# MONITORING OF CONCENTRATION OF AIR POLLUTANTS FROM VEHICULAR EMISSION ALONG MAJOR HIGHWAYS AND BYPASS WITHIN KOSOFE LOCAL GOVERNMENT AREA, LAGOS STATE

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***ABSTRACT***
*Vehicular emissions are considered a major source of urban air pollution. Pollutants from these emissions whether as individual compounds or by synergistic interaction impacts negatively on public health, vegetation and climate. In this paper, we evaluate baseline concentration of carbon monoxide (CO), oxides of nitrogen (NOx), sulphur dioxide ($SO_2$) and particulate matter (PM) from vehicular emissions during peak and off-peak periods along 3 major highways within Kosofe and Ikeja Local Government Areas (LGA) of Lagos State. Air quality monitoring/gas detection equipment were used to measure (in-situ method) ambient levels of the pollutant in nine locations within the selected area. The results revealed that the Federal Ministry of Environment's Ambient Air Quality Standard limit was exceeded by most of the gases in majority of the locations. Statistical analysis revealed significant variations in the concentration of these gases across locations. Heavy vehicular traffic, poor traffic management and frequent traffic congestion were observed as factors responsible for the high pollutant concentration.*

**Keywords**: Air Pollution, Gaseous Pollutants, Lagos, Traffic, Vehicular Emissions

## INTRODUCTION

The state of the environment is a major determinant of health as air quality in an area is often linked with respiratory and cardiovascular health of the public. Lagos popularly referred to as the commercial hub of Nigeria is a typical urban settlement. It is considered the fastest developing city and is plagued with heavy vehicular traffic in many areas. Lagos State is the smallest in terms of land mass but most populous city in Nigeria and in Africa .The population of Lagos has been estimated to be between 15 – 18 million, expected to reach 35 million by 2020 (Olukayode, 2005) with an annual growth rate of 6%. Lagos is estimated to have about 2,600 km of roads frequently congested, with over 1 million vehicles plying the roads on a daily basis (Nwosu, 2014). With the over 15 million people working, living and commuting everyday with the use of motor vehicles as the major means of transportation, the result is a mélange of air pollutants covering a major part of the city.

Increase in air pollutants from exhaust emissions have negative impacts on public health and the environment. Motor vehicle had been recognized as an important contributor to the regulated pollutants, such as CO, NOx, SOx and PM, due to the rapid growth and large population of vehicle in any metropolitan city (Lang *et al.*, 2016). In Lagos, transport induced air pollution has become an issue of concern to government and researchers. The congested state of roads and highways, dysfunctional public transport system and lack of non-motorized transport infrastructure are an increasing concern to public health analyst, researchers and the government (Uhuegbu, 2013).

The vehicles in Lagos are majorly run on petrol (gasoline) and diesel engines. Incomplete combustion of these fuels gives rise to the release of CO, NOx, SOx, PM, VOCs, PAHs, Pb among other pollutants (Chiang *et al.*, 2012). It is estimated that vehicular emissions account for 89% of CO emissions from anthropogenic sources in developed countries (Flachsbart, 1999). In an investigative study on the effects of vehicular emissions on human health, vegetation and environment in four locations within Lagos state Ojolo *et al.* (2007), showed that residents from the three of the areas suffer sleeplessness, running nose, heavy eyes, asthmatic attack and headache. In another research conducted under the African Monsoon Multi-disciplinary Analysis (AMMA) to determine the direct estimates of emissions (CO, NOx, VOCs, $O_3$, acetylene) from the megacity of Lagos, Hopkins *et al.* (2002) reported that the annual emission fluxes of CO and VOCs in Lagos were among the highest calculated comparative to those calculated for other selected megacities.

In an EIA study carried out by Mechelec Construction (Nigeria) on behalf of Lagos Urban Transport Project (LUTP) in 1996, atmospheric emissions of pollutants from three sources: stationary, mobile and industry were identified. The profile of air pollution by type and source, in Metropolitan Lagos, revealed road traffic as the major source of air pollution. A similar air quality management study conducted by Multi Development Services Consortium on behalf of Lagos Metropolitan Area Transport Authority in 2007/2008 in eight sample points across the state for both rainy and dry seasons, revealed that vehicular emission accounted for a greater part of total particulate matter, CO, $NO_2$, $SO_2$ and benzene, toluene, ethylbenzene and xylene (BTEX) emissions within the study areas. Among the pollutants emitted by motor vehicles, fine particulate matters

($PM_{2.5}$), and inhalable particulate matters ($PM_{10}$) can lower visibility by the extinction process.

Other gaseous pollutants are important precursors of secondary aerosols and ozone because they can generate a series of photochemical reactions which may have a great influence on visibility, accelerate the formation of haze, and exacerbate the photochemical pollution problem (Tang *et al.*, 2015). Nwosu, (2014) noted that the consequences of air pollution from vehicular sources include corrosion, acid rain, soiling of fabrics, damage to crops and other vegetation including damage to aesthetic values. It was suggested that priority should be given to the assessment of existing vehicular emissions, clean fuel programmes, fuel quality control and traffic management in order to eliminate the risks associated with environmental pollution.

In this study, we provide insights into the obtainable emission levels in the selected sampling locations. In particular, we evaluate baseline concentration of carbon monoxide (CO), oxides of nitrogen (NOx), sulphur dioxide ($SO_2$) and particulate matter (PM) from vehicular emissions during peak and off-peak periods along two major highways within Kosofe and Ikeja Local Government Areas of Lagos State, selected highways include Ikorodu road, Apapa-Oworonshoki Express way and Lagos-Ibadan Expressway/Third Mainland bridge Axial road.

The aim of this study was to quantify the levels of commuter exposure to pollutants such as CO, NOx, SOx and Particulate Matter (PM) at peak and off-peak hours. This work also examined the statistical variations in the spatial distribution of the gases.

## MATERIALS AND METHODS

### *Data Collection*

Data for this study was collected primarily from air quality measurements (*in-situ*) and vehicular counts. The study areas were locations along a loop of road networks located around the corridors of the Kosofe expressway and Ikeja LGA of Lagos State. The locations were carefully selected away from industrial sources of emission to ensure there was little or no interference with the outcome of the measurement. Figure 1 gives a graphical representation of the eight sampling points.


**Fig1: Map of the sampling locations**

The considered locations included Toll Gate along the Lagos-Ibadan Expressway, Ojota, Maryland, Anthony, Gbagada (Gbagada Estate Junction), Oworonshoki (New Garage), Ogudu Ojota and Ketu. The two major roads Ikorodu road and Oworonshoki-Lagos-Ibadan Expressway are strategically significant as they link most of the parts of the city to Victoria Island (the commercial hub of Lagos). The number of vehicles that ply these roads as well as business activities that take place along these roads contributes to the high traffic being experienced thereby increasing traffic congestion and thus air pollution.

**Table 1: Coordinates of the sampling locations**

| S/N | Location | Coordinates | Remarks |
|---|---|---|---|
| 1. | Toll Gate (Berger) | N06º 59′ 91.90″<br>E03º 37 82.0″ | High traffic flow. Gateway to Lagos city |
| 2. | Ojota | N06º 58′ 80.33″<br>E03º 37′ 89.31″ | High traffic area with many bus garages |
| 3. | Maryland | N06º 34′ 17.17″<br>E03º 22′ 03.52″ | Main traffic highway with heavy traffic |
| 4. | Anthony | N06º 33′ 31.41″<br>E03º 22′ 01.04″ | Mainly residential area with commercial vehicles |
| 5. | Gbagada | N06º 32′ 55.33″<br>E03º 23′ 17.20″ | Mainly residential area with commercial vehicles |
| 6. | Oworonsoki | N06º 33′ 19.02″<br>E03º 23′ 47.25″ | One of the main feeders to the 3rd Mainland bridge |
| 7. | Ogudu | N06º 34′ 19.38″<br>E03º 23′ 49.52″ | Continuous flow of traffic with major bus stops along the way |
| 8. | Ketu | N06º 34′ 54.69″<br>E03º 23′ 12.20″ | Heavy traffic on the corridor of a major busy market |
| 9. | UNILAG Botanical Garden | N06º 34′ 78.80″<br>E03º 19′ 95.9″ | Control site, serene and undisturbed by traffic. |

*In-situ* measurement of air quality parameters for CO, $SO_2$, NO, $NO_2$, $PM_{0.5}$, $PM_{1.0}$, $PM_{2.0}$, $PM_{5.0}$, at the eight sampling points using handheld air quality monitoring equipment viz: QRAE plus PGM-2000/2020, QRAE II gas detector, GT-321 hand held Particle Counter, ToxiRAE II gas monitor as well as the Testos 350 Combustion & Emission Analyser. The Q-Rae Plus Multi-gas Monitor, PGM-2000/2020, and ToxiRAE II Single gas monitor were used to continuously measure and record $NO_x$ and $SO_2$ concentrations respectively. Gases were measured by electrochemical sensors with a range of 0 to 20 ppm and a 0.1 ppm resolution. The sensor response time was 35 seconds for $SO_2$ and 25 seconds for $NO_2$. The operating temperature for both equipment was between -20 $^oC$ – 45 $^oC$ and 15.56 $^oC$ – 45 $^oC$ respectively while their operating humidity was between 0% and 95%.

Three measurements were taken at each sampling point within a space of 10mins to find the mean concentration at that point. The sampling positions were divided into two sets, with the first set of measurements taken at Toll Gate, Ojota, Maryland and Anthony while the second set included Gbagada, Oworonshoki, Ogudu and Ketu. The control for the study was taken at University of Lagos Botanical/Zoological Garden. In each set of sampling points, measurement were taken on one day and repeated subsequently on another day to observe the trend. Therefore, the sampling for the eight points was carried out in batches of four sampling points per day, making it four days in total namely: Monday, Tuesday, Wednesday and Friday for both peak and off-peak periods. Thursday was deliberately excluded because of the routine weekly sanitation exercise that holds from 8am to 10am for traders and shop owners. It was envisaged that this was going to affect the flow of traffic during the morning peak hours.

**Statistical Analysis**

The Levene's test for equality of variances was employed to determine the variation between the concentrations of pollutants at various locations. The test was carried out at 95% confidence level so that so that a p-value less than 0.05 would lead to a conclusion of unequal variance between concentration of pollutants at the various factor levels considered. A Generalised Linear Model (GLM) including interactions between the day, period and location of pollutants was developed. A wald test at 95% confidence was conducted on the model.

Tukey HSD test, the Scheffe's test, the LSD test and the Boneferroni post hoc tests were carried out also at 95% level of significance, to show the differences in model-predicted means for each pair of factor levels so that a p-value less than

0.05 would lead to a statistically significant difference between the model predicted means between each pair of factor levels. Profile plots of the estimated marginal means were employed to test for interaction effects. In the absence of interaction effects, we would expect the lines on the chart to be parallel.

## RESULTS AND DISCUSSION

Globally, the transportation sector is a major source of greenhouse gas emissions (GHGs). The largest anthropogenic source of CO is vehicle emissions. Figure 2 reveals high levels for carbon monoxide (CO) at most sampling locations on both days during peak periods as well as on day 2 during the off-peak period. Breathing the high concentrations of CO typical of a polluted environment leads to reduced oxygen ($O_2$) transport by hemoglobin and has health effects that include headaches and increased risk of chest pain for persons with heart disease. Motor-vehicle emissions are the primary source of CO in outdoor air in populated areas and are associated with the highest outdoor CO exposure in nonsmokers. Outdoor concentrations of CO tend to be higher in urban areas such as the sampling locations in this study which increases with the density of vehicles and miles driven. This result is similar to that obtained from Olajire *et al.*, (2011) were highly traffic-related with possibly severe health consequences. Strong traffic impacts were observed from the concentrations of these pollutants measured which was a clear reflection of diesel truck traffic activity rich in black carbon concentrations.

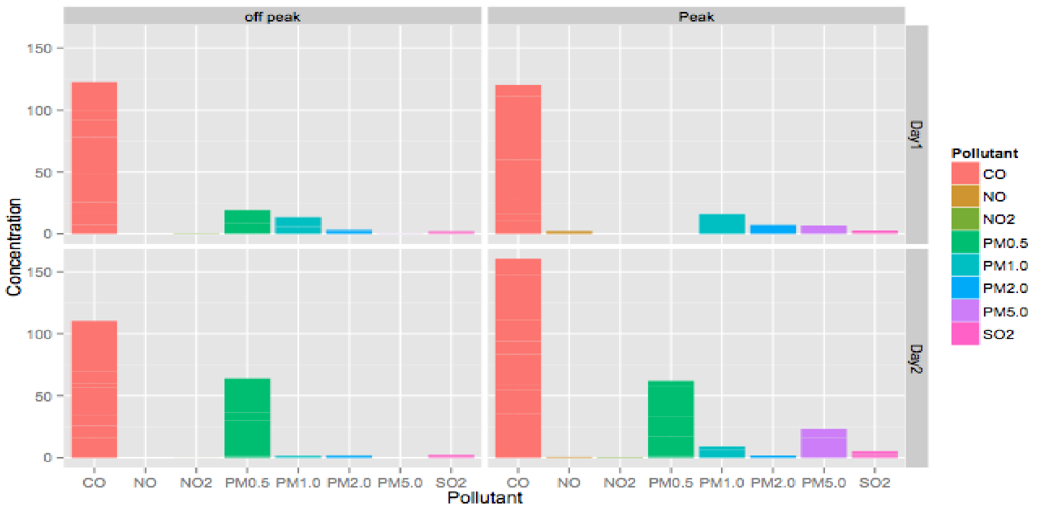


**Fig 2: Average Concentration of pollutants by period and Day**

The incomplete combustion of fossil fuels especially from motor vehicles, which is responsible for CO emissions, also causes emissions of fine particles – particulate matter (PM) and toxic organic air contaminants. Epidemiological studies have linked exposure to fine PMs with various adverse health effects, including premature mortality, exacerbation of asthma and other respiratory tract diseases, and decreased lung function. $PM_{0.5}$ was found to have the highest concentrations among the PMs measured with the highest concentration recorded on day 2 in Ketu and Maryland axis during the off-peak period and at Oworonshoki at peak period. Vehicular exhaust particles are found to be most responsible for small-sized airborne PM air pollution in urban areas. These particles, which have less mass but might be more respirable and hence toxic as they are easily inhaled through the respiratory tract.

The results obtained from this study further revealed CO as the most prominent pollutant followed by $PM_{0.5}$, while NO and $NO_2$ are the least prominent across the days and periods measured. Furthermore, we observed that maximum value of NO and $NO_2$ recorded was during the off-peak period with concentration as high as 0.2 ppm. Concentration of $SO_2$ was recorded at a maximum of about 1.9 ppm while it was not detected in some of the locations especially during off peak periods. Figure 4 gives the indication of a skewed distribution of pollutants across the days and periods measured.

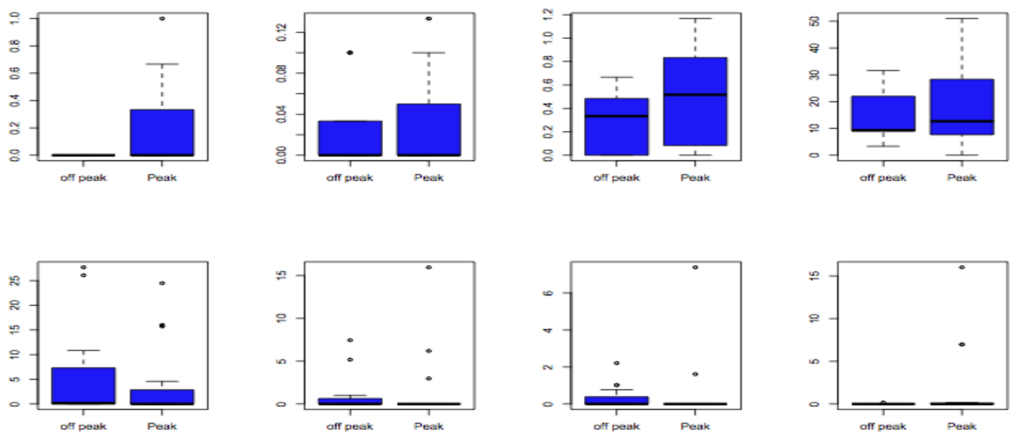


**Fig 3: Distribution of concentration of pollutants across the days and periods**

The Levene's test of equality of variance at 95% gave a Fisher's statistic of 3.73 with a corresponding p-value of 0.00, giving us reason to believe that variations in concentration of pollutants are not the same across some or all of the observed groups, factors and interactions.

The model developed is summarized as:
*Concentration of pollutants= Intercept + Day + Time + Location + Pollutants + Day * Pollutants + Time * Pollutants + Location * Pollutants*

The result of which is presented in Table 2.

**Table 2: Generalised linear model of factors considered**

| Source | Degrees of freedom | F-Statistic | P-Value |
|---|---|---|---|
| Corrected Model | 79 | 5.123 | 0.000* |
| Intercept | 1 | 93.314 | 0.000* |
| Day | 1 | 2.656 | 0.104 |
| Time | 1 | .250 | 0.617 |
| Location | 7 | 1.153 | 0.328 |
| Pollutants | 7 | 38.400 | 0.000* |
| Day * Pollutants | 7 | 2.790 | 0.007* |
| Time * Pollutants | 7 | 1.405 | 0.200 |
| Location * Pollutants | 49 | 1.440 | 0.029* |
| Error | 646 | | |
| Total | 726 | | |
| Corrected Total | 725 | | |

*** indicates significance at 0.05**

Tables 2 and 3 indicate that day, time and location alone (as individual components) as well as the interaction between time and pollutants contribute almost nothing to the model. However, the interaction between the day and the pollutants, the locations of the pollutants, and the interaction between the pollutants and the time periods as well as the pollutants themselves contribute significantly to the model.

**Table 3: Wald Chi-square Test**

| Source | Wald Chi-Square | df | P-value |
|---|---|---|---|
| (Intercept) | 88.649 | 1 | 0.000 |
| Day | 3.538 | 1 | 0.060 |
| Time | 11.642 | 1 | 0.001 |
| Location | 25.174 | 7 | 0.001 |
| Pollutants | 1149.503 | 7 | 0.000 |
| Day * Pollutants | 21.224 | 7 | 0.003 |
| Time * Pollutants | 19.317 | 4 | 0.001 |
| Location * Pollutants | 80.509 | 29 | 0 |

The insignificance of the interaction between time and pollutants can be explained by the fact that Lagos is generally a densely-populated city with a huge traffic of cars plying the road at all times daily so that both peak and off-peak periods would most likely record only minimal statistical difference in the concentration of pollutant so that it would not matter what time of the day the data was collected at each location. The results show that the data collection day also does not matter. This should be the case as the data was collected over two business days with similar traffic patterns.

The results of post hoc tests carried out in homogenous subsets by location and by pollutants revealed a significant difference between pollutant concentration between Ojota and Ogudu (p-value = 0.005), Maryland and Ogudu (p-value=0.037) and Gbagada and Ogudu (p-value=0.045).

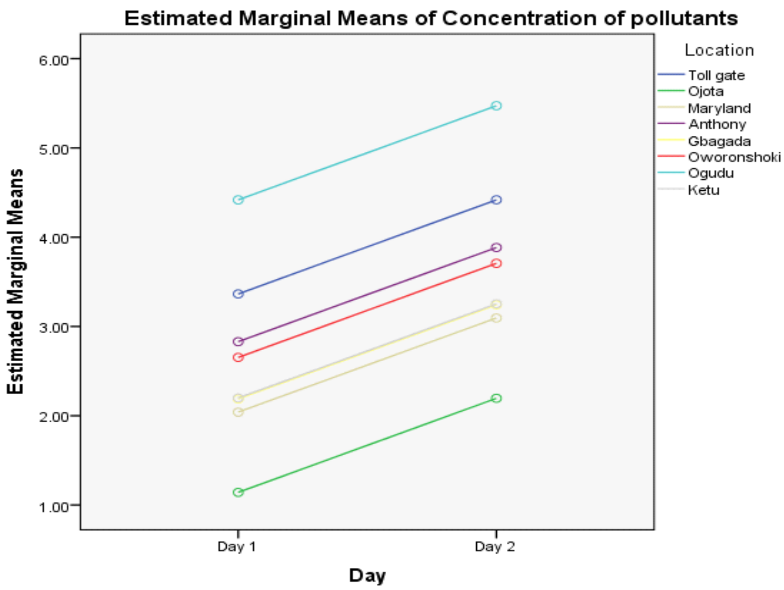


**Fig 4: Profile plots of estimated marginal mean conc. of pollutant by day against location**

A plot of the estimated marginal mean concentration of pollutants by day against the locations considered (Fig. 4) gives parallel lines, indicating that concentration of pollutants in each location did not change significantly between Day 1 and Day 2.

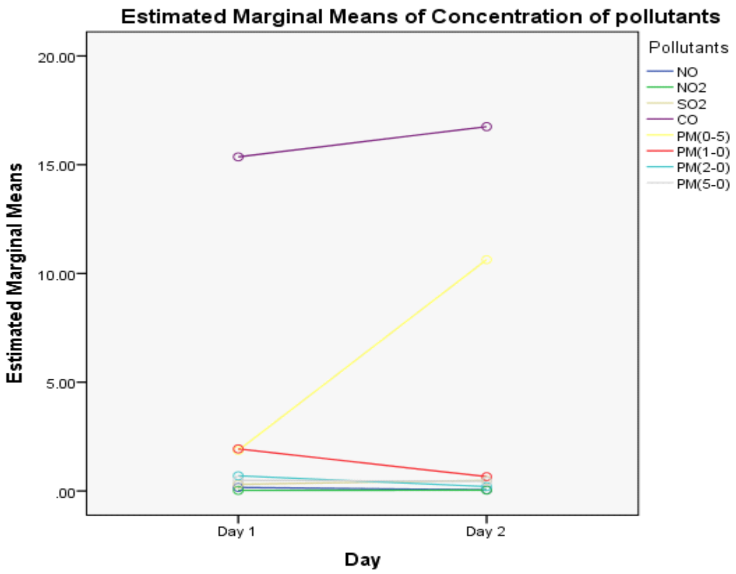


**Fig 5: Profile plots of estimated marginal mean conc. by pollutants against day**

A plot of the estimated marginal mean concentration of pollutants by period of the day against the day considered (Fig. 5) gives parallel lines giving us reason to believe that there are no interaction effects between period and day, indicating that concentration of pollutants at peak and off-peak period does not change significantly between Day 1 and Day 2.

## CONCLUSION

This study was aimed at acquiring baseline data in parts of the populated city of Lagos on air quality and the danger inherent in its deterioration.

It was observed that traffic congestion during peak and off-peak periods contribute immensely to high concentration of $NO_2$, $SO_2$, CO and PM in the air at the locations studied. The concentration of CO, $NO_2$, and $SO_2$ during traffic peak periods in some locations exceeded the maximum threshold limit of the Ambient Air Quality Standard of the Federal Ministry of Environment. The concentration of CO observed requires immediate attention due to the serious implications of the effects of these pollutants on human health and environment.

Based on the findings of this study, we propose that the government should:

- Develop and implement control measures/strategies (policy, legislation etc.) to ensure poorly maintained vehicles that emit high concentrations of exhaust gases are impounded.
- Ensure strict enforcement of Vehicle Maintenance Plans (VMP) for Trucks and other heavy duty vehicles owners.
- Develop strategies for effective traffic management and discipline.
- Promote and encourage the use of vehicles with alternative sources of energy like electricity, bio-fuel or natural gas.
- Encourage residents to reduce the number of vehicles on the road by patronizing the bus rapid transportation (BRT) scheme.
- Improve on the railway network in the country to reduce the number of heavy goods vehicles (HGV) that ply the major highways.

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