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Multivariate Analysis of Vehicular Emissions in Parts of Benin City, Edo State, Nigeria

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ABSTRACT: The focus of this study is to monitor the incidence of vehicular emissions in some parts of Benin City in addition to studying the spatial variation of the pollutant using multivariate analysis of variance (MANOVA). Seven (7) georeferenced sampling points were employed for data collection and gaseous pollutants such as; dinitrogen oxide (NO_2), carbon monoxide (CO) including the total radiation were monitored in the morning and evening for 35 days with the aid of portable toxic gas monitors and radiation alert meters. Also measured were maximum temperature and wind speed using infra-red thermometers and portable anemometer respectively. From the result, it was observed that for temperature, the mean ± standard deviation during morning session was 30.549 ± 1.3716 and during evening season it was 28.879 ± 1.1788. For NO_2, the mean ± standard deviation during morning session was 0.0181 ± 0.01119 and during evening season it was 0.0230 ± 0.01282. For CO, the mean ± standard deviation during morning session was 0.5428 ± 0.36396 and during evening season it was 0.6169 ± 0.32395. For total radiation, the mean ± standard deviation during morning session was 0.247 ± 0.1285 and during evening season it was 0.281 ± 0.1298. On the significance difference of the overall results, it was revealed that the difference in concentration of vehicular emissions during the early hours of the morning and peak hours of evening is significant. With a calculated partial Eta squared based on Pillai's trace of 0.325, it was concluded that; there exist about 32.50% variability among the dependent variables.

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The lack of air quality data in most parts of Nigeria, results in low levels of awareness about air pollution and their resultant implications to human. It also limits people's capacity to predict the future challenges of air pollution thereby reducing their level preparedness towards future eventualities (Etim, 2016). African continent has the most notable lack of accessible air quality monitoring data, whilst facing numerous challenges related to air quality in the region (Abam and Unachukwu, 2009). It also has one of the urbanization rates of any region, with growing numbers of the population moving to large cities, where air pollution levels tend to be higher. In Nigeria, vehicular emissions are significantly on the rise due to the lack of poor transportation systems, giving way for unworthy road vehicles and unchecked use of private vehicles on the roads (Akpan and Ndoke, 1999). Many urban trips cover distances of less than 6 km. Since the effectiveness of catalytic converters in the initial minutes of engine operation is small, the average emission per distance driven is very high in urban areas. Also, poorly maintained vehicles that lack exhaust after treatment systems are responsible for a major part of pollutant emissions (Han and Naeher, 2006). Traffic contributes to a range of gaseous air pollutants and to suspended particulate matter (PM) of different sizes and composition. Tail pipe emissions of primary particles from road transport account for up to 30% of PM2.5 in urban areas and other emissions related to road transport (such as those from re-suspended road dust, and wear of tyres and brake linings) are the most important source of the coarse fraction of PM10 (Han and Naeher, 2006; Fu, 2001). According to the World Health Organization, Nigeria has a mortality rate for air pollution of 307.4 for every 100,000 people with an annual mean $PM_{2.5}$ concentrations of 46.3μg/m^3 which is 4.5 times above the WHO guidelines for outdoor air quality. With the most polluted cities being Kano and Onitsha. Microscopic particles of $PM_{2.5}$ micrometers or less in diameter can clog in human lungs and are linked to heart disease, stroke and lung cancer. The WHO recommends an annual mean exposure threshold of 10μg/m^3 to minimize the risk of health impacts from $PM_{2.5}$. It is the general believe that real-time, public air quality information is essential not only to empower populations to respond to current conditions and protect human health, but also is a cornerstone in

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generating public awareness and driving action to combat air pollution in the long-term (Koku and Osuntogun, 2007). The objective of this study is to evaluate the spatial variability of vehicular emissions in some parts of Benin City, Nigeria using multivariate analysis of variance

MATERIALS AND METHODS

Description of study area: The study area is limited to some parts of Benin City particularly Ugbowo and environs where serious traffic jam is experienced on daily bases. Benin City serves as the principal administrative and socio-economic center for both Oredo Local Government Area and Edo State in Nigeria. Benin City is a humid tropical urban settlement which comprises three Local Government Areas namely Egor, Ikpoba Okha and Oredo. It is located within latitudes $6^{0}20^{'}$N and $6^{0}58^{'}$N and longitudes $5^{0}35^{'}$E and $5^{0}41'$E. It broadly occupies an area of approximately 112.552 sq km. This extensive coverage suggests spatial variability of weather and climatic elements. Benin City lies visibly in the southern most corner of a dissected margin: a prominent topographical unit which lies north of the Niger Delta, West of the lower Niger Valley, and South of the Western Plain (Okhakhu, 2010). The specific locations employed for data collection are presented in Figure 1

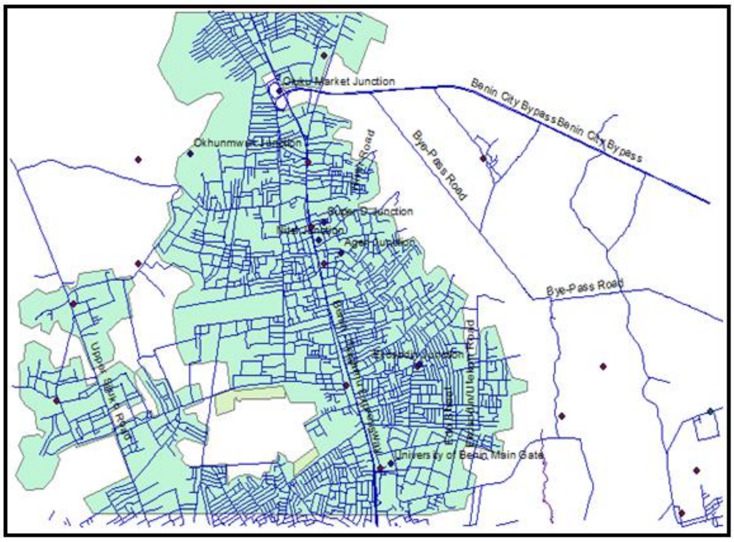

Fig 1: Map of study area

Data collection/Preliminary Analysis: Seven (7) georeferenced points, namely; University of Benin Main Gate, Ekosodin junction, Agen Junction, Super D junction, Nitel junction, Okhunmwun junction and Oluku Market junction were used for data collection. Dinitrogen oxide (NO_2), carbon monoxide (CO) and total radiation were monitored in the morning and evening for 35 days with the aid of portable toxic gas monitors and radiation alert meters. Maximum temperature and wind speed were also measured using infra-red thermometers and portable anemometer. To ascertain the quality of the data, selected preliminary analysis using different statistical techniques, namely outlier detection using seasonal box plot method as proposed by Levi *et al*., (2009), test of homogeneity of data using the residual mass curve as proposed by Raes *et al.*, (2006), test of normality using Jarque-Bera method and test of reliability using one-way analysis of variance were done.

Assessment of temporal variability: To study the variation in the concentration of vehicular emission occasioned by temporal variability (time of measurement), multivariate analysis of variance (MANOVA) was employed (Alkarkhi *et al.*, 2008).

RESULTS AND DISCUSSION

To ascertain the normality of the data, Jarque-Bera test statistics was computed and presented in Figure 2

From the result of Figure 2, the calculated Jarque-Bera test value was observed to be 20.50813. Since the Jarque-Bera test value is greater than 10 with a (p-value) that is less than the 5% significant value, the null hypothesis of normality was rejected and it was concluded that the measured NO_2 records did not follow a normal distribution. This was expected owing to the influence of temperature and wind speed on the dynamic dispersion of gaseous air pollutants. The same approach was applied to other pollutants and the results showed a non-normally distributed trend. On whether the data employed for the analysis is devoid of outlier, the seasonal box plot presented in Figure 3 was employed.

The presence of outlier is normally indicated with a square box or circle containing a value inside it. This was not noticeable in Figure 3 hence; it was concluded that the measured NO_2 data were devoid of possible outlier. The same approach was applied to other pollutants and the results showed that all the variables (air quality data) were devoid of outlier.

To ascertain the reliability of the data, two-way mixed model having a confidence interval of 95% (p-value=0.05) and initial test value of 0 was employed. The null hypothesis of reliability was formulated as follows;

H0: Data are reliable

H1: Data are not reliable

Using the Fisher's probability test (F-test), the analysis was conducted and the one-way analysis of variance (ANOVA) table was generated and presented in Table 1

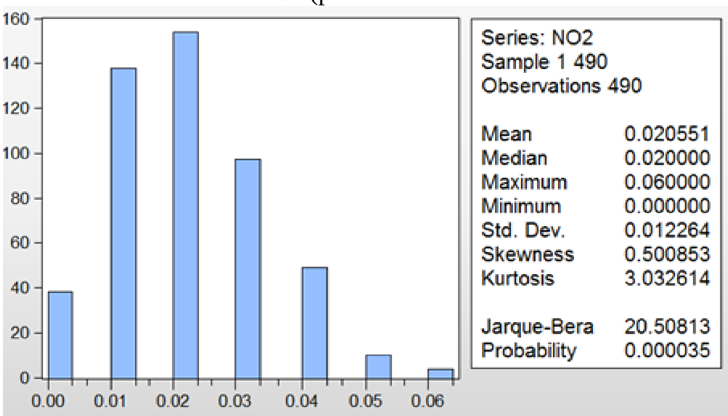

Fig 2: Normality test result of NO_2 records around the study area

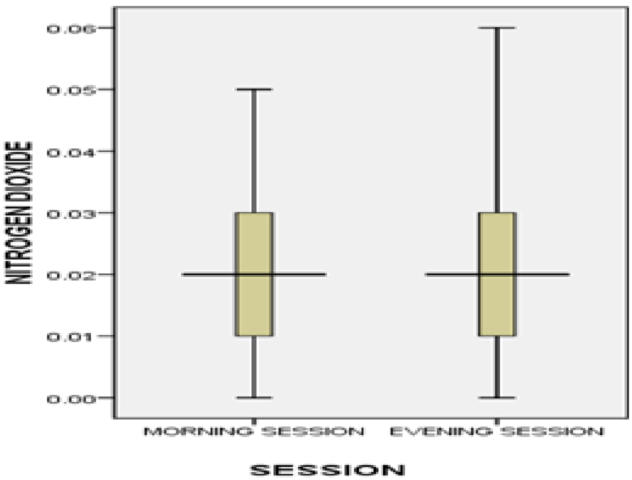

Fig 3: Seasonal box plot for assessing the presence of outliers in NO_2 data

Table 1: Analysis of variance (ANOVA)

	Sum of Squares	df	Mean Square	F	Sig
Between People	282.353	489	0.577		
Within People Between items	318289.685	3	106096.562	1.683E5	0.00
Residual	924.584	1467	0.630		
Total	319214.269	1470	217.153		
Total	319496.622	1959	163.092		

At 0.05 df, with a computed p-value of 0.000 as observed in Table 1, the null hypothesis was accepted and it was concluded that the data are good and cam be employed for further analysis.

To ascertain the presence of temporal variability occasioned by change in the time of measurement and also determine the degree of variability, multivariate analysis of variance was employed. The first step in the assessment of temporal variability is to compute the Mahalanobis constant and the descriptive statistics of all the dependent variables (air quality data). The maximum calculated value of Mahalanobis constant based on MANOVA was observed to be 15.86648. With degree of freedom equals 4 (number of dependent variables) the critical value of Mahalanobis constant was (20.52). Since 15.86648 < 20.52, it was concluded that the assumptions of multivariate outliers have not been violated hence the use of multivariate analysis of variance to study the presence of temporal variability was justified. The descriptive statistics is presented in Table 2

Table 2: Descriptive statistics of air quality data

Session	Mean	Std. Deviation	N
Temperature			
Morning Session	30.549	1.3716	245
Evening Session	28.879	1.1788	245
Total	29.714	1.5268	490
Nitrogen Dioxide			
Morning Session	0.0181	0.01119	245
Evening Session	0.0230	0.01282	245
Total	0.0206	0.01226	490
Carbon Monoxide			
Morning Session	0.5428	0.36396	245
Evening Session	0.6169	0.32395	245
Total	0.5799	0.34618	490
Total Radiation			
Morning Session	0.247	0.1285	245
Evening Session	0.281	0.1298	245
Total	0.264	0.1302	490

From the results of Table 2, it was observed that there is a significant difference between the calculated mean and standard deviation of all the dependent variables as a function of sampling time (morning and evening). For temperature, the mean ± standard deviation during morning session was observed to be 30.549 ± 1.3716 and during evening season it was observed to be 28.879 ± 1.1788. For NO_2, the mean ± standard deviation during morning session was observed to be 0.0181 ± 0.01119 and during evening season it was observed to be 0.0230 ± 0.01282. For CO, the mean ± standard deviation during morning session was observed to be 0.5428 ± 0.36396 and during evening season it was observed to be 0.6169 ± 0.32395. For total radiation, the mean ± standard deviation during morning session was observed to be 0.247 ± 0.1285 and during evening season it was observed to be 0.281 ± 0.1298. The difference in the mean and standard deviation suggest the presence of imaginative variance which is temporal variation occasioned by change in sampling time (morning and evening). In multivariate analysis of variance, we set out to test the null hypothesis that observed covariance matrix of all the dependent variables (gaseous emission concentration) are equal across group (morning and evening) that is; there is no variation in the concentration of the measured parameters. If the calculated p-value is less than 0.05 ($p < 0.05$) we reject the null hypothesis and conclude that the assumption of equal covariance matrices across group has not been satisfied; an indication that temporal variability exists among the group. The computed covariance matrix for the corrected model and season is presented in Table 3.

Table 3: Computed covariance matrix for corrected model

Source	Type II Sum of Square	df	Mean Square	F	Sig.	Partial Eta Square	Noncent Parameter	Observed Power
Corrected Model Temperature	344.891	1	344.891	209.055	.000	.300	209.055	1.000
Nitrigen Dioxide	.003[c]	1	.003	19.959	.000	.039	19.959	.994
Carbon Monoxide	.674[d]	1	.674	5.676	.018	.011	5.676	.662
Total Radiation	.144[e]	1	.144	8.629	.003	.017	8.629	834
Intercept Temperature	432634.057	1	432634.057	2.645E5	.000	.998	264540.998	1.000
Nitrigen Dioxide	.207	1	.207	1.429E3	.000	.745	1429.228	1.000
Carbon Monoxide	164.755	1	164.755	1.388E3	.000	.740	1387.909	1.000
Total Radiation	34.172	1	34.172	2.048E3	.000	.808	2047.685	1.000
Session Temperature	341.891	1	341.891	209.055	.000	.300	209.055	1.000
Nitrigen Dioxide	.003	1	.003	19.959	.000	.039	19.959	.994
Carbon Monoxide	.674	1	.674	5.676	.018	.011	5.676	.662
Total Radiation	.144	1	.144	8.629	.003	.017	8.629	.834
Error Temperature	798.082	488	1.635					
Nitrigen Dioxide	.071	488	.000					
Carbon Monoxide	57.929	488	.119					
Total Radiation	8.144	488	.017					
Total Temperature	433774.030	490						
Nitrigen Dioxide	.281	490						
Carbon Monoxide	223.358	490						
Total Radiation	42.460	490						
Corrected Total Temperature	1139.973	489						
Nitrigen Dioxide	.074	489						
Carbon Monoxide	58.603	489						
Total Radiation	8.288	489						

From the results of Tables 3, it was observed that the computed significant values (p-value) for both the corrected model and season were less than 0.05; ($p < 0.05$), hence the null hypothesis was rejected and it was concluded that the covariance matrix assumption was not satisfied. This means that the covariance matrices of the dependent variables are not equal across group an indication that temporal variability exists. It was concluded based on the covariance matrix that the variation in the dependent variables is due to variation in time of sampling.

Different statistical method for computing the F-value for multivariate analysis of variance exits in literature. One of them is the Roy's largest root which is probably the most acceptable and also the most susceptible to deviation in the covariance matrix. The next is the Pillai's Trace followed by Wilk's Lambda. Pillai's Trace is the least sensitive to the violation of the assumption of covariance matrix hence it was selected for this study. Result of multivariate test statistics computed to study the effect of temporal variability is presented in Table 4.

Table 4: Result of multivariate statistics

Effect:	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Square	Noncent Parameter	Observed Power
Intercept								
Pillai's Trace	.998	6.922E4[a]	4.000	485.00	.000	.998	276887.663	1.000
Wilks' Lambda	.002	6.922E4[a]	4.000	485.00	.000	.998	276887.663	1.000
Hotellimg's Trace	570.902	6.922E4[a]	4.000	485.00	.000	.998	276887.663	1.000
Roy's Largest Root	570.902	6.922E4[a]	4.000	485.00	.000	.998	276887.663	1.000
Session:								
Pillai's Trace	.325	58.497[a]	4.000	485.00	.000	.325	233.986	1.000
Wilks' Lambda	.675	58.497[a]	4.000	485.00	.000	.325	233.986	1.000
Hotellimg's Trace	.482	58.497[a]	4.000	485.00	.000	.325	233.986	1.000
Roy's Largest Root	.482	58.497[a]	4.000	485.00	.000	.325	233.986	1.000

From the result of Table 4, it was observed that the computed significant value (p-value) based on Roy's largest root, Wilk's Lambda, Hotelling's Trace and the Pillai's Trace were less than 0.05 ($p = 0.00$) hence, the null hypothesis that the air quality parameters are the same for the two groups (morning and evening) was rejected and it was concluded that temporal variability actually exist. To calculate the percentage variability that is accounted for due to temporal variation, the partial Eta squared value of the Pillai's trace was employed. From the result of Table 4, the calculated partial Eta squared of the Pillai's trace was observed to be 0.325 which indicates 32.50% variability among the dependent variables occasioned by change in the period of measurement. In addition, when the null hypothesis of equal variance assumption is rejected, then the observed power function based on Pillai's trace must be between 0.9-1.00. Again from the result of Table 4, it was observed that the calculated power function based on Pillai's trace is 1.00 for both intercept and session. This validates the initial claim that temporal variability exists between the dependent variables.

Conclusion: Since the critical value of Mahalanobis constant was less than the calculated value, it was concluded that the assumptions of multivariate outliers have not been violated hence the use of multivariate analysis of variance to study the presence of temporal variability. In addition, with a calculated partial Eta squared based on Pillai's trace of 0.325, it was concluded that; there exist about 32.50% variability among the dependent variables occasioned by change in the period of measurement. It is important to note that temperature and wind spend are important variables that can affect the dispersion of pollutants

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