# ASSESSMENT OF SEASONAL VARIATION OF AMBIENT AIR POLLUTANT CONCENTRATIONS AROUND SLUM SETTLEMENTS IN LAGOS METROPOLIS, NIGERIA

**Okimiji O. P.[1*], Ezennia O. J.[1], Okafor A.T.[2] and Abdussalaam S. A.[1]**

[1]Department of Environmental Management and Toxicology, College of Environmental Resource Management, Federal University of Agriculture, Abeokuta, P. M. B. 2240, Ogun State, Nigeria.
[2]Department of Environmental Management and Toxicology, College of Natural Resources and Environmental Management, Michael Okpara University of Agriculture, Umudike, P. M. B. 7267, Abia State, Nigeria.
*Corresponding author: princessokimiji@yahoo.com. Tel: +2348035665979.

**Accepted 21st May, 2020**

This study assessed the effect of seasonal variations on the air quality around slum settlements within Lagos Metropolis. Air parameters were monitored from different slums around the settlement of Majidun (Group A), Oworoshoki (Group B), Bariga (Group C), Iwaya (Group D) and Ijora Badia (Group E) for wet and dry seasons from 2018 to 2019. Parameters analysed are volatile organic compounds (VOC), carbon dioxide ($CO_2$), nitrogen dioxide ($NO_2$) and sulphur dioxide ($SO_2$) using Aeroqual gas monitor. The data obtained were analysed using statistical package for social sciences (SPSS) for Windows. The result of the analyses showed that all the parameters have higher concentration during the dry season than in the wet season across the Groups, except VOC. Pressure and relative humidity have higher concentration during wet season than dry season among the groups. Paired sample t-test results revealed that VOC, $CO_2$, $NO_2$ and $SO_2$ showed no significant variation in all Groups. Pressure and relative humidity had significant variation across the groups. Most of the parameters have their mean values within the WHO standards in both seasons. Mean values for $NO_2$ and $SO_2$ are higher than the guideline provisions. Results of principal component analysis (PCA) revealed that $CO_2$ contributed a strong positive loading across the groups except for Group C, while VOC had a strong positive loading in Group C and D during wet season. Temperature and relative humidity (RH) contributed to a strong positive loading across the Groups except for Group C during wet season. $CO_2$ and VOC have a strong positive loading across the Groups except for Group E and B during dry season. More so, temperature and pressure exhibited a strong positive loading across the Groups except for Group A, C, and E respectively. The study concludes that seasons significantly influence the concentration of pollutants in the slums. Therefore, the need for monitoring and enforcement of appropriate laws should be considered in the slum settlement to reduce the risks associated with these pollutants.

**Key words:** Assessment, seasonal variation, air pollutant, slum settlements, meteorology

## INTRODUCTION

The atmosphere is the gaseous envelope surrounding the earth, whereby it constitutes the transition between the surface and vacuum of space (Bhatia, 2009). Thus, it primarily comprises of nitrogen ($N_2$) and oxygen ($O_2$) and is made up of many layers of air. Hence, each one is identified by their thermal characteristics, chemical composition, movement and density (Narayanan, 2009). Therefore, seasonality has always been a factor determining the concentration of pollution in the lower atmosphere. Bhatia (2009) reported that air pollution is the introduction of chemicals, particulate matter or biological materials that can be harmful and causes discomfort to humans and other living organisms. Lutgens and Edward (2000) reported that air pollutants commonly found in the urban environment are as follows: sulphur dioxide ($SO_2$); oxides of nitrogen (NOx), nitrogen dioxide ($NO_2$); carbon monoxide (CO); volatile organic compounds (VOCs); ozone ($O_3$);

particulates matters; and lead (Pb). However, USEPA (2006) ascertained that air pollution could be in the form of solid particles, liquid droplets or gases; and they may be natural or man-made (Narayanan, 2009). Komolafe et al. (2014) documented that air pollution source include vehicle exhaust emission (traffic), oil and gas production (Industry), generating sets and power plants, anthropogenic activities (heating and cooking with solid fuels, forest fires and open burning of municipal waste and agricultural residues). Furthermore, Akanni (2010) stressed that air pollution has become a topic of intense research at all levels because of its increase, which has led to climatic changes in recent times. Komolafe et al. (2014) has also reported that air pollution in the urban centers is increasing rapidly due to high population density, increased number of motor vehicles, use of fuels with poor environmental performance, poorly maintained transportation systems and ineffective environmental regulations and policies. Hence, Cohen et al. (2017) opine that air pollution provides insidious challenge to environment and public health; whereas the long-term exposure to ambient air pollutants increases morbidity and mortality. The introduction of air contamination in higher scale is said to affect the prosperity of people such as kids, elderly and individuals with asthma or cardiopulmonary ailments (Buteau and Goldberg, 2016). Air pollution is believed to kill more people worldwide than AIDS, malaria, breast cancer and tuberculosis (WHO, 2014). In China, air pollution was previously estimated to contribute to 1.2 to 2 million deaths annually (WHO, 2014; Yang et al., 2013). Moreover, In Nigeria, especially Lagos State, the major environmental problems confronting the region are anthropogenic activities, traffic and industrial air pollution (Tawari and Abowei, 2012). Over two million premature deaths recorded each year are attributed to the effects of urban outdoor air pollution in developing countries (Mabahwi et al., 2014). This study, therefore, assessed air pollutant concentrations around slum settlements within Lagos metropolis, in order to evaluate the health implications.

## MATERIALS AND METHODS

### Study area

The study was carried out in slum settlements within Lagos Metropolis, south-western Nigeria around Longitudes 3° 249 ’E and latitudes 6° 279 ’N with a coastline of approximately 180 km (BRNCC, 2012; Odunuga et al., 2012). Lagos has a total land area of 3577.28 km$^2$ out of which 22% is wetland and population density of approximately 5926 persons per km$^2$ (Oshodi, 2013). The population of Lagos State is estimated to be 24.5 million in 2015 (UN-Habitat, United Nations Human Settlements Programme, 2008) and 29 million by 2020 (George, 2010; Lagos Water Corporation, 2011) with a growth rate of 3.2 and 8% (Oyegoke et al., 2012; World Bank, 2013).

Lagos State geology comprises of coastal plain sands and a tidal flat with alluvium (BRNCC, 2012); while vegetation is tropical rainforest zone, consisting of mangrove swamps, freshwater swamps, lagoons and creeks. The relief occupies a low-lying topography of 1- 4% slope, elevation of 0-2 m above sea level (Awosika et al., 2000) which is characterized by dendritic drainage system of Rivers Ogun, Adiyan and Ossa (Idowu and Martins, 2007). Lagos ranked 15th in the world in terms of population exposed to coastal flooding, because over 70% of its population are living in unplanned settlements such as slums (Adelekan, 2010). This is not surprising as only 45.2% of its built-up areas are connected to drains (Nwigwe and Emberga, 2014) and only less than 30% of the existing drains are maintained (Aderogba, 2012). Lagos State has two distinct climatic seasons, dry and wet (rainy). It also experiences high air temperatures ranging from 30.0 to 38.0˚ C (Uluocha & Ekop, 2002; Adejuwon, 2004). Figure 1 presents the map of the study area, indicating the sample locations.

### Sampling locations

A total of five selected slum settlements were designated for this study in Lagos metropolis. At each slum settlement, VOC, $CO_2$, $NO_2$ and $SO_2$ were monitored every month for six months of the wet and dry seasons each, from 2018 to 2019. This gave a total of 12 months of air pollutants monitoring across the sampling duration. The measurements were determined in triplicates. Each of the selected slums was classified into

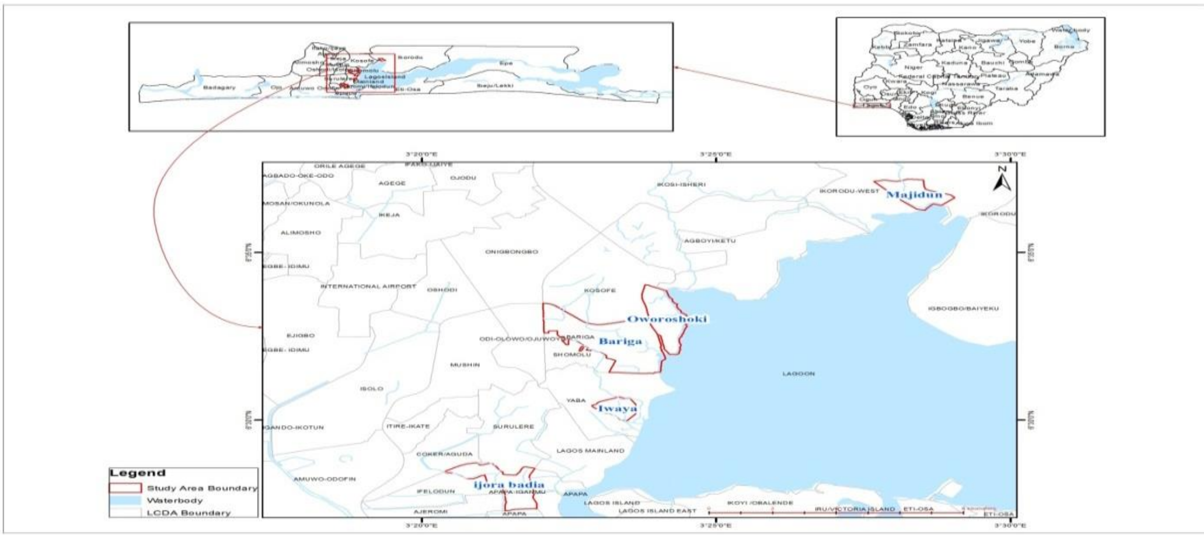


**Figure 1.** Map of the study area.

five groups as follows:

Group A: monitoring within Majidun
Group B: monitoring within Oworoshoki
Group C: monitoring within Bariga
Group D: monitoring within Iwaya
Group E: monitoring within Ijora Badia

Geographical coordinates (latitude and longitude) of the sample sites were determined using a GPS device Garmin (GPSMAP 76CSX model). Map of Lagos metropolis was obtained and gridded to create cells of 300 $m^2$ using Arc Map 10.1 (Figure 2) for a representative collection of data across the entire slums. Ten cells out of the existing cells were randomly selected from each of the study areas using random number table, according to the method proposed by Kriging (Sajil et al., 2011). Figure 2 presents grid map of the study area indicating the sample locations.

**Measurement procedures**

The sampling parameters were measured in the windward direction of the sampling locations using a hand-held portable gas analyzer (multi RAE PGM-6208). The equipment is a digital meter, which takes measurements at a time-weighted average. The equipment initializes for exactly 3 min before displaying the concentration. Measurements were taken at a height of 2 m from the ground level (level at which humans are most likely to be exposed). This procedure was followed in order to ensure accurate and reliable measurements. The equipment was calibrated as recommended by the manufacturer before and after each batch of sampling.

**Meteorological data**

Allied to the parameters monitoring, meteorological data such as temperature, relative humidity and pressure were measured at each slum settlements of Bariga, Majidun, Oworoshoki, Iwaya and Ijora Badia respectively. The measurements were observed every month in triplicates for 6 months, covering wet and dry seasons from 2018 to 2019. This gave a total of 12 months of monitoring across the sampling duration. The Wind Mate (WM 350) equipment was used to obtain the in situ meteorological data.

**Statistical analyses**

Data collected for air pollutant and meteorological parameters were analysed for inferential statistics (analysis of variance, paired sample student t-test and principal component analysis), using SPSS for Windows (version 21.0).

**RESULTS AND DISCUSSION**

The results of the analysis of air pollutant parameters for wet and dry seasons are presented in Tables 1, 2, 3, 4 and 5 respectively. In Group A, air parameters mean values of VOC were

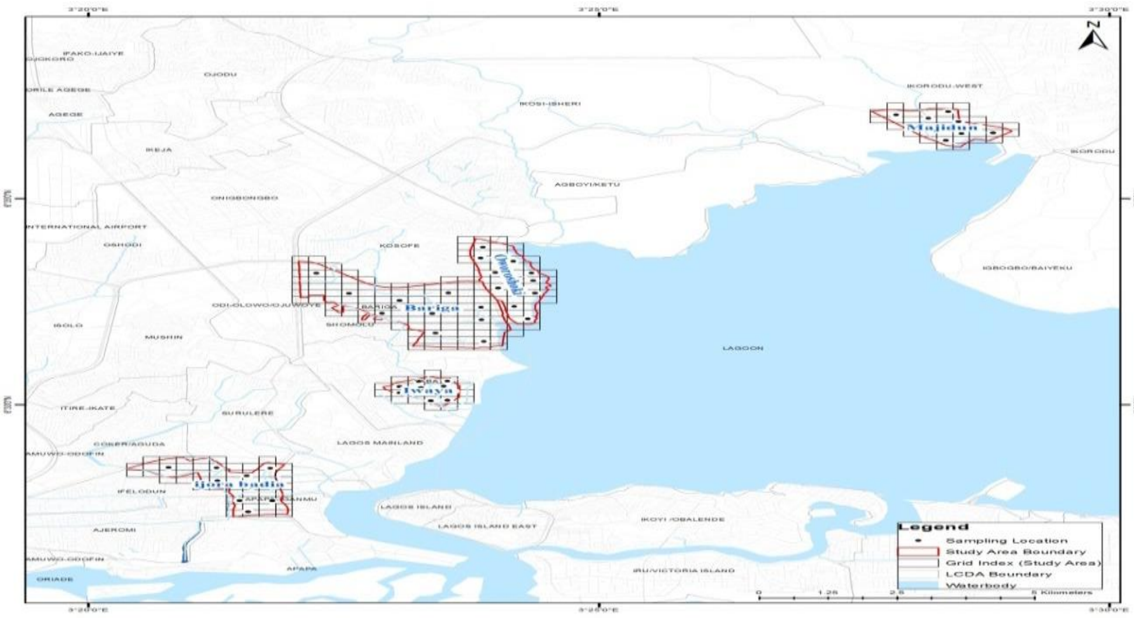


**Figure 2.** Grid map of the study area.

**Table 1.** Paired sample t-test for difference in Concentration between wet and dry season air pollutant and Meteorology parameters within Majidun (Group A).

| Location | Parameter | Pair | Mean ± Std. Error | N | Std. Deviation | d.f | t-calculated | Sig level | Rmks |
|---|---|---|---|---|---|---|---|---|---|
| **Majidun** | VOC mg/m$^3$ | Wet Season | 2.00±0.000 | 45 | 0.000 | 44 | 7.091 | 0.000 | S |
| | | Dry Season | 1.47±0.075 | 45 | 0.505 | 44 | | | |
| | $CO_2$ mg/m$^3$ | Wet Season | 38.20±1.381 | 45 | 9.263 | 44 | -7.993 | 0.000 | NS |
| | | Dry Season | 49.44±0.075 | 45 | 0.503 | 44 | | | |
| | $NO_2$ mg/m$^3$ | Wet Season | <0.01 | 45 | 0.000 | 44 | 0.000 | 0.000 | NS |
| | | Dry season | 0.01±0.000 | 45 | 0.000 | 44 | | | |
| | $SO_2$ mg/m$^3$ | Wet Season | 0.001±0.000 | 45 | 0.000 | 44 | 0.000 | 0.000 | NS |
| | | Dry Season | 0.002±0.000 | 45 | 0.000 | 44 | | | |
| | Temperature °C | Wet Season | 26.29±0.184 | 45 | 1.236 | 44 | -26.013 | 0.000 | NS |
| | | Dry Season | 33.64±0.225 | 45 | 1.510 | 44 | | | |
| | Pressure N/m$^2$ | Wet Season | 1015.73±0.267 | 45 | 1.789 | 44 | 19.733 | 0.000 | S |
| | | Dry Season | 1009.07±0.116 | 45 | 0.780 | 44 | | | |
| | Relative Humidity % | Wet Season | 78.47±0.408 | 45 | 2.735 | 44 | 20.657 | 0.000 | S |
| | | Dry Season | 67.67±0.466 | 45 | 3.126 | 44 | | | |

Note: S= significant, NS= not significant
Source: Field Work, Lagos Metropolis slums 2018/2019.

higher during the wet season, while $CO_2$ mean values were higher during the dry season. Paired sample student t-test for Group A (Majidun) air pollutant parameters in Table 1 shows that VOC and $SO_2$ have their calculated values (t- calculated) greater than the table value at $p<0.05$, which indicates significant seasonal variation. Likewise, parameters such as $CO_2$ and $NO_2$ showed no significant seasonal variation because their calculated values are less than the

**Table 2.** Paired sample t-test for difference in Concentration between wet and dry season air pollutant and Meteorology parameters within Oworoshoki (Group B).

| Location | Parameter | Pair | Mean±Std. Error | N | Std.Deviation | d.f | t-calculated | Sig level | Rmks |
|---|---|---|---|---|---|---|---|---|---|
| **Oworoshoki** | VOC mg/m$^3$ | Wet Season | 1.07±0.038 | 45 | 0.252 | 44 | -3.708 | 0.001 | NS |
| | | Dry Season | 1.40±0.074 | 45 | 0.495 | 44 | | | |
| | $CO_2$ mg/m$^3$ | Wet Season | 43.84±0.063 | 45 | 0.424 | 44 | -34.333 | 0.000 | NS |
| | | Dry Season | 49.22±0.145 | 45 | 0.974 | 44 | | | |
| | $NO_2$ mg/m$^3$ | Wet Season | 0.02±0.010 | 45 | 0.000 | 44 | 0.000 | 0.000 | NS |
| | | Dry season | 0.05±0.010 | 45 | 0.000 | 44 | | | |
| | $SO_2$ mg/m$^3$ | Wet Season | 0.01±0.000 | 45 | 0.000 | 44 | 0.000 | 0.000 | NS |
| | | Dry Season | 0.03±0.010 | 45 | 0.000 | 44 | | | |
| | Temperature °C | Wet Season | 26.60±0.197 | 45 | 1.321 | 44 | -35.227 | 0.000 | NS |
| | | Dry Season | 32.93±0.038 | 45 | 0.252 | 44 | | | |
| | Pressure N/m$^2$ | Wet Season | 1015.73±0.267 | 45 | 1.789 | 44 | 19.733 | 0.000 | S |
| | | Dry Season | 1009.07±0.116 | 45 | 0.780 | 44 | | | |
| | Relative Humidity % | Wet Season | 78.53±0.411 | 45 | 2.760 | 44 | 20.375 | 0.000 | S |
| | | Dry Season | 67.67±0.466 | 45 | 3.126 | 44 | | | |

Note: S= significant, NS= not significant
Source: Field Work, Lagos Metropolis slums 2018/2019.

**Table 3.** Paired sample t-test for difference in Concentration between wet and dry season air pollutant and Meteorology parameters within Bariga (Group C).

| Location | Parameter | Pair | Mean±Std. Error | N | Std. Deviation | d.f | t-calculated | Sig level | Rmks |
|---|---|---|---|---|---|---|---|---|---|
| Bariga | VOC mg/m$^3$ | Wet Season | 1.53±0.075 | 45 | 0.505 | 44 | 0.000 | 1.000 | NS |
| | | Dry Season | 1.53±0.075 | 45 | 0.505 | 44 | | | |
| | $CO_2$ mg/m$^3$ | Wet Season | 43.27±0.102 | 45 | 0.688 | 44 | -47.785 | 0.000 | NS |
| | | Dry Season | 48.84±0.071 | 45 | 0.475 | 44 | | | |
| | $NO_2$ mg/m$^3$ | Wet Season | 0.02±0.010 | 45 | 0.000 | 44 | 0.000 | 0.000 | NS |
| | | Dry season | 0.05±0.010 | 45 | 0.000 | 44 | | | |
| | $SO_2$ mg/m$^3$ | Wet Season | 0.002±0.00 | 45 | 0.000 | 44 | 0.000 | 0.000 | NS |
| | | Dry Season | 0.03±0.010 | 45 | 0.000 | 44 | | | |
| | Temperature °C | Wet Season | 26.53±0.190 | 45 | 1.272 | 44 | -24.744 | 0.000 | NS |
| | | Dry Season | 31.09±0.043 | 45 | 0.288 | 44 | | | |
| | Pressure N/m$^2$ | Wet Season | 1015.73±0.267 | 45 | 1.789 | 44 | 22.341 | 0.000 | S |
| | | Dry Season | 1009.13±0.121 | 45 | 0.815 | 44 | | | |
| | Relative Humidity % | Wet Season | 78.33±0.411 | 45 | 2.755 | 44 | 17.186 | 0.000 | S |
| | | Dry Season | 64.33±0.607 | 45 | 4.073 | 44 | | | |

Note: S= significant, NS= not significant
Source: Field Work, Lagos Metropolis slums 2018/2019.

**Table 4.** Paired sample t-test for difference in Concentration between wet and dry season air pollutant and Meteorology parameters within Iwaya (Group D).

| Location | Parameter | Pair | Mean±Std. Error | N | Std. Deviation | d.f | t-calculated | Sig level | Rmks |
|---|---|---|---|---|---|---|---|---|---|
| **Iwaya** | VOC mg/m$^3$ | Wet Season | 1.00±0.000 | 45 | 0.000 | 44 | -6.205 | 0.000 | NS |
| | | Dry Season | 1.47±0.075 | 45 | 0.505 | 44 | | | |
| | $CO_2$ mg/m$^3$ | Wet Season | 43.87±0.093 | 45 | 0.625 | 44 | -13.181 | 0.000 | NS |
| | | Dry Season | 50.71±0.517 | 45 | 3.468 | 44 | | | |
| | $NO_2$ mg/m$^3$ | Wet Season | 0.002±0.010 | 45 | 0.000 | 44 | 0.000 | 0.000 | NS |
| | | Dry season | 0.02±0.010 | 45 | 0.000 | 44 | | | |
| | $SO_2$ mg/m$^3$ | Wet Season | 0.003±0.01 | 45 | 0.000 | 44 | 0.000 | 0.000 | NS |
| | | Dry Season | 0.02±0.010 | 45 | 0.000 | 44 | | | |
| | Temperature °C | Wet Season | 26.56±0.179 | 45 | 1.198 | 44 | -31.095 | 0.000 | NS |
| | | Dry Season | 31.82±0.066 | 45 | 0.442 | 44 | | | |
| | Pressure N/m$^2$ | Wet Season | 1015.73±0.267 | 45 | 1.789 | 44 | 23.452 | 0.000 | S |
| | | Dry Season | 1009.07±0.116 | 45 | 0.780 | 44 | | | |
| | Relative Humidity % | Wet Season | 78.53±0.411 | 45 | 2.760 | 44 | 16.532 | 0.000 | S |
| | | Dry Season | 69.33±0.541 | 45 | 3.631 | 44 | | | |

Note: S= significant, NS= not significant
Source: Field Work, Lagos Metropolis slums 2018/2019.

**Table 5.** Paired sample t-test for difference in Concentration between wet and dry season air pollutant and Meteorology parameters within Ijora Badia (Group E).

| Location | Parameter | Pair | Mean ± Std. Error | N | Std. Deviation | d.f | t-calculated | Sig level | Rmks |
|---|---|---|---|---|---|---|---|---|---|
| **Ijora Badia** | VOC mg/m$^3$ | Wet Season | 2.00±0.000 | 45 | 0.000 | 44 | 8.124 | 0.000 | S |
| | | Dry Season | 1.40±0.074 | 45 | 0.495 | 44 | | | |
| | $CO_2$ mg/m$^3$ | Wet Season | 38.76±0.128 | 45 | 0.857 | 44 | -55.561 | 0.000 | NS |
| | | Dry Season | 52.07±0.186 | 45 | 1.250 | 44 | | | |
| | $NO_2$ mg/m$^3$ | Wet Season | 0.02±0.010 | 45 | 0.000 | 44 | 0.000 | 0.000 | NS |
| | | Dry season | 0.05±0.010 | 45 | 0.000 | 44 | | | |
| | $SO_2$ mg/m$^3$ | Wet Season | 0.02±0.010 | 45 | 0.000 | 44 | 0.000 | 0.000 | NS |
| | | Dry Season | 0.04±0.010 | 45 | 0.000 | 44 | | | |
| | Temperature °C | Wet Season | 25.73±0.129 | 45 | 0.863 | 44 | -53.756 | 0.000 | NS |
| | | Dry Season | 35.69±0.109 | 45 | 0.733 | 44 | | | |
| | Pressure N/m$^2$ | Wet Season | 1015.73±0.267 | 45 | 1.789 | 44 | 21.039 | 0.000 | S |
| | | Dry Season | 1009.0±0.123 | 45 | 0.826 | 44 | | | |
| | Relative Humidity % | Wet Season | 79.20±0.451 | 45 | 3.027 | 44 | 16.840 | 0.000 | S |
| | | Dry Season | 67.00±0.603 | 45 | 4.045 | 44 | | | |

Note: S= significant, NS= not significant
Source: Field Work, Lagos Metropolis slums 2018/2019.

table values. The air pollution experienced in the slum settlement is as a result of anthropogenic activities. Thus, pollution could damage the natural processes in the atmosphere and negatively affect human health. This could explain the reason for the significant seasonal variation in the concentration of most air parameters for Group A.

Table 2 shows that the results of Group B (Oworoshoki) air parameters such as VOC, $CO_2$, $NO_2$ and $SO_2$ had higher mean value in dry season. Paired sample T-test for Group B revealed that VOC, $CO_2$, $SO_2$ and $NO_2$ had no significant seasonal variation because their calculated values are less than the table values.

Group C (Bariga) result of air parameters revealed that $CO_2$, $NO_2$ and $SO_2$ have higher mean values in dry season. The mean values of VOC have the same value for both wet and dry season. Paired sample T-test result for Group C (Table 3) depicts that VOC,$CO_2$, $NO_2$ and $SO_2$ have their calculated values (t-calculated) less than the table value at $p<0.05$; thus indicating no significant seasonal variation.

The result for Group D (Iwaya) showed that VOC and $CO_2$ have higher mean values in dry season (Table 4). Furthermore, $NO_2$ and $SO_2$ had the same mean values for both wet and dry season. Paired sample T-test result for Group D Iwaya revealed that VOC, $CO_2$, $NO_2$ and $SO_2$ have their calculated values (t-calculated) less than the table value at $p<0.05$; therefore indicating no significant seasonal variation.

Table 5 showed that the result obtained for Ijora Badia (Group E) air parameters which are $CO_2$, $NO_2$ and $SO_2$ had higher mean values in dry season. Whereas VOC has higher mean values in wet season. Paired sample T-test result for Group E Ijora Badia air parameters revealed that $CO_2$, $NO_2$, and $SO_2$ have their calculated values (t calculated) less than the table values (at $p<0.05$). Thus, indicating no significant seasonal variation, while VOC have their calculated values greater than the table values; thereby showing significant seasonal variation.

The mean values of VOC across the groups ranged from 1.00 to 2.00 mg/m$^3$ for wet season, while those of the dry season ranged from 1.40 to 1.53 mg/m$^3$ among the slums. The obtained values were within WHO (2005) permissible limit of 0.20 -3.0 mg/m$^3$. The mean values for Carbon Dioxide ($CO_2$) obtained for this study ranged from 38.20 to 43.87 mg/m$^3$ for wet season and 48.84 to 52.07 mg/m$^3$ for dry season among the groups. The obtained values were within USEPA (2000) recommended standard of 250 - 350 mg/m$^3$. Fossil fuel combustion could be regarded as the primary source of $CO_2$ emissions which could be above the recommended limits over a long period (USEPA 2007). Venkataraman et al. (2005); Koch and Hansen (2005) Stated that black carbon from biomass emissions contributes to regional and global climate change as well as adverse health effects in some parts of the world.

The mean concentration of Sulphur Dioxide ($SO_2$) ranged from 0.001 to 0.02 mg/m$^3$ for wet season and 0.002 to 0.04 mg/m$^3$ for dry season across the groups. The values obtained for dry season exceeded WHO (2018) recommended standard of 0.02 mg/m$^3$ for 24 h daily average. Research have shown that air pollution gets worse during the dry season because pollutants remain suspended and concentrated in the atmosphere, as there is lack of rain to wash and dissolve them properly (Gunnar et al., 2002).

Nitrogen Dioxide ($NO_2$) mean values ranged from <0.01 to 0.02 mg/m$^3$ for wet season and 0.01 to 0.05 mg/m$^3$ for dry season across the groups. The values obtained for dry season exceeded the recommended USEPA (2000) limit of 0.04 mg/m$^3$.This may suggest the general increase noticed in the concentration of some pollutants during the dry season. This is in agreement with the fact that pollutant dispersion is highest in dry season and lower in wet season (Bhatia, 2002).

**Meteorology parameters across Group A - E**

The results of the meteorology parameters for Group A (Majidun), shown in Table 1, revealed that pressure and relative humidity have their calculated values (t- calculated) greater than the table value by $p<0.05$; indicating significant seasonal variation. However, temperature had no significant seasonal variation because their calculated values are less than the table values. This implies that the increase in air pollutant concentrations around the slum settlement do not typically result from sudden increase in emissions but rather from meteorological conditions that impede dispersion in the atmosphere. This could explain the reason for the significant seasonal variation in the concentration of most air parameters for Group A.

Oworoshoki results for Group B meteorology parameters depicts that pressure and relative humidity recorded a higher mean values in wet season while temperature has higher value during dry season (Table 2). Paired sample T-test result for Group B also revealed that pressure and relative humidity have their calculated values (t calculated) greater than the table value at $p<0.05$ which means there is significant seasonal variation. More so, temperature showed no significant seasonal variation, because their calculated values are less than the table values. The obtained results for Bariga (Group C) analysis revealed that temperature gave a higher mean values during dry season, whereas pressure and relative humidity had higher mean values in wet season. Table 3 showed paired sample T-test result for Group C. Temperature calculated values (t-calculated) was less than the table value at $p<0.05$; hence, it indicates no significant seasonal variation. However, the other parameters such as pressure and relative humidity have their calculated t values greater than the table values which therefore shows significant seasonal variation.

The Group D (Iwaya) results shows that pressure and relative humidity displayed a higher mean values in wet season and temperature had higher mean values in dry season. Paired sample T-test result for Group D (Table 4) revealed that temperature calculated values (t-calculated) was less than the table value at $p<0.05$, these indicates no significant seasonal variation, while parameters such as pressure and relative humidity had their calculated t-values greater than the table values; thereby resulting to significant seasonal variation.

Meteorology parameters for Ijora Badia (Group E) revealed that temperature recorded higher mean values during dry season; while wet season had higher mean values for pressure and relative humidity. Paired sample T-test result for Group E Ijora Badia (Table 5) depicts that temperature calculated values (t-calculated) was less than the table values (at $p<0.05$). Thus, it indicates no significant seasonal variation. Pressure and relative humidity have their calculated values greater than the table values, thus showing significant seasonal variation. The result from this study implies that urban cities in the developing countries, especially Lagos State, are experiencing high levels of visibility degradation due to high emission intensity and adverse meteorology (Jimoda, 2012). The mean temperature across the groups is higher during the dry season. It ranged from 31.09 to 35.69°C, while those of the wet season ranged from 25.73 to 26.60°C. Ukpebor et al. (2006) ascertained that dry seasons are characterized by high temperatures and low humidity in Nigeria, while the reverse is the case for wet seasons. This explains why higher readings were recorded for almost all pollutants during the dry season months, when compared with lower readings recorded during the wet season.

Pressure mean values in dry season ranged from 1008.07 to 1009.13 $N/m^2$ while value for wet season ranged from 1014.73 to 1015.73 $N/m^2$ among the groups. Meteorological factors such as temperature, pressure and relative humidity can significantly affect air quality (Elminir, 2005; Beaver and Palzazogiu, 2009; Csavina et al., 2014). Relative humidity mean values in dry season ranged from 64.33 to 69.33%, while wet season value ranged between 78.33 to 79.20% across the groups. Hence, the most important role of meteorology is in the dispersion, transformation and removal of air pollutants from the atmosphere (Ocak and Turallogiu, 2008). The rotate principal component analysis (PCA) of air pollutant parameters for wet and dry seasons are presented in Tables 6, 7, 8, 9 and 10 (Group A to E) respectively. The result showed Group A (Majidun) wet season variables on PC 4, which explained 14.92% of the total variance exhibited by $CO_2$ with a strong positive loading (Table 6). Group A (Majidun) dry season variables on PC 1 represents 32.40% of the total variance and $CO_2$ contributed to having strong positive loading. $CO_2$ are largely traffic-related emissions (Masiol et al., 2014).

Table 7 shows Group B (Oworoshoki) wet season variables. PC 2 explained 18.92% of the total variance on $CO_2$, having strong positive loading. While Group B (Oworoshoki) dry season variables is represented under PC 1, having

**Table 6.** Factor loading of Air pollutants and Meteorology parameters for wet and dry season Majidun (Group A).

| A: Majidun Wet Season variables on 4 PC | Component | | | |
|---|---|---|---|---|
| | PC1 | PC2 | PC3 | PC4 |
| Relative Humidity % | **0.885** | 0.042 | 0.284 | -0.016 |
| Pressure N/m$^2$ | 0.608 | 0.233 | 0.193 | -0.12 |
| Temperature °C | -0.143 | **0.886** | 0.014 | 0.064 |
| $CO_2$ mg/m$^3$ | 0.282 | -0.475 | -0.432 | **0.669** |
| Eigenvalue | 2.083 | 1.485 | 1.158 | 1.045 |
| Variance (%) | 29.764 | 21.21 | 16.544 | 14.924 |
| Cumulative variance (%) | 29.764 | 50.974 | 67.518 | 82.441 |

| B: Majidun Dry Season variables on 3 PC | Component | | |
|---|---|---|---|
| | PC1 | PC2 | PC3 |
| $CO_2$ mg/m$^3$ | **0.801** | 0.361 | -0.061 |
| VOC mg/m$^3$ | -0.66 | -0.037 | -0.448 |
| Temperature °C | 0.465 | **0.751** | -0.36 |
| Relative Humidity % | -0.395 | 0.667 | 0.241 |
| Pressure N/m$^2$ | 0.434 | -0.388 | **0.581** |
| Eigenvalue | 2.592 | 1.87 | 1.479 |
| Variance (%) | 32.402 | 23.371 | 18.487 |
| Cumulative variance (%) | 32.402 | 55.772 | 74.26 |

**Table 7.** Factor loading of Air pollutants and Meteorology parameters for wet and dry season Oworoshoki (Group B).

| A: Oworoshoki Wet Season variables on 3 PC | Component | | |
|---|---|---|---|
| | PC1 | PC2 | PC3 |
| Relative Humidity % | **0.859** | -0.171 | -0.045 |
| VOC mg/m$^3$ | 0.54 | -0.124 | 0.531 |
| $CO_2$ mg/m$^3$ | 0.513 | **0.689** | -0.062 |
| Pressure N/m$^2$ | 0.418 | -0.622 | -0.453 |
| Temperature °C | 0.251 | 0.016 | **0.797** |
| Eigenvalue | 2.377 | 1.325 | 1.254 |
| Variance (%) | 33.96 | 18.929 | 17.914 |
| Cumulative variance (%) | 33.96 | 52.889 | 70.803 |

| B: Oworoshoki Dry Season variables on 3 PC | Component | | |
|---|---|---|---|
| | PC1 | PC2 | PC3 |
| VOC mg/m$^3$ | **0.922** | 0.075 | -0.204 |
| Pressure N/m$^2$ | 0.716 | -0.134 | 0.484 |
| Relative Humidity % | -0.02 | -0.765 | -0.316 |
| $CO_2$ mg/m$^3$ | 0.614 | **0.737** | -0.113 |
| Temperature °C | -0.319 | 0.047 | **0.776** |
| Eigenvalue | 3.046 | 1.946 | 1.386 |
| Variance (%) | 38.077 | 24.331 | 17.323 |
| Cumulative variance (%) | 38.077 | 62.408 | 79.731 |

38.07% of the total variance on VOC with a strong positive loading. PC 2 accounted for 24.33% of the total variance showing a strong positive loading on $CO_2$. This could be attributed to the fact that urban cities, especially the slum settlement, remain air pollution hotspots with driving habits which largely determine daily and weekly patterns of pollution levels (Grimm et al., 2008).

The analyses for Bariga Group C wet season

**Table 8.** Factor loading of Air pollutants and Meteorology parameters for wet and dry season Bariga (Group C).

| Group C: Bariga wet season variables on 4 PC | Component | | | |
|---|---|---|---|---|
| | PC1 | PC2 | PC3 | PC4 |
| Relative Humidity % | -0.9 | 0.314 | 0.088 | -0.027 |
| VOC mg/m$^3$ | **0.819** | -0.458 | -0.026 | -0.192 |
| Pressure N/m$^2$ | -0.67 | -0.29 | 0.014 | 0.191 |
| $CO_2$ mg/m$^3$ | -0.034 | 0.292 | -0.818 | 0.218 |
| Temperature °C | 0.088 | **0.393** | **0.783** | 0.075 |
| Eigenvalue | 2.3 | 1.48 | 1.353 | 1.147 |
| Variance (%) | 28.753 | 18.496 | 16.91 | 14.335 |
| Cumulative variance (%) | 28.753 | 47.249 | 64.159 | 78.495 |

| Group C: Bariga dry season variables on 3 PC | Component | | |
|---|---|---|---|
| | PC1 | PC2 | PC3 |
| $CO_2$ mg/m$^3$ | **0.567** | -0.145 | 0.323 |
| VOC mg/m$^3$ | -0.055 | -0.791 | 0.355 |
| Temperature °C | 0.41 | -0.453 | 0.328 |
| Pressure N/m$^2$ | 0.089 | **0.383** | **0.745** |
| Relative Humidity % | -0.187 | 0.378 | 0.557 |
| Eigenvalue | 2.296 | 1.619 | 1.306 |
| Variance (%) | 28.695 | 20.235 | 16.324 |
| Cumulative variance (%) | 28.695 | 48.931 | 65.255 |

**Table 9.** Factor loading of Air pollutants and Meteorology parameters for wet and dry season Iwaya (Group D).

| Group D: Iwaya dry season variables on 4 PC | Component | | | |
|---|---|---|---|---|
| | PC1 | PC2 | PC3 | PC4 |
| $CO_2$ mg/m$^3$ | **0.92** | 0.25 | 0.007 | -0.096 |
| Pressure N/m$^2$ | 0.756 | 0.044 | -0.32 | 0.249 |
| Temperature °C | 0.165 | **0.759** | -0.418 | 0.407 |
| VOC mg/m$^3$ | 0.486 | 0.547 | **0.432** | -0.351 |
| Relative Humidity % | 0.544 | -0.377 | 0.331 | **0.611** |
| Eigenvalue | 2.465 | 1.863 | 1.458 | 1.097 |
| Variance (%) | 30.814 | 23.289 | 18.23 | 13.715 |
| Cumulative variance (%) | 30.814 | 54.104 | 72.334 | 86.049 |

| Group D: Iwaya wet season variables on 2 PC | Component | |
|---|---|---|
| | PC1 | PC2 |
| Relative Humidity % | -0.879 | 0.365 |
| $CO_2$ mg/m$^3$ | 0.038 | **0.709** |
| Pressure N/m$^2$ | -0.138 | 0.703 |
| Temperature °C | **0.432** | 0.647 |
| Eigenvalue | 1.758 | 1.566 |
| Variance (%) | 35.155 | 31.316 |
| Cumulative variance (%) | 35.155 | 66.471 |

variables unveil that 28.75% of the total variance under PC 1 displays a strong positive loading on VOC (Table 8). Hence, Group C (Bariga) dry season variables revealed 28.69% of the total variance on $CO_2$ has a strong positive loading. The significant contributing factors from this group are VOC and $CO_2$. Thus, both primary anthropogenic precursors in the presence of sunlight to form ozone. The sources of these two pollutants are industrial and vehicular emissions (Abdul-Wahab et al., 2005).

The result in Table 9 for Group D (Iwaya) wet

**Table 10.** Factor loading of air pollutants and meteorology parameters for wet and dry season Ijora Badia (Group E).

| **Group E: Ijora Badia Wet season variables on 3 PC** | **Component** | | |
|---|---|---|---|
| | **PC1** | **PC2** | **PC3** |
| Relative Humidity % | **0.876** | 0.3 | 0.168 |
| Pressure $N/m^2$ | 0.734 | -0.337 | 0.114 |
| $CO_2$ $mg/m^3$ | -0.244 | **0.744** | -0.337 |
| Temperature °C | -0.198 | 0.357 | **0.699** |
| Eigenvalue | 2.053 | 1.533 | 1.138 |
| Variance (%) | 29.33 | 21.906 | 16.259 |
| Cumulative variance (%) | 29.33 | 51.236 | 67.495 |

| **Group E: Ijora badia Dry Season variables on 3 PC** | **Component** | | |
|---|---|---|---|
| | **PC1** | **PC2** | **PC3** |
| $CO_2$ $mg/m^3$ | **0.739** | **0.461** | 0.169 |
| Temperature °C | -0.714 | 0.198 | 0.386 |
| VOC $mg/m^3$ | 0.607 | 0.428 | **0.495** |
| Relative Humidity % | -0.105 | -0.76 | 0.441 |
| Pressure $N/m^2$ | 0.056 | 0.218 | -0.692 |
| Eigenvalue | 2.312 | 1.66 | 1.126 |
| Variance (%) | 33.026 | 23.709 | 16.087 |
| Cumulative variance (%) | 33.026 | 56.735 | 72.822 |

season variables revealed that PC 2 contributes 31.31% of the total variance. $CO_2$ contributed to having a strong positive loading (Table 9). Although, dry season variables revealed 30.81% of the total variance on $CO_2$, showing strong positive loading under PC 2 (Iwaya) Group D. PC 3 explained 18.23% of the total variance with a weak positive loading on VOC. The factor contributing to air pollution is $CO_2$. More so, fossil fuel combustion is the primary source contributing to $CO_2$ emissions (USEPA, 2007). Exposure to $CO_2$ concentration levels can increase the risk of acute lower respiratory diseases and mortality (Khan & Siddiqui, 2014).

Ijora Badia wet season results for Group E unveil that PC 2 constitutes 11.90% of the total variance; although, $CO_2$ mostly contributed to strong positive loading. Whereas, Group E (Ijora Badia) dry season variables revealed 33.02 % of the total variance under PC 1 having strong positive loading on $CO_2$ (Table 10). Additionally, 23.70% of the total variance is exhibited by $CO_2$ with a weak positive loading; while PC 3 explained 16.08% of the total variance on VOC having a weak positive loading. The contributing factors from this group that are of significance are $CO_2$ and VOC. Generally, motor vehicles are the major source of air pollution in urban areas which accounts for approximately 48% CO, 32% $NO_x$ and 59% VOC; thereby, having adverse effects on the environment and humans (Park et al., 2005; Corson, 2006; Ideriah, 2008).

The wet and dry season results for meteorology parameters is displayed in Tables 6, 7, 8, 9 and 10 (Group A to E) respectively. Group A (Majidun) wet season variables is shown under PC 1, which accounts for 29.76% of the total variance on relative humidity having a strong positive loading (Table 6). PC 2 contributed 21.21% of the total variance on temperature with strong positive loading. The most contributing factor in the group is relative humidity and temperature. Temperature level influences the concentrations of air pollutants in an area (Igweze, 2014), and any emitted substances are temperature dependent (Cox et al., 2005)

Group A (Majidun) dry season variables showed PC 2 contributing 23.37% of the total variance on temperature having strong positive loading (Table 6). While PC 3 accounted for 18.48% of the total variance on pressure, with a moderate positive loading. The reason for the temperature disparity between the two seasons is due to the tropical nature of the study area and the transition phase between dry season and rainy season (Adejuwon, 2012). These explained seasonal differences in concentration of pollutants. Jacobson (2008) reported that low wind speed, high temperature and low humidity reduce the rate of dispersion of air pollutants, thus increasing ground concentration of same pollutants and vice versa.

The wet season (Group B) results for Oworoshoki is shown under PC 1, contributing 33.90% of the total variance. Thus, it displays a strong positive loading on relative humidity (Table 7). PC 3 accounts for 17.91% of the total variance on temperature with a moderate positive loading. Hence, dry season variables for Group B revealed that PC 3 constitutes 17.32% of the total variance. It is mainly characterized by temperature with a strong positive loading. The significant contributing factors are temperature and relative humidity which imply that high relative humidity is normal in the rainy season (Adejuwon, 2012) because of the continuous complete cloud cover observable in this period, while on the other hand, if temperature of ambient air is higher, pollutant gases become concentrated at ground level (Jacobson, 2008).

Bariga analysis results for wet season unveil that PC 2 constituted about 18.49% of the total variance (Group C). Hence, it is characterized by temperature displaying a moderate positive loading. Whereas PC 3 explained 16.91% of the total variance on temperature having a strong positive loading (Table 8). Group C (Bariga) dry season variables revealed 20.23% of the total variance on pressure with a weak positive loading under PC 2. Also, 16.32% of the total variance is exhibited by pressure with a strong positive loading under PC 3. Temperature and relative humidity are the significant factors contributing to higher concentration of pollutants during dry seasons. This implies that automobile exhaust, open solid waste burning, industrial emission and fugitive dusts from non-tar road surfaces could be the main sources of air pollutants in the slums (Ukpebor et al., 2006).

The results of Group D (Iwaya) wet season variables revealed that PC 1 accounted for 35.15% of the total variance having a weak positive loading on temperature (Table 9). Group D (Iwaya) dry season variables shows that PC 2 constituted 23.28% total variance with a strong positive loading on temperature. Also, 13.71% of the total variance is exhibited by relative humidity having a moderate positive loading under PC 4 (Table 9). Temperature and relative humidity are the factors contributing to the higher concentration of pollutants across the slums. Rene (2008) revealed that relative humidity is generally higher during the wet season and higher relative humidity lower atmospheric temperature.

Group E results for Ijora Badia wet season variables unveil that 29.33% of the total variance under PC 1 showed a strong positive loading on relative humidity (Table 10). Hence, PC 3 consists of 16.25% of the total variance, this results in the temperature having a moderate positive loading. Generally, relative humidity plays an important role in many chemical reactions (thermal and photochemical) in the atmosphere. As water molecule, it has the ability to attach strongly to many substances anywhere including the atmosphere (Tecer et al., 2008).

## Conclusion

This study assessed air pollutant concentrations around slum settlements within Lagos metropolis, Nigeria, in order to evaluate its health associated problems. The result of the paired sample t-test analyses showed that all the parameters have higher concentrations in dry season than in the wet season across the Groups; except for VOC. Pressure and relative humidity have higher concentrations in wet season than dry season among the Groups. Furthermore, pressure and relative humidity showed different levels of seasonal variation across the groups, while the other parameters had no significant variation. Most of the parameters mean values were within the World Health Organization (2018) guidelines in both seasons. Hence, the increased air pollutant concentrations in the slum environment do not typically result from sudden increases in emissions, but rather from meteorological conditions that impede dispersion in the atmosphere. The rotated PCA analyses revealed that $CO_2$ and VOC contribute more to the air pollution across the slums; while temperature, pressure and relative humidity are the meteorological factors influencing the dispersion and dilution of pollutants among the locations. These explained the seasonal differences in concentration of pollutants. The study concludes that seasonality significantly influences the concentration of pollutants in the slum. The air pollution in the study area is as a result of human activities. These, damage the natural processes in the atmosphere, and negatively affect human health. This study recommends that appropriate air pollution control should be considered in the study area to reduce the risks associated with these pollutants. There is also need to develop monitoring mechanisms, regulations and enforcement measures by relevant regulatory bodies.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENT

The authors express their gratitude to one another for their financial contributions to procure the equipment used for this research and logistics to achieve objectives of the work. The authors appreciate the residents of the selected slums for accommodating the research team during their visitation in the course of the project exercise.

## REFERENCES

**Abdul-Wahab, S. A, Bakheit, C. S and Al-Alawi, S. M. (2005).** Principal component and multiple regression analysis in modelling of ground-level ozone and factors affecting its concentrations. *Environmental Modelling and Software*. 20(10): 1263-71.

**Adejuwon, J. O. (2012).** Rainfall seasonality in the Niger Delta Belt, Nigeria. *Journal of Geography and Regional Planning*. 5(2): 51-60.

**Adejuwon, S. A. (2004).** Impacts of Climate Variability and Climate Change on Crop Yield in Nigeria, Stakeholders' Workshop on Assessment of Impacts and Adaptation to Climate Change (AIACC), Conference Centre Obafemi Awolowo University, Ile-Ife 20 – 21 September 2004.

**Adelekan, I. O. (2012).** Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. Environment & Urbanization, 22: 433–450.

**Aderogba, K. A. (2012).** Qualitative studies of recent floods and sustainable growth and development of cities and towns in Nigeria. International Journal of Academic Research in Economics and Management Sciences, 1(3): 1–25.

**Akanni, C.O. (2010).** Spatial and seasonal analysis of traffic-related pollutant concentrations in Lagos Metropolis, Nigeria. *African Journal of Agricultural Research*. 5: 1264-1272.

**Awosika, L. F., Folorunsho, R., Dublin-Green, C. O and Imevbore, V. O. (2000).** Review of the coastal erosion at Awoye and Molume areas of Ondo State. A Consultancy Report for Chevron Nigeria Limited. p.75.

**Beaver, S., and Palazoglu, A. (2009).** Influence of synoptic and mesoscale meteorology on ozone pollution potential for San Joaquin Valley of California. Atmos Environ 4(3): 1779-1788.

**Bhatia, S. C. (2002).** Environmental Chemistry, CBS Publishers, New Delhi-110002 (India). pp. 132-161.

**Bhatia, S. C. (2009).** Environmental pollution and control in chemical process industries. Khanna publishers. p.163.

**BRNCC (2012).** Towards Lagos State climate change adaptation strategy. Building Nigeria's Response to Climate Change. 10pp

**Buteau, S. and Goldberg, M. S. (2016).** A Structured Review of Panel Studies Used To Investigate Associations Between Ambient Air Pollution and Heart Rate Variability. Environmental Research, 148. pp. 207-247.

**Cohen, A. J., Brauer, M., Burnett, R., Anderson, H. R., Frostad, J., Estep, K.,**

**Balakrishnan, K., Brunekreef, B., Dandona, L., Dandona, R., and Feigin, V. (2017).** Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. The lancet. 389(10082): 1907-1918.

**Corson, S. (2006).** Private Transportation Vs Mass Transit."The Environmental ASPECTS. Pp 1-4.

**Cox, S. S, Little, J. C, and Hodgson, A. T. (2005).** Effect of glass transition temperature on volatile emissions from polymer materials. Proceedings of Indoor Air II 1(1): 1845-1849.

**Csavina, J., Field, J., Félix, O., Corral-Avitia, A. Y, and Sáez, A. E. (2014).** Effect of Wind Speed and Relative Humidity on Atmospheric Dust Concentrations in Semi-Arid Climates. *Science of the Total Environment* 4(87): 82-90.

**Elminir, H. K. (2005).** Dependence of urban air pollutants on meteorology. *Science of the Total Environment* 3(50): 225-237.

**George, C. K. (2010).** Challenges of Lagos as aMega-city. Available at: http://www.allafrica.com/stories/201002221420.html. Accessed 07 Dec 2010.

**Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., and Briggs, J. M. (2008).** Global change and the ecology of cities. Science. 319(5864): 756–760.

**Gunnar, D. N., Jitka, S. H., and Rikke, M. L. (2002).** Mediated Asthma and Rhinitis: A Role of Allergen Exposure? *Pharmacology and Toxicology*. 90(5): 2-31.

**Ideriah, T. J. K., Warmate, A. G., and Alabraba, M. A. (2008).** Effect of Naked Lamp on levels of Air pollutants in Port Harcourt, Nigeria. *Research Journal of Applied Sciences* 3(1): 77-80.

**Idowu, O. A. and Martins, O. (2007).** Hydrograph analysis for groundwater recharge in the phreatic basement aquifer of the Opeki River basin, Southwestern Nigeria. Asset Series B, 6(2), 132–141.

**Igweze, A. H, Amagoh, M. N and Ashinze, A. N. (2014).** Analysis of rainfall variations in the Niger Delta Region of Nigeria. IOSR *Journal of Environmental Science, Toxicology and Food Technology* (IOSR-JESTFT).8(1):25-30.

**Jacobson, M. Z. (2008).** Fundamentals of Atmospheric Modelling. 2nd Edition, Cambridge University Press, New York. http://dx.doi.org/10.1017/CBO9781139165389

**Jimoda, L. A. (2012).** Effects of Particulate Matter on Human Health, the Ecosystem, Climate and Materials: A Review. Facta Universitatis Series: Working and Living Environmental Protection 9(1): 27 – 44.

**Khan, R. R. and Siddiqui, M. J. (2014).** Review on effects of particulates; sulfur dioxide and nitrogen dioxide on human health. *International Research Journal of Environment Sciences* 3(4):70-73.

**Koch, D., and Hansen, J. (2005).** Distant origins of Arctic black carbon:A Goddard Institute for Space Studies Model Eexperiment. *J.Geophys. Res*. 1(10):4-204.

**Komolafe, A. A., Adegboyega, S. A., Anifowose, A. Y. B., Akinluyi, F. O., and Awoniran, D. R. (2014).** Air Pollution and Climate Change in Lagos, Nigeria: Needs for Proactive Approaches to Risk Management and Adaptation. *American Journal of Environmental Sciences*. 10(4): 412-423.

**Lagos Water Corporation (2011).** LWC targets 733 million daily by 2020. http://www.lagoswater.org/news.php?page=45.Accessed 29 March 2011.

**Lutgens, F. K., and Edward, J. T. (2000).** The Atmosphere: An Introduction to Meteorology. 8th ed. Prentice Hall, New Jersey. 512pp.

**Mabahwi, N. A., Oliver, L. H. and Dasimah, O. (2014).** Procedia Social and Behavioral Sciences. pp. 1-5.

**Masiol, M., Agostinelli, C., Formenton, G., Tarabotti, E., and Pavoni, B. (2014).** Thirteen years of air pollution hourly monitoring in a large city: Potential sources, trends, cycles and effects of car-free days. Sci. Total Eviron. 494(495):84-96.

**Narayanan, P. (2009).** Environmental pollution, principles, analysis and control. CBS publishers. New Delhi. 671pp.

**Nwigwe, C., and Emberga, T. T. (2014).** An assessment of causes and effects of flood in Nigeria. Standard Scientific Research and Essays. 2(7):307–315.

**Ocak, S, and Turalioglu, F. S. (2008).** Effect of Meteorology on the Atmospheric Concentrations of Traffic- Related Pollutants in Erzurum, Turkey. *J. Int. Environmental Application and Science*. 1(3): 325-335.

**Odunuga, S., Oyebande, L. and Omojola, A. S. (2012).** Socioeconomic indicators and public perception on urban flooding in Lagos, Nigeria. Hydrology for Disaster Management. Nigerian Association of Hydrological Sciences, 82–96.

**Oshodi, L. (2013).** Flood management and governance structure in Lagos, Nigeria. Accessed 10 January 2016.

**Oyegoke, S. O., Adeyemi, A. O., and Sojobi, A. O. (2012).** The challenges of water supply for a megacity: a case study of Lagos metropolis. *International Journal of Scientific and Engineering Research*. 3(2):1–10.

**Park, S.U., Chang, L. S and Lee, E. H. (2005).** Direct radioactive forcing due to aerosols in East Asia during a Hwangsa (Asia dust) Event Observed on 19-23 March 2002 in Korea. Atmospheric Environment, 39(2): 593-606.

**Rene, G. T. (2008).** An Air Quality Baseline Assessment for the Vaal Air Shed in South Africa. A Master Thesis Dissertation, Geoinformatics and Meteorology Department, University of Pretoria, South Africa. p.20.

**Sajil Kumar, P. J., Jegathambal, P. and James, E. J. (2011).** Multivariate and Geostatistical Analysis of Groundwater Quality in Palar River Basin . *International Journal of Geology*. 5: 108-119

**Tawari, C. C and Abowei, J. F. (2012).** Air Pollution in the Niger Delta Area of Nigeria. *International Journal of Fisheries and Aquatic Science*. 1(2): 94-117.

**Tercer, L. K, Suren, P., Alagha, O., Karaca, F., and Tuncel, G. (2008).** Effect of Meteorological Parameters on Fine and Coarse articulate Matter Mass Concentration in a Coal-Mining Area in Zonguldak, Turkey. *Journal of the Air and Waste Management Association.* 58(4):543-552

**Ukpebor, E. E., Ukpebor, J. E., Oviasogie, P. O., Odiase, J. I. and Egbeme, M. A. (2006).** Field Comparison of Total Suspended Particulates (TSP) Samplers to Assess Spatial Variation. *International Journal of Environmental Studies.* 6(1):567-577.

**Uluocha, N. O. and Ekop, G. (2002).** Nigeria: Geography in History and Cultures of Nigeria up to AD 2000, Edited by Osuntokun, A.; Aworawo and F. Masajuwa, Lagos, Frankad Publishers, pp. 3-19.

**UN-Habitat (United Nations Human Settlements Programme). (2008).** State of the world's cities 2010/2011-Cities for all: Bridging the urban divide. Nairobi, Kenya. Accessed 10th March 2016.

**United State Environmental Protection Agency USEPA. (2000).** US Environmental Protection Agency Safe Drinking Water Act.(Online).http://www.epa. gov/safe water /mcl.html(10 Sept.2014)

**United States Environmental Protection Agency USEPA (2006).** Air Pollutants. Accessed on 19th December, 2015. Retrieved from http://www.epa.gov/ebtpages/airpollutants

**United States Environmental Protection Agency USEPA (2007).** Emissions. Retrieved from: http://epa.gov/climatechange/emissions/us inventoryreport.html). Accessed on 29th January, 2016.

**Venkataraman, C., Habib, G., Eiguren-Fernandez, A., Miguel, A. H. and Friedlander, S. K. (2005).** Residential biofuels in South Asia: Carbonaceous aerosol emissions and climate impacts science. 3(7): 1454–1456.

**WHO (2005).** Particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Air Quality Guidelines Global Update. p.20.

**World Bank (2013).** Cost of pollution in China: Economic estimates of physical damages. Rural Development, Natural Resources and Environment Management Unit. Washington D.C. p.20.

**World Bank (2013).** Cost of pollution in China: Economic estimates of physical damages. Rural Development, Natural Resources and Environment Management Unit. Washington D.C. p.20.

**World Health Organization (2014).** WHO methods and data sources for global causes of death 2000-2012. Global Health Estimates Technical Paper WHO/HIS/HSI/GHE/2014.7. Available: http://www.who.int/entity/healthinfo/global_burden_disease/GlobalCOD_method_2000_2012.pdf. Accessed on 29th November, 2015.

**World Health Organization (2018).** Global Health Risks: Mortality and burden of disease attributable to selected major risks, World Health Organization, Geneva. 20pp

**Yang, G., Wang, Y., Zeng, Y., Gao, G. F. and Liang X (2013).** Rapid health transition in China, 1990–2010: findings from the Global Burden of Disease Study 2010. Lancet 381: 1987 –2015.