Research Article
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Evaluation of the meteorological, air quality in the urban and rural areas of rivers state, South-South, Nigeria

Abstract

The increasing concentrations of air pollutants are now a global challenge. This research aimed to assess the meteorological parameters and atmospheric pollution in urban and rural areas of River State in Nigeria using Air Quality Index (AQI) ratings. The atmospheric quality status of the survey areas was analysed during the rainy season from April to July, 2018. In this study, Nwaja, Trans Amadi Industrial Layout, Port Harcourt Local Government Area (urban) and Umuazu village, Igbo-Etche, Etche Local Government Area (rural) in Rivers State, Nigeria gave recorded mean values for particulate matter as follows; $PM_{2.5}$ ranging from 107.30-113.00 µg/m^3 and PM_{10} (145.30-153.00 µg/m^3) in both areas. Other parameters analysed showed relative humidity (84.67-95.00 %), wind speed (0.97-2.97 m/s), elevation (40.33-108.30 m), cloud cover (98.33-99.33 %) and temperature (24.30-26.00 °C). Other results (ppm) were; CO_2 (8600.00-17500.00), Cl_2 (1.85-2.39), CO (29.67-44.30), SO_2 (0.60-0.75) and NO_2 (0.33-0.43) in both locations. From the obtained results, the study areas showed high concentrations of air pollutants which might be toxic to humans as well as plants and animals in the environment. The Air Quality Index (AQI) ratings of the obtained results showed that the area with high industrial activities (urban) was rated from Very Poor (E) to Hazardous (F) while in the area with less industrial activities (rural), it was rated from Moderate (C) to hazardous (F). Hence, there is a need for routine monitoring of the atmospheric pollutants in Rivers State and in South-South Nigeria as a whole to ensure safety.

Keywords: air quality, meteorological, climate change, air quality index, atmospheric pollution, particulate matter; gas emission

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Introduction

Air pollution has recently received much attention because of its threats to the health of humans and other living beings in the world. Air pollution is simply defined as some gases in the atmosphere that exist at higher concentrations than in normal limits thereby decreasing the quality of air in the environment, which could be harmful to the well-being of the people.[1] The well-being of people can be affected by various industrial activities, traffic and vehicular discharge and emissions which are from different airborne heavy/toxic metals (lead, mercury and cadmium), volatile compounds and other air pollutants which pollute the atmosphere with resultant negative impacts on the air quality and the environment.[1–5] Meteorology is the science of atmosphere, atmospheric phenomena, climate change and atmospheric effects on our weather and meteorologists use scientific principles and methods to explain, observe and even forecast our weather.[6] The weather and atmospheric pollution can have negative effects on human beings.[7] Particulate matter carries elements with various degrees of toxicity.[2,8] When air pollutants are taken off in all directions by the wind, these atmospheric pollutants persist long enough to pose serious problems in distant areas and some cases causing further problems of trans-boundary pollution in the air quality of the environment.[1,3,9,10] The human exposure to air pollutants is mostly connected and associated with outdoor and indoor air pollution and also through emissions from homes.[11] The high rate of indoor pollution which is a result of weak dilution of emissions from indoor sources is principally caused by poor ventilation and other uncountable sources of indoor air pollutants, including combustion of domestic fuels such as coal, wood, paraffin, tobacco smoke, asbestos products, pesticides used in the home, and household cleaning products contributing to poor ambient air quality.[12–14] Air quality is defined as the condition of the air within our surroundings or environment and it can be affected in many ways by the pollution emitted from these sources15. The quality of air is said to be good when it is within the set standard by USEPA for good air quality being free from gaseous pollutants such as smoke, dust and smog including other gaseous impurities in the atmosphere.[15,16]

The United States Environmental Protection Agency[17–21] has classified these pollutants into six principal categories and the classifications of these air pollutants for the air quality index (AQI) ratings. The air quality index (AQI) rating is a number used by government agencies to communicate to the public how the air currently is or how the air is forecasted to become polluted and as the air quality index increases due to an increase of air pollutants (for example, during working or rush hour's traffic or when there is an upwind forest fire), an increasingly large percentage of the population is likely to experience rapidly severe adverse health effects.[15] Air quality index (AQI) ratings are as follows; A (0-15, Very Good, Green colour), B (16-31, Good, Green colour), C (32-49, Moderate, Yellow colour), D (50-99, Poor, Yellow colour), E (100, Very Poor, Orange, red and purple colours) and F (>100, Hazardous, Maroon colour) as presented in Table 1 below.

The Air Quality Index (AQI) value ratings for $PM_{2.5}$ and $PM_{10}$and the indication of the air quality and its related health effects are presented in Table 2 and Table 3 below.[13]

Table 1 Classifications of the air pollutants for the air quality index (AQI) value ratings

S/N	Classifications	Indicator light	Air Quality Index (AQI) category	Air Quality Index (AQI) value
1	A	Green	Very Good	0-15
2	B	Green	Good	16-31
3	C	Yellow	Moderate	32-49
4	D	Yellow	Poor	50-99
5	E	Red and Purple	Very Poor	100
6	F	Maroon	Hazardous	> 100

USEPA, [17-21]

Table 2 Air Quality Index (AQI) ratings for $PM_{2.5}$

Air Quality Index (AQI) category	Air Quality Index (AQI) value	24 hrs Average PM2.5 concentrations (µg/m³)
Good	0-50	0-15.4
Moderate	51-100	15.5-40.4
Unhealthy for sensitive group	101-150	40.5-65.4
Unhealthy	151-200	65.5-150.4
Very unhealthy	201-300	150.5-250.4
Hazardous	301-500	250.5-500.4

USEPA, [21]

Table 3 Air Quality Index (AQI) ratings for PM_{10}

Air Quality Index (AQI) category	Air Quality Index (AQI) value	24 hrs Average for PM10 concentrations (µg/m³)
Good	0-50	0-54
Moderate	51-100	55-154
Unhealthy for sensitive group	101-150	155-254
Unhealthy	151-200	255-354
Very unhealthy	201-300	355-424
Hazardous	301-500	425-604

USEPA, [21]

According to USEPA[21] which states that, when the daily mean concentration of $PM_{2.5}$ is between 0-15.4 µg/m³, it is classified as good air quality and when it is between 15.5-40.4 µg/m³, it is classified as moderate air quality and when it is between 40.5-65.4 µg/m³ ,the air quality is classified as being unhealthy for sensitive groups (elderly persons, infants and others people with illnesses like bronchitis, emphysema, pneumonia and asthma) and the air quality concentrations between 65.5-150.4 µg/m³ is classified to be very unhealthy and the hazardous air quality is classified to be between 250.5-500.4 µg/m³ as shown in Table 2 above.

USEPA also stated that, in PM10, when the daily mean concentration is between 0-54 µg/m³, it is classified as good air quality and when the mean value is between 55-154 µg/m³, it is classified as moderate air quality[21] and when the concentrations are between 155-254 µg/m³, it is classified as unhealthy for the sensitive groups and when the mean values are between 255-354 µg/m³, it is classified as being unhealthy for everyone and when the mean concentrations are between 355-424 µg/m³, the air quality is said to be very unhealthy and when the mean concentrations are between 425-604 µg/m³, it is said to be hazardous air quality as shown in Table 3 above by USPA.[21] Earlier findings from some researchers in the climate change monitoring agencies have justifications that, the earth is presently facing enormous challenges due to rapid global warming, which is caused by rising levels of greenhouse gases in the atmosphere. Nicholas and Ukoha stated in their earlier findings that the increment in population has led to increased economic activities which have resulted in more extensive urbanization, automobile exhaust emission and indiscriminate refuse disposal which turned out to have negative impacts on humans and the environment.[1,3] Many researchers have investigated, as well as monitored the atmospheric pollution within the Niger Delta region and have reported that the toxic substances found in the environment/atmosphere in higher concentrations are a result of natural occurrences and anthropogenic activities.[1,3,8,22–27]

This research work was carried out in Nwaja, Trans Amadi Industrial Layout, Port Harcourt Local Government Area (urban) and Umuazu village, Igbo-Etche, Etche Local Government Area (rural) in Rivers State, Nigeria. It was aimed at assessing the atmospheric pollution in the study areas and comparing the record of the meteorology monitoring with Air Quality Index (AQI) ratings by USEPA. This is because of the increase in global interest in air pollutants and their associated health risks and effects on the environment. There is need for continuous evaluation of atmospheric pollution for ascertaining the air quality in the environment and to ensure that, it is within acceptable limits for ambient air.[17–21,28–30]

Methodology

Study area

The study areas were Nwaja Roundabout, Trans Amadi Industrial Layout, Port Harcourt Local Government Area (urban) and Umuazu village, Igbo-Etche, Etche Local Government Area (rural) in Rivers State, Nigeria as shown in Figure 1 below.

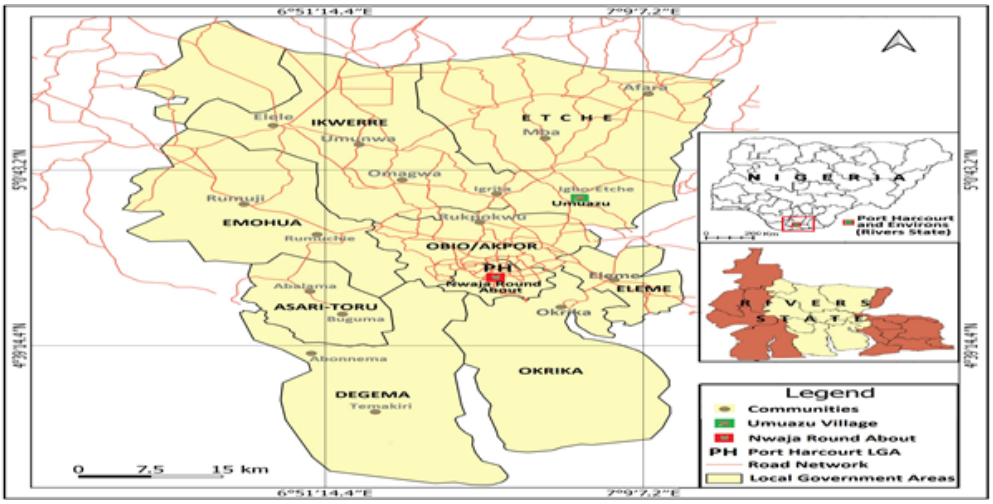

Figure 1 Map of the study area showing sample locations with their coordinates.

Economic and industrial activities of the study areas

Rivers State is one of the major oil-producing states in the South-South region of Nigeria. This state was selected because of its well-known industrial activities in Nigeria. In this study, two locations (sampled areas) in Rivers State were used for this research work which were as follows; Nwaja Roundabout, Taxis loading bay, Trans Amadi Industrial Layout in Port Harcourt local government area (urban) and Umuazu village, T- junction, Igbo-Etche, Etche local government area (rural). Trans Amadi Industrial Layout is a thousand-hectare industrial area and is considered to be a major industrial zone in Port Harcourt. Its coordinates are 4°48′53″N and 7°2′14″E. Major companies or industries in Trans Amadi Industrial Layouts are; Japaul Limited, Heir Oil and Gas Nigeria Limited, Michelin Tyres Africa and other industries producing materials such as glass bottles, tyres, aluminium and paper have their production/manufacturing plants.[31] Boundaries of the Trans Amadi industrial layout lie within the north and are bordered by D/line in the southwest, Woji Township to the east and Rumuola to the North- West. The main abattoir of the city is located along Trans Amadi industrial layout area.[31,32] Etche people occupy two local government areas in the Rivers State, namely; Etche and Omuma Local Government Area. Etche people are mostly engaged in agriculture and their main cultivated crops are cassava and yam which are very important in Africa as a whole. Most of the Etche people make use of tractors for farming their crops for commercial purposes. Another important economic product of the Etche people is palm oil production.[32,33]

The assessment of the meteorological and air quality in the study areas

This study was carried out in Nwaja Roundabout, Taxis loading bay, Trans Amadi Industrial Layout, Port Harcourt Local Government Area (urban) and in Umuazu village, T-Junction, Igbo-Etche, Etche Local Government Area (rural-this serve as a control) in Rivers State, Nigeria during the rainy season from April to July, 2018. The meteorological and air quality parameters were assessed using the following instrument; Handheld Gasman Air Monitoring Meter (Models: 1200-19831) and Haz-Dust ^{Tm}; Air Ae Steward Meter; (Model: HD1000) as shown in Table 4 below. The air quality assessment of the study area was carried out on an hourly basis for 3 h per sampling station in triplicate; the periods of measuring data from the selected sites were as follows for the four working days (morning; peak hours, afternoon; off-peak period and Evening; peak hours) in both locations. After calibrating the instrument according to the manufacturer's specification and guidelines, at each designated position, the instrument for the air pollutant assessment was held at arm's length in an open space in each of these areas according to the periods of measuring data. The knob on the instrument was adjusted to the TEST/GAS position and then allowed to stand for some minutes and thereafter, readings were taken when the display on the LCD lens of the instrument was stable for recording. The results obtained in this study area were recorded in triplicate for mean values.

Table 4 Names of instruments and their manufacturers

Instrument		Manufacturer
	SO_2 gas monitor	Model: 19648H, Range; 0-10 ppm, Alarm levels; 2.0 ppm
	NO_2 gas monitor	Model: 19831N, Range; 0-10 ppm, Alarm levels; 3.0 ppm
Handheld GasMan	CO gas monitor	Model: 19252H, Range; 0-500 ppm, Alarm levels; 50 ppm
	Cl_2 gas monitor	Model: 19812H, Range; 0-5 ppm, Alarm levels; 0.5 ppm
	CO_2 Land Duo Multi	Model: PDR1200, Range; 0-50,000 ppm
Air Ae Steward		Model: HD1000, Haz-Dust Tm, Air Quality Monitor for PM 2.5 and PM 10
Max-min thermometer		Handheld HYGROMETER MODEL: KTJTA318
Digital Anemometer		Handheld MASTECH MS6252A
Sun Road Digital Compass (Altimeter)		Handheld Altimeter Model: CR2032

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Statistical analysis

Statistical analysis was done using Statistical Package for Social Sciences (SPSS) version 20. Data generated in this study were analysed for mean and standard deviation (SD) and were reported in two significant figures.

Results

Meteorology record, air quality in the urban and rural areas of Rivers State, Nigeria

The range of values of carbon monoxide, chlorine gas, NO_2, SO_2, CO_2, particulate matter ($PM_{2.5}$ and PM_{10}), temperature, relative humidity, pressure, wind speed, elevation and cloud cover determination in both locations of Rivers State, Nigeria as shown in Table 5, Table 6 and Figures 2–4 below.

Table 5 Meteorology record, air quality in taxi loading bay Nwaja, Trans Amadi Industrial Layout, Port Harcourt local government area (urban) in Rivers State, Nigeria

S/N	Parameters	Concentrations	Air Quality Index (AQI) ratings
1	PM 2.5 (μg/m³)	113.00±4.58	Very Poor (E), Unhealthy
2	PM 10 (μg/m³)	153.00±6.56	Very Poor (E), Unhealthy
3	CO (ppm)	44.80±10.01	Poor (D)
4	CO2 (ppm)	17,500.00±1228.80	Hazardous (F)
5	NO2 (ppm)	0.43±0.15	Poor (D)
6	SO2 (ppm)	0.60±0.10	Poor (D)
7	Cl2 (ppm)	1.85±0.21	Poor (D)
8	Temperature (°C)	26.00±3.00	Good (B)
9	RH (%)	84.67±13.50	
10	WS (m/s)	0.97±0.40	
11	Elevation (m)	40.33±9.61	
12	Pressure (hpa)	1,012.00±1732.00	
13	Cloud cover (%)	99.33±1.15	

PM, particulate matter; RH, relative humidity; WS, wind speed

Table 6 Meteorology record, air quality in T- Junction Umuazu village, Igbo-Etche, Etche local government area (rural) in Rivers State, Nigeria

S/N	Parameters	Concentrations	Air Quality Index (AQI) Ratings
1	NO_2 (ppm)	0.33±0.15	Poor (D)
2	SO_2 (ppm)	0.75±0.15	Poor (D)
3	CO (ppm)	29.67±1.53	Moderate (C)
4	CO_2 (ppm)	8,600.00±556.78	Hazardous (F)
5	Cl_2 (ppm)	2.39±0.48	Very Poor (E), Unhealthy
6	PM 2.5 (μg/m³)	107.30±6.03	Very Poor (E), Unhealthy
7	PM 10 (μg/m³)	145.30±8.02	Very Poor (E)
8	Temperature (°C)	24.30±1.52	Good (B)
9	Pressure (hpa)	1,012.00±1732.00	
10	Cloud cover (%)	98.33±2.87	
11	RH (%)	95.00±1.00	
12	WS (m/s)	2.97±1.00	
13	Elevation (m)	108.30±3.51	

PM, particulate matter; RH, relative humidity; WS, wind speed

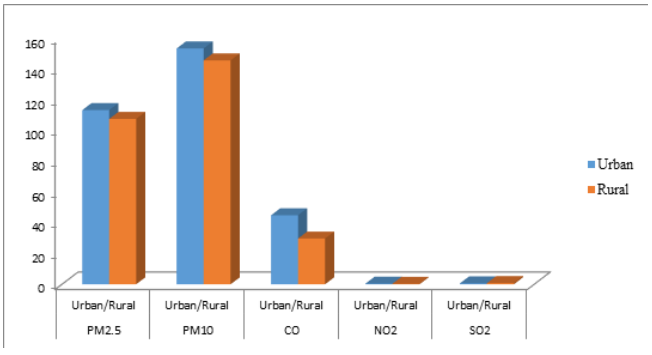

Figure 2 Field Meteorology and Air Quality record in Rivers State (urban/rural) areas.

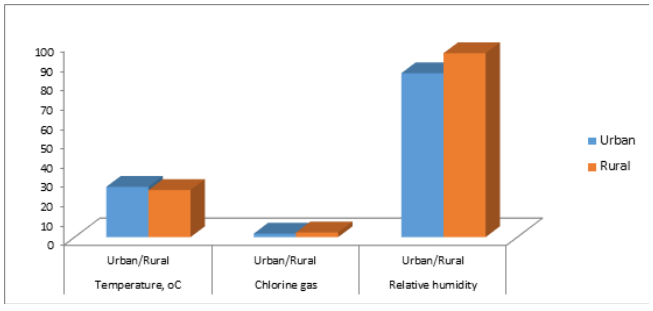

Figure 3 Field Meteorology and Air Quality record in Rivers State (urban/rural) areas.

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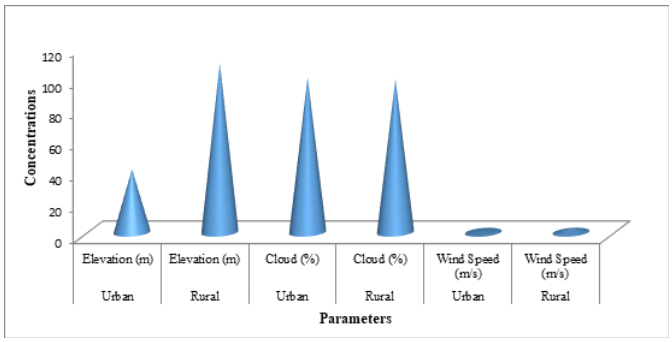

Figure 4 Field Meteorology and Air Quality record in Rivers State (urban/rural) areas.

Discussion

In this study, the field meteorology and air quality record of Taxis loading bay Nwaja roundabout, Trans Amadi Industrial Layout Port Harcourt local government area and T-Junction Umuazu village, Igbo-Etche, Etche local government area in Rivers State gave mean values for particulate matter; $PM_{2.5}$ ranging from 107.30-113.00 µg/m^3 and PM_{10} (145.30-153.00 µg/m^3), relative humidity (84.67-95.00 %), wind speed (0.97-2.97 m/s), elevation (40.33-108.30 m), cloud cover (98.33-99.33 %), chlorine gas (1.85-2.39 ppm), temperature (24.30-26.00 °C), pressure (1012.00-1012.00 hpa) and Other results (ppm) were; CO_2 (8,600.00-17,500.00), Cl_2 (1.85-2.39), CO (29.67-44.30), SO_2 (0.60-0.75) and NO_2 (0.33-0.43) as shown in Table 5 and Table 6 above.

The obtained results for the atmospheric pollutants assessment gave mean concentrations (ppm) ranging from 0.33±0.15-0.43±0.15 for NO_2, SO_2 (0.60±0.10-0.75±0.15), CO_2 (8,600.00±556.78-17,500.00±1228.80) and Cl_2 (1.85±0.21-2.39±0.48) in the urban and rural areas as shown in Table 4, Table 5 and Figure 2 above. The obtained values for NO_2, SO_2, CO_2 and Cl_2 were above the set standards of 0.04-0.06 ppm for NO_2, SO_2 (0.04-0.06 ppm), CO_2 (500 ppm) and Cl_2 (0.01 ppm) by USEPA[19,20] and WHO.[28,30,34] Comparing the values obtained with the set standard Air Quality Index (AQI) value ratings; NO_2, Cl_2 and SO_2 were rated very poor (E) while CO_2 was rated hazardous (F) in the urban and rural areas indicating that hazardous pollution which could have risen from burning fossil fuels, smelting of metals, vehicular emission and industrial activities like flaring of gases from the oil and gas sector, and other stationary industrial sources accounting for more than 60 % of global greenhouse gas emissions.[5]

Different monitoring points for all the atmospheric pollution in these sampled areas gave higher concentrations than the recommended set standards by USEPA and WHO. These obtained results were in agreement with the earlier findings by Nicholas and Ukoha who reported higher values (ppm) of SO_2 (0.63±0.15-0.70±0.20), NO_2 (0.27±0.15-0.37±0.15) and CO_2 (6,500.00±984.89-10,166.27±450.93) in their study carried out in Douglas road, Owerri municipal Council and Ezihe village (village square area), Uzii, Ideato North local government area in Imo State, Nigeria[1] and also in line with another findings of Nicholas and Ukoha who reported higher values (ppm) of SO_2 (0.63±0.25-0.73±0.15), NO_2 (0.40±0.10-0.76±0.15) and CO_2 (16,800.00±1760.34-28,900.00±3207.80) in their study carried out in Warri and Okpanam, Delta State, Nigeria.[3] The values obtained in this study were also in line with the findings of Umunnakwe and Aharanwa who reported high concentrations of SO_2 (0.146 ppm) and NO_2 (0.108 ppm) in Owerri municipal road, Imo State, Nigeria[4] and that of Okunola et al.[14] carried out in Kano State, Nigeria[14] which were of high values as well but not in accordance with the research work carried out by Antai et al. which gave lower values of SO_2 (<0.01-0.30 ppm) in Uyo, Akwa Ibom State, Nigeria.[8]

The obtained values of the air quality assessment for particulate matter (PM) showed mean concentration of 107.30±6.03-113.00±4.58 µg/m^3 for $PM_{2.5}$ and 145.30±8.02-153.00±6.56 µg/m^3 for PM_{10} in Trans Amadi Industrial Layout, Port Harcourt local government area (Taxis loading bay Nwaja roundabout) and in Umuazu village, Igbo-Etche, Etche local government area (T-Junction). The obtained results when compared with WHO limits, it was observed to be above the average annual set standards of 25.00 µg/m^3 and 50.00 µg/m^3 for $PM_{2.5}$ and PM_{10} respectively[28–30] in both areas as presented in Table 5, Table 6 and Figure 2 above which was due to increase industrial/commercial activities in these areas. The results were also compared with the USEPA limits and it was observed that PM_{10} was found to be above the permissible limits of 150.00 µg/m^{3}for ambient air quality[17–21] in the urban area while it was seen to be within the permissible limits in the rural area.

The high levels of $PM_{2.5}$ and PM_{10} are a result of industrial activity, construction, forest fires and other numerous anthropogenic activities. Comparing the obtained values with the Air Quality Index (AQI) ratings,[17–21] it was indicated that $PM_{2.5}$ and PM_{10} were rated poor (D) in the urban and rural areas which was unhealthy for the sensitive groups/everyone. The effect of particulate matter (PM) and particles of variable in human health is that, though in very small diameter, it penetrates the respiratory system through the means of inhalation and it causes respiratory and cardiovascular diseases, cancer, and central nervous/respiratory system dysfunctions.

Earlier findings by Nicholas and Ukoha reported high concentrations of particulate matter ranging from 99.30 -124.70 µg/m^3 for $PM_{2.5}$ and PM_{10} (138.70 -168.00 µg/m^3) in their study carried out in Douglas Road, Owerri municipal Council and Ezihe village (village square area), Uzii, Ideato North local government area in Imo State, Nigeria[1] were in supports with results obtained in this study.

Other findings by Okudo et al. also reported values of particulate matter; 23.06±1.53-153.23±28.73 µg/m^3 for $PM_{2.5}$ and PM_{10} (37.49±3.75-336.49±47.05 µg/m^3) in their research work in Enugu Urban, Enugu State, Nigeria which were within and above the set standards by WHO and USEPA for good air quality.[4] Nicholas and Ukoha also reported higher values of particulate matter, $PM_{2.5}$ (113.00±7.00-133.00±36.07 µg/m^3) and PM_{10} (153.30±9.07-179.67±48.01 µg/m^3) in their previous findings on air quality assessment carried out in Warri and Okpanam in Delta State, Nigeria[3] and the results were also in line with the obtained values in this study.

Antai et al.[8] also reported higher values of particulate matter, $PM_{2.5}$ (20.50-51.50 µg/m^3) and PM_{10} (56.00-279.70 µg/m^3) in their study carried out in Uyo, Akwa Ibom State, Nigeria[8] and the study of Umunnakwe and Aharanwa whose work showed PM_{10} (0.140 mg/mm^3) in Owerri municipal road, Imo State, Nigeria[4] and that of Okunola et al.[14] in Kano State, Nigeria.[14] This study was also in accord with the previous research work carried out by Augustine[5] in Port Harcourt which states that the following factors such as heavy traffic congestion, industrial activity, gas flaring from oil and gas sector, densely population, road intersection and generator power plants could be attributed to the sources of air pollution in Rivers State which could be harmful to human health and its environment.

The carbon monoxide (CO) values gave mean concentrations ranging from 29.67±1.53- 44.80±10.01 ppm for these locations area

as shown in Table 5, Table 6 and Figure 1 above. The obtained results were found to be above the permissible limit of (10) ppm by USEPA[19,20] for ambient air quality. The high concentrations of carbon monoxide observed in the sampled areas were a result of incomplete combustion of fuels which was due to generating sets and heavy motorized traffic. When carbon monoxide is breathed into the human system at high concentrations, it could be harmful to the human body because it is poisonous at such levels. Comparing the values obtained in this work with the set standards for the Air Quality Index (AQI) value ratings, it was observed that, carbon monoxide concentrations was rated moderate (C) in the rural area and poor (D) in the urban area as shown in Table 5 and Table 6 above. The obtained results in this study were in agreement with the earlier findings by Nicholas and Ukoha who reported lower values (ppm) of CO (33.00±3.61-38.67±7.02) in their study carried out in Douglas Road, Owerri municipal Council and Ezihe village (village square area), Uzii, Ideato North local government area in Imo State, Nigeria.[1]

Results obtained in this study were of low values and were not in total support with that of Adelagun et al.,[35] which reported low and high concentrations of CO (30-70 ppm) in their findings carried out at Oko-Baba (Ebute-Meta, Lagos), Nigeria[35] and not also in line with that of Antai et al.,[8] who reported lower concentrations of CO (0.30-0.76 ppm) in Uyo metropolis, Akwa Ibom State, Nigeria.[7] The obtained values were not in line with the research work carried out by Nicholas and Ukoha who reported higher concentrations of CO (147.30±31.56-266.50±7.10 ppm) in Warri and Okpanam, Delta State, Nigeria[3] and that of Augustine in Rivers State, Nigeria[5] and was also in support with the research work carried out by Okunola et al. which gave higher concentrations of carbon monoxide in Kano State, Nigeria.[14]

The results of the chlorine gas gave mean concentrations ranging from 1.85±0.21-2.39±0.48 as shown in Table 5, Table 6 and Figure 4 above. Comparing the obtained values with the air quality index (AQI) rating, chlorine gas values were rated Poor (D) in the urban area and Very Poor (E) in the rural areas which was a result of the industrial activities of both areas of the state. The results obtained for chlorine gas in this study in the urban and rural areas were in agreement with the earlier findings by Nicholas and Ukoha who gave higher values of chlorine gas (1.00±0.09-2.68±0.63) in Douglas Road, Market area (Taxis loading Bay), Owerri Municipal Council (urban) and in Ezihe village (village square area), Uzii, Ideato North Local Government Area (rural), Imo State, Nigeria.[1]

The temperature values gave mean concentrations ranging from 24.30±1.52-26.00±3.00 ^{o}C as shown in Table 5, Table 6 and Figure 3 above. The results were found to be within and above the ambient temperature of 25 ^{o}C by USEPA[19] and WHO[30] for good air quality. Comparing the obtained values with the air quality index (AQI) rating, temperature values were rated good (B) in both locations. However, the temperature levels were seen to be varying with time of the assessment and the changes in the temperature have a lot to do with the atmosphere and surroundings as well as the industrial activity of an area/location. The results obtained for temperature in this study in the urban area were in agreement with the earlier findings by Nicholas and Ukoha who gave higher values of temperature (26.89±1.17-29.33±2.52 ^{o}C) in Warri and Okpanam, Delta State, Nigeria[3] and that of Antai et al.[8] reported from Uyo metropolis, Akwa Ibom State, Nigeria[8] and were also in accord with the earlier findings of Augustine in Rivers State, Nigeria.[5]

The values obtained for cloud cover (%) gave mean concentrations ranging from 98.33±1.15-98.33±2.87 % as shown in Table 5, Table 6 and Figure 4 above. The results obtained for cloud cover in this study in both areas of the state were in agreement with the earlier findings by Nicholas and Ukoha who gave cloud cover values of 85.33±10.50-87.33±15.04 % in Warri and Okpanam, Delta State, Nigeria.[3]

The elevation (m) values gave mean concentrations ranging from 40.33±9.61-108.30±3.51 m as shown in Table 5, Table 6 and Figure 4 above. The results obtained for elevation in this study in the urban and rural areas of the Rivers state were in agreement with the earlier findings by Nicholas and Ukoha who gave elevation (m) values of 23.00±7.00-67.33±10.41and 18.70±7.02-82.67±5.03 in Warri and Okpanam, Delta State[3] and in Douglas Road, Owerri Municipal Council and in Ezihe village, Uzii, Ideato North, Imo State, both in Nigeria[1] respectively.

The values obtained for wind speed (m/s) gave mean concentrations ranging from 0.97±0.40-2.97±1.00 m/s as shown in Table 5, Table 6 and Figure 4 above. The results obtained for wind speed in both areas of the state were in agreement with the earlier findings by Nicholas and Ukoha who gave wind speed (m/s) values of 1.07±0.72-1.13±0.97 and 1.57±0.90-1.29±0.71 in Warri and Okpanam, Delta State, Nigeria[3] and in Douglas Road, Owerri Municipal Council and in Ezihe village, Uzii, Ideato North local government area, Imo State in Nigeria[1] respectively.

Conclusion

Generally, air pollution is caused by numerous factors which are discharged into the atmosphere by natural occurrences and anthropogenic activities. Based on the results obtained in this study as shown by the air quality indexes, the mean concentrations of $PM_{2.5}$, PM_{10}, CO, SO_2, NO_2 and CO_2 were of higher concentrations, which were above the set standard by USEPA and WHO. Comparing the obtained values with the Air Quality Index (AQI) ratings, it was observed that, the location with less industrial activities (rural) gave concentrations which were rated from moderate to hazardous air quality whereas the location with enormous industrial activities (urban) were rated from very poor to hazardous air quality. However, the effect of air pollutants on the public and individual health is quite alarming due to the increased rate of morbidity and mortality being observed globally, resulting from the rapid increase rate in global warming from greenhouse gases facing the world today at large. Therefore, pollutants from the sources such as particulate matter, vehicular emissions, gas flaring and numerous other anthropogenic activities affects the atmosphere causing air pollution in these study locations and its resultant effect on human health could be dangerous.

Recommendations

a) Environmental monitoring/measures should be properly adopted in Nwaja, Trans Amadi Industrial Layout, Port Harcourt local government area which the sampled location was and in Umuazu village, Igbo-Etche, Etche local government area (T-Junction area) to control the atmospheric pollution and anthropogenic emissions in these areas for the well-being of the people

b) Human health, ecosystems, food security and the entire climate within the region experienced emissions impact which was increasing at a very dangerous proportion and the government should urgently establish and equip air pollution monitoring centres and network the agencies especially in the oil and gas industrialization areas.

c) Relevant government agencies should create awareness of the safety level of the environment since there is a global interest in

the sudden increase/rising concentrations of air pollution, mainly from traffic/vehicular discharge and emissions, oil and gas flaring from companies, domestic use of wood and its compliance with the ambient set standards [17-21], [28-30, 34].

d) The federal, state and local governments should organize and launch an enlightenment campaign on the importance of routine air quality assessment in our environment.

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Credit authorship contribution statement

Nicholas, Eno-obong Sunday participated in field work assessment, manuscript drafting and in the analysis of results. Okudo, Calistus Chidebelu participated in manuscript editing and drafting and in the analysis of results.Ukoha, Pius Onyeoziri participated in field work assessment, manuscript editing and in the analysis of results.

Ethical approval: All ethical guidelines have been adhered to.

Availability of data and materials: All data and materials are included in the manuscript.

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Conflicts of interest

The authors declare that there is no conflict of interest as regards this study.

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