Open Access Research Journal of
Engineering and Technology
Journals home page: https://oarjpublication/journals/oarjet/
ISSN: 2783-0128 (Online)

OARJ OPEN ACCESS RESEARCH JOURNALS

(RESEARCH ARTICLE)

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Influence of meteorological variables on air characteristics of Onitsha, Nigeria

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Open Access Research Journal of Engineering and Technology, 2022, 02(01), 001–011

Publication history: Received on 03 December 2021; revised on 18 January 2022; accepted on 20 January 2022

Article DOI: https://doi.org/10.53022/oarjet.2022.2.1.0021

Abstract

This study evaluated the influence of prevailing meteorological characteristics on the concentration of air parameters in Onitsha metropolis, Anambra State, Nigeria in 2019. The information is required in meteorological forecasts, wind climatology, weather characteristics for planning control measures which might improve or worsen air quality, essential to evaluating air pollution control in the study area. A total of forty sampling points and one control point were selected and used for the study across Onitsha metropolis. The sampling points were selected in accordance with WHO guidelines for sampling point selection. Air quality and meteorological data were collected *in-situ* from primary sources in the field via portable air quality instrument and *Kestrel 4500NV* weather tracker. The results showed that wind direction was predominantly North-east in the dry season and South-west in the wet season. Temperature levels in the area were found to be higher in the dry season than in the wet season. Conversely, relative humidity levels were higher in the wet season than in the dry seasons. It also showed that some parameters such as SO_2, NO_2, H_2S, VOC_2, CO, $PM_{2.5}$ and PM_{10} had higher concentrations in the dry season than in the wet season. On the other hand, TSP, PM_{10} and PM_7 showed higher concentrations in the wet season than during dry season. High levels of measured air quality parameters were recorded around major junctions and market places within Onitsha, which are harmful to public health. Air movements influenced the fate of air pollutants; If the air was calm and pollutants couldn't disperse, then the concentration of these pollutants would build up. On the other hand, when strong, turbulent winds blew, pollutants dispersed quickly, resulting in lower pollutant concentrations. The study further showed that transportation activities and trading activities at the market places were the main sources of high concentration levels of air parameters in the study area. Health impact assessment should be conducted in Onitsha metropolis for residents. State government should enforce compliance laws and regulate the activities of industries in the areas. The findings showed that meteorological data could help identify the source of pollutants, predict air pollution events, simulate and predict air quality using computer models. Identifying the sources means planning to reduce the impacts on air quality by anthropogenic activities.

Keywords: Onitsha; Dry; Wet; Meteorology; Air; Temperature

1. Introduction

The socio economy of Onitsha in Anambra State, South East of Nigeria is basically commerce, agrarian and a few industrial activities. The Onitsha city is the major commercial and business hub in the entire West African sub region and this has created a lot of pollution in the atmosphere through dispersion. Meteorology represents the whole science of the atmosphere including weather elements such as; rainfall, temperature, relative humidity, wind speed and direction, cloud cover and sunshine hours and many of its direct effects upon the earth's surface, the oceans and life in general [1]. There are basically two seasons obtainable in Onitsha; the Dry (December – March) and Rainy seasons (April – October) whereas the remaining month of November is harmattan marked with a dry chilly cold monsoon wind from the Northern hemisphere witnessed across the entire state. But in recent times, there is death of exquisite harmattan,

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which has elicited complaints from farmers and agriculturists. These may not be unconnected with climate change and global warming as a result of mans' anthropogenic activities, developments that are insensitive to nature and no thought or plan for environmental sustainability ([2];[3;][4].

The air pollutants dispersion rates and pattern can be statistically analyzed by computation and calculation of the minimum and maximum of each air pollutant concentration, standard deviation and coefficient of variation in concentration of air pollutants; also, critical air pollutants of a study area can also be determined by using exceeding factor [5].

Due to the negative impacts and health implications, it is therefore penitent to regularly assess the air quality of Onitsha metropolis by deploying the standard procedures and methodologies for air quality field data gathering, data storage, data analysis/management and report writing [6];[7]; [8];[9]. Air movements influence the fate of air pollutants. If the air is calm and pollutants cannot disperse, then the concentration of these pollutants will build up. On the other hand, when strong, turbulent winds blow, pollutants disperse quickly, resulting in lower pollutant concentrations [10]. Meteorological data help identify the source of pollutants, predict air pollution events, simulate and predict air quality using computer models. When high pollutant concentrations occur at a monitoring station, wind data records can determine the general direction and area of the emissions. Identifying the sources means planning to reduce the impacts on air quality by anthropogenic activities. Measuring temperature supports air quality modelling and forecasting activities. Rain has a scavenging effect when it washes particulate matter out of the atmosphere and dissolves gaseous pollutants which improves visibility. Where there is frequent high rainfall, air quality is generally better. Relative humidity is generally higher during summer when temperature and rainfall are also at their highest [11].

2. Study Area

The study area coverage is approximately16kilometer square and is located in Onitsha commercial city and three adjoining LGAs. It lies in the outer fringes of Eastern Nigeria. The datum point is *Borromeo*/*Ziks* roundabout within latitudes N 06º 08'.801" and longitudes E 006º 48'. 831" and Control (O) point at *Ideani/Nnobi* - *Nkpor* Road junction in *Idemili* LGA which lies within latitudes N 06º 05'. 282" and longitudes E 006º 55'.891" which denote the approximate elevation of the stations in meters and is the datum level to which barometric pressure reports at the station referred, or the elevation of the ground in the vicinity of the stations. The site central location is *ZIK/BOROMEO* junction which situates at an intersection adjoining four major streets in Onitsha North Local Government area namely *Azikiwe* Road Onitsha Enugu Express Road, Awka road, *Omaba* street and *Upper Iweka* road. It is the second major intersection on the Owerri – Onitsha Main Market Road before famous *Ozomagala* building material market axis. It is a get way point to other neighbouring LGAs of *Ogbaru, Oyi* and *Idemili* in Anambra state and neighbouring states of Delta, Imo, Kogi and Enugu.

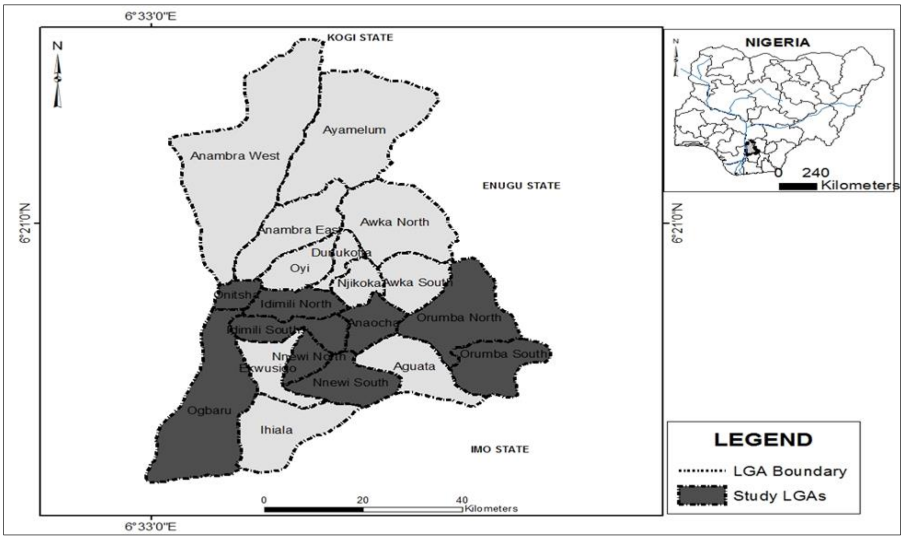

Figure 1 Map of Anambra State Showing Onitsha Metropolis

Geologically Anambra state and by extension, Onitsha lies within *AGBADA* geological formation belt. Relief and Drainage pattern in Onitsha is a combination of plain arable land around the southern part. This combination of relief and natural drainage pattern makes it difficult for flooding, though sometimes River Niger over flows its banks due to changes in tidal waves. The soils of Onitsha and environs is a bit complex in the sense that it ranges from humus soils in some areas, sand-stones and lateritic soils (red mud). The vegetation of Onitsha is rain forest at the fringes in the North westerly direction and some areas located at the South. Onitsha is populated with tropical rain forest and this is interlaced with grassland, and arable lowland and high land vegetation especially in the central and eastern boarder of the city. It is really difficult to have a virgin vegetation around Onitsha, because of overpopulation, rapid urbanization, conurbation and ever vibrant commercial nerve base.

3. Material and methods

3.1. Sample and Sampling Techniques

The research adopted the sampling point’s selection and field data collection standard procedures. A total of forty sampling points and one control point were selected and used for the study across Onitsha metropolis. The sampling points were selected in accordance with [12] guidelines for sampling point selection.

Air quality and meteorological data were collected *in-situ* from primary sources in the field via portable air quality instrument.

Table 1 Description of Sampling Point and Coordinates

S/N	Sampling Point Key	Sampling Point Location	Coordinates
1	SP 1	Upper Iweka Flyover, Odoakpu	N 06^{o} 07’. 892” E 006^{o} 47’. 627”
2	SP 2	Ochanja Market Round-About Odoakpu	N 06^{o} 08’. 446” E 006^{o} 47’. 070”
3	SP 3	Modebe Avenue/Iweka Road Junction Odoakpu	N 06^{o} 08’. 693” E 006^{o} 46’.801”
4	SP 4	Zik Avenue/Belewa Junction, Govt Field Fegge	N 06^{o} 08’.259” E 006^{o} 46’.521”
5	SP 5	Uga Road Building Materials/PH Road, Fegge,	N 06^{o} 07”.976” E 006^{o} 46’.437”
6	SP 6	Niger Head Bridge By Timber Market, Fegge	N 06^{o} 07’. 898” E 006^{o} 46’. 022”
7	SP 7	Main Market/Bida Road/Bright Street/ New Mkt Road Junction, Otu Onitsha	N 06^{o} 09’. 014” E 006^{o} 46’. 453”
8	SP 8	Oseokwa Odu Market/Main Market/ Old Mkt Road Junction, Otu Onitsha	N 06^{o} 09’ 305” E 006^{o} 46’ 452”
9	SP 9	Old Nkisi Road/Ridge Road (Holy Trinity) , European Qtrs	N 06^{o} 09’.709” E 006^{o} 46’.777”
10	SP 10	Akpaka GRA/Nigeria Prisons	N 06^{o} 10’.232” E 006^{o} 46’.735”
11	SP 11	Onitsha “33” Reserve Area	N 06^{o} 09’.737” E 006^{o} 47’.867”
12	SP 12	DMGS/All Saints Cath/Ziks Round About, Inland Town	N 06^{o} 09’.164” E 006^{o} 47’.311”
13	SP 13	Emmanuel Church St/Awka Rd/ St Mary Cath. Church Junction, Inland Town	N 06^{o} 09’ 101” E 006^{o} 48’.081 ”
14	SP 14	Savoy/Water Works Road/Awka Road Junction, Inland Town	N 06^{o} 08’.792” E 006^{o} 48’.673”
15	SP 15	Borromeo/Ziks Round About (Onosi Onira Retreat)	N 06^{o} 08’.801” E 006^{o} 48’. 831”
16	SP 16	Nkpor Junction	N 06^{o} 08’.836” E 006^{o} 50’.013”
17	SP 17	New Spare Parts Market/Enugu-Onitsha	N 06^{o} 09’.099” E 006^{o} 49’. 983”
18	SP 18	Oye – Nkpor/Awka Old Road Junction	N 06^{o} 09’ 173” E 006^{o} 50’.740”
19	SP 19	St Peters/Tarzan/Nkpor Express Junction	N 06^{o} 09’.502” E 006^{o} 50’.613”
20	SP 20	Ogbunike Building Materials (Km 8 Onitsha-Enugu Express Road	N 06^{o} 09’.918” E 006^{o} 51’.448”
21	SP 21	UgwuNwasike Round- About/OldAwka Road	N 06^{o} 09’.126” E 006^{o} 51’.837”
22	SP 22	Abatete/Alor/Ogidi/Ideani Junction	N 06^{o} 07’.658’’ E 006^{o} 55’.740”

23	SP23	Eke Nkpor (Umuoji/Npor/Obosi) Junction	N 06º 07'. 550'' E 006º 51'.740''
24	SP 24	Iyasele Obosi Road, Ukwu-Udara Junction	N 06º 07'.441'' E 006º 50'.088''
25	SP 25	Akaora/Minaj Junction, Obosi	N 06º 06'.513'' E 006º 49'. 148''
26	SP 26	Idemili/Obosi Flyover	N 06º 05' 759'' E 006º 48'. 571''
27	SP 17	Open Waste Dump Opposite Metallurgical Training Institute.	N 06º 06'.134'' E 006º 47'.980''
28	SP 28	Ngbuka-Obosi (Old Spare Parts Market)	N 06º 06'.400'' E 006º 47' 947''
29	SP 29	Amanato/ Lord Chosen Church/ Transformer Junction	N 06º 06' 825'' E 006º 47'.738''
30	SP 30	Eze Iweka/Ezenwa Junction	N 06º 07'. 771'' E 006º 47'. 814''
31	SP 31	14 Field Engr Regiment (Sign Post), Millitary Catonement, Onitsha.	N 06º 08'.300'' E 006º 48' 689''
32	SP 32	Open Field Omoba, Phase 2	N 06º 09'.165'' E 006º 49'.355''
33	SP 33	CKC/QRC /Ugwunakpankpa Junction, Woliwo	N 06º 08'. 506'' E 006º 47'.499''
34	SP 34	Atani Road By Sir Tony Ezenwa Road Junction, Harbour Industrial Layout 1, Ogbaru LGA.	N 06º 07'.576'' E 006º 46'314''
35	SP 35	New Era Goat Market/Batho-Way, Habour Industrial Layout 2, Ogbaru LGA	N 06º 07'. 337'' E 006º 45'.966''
36	SP 36	Second Niger Bridge Head, Ogbaru LGA	N 06º 06'.928'' E 006º 45'.949''
37	SP 37	GMO Company Road, Okpoko, Ogbaru LGA	N 06º 07'.073'' E 006º 46'.468''
38	SP 38	Ogboefere Industrial Market, Okpoko	N 06º 07'. 428'' E 006º 47'.671''
39	SP 39	New Heaven Layout, Okpoko (St Rita Cath Church/ Christ Holy Church)	N 06º 07'.419'' E 006º 47'.054''
40	SP 40	New Heaven Layout 2 (Diocese Of Ogbaru, El Shalom Convent, Okpoko.	N 06º 07'. 223'' E 006º 47' 237''
41	Control Point	Ideani/Nnobi Junction, Ideani, Idemili LGA	N 06º 05'.282'' E 006º 55'.891''

4. Methods of Data Collection, Analysis and Instrumentation

The portable air quality digital equipment were deployed to collect air quality data *in situ*. *Aarocet* 531S was used for particulate matter, while other gaseous parameters were measured by the use of *Aaroqual* 500 series. Also, GPS map model 76Cx was used for sampling points coordinates while meteorological parameters were sampled using Kestrel 4500NV weather tracker.

The portable meters were held in the prevailing wind direction at about two meters height with three minutes exposure for air pollutant logging/reading and it was recorded in the field note book. The data collection was done by using portable air quality meters. This was done in hourly basis for 3 times daily (3 hours a day) morning, afternoon and evening.

Data analysis was carried out using XLSTAT software, premium version [13]. Mean values, standard deviations and coefficient of variations (CV) were computed. Meteorological wind roses for the study area were plotted using R programming language version 3.5.3[14].

Mean concentration of particulate was computed using equation (3.1)

$$\overline{X} = \frac{\sum_{i=1}^{n} X_{meas,i}}{N} \tag{3.1}$$

Standard deviation was computed using equation (3.2)

(3.2)

$$s = \sqrt{\frac{\sum\left(X_{meas,i} - \bar{X}\right)}{N-1}}$$

Standard error estimate was determined using equation (3.3)

$$\sigma_{\bar{X}} = \frac{s}{\sqrt{N}} \qquad (3.3)$$

Where, s is the standard deviation, $X_{meas,i}$ is the measured i[th] data point, $\bar{X}$ is the mean and N is the total number of data set.

4.1. Coefficient of variation of particulates

The coefficient of variation of each parameter was computed using Equation (3.4)

$$\%CV = \frac{S}{\bar{X}} = \frac{\sqrt{\frac{\sum\left(X_{meas,i} - \bar{X}\right)^2}{N-1}}}{\frac{\sum_{i=1}^{N} X_{meas,i}}{N}} \qquad (3.4)$$

Computation of Exceedance Factor (EF)

The determination of the pollution level of air pollutants in the study area was done using Exceedance Factor [15];[16]. EF is the computed as the ratio of the measure concentration of air pollutant to the stipulated standards as shown in Equation (3.5).

The Exceedance Factor (EF) was calculated using equation (3.5) as follows:

$$\text{Excedence Factor (EF)} = \left(100 \times \frac{C_{0i}}{C_{si}}\right) \qquad (3.5)$$

Where C_{0i} is the measured concentration of the i[th] parameter in the ambient air. C_{si} is the regulatory standard recommended for the i[th] parameter.

For EF < 100, the parameter is said to be within permissible limit, and for EF > 100, the parameter is said to exceed permissible limit. The EF for each pollutant was computed based on the Federal Ministry of Environment (FMEnv) stipulated permissible limit as contained in [15] F and National Ambient Air Quality Standards.The concentrations of pollutants were expressed in terms of low, moderate, high and critical based on the computed values of EF[16],[17]

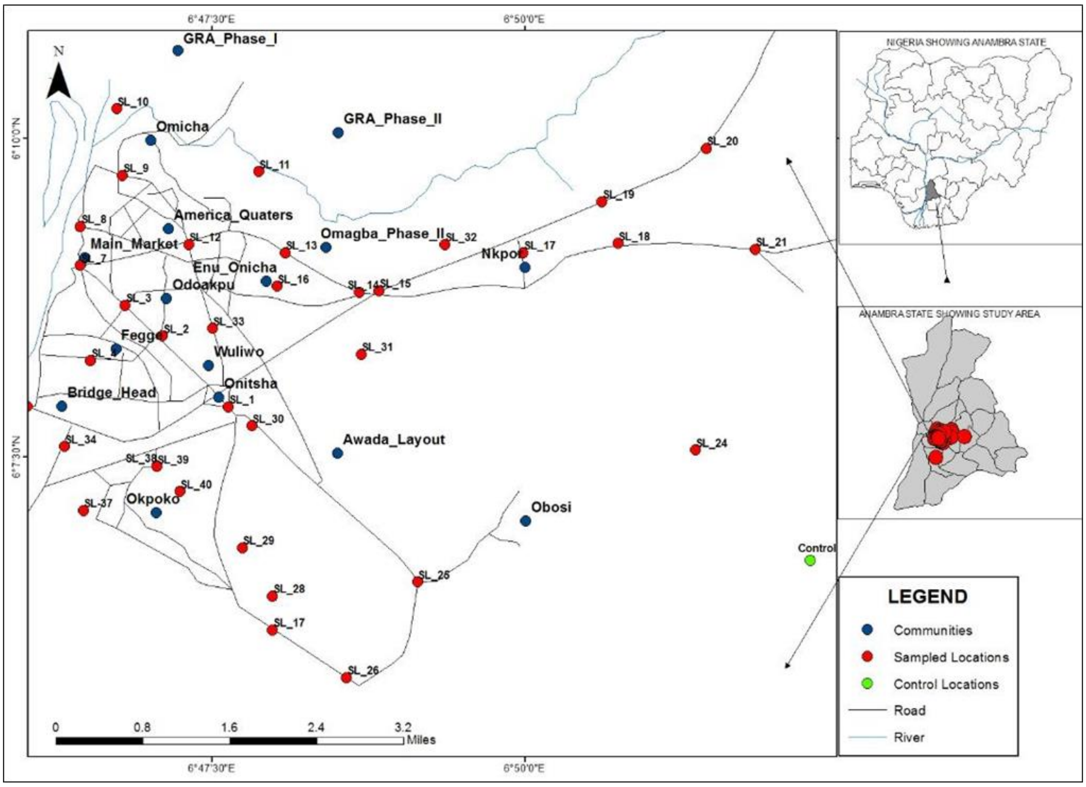

Figure 2 Map of Description of the Study Area

5. Results and discussion

5.1. Meteorology of the study area

5.1.1. Trend in Wind Speed and Direction

The mean values of wind speed obtained in the area in the dry season vary from 1.0m/s to 3.2m/s with a mean value of 2.4m/s and a standard deviation of 0.6m/s; while mean values in the wet season (Figure 3) vary from 0.3m/s to 2.3m/s with a mean value of 1.2m/s and a standard deviation of 0.5m/s. Wind speed values of 3.3m/s and 1.9m/s were recorded in the dry and wet seasons respectively at the control station. The dry season Wind Rose (Figure 4) shows that the wind direction is predominantly North-east in the dry season, while the Wind Rose of Figure 5 indicates that the wind direction is predominantly South-west in the wet season.

5.1.2. Trend in Air Temperature

Dry season temperature obtained in the area ranged from 31.0^0C to 47.0^0C with a mean value of 33.4^0C and a standard deviation of 2.5^0C; while wet season values ranged from 27.0^0C to 33.7^0C with a mean value of 30.0^0C and a standard deviation of 1.6^0C. Temperature values of 21.7^0C and 20.0_0C were measured in the dry and wet season respectively at the control station. Measured air temperature variations in the area for both the dry and wet seasons are shown in Figure 6.

5.1.3. Trend in Relative Humidity

The levels of mean relative humidity measured in the area in the dry season ranged from 67.3% to 94.4% with a mean value of 87.1% and a standard deviation of 6.5%; while the wet season values ranged from 63.0% to 94.5% with a mean value of 81.6% and a standard deviation of 7.7%. The control station showed relative humidity values of 50.7% and 54.3% in the dry and wet seasons respectively. Variations of relative humidity in the area for both the dry and wet seasons are shown in fig 7.

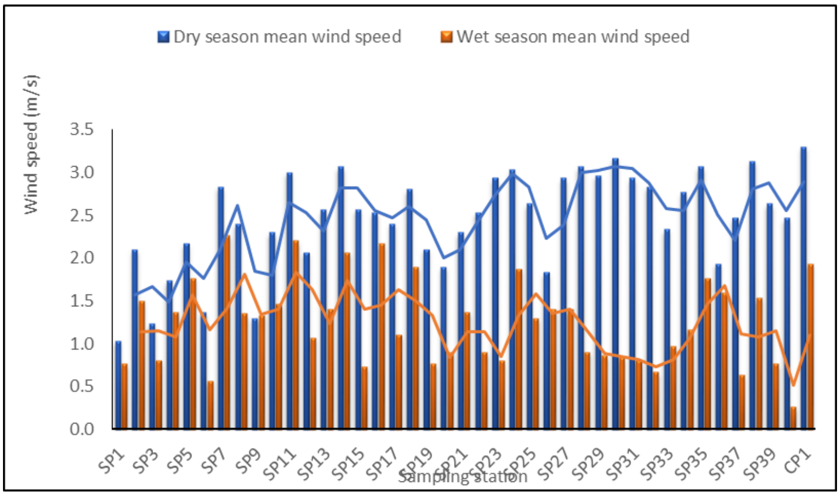

Figure 3 Seasonal Variation in Wind Speed of the Study Area

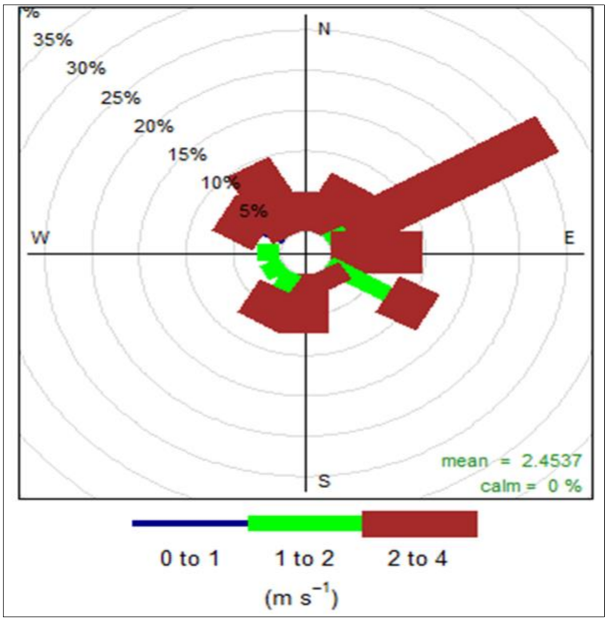

Figure 4 Dry Season Wind Rose of the Study Area

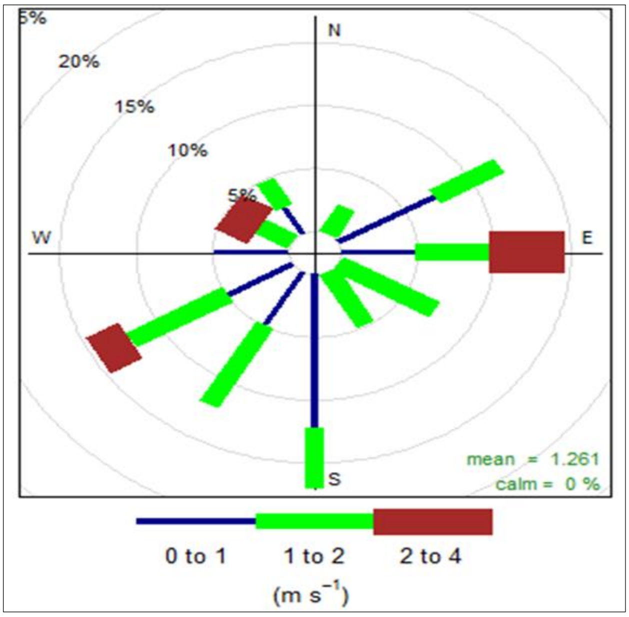

Figure 5 Wet Season Wind Rose of the Study Area

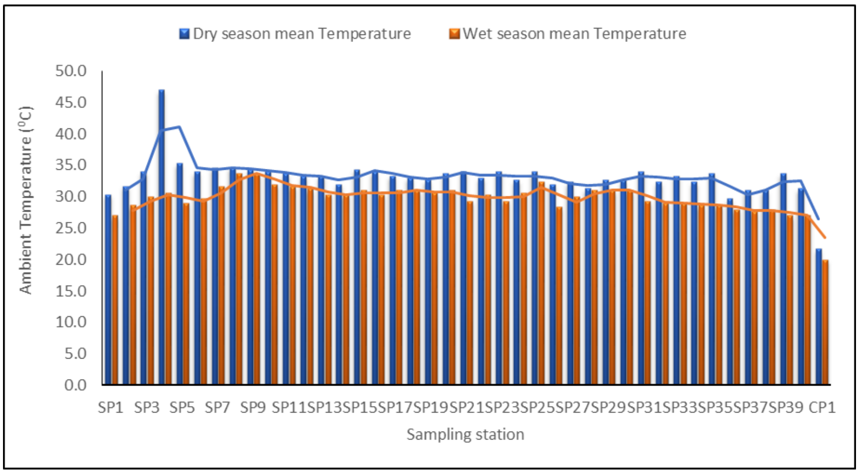

Figure 6 Seasonal Variation in Ambient Temperature of the Study Area

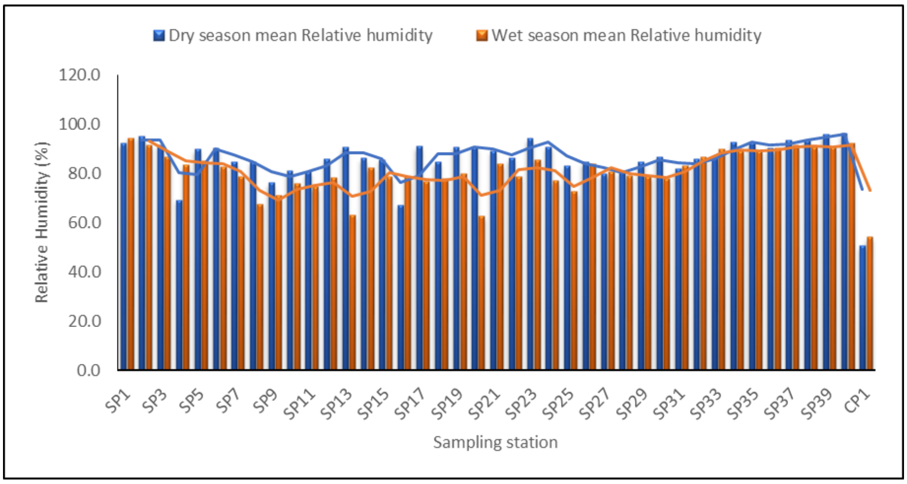

Figure 7 Seasonal Variation in Relative Humidity of the Study Area

6. Data Analysis

6.1. Statistical Analysis of Air Quality in the Study Area

Statistical analysis of air pollutants measured in the study area in the dry and wet seasons are presented in Tables 2and 3. The minimum and maximum concentrations of each air pollutant were calculated as presented in the Tables. Also, the mean, standard deviation, and coefficient of variation were statistically computed as presented in Tables 2and 3. The Coefficient of Variation (CV) for the concentrations of each pollutant was computed using Equation (3.1) as the ratio between the standard deviation and the mean and determines the relative measure of dispersion of pollutants in the study area.

Table 2 Statistical Summary of Air Pollutants in the Dry Season

Parameter	Min	Max	Mean	Standard deviation	CV (%)	NAAQS limit	EF (%)	Rating
SO_2 (ppm)	0.50	2.80	1.86	0.58	31.2	0.14	13.3	Very high
NO_2 (ppm)	0.33	3.00	1.71	0.67	39.2	0.1	17.1	Very high
H_2S (ppm)	0.67	2.33	1.54	0.50	32.5			
VOCs (ppm)	0.00	2.33	0.91	0.54	59.3			
CO (ppm)	2.00	33.00	12.31	6.66	54.1	9	1.4	Very high
NH_3 (ppm)	0.07	3.33	1.31	0.87	66.4			
TSP (µg/m^3)	18.3	1506.5	376.7	269.6	71.6			
PM_{10} (µg/m^3)	76.3	1070.9	263.3	171	64.9	150	1.8	Very high
PM_7 (µg/m3)	72.6	669.0	182.2	110	60.4			
PM_4 (µg/m3)	47.1	212.3	102.6	35.4	34.5			
$PM_{2.5}$ (µg/m^3)	25.1	133.1	68.7	18.5	26.9	35	2.0	Very high
PM_1 (µg/m3)	13.1	63.9	46.5	12.2	26.2			

Table 3 Statistical Summary of Air Pollutants in the Wet Season

Parameter	Min	Max	Mean	Standard deviation	CV (%)	NAAQS limit	EF (%)	Rating
SO_2 (ppm)	0.00	1.33	0.73	0.41	56.2	0.14	5.2	Very high
NO_2 (ppm)	0.00	1.33	0.30	0.29	96.7	0.1	3.0	Very high
H_2S (ppm)	0.00	1.00	0.42	0.32	76.2			
VOCs (ppm)	0.00	0.33	0.01	0.05	500.0			
CO (ppm)	0.00	20.70	5.27	5.56	105.5	9	0.6	Moderate
NH_3 (ppm)	0.00	2.33	0.16	0.43	268.8			
TSP (μg/m^3)	86.4	1835.3	464.9	378.4	81.4			
PM_{10} (μg/m^3)	40.9	1110.3	313.1	236.8	75.6	150	2.1	Very high
PM_7 (μg/m3)	60.1	640.3	213.9	133.4	62.4			
PM_4 (μg/m3)	44.7	205.6	102.6	40.1	39.1			
$PM_{2.5}$ (μg/m^3)	31.9	184.0	62.2	26.2	42.1	35	1.8	
PM_1 (μg/m3)	20.2	52.6	32.3	8.0	24.8			

Wind direction is predominantly North-east in the dry season and South-west in the wet season. Temperature levels in the area were found to be higher in the dry season than in the wet seasons. Conversely, relative humidity levels were higher in the wet season than in the dry seasons.

Result indicates that SO_2 showed a mean concentration of 1.86ppm in the dry season and 0.73ppm in the wet season; NO_2 showed mean concentration of 1.71ppm in the dry season and 0.30ppm in the wet season; the mean value of H_2S was 1.54ppm in dry season and 0.42ppm in the wet season; VOCs showed a mean value of 0.91ppm in the dry season and 0.01ppm in the wet season. Similarly, the mean concentration of CO was 12.31ppm in the dry season and 5.27ppm in the wet season; Ammonia showed a mean value of 1.31ppm in the dry season and 0.16ppm in the wet season. Furthermore, TSP showed a mean concentration of 376.7μg/m^3 in the dry season and 464.9μg/m^3 and in the wet season; PM_{10} showed a mean concentrations of 263.3μg/m^3 in the dry season and 313.1μg/m^3 in the wet season; the mean concentration of PM_7 was 182.2μg/m^3 in the dry season and 213.9μg/m^3 in the wet season; the mean concentration of PM_4 was 102.6μg/m^3 in the dry season and 102.6μg/m^3 in the wet season; $PM_{2.5}$ showed a mean concentration of 68.7μg/m^3 in the dry season and 62.2μg/m^3 in the wet season; while PM_1 showed a mean concentration of 46.5μg/m^3 in the dry season and 32.3μg/m^3 in the wet season.

7. Discussion

The concentrations of SO_2 in the area were found to be high in dry season compared to the wet season. The mean values of SO_2 exceeded permissible limits in both the dry and wet seasons. The mean values of NO_2 far exceeded both the FMEnv and NAAQS permissible limits. The mean concentrations of CO exceeded stipulated limit in the dry season, but within limit in the wet season. The mean TSP concentrations in the dry and wet seasons exceeded FMEnv permissible limit by 7.84% and 51.36% respectively; the dry and wet season mean values of PM_{10} exceeded NAAQS permissible limit by 75.5% and 108.7% respectively; while, the dry and wet season mean values of $PM_{2.5}$ exceeded NAAQS permissible limit by 96.3% and 77.7% respectively.

SO_2 and NO_2 hotspot is observed around *Nkpo* area dispersing from the central region of the study area to the North Eastern and Western parts. SO_2 has a great influence on a larger part of the study area, but less on Main Market, *Onicha* and *Nnobi* junction area in the dry season. *Nkpo* remains the area with the highest SO_2 concentrations; while main market is the least affected area in the wet season. NO_2 has a great influence on *Nkpo, Omagba* Phase 2, and *Enu Onicha* area, but less on Main Market, *Wuliwo, Awada* layout, *Obosi* and Bridge Head area. *Nkpo* and Southern Bridge Head is the most affected, while Main Market and *Nnobi* junction (East of *Obosi*) is the least affected area by NO_2 pollution in the dry season. CO hotspot was observed around Main Market in the dry season with least influence around *Fegg*, GRA

Phase 1, and *Nnobi* junction. CO concentrations were relatively low in the wet season. Main Market, *Nkpo* and Onitsha areas were found to be the epicenter of CO pollution in the dry season.

H_2S hotspot was observed around the Southern Part of the study area in the dry season with a great influence on a larger part of the study area. H_2S hotspot was observed around Bridge Head, Onitsha, *Wuliwo*, and North East of *Obosi* area in the wet season. *Fegg, Enu Onucha* and main market are the least affected area by H_2S pollution. NH_3 hotspot was observed around the Southern Part of the study area dispersing northward in the dry season; while NH_3 hotspots were observed around Bridge Head, Onitsha, *Wuliwo*, and North East of *Obosi* area in the wet season. Interpolated concentrations of NH_3 are highest around Awka Old Road junction. *Fegg, Enu Onucha* and main market are the least affected area by NH_3 pollution. VOCs hotspot was observed around the Southern part the study area close to *Awada* Layout in the dry season with influence around *Obosi* and *Nkpo* areas. The concentrations of VOCs were generally low in the wet season

PM_{10} hotspot was observed around the Main Market in the dry season, while the hotspot was observed close to Onitsha in the wet season. Main market area and Onitsha were the worst affected by PM_{10} pollution in the dry season, while Bridge head and *Awada* Layout were the worst affected in the wet season. *Onicha, Feggae*, and *Obosi* were the least affected. In the dry season, $PM_{2.5}$ hotspot was observed around the Central Part of the study area dispersing along the North East- South West region. Bridge head and *Awada* Layout being the worst affected, while *Onicha* was the least affected. $PM_{2.5}$ hotspot was localized around Onitsha area in the wet season with Main Market, Bridge Head, *Feggae*, and *Obosi* being the least affected. The exceedance factors (EF) for criteria pollutants were calculated using Equation (3.2) the measured value of the i^{th} parameter and the NAAQS regulatory permissible standard value. Exceedance factor less than 100 (EF < 1) is below prescribed limit, while exceedance factor greater than 100 (EF > 1) exceeds prescribed limit. Computed exceedance factors for all the criteria pollutants in the dry season were greater than 100 (>1) and are thus rated as very high (Table 2). This indicates that the mean values of all the criteria pollutants in the area exceeded stipulated NAAQS limits in the dry season and pose serious hazards to human health in the dry season period. Similarly, computed exceedance factors in the wet season (Table3) indicated very high mean concentrations of SO_2, NO_2, PM_{10}, and $PM_{2.5}$ and moderate mean concentrations of CO; while This shows that SO_2, NO_2, PM_{10} and $PM_{2.5}$ pose greater risk to public health in the wet season and people with respiratory disease such as asthma might be at greater risk; while CO poses low immediate hazard to human health.

Transportation activities, the combustion of fossil fuel by industrial activities, electric generators, dust particles from untarred roads and local combustion activities were identified as the main sources of air pollution in the study area.

8. Conclusion

The study showed that North-east wind and South-west wind dominated the study area in the dry and wet seasons respectively. Ambient temperature was higher in the dry season than in the wet seasons; while. Relative humidity was higher in the wet season than in the dry season.

Recommendations

The following recommendations were made based on the outcomes and findings of the study.

- Regular medical check-ups are required for residents of Onitsha metropolis.
- Air quality monitoring stations should be established around Onitsha metropolis.
- Further studies should be carried out to assess the impacts of air pollution on the health of the people of Onitsha metropolis.

Advanced modelling should be carried out to evaluate the nonlinear relationship between air pollutants and meteorological parameters.

Compliance with ethical standards

Acknowledgments

We acknowledge the contributions of the Director, staff and members of the Institute of Natural Resources and Environmental Sustainability University of Port Harcourt to the success of this research work. The immense contributions of Prof. Leo. O. Osuji and Dr. Vincent Wali are appreciated. Dr Mrs Bernadine Umunnakwe who assisted in reading and arranging the work deserve a thank you. Special recognition also goes to the field workers, laboratory and data analysts.

Disclosure of conflict of interest

There is no conflict of interest with the publication of the manuscript or an institution or product that is mentioned in this manuscript. There is also no conflict of interests with the products that compete with those mentioned here.

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