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Research Article
Ambient Air Quality Assessment of Orlu, Southeastern, Nigeria

[1]Ibe Francis Chizoruo, [2]Opara Alexander Iheanyichukwu, [3]Njoku Pascal Chukwuemeka and [3]Alinnor Jude Ikechukwu

[1]Department of Chemistry, Imo State University, P.M.B 2000 Owerri, Imo State, Nigeria
[2]Department of Geology, Federal University of Technology, P.M.B. 1526 Owerri, Imo State, Nigeria
[3]Department of Chemistry, Federal University of Technology P.M.B. 1526 Owerri, Imo State, Nigeria

Abstract

Background and Objective: Ambient air quality assessment of Orlu was carried out with reference to four criteria air pollutants which include particulate matter (PM_{10}), nitrogen dioxide (NO_2), sulfur (iv) oxide (SO_2) and carbon monoxide (CO). The objective of the study was to determine the atmospheric concentration and to further assess the air quality level of Orlu. **Methodology:** Five locations were studied within the months of November, 2014-February, 2015 using mobile air quality monitoring devices. The sampling was carried out once a week in each of the five air monitoring locations, 3 times/day (morning, afternoon and evening) and 4 times a month for a period of 3 months. The measured air quality data were analyzed using one way ANOVA ($p<0.05$) while its spatial distribution was studied using the Box and Whiskers plots. Similarly, the influence of wind speed and wind direction on atmospheric dynamics was assessed with the aid of wind rose diagrams while air quality condition was determined by using air quality index technique (AQI). **Results:** The result of the study showed that the mean concentration of the air pollutants ranged as follows: PM_{10} (3.40-11.53) mg m^{-3}, NO_2 (0.20-0.70) ppm, SO_2 (0.17-0.75) ppm and CO (26.00-51.00) ppm. The observed variations of mean levels of the atmospheric pollutants are in the order: Umuna junction>Banana junction>Umuaka>Ogboko junction>Umuago Urualla. The mean level of PM_{10}, NO_2 and CO in all the air quality monitoring locations exceeded the US NAAQS (US National Ambient Air Quality Standard) and Nigerian National ambient Air Quality Standards except the NO_2 concentration at Umuago Urualla, while SO_2 level was within Nigerian NAAQS limit but above US NAAQS. ANOVA ($p<0.05$) analysis revealed no significant difference in the mean concentrations of the measured air pollutants except NO_2 at Banana junction, PM_{10} at Umuaka junction and Ogboko junction. Results of the AQI analysis ranged from 151-225 which implies unhealthy and very unhealthy atmosphere. The wind rose diagrams revealed that the wind speed and wind direction contributed significantly to the dispersion and transportation of the atmospheric pollutants. **Conclusion:** The findings of the present study suggests that anthropogenic activities in the area and environs are responsible for the observed air quality levels. Strict monitoring of the atmospheric conditions of the study area is, therefore, recommended in view of the adverse health implications.

Key words: Atmospheric pollution monitoring, ambient air quality, air pollutants, windrose, anthropogenic factors

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Corresponding Author: Opara Alexander Iheanyichukwu, Department of Geology, Federal University of Technology, P. M.B. 1526 Owerri, Imo State, Nigeria Tel: +234-8038943579

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

One of the major challenging environmental problems that has bedeviled both the developed and developing countries of the world today is air pollution which has recently been linked to increased morbidity and mortality rates[1,2]. Atmospheric pollution is a condition in which certain substances, which include gases (sulphur dioxide, nitrogen oxides, carbon monoxides, hydrocarbons, etc.), particulate matters (smoke, dust, fumes, aerosols, etc.), radioactive materials and many others are present in such concentrations that may produce undesirable effects on man and ecosystem[3]. Human exposure to air pollutants is unavoidable in today's perspective especially in the urban areas of most developing countries[4]. Though, air pollution could be due to natural sources, a major anthropogenic source of air pollution is due to man's quest for a better standard of living and the utilization of natural resources for rapid industrialization, urbanization and consequently causing excessive air pollution[5]. Therefore, air pollution problems have continued to receive a great deal of interest worldwide due to its negative impacts on human health and welfare[6-9]. Among the reported cases of extreme air pollution conditions that affects humanity include the issues of high blood pressure and other cardiovascular problems[10,11]. Air pollution, therefore, is a serious threat to environmental health in many cities of the world today[12-14]. It is very pertinent to note that this condition is not unconnected to the fact that one of the basic requirements of human health and existence is clean air[15,16].

The level of air pollutant concentration depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions[17]. This is hinged on space variation of sources as well as atmospheric gradients which most often results in the diffusion and transportation of the pollutants to areas outside the source of the air pollution[18]. Atmospheric dynamics which are generally controlled by meteorological factors (including temperature, humidity, wind speed and direction, etc) remarkably influence the tendency for the release of atmospheric toxins to the environment[19]. In view of this, therefore, atmospheric pollutant conditions most often are subjected to spatio-temporal variations causing the air pollution pattern to change with space and time due to changes in meteorological and topographical conditions[17].

Air quality assessment and monitoring is, therefore, very important in determining the nature of population exposure to atmospheric pollutants which may result in a variety of health effects. These health effects generally depend on the type of pollutant, its magnitude, duration and frequency of exposure and of course the toxicity of the pollutant[20]. The way people live and breathe could be affected by the air quality of a particular locality and air quality like weather normally changes from time to time. Report of the air quality index of a locality is therefore important in ambient air quality assessment and monitoring. Air quality index (AQI) rating therefore, may be useful in understanding the atmospheric concentration levels of a locality since it helps in the classification of the health conditions inherent in human exposure to air pollution[21]. There is, therefore, the urgent need of assessing the air quality condition within Orlu metropolis owing to increase in population, industrialization and urbanization levels of the area.

The objective of this study was to assess the air pollution level of Orlu and environs in Imo State, Southeastern Nigeria within the geographical locations geo-referenced with the GARMIN GPSmap76 equipment as shown in Table 1. The acquisition of ambient air quality data in the study area has become necessary due to the paucity of data on atmospheric pollutant concentrations. Nigeria like most developing countries lack the capacity for continuous air pollution monitoring. Therefore, there is need for acquisition of air pollution data at regular intervals in the study area to ascertain the air quality conditions. In this regard, therefore, air pollution level of the study area was determined with emphasis to particulate matter (PM_{10}), nitrogen (iv) oxide (NO_2), sulphur (iv) oxide (SO_2) and carbon monoxide (CO). Similarly, since atmospheric pollutant concentrations could be influenced by meteorological factors, therefore, meteorological variables (wind speed and wind directions) were also measured in order to assess the dynamics of atmospheric dispersion of the air pollutants in the study locations. The air quality data measured were analyzed with reference to the specified threshold limits prescribed by the Nigerian National Ambient Air Quality Standards (Nigerian NAAQS)[22] and the United States National Ambient Air Quality Standards (US NAAQS)[23].

MATERIALS AND METHODS

Study area: The study was carried out in Orlu area of Imo State, Nigeria between the months of November, 2014-February, 2015. The need for this research was necessitated by the fact that Orlu is very close to Ohaji/Egbema/Oguta area of Imo State known for crude oil related activities and gas flaring[24]. This is also in addition to the glaring fact that Orlu is undergoing a rapid population, industrialization and urbanization growth[25]. The increasing level of urbanization in the area is associated with a lot of commercial and industrial activities including the use

Table 1: Air quality monitoring locations of Orlu and environs, Southeastern Nigeria

Location	Latitude	Longitude	Elevation (m)	Characteristics
Umuaka	5°40'15.50"N	7°00'50.92"E	180	High vehicular and motorcycle traffic, market, motor park, many commercial activities including artisan workshops
Banana junction	5°47'54.79"N	7°01'14.86"E	208	High vehicular, motorcycle traffic. Many commercial activities abound including artisan workshops. Highly built up area with many residential and commercial buildings
Umuna junction	5°47'41.79"N	7°02'19.94"E	196	High vehicular, motorcycle and human traffic. Highly built up with a lot of commercial activities including markets, motor parks and artisan workshops
Ogboko junction	5°49'56.57"N	7°04'43.82"E	172	Low vehicular, motorcycle and human traffic. There is also low commercial activity within the area. The main roads in the area are under construction and few nearby residential buildings
Umuago Urualla	5°51'09.36"N	7°04'51.68"E	196	Very low vehicular, motorcycle and human traffic with little or no noticeable commercial activities. Only few residential buildings were sited in the area

of power generators and high volume of vehicular traffic. There is also the prevalence of two stroke engine automobiles (mainly motorcycles and tricycles) used mainly for transportation in the study area. These two stroke engines are well known for incomplete combustion of fossil fuels which generally leads to the emission of noxious atmospheric air pollutants[17,26]. Orlu is located by the geographical coordinate given by latitudes 5°40'15.50''-5°51'09.36''N and longitudes 7°00'59.92''-7°04'51.68''E and is within the tropical rainforest region with two distinct seasons which include wet and dry seasons. It has an annual rainfall of about 1700-2500 mm, which is observed almost entirely within the months of March and October. Average relative humidity is about 80% with up to 90% occurring during the rainy season. The mean daily maximum air temperatures ranges from about 28-35°C, while the mean daily air temperature minimum ranges from about 19-24°C[27]. The air quality sampling was carried out at five different locations within Orlu area as shown in Table 1. A measuring location sited at Umuago Urualla was chosen to serve as the control during the field study.

Air quality sampling procedure: The air pollutants SO_2, CO, NO_2 and $PM_{10,}$ commonly used in air quality index (AQI) assessment were sampled 3 times a day (morning, afternoon and evening)[15,28]. The SO_2, CO and NO_2 were determined with the specific Gasman air monitor, Crowcon Instruments Ltd., England, while PM_{10} was measured with Haze-dust particulate monitor 10 μm, model HD1000, Environmental Device Corporation, USA. The meteorological parameters which include wind speed and wind direction were measured with a Multifunctional Microprocessor digital meter Anemometer, Model Am-4836C, China. The geographical coordinates and elevation were determined with the aid of the Garmin, GPSmap 76. Sampling was carried out during dry season within the months of November, 2014-February, 2015. This involved 3 months of air quality monitoring for a period of 12 weeks. The sampling was carried out once a week in each of the five air monitoring stations, 3 times/day (morning, afternoon and evening) and 4 times a month for a period of 3 months.

Method of data interpretation: Data was analyzed using geospatial and geostatistical techniques with the mean values of the air pollutant concentrations estimated for measurements made in the morning, afternoon and evening hours. The standard deviation (SD) and variance were determined while the estimated co-efficient of variation (CV%) was used to assess the variation in the concentration levels of the air pollutant monitored using Eq. 1:

$$CV(\%) = \frac{SD}{Mean} \times 100 \quad (1)$$

Where:
CV (%) = Coefficient of variation in percentage
SD = Standard deviation

Variation in the concentration levels was categorized as little variation (CV %<20), moderate variation (CV % = 20-50) and high variation (CV %>50)[29]. Box and Whiskers plots and one way ANOVA ($p<0.05$) were carried out with the help of Matlab software version 7.9, while Grapher 10 was used to develop the dominant wind dynamics (wind rose). Sim-air quality software was used to calculate the air quality index of the air pollutants using Eq. 2:

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}}\left(C_p - BP_{Lo}\right) + I_{Lo} \quad (2)$$

Where:
I_p = Index for pollutant
C_p = Rounded concentration of pollutant p

BP_{Hi} = Breakpoint that is>C_p
BP_{Lo} = Breakpoint that is<C_p
I_{Hi} = AQI value corresponding to BP_{Hi}
IL_o = AQI value corresponding to BP_{Lo}

RESULTS AND DISCUSSION

Variation of atmospheric pollutant concentration: The mobile air monitoring devices were deployed at five different locations, out of which one location at Umuago Urualla was chosen as the control for the field acquisition. It was observed that the lowest concentration of the air pollutants were recorded at this location. Elevated concentration of the air pollutants were observed in most of the areas with higher commercial activities as indicated in Table 1. The observed level of the ambient air pollutants at the locations may be attributed to the influence of meteorological factors such as wind speed and wind direction in addition to anthropogenic activities. The summary of air pollutant concentration levels in Orlu is presented in Table 2. The result revealed that higher mean level of NO_2 were observed in the afternoon than in the morning and evening. Table 2 also shows that the mean level of SO_2 recorded in the afternoon was higher when compared with values recorded in the morning and evening. In the case of PM_{10}, the highest mean concentrations were also observed in the afternoon. Though elevated mean levels of CO was obtained in the afternoon, the maximum value was observed in the evening while the minimum value was observed in the morning.

Figure 1a-d are the results of air quality data obtained from the 5 locations studied within Orlu and environs, indicating the concentration levels of the atmospheric pollutants within the 12 weeks of air quality study. In the case of PM_{10}, the result as shown in Fig. 1a ranged from 3.40-11.53 mg m^{-3} with higher levels of PM_{10} recorded at all the air sampling sites when compared with the control. Highest PM_{10} concentration level was recorded at Banana and Umuna junctions. This may not be unconnected with the level of commercial activities and traffic situation at the locations. The concentration levels of PM_{10} recorded across the study area is in the increasing order of Umuna junction>Banana junction>Umuaka junction>Ogboko>Umuago Urualla.

Figure 1b shows the level of NO_2 values observed at the locations which revealed that the values ranged from 0.20-0.70 ppm. However, higher values of NO_2 was observed at Umuna junction when compared with other sites including the control station. The values observed are in the order: Umuna junction>Banana junction>Umuaka>Ogboko junction>Umuago Urualla.

Similarly, Fig.1c shows the level of SO_2 at the locations sampled with the values ranging from 0.17-0.75 ppm. Elevated values of SO_2 were observed at Umuna junction. The observed values are in the increasing order of Umuna junction>Banana junction>Umuaka>Ogboko junction>Umuago Urualla. The observed elevated levels of NO_2 and SO_2 at some stations could be attributed to higher vehicular traffic, presence of three stroke engine tricycles and higher commercial activities including the use of power generating sets[30].

The result of CO levels across the study area is shown in Fig. 1d. The result revealed that the values ranged from 26.00-51.00 ppm across the study area. It was observed that the CO levels were high in all the locations including the control. This calls for attention and proper monitoring on a regular basis. The recorded high values is believed to be a reflection of the activities going on in the area including high volume of traffic, numerous commercial activities, rampant use of power generating sets and other domestic activities including combustion of biomass[17,31]. The observed values were also noticed to have the same trend and order as PM_{10}, NO_2 and SO_2 values earlier discussed. The observed elevated concentration of the studied air pollutants in the afternoon is an indication that the sources of these pollutants are due to increased commercial activities during working hours. The mean level of NO_2 and SO_2 observed in this study are within the annual and 24 h stipulated values, while the mean level of PM_{10} and CO exceeded both the annual and 24 h limits recommended by NAAQS and US NAAQS.

Table 2: Summary of air pollutant concentration level

	NO_2 (ppm)			SO_2 (ppm)			PM_{10} (mg m^{-3})			CO (ppm)		
	M	A	E	M	A	E	M	A	E	M	A	E
Max	0.63	0.63	0.52	0.55	0.60	0.60	8.91	10.13	9.20	46.75	47.25	49.25
Min	0.42	0.37	0.42	0.33	0.32	0.33	5.13	6.35	6.80	37.75	37.00	38.25
Mean	0.49	0.50	0.48	0.42	0.48	0.45	7.01	7.87	7.69	42.42	43.29	42.33
SD	0.07	0.06	0.04	0.07	0.10	0.09	1.02	1.35	0.85	2.64	2.91	3.22
Var	0.00	0.00	0.00	0.00	0.01	0.01	1.03	1.81	0.72	6.98	8.48	10.39
CV%	3.43	12.00	8.33	16.67	20.83	20.00	14.55	17.15	11.08	6.22	6.72	7.61

M: Morning, A: Afternoon, E: Evening, Min: Minimum value, Max: Maximum value, SD: Standard deviation, Var: Variance and CV: Coefficient of variation

Statistical analysis of the air pollutant concentration: Variation of the air pollutants in the morning, afternoon and evening as shown in Table 2 revealed that for NO_2, the co-efficient of variation is in the order: A>E>M. The highest

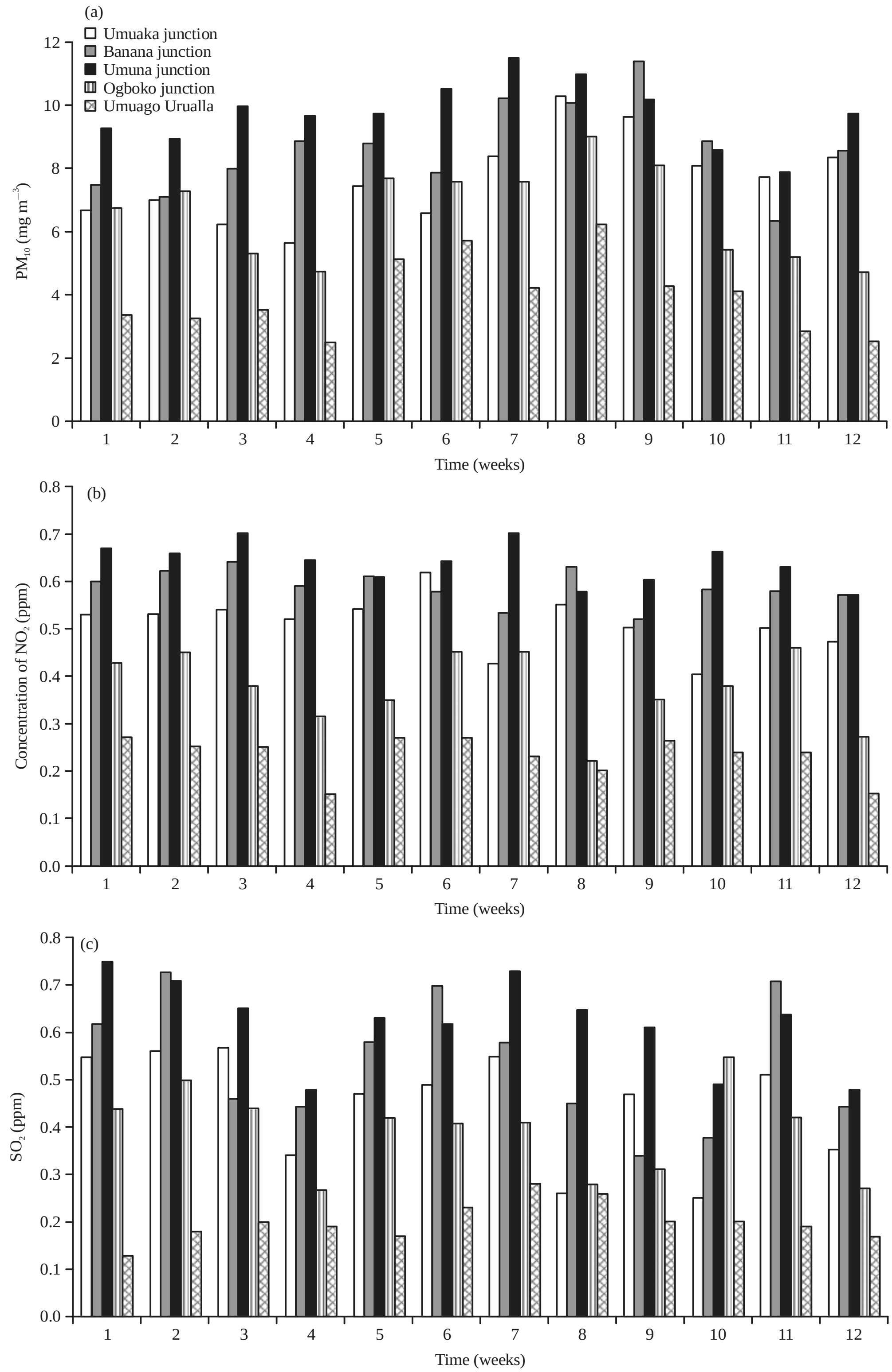

Fig. 1(a-d): Continue

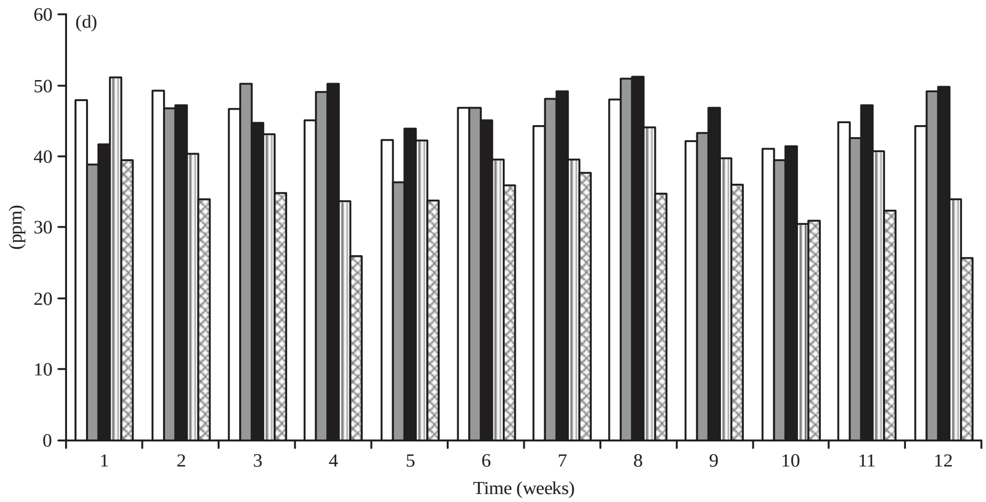

Fig. 1(a-d): (a) Variation of weekly PM_{10} concentration levels at different monitoring locations, (b) Variation of weekly concentration levels of NO_2 at different monitoring locations, (c) Variation of weekly levels of SO_2 at different monitoring locations and (d) Variation of weekly levels of CO at different monitoring locations

variation (12%) was observed in the afternoon. The order of the variation of SO_2 is also is given as A>E>M, while the order of variation of PM_{10} is A>M>E. Similarly, Table 2 revealed that for CO, the co-efficient of variation is in the order A>E>M.

The distribution of the concentrations of the air pollutants in the study locations are represented with Box and Whisker plots as shown in Fig. 2-6. In Fig. 2a at Umuago Urualla, the plot revealed that in the morning, afternoon and evening, 25% CO concentration recorded is within 29-32 ppm while 75% of the value is within 33-37 ppm. ANOVA result (F = 2.7, sig. value = 0.0823, $p<0.05$) shows that there is no significant difference in the mean level of CO. Figure 2b shows that for SO_2, 25 and 75% of the values observed in the morning, afternoon and evening are within 0.15-0.17 and 0.22-0.24 ppm, respectively. ANOVA result (F = 0.26, Sig. value = 0.78, $p<0.05$) indicates that there is no significant difference in the mean value of SO_2 recorded. In Fig. 2c, the box and whisker plot shows that 25 and 75% concentration of NO_2 are respectively within 0.18-0.21 and 0.25-0.28 ppm, respectively in the morning, afternoon and evening. ANOVA result (F = 0.04, Sig. value = 0.96, $p<0.05$) reveals no significant difference in the mean value of NO_2. Similarly, Fig. 2d shows that in the morning, afternoon and evening, 25 and 75% values of PM_{10} recorded are within 2.6-3.2 and 4.8-5.2 mg m^{-3}, respectively. The result of the ANOVA interpretation (F = 0.09, sig. value 0.92, $p<0.05$) revealed no significant difference in the mean level of PM_{10} at Umuago Urualla.

At Ogboko junction, it was clearly shown by Fig. 3a that for CO, 25 and 75% of the values recorded in the morning, afternoon and evening are within 34-37 and 40-47 ppm, respectively. Results of the ANOVA analysis (F = 1.62, Sig. value = 0.214, $p<0.05$) showed that the difference in the average value of CO do not differ significantly. Figure 3b revealed that 25 and 75% of the observed values of SO_2 lie, respectively within 0.30-0.32 and 0.40-0.53 ppm in the morning, afternoon and evening. Similarly, results of the ANOVA analysis (F = 0.74, sig. value = 0.49, $p<0.05$) revealed that there is no significant difference in the SO_2 mean concentration. Figure 3c indicated that 25 and 75% concentration of NO_2 recorded are respectively within 0.13-0.34 ppm and 0.43 and 0.48 ppm in the morning, afternoon and evening with the result of the ANOVA analysis (F = 0.22, sig. value 0.80, $p<0.05$) showing that the p-value is less than the significant value meaning that there is no significant statistical difference in the mean concentration of NO_2 observed. Figure 3d showed that the values, 4.50-5.90 and 6.10-8.80 mg m^{-3} are, respectively the 25 and 75% of the PM_{10} values observed in the morning, afternoon and evening. On the other hand ANOVA result (F = 3.92, sig. value = 0.03, $p<0.05$) shows that there is a statistical significant difference in the mean concentration of PM_{10} level observed in this location in the morning, afternoon and evening. This could be attributed to the influence of meteorological parameters, seasonal and spatial variations.

For Umuna junction, the Box and Whiskers plots shown in Fig. 4a revealed that 25 and 75% of the values of CO recorded are respectively within 43.00-46.50 and 48.00-50.50 ppm in the morning, afternoon and evening. Analysis of the ANOVA statistical interpretation (F = 0.34, sig.

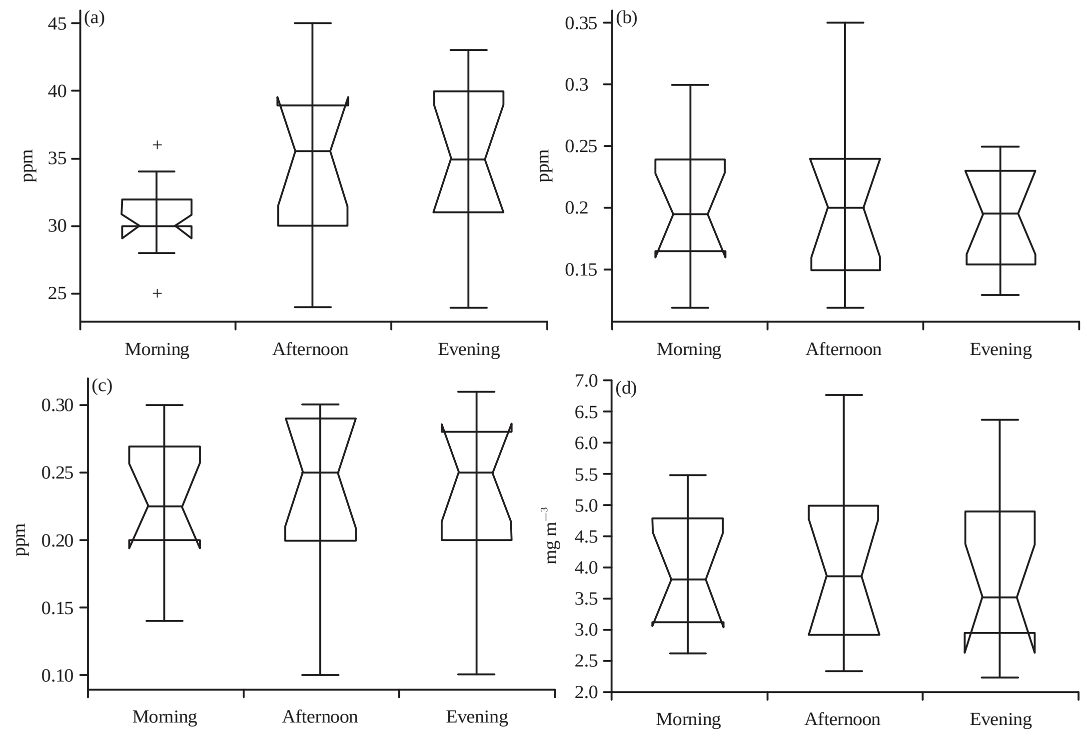

Fig. 2(a-d): Box and whiskers plots of (a) CO, (b) SO_2, (c) NO_2 and (d) PM_{10} at Umuago Urualla

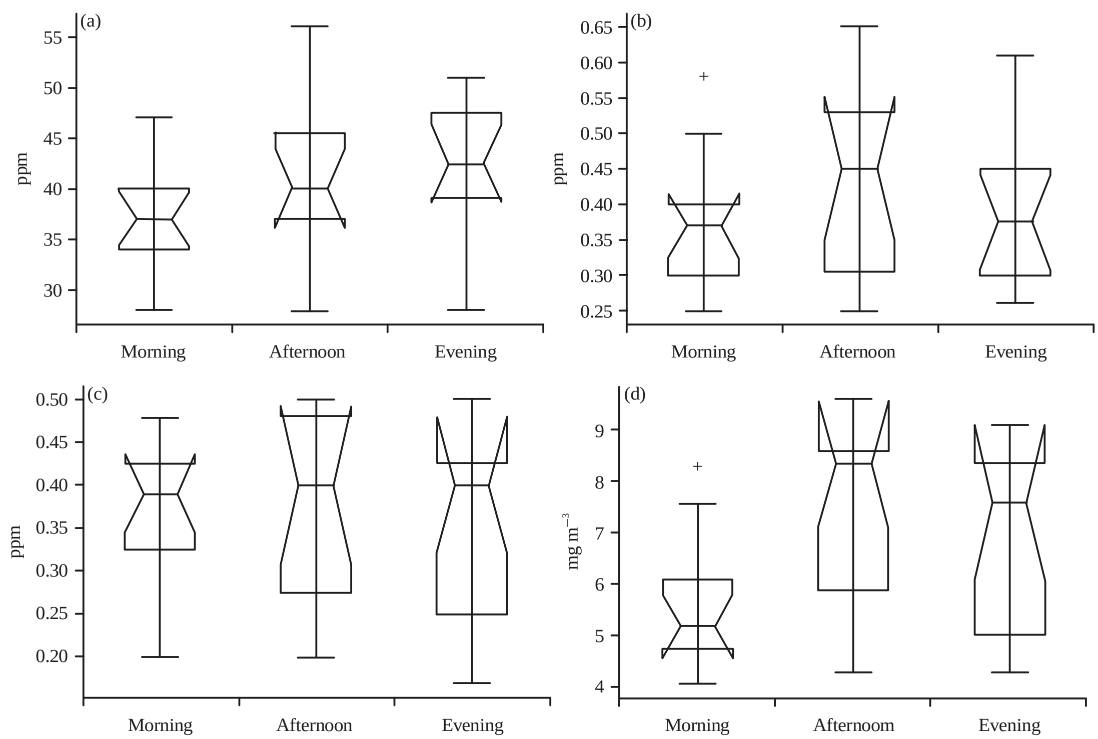

Fig. 3(a-d): Box and whiskers plots of (a) CO, (b) SO_2, (c) NO_2 and (d) PM_{10} at Ogboko junction

value = 0.713, $p<0.05$) revealed that there is no statistical significant difference in the mean concentration of the pollutant in this location. Figure 4b shows that for SO_2, the values given as 0.52-0.54 and 0.68-0.76 ppm are, respectively

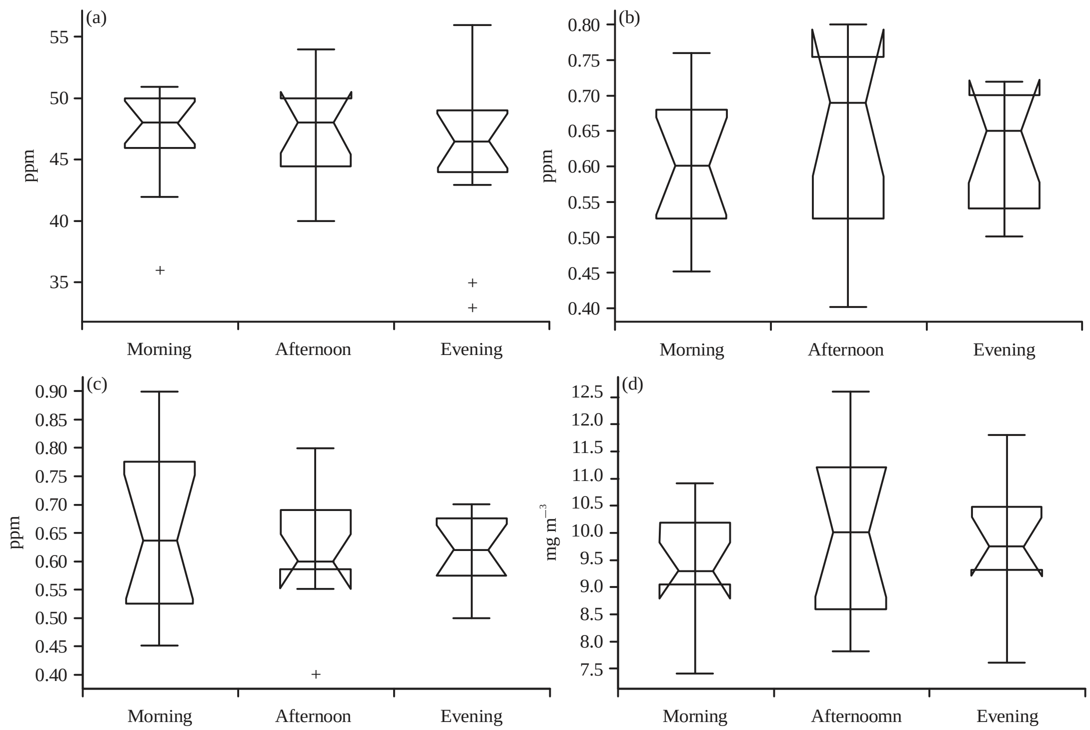

Fig. 4(a-d): Box and whiskers plots of (a) CO, (b) SO_2, (c) NO_2 and (d) PM_{10} at Umuna junction

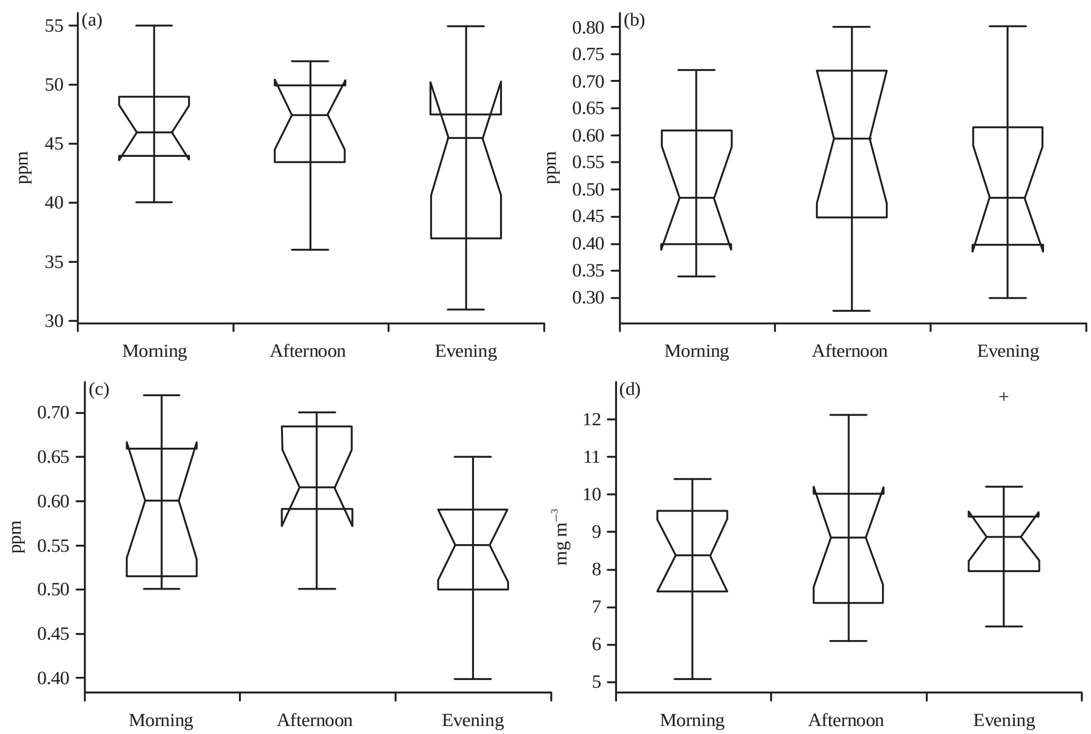

Fig. 5(a-d): Box and whiskers plots of (a) CO, (b) SO_2, (c) NO_2 and (d) PM_{10} at Banana junction

the 25 and 75% of the concentration recorded in the morning, afternoon and evening. The result obtained from ANOVA (F = 0.38, sig. value = 0.68, $p<0.05$) indicated that there is no statistical significant difference in the mean concentration of

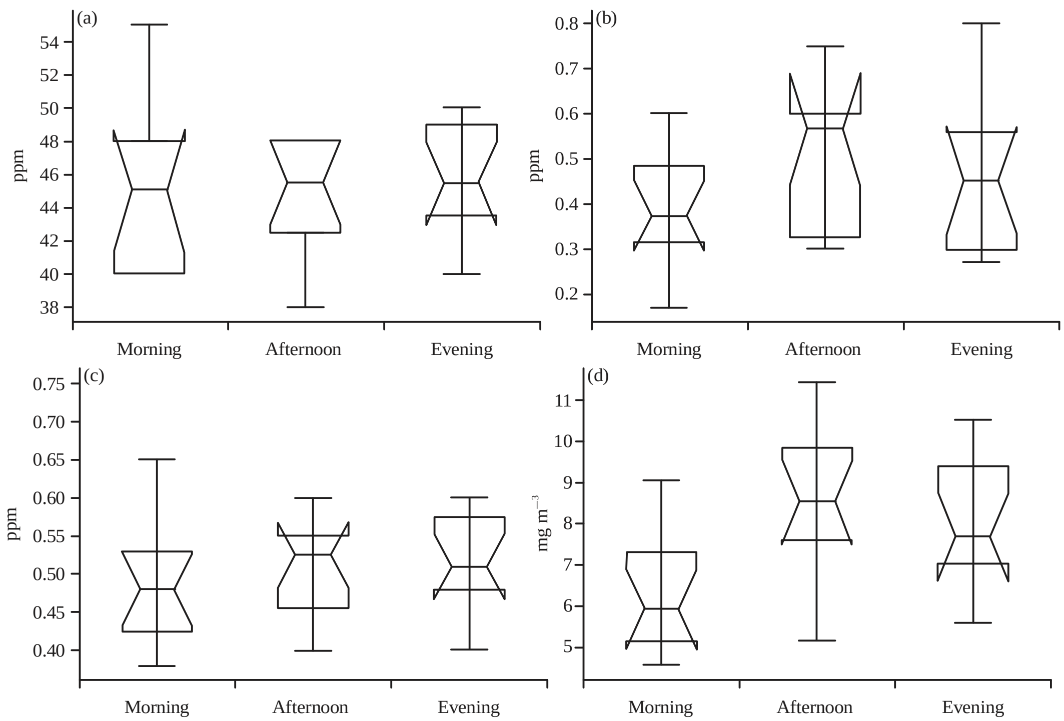

Fig. 6(a-d): Box and whiskers plots of (a) CO, (b) SO_2, (c) NO_2 and (d) PM_{10} at Umuaka

the atmospheric pollutant. Similarly, the 25 and 75% of NO_2 concentration as shown in Fig. 4c are respectively within 0.53-0.57 and 0.67-0.77 ppm of the values recorded in the morning, afternoon and evening. The result of the ANOVA interpretation (F = 0.27, sig. value = 0.77, p<0.05) revealed that the values do not statistically differ significantly. Figure 4d implies that 25 and 75% of PM_{10} concentration observed are respectively within 8.60-9.30 and 10.30-11.20 mg m^{-3}, respectively in the morning, afternoon and evening. Results deduced from ANOVA analysis (F = 0.62, sig. value = 0.55, p<0.05) revealed that there is no statistical difference in the mean level of PM_{10} as any variation in concentration could be due to chance.

At Banana junction, the Box and Whiskers plots presented in Fig. 5a revealed that the 25 and 75% of CO values recorded, respectively lie within 37.00-43.80 and 47.00-50.00 ppm in the morning, afternoon and evening. It was also observed that the mean values are not statistically significant as indicated by the results of the ANOVA (F = 1.71, sig. value = 0.19, p<0.05). Any observed difference therefore could be attributed to chance. Similarly, Fig. 5b revealed that 0.40-0.46 and 0.61- 0.73 ppm of SO_2 concentration recorded are respectively the 25 and 75% of the values observed in the morning, afternoon and evening. The ANOVA result (F = 0.95, sig. value = 0.39, p<0.05) showed that the difference in the mean concentration of SO_2 obtained is not statistically significant. Figure 5c indicated that in the morning, afternoon and evening, 25 and 75% of NO_2 values obtained in this location are respectively within 0.52-0.57 and 0.58-0.67 ppm. The ANOVA result (F = 3.93, sig. value = 0.029, p<0.05) implies that the difference in the mean concentration of this air pollutant obtained in this location differ statistically. This could be due to the effect of meteorological parameters, location and season. On the other hand, Fig. 5d revealed that 25 and 75% of PM_{10} values recorded are respectively within 7.20-8.10 and 9.50-10.10 mg m^{-3} in the morning, afternoon and evening. Analysis of variance (F = 0.37, sig. value = 0.695, p<0.05) indicated that the difference in average concentration of PM_{10} at this location is not significant and any difference that may exist therefore may be due to chance.

The Box and Whiskers plots of Umuaka and environs revealed that 25 and 75% of the CO values recorded are within 40.00-43.00 and 48.50-49.50 ppm in the morning, afternoon and evening, respectively (Fig. 6a). ANOVA result (F = 0.16, sig. value = 0.85, p<0.05) revealed that the difference in the mean concentration of the parameters are not statistically significant and any variation may be as result of chance. However, the recorded values are ranged between 0.30-0.32 and 0.49-0.61 ppm, respectively for the 25 and 75% of the data obtained in the morning, afternoon and evening for SO_2. (Fig. 6b). The results from ANOVA (F = 1.94, sig. value = 0.16, p<0.05) revealed that the mean concentration do not differ significantly at this location. Figure 6c showed that 25 and

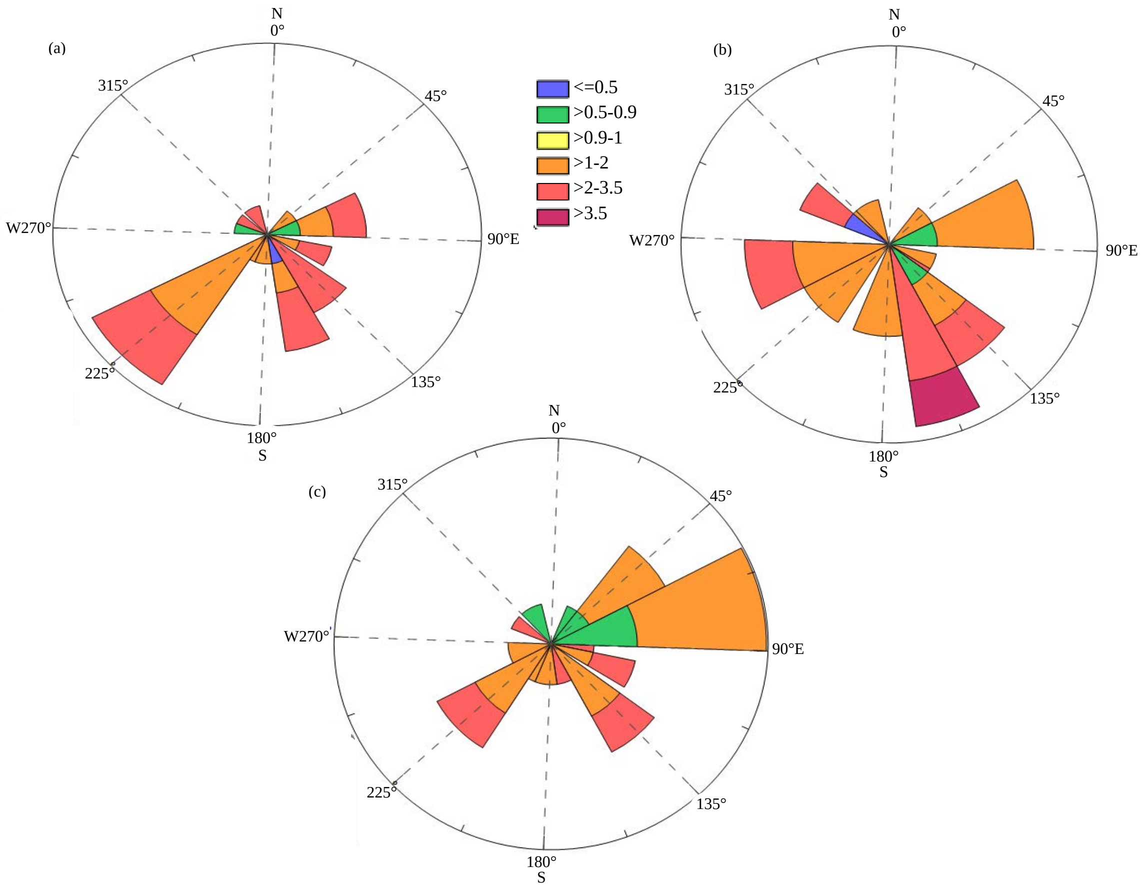

Fig. 7(a-c): Wind rose diagrams generated at Umuaka junction, (a) Morning, (b) Afternoon and (c) Evening

75% of NO_2 values recorded are respectively within 0.43-0.47 and 0.53-0.58 ppm in the morning, afternoon and evening. The result of ANOVA (F = 0.67, sig. value = 0.519, $p<0.05$) showed that the difference in mean concentration of NO_2 is not statistically significant and any variation may be due to chance. On the other hand Fig. 6d indicated that the 25 and 75% of PM_{10} concentration recorded in the area lie within 5.10-7.30 and 7.00-9.80 mg m^{-3} in the morning, afternoon and evening. ANOVA result (F = 7.12, sig. value = 0.003, $p<0.05$) showed that the difference in the mean concentration of the atmospheric pollutant is statistically significant. This difference could be associated with influence of meteorological parameters, location and season.

Analysis of air pollutant migration and dispersion using the Wind rose diagrams: The active agents responsible for mixing of atmospheric pollutants are the meteorological variables such as wind speed, wind direction, relative humidity and ambient temperature[32]. Giri *et al*.[33] noted that among the array of climatic factors, the most important is wind, which helps in the dispersion, transformation and removal of air pollutants from the ambient environment. Meteorological factors such as wind speed and direction which are used together to generate the windrose, is a veritable tool that can be used to predict the dynamical processes of atmospheric dispersion, inversion and turbulence. The windrose diagram provides real-time information on the migration and dispersal of air pollutants in an area in relationship with sources and pollutant levels[34]. The windrose diagrams in Fig. 7-11 were used to explain the process of dispersion of the measured atmospheric pollutants in the study locations. Results of the wind rose diagrams suggest that the dispersion and migration of the measured air pollutants are associated with the prevailing wind speed and directions observed at the study locations.

Figure 7 revealed that at Umuaka junction, the dominant wind speed in the morning, afternoon and evening ranged from 0.90->3.50 sec^{-1} in NE, SE and SW directions. In Fig. 8, the dominant wind speed at Banana junction in the morning, afternoon and evening ranged from>0.05->3.50 sec^{-1} in the SE, NW, NE and SW directions. At Umuna junction, the

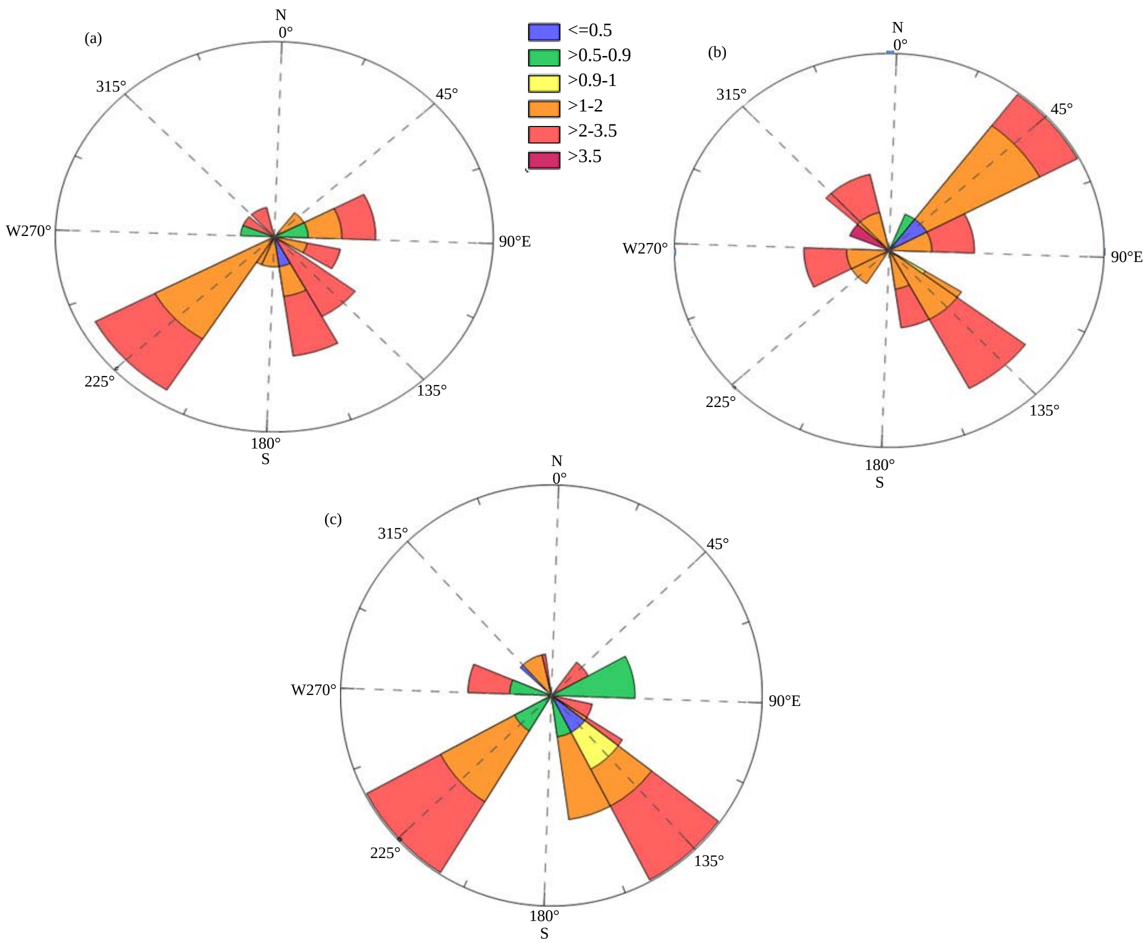

Fig. 8(a-c): Wind rose diagrams generated at Banana junction, (a) Morning, (b) Afternoon and (c) Evening

Table 3: AQI values, level of health concern and colours

Descriptor	AQI	Risk message	Colours
Good	0-50	No message	Green
Moderate	51-100	Unusually sensitive individual (ozone)	Yellow
Unhealthy for sensitive group	101-150	Identifiable groups at risk, different groups for different pollutants	Brown
Unhealthy	151-200	General public at risk, groups at greater risk	Red
Very unhealthy	201-300	General public at greater risk, groups at greatest risk	Purple

AQI: Air quality index

dominant wind speed and direction in Fig 9a, b ranges from>0.50->3.50 sec^{-1} in the NE, SE, SW and NW direction, while in Fig. 9c, the dominant wind speed is in the range>2.00-3.5 sec^{-1} in the SE direction. Figuer 10 revealed that in the morning and evening (Fig. 10b, c) at Ogboko, the dominant speed is between>2.00-3.50 sec^{-1} in the NE direction, while Fig. 10a suggests that the dominant wind direction is also within>2.00-3.50 sec^{-1} but in the SE direction. At Umuago Urualla (Fig. 11), it was shown that the prevailing wind speed ranged from>0.90->3.50 sec^{-1} in the SW, NW, NE and SE directions. The above highlighted dominant wind speed and direction in Fig. 7-11 generally revealed the prevailing directions along which the dispersion and migration of the atmospheric pollutants in the study area may have taken.

Air quality index analysis: In order to assess possible effects of population exposure to the air quality level, AQI evaluation of the air pollutants studied were carried out. The result of the AQI evaluation is presented in Table 4, while Table 3 is the AQI values, level of health concern and colours. The result as presented in Table 3 shows the individual AQI, conditional pollutant and the average AQI values. The individual AQI for

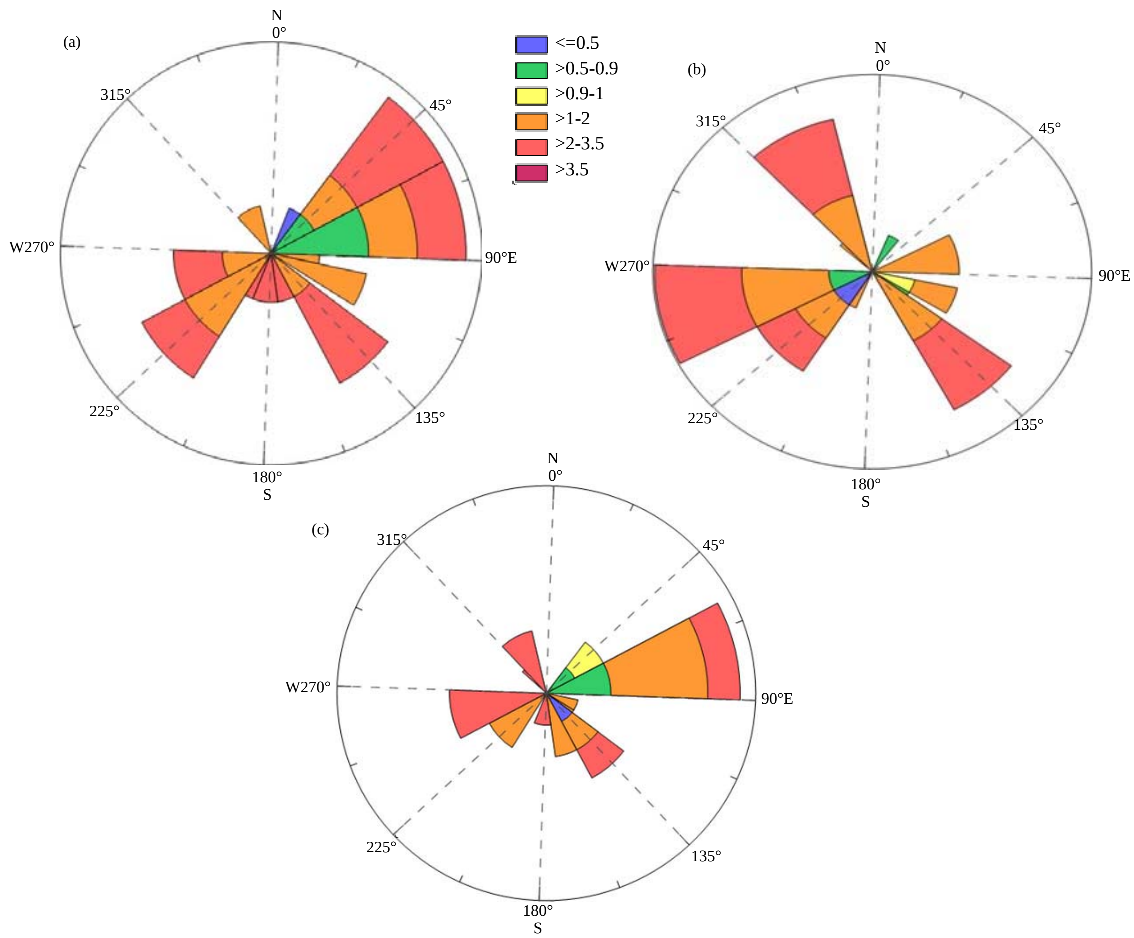

Fig. 9(a-c): Wind rose diagrams of Umuna junction, (a) Morning, (b) Afternoon and (c) Evening

Table 4: Individual and average AQI for Orlu (wet season)

	Individual AQI					
Location	PM_{10}	NO	SO	CO	Conditional pollutant	Average AQI
Umuaka junction	0.006	0.00	264.29	387.37	CO	217.22
Banana junction	0.007	0.00	323.73	350.30	CO	224.68
Umuna junction	0.007	0.00	292.68	359.71	CO	217.46
Ogboko	0.006	0.00	264.56	350.57	CO	205.05
Umuago urualla	0.004	0.00	243.02	312.97	CO	185.33

AQI: Air quality index

NO_2 is 0.00 because the observed mean values were less than 0.65 ppm, the minimum value required by the Sim-air Quality software for AQI determination of the criteria air pollutants. CO is the conditional pollutant and its individual AQI contribution is the highest too. This implies that CO is the dominant pollutant and therefore mainly responsible for the air quality condition. The AQI values of the measured atmospheric pollutants is in the order $CO>SO_2>PM_{10}>NO_2$. AQI results values are of the study locations as shown in Table 4 revealed that the AQI values are between 151-225 which implies that the atmospheric environment in this area is both unhealthy and very unhealthy for the general public as certain groups of people could be at greatest risk. The observed AQI levels are indications of atmospheric pollution resulted from elevated concentrations of the measured atmospheric pollutants. This calls for best environmental management practices to mitigate and ameliorate the risk associated with exposure to air pollution in the study area. The unregulated use of two stroke tricycles and generators that are the major sources of CO should be discouraged by the government. Similarly, old vehicles with poor engine conditions which oozes black smoke while in motion should be banned immediately to reduce unnecessary release of poisonous gases.

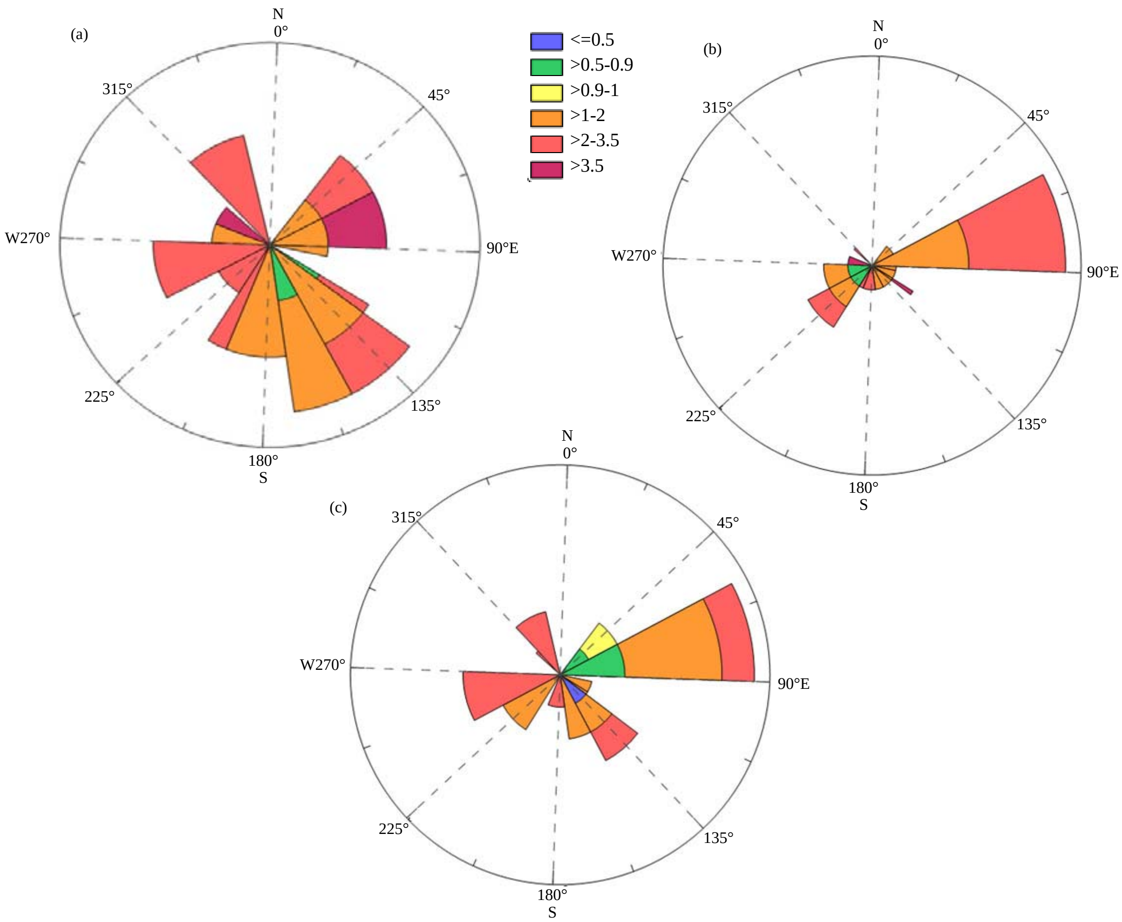

Fig. 10(a-c): Wind rose diagrams of Ogboko junction, (a) Morning, (b) Afternoon and (c) Evening

Results of this study revealed that some of the ambient air pollutants studied have high concentration levels. The observed high concentration of PM_{10} in this study when compared with earlier reports of particulate matter in this area are generally high. Though the assessment of the ambient air particulate matter level in Orlu urban reported lower concentrations of PM_{10}, however, the reported values were still above international air quality standard[35]. Elevated concentration of PM_{10} has been reported elsewhere in a related study[36]. The high concentration of PM_{10} reported in this study may be attributed to a number of factors. Firstly, the months of November-February in Nigeria are the peak of the harmattan period with its dominant Northeast trending wind usually heavily loaded with dust and other particles. This may have contributed significantly-the elevated concentration of PM_{10}. Similarly, the harmattan period is associated with heat emission which has a strong link with some dynamical processes which may lead to increased particulate concentrations. The observed elevated values of PM_{10} could also result from bush burning and other agricultural practices[37]. In addition, there were a lot of ongoing road constructions yet to be asphalted within the study area which could have significantly contributed to PM_{10} level in the area. The observed relatively high human activities such high vehicular and motorcycle traffic, market, motor park, commercial activities, artisan workshops as indicated in Table 1 may have also added to the elevated PM_{10} level. Finally, gas flaring from the nearby oil fields in the Egbema/Izombe/Osssu axis close to the area may have also contributed to the high PM_{10} level. The results of this study are in agreement with earlier studies which reported higher particulate matter levels in areas of high human activities[38].

Though elevated concentration of NO_2 was observed in most of the areas monitored, the mean concentrations are within the annual (53 ppb) US NAAQS but above the 24 h (120 µmg m^{-3}) Nigerian NAAQS guideline values for NO_2. The mean concentrations range of 0.48-0.50 ppm for NO_2 recorded in this study is below some of the values reported for some air pollution studies in the region. A study on the assessment of air quality and noise pollution around Okrika community, River

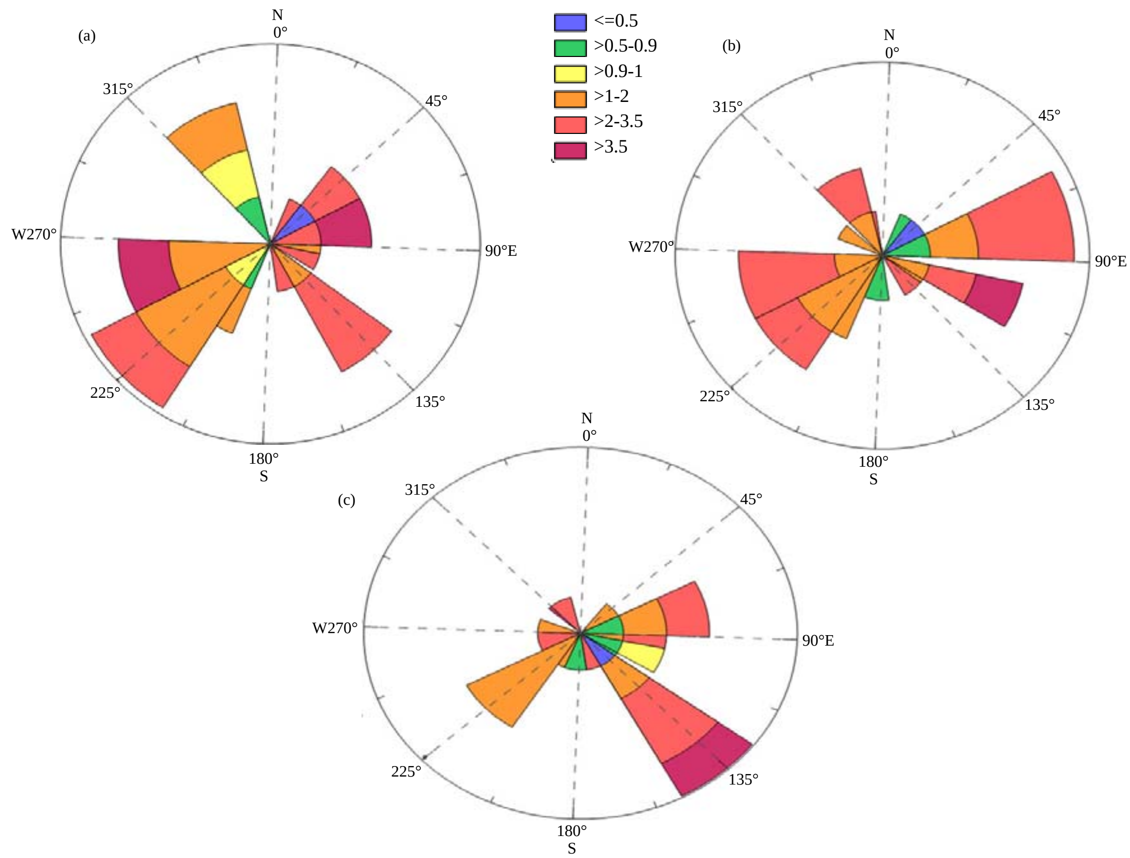

Fig. 11(a-c): Wind rose diagrams of Umuago Urualla junction, (a) Morning, (b) Afternoon and (c) Evening

State, Nigeria reported higher mean concentration (1.7 ppm) of NO_2 in dry season above result of the present study[39]. However, a related work on seasonal analysis of atmospheric pollutant concentrations in urban and rural land use areas of Rivers State, Nigeria also reported lower concentration of NO_2 than the present study[40].

The mean concentration of SO_2 as shown in Table 2 is slightly below the 3 h 0.5 ppm and 1 h 0.75 ppb permissible limits of US NAAQS but above the annual and 24 h guideline values of Nigerian NAAQS. However, the result of the present study is in agreement with earlier assessment of some air pollutants and their corresponding air quality at selected activity areas in Kaduna metropolis, Nigeria[16]. Sulphur and sulphur gases are emitted in large quantities as a result of volcanic activity and forest fire[41]. The concentration of these atmospheric pollutants must have increased significantly due to the large influx of old and fairly used vehicles imported into the country following the economic situation of the country with the associated high inflation[26]. This is compounded by poor vehicle maintenance culture and presence of a class of vehicles known as "super emitters" that emits more harmful air pollutants which may elevate the level of these pollutants[42]. This assertion was also supported by the fact that increases in SO2 emissions could be associated with increase in motor vehicle population since combustion of fossil fuels is an important source of SO_2 emission into the atmospheric environment[43,44].

Elevated concentrations of CO above Nigeria NAAQS and US NAAQS for CO was recorded in this study. The result of this study is comparable to the values reported by some related studies in Nigeria[39,16,45]. The mean value recorded in this study is above the value reported for Blantyre province, Malawi[46] and for the Peninsular, Malaysia[47]. Higher concentrations of CO observed in this study could be attributed to high vehicular traffic[29], presence of three stroke engine tricycles known for incomplete combustion[17] and combustion of biomass[31]. In all, the highest level of variation in the concentrations of the air pollutants were observed in the afternoon followed by evening hours, while the least variation was recorded in the morning except for PM_{10}. Though the co-efficient of variation for air pollutants in the study area do not differ significantly, however, the observed level of variation is generally related to the activities going on this area. This is exemplified in the case of commercial activities and traffic events that generally contribute significantly to air pollution[29]. Air pollution events such as dust storms, biomass combustion and firework displays which are normal occurrences during the months of data acquisition may have impacted negatively to the air quality level[48]. Another reason could be due to the life cycle of some of these air pollutants. For example, PM_{10} has a life span of about two weeks in the atmosphere before being deposited on the earth surface due to gravity while CO, which is a very poisonous gas having a life span of two months in the atmosphere before being converted to CO_2 where it plays a major role in the generation of greenhouse gases and formation of ozone O_3[33,34]. Similarly, SO_2 may be released into the atmosphere in large quantities by natural processess. One of the major sources is the action of anaerobic bacteria in marshes, forming hydrogen sulphide (H_2S), which is further oxidized to sulphur dioxide (SO_2) and sulphur trioxide (SO_3) in the atmosphere[35]. The implication of the observed high concentration of the ambient air pollutants could be as well linked to the activities that generate these pollutants and the meteorological variables in these locations which do not differ markedly.

CONCLUSION

The findings of this study generally revealed high concentration levels of most of the measured pollutants especially CO and PM_{10}. The observed elevated concentrations of the studied air pollutants in the afternoon is an indication that the sources of these pollutants are due to increased commercial activities during working hours. The concentration of these atmospheric pollutants must have increased significantly due to the large influx of old and fairly used vehicles imported into the country following the economic situation of the country with the associated high inflation. This is compounded by poor vehicle maintenance culture. Higher concentrations of CO observed in this study could be attributed to high vehicular traffic, presence of three stroke engine tricycles known for incomplete combustion and combustion of biomass. The observed AQI level is an indication of atmospheric pollution arising due to elevated concentrations of the measured atmospheric pollutants. This calls for best environmental management practices to mitigate and ameliorate the associated risks.

SIGNIFICANCE STATEMENT

The study discovered that most of the pollution indices analyzed in this study, nitrogen oxides (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2) and particulate matter (PM_{10}), are ubiquitous in the ambient environment. These atmospheric pollutants pose the greatest negative effects on the environment. Models that can elucidate the distribution of these pollutants like the Box and Whisker plots using Matlab software 7.9 is of immense benefit for the management of air pollution problems. The use of Grapher 10 to plot the wind rose models which accounts for the migration and diffusion of the air pollutants is significant in this study. It determines the dispersion of ambient air pollutants. The observed AQI of the study area therefore, demands serious attention by environmentalist, researchers, regulatory bodies and of course the government at the various levels in order to mitigate the anthropogenic sources of these pollutants.

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REFERENCES

1. Pope, C.A., R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito and G.D. Thurston, 2002. Lung cancer, cardiopulmonary mortality and long-term exposure to fine particulate air pollution. J. Am. Med. Assoc., 287: 1132-1141.
2. Laden, F., L.M. Neas, D.W. Dockery and J. Schwartz, 2000. Association of fine particulate matter from different sources with daily mortality in six U.S. cities. Environ. Health Perspect., 108: 941-947.
3. Rai, R., M. Rajput, M. Agrawal and S.B. Agrawal, 2011. Gaseous air pollutants: A review on current and future trends of emissions and impact on agriculture. J. Scient. Res., 55: 77-102.
4. Barman, S.C., G.C. Kisku, A.H. Khan, T. Ahmed and P. Shukla *et al*., 2012. Assessment of ambient air quality of Lucknow City during pre-monsoon, findings of a random survey. Proceedings of the World Environment Day, June 5, 2012, CSIR-Indian Institute of Toxicology Research, Mahatma Gandhi Marg, Lucknow, India, pp: 1-26.
5. Tawari, C.C. and J.F.N. Abowei, 2012. Air pollution in the Niger Delta area of Nigeria. Int. J. Fish. Aquat. Sci., 1: 94-117.
6. Brunekreef, B. and S.T. Holgate, 2002. Air pollution and health. Lancet, 360: 1233-1242.

7. Al-Salem, S.M. and W.S. Bouhamrah, 2006. Ambient concentrations of benzene and other VOC's at typical industrial sites in Kuwait and their cancer risk assessment. Res. J. Chem. Environ., 10: 42-46.
8. Al-Salem, S.M., A.A. Al-Fadhlee and A.R. Khan, 2009. Ambient air quality assessment of Al-Mansoriah residential area in the State of Kuwait. J. Eng. Res., 6: 52-63.
9. Abu-Allaban, M. and H. Abu-Qudais, 2011. Impact assessment of ambient air quality by cement industry: A case study in Jordan. Aerosol Air Qual. Res., 11: 802-810.
10. Pope, C.A., M.J. Thun, M. Namboodira, D.W. Dockery, J.S. Evans, F.E. Speizer, C.W. Health Jr., 1995. Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. Am. J. Respir. Crit. Care Med., 151: 669-674.
11. Sanjay, R., 2008. Exposure to bad air raises blood pressure, study shows. Ohio State University. http://www.sciencedaily.com/releases/2008/07/080728114026.htm
12. McCarthy, M.C., H.R. Hafner, L.R. Chinkin and J.G. Charrier, 2007. Temporal variability of selected air toxics in the United States. Atmos. Environ., 41: 7180-7194.
13. Wong, C.M., N. Vichit-Vadakan, H. Kan and Z. Qian, 2008. Public Health and Air Pollution in Asia (PAPA): A multicity study of short-term effects of air pollution on mortality. Environ. Health Perspect., 116: 1195-1202.
14. Kan, H., B. Chen and C. Hong, 2009. Health impact of outdoor air pollution in China: Current knowledge and future research needs. Environ. Health Perspect., 117: A187-A187.
15. Hassan, S.M. and M.E. Abdullahi, 2012. Evaluation of pollutants in ambient air: A case study of Abuja-Nigeria. Int. J. Sci. Res., 2: 1-9.
16. Mohammed, Y. and J.J. Caleb, 2014. Assessment of some air pollutants and their corresponding air quality at selected activity areas in Kaduna metropolis. Proceedings of the 37th Annual International Conference of Chemical of Nigeria, September 7-12, 2014, Uyo, Akwa Ibom State, Nigeria, pp: 38-44.
17. Sengupta, B., 2003. Guidelines for ambient air quality monitoring. National Ambient Air Quality Monitoring Series, Central Pollution Control Board, Parivesh Bhawan, East Ajun Nagar, Delhi, April 2003.
18. Ogba, C.O. and B.P. Utang, 2009. Air pollution climatology in spatial planning for sustainable development in the Niger Delta, Nigeria. Proceedings of the FIG Working Week: Surveyors Key Role in Accelerated Development, May 3-8, 2009, Eilat, Israel.
19. Ibe, F.C. and B.O. Ibe, 2016. Roof runoff water as source of pollution: A case study of some selected roofs in Orlu metropolis, Imo State, Nigeria. Int. Lett. Nat. Sci., 50: 53-61.
20. Hanninen, O., A. Economopoulos and H. OzKaynak, 1999. Information on Air Quality Required for Health Impact Assessment. In: Monitoring Ambient Air Quality for Health Impact Assessment, WHO (Eds.). Chapter 2, WHO Regional Office Europe, Copenhagen, Denmark, ISBN-13: 9789289013512, pp: 9-36.
21. EPA., 2014. Air Quality Index (AQI): A guide to air quality and your health. EPA-456/F-14-002/February, 2014, U.S Environmental Protection Agency, Office of Air Quality Planning and Standards, Outreach and Information Division Research, Triangle Park, NC., USA.
22. FRN., 2011. Official gazette national environmental (non-metallic minerals manufacturing industries sector) regulation. Federal Republic of Nigeria Official Gazette Government Notice No. 134, Vol. 98, May 23, 2011, Lagos, pp: B637-B692.
23. USEPA., 2016. US National Ambient Air Quality Standards (NAAQS). https://www.epa.gov/criteria-air-pollutants/naaqs-table
24. Egwurugwu, J.N., A. Nwafor, O.J. Oluronfemi, S.C. Iwuji and E.A. Alagwu, 2013. Impact of prolonged exposure to oil and gas flares on human renal functions. Int. Res. J. Med. Sci., 1: 9-16.
25. FRN., 2007. Legal notice on publication of the details of the breakdown of the national and state provisional total, 2006 census. Federal Republic of Nigeria Official Gazette, Government Notice No. 21, May 15, 2007, Vol. 94, Lagos, pp: 1-26.
26. Abam, F.I. and C.O. Unwachukwu, 2009. Vehicular emissions and air quality standards in Nigeria. Eur. J. Sci. Res., 34: 550-560.
27. Okoro, U.K., W. Chen, T.C. Chineke and O.K. Nwofor, 2014. Recent monsoon rainfall characteristics over the Niger Delta region of Nigeria: A casual link. Int. J. Sci. Environ. Technol., 3: 634-651.
28. Wong, T.W., W.W.S. Tam, A.K.H. Lau, S.K.W. Ng, I.T.S. Yu, A.H.S. Wong and D. Yeung, 2012. A study of the air pollution index reporting system. Tender Ref. AP 07-085, Final Report/June 27, 2012, Environmental Protection Department (EPD) of the Hong Kong.
29. Njoku, P.C., F.C. Ibe, J. Alinnor and A. Opara, 2016. Seasonal variability of carbon monoxide (CO) in the ambient environment of Imo State, Nigeria. Int. Lett. Nat. Sci., 53: 40-52.
30. Ibe, F.C., P.C. Njoku, J.I. Alinnor and A.I.Opara, 2016. Spatial variation of NO_2 and SO_2 in the ambient environment of Imo state, Nigeria. Int. J. Sci. Environ. Technol., 5: 33-46.
31. Musialik-Piotrowska, A., W. Kordylewski, J. Ciolek and K. Moscicki, 2010. Characteristics of fair pollutants emitted from biomass combustion in small retort boiler. Environ. Protect. Eng., 36: 123-131.
32. Ocak, S. and F.S. Turalioglu, 2008. Effect of meteorology on the atmospheric concentrations of traffic-related pollutants in Erzurum, Turkey. J. Int. Environ. Appl. Sci., 3: 325-335.

33. Giri, D., M.V. Krishna and P.R. Adhikary, 2008. The influence of meteorological conditions on PM_{10} concentrations in Kathmandu valley. Int. J. Environ. Res., 2: 49-60.
34. Opara, A.I., F.C. Ibe, P.C. Njoku, J.I. Alinnor and C.K. Enenebeaku, 2016. Geospatial and geostatistical analyses of particulate matter (PM_{10}) concentrations in Imo state, Nigeria. Int. Lett. Natl. Sci., 57: 89-107.
35. Ngele, S.O. and F.K. Onwu, 2014. Assessment of ambient air particulate matter level in Orlu urban. Chem. Pharm. Res., 6: 871-875.
36. Efe, S.I. and A.T. Efe, 2008. Spatial distribution of particulate matter (PM10) in Warri metropolis, Nigeria. Environmentalist, 28: 385-394.
37. Arslan, S., A. Aybeka and H.C. Ekerbdcer, 2010. Measurement of personal PM_{10}, $PM_{2.5}$ and PM_1 exposures in tractor and combine operations and evaluation of health disturbances of operators. J. Agric. Sci., 16: 104-115.
38. Ngele, S.O. and F.K. Onwu, 2015. Comparison of particulate matter levels in major urban centres in Eastern Nigeria. Int. J. Environ. Sci., 5: 765-775.
39. Gobo, A.E., T.J.K. Ideriah, T.E. Francis and H.O. Stanley, 2012. Assessment of air quality and noise around Okrika communities, Rivers State, Nigeria. J. Applied Sci. Environ. Manage., 16: 75-83.
40. Weli, V.E. and J.O. Ayoade, 2014. Seasonal analysis of atmospheric pollutants concentrations in urban and rural land use areas of Rivers State, Nigeria. Int. J. Environ. Pollut. Res., 2: 1-16.
41. Mohammed, Y., A. Uzairu and J.O. Ujoh, 2013. Determination of sulphur dioxide concentrations in ambient air of some selected traffic areas in Kaduna metropolis. Res. J. Applied Sci. Eng. Technol., 6: 2923-2930.
42. EPA., 2009. Air pollutants. In: Guide to Environmental Issues, Doc. No. 520/B-94-01, United States Environmental Protection Agency, Washington, DC., USA.
43. Gurjar, B.R., J.A. van Aardenne, J. Lelieveld and M. Mohan, 2004. Emission estimates and trends (1990-2000) for megacity Delhi and implications. Atmos. Environ., 38: 5663-5681.
44. Pan, Y.P., Y.S. Wang, G.Q. Tang and D. Wu, 2013. Spatial distribution and temporal variations of atmospheric sulfur deposition in Northern China: Insights into the potential acidification risks. Atmos. Chem. Phys., 13: 1675-1688.
45. Ubuoh, E.A. and S.M.O. Akhionbare, 2011. Effect of pig production on the ambient air quality of Egbeada in Mbaitoli LGA of Imo State, Nigeria. J. Sci. Multidisciplin. Res., 3: 8-16.
46. Mapoma, H.W.T., C. Tenthani, M. Tsakama and I.B.M. Kosamu, 2014. Air quality assessment of carbon monoxide, nitrogen dioxide and sulfur dioxide levels in Blantyre, Malawi: A statistical approach to a stationary environmental monitoring station. Afr. J. Environ. Sci. Technol., 8: 330-343.
47. Ismail, A.S., A.M. Abdullah and M.A.A. Samah, 2017. Environmetric study on air quality pattern for assessment in Northern region of Peninsular Malaysia. J. Environ. Sci. Technol., 10: 186-196.
48. Huang, W., E. Long, J. Wang, R. Huang and L. Ma, 2015. Characterizing spatial distribution and temporal variation of PM_{10} and $PM_{2.5}$ mass concentrations in an urban area of Southwest China. Atmos. Pollut. Res., 6: 842-848.