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# Ambient Air Quality and Noise Assessment in Eleme Communities, Rivers State, Nigeria

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## Abstract

Problems caused by ambient air pollution on human and the environment can be averted by steadily and strictly monitoring of the concentrations of outdoor pollutants. Human activities have triggered changes in the earths atmosphere. In this research, 7(Seven) selected Eleme communities, 4(four) zones in each community and 28(Twenty eight) sampling points in all locations were assessed for the concentrations of CO, $SO_2$ , $NO_2$ , NO, $CO_2$ , SPM, $O_2$ , noise level and as well Meteorological parameters using methods recommended by ASTM for air pollutants measurement and meteorological parameters. Findings of this research showed that, measured level of CO (1.00 - 43.00 ppm) at Akpajo, Aleto and Onne zone "B" exceeded the stipulated limit by NAAQS. Measured level of $SO_2$ (0.00 - 1.30 ppm) at zone "B" and "D" in all locations were above permissible limit except in Alode and Ogale in which the concentrations of $SO_2$ were 0.00 ppm through out the zones. $NO_2$ (0.00 - 3.10 ppm) and NO (0.00 - 1.05 ppm) concentrations in zone "B" in all the sampling locations exceeded the permissible limit by NAAQS except in Alode and Ogale. Aleto and Ogale zone "D" were also above limits. SPM(0.01 - 4.83 ppm) Levels in all locations and zones exceeded the limit given by W.H.O except in Ogale residential area. Noise Level (40.20 - 102 dBA) at Alesa, Aleto, Akpajo and Ebubu zone "B" were as well above limits. In order to address the risk connected with the identified pollutants in the study area, more endeavour should be conveyed to the use of renewable energy and as well, cleaner air initiatives should be embarked upon.

**Keywords:** Ambient Air; Pollution; Assessment; Eleme communities; Rivers Sate; Nigeria

## 1. Introduction

Activities and processes which include urbanization, population explosion industrialization and as well as intensive agricultural activities and bush burning have caused colossal damage to our environment [1,2,3]. Increase in population of human beings is closely associated with increase in industrialization and urbanization thereby resulting to the destruction of natural habitat and pollution of the biosphere more and more. Air pollution may be defined as any atmospheric condition in which certain substances are present in such concentrations that they can produce undesirable effects on Man and his environment [2]. These substances include gases which are Sulphur Oxides, Nitrogen Oxides, Carbon Monoxide, Hydrocarbons and as well, particulate matter which are Smoke, Dust, Fumes, Aerosols among others. Moreover, radioactive materials and many others are also considered as air pollutants. Most of these substances are naturally present in low concentrations in the atmosphere and are usually considered to be harmless[3]. considering the sources of these pollutants, quite a number of them enters the atmosphere as a result of anthropogenic activities( human activities). On the basis of physical states, there are two major groups of air pollutants which are simply gaseous and particulates.

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### 1.1. Gaseous Pollutants

Common gaseous air pollutants are also included in the category of pollutants referred to as "criteria" air pollutants based on their primary concerns and effects. Criteria pollutants as they are referred to by the United State Environmental Protection Agency (U.S EPA) simply means that, their concentrations in the atmosphere are useful indicators of all-encompassing air quality [4, 10]. The common gaseous criteria air pollutants of primary concern in urban areas include; oxides of Sulphur, oxides of Nitrogen and Carbon monoxide.

### 1.2. Oxides of Sulphur

A mixture of $SO_2$ and $SO_3$ is simply represented as $SO_X$. Sources of oxides of sulphur are from both natural and anthropogenic which include; volcanic activity, smelting of sulphur ores in metallurgical operations, combustion of any sulphur containing materials in coal-fired power stations, refinery operation and vehicular emission [5]. Atmospheric sulphur dioxide absorbed solar energy in the range of 300-400nm and this led to the production of electronically excited states of $SO_2$ [5]. $SO_2$ can undergo oxidation reaction to form $SO_3$. $SO_3$ in the presence of water vapour is converted to $H_2SO_4$ which its aerosol droplets can result to acid rain. Low concentrations of oxides of sulphur most especially, sulphur dioxide is capable of causing respiratory problems such as asthma, bronchitis, pneumonia, emphysema among others [6].

### 1.3. Oxides of Nitrogen

Mixture of gases composing of nitrogen and oxygen are referred to as oxides of nitrogen [5]. The two most toxicological of its compounds are nitric oxide (NO) and nitrogen dioxide($NO_2$) [5]. Other gases belonging to this category are nitrogen pent-oxide ($NO_5$) and nitrogen oxide($N_2O$). They are represented jointly as $NO_X$. $NO_2$ is formed by photolytic reactions in the atmosphere. Oxide of nitrogen may also be formed by natural or artificial fixation of nitrogen from the atmosphere or from nitrogen compounds present in organic matter [5]. $NO_X$ can mostly be produced by the combustion of coal, oil, natural gas and other organic matter. In other words, $NO_X$ is introduced into the atmosphere from incineration of coal based power plant, automobile exhausts among others. Animal toxicity for rat by inhalation $LC_{50}$(mortality) is 88ppm for 4 hours [6]. The most common reaction of nitrogen oxides is primary photochemical reactions which can result to the formation of NO from $NO_2$ through dissociation. The NO that is formed may be oxidized by $O_3$ (Ozone) thus resulting to cyclic chain reactions. Oxides of nitrogen contributed to global climate change, acid rain, photochemical smogs, ozone layer depletion and health issues [7]. Nitrogen dioxide is capable of decreasing lung function and make respiratory problems such as asthma worse. Long term exposure to low concentrations of nitrogen dioxide can cause problems such as coughing, wheezing among others[7].

### 1.4. Carbon Monoxide

Basically, there are two sources of carbon monoxide in the atmosphere, the human activity which is commonly referred to as anthropogenic and the natural processes. The anthropogenic sources of carbon monoxide include activities such as Agricultural burning , industrial operations such as petroleum refining, paper production, electric and blast furnaces in iron and steel industry, coal mining and automobile exhausts[2,3,8]. The natural processes include volcanic eruption, natural gas and marsh gas emission, seed germination, electrical discharges in the atmosphere during storms among others. Carbon monoxide caused problems in cases of locally high concentrations because of its toxicity. The overall concentrations of atmospheric carbon monoxide is about 0.1ppm corresponding to a burden in the earths atmosphere of approximately 500million metric tonnes with an average residence time ranging from 36 to 110days [2,3,8]. Because of carbon monoxide emissions from the internal combustion engines, highest level of this toxic gas tend to occur in congested urban areas at times when the maximum number of people are exposed, such as during rush hours[2,8]. At such times, carbon monoxide levels in the atmosphere may become as high as 50-100ppm [3, 8]. The level of atmospheric carbon monoxide in urban areas shows a positive correlation with the density of vehicular traffic and a negative correlation with wind speed[2, 3,8]. Carbon Monoxide even in its low concentrations can perilously reduce hemoglobin ability to transport oxygen. Common symptoms of Carbon monoxide exposure include, rapid breathing, confusion, headache, nausea,weakness, dizziness and exhaustion[8].

### 1.5. Suspended Particulate Matter

Suspended particulate matter frequently abbreviated as SPM are basically aerosols i.e finely divided liquids or solids particles dispersed through the air from industrial activities, combustion processes or natural sources such as volcanic eruption, salt spray and as well wind and dust storms [9]. Particulate matter appears as fume, smoke, dust and mist suspended in the atmosphere. According to the United States Environmental Protection Agency(U.S .EPA, 1999), suspended particulate matter decreased lung function, increased respiratory symptoms such as coughing, irritation of the airways or difficult breathing [10].

## 2. Material and methods

### 2.1. Apparatus used

RISEPRO Decibel noise meter, BT-meter Hand-held Anemometer, Thermopro-Tp60S Digital Hygrometer Outdoor/indoor wireless Thermometer for Temperature and Humidity Gauge, Testo Multi Gas Analyzer and Moudi-impactor.

### 2.2. Study Area

Eleme is one of the twenty three Local Government Areas in Rivers State, Nigeria[11]. It is a coastal area between Longitude 706’10” E and Latitude 4047’57” N [12]. Eleme is a famous town characterized with many industries including Indorama, a fertilizer manufacturing company, Hamilton Technologies Nig LTD, Eleme petroleum Refinery, Dangote cement, a sea port, Federal Lighter Terminal, Eleme Petrochemicals Limited among others[11, 12]. The popular East-West road passes through the length and width of Eleme, and as a matter of fact, serious vehicular traffic is frequently experienced [13]. Eleme covers an area of $138KM^2$ and according to 2006 census, its population was 190,884[13]. The occupation of most Eleme people is subsistence Agriculture and the following crops are grown, yam, oil palm fruit, bitter leaf, banana and plantain, sugar cane, cassava, vegetables among others[14].

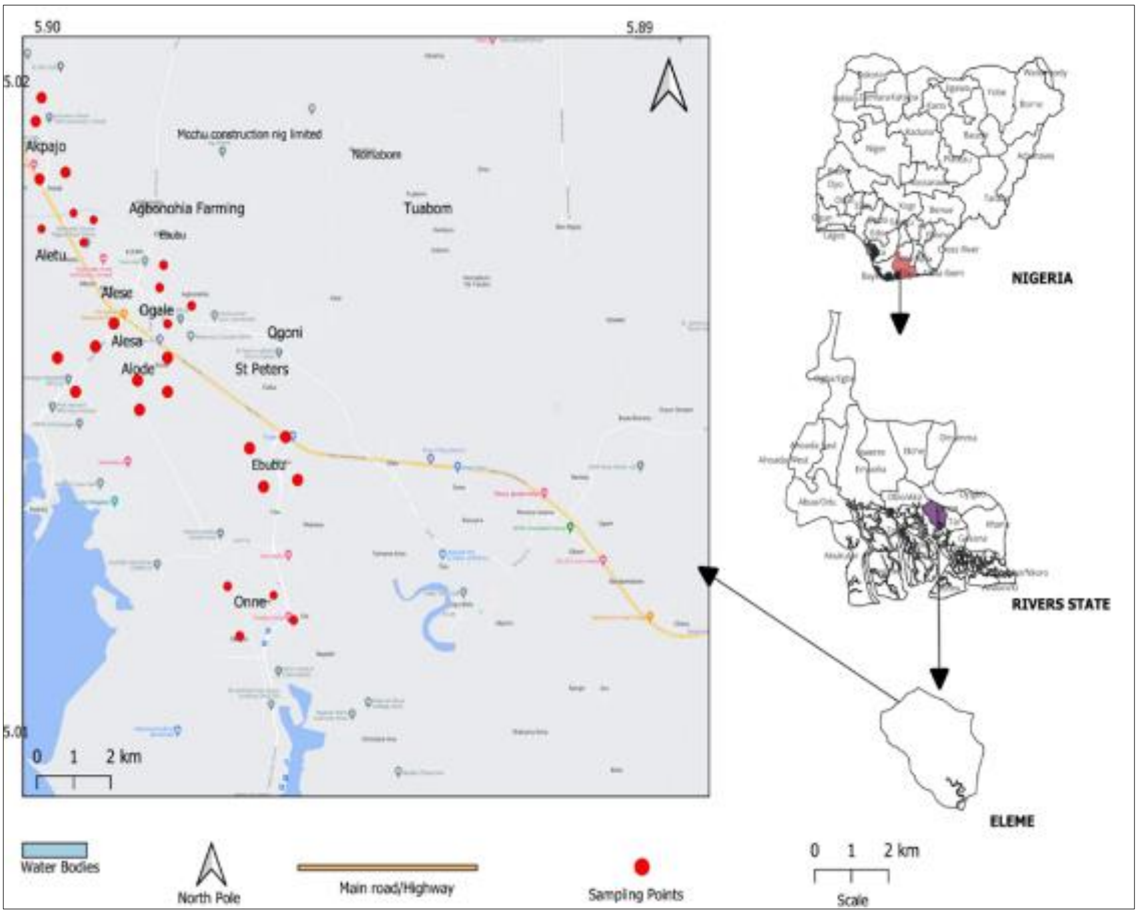


**Figure 1** Map of the Study Area Showing Sampling Locations and Zones

### 2.3. Methods

Testo multi gas analyzer was used to detect gaseous air pollutants and to monitor air quality at strategic locations within the study area. Standard instruments for meteorological parameters detection were also used.

#### *2.3.1. Measurement of Air Pollutants, Oxygen and Carbon dioxide using Testo Multi Gas Analyzer*

Standard multi gas emission analyzer from Testo Inc., precisely Testo 350 and 340 (2010 model) were used to measure CO, $CO_2$, $SO_2$, NO, $NO_2$ and $O_2$. It is anchored on ASTM D6522 requirements and capable of collecting and storing information autonomously for up to 49 hours. Its primary features include LCD display and a menu driven user interface. CO was detected by means of an electro-chemical sensor that produces a signal linearly proportional to the pollutants concentration. Continuous monitoring of CO was done by non-dispersive infrared photometry which indicates that the process of detection was anchored on the absorption of infrared light by CO. $SO_2$ was continuously monitored via pulsed fluorescence. In this process air was drown via a sample chamber where it was irradiated with pulses of UV light. As a result, $SO_2$ in the sample became excited and migrated to a higher energy level and on returning to the ground state, light was emitted and the amount of photon measured was proportional to the concentration of $SO_2$. Other parameters of interest such as $CO_2$, NO, $NO_2$ and $O_2$ were detected based on automated configured processes of Testo 350 multi gas analyzer for 1hour time exposure. Moudi-Impactor was used in measuring suspended particulate matter (SPM) by In-Situ method.

*2.3.2. Measurement of Meteorological Parameters and Noise Levels*

Meteorological parameters such as Temperature, Humidity, Wind speed, and as well, Wind direction were all detected and measured. Thermopro TP60S Digital indoor/outdoor Temperature and Humidity Gauge was used to measure the temperature and Humidity of the respective areas in degree Celsius (°C) and percentage (%) respectively. It was hand-held a distance in an open space from the source. The average readings were taken over a period of 20-30 minutes records. RISEPRO decibel noise meter was actually used to measure the level of noise at the respective points in decibels. The probe of RISEPRO noise meter was faced to the source of noise and average measurement was taken over the period of 1 hour. Wind speed and direction was measured using BT-Meter Hand-held Anemometer). Measurement was taken on hourly basis in meter per seconds (M/S).

## 2.4. Sampling

Reconnaissance survey was first of all carried out to study the terrain and to identify the various sampling locations. As a result, the following sampling locations were identified; Alesa, Aleto, Alode, Akpajo, Ebubu, Ogale and Onne. In each of these locations , four(4) zones labeled A,B,C and D were sampled. Zone (A) represents residential area, zone (B) represents traffic junction, zone (C) is for incineration/farmland and zone (D) represents industrial area. In all, twenty eight(28) points were sampled. Sampling of the twenty eight points was carried out within the period of four Months, from February to May, 2023. Parameters of ambient air and air pollutants measurements were anchored on ASTM (2001) requirements. All meters and equipment were painstakingly re-calibrated before each usage to comply with quality assurance. Automated GPS installed on android was used to obtain the sampling point coordinates.

**Table 1** Locations, Zones and Sampling Points in Eleme Communities

| Locations | Zones | Sampling points | Global Positioning System(GPS) in dec degs micro |
|---|---|---|---|
| ALESA | A | Alesa residential area, behind mordern primary school | 4.789293N , 7.116927E |
| | B | Refinery junction | 4.781208N , 7.121637E |
| | C | Refuge dump site at Alesa, by refinery road | 4.773197N , 7.150241E |
| | D | N.N.P.C surrounding | 4.772393N , 7.103808E |
| ALETO | A | Aleto residential area, behind state primary school | 4.796136N , 7.108180E |
| | B | Indorama toll gate on east-west road | 4.803259N , 7.103471E |
| | C | Dump site at Aleto farm road | 4.800962N , 7.107844E |
| | D | Indorama surroundings | 4.810451N , 7.105360E |
| ALODE | A | Alode residential area | 4.779506N , 7.130722E |
| | B | Alode junction | 4.779181N , 7.131058E |
| | C | Alode farm road | 4.779070N , 7.130147E |
| | D | Back of PortHarcourt refinery surroundings through Alode | 4.778072N , 7.120078E |

| | | | |
|---|---|---|---|
| AKPAJO | A | Akpajo residential area | 4.816035N , 7.084435E |
| | B | Akpajo junction | 4.817146N , 7.094646E |
| | C | Dump site at Akpajo market road | 4.823128N , 7.087716E |
| | D | Eleme petrochemical surrounding through Akpajo | 4.803148N , 7.102360E |
| EBUBU | A | Ebubu residential area | 4.779005N , 7.147843E |
| | B | Trailer park junction | 4.757407N , 7.154617E |
| | C | Ebubu farm road dump site | 4.773197N , 7.150241E |
| | D | Hamilton technologies environs | 4.758586N , 7.157942E |
| OGALE | A | Ogale residential area, behind polaris bank | 4.788895N , 7.124329E |
| | B | Ogale junction from Nchia market road | 4.793147N , 7.117263E |
| | C | Ogale farm road, dump site | 4.787916N , 7.125674E |
| | D | Within pipeline facilities, Ogale | 4.786589N , 7.129712E |
| ONNE | A | Onne residential area by Alejor road | 4.734599N , 7.154954E |
| | B | Onne, F.O.T junction | 4.719702N , 7.158486E |
| | C | NPA road dump site | 4.739095N , 7.154954E |
| | D | Industral zone Onne, by Notore | 4.732593N , 7.131395E |

### 2.5. Air Quality Index (AQI) and National Ambient Air Quality Standard (NAAQS)

Air Quality Index is a tool for reporting ambient air quality. It indicates that, the lower the air quality index value, the better the air quality. Public health risk rises as the air quality index values increases [15]. Each of the pollutants indices were calculated using the arithmetic expression,

$$AQI_{pollutants} = \text{Data reading of pollutants/ standard value x100}$$

National Ambient Air Quality Standards pronounced limits on atmospheric concentration of the six criteria air pollutants [16].

### 2.6. Statistical Concept used for Data Interpretations

Descriptive Statistical methods such as Standard deviation, Mean, ANOVA, Bar Charts were adopted for interpretation of the results.

## 3. Results

The results are presented in bar charts, which shows measured and statistically evaluated values/level of meteorological parameters and air pollutants in relation to standard permissible limits, sampling locations and zones.

## 4. Discussion

### 4.1. For Meteorological Parameters and Noise Levels

Ambient Temperature at all the locations in zone (A) which represented residential zones extent between 28.10 °C to 29.76 °C with the lowest value recorded at Ogale residential area and the highest value recorded at Aleto residential area respectively. For zone (B) which represented major traffic junction, temperature range was between 32.10 °C to 34.60 °C with the highest value recorded at Indorama toll-gate on East-West road Aleto and the lowest value was recorded at Alode junction. For zone (C) which represented incineration/ farmland, temperature here was between the range of 32.00 °C to 35.30 °C with the highest value recorded at incineration/ Dump-site at Aleto farm road while the lowest value was recorded at farm road Ogale. For zone (D) which represented industrial zones/ areas, temperature range was between 30.60 °C to 33.20 °C with the highest value recorded near NNPC facilities at Alesa while the lowest value was recorded within pipeline facilities at Ogale. However, the highest temperature value among all the zones was noticed at incineration/ dump-site at Aleto farm road, which could be attributed to frequent incineration of refuge at the dump-site and as well, constant bush burning practices by peasant farmers. Relative Humidity at all the locations in zone (A) which connote residential zones was between the range of 66.50% to 68.82% with the lowest value recorded at Ogale residential area, and the highest value recorded at Aleto residential area. For zone (B) which signifies major traffic junctions, relative humidity value range between 51.12% to 58.40% with the lowest value recorded at Indorama toll-gate, Aleto while the highest value was recorded at Alode junction. For zone (C) which connote incineration/farmland areas, relative humidity range was between 50.20% to 57.60% with the lowest value recorded at Aleto farm road and the highest value recorded at dump-site at Akpajo market road. For zone (D) which represented Industrial zones, relative humidity value range was between 54.10% to 59.45% with the lowest value recorded at NNPC surroundings while the highest value was recorded at Ogale pipeline facilities. The noise level at all the locations in zone (A) was within the range 52.00 dBA to 65.30 dBA with the lowest level at Ogale residential zone or area and the highest level at Akpajo residential area. At major traffic junctions, the lowest noise level was recorded at Ogale market junction while the highest noise level was recorded at Akpajo round about. The lowest and highest level was within the range 65.30 dBA to 102.00 dBA respectively. It was observed that, the acceptable standard limit of 90 dBA of noise level given by NAAQS was exceeded at Akpajo round about which could be attributed to loud sounds from heavy- duty trucks, audio CD sellers at the junction and as well, noise generated by passers-by and traders selling along the road due to frequent traffic congestion. At incineration/farmland in all the locations in zone (C), noise level was within the range of 40.20 dBA to 50.70 dBA with the lowest level recorded at Ogale farm road while the highest level was recorded at NPA road dump site. It was observed that the noise level at the locations in zone (C) was the lowest compared to all other zones. This could be attributed to the zones been located at the outskirts of the communities which are somewhat quiet due to absence of human being and vehicular movement. For zone (D), noise level was between the range of 58.30 dBA to 67.50 dBA with the lowest level recorded at Indorama surroundings and the highest level recorded at Hamilton Technologies surroundings. Wind speed and direction at all the locations in zone (A) was within the range of 0.55 m/s to 1.70 m/s with the lowest value recorded at Aleto (0.55 m/s) and the highest value recorded at Onne (1.70 m/s) respectively. South-West (S.W) wind direction was measured in all the location at zone (A) except in Ebubu which North-West direction was measured. Wind speed at all the locations in zone (B) was within the range of 1.20 to 1.80 m/s with the lowest value recorded at Alesa and the highest recorded at Aleto. For wind direction, South-West direction was measured in all the locations in zone (B). The correlation between wind speed and the concentration of air pollutants suggest that, wind speed above 2.0 m/s is capable of diluting or reducing the level of air pollutants in any location. Based on this note, the range of values obtained for wind speed in this research work, was clear that, the level of air pollutants was higher since the values of wind speed was less than 2.0 m/s as stipulated. In zone (C) wind speed at all locations was recorded within the range of 0.55 to 1.90 m/s with the lowest value recorded at Ogale and the highest value at Onne respectively. For the direction of wind, South-West was measured in all the locations in zone (C). In zone (D), wind speed at all the location was recorded within the range of 0.65 to 1.70 m/s with the lowest value recorded at Aleto and the highest recorded at Onne. For wind direction, South-West was measured in all the locations in zone (D).

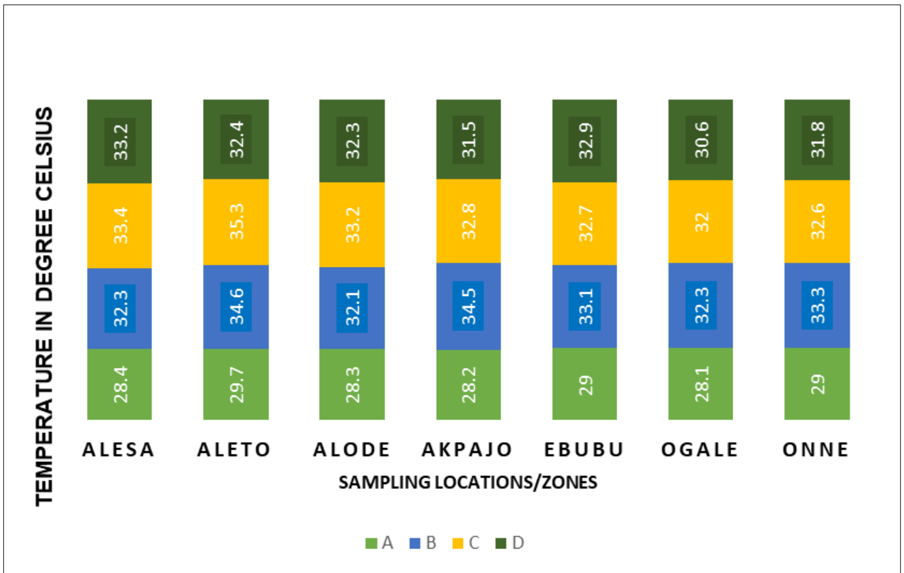


**Figure 2** Variations in Temperature of the Sampling Locations and Zones

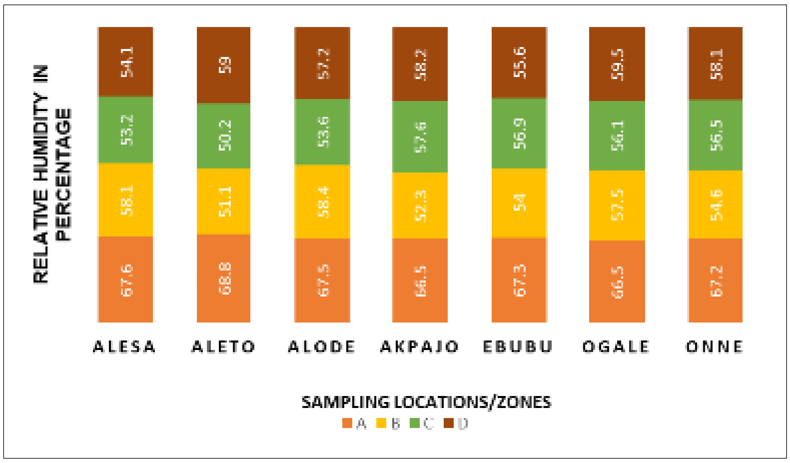


**Figure 3** Variation in Relative Humidity of the Sampling Locations/Zones

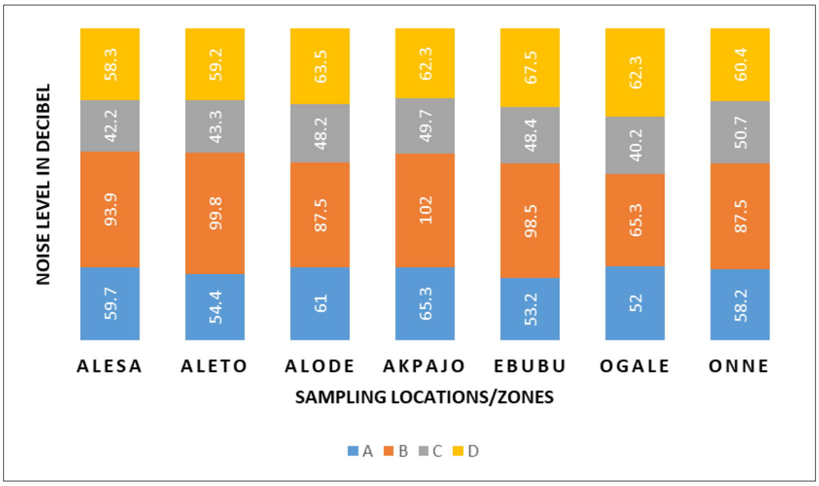


**Figure 4** Variation in Noise Level of the Sampling Locations/ Zones

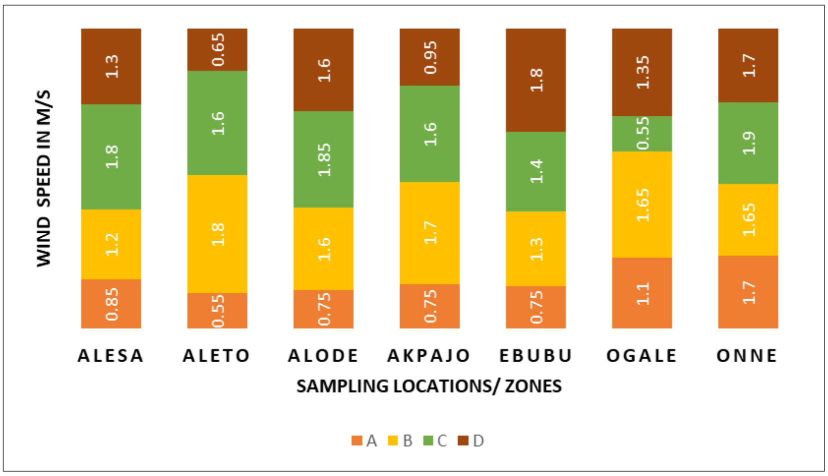


**Figure 5** Variation in Wind Speed of the Sampling Locations/ Zones

For Sampled Carbon Monoxide, Sulphur dioxide, Nitrogen dioxide, Nitric oxide, Carbon dioxide, Suspended particulate matter and Oxygen.

### 4.2. Carbon Monoxide (CO)

For sampled carbon monoxide levels throughout the locations in zone (A), was within the range of 1.00 ppm to 18.10 ppm. The highest concentration was recorded as 18.10 ppm at Akpajo residential area while the lowest concentration was recorded as 1.00 ppm at Alode, Ebubu and Ogale residential areas. The high concentration of CO recorded at Akpajo residential area could be attributed to incessant use of gasoline generator by the residents. Therefore, it is imperative for the populace of Akpajo residential area to reduced the use of gasoline generator. For zone (B) which connote major traffic junctions, sampled concentration of CO was within the range of 12.20 ppm to 43.00 ppm with the lowest concentration recorded at Alode junction as 12.20 ppm and the highest concentration recorded at Akpajo round about as 43.00 ppm. For zone (C), concentration of sampled carbon monoxide was within the range of 2.00 ppm to 9.30 ppm with the lowest concentration recorded as 2.00 ppm at Alode farm road and the highest concentration recorded as 9.30 ppm at Alesa refuge dump site. For zone (D), concentration of sampled CO was within the range of 2.10 ppm to 18.40 ppm with the lowest concentration recorded as 2.10 ppm at Ogale pipeline and the highest recorded as 18.40 ppm at Alesa refinery surrounding. It was observed that, the concentration of CO at Akpajo round about(43.0 ppm) was the highest compared to all sampling locations and zones and could be attributed to heavy traffic due to the presence of numerous vehicles as at the time of sampling. From statistical one way ANOVA, there was significant difference($P<0.05$) of the concentration of CO from all the sampling locations and zones considered. Comparing the concentration of CO at all the sampling locations and zones with the United State National Ambient Air Quality Standards (NAAQS) at 1(one) hour exposure limit, it was noted that, the concentration recorded at Akpajo round about(43.00 ppm), Indorama toll-gate on East- West road(42.20 ppm) and Onne, F.O.T junction(41.80 ppm) exceeded the stipulated 35 ppm recommended. The major reasons for high CO concentrations at the aforementioned sampling locations was due to heavy traffic congestion. The common outdoor sources of CO include, motor vehicles or machinery that burn fossil fuels[17]. CO is harmful due to the fact that, its capable of binding to hemoglobin in the blood, thereby reducing the ability of blood to transport oxygen to the body organs and tissues[18]. Effects of exposure to CO are headaches, dizziness, fatigue, confusion among others[18].

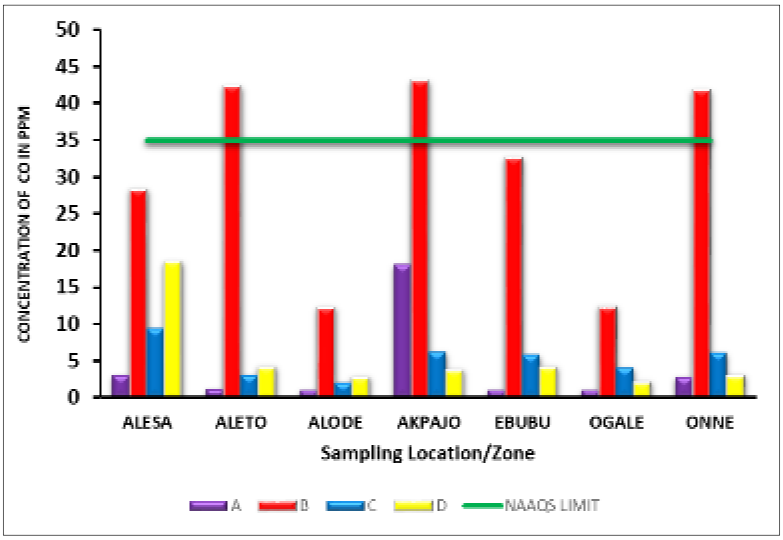


**Figure 6** Variation in the Concentration of CO in Sampling Locations and Zones compared with Standard Permissible Limit

### 4.3. Sulphur Dioxide ($SO_2$)

For sampled Sulphur dioxide level in all the locations in zone (A), were below detection limit recorded as 0.00 ppm. For zone (B), $SO_2$ concentration was within the range of 0.10 ppm to 1.30 ppm with the highest concentration recorded at Akpajo junction. For zone (C), $SO_2$ level was below detection limit, recorded as 0.00 ppm in all locations. For zone (D), sampled concentration of $SO_2$ was within the range of 0.10 ppm to 1.30 ppm with the lowest level recorded at Hamilton Technologies and Indorama surroundings while the highest level was recorded as 1.30 ppm at Eleme petrochemical company. In all locations and zones, it was observed that, Akpajo industrial zones and major traffic junctions have the highest level of sulphur dioxide which was recorded as 1.30 ppm in both zones. The major sources of $SO_2$ in the atmosphere include, burning of fossil fuels by power plants, industrial processes such as metal processing, petroleum refining among others[19]. Comparing the concentration of $SO_2$ recorded at all the sampling locations and zones with the United State NAAQS at 1 hour exposure limit, showed that, the sampled concentrations recorded at refinery junction, Alesa industrial area, Indorama toll-gate on East-West road, Aleto industrial zone, Akpajo round about, Eleme petrochemical company surroundings, Trailer park junction, Hamilton Technologies surroundings, Onne F.O.T junction and Onne industrial area were above the 75 ppb (0.075 ppm) recommended by the NAAQS. $SO_2$ irritates mucous membranes of the nose, lungs, eyes and throat among other effects on human[20].

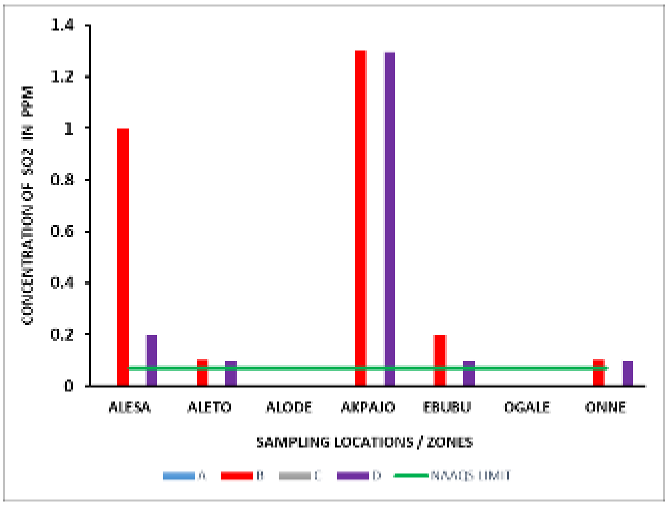


**Figure 7** Variation in the Concentration of $SO_2$ in Sampling Locations and Zones Compared with Standard Permissible Limit

### 4.4. Nitrogen Dioxide ($NO_2$) and Nitric Oxide (NO)

For sampled Nitrogen dioxide and Nitric Oxide concentrations in all the locations in zone (A), were below detection limit. For zone (B), Sampled level of of $NO_2$ was within the range of 0.80 ppm to 3.10 ppm with the lowest level recorded at Alesa (90.80 ppm) and the highest level was recorded at Akpajo (3.10 ppm) while for NO, sampled concentrations range from 0.10 ppm to 1.05 ppm and the lowest level was recorded at Alode while the highest level was recorded at Ebubu respectively. For zone (C), sampled $NO_2$ in all locations were below detection limit and sampled NO concentrations was within the range of 0.00 ppm to 0.10 ppm. For zone (D), Sampled $NO_2$ was within the range of 0.00 ppm to 1.00 ppm while that of NO was within the range of 0.10 ppm to 0.60 ppm with the lowest level recorded as 0.10 ppm at Ebubu and the highest level recorded as 0.60 ppm at Alesa respectively. In all sampling locations and zones, Akpajo major traffic junction has the highest level of $NO_2$ (3.10 ppm) while that of NO was recorded at Trailer park junction as (1.05 ppm). It was observed that, oxides of nitrogen were mostly recorded at major traffic junctions and industrial zones,

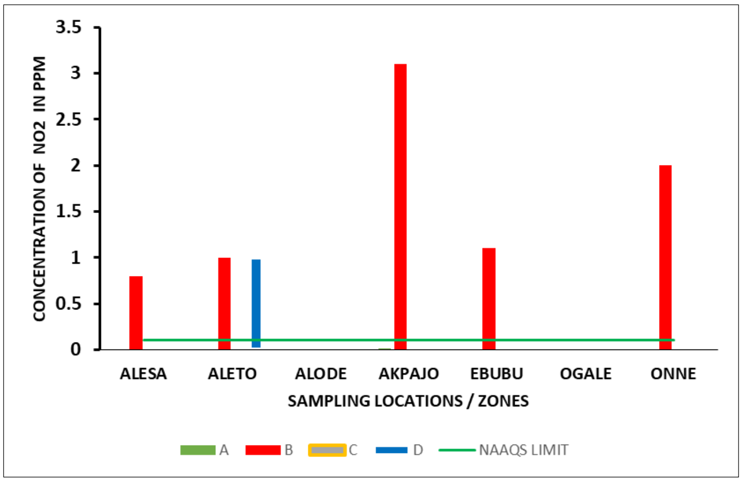


**Figure 8** Variation in the Concentration of $NO_2$ in Sampling Locations and Zones Compared with Standard Permissible Limit

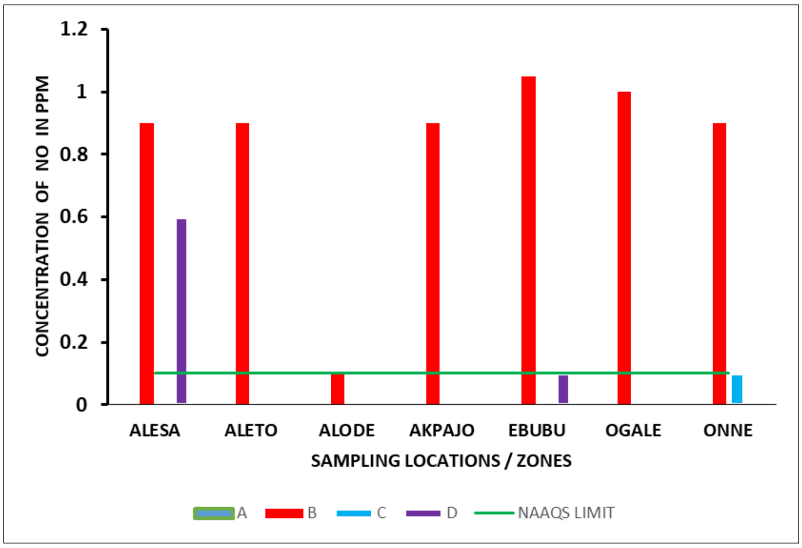


**Figure 9** Variation in the Concentration of NO in Sampling locations and Zones Compared with Standard Permissible Limit

Which is also in accordance with the publication of the International Programme on Chemical Safety, which states that, the main sources of oxides of Nitrogen are vehicular and industrial combustion of fossil fuels[21]. For $NO_2$ there was significant difference at ($P<0.05$) between major traffic junctions and other zones. Comparing the concentrations of $NO_2$ in all the sampling locations and zones with the stipulated recommendation of the U.S NAAQS for the averaging time of 1 hour exposure of (100 ppb) which is equal to ( 0.1 ppm), it was noted that the following zones exceeded the limit, Refinery junction(0.80 ppm), Indorama toll-gate on East-West road (1.00 ppm), Indorama surroundings (1.00 ppm), Akpajo round-about (3.10 ppm), Trailer park junction (1.10 ppm) and Onne junction (2.00 ppm). this observation was linked to the characteristic of traffic congestion at the aforementioned locations and zones as a result of poor road network and infrastructure. Major sources for the emission of $NO_x$ include, the exhaust gases of trucks and cars and as well, industrial electrical power generation plants[22]. with reference to AQI rating, the air quality for $NO_2$ in the following locations and zones were the best (Green); All the zones in Ogale, Alode, Alesa residential area and farmlands, Aleto residential area and farmlands, Akpajo farmland and industrial areas, Ebubu residential area and farmlands area and Onne residential area and farmland. Air quality of all major traffic junctions and some industrial zones at ALESA, ALETO, AKPAJO, EBUBU and ONNE were poor(red).

### 4.5. Suspended Particulate Matter (SPM)

SPM concentrations in all locations in zone (A) was between the range of 0.01ppm to 0.35 ppm with the lowest level recorded at Ogale residential area and the highest level at Alesa residential zone. For zone (B), SPM level was within the range of 0.1ppm to 0.65 ppm with the lowest value recorded at Ogale while the highest value recorded at Akpajo junction. For all the locations in zone (C), SPM concentrations was within the range of 0.25 ppm to 4.83 ppm with the lowest level recorded at Alode incineration site and the highest level recorded at Alesa incineration/ farmland. For all the locations in zone (D), SPM concentrations was within the range of 0.20 ppm to 0.40 ppm with the lowest level recorded at Ogale area and the highest level at Alesa industrial area. Comparing the concentrations of SPM in all the locations and zones with the permissible limits stipulated by the W.H.O and U.S. EPA, it was observed that, concentrations recorded in all locations and zones exceeded the permissible limits except in Ogale residential area that was within the W.H.O range in which, reasons for lower SPM concentration could be attributed to reduced or non-industrial activities in the area. Among all the locations and zones, Alesa Incineration/farmland has the highest concentration of SPM. This could be linked to the following factors; more industrial activities and processes in the area, incessant used of power plants by industries located within the area, constant incineration of refuge and most importantly, illegal oil refining popularly called KPOFIRE within the area and neighbouring communities. Significant SPM concentrations were also recorded at Akpajo, Ebubu, Onne and Ogale incineration/farmlands and traffic junctions which could be linked to constant burning of refuge at dump sites and road traffic congestion in these areas.

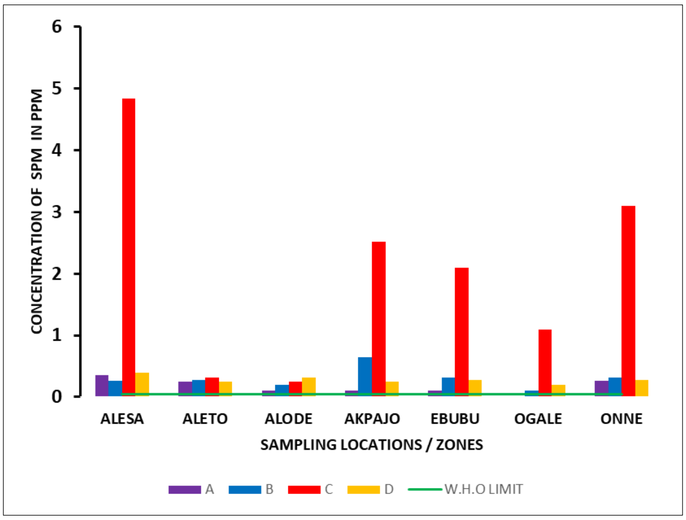


**Figure 10** Variation in the Concentration of SPM in Sampling Locations and Zones Compared with Standard Permissible Limit

### 4.6. Carbon Dioxide ($CO_2$)

Sampled $CO_2$ level in all the locations in zone (A) was within the range of 6.00 ppm to 6.83 ppm with the lowest level recorded at Ogale and the highest level was recorded at Akpajo residential area respectively. For zone (B), recorded concentrations of $CO_2$ was within the range of 7.20 ppm to 9.34 ppm. For zone (C), $CO_2$ level was within the range of 6.30 ppm to 8.90 ppm with the lowest concentration recorded at Ebubu farm road dump site and the highest level recorded at Aleto farm road dump site. For zone (D), $CO_2$ level was recorded within the range of 6.40 ppm to 7.10 ppm with the lowest level at Aleto Indorama surroundings and the highest level at Hamilton Technologies surroundings. Considering all the locations and zones, the level of $CO_2$ recorded at Akpajo round - about, precisely, 9.34 ppm was the highest. No significant difference at ($P>0.05$) was observed. The high concentration of $CO_2$ recorded at Akpajo round-about could be linked to the use and combustion of fossil fuels by motor vehicles(medium, heavy trucks and buses) and as well, deforestation trends with urban development of Akpajo community.

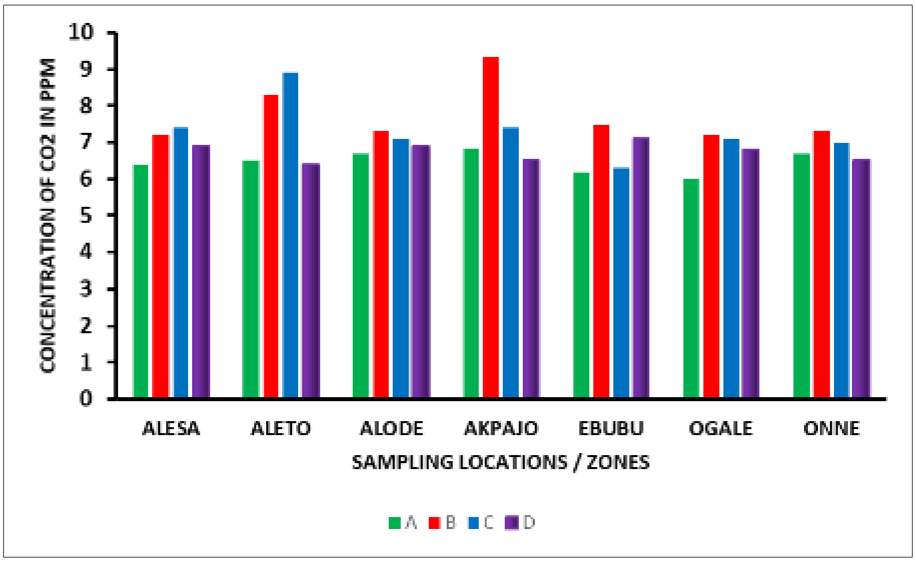


**Figure 11** Variation in the Concentration of $CO_2$ in Sampling Locations and Zones

### 4.7. Oxygen ($O_2$)

Measured oxygen level in all the locations in zone (A) which connote residential areas, was within the range of 65.10 ppm to 67.70 ppm with the lowest value measured at Akpajo residential area and the highest level measured at Ogale residential area. For zone (B), measured oxygen level was between the range of 56.40 ppm to 65.30 ppm with the lowest level measured at Akpajo junction and the highest level measured at Ogale market road junction. For all the locations in zone (C), oxygen level was between the range of 63.20 ppm to 65.80 ppm with the lowest level measured at Aleto incineration site and the highest level measured at Ogale farmland. For locations in zone (D), it was within the range of 64.30 ppm to 65.90 ppm with the lowest level measured at Aleto, by chipping company, close to Indorama and the highest level measured at Onne by Notore. It was observed that, the concentration of oxygen decreases at zone (C) which connote incineration areas and it could be liked to oxygen consumption due to incessant burning of dumped materials.

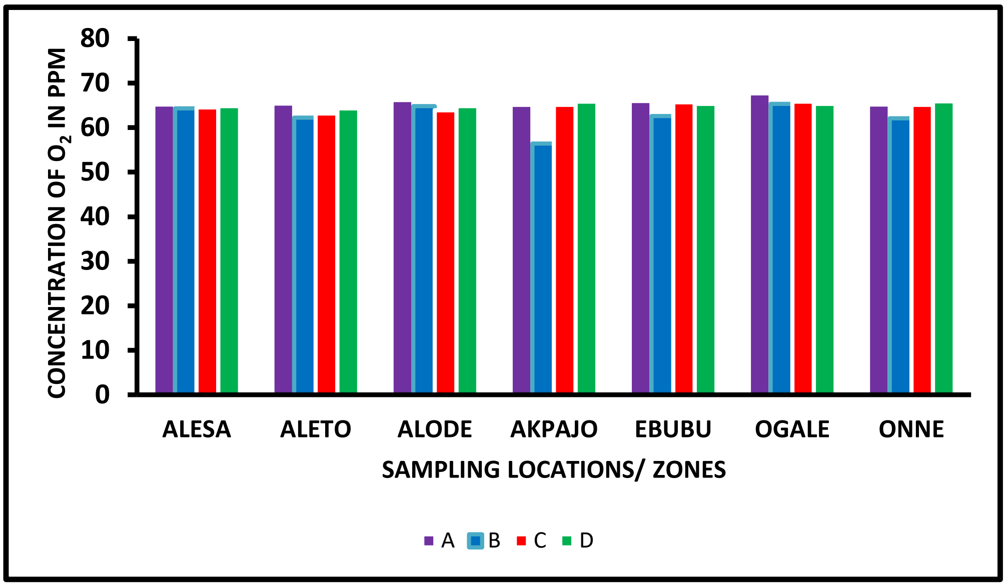


**Figure 12** Variation in the Concentration of Oxygen in Sampling Locations and Zones

## 5. Conclusion

Anthropogenic sources are the major origins of air pollutants. Significant contributors of air pollution are from industrial processes, transportation, agricultural activities and as well as residential electricity generation and heating processes. The research showed that, measured concentrations of CO, NO, $NO_2$ and SPM in all sampling areas were higher than the stipulated limits given by the regulatory bodies, although there was no significant difference except in $NO_2$ and NO only in major traffic junction and SPM at all the sampling zones. Based on the yardstick of Air Quality Index (AQI), the outdoor air can be classified as poor for SPM, varied between good, poor and very poor on CO and very good on NO and $NO_2$ except in major traffic junctions where they are classified as poor and very poor. In order to tackle the risk associated with the identified pollutants in the study area, more effort should be channeled to the use of renewable energy and as well, cleaner air initiatives should be embarked upon. Considering the four zones covered by the research( A,B,C and D), residential areas were the least source of sampled pollutants.

## Compliance with ethical standards

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*Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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