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Evaluation of Ambient Air quality in parts of Imo state, Nigeria

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Abstract

Evaluation of the ambient air quality in Imo State, Nigeria was carried out with reference to four criteria air pollutants which include PM_{10}, NO_2, SO_2 and CO using Haze dust particulate monitor (µ10m) and Gasman air monitors. Air quality monitoring was conducted in three times daily (morning, Afternoon and evening) in 22 locations within the months of November, 2014 and June, 2015. The result showed that the mean concentration of the air pollutants ranged as follows: PM_{10} (5.22 – 7.43) mg/m^3, NO_2 (0.46 - 0.58) ppm, SO_2 (0.46 - 0.56) ppm and CO (30.15 – 40.98) ppm. The mean concentration of the air pollutants obtained exceeded the Nigerian NAAQS and US NAAAQS but NO_2 and SO_2 are within the permissible limit in some of the monitoring stations. Also AQI (air quality index) analysis revealed that CO is the conditional pollutant responsible for the observed deteriorated air quality index in the study area which calls for adequate attention and concern.

Keyword: Air pollution, Pollutants, Air quality, Environment, Imo State.

Introduction

One of the major challenging environmental problems that has bedeviled both the developed and developing countries in the world today is atmospheric pollution, which has been associated with increased morbidity and date rates[1,2]. It is a condition in which certain substances, which include gases (sulphur dioxide, nitrogen oxides, carbon monoxides, hydrocarbons, etc.), particulates (smoke, dust, fumes, aerosols, etc), radioactive materials and others are present in high concentrations that could result in an undesirable effects to man and the environment[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[5]. A major anthropogenic source of air pollution is due to man's quest for a better standard of living, utilizing the natural resources for rapid industrialization, urbanization and consequently causing excessive air pollution. Therefore, air pollution problems have continued to attract a lot of attention worldwide because of its negative effects on human health and well-being[6-9]. Among the extreme air pollution related effects include high blood pressure and cardiovascular problems[10,11]. Pollution of the atmospheric environment posses significant threat to environmental well-being in most cities of the world[12-14], this is not unconnected to the fact that one of the basic requirements of human existence and fundamental human necessity is clean air[15,16]. The degree of air pollution do not only depend on the amount that are generated from pollution sources but also on the capacity of the atmospheric environment to either absorb or disperse these pollutants which may vary spatially and temporarily resulting in the air pollution pattern to differ in many places at different times as a result of changes in topographical and weather condition[17].

The air quality of a particular locality affects how they people live and breathe. Air quality like weather could change daily or even hourly, hence the need to make information regarding the air quality of an area available is imperative for air quality evaluation and forecast. An important tool in this regard is the Air Quality Index (AQI), which can be used to provide information about the local air quality, as it regards to effect of unhealthy air and how to protect once health. AQI lays emphasis on the probable health effects that people may experience on few hours or days of exposure to polluted atmosphere[18].

Evaluation of air quality is necessary in view of its import ants in determining level of population exposure to atmospheric pollution which may cause unpleasant health conditions depending on the type of pollutant; its degree of occurrence, length of time and rate of exposure; and the toxic level of the air pollutants in question[19]. This has become so important to carry out at intervals owing to increase in population, industrialization, urbanization and paucity of air quality reports in Imo State.

Materials and Methods

Study Area: The study was carried out in Imo State as shown in figure-1 The State is located in the tropical rainforest zone climate. The area is dominated by plains with elevation ranging from 50-200m above sea level. The annual rainfall is about 2400mm to 4000mm, which is concentrated almost entirely between April and October, with average relative humidity of about 80% and up to 90% occurring during the wet season. The maximum air temperature ranges from 28 to 38^0C, while the minimum air temperature ranges from 19^0C to 24^0C[20-23].

Description of Study area: The population of Imo State as at 2006 is about 3,934,899[24]. Imo State is blessed a lot natural resources among which include natural gas and crude oil mainly within Ohaji, Egbema and Oguta, and most of the oil wells have enormous natural gas associated with them, which has a rough estimated future supply of about 1422 billion cubic meters[25]. Part of this gas has been continuously flared in the Niger Delta region since 1970 [26]. Also, the presence of stone mining sites in Okigwe and quarrying activities in neighbouring towns could be a huge source of particulate matter emission into the atmospheric environment of the state, and this quarry products or stones are transported to different places by heavy duty trucks that uses diesel which could contribute significantly to air quality deterioration. Also Orlu city is fast growing with a lot of commercial activities, use of power generators, high volume of vehicular traffic and presence of two stroke engine automobiles like motorcycles and tricycle. Owerri, the capital of Imo State has high population density[24], with a lot of commercial activities, use of power generators, high volume of vehicular traffic and presence of two stroke engine automobiles like motorcycles and tricycles used for transportation, known for their incomplete combustion of fuel which could lead to the emission of noxious atmospheric air pollutants[17]. The study therefore was carried out in these areas described above which include Owerri, Orlu, Okigwe and Egbema area of Imo and air quality monitoring sites were chosen in these locations to evaluate the ambient air quality level in Imo State, Nigeria.

Air quality sampling Procedure: The air pollutants SO_2, CO, NO_2 and $PM_{10,}$ commonly used in air quality index AQI [27], were sampled three times a day (morning, afternoon and evening)[15], with Gasman hand held detector (Crowcon Instruments Ltd, England), and Haze-dust particulate monitor 10µm, model HD1000, Environmental Device Corporation, USA was used for PM_{10}. The concentration of the air pollutants were determined by the detector specific for the pollutants switch on and held at about 2m above ground level, then concentration recorded from the digital display when the reading becomes stabilized, and this was done in each of the 22 air quality sampling sites. Sampling was carried out for six month during dry and wet seasons, between November 2014 and June 2015. The sampling was carried out once a week at each of the 22 air monitoring locations, three times per day, four times a month for a period of six (6) months. Therefore, the four air pollutants being monitored equal to a total of 1584 round of air sampling. The air quality sampling which was in two seasons, wet and dry season was monitored for three months during each season.

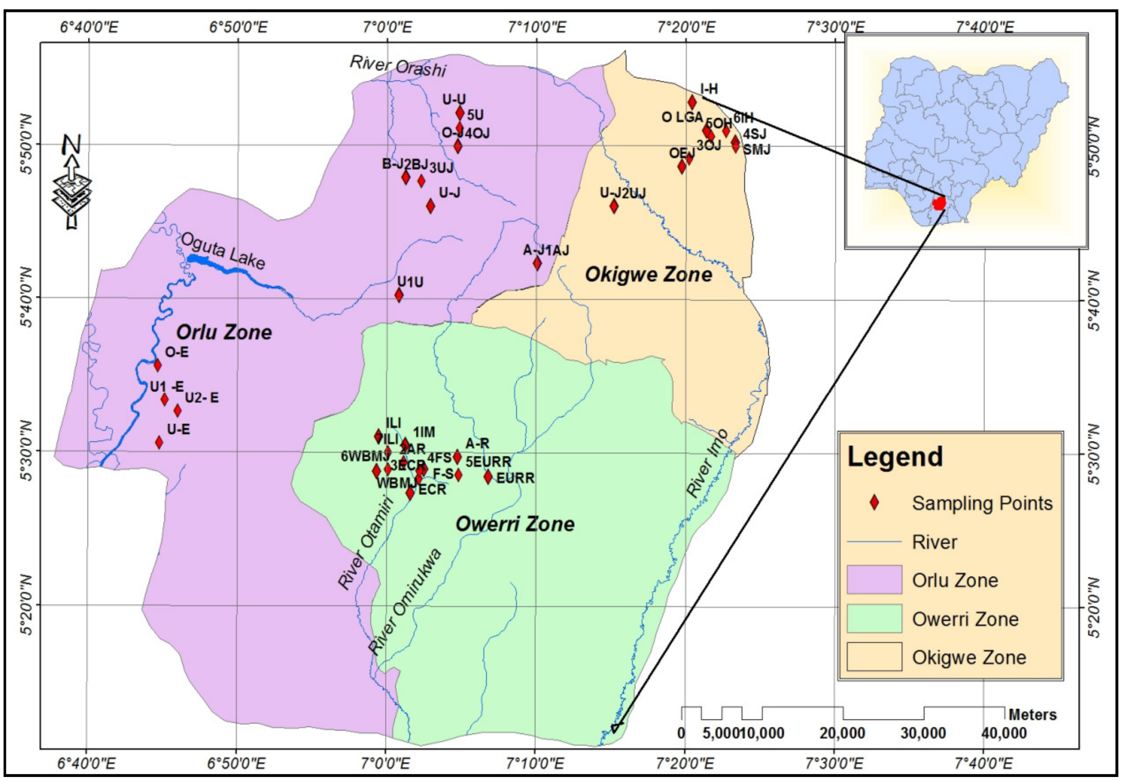


Figure-1
Map of Orlu showing air pollution monitoring locations

Method of Data Interpretation: Data analysis was done using Microsoft excel 2007 and values of all the results from the 22 sampling points in the four locations were recorded as calculated mean values for air pollutant concentration in the morning, afternoon and evening hours, in addition the standard deviation (SD) and variance (VAR) were calculated. Spatial variation and 3-D surface plots of the air pollutant concentrations were modeled using Surfer 12 software. Sim – Air Quality software was also used to calculate the air quality index of the air pollutants using equation (1) below:

$$Ip = \frac{IHi - ILo}{BPHi - BPLo}\ (C_P - BP_{Lo}) + I_{Lo} \quad (1)$$

Where: Ip = the index for pollutant, Cp = the rounded concentration of pollutant p, BP_{Hi} = the breakpoint that is ≥ Cp, BP_{Lo} = the breakpoint that is ≤ Cp, I_{Hi} = the AQI value corresponding to BP_{Hi} and I_{Lo} = the AQI value corresponding to BP_{Lo}.

Results and Discussion

The results in Tables-1 and 2 shows the , mean, maximum, minimum values, standard deviation and variance of the air pollutants concentration observed at the 22 monitoring locations. The values for CO, SO_2, NO_2, and PM_{10} are presented in the tables. The result shown in table 1 and 2 is the average of the data collected from all the locations monitored during wet and dry season respectively and each table represents three months air quality data result. The concentration of the air pollutants in wet season as shown in Table-1, PM_{10} ranged from 3.38 – 8.23mg/m^3 in the morning 3.38 – 8.23, mg/m^3 in the afternoon 4.13 - 10.98 and 4.22 - 11.31mg/m^3 in the evening The values obtained for NO_2 ranged from 0.26 – 0.59 ppm, 0.29 – 0.71 and 0.32 – 0.95 for morning, afternoon and evening hours respectively, while the concentration of SO_2 ranged from 0.20 – 0.72, 0.24 – 0.87 and 0.25 – 0.85 respectively for morning, afternoon and evening. Also the wet season concentration of carbon monoxide as shown in Table-1 indicates that the values ranges from 23.67 - 37.67 ppm, 30.00 - 45.25 ppm and 32.25 - 47.08 ppm for morning, afternoon and evening respectively.

In table-2 the dry season air pollutant concentration ranged from 3.93 - 10.16 mg/m^3, 4.12 -11.51 mg/m^3 and 4.22 - 11.73 mg/m^3 in the morning, afternoon and evening respectively for PM_{10}. NO_2 values ranged from 0.22 - 0.65 ppm, 0.23 - 0.66 ppm and 0.23 - 0.62 ppm in the morning, afternoon and evening respectively, while SO_2 values in Table-2 ranged from 0.14 - 0.60ppm, 0.21- 0.65 ppm and 0.18-0.82ppm respectively for morning, afternoon and evening hours. The values of CO ranged from 30.08-50.75 ppm, 33.25 - 51.75 ppm and 35.08 - 51.08 ppm respectively for morning, afternoon and evening. Higher concentrations of most of the air pollutants were observed in the dry season than in the wet season. This could be attributed to lower pollutant emission during the wet season and higher pollutant dispersion in dry season than in the wet season [28]. Another factor could be due to scavenging of the atmosphere pollutants emitted from natural and anthropogenic sources by rain events [29]. The concentrations of the air pollutant observed in this study were compared with permissible limits recommended by Nigerian NAAQS and US NAAQS[30,31]. The result indicates that the mean concentration of $PM_{10,}$ $NO_{2,}$ SO_2 and CO in all the air quality monitoring stations exceeded both the annual and 24 hours limit of Nigerian NAAQS and US NAAQS of 150µg/m^3 (0.15mg/m^3) for PM_{10}, 0.5ppm for SO_2 and (9 ppm and 35 ppm) for CO and 0.1 ppm for NO_2 in most of the locations but some of the locations are within the permissible limit for this air pollutant.

The result presented in Figure-2 to 5 is the spatial variation and 3-D surface plots of the air pollutant concentration as observed in each of the air quality monitoring location in the wet season. Higher concentration of CO was observed in Okigwe area followed by Egbema. This could be attributed to higher presence of vehicular traffic more especially heavy duty trucks that is visibly present in Okigwe that transports stone and quarry products from this area. The elevated CO level Observed in Egbema may be associated with gas flaring taking place in this area. NO_2 as shown in Figure-3 indicates that higher concentration was obtained at Owerri when compared with other areas. In the case of SO_2 the concentration obtained for the locations, Owerri, Okigwe, Orlu and Egbema do not differ significantly as can be seen in Figure-4. The level of PM_{10} observed is higher in Okigwe than others areas which could be associated with stone mining and quarrying activity in this area and presence of heavy duty trucks that transport these quarry products from these area. The result presented in figure 6 to 9 is the spatial variation and 3-D surface plots of the air pollutant concentration as observed in each of the air quality monitoring location in the dry season. The CO values obtained in the dry season are in the order Okigwe > Egbema > Orlu > Owerri. And the value for NO_2 are in the order Orlu > Okigwe > Egbema > Owerri, while the order for SO_2 is Egbema>Orlu >Owerri > Okigwe. Figure 9 indicates that PM_{10} is in the order Okigwe > Orlu >Egbema > Owerri.

Air Quality Index (AQI) of the Pollutants: AQI of the pollutants were determined in order to evaluate the health risk which the public are exposed due to atmospheric pollution. The result of AQI data for the four air pollutants monitored in the four locations with a total of 22 sampling points are presented in Table- 4 – 11 for the wet and dry season, while in Table-3, the AQI values, health concern and associated colours are shown. Also the AQI results shown on Table-4 - 11are based on the individual pollutants and the average of the AQI. The risk or message of AQI is indicated with the respective colour as shown in Table-3. Again, the AQI result in Table-4 - 11 indicates the conditional pollutant which is the air pollutant responsible for the observed AQI. Also in most of the AQI tables the value for NO_2 is 0.00 because in most of the areas monitored the concentration of NO_2 was less than 0.65ppm which is a requirement for calculating AQI using SIM-Air quality software. The result indicates that for the wet season (Table 4 – 7) CO being the conditional pollutant possesses the greatest risk among all the pollutants monitored. The health message ranged from moderate to very unhealthy. In table the risk message is unhealthy at Anara junction, Okigwe LGA HQ and Ihube but very unhealthy at Umuna junction, Okigwe Express junction and St. Mary's junction. The observed AQI is due to contribution by CO and SO_2, when the individual contribution to the average AQI is compared with that of PM_{10} and NO_2. The AQI shown in table 5 indicates that the risk message associated with the pollutants is very unhealthy for all the air quality monitoring sites, the exception to this is at Egbu – Uratta ring road in Owerri in wet season that the risk message is moderate and the conditional pollutants are CO and SO_2. In table 6 the risk message for the AQI is unhealthy for Umuaka Junction, Banana Junction Umuna Junction and Ogboko except Umuago Urrualla, the control that the message is unhealthy and CO is responsible for the observed AQI. For table-7, the message is very unhealthy at the four monitoring site, the conditional pollutants is CO with the greatest individual AQI contribution when compared with other pollutants.

In dry season shown in table 8 – 11, the AQI result for Owerri indicates that apart from Industrial Layout Irete and Egbu Uratta ring road (control) that the risk message is unhealthy and the rest have very unhealthy risk report. CO is the conditional pollutant followed by SO_2 and PM_{10} while the contribution of NO_2 is insignificant in the overall AQI at each sampling site. In table 9, the risk message for Okigwe AQI ranged from unhealthy for sensitive groups at Ihube, unhealthy at Okigwe LGA HQ and very unhealthy at Anara junction, Umuna junction and Okigwe express junction. At all the air quality monitoring site CO is the conditional pollutant, this is followed by SO_2, PM_{10}, and with NO_2 contributing insignificantly to the average AQI. Table 10 showing the AQI of Orlu in dry season indicates that the AQI risk message is very unhealthy for all the five air monitoring sites. The conditional pollutant is CO, this followed by SO_2, PM_{10} and NO_2 made no contribution to average AQI. Also, in Table-11 the AQI for Egbema indicates that the risk message is very unhealthy for all the air monitoring sites with CO being the conditional pollutant, while the contribution of other pollutants are not significant except SO_2.

Table-1
Wet season result of air pollutant concentration

		PM_{10} (mg/m^3)			**NO_2 (ppm)**			**SO_2 (ppm)**			**CO (ppm)**	
	M	**A**	**E**	**M**	**A**	**E**	**M**	**A**	**E**	**M**	**A**	**E**
Mean	5.22	6.90	7.43	0.46	0.54	0.58	0.46	0.54	0.56	30.15	37.60	40.98
Min	3.38	4.13	4.22	0.26	0.29	0.32	0.20	0.24	0.25	23.67	30.00	32.25
Max	8.23	10.98	11.31	0.59	0.71	0.95	0.72	0.87	0.85	37.67	45.25	47.08
Sd	1.29	1.57	1.56	0.08	0.09	0.13	0.16	0.15	0.16	3.69	3.64	3.04
Var	1.68	2.47	2.45	0.01	0.01	0.02	0.02	0.02	0.02	13.57	13.22	9.22

Table-2
Dry season result of air pollutant concentration

		PM_{10} (mg/m^3)			**NO_2 (ppm)**			**SO_2 (ppm)**			**CO (ppm)**	
	M	**A**	**E**	**M**	**A**	**E**	**M**	**A**	**E**	**M**	**A**	**E**
Mean	6.61	7.74	7.51	0.44	0.48	0.46	0.37	0.43	0.45	41.11	42.90	44.85
Min	3.93	4.12	3.82	0.22	0.23	0.23	0.14	0.21	0.18	30.08	33.25	35.08
Max	10.16	11.51	11.73	0.65	0.66	0.62	0.60	0.65	0.82	50.75	51.75	51.08
Sd	1.60	1.74	1.91	0.12	0.12	0.11	0.13	0.14	0.18	6.42	4.94	4.63
Var	2.57	3.03	3.65	0.014	0.014	0.01	0.02	0.02	0.03	41.20	24.36	21.44

Where: M = morning, A = afternoon, E = evening, Min = minimum value, Max =maximum value, SD = Standard deviation, VAR = variance

Abam and Unachukwu reported that the AQI level of the air pollutants PM_{10}, SO_2, NO_2 and CO studied in Calabar, Nigeria were significant having possible severe consequences [32]. Also Mohammed and Caleb used AQI for the assessment of some air pollutants at selected activity areas in Kaduna metropolis, Nigeria and reported that the AQI is very unhealthy with respect to CO concentration in all the location monitored[16]. Study on the assessment of air quality and noise around Okrika communities in Rivers State, Nigeria, reported poor air quality in the study area, they submitted that the concentrations of the air pollutants such as hydrogen sulphide (H_2S), volatile organic compounds (VOC), nitrogen (iv) oxide (NO_2), sulphur (iv) oxide (SO_2) and ammonia (NH_4) exceeded the permissible limits and therefore pose serious environmental and health problems in the area [33]. Furthermore, a similar report determined the air quality indices which include odour, NO_2, SO_2, NH_3, CO, H_2S, CH_4, and TSP in Egbeada, Mbaitoli LGA in Imo State, Nigeria, and concluded that apart from methane, all other air pollutants were above the WHO/FMENV, Standards for ambient air quality[21].

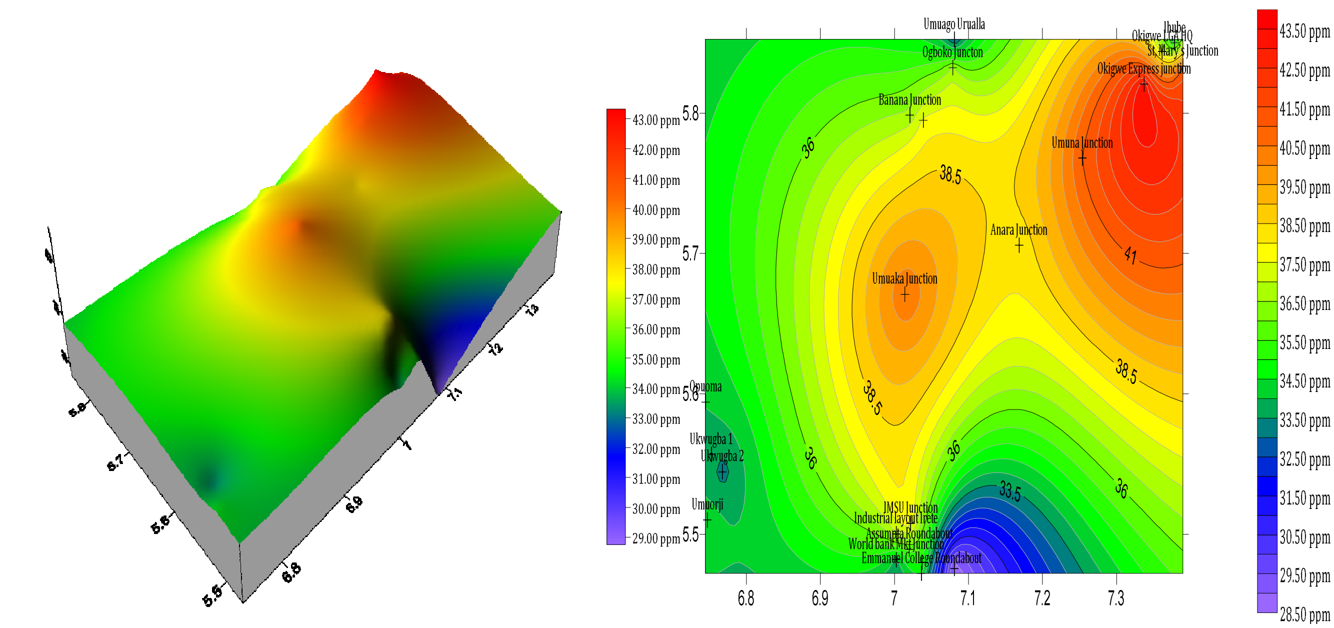
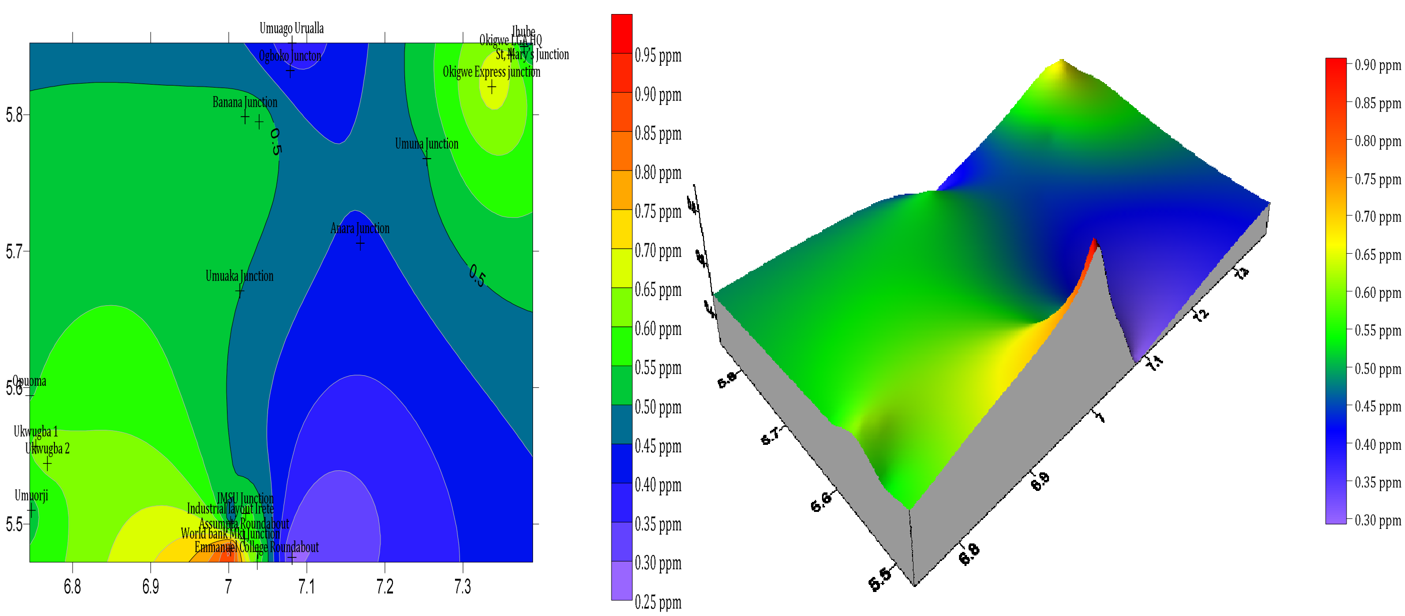


Figure-2
Spatial variation plots and 3-D surface plots of CO concentration in wet season



Figrue-3
Spatial variation and 3-D surface plots of NO_2 concentration in wet season

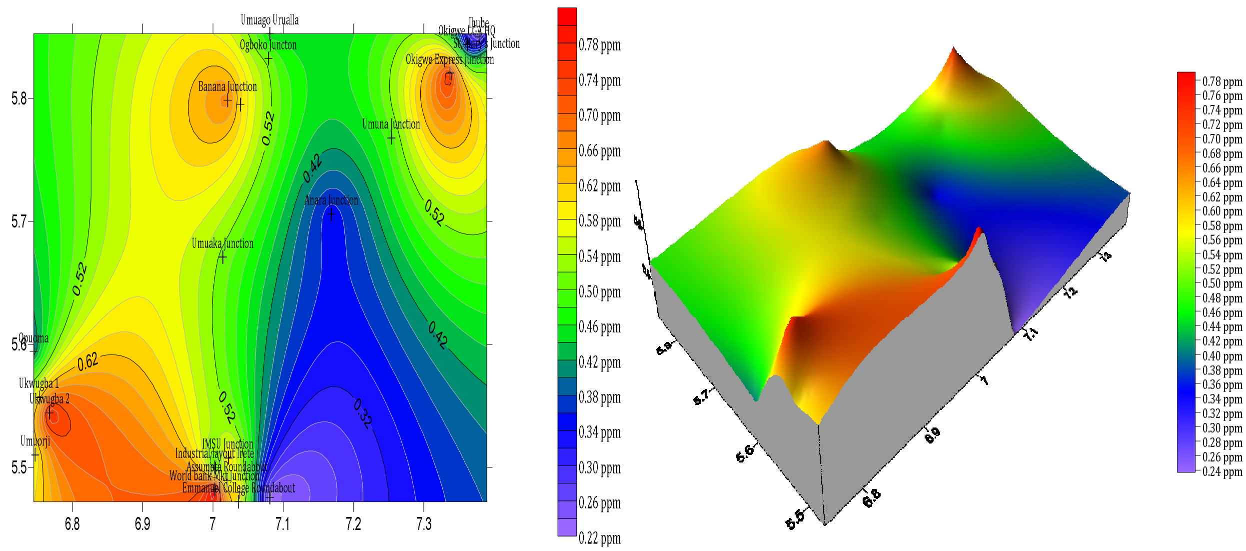


Figure-4
Spatial variation and 3-D surface plots of SO_2 concentration in wet season

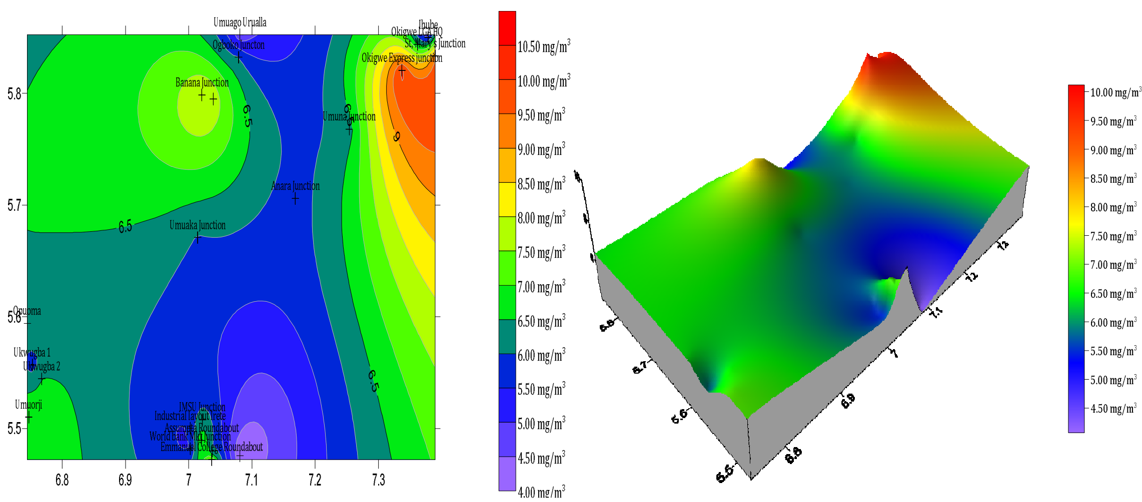


Figure-5
Spatial variation and 3-D surface plots of PM_{10} concentration in wet season

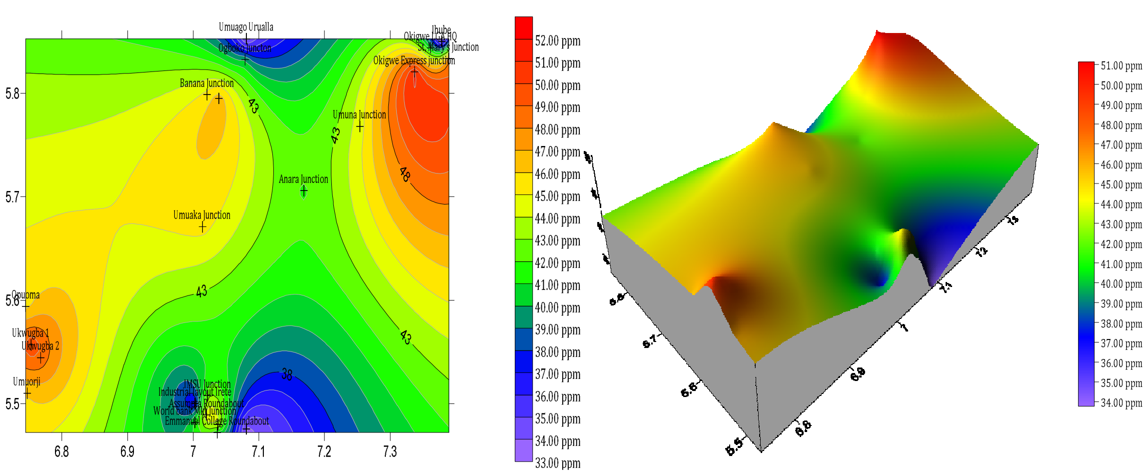


Figure-6
Spatial variation and 3 –D surface plots of CO concentration in dry season

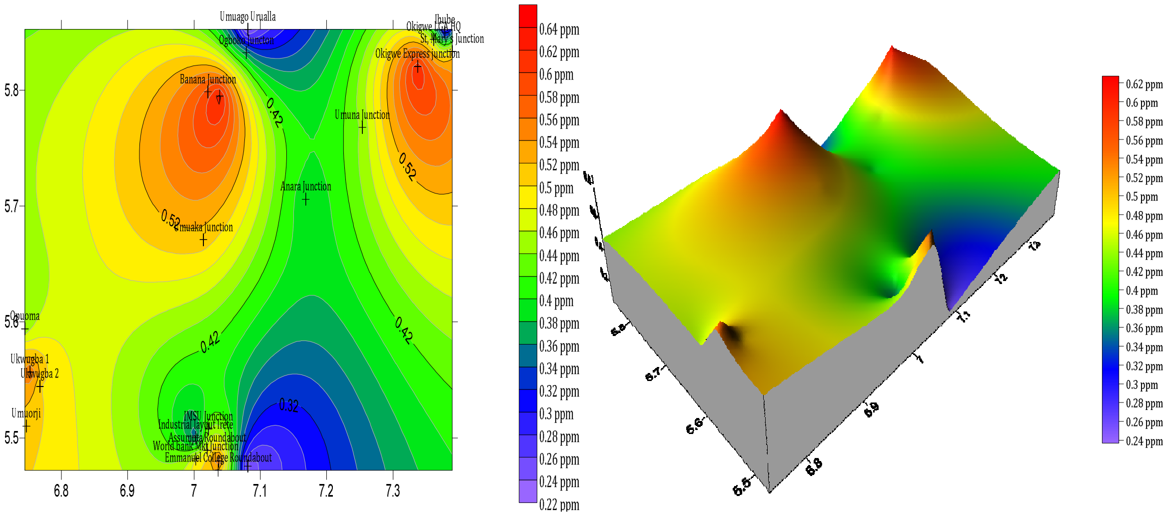


Figure7

Spatial variation and 3–D surface plots of NO_2 concentration in dry season

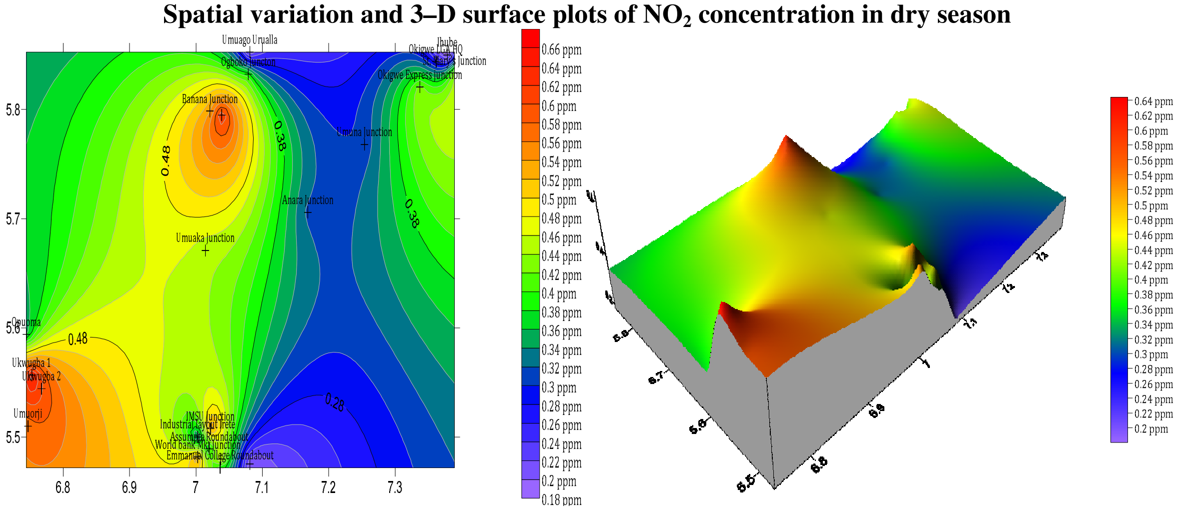


Figure-8

Spatial variation and 3 –D surface plots of SO_2 concentration in dry season

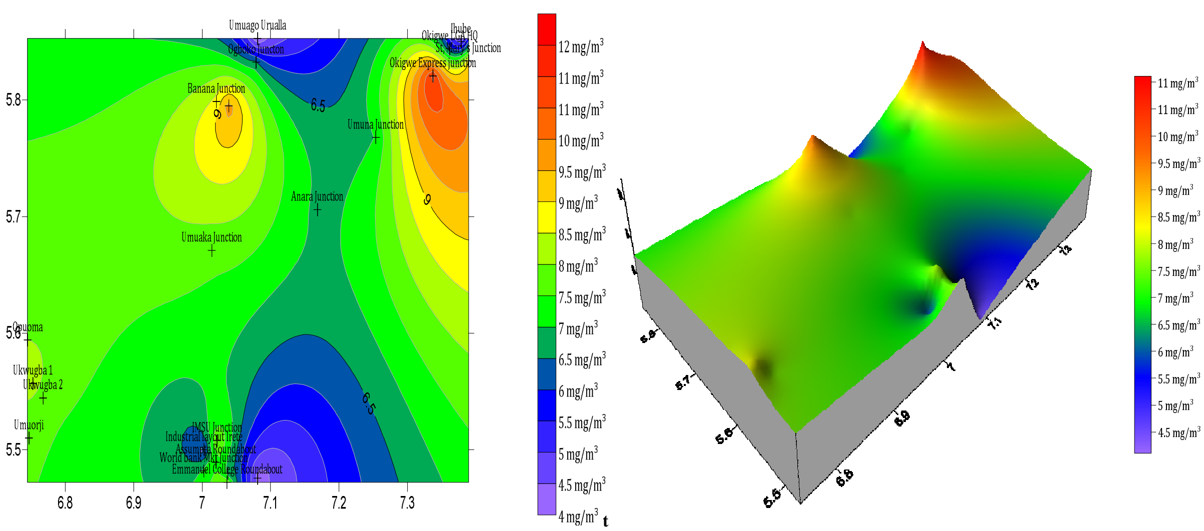


Figure-9

Spatial variation and 3 –D surface plots of PM_{10} concentration in dry season

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

Descriptor	AQI	Risk Message
Good	0-50	No Message
Moderate	51-100	Unusually sensitive Individuals (ozone)
Unhealthy for Sensitive Groups	101-150	Identifible group at risk different groups for different pollutants
Unhealthy	151-200	General public at risk; groups at greater risk
Very unhealthy	201-300	General public at greater risk; groups at greatest risk

(source: Sim air quality software)

Table-4
Individual and average AQI for Okigwe (wet season)

Location	Individual AQI				Conditional Pollutant	Average AQI
	PM_{10}	NO_2	SO_2	CO		
Anara Junction	0.005	0.00	210.81	364.81	CO	191.87
Umuna Junction	0.006	0.00	257.53	392.48	CO	216.67
Okigwe Express Junction	0.009	202.05	357.96	415.04	CO	243.77
St. Mary's Junction	0.009	0.00	255.30	393.55	CO	216.29
Okigwe Lga Hq	0.006	0.00	205.11	355.95	CO	187.02
Ihube	0.005	0.00	158.98	329.89	CO	162.96

Table-5
Individual and average AQI for Owerri (wet season)

Location	Individual AQI				Conditional Pollutant	Average AQI
	PM_{10}	NO_2	SO_2	CO		
Imsu Junction	0.006	0.00	296.60	361.32	CO	219.31
Assumpta Roundabout	0.006	0.00	272.12	340.37	CO	204.17
Emmanuel College Roundabout	0.007	0.00	282.80	330.43	CO	204.41
Fire Service Roundabout	0.006	0.00	295.62	333.92	CO	209.85
World Bank Mkt Junction	0.005	0.00	389.92	323.44	SO_2	237.79
Industrial Layout Irete	0.005	243.86	389.92	323.44	CO	201.55
Egbu - Uratta Ring Road	0.004	0.00	148.93	282.02	CO	143.65

Table-6
Individual and average AQI for Orlu (wet season)

Location	**Individual AQI**				**Conditional Pollutant**	**Average AQI**
	PM_{10}	NO_2	SO_2	CO		
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

Table-7
Individual and average AQI for Egbema (Wet Season)

Location	**Individual AQI**				**Conditional Pollutant**	**Average AQI**
	PM10	NO_2	SO_2	CO		
Umuorji	0.01	0.00	286.54	328.28	CO	204.94
Ukwugba I	0.01	0.00	294.73	322.64	CO	205.79
Ukwugba Ii	0.01	0.00	297.13	317.80	CO	204.98
Opuoma	0.01	0.00	228.34	325.05	CO	184.47

Table-8
Individual and average AQI for Owerri (dry season)

Location	**Individual AQI**				**Conditional Pollutant**	**Average AQI**
	PM_{10}	NO_2	SO_2	CO		
Imsu Junction	0.007	0.00	274.70	409.67	CO	228.13
Assumpta Roundabout	0.007	0.00	218.02	430.89	CO	216.30
Emmanuel College Roundabout	0.007	0.00	221.49	390.06	CO	203.85
Fire Service Roundabout	0.006	0.00	250.68	423.64	CO	224.77
World Bank Mkt Junction	0.007	0.00	273.19	394.89	CO	222.70
Industrial Layout Irete	0.005	0.00	201.20	350.84	CO	184.01
Egbu - Uratta Ring Road	0.004	0.00	129.59	321.29	CO	150.30

Table-9
Individual and average AQI for Okigwe (dry season)

Location	**Individual AQI**				**Conditional Pollutant**	**Average AQI**
	PM_{10}	NO_2	SO_2	CO		
Anara Junction	0.006	0.00	-0.96	401.07	CO	200.54
Umuna Junction	0.007	0.00	194.32	426.59	CO	206.97
Okigwe Express Junction	0.010	0.00	237.59	490.52	CO	242.71
St. Mary's Junction	0.008	0.00	240.80	457.75	CO	232.85
Okigwe Lga Hq	0.006	0.00	172.82	388.72	CO	187.18
Ihube	0.004	0.00	117.26	323.17	CO	146.81

Table-10
Individual and average AQI for Orlu (dry season)

Location	**Individual AQI**				**Conditional Pollutant**	**Average AQI**
	PM_{10}	NO_2	SO_2	CO		
Umuaka Junction	0.007	0.00	243.65	434.11	CO	225.92
Banana Junction	0.008	0.00	271.68	433.58	CO	235.09
Umuna Junction	0.009	0.00	298.73	447.28	CO	248.67
Ogboko	0.006	0.00	226.03	382.81	CO	202.95
Umuago Urualla	0.004	0.00	131.26	319.95	CO	150.40

Table-11
Individual and average AQI for Egbema (dry season)

Location	**Individual AQI**				**Conditional Pollutant**	**Average AQI**
	PM_{10}	NO_2	SO_2	CO		
Umuorji	0.007	0.00	282.36	441.63	CO	241.33
Ukwugba I	0.008	0.00	314.91	477.90	CO	264.27
Ukwugba Ii	0.007	0.00	292.50	466.62	CO	253.04
Opuoma	0.007	0.00	212.77	437.34	CO	216.70

Conclusion

Result of the study indicates poor air quality in the study area which implies atmospheric pollution due to elevated concentration of PM_{10}, NO_2 SO_2 and CO above permissible limits. This could be attributed to poor environmental management practices resulting from anthropogenic emissions due to traffic, industrial activities, use of power generating sets and other domestic activities. The AQI which is significant in the study locations may pose severe health consequences for the general public and the environment hence. This calls for adequate attention and best environmental management practices to reduce the level of air quality deterioration.

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