has established alarming pollutant levels and how they contribute to the respiratory wellbeing of the exposed population [3], there is a need to further establish the relationship between the categories of the existing vehicular traffic surge and corresponding criteria pollutant levels observed. This will facilitate the process of the traffic-related atmospheric air pollution management plan in many Nigerian cities. For familiarity with the terminology, Table 1 highlights a list of abbreviations and units utilized for this study.

### Table 1.
List of abbreviations and units.

| Abbreviation | Description |
|--------------|-------------|
| \(\mu g\ m^{-3}\) | Microgram per meter cube |
| 2-W | Two-wheeler (motorcycle) |
| 3-W | Three-wheeler (tricycle) |
| CO | Carbon monoxide |
| HDV | Heavy-duty vehicle |
| LDV | Light-duty vehicle |
| PM\(_{2.5}\) | Particulate matter, with a diameter of <2.5 \(\mu m\) |
| PM\(_{10}\) | Particulate matter, with a diameter of <10 \(\mu m\) |
| ppm | Parts per million |
| SO\(_2\) | Sulfur dioxide |
| TSP | Totally suspended particles |

2. Methodology

2.1 Study area

Zaria metropolis described in Figure 1, has an estimated area of 296.04 km\(^2\). Its estimated population as reported in 2014 is 938,521. The city climate characteristics are divided into two. The dry season ranges from October to May, and the rainy season ranges from June to September. The altitude is averagely 670 m above mean sea level [7]. Major road intersections are the concept adopted for the selection of the 19 study sites.

2.2 Instrumentation and methods

There is increasing use of portable devices for examining outdoor air (atmospheric) quality. With comparison to established reference devices, their reliability allows for effective real-time data acquisition, especially in limited resource
This study employed the CW-HAT200 particulate counter and the MSA Altair 5x multi-gas sensor to collect particulate matter (PM$_{2.5}$ and PM$_{10}$) while the MSA Altair 5x collect carbon monoxide (CO) and sulfur dioxide (SO$_2$) respectively. The instrument re-calibration was conducted using manufacturer’s span calibration mixed gas specifications.

Owing to the unavailability of real-time reference air pollution monitors within the study region, the devices were validated the portable pollutants monitors using the WHO air filter sampling model Eq. (1). To validate the portable devices, total suspended particulates (TSP) were collected at two distinct sample test stations at 1.5 m above the existing ground level. Validation site 1 had dense outdoor traffic activity, while validation site 2 had minimal outdoor traffic activity tagged control site. The validation samples and synchronized portable monitor measurements were obtained across three epochs, that are, morning, afternoon and evening for 17 days. TSP is described as particulate fraction ranging from 0.1 to about 100 μm in size (diameters). Particulates matter PM$_{2.5}$ (diameter < 2.5 μm) and PM$_{10}$ (diameter < 10 μm) fall within the specified range. Based on [9] which identified a significant relationship between total suspended particulates, PM$_{10}$ and PM$_{2.5}$ and [10] which reported that there is a significant correlation among pollutant emissions resulting from a common source, the study validated the portable devices using the WHO air sampling filter technique. Eq. (1) describes the WHO air sample model technique [11].

$$\text{total suspended particulates (μg m}^{-3}) = \frac{M_S - M_O}{V} \quad (1)$$

where $M_O$ is the filter paper mass without TSP samples, $M_S$ is the filter paper mass with TSP samples, $V$ is the TSP volume. To determine the concentration (μg m$^{-3}$), model Eq. (1) was divided by the sample time (in hours).

In line with Eq. (1), the validation samples were collected individually on filter papers and collocating pollutant measurements with the portable device over the environments [8].

Figure 1.
The 19 study sites adopted for study data acquisition.
study duration. The particulate filter samples were processed in the laboratory to obtain their individual concentrations using Eq. (1). They were then compared with the separately recorded collocating pollutant measurements from the portable devices. The collocating measurements were then analyzed using linear regression and bias, for the validation of the portable monitors. The analysis is described in Figures 2 and 3. The observed measurements for the validation procedure were normal distributed [skewness (−0.334); kurtosis (0.301)]. The study adopted two performance indicators for the purpose of validating the portable pollutant instrument. The performance indicators are the Bland-Altman agreement plot and the coefficient of determination (R²). The Bland-Altman plot evaluates the systematic bias between the two measurements techniques, while the coefficient of determination indicates how strongly related the pair(s) of variables are. The Bland-Altman agreement plot can be seen in Figure 2.

From Figure 2, it can be seen that there is no significant systematic difference in the measurements. Additionally, the coefficient of determination (R²) across the two test sites showed that the TSP measurements from the WHO model technique and criteria pollutant measurements from the MSA Altair 5x/CW-HAT200 devices were significantly correlated. The linear regression can be seen in Figure 3. Figures 2 and 3 illustrate that the reliability of the portable pollutant monitors has been validated based on [9, 10].

Figure 2.
Bland-Altman bias plot highlighting the agreement of observed validation measurements (PM$_{2.5}$ and PM$_{10}$) within the 95% confidence interval: (a) less densely populated site and (b) densely populated site.
Figure 3. Scatter plots showing the linear regression and coefficient of determination between the TSP and the portable monitor samples: (a) densely populated site and (b) control site.
| Study sites | s1   | s2   | s3   | s4   | s5   | s6   | s7   | s8   | s9   | s10  | s11  | s12  | s13  | s14  | s15  | s16  | s17  | s18  | s19  |
|------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| s1         | 1    | 0.997| 0.878| 0.998| 0.983| 0.858| 0.997| 0.999| 0.995| 0.997| 0.986| 0.994| 0.996| 0.988| 0.994| 0.995| 0.989| 0.960| 0.995|
| s2         | 1    | 0.907| 0.993| 0.992| 0.888| 0.989| 0.998| 0.985| **1.000**| 0.993| 0.984| 0.987| 0.974| 0.988| 0.985| 0.994| 0.977| 0.977| 0.997|
| s3         | 1    | 0.851| 0.951| 0.997| 0.841| 0.895| 0.834| 0.910| 0.906| 0.837| 0.847| 0.797| 0.833| 0.826| 0.897| 0.961| 0.897| 0.897| 0.897|
| s4         | 1    | 0.971| 0.828| 0.998| 0.994| 0.995| 0.992| 0.983| 0.993| 0.994| 0.993| 0.999| 0.998| 0.998| 0.989| 0.950| 0.993| 0.993| 0.993|
| s5         | 1    | 0.938| 0.967| 0.989| 0.963| 0.993| 0.982| 0.964| 0.969| 0.944| 0.961| 0.959| 0.982| 0.988| 0.986| 0.897| 0.897| 0.897| 0.897|
| s6         | 1    | 0.820| 0.878| 0.815| 0.892| 0.881| 0.820| 0.829| 0.775| 0.808| 0.803| 0.873| 0.944| 0.875| 0.944| 0.944| 0.944| 0.944| 0.944|
| s7         | 1    | 0.994| 0.999| 0.989| 0.975| 0.998| 0.998| 0.997| 0.996| 0.999| 0.980| 0.937| 0.987| 0.987| 0.987| 0.987| 0.987| 0.987| 0.987|
| s8         | 1    | 0.991| 0.999| 0.985| 0.992| 0.993| 0.982| 0.990| 0.990| 0.990| 0.990| 0.968| 0.996| 0.996| 0.996| 0.996| 0.996| 0.996| 0.996|
| s9         | 1    | 0.985| 0.967| 0.999| **1.000**| 0.997| 0.992| 0.998| 0.973| 0.928| 0.982| 0.982| 0.982| 0.982| 0.982| 0.982| 0.982| 0.982| 0.982|
| s10        | 1    | 0.991| 0.985| 0.988| 0.987| 0.974| 0.987| 0.985| 0.993| 0.978| 0.997| 0.997| 0.997| 0.997| 0.997| 0.997| 0.997| 0.997| 0.997|
| s11        | 1    | 0.963| 0.968| 0.957| 0.980| 0.971| 0.995| 0.981| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991|
| s12        | 1    | 0.999| 0.996| 0.990| 0.997| 0.971| 0.928| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981|
| s13        | 1    | 0.994| 0.990| 0.996| 0.973| 0.933| 0.983| 0.983| 0.983| 0.983| 0.983| 0.983| 0.983| 0.983| 0.983| 0.983| 0.983| 0.983| 0.983|
| s14        | 1    | 0.993| 0.998| 0.965| 0.909| 0.974| 0.974| 0.974| 0.974| 0.974| 0.974| 0.974| 0.974| 0.974| 0.974| 0.974| 0.974| 0.974| 0.974|
| s15        | 1    | 0.997| 0.988| 0.943| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991| 0.991|
| s16        | 1    | 0.979| 0.931| 0.985| 0.985| 0.985| 0.985| 0.985| 0.985| 0.985| 0.985| 0.985| 0.985| 0.985| 0.985| 0.985| 0.985| 0.985| 0.985|
| s17        | 1    | 0.981| 0.998| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981| 0.981|
| s18        | 1    | 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978|
| s19        | 1    | 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978| 0.978|

Table 2. Pearson’s correlation coefficient matrix of seasonal pollutant measurement across the 19 study sites (significant at 0.01 levels).
With the above-described validation, the portable instruments were utilized to commence the measurement of ground level roadside pollution concentrations. The duration of the sampling measurement was from 01 December 2015 to 30 November 2016. The outdoor concentration levels were observed using the approach described in [12, 13]. The vehicular traffic count was also conducted to obtain the volume of vehicles contributing to the outdoor air pollution across the sampling sites. The vehicular count was obtained to determine the contributory level of vehicular density to outdoor air pollution. The vehicles are categorized as follows: motorcycles (2-W), tricycles (3-W), cars, buses, light-duty vehicles (LDV) and heavy-duty vehicles (HDV). The study analysis was performed using software: SPSS, Microsoft Excel and MATLAB.

3. Results and discussion

Table 2 highlights the dispersal relationship of the observed CO, SO₂, PM₂.₅ and PM₁₀ across the 19 study sites. This was achieved using Pearson’s correlation coefficient. The inter-study-site correlation matrix (Table 2), showed that the relationship of the measured pollutants was significant at the 0.01 level across all the study sites. And only study site 6 (a control site) revealed lower coefficient values in comparison to the remaining study sites. From Table 2, study sites 2 and 9 produced a perfect relationship with site 10 and site 13, respectively.

| Study site | 2-W    | 3-W    | Car    | Bus    | LDV    | HDV    |
|------------|--------|--------|--------|--------|--------|--------|
| 1          | 16,034 ± 17 | 3186 ± 4 | 10,242 ± 11 | 5613 ± 6 | 958 ± 1 | 1417 ± 2 |
| 2          | 15,111 ± 16 | 2955 ± 4 | 8443 ± 9  | 4971 ± 6 | 643 ± 1 | 1204 ± 2 |
| 3          | 8554 ± 8   | 888 ± 1  | 3021 ± 3  | 1177 ± 1 | 2571 ± 1 | 641 ± 1  |
| 4          | 19,948 ± 22| 3731 ± 4 | 11,785 ± 12| 7279 ± 8 | 1561 ± 2| 3444 ± 4 |
| 5          | 11,688 ± 12| 2063 ± 2 | 2960 ± 4  | 1418 ± 2 | 340 ± 1 | 571 ± 1  |
| 6          | 5602 ± 6   | 615 ± 1  | 1585 ± 2  | 542 ± 1  | 241 ± 1 | 412 ± 1  |
| 7          | 18,012 ± 18| 3954 ± 5 | 4045 ± 6  | 6656 ± 7 | 502 ± 2 | 442 ± 1  |
| 8          | 17,069 ± 17| 3556 ± 4 | 5153 ± 5  | 6353 ± 7 | 428 ± 1 | 211 ± 1  |
| 9          | 27,008 ± 27| 5529 ± 7 | 16,307 ± 17| 9352 ± 10| 1495 ± 2| 1628 ± 2 |
| 10         | 14,870 ± 15| 3575 ± 4 | 8628 ± 9  | 3667 ± 5 | 784 ± 2 | 1320 ± 1 |
| 11         | 14,453 ± 16| 4446 ± 6 | 7089 ± 8  | 2321 ± 3 | 296 ± 1 | 369 ± 1  |
| 12         | 27,058 ± 28| 5720 ± 6 | 15,746 ± 17| 9643 ± 10| 1436 ± 2| 929 ± 2  |
| 13         | 22,012 ± 23| 4982 ± 6 | 9559 ± 10 | 8551 ± 9 | 919 ± 2 | 537 ± 1  |
| 14         | 28,897 ± 29| 6205 ± 7 | 5123 ± 6  | 6797 ± 8 | 897 ± 2 | 500 ± 1  |
| 15         | 17,482 ± 18| 3736 ± 5 | 11,748 ± 13| 6761 ± 7 | 1343 ± 2| 899 ± 2  |
| 16         | 20,678 ± 22| 4672 ± 6 | 22,656 ± 24| 13,050 ± 14| 2405 ± 3| 2666 ± 4 |
| 17         | 11,167 ± 12| 2241 ± 3 | 12,647 ± 13| 6447 ± 8 | 1013 ± 2| 1131 ± 2 |
| 18         | 6710 ± 7   | 756 ± 1  | 4194 ± 5  | 2528 ± 3 | 364 ± 1 | 713 ± 1  |
| 19         | 10,529 ± 11| 2048 ± 3 | 9781 ± 10 | 6063 ± 7 | 872 ± 2 | 896 ± 2  |
| Total      | 312,882  | 64,858  | 170,712 | 109,189 | 19,068 | 19,930 |

Table 3.
Vehicular traffic density (total ± average per 3 min) across the 19 sampling sites in the study.
The traffic count for the individual sampling site per epoch was computed based on the vehicular category, as shown in Table 3. In general, the study site with the highest weighted average of the criteria pollutants measured over the 19 study locations is study site 14. The reason for the high measurements is because the site is within the study area’s main market (Sabon-Gari market) with the highest average count of 2-W and 3-W vehicle density (Table 3). The traffic volume was determined by direct counting the traffic during the daily sampling epoch for the study period (1 year).

Figure 4 displays the time-series plots of vehicular traffic count and resulting criteria pollutants measurements collected over selected study sites 3, 9 and 15. It can be observed that the study sites 3 which is a control site, did have the majority of its pollutant concentration levels below 40 ppm, 0.6 ppm, 300 \( \mu \text{gm}/\text{C0} \) and

![Figure 4](image-url)
600 μg m⁻³ for CO, SO₂, PM₂.₅ and PM₁₀ respectively. Except for PM during the Harmattan season which falls between sample days 1–91. For sites 9 and 15, the majority of the observed criteria pollutant measurements were above the earlier described values.

Table 4 presents the computed 1-year weighted average of the measured criteria pollutants concentrations across the 19 study sites [14]. Study sites 3 and 6 recorded the least pollutant measurements CO/SO₂ and PM₂.₅/PM₁₀. This could attribute to minimal population activities at the sites. The sites 3, 6 and 18 were actually selected to serve as control sites for the study. From Table 4, the weighted average of the observed criteria pollutants for the study area is deduced as CO (29.220 ppm), SO₂ (0.319 ppm), PM₂.₅ (219.729 μg m⁻³) and PM₁₀ (451.958 μg m⁻³).

Additionally, the weighted average computed for the observed criteria pollutant was compared against the stipulated guidelines in the WHO air quality document [15]. The comparison revealed that the weighted average of criteria pollutants observed over the 19 study sites did exceed the WHO stipulated threshold (blue line across bar charts) for SO₂, PM₂.₅ and PM₁₀ in all the study sites, except for CO, whose weighted average stayed within the stipulated limits only in sites 3, 6 and 18. This is illustrated in Figure 5.

Pearson’s correlation matrix was utilized to investigate the seasonal level of association between measured criteria pollutants and traffic activities within the 19

| Site | Latitude | Longitude | Description | CO (ppm) | SO₂ (ppm) | PM₂.₅ (μg m⁻³) | PM₁₀ (μg m⁻³) |
|------|----------|-----------|-------------|----------|-----------|----------------|----------------|
| 1    | 11.080   | 7.695     | Kofar Kibo  | 33.036   | 0.363     | 258.873        | 528.000        |
| 2    | 11.078   | 7.686     | Dannagaji, Wusasa | 20.838   | 0.264     | 214.720        | 432.571        |
| 3    | 11.064   | 7.673     | Madaci, Saye | 7.994    | 0.159     | 117.177        | 232.246        |
| 4    | 11.054   | 7.682     | Gwargwaje   | 29.703   | 0.351     | 250.294        | 509.957        |
| 5    | 11.044   | 7.701     | Kofar Gayan | 16.811   | 0.212     | 182.562        | 372.982        |
| 6    | 11.041   | 7.720     | Kofar Kona  | 4.586    | 0.137     | 99.068         | 202.008        |
| 7    | 11.051   | 7.699     | Zaria City market | 38.281   | 0.383     | 276.448        | 561.482        |
| 8    | 11.066   | 7.706     | Babban Dodo | 27.242   | 0.290     | 220.292        | 448.332        |
| 9    | 11.081   | 7.710     | Kofar Doka  | 46.844   | 0.449     | 312.469        | 631.429        |
| 10   | 11.074   | 7.725     | Banzazzau   | 22.880   | 0.260     | 208.111        | 424.255        |
| 11   | 11.079   | 7.735     | FCE/Ungwan Kaya | 19.728   | 0.243     | 179.426        | 367.067        |
| 12   | 11.093   | 7.717     | Agwara, Tudun Wada | 55.959   | 0.525     | 328.026        | 662.063        |
| 13   | 11.104   | 7.721     | PZ          | 38.848   | 0.399     | 282.524        | 573.486        |
| 14   | 11.113   | 7.730     | Sabon Gari market | 65.073   | 0.627     | 342.588        | 704.262        |
| 15   | 11.124   | 7.715     | MTD         | 29.600   | 0.302     | 173.255        | 448.810        |
| 16   | 11.130   | 7.703     | Kwangila bridge | 50.130   | 0.465     | 282.891        | 576.923        |
| 17   | 11.139   | 7.686     | Aviation by NITT road | 19.180   | 0.238     | 167.004        | 352.324        |
| 18   | 11.177   | 7.672     | Basawa by Hayin Dogo | 8.795    | 0.167     | 93.807         | 189.041        |
| 19   | 11.159   | 7.651     | Samaru market | 19.652   | 0.244     | 185.319        | 369.965        |

Table 4. The 1-year weighted average of the observed pollutants (N = 19, 104).
Figure 5.
The comparison of weighted criteria pollutants average: (a) CO; (b) SO2; (c) PM$_{2.5}$; and (d) PM$_{10}$ against the WHO air quality guidelines.
| Pollutants | Seasons | DJF | MAM | JJA | SON | DJF | MAM | JJA | SON | DJF | MAM | JJA | SON | DJF | MAM | JJA | SON |
|-----------|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| CO        | DJF     | 1   | 0.983 | 0.975 | 0.940 | 0.962 | 0.957 | 0.963 | 0.927 | 0.778 | 0.951 | 0.941 | 0.900 | 0.779 | 0.948 | 0.941 | 0.910 |
|           | MAM     | 1   | 0.992 | 0.972 | 0.976 | 0.984 | 0.988 | 0.958 | 0.782 | 0.968 | 0.960 | 0.916 | 0.783 | 0.966 | 0.960 | 0.930 | 0.882 |
|           | JJA     | 1   | 0.984 | 0.969 | 0.976 | 0.995 | 0.975 | 0.780 | 0.970 | 0.971 | 0.934 | 0.781 | 0.969 | 0.971 | 0.949 | 0.882 | 0.898 |
|           | SON     | 1   | 0.946 | 0.949 | 0.979 | 0.992 | 0.749 | 0.949 | 0.958 | 0.943 | 0.752 | 0.951 | 0.959 | 0.954 | 0.894 | 0.903 | 0.882 |
| SO₂       | DJF     | 1   | 0.985 | 0.968 | 0.929 | 0.747 | 0.930 | 0.922 | 0.879 | 0.750 | 0.929 | 0.922 | 0.898 | 0.816 | 0.837 | 0.781 | 0.737 |
|           | MAM     | 1   | 0.983 | 0.930 | 0.751 | 0.935 | 0.923 | 0.861 | 0.752 | 0.931 | 0.923 | 0.885 | 0.828 | 0.842 | 0.791 | 0.749 |
|           | JJA     | 1   | 0.972 | 0.789 | 0.966 | 0.963 | 0.917 | 0.790 | 0.963 | 0.933 | 0.867 | 0.887 | 0.845 | 0.804 |
|           | SON     | 1   | 0.761 | 0.955 | 0.971 | 0.968 | 0.766 | 0.957 | 0.972 | 0.975 | 0.909 | 0.914 | 0.891 | 0.864 |
| PM₂.₅     | DJF     | 1   | 0.871 | 0.837 | 0.778 | 0.999 | 0.864 | 0.836 | 0.785 | 0.673 | 0.691 | 0.664 | 0.619 |
|           | MAM     | 1   | 0.989 | 0.952 | 0.871 | 0.999 | 0.989 | 0.960 | 0.885 | 0.904 | 0.858 | 0.815 |
|           | JJA     | 1   | 0.977 | 0.837 | 0.992 | 1.000 | 0.984 | 0.892 | 0.911 | 0.874 | 0.831 |
|           | SON     | 1   | 0.783 | 0.960 | 0.977 | 0.996 | 0.919 | 0.922 | 0.896 | 0.861 |
| PM₁₀      | DJF     | 1   | 0.864 | 0.837 | 0.790 | 0.676 | 0.694 | 0.667 | 0.622 |
|           | MAM     | 1   | 0.992 | 0.967 | 0.886 | 0.905 | 0.861 | 0.819 |
|           | JJA     | 1   | 0.985 | 0.893 | 0.911 | 0.875 | 0.832 |
|           | SON     | 1   | 0.898 | 0.903 | 0.872 | 0.834 |
| Traffic count | DJF     | 1   | 0.985 | 0.973 | 0.955 |
|           | MAM     | 1   | 0.986 | 0.964 |
|           | JJA     | 1   | 0.992 |
|           | SON     | 1   | 0.973 |

Table 5.
Seasonal correlation of the measured pollutants against the traffic variables (significant at 0.01 levels).
sampling locations. The data capture period was categorized into seasons that include December-January-February (DJF); March-April-May (MAM); June-July-August (JJA) and September-October-November (SON). This aims to appraise the environmental implication of road traffic movement to outdoor air pollution in Zaria across the seasons. From Table 5, it can be observed that all the measured variables were correlated positively at 0.01 p-levels. The analysis also indicates that the traffic activities (that is, the vehicular counts at the time of criteria pollutant observations) contributed significantly to observed criteria pollutants concentration levels except for the December-January-February (DJF) season. The DJF season (Table 5, red text) recorded lower correlation coefficients compared to the remaining seasons. The lower Pearson’s coefficients during the DJF season can be attributed to the Harmattan and the holiday season within the study area. The Harmattan season is characterized by natural dusty-windy conditions and low temperatures, while the holiday season attributed to the lesser than usual traffic activities within the study area. From Table 5, this study concludes that emissions from vehicular activities are significantly responsible for measured pollutants observations in this study.

The contribution of traffic variables to the outdoor air pollution level is further evaluated with the consideration of the various vehicle categories (2-W, 3-W, cars, buses, LDV and HDV). Table 6 described the contributory relationship between the observed criteria pollutants and the vehicular category. From Table 6, it can be observed that 2-W (motorcycles) counts showed the strongest relationship with the individual criteria pollutants measured, this followed by the 3-W (tricycles) and then buses. These findings confirmed the theory of the terrible state of these categories of the vehicle in the study.

4. Conclusions

Urban air quality management remains a continuous task for Nigerian policymakers. This study assessed the implication of varying categories of vehicular traffic on outdoor air pollution over a developing Nigeria city. This was achieved through day-time primary data capture of vehicular traffic and corresponding criteria pollutant measurements over a period of 1 year (December 2015–November 2016). The result of the criteria pollutant measurements was alarmingly high as confirmed by similar studies. Furthermore, the study concluded that the combined vehicular traffic did contribute significantly (R ≥ 0.619) to the observed pollutant measurements all through the study. The 2-W (motorcycle) was found to be the vehicular category that attributed the most significant relationship with observed
outdoor pollutant measurements. This is followed by the 3-W (tricycles) and buses. The findings of the study will assist Nigerian policymakers on decisive steps for vehicular worthiness to urban air quality management.

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Conflict of interest

The authors declare no conflict of interest.

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References

[1] Patton AP, Laumbach R, Ohman-Strickland P, Black K, Alimokhtari S, Lioy PJ, et al. Scripted drives: A robust protocol for generating exposures to traffic-related air pollution. Atmospheric Environment. 2016;143:290-299

[2] Gorai AK, Tchounwou PB, Mitra G. Spatial variation of ground-level ozone concentrations and its health impacts in an urban area in India. Aerosol and Air Quality Research. 2017;17(4):951-964

[3] Aliyu YA, Botai JO. An exposure appraisal of outdoor air pollution on the respiratory well-being of a developing city population. Journal of Epidemiology and Global Health. 2018;8(1):91-100

[4] Al-Awadi LT, Popov V, Khan AR. Seasonal effects of major primary pollutants in Ali Sabah Al-Salem residential area in Kuwait. International Journal of Environmental Technology and Management. 2015;18(1):54-82

[5] Marais EA, Jacob DJ, Wecht K, Lerot C, Zhang L, Yu K, et al. Anthropogenic emissions in Nigeria and implications for atmospheric ozone pollution: A view from space. Atmospheric Environment. 2014;99:32-40

[6] Aliyu YA, Musa IJ, Jeb DN. Geostatistics of pollutant gases along high traffic points in urban Zaria, Nigeria. International Journal of Geomatics and Geosciences. 2014;5(1):19-31

[7] Aliyu YA, Botai JO. Reviewing the local and global implications of air pollution trend in Zaria, northern Nigeria. Urban Climate. 2018;26:51-59

[8] Snyder EG, Watkins TH, Solomon PA, Thoma ED, Williams RW, Hagler GSW, et al. The changing paradigm of air pollution monitoring. Environmental Science & Technology. 2013;47:11369-11377

[9] Brook JR, Dann TF, Burnett RT. The relationship among TSP, PM10, PM2.5, and inorganic constituents of atmospheric particulate matter at multiple Canadian locations. Journal of the Air & Waste Management Association. 1997;47(1):2-19

[10] Guo H, Wang Y, Zhang H. Characterization of criteria air pollutants in Beijing during 2014–2015. Environmental Research. 2017;154:334-344

[11] Efe SI, Efe AT. Spatial distribution of particulate matter (PM10) in Warri metropolis, Nigeria. The Environmentalist. 2008;28(4):385-394

[12] Yazdi MN, Delavarrafiee M, Arhami M. Evaluating near highway air pollutant levels and estimating emission factors: Case study of Tehran, Iran. Science of the Total Environment. 2015;538:375-384

[13] Aliyu YA, Botai JO. Appraising city-scale pollution monitoring capabilities of multi-satellite datasets using portable pollutant monitors. Atmospheric Environment. 2018;179:239-249

[14] Llanes S. How to calculate time-weighted average (TWA). In: 26th Annual California Industrial Hygiene Council (CIHC) Conference; 2016; San Diego, USA. Available from: http://www.thecohengroup.com/article/calculate-time-weighted-average-twa/ [Accessed: 07-10-2017]

[15] WHO. Evolution of WHO Air Quality Guidelines. Past, Present and Future. World Health Organization; 2017. Available from: http://www.euro.who.int/__data/assets/pdf_file/0019/331660/Evolution-air-quality.pdf [Accessed: 26-09-2017]