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Research Article

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Assessment of Particulate Matter-Based Air Quality Index in Port Harcourt, Nigeria

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Abstract

Due to the desire of nations to enhance their economic status, industrialization is vigorously pursued. Industrialization is historically associated with environmental degradation. In developing countries, due to lack of environmental awareness, the level of industrialization is not commensurate with environmental studies and monitoring. This study was designed to assess the status of particulate matter at three emerging industrial sites in Port Harcourt. To achieve this, Aerocet 531 monitor was used. To be able to communicate properly with the general public, data obtained were expressed in terms of Air Quality Index (AQI). The results showed that industrial sites had higher concentrations compared to the control for both $PM_{2.5}$ and PM_{10}. Seasonal variation of $PM_{2.5}$ and PM_{10} were observed with the dry season indicating concentrations higher than the local acceptable limits of 150 µg/m^3 and 230 µg/m^3. The AQI of the three emerging industrial sites indicated a category for 'good' to 'moderate' for wet season while for dry season, they varied from 'very unhealthy' to 'hazardous' in all the sampling areas. This poses a great threat to health and environment of the inhabitants.

Keywords: Air quality index; Index values; Air pollutants; Industrial areas; Port Harcourt

Introduction

One of the basic necessities and requirements of human existence is clean air [1,2]. Contamination of air arises from anthropogenic activities and natural events (e.g., volcano) which has been on increase due to industrialization and human quest for development. These activities release some gaseous emissions (SO_2, NO_2, CO, H_2S, VOCs and hydrocarbons) and particulates (smoke, soot, metallic, dust, fumes and aerosols) that contaminate air, and when in high concentrations could cause damage to environment and human health [3]. Industrial activities that contaminate air are distributed globally [4,5]. In Port Harcourt, one of the cities in Nigeria, only few studies have been conducted on the quality of air [6-9]. The few previous studies however presented air data and compared same with standard limits. Their data did not convey information on the air quality status to the public in an explicit manner. AQI has been developed to integrate air quality characteristics worldwide [10-13].

AQI is used for reporting daily air quality of how clean or polluted the air is and its associated health effects of concern [14]. It is obtained by evaluating measured pollutant concentrations into index values. Air Index value is the pollutant concentration expressed as a proportion of the threshold value. It makes it easier to interpret air quality data because it reduces the complexity associated with pollutant concentration. Index value over 100 suggests the pollutant concentration exceeds the air quality standard, and is considered to be unhealthy at first for certain sensitive groups of people, then for everyone as AQI values get higher. The AQI has always been used for five air pollutants: CO, SO_2, NO_2, $PM_{2.5}$ and PM_{10}. The aim of this study is to assess air quality index of emerging industrial sites in Port Harcourt.

Study area

Port Harcourt (latitudes 4°49/N, longitudes 7°2/E), the capital city of Rivers State, the hub of oil and gas industry in Nigeria is situated along the Bonny River. Its metropolis stretches from International airport at Omagwa and also from the Refinery at Eleme to Choba Community. The entire metropolis is an area between 1300 and 1800 km^2 with an active population of over six million people [15].

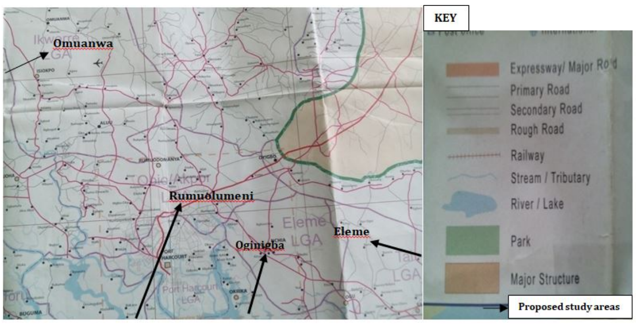

Figure 1: Map of the study area showing sampling locations.

The city has a tropical wet climate with long and heavy rainy season and very short dry season. The average monthly rainfall ranges between 20.7 and 434.0 mm, with an annual level of more than 3000 mm [15,16]. November to January is its lowest rainfall period while February to June is its first peak, followed by the second peak in September [16]. The temperature has little variation average between 25-28°C [15,16]. Three emerging industrial areas were selected namely Rumuolumeni (Rm), Oginigba (Og) and Eleme (El), and one non-industrial site at Omuanwa (Om), as control for sampling locations (Figure 1). Activities around these areas included commercial,

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construction works, cement-block molding industries, building infrastructures, dredging of white sand, and farming, alongside other non-point industrial activities.

Materials and Methods

Sampling: Twelve points were sampled for PM_{10}, $PM_{2.5}$, 3 points each from industrial areas and 3 points from the control. Potential air contaminants commonly used in AQI were measured in the study areas. The equipment used was potable digital hand held air monitors. These monitors include Aerocet 531 monitor for PM_{10} and $PM_{2.5}$ and Automated GPS for sampling points coordinates. All equipment was pre-calibrated before usage for quality assurance purposes. The air quality sampling was conducted in 2016 for wet and dry seasons.

Data analysis and interpretation

Mean levels of each air parameter were calculated using excel spreadsheet. The AQI was calculated for all the sampling areas using the daily average concentration of the measured parameters. The AQI is divided into six groups with a specific colour assigned to each in order to comprehend at first glance whether air contaminants are approaching unhealthy levels in the area (Table 1).

AQI	Levels of health concern	Colours
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for sensitive groups	Orange
151-200	Unhealthy	Red
201-300	Very unhealthy	Purple
301-500	Hazardous	Maroon

Table 1: Air Quality Index (AQI) values, health concerns and color codes. *Source: https://www.airnow.gov

The AQI was computed by a linear function by interpolating the concentration of the pollutant in the equation below:

$$Ip = I_{Hi} - I_{Lo} / BP_{Hi} - BP_{Lo} \, (C_p - BP_{Lo}) + I_{Lo}$$

*Source: https://stimulatedemissions.wordpress.com

Where I_{Lo}=the AQI of pollutant 'p'; C_p=the actual ambient concentration of the pollutant 'p'; BP_{Hi}=the breakpoint that is $\geq C_p$ (upper limit); BP_{Lo}=the breakpoint that is $\leq C_p$ (lower limit); I_{Hi}=the AQI value corresponding to BP_{Hi} and I_{Lo}=the AQI value corresponding to BP_{Lo}.

Results and Discussion

Details of GPS coordinates for Rm, Og, El and Om and their corresponding concentrations of particulate matter ($PM_{2.5}$) for both wet and dry season are provided in Table 2.

Results for particulate matter (PM_{10}) for the four sampled locations and their geo-locations are listed in Table 3.

Outputs from AQI model for wet and dry seasons are listed in Tables 4 and 5 respectively.

$PM_{2.5}$ µm

Concentrations of the <2.5 µm particulate matter for the wet season ranged from 8.90-22.40 µg/m^3, 18.70-34.75 µg/m^3, 11.05-31.35 µg/m^3 and 2.90- 7.85 µg/m^3 for Rumuolumeni, Oginigba, Eleme and Omuanwa, respectively (Table 2). Concentrations of <2.5 µm particulate matter for dry season ranged from 181.35-245.65 µg/m^3, 148.85-300.35 µg/m^3, 149.90-182.30 µg/m^3 and 143.80-156.75 µg/m^3 for Rumuolumeni, Oginigba, Eleme and Omuanwa, respectively (Table 2). The <2.5 µm particulate matter concentrations observed in this study for dry season were about ten times higher than those reported by Gupta [17] following satellite remote sensing of cities in India, Australia, Hong Kong, Switzerland and USA. However, the values, 16.25 ± 6.91 µg/m^3, 26.17 ± 8.08 µg/m^3, 22.75 ± 10.50 µg/m^3 and 5.52 ± 2.49 µg/m^3 observed for the four stations in this study are very similar to 16.2 ± 7.50 µg/m^3, 22.5 ± 13.50 µg/m^3, 15.20 ± 12.00 µg/m^3 reported by Gupta for Richmond, Australia, Lugano, Switzerland and New York, USA, respectively [17].

	$PM_{2.5}$ Concentration (µg/m^3)							
	Rm		Og		El		Om	
	N 04° 43' E 006° 57'-		N 04° 50' E 007° 02'-		N 04° 43' E 007° 06'-		N 05° 01' E 006° 52'-	
	N 04° 49' E 006° 57'		N 04° 50' E 007° 01'		N 04° 48' E 007° 06'		N 05° 02' E 006° 50'	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mean	16.25	222.95	26.17	199.7	22.75	174.62	5.52	150.27
Min	8.9	181.35	18.7	148.85	11.05	166.55	2.9	143.8
Max	22.4	245.65	34.75	300.35	31.35	182.3	7.85	175
Sd	6.91	36.08	8.08	87.17	10.5	7.88	2.49	9.16

Table 2: Mean, minimum, maximum and standard deviations of ($PM_{2.5}$) for both dry and wet seasons, where, Rm=Rumuolumeni; Og=Oginigba; El=Eleme; Om=Omuanwa.

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PM_{10} µm

Concentrations of the <10 µm particulate matter for wet season ranged from 30.85-82.75 µg/m^3, 42.80-65.50 µg/m^3, 22.60-135.50 µg/m^3 and 5.65-15.45 µg/m^3 for Rumuolumeni, Oginigba, Eleme and Omuanwa, respectively (Table 3). Concentrations for dry season ranged from 236.00-1926.30 µg/m^3, 940.25-1399.80 µg/m^3, 960.20-1154.45 µg/m^3 and 177.85-855.60 µg/m^3 for Rumuolumeni, Oginigba, Eleme and Omuanwa, respectively (Table 3). The observed values in this study showed that the concentrations in the dry season were more than thirteen times those of the wet season. However, the mean values of 54.17 µg/m^3, 50.40 µg/m^3 and 78.78 µg/m^3 for Rumuolumeni, Oginigba and Eleme respectively were higher than those reported by Jonathan [18] for Phoenix, in Arizona, Santa Ana-Anaheim, in California and in Los Angeles, with mean concentrations of 39.70 µg/m^3, 37.40 µg/m^3 and 46.00 µg/m^3 respectively.

	PM_{10} Concentration (µg/m^3)							
	Rm		**Og**		**El**		**Om**	
	N 04° 43' E 006° 57'-		N 04° 50' E 007° 02'-		N 04° 43' E 007° 06'-		N 05° 01' E 006° 52'-	
	N 04° 49' E 006° 57'		N 04° 50' E 007° 01'		N 04° 48' E 007° 06'		N 05° 02' E 006° 50'	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mean	54.17	1139.63	50.4	1099.45	78.78	1053.97	11.45	516.73
Min	30.85	236	42.8	940.25	22.6	960.2	5.65	177.85
Max	82.75	1926.3	65.5	1399.8	135.5	1154.45	15.45	855.6
Sd	26.35	851.2	13.08	260.27	56.45	97.3	5.14	479.24

Table 3: Mean, minimum, maximum and standard deviations of (PM_{10}) for both dry and wet season.

Seasonal variation

Higher concentrations of $PM_{2.5}$ and PM_{10} were observed in the dry than in wet season. This agrees with the studies carried out by Ede and Gobo [7,9]. The higher concentrations reported could be attributed a scavenging effect of the atmosphere and dissolving gaseous pollutants during the wet season [19,20]. Where there is high rainfall, air quality is generally better. The mean levels of particulate matters (PM_{10}) for dry season, in all the sampling areas were higher than the DPR limits of 150 and 230 µg/m^3; while within for $PM_{2.5}$. There was significant difference between the wet and dry season ($p<0.05$). The particulate matters in all the sampling locations were higher in the industrial areas than Omuanwa, the control, being the non-industrial site. Studies have shown that suspended particulate matter in industrial zones are higher due to wind-blown dust from roads, emissions from machineries in the industry and industrial vehicles [21,22]. Comparatively, the means levels of PM_{10} obtained in wet and dry seasons followed the trend Rm>Og>El>Om.

Particulate matter may cause damage by discoloring or destroying painted surfaces, corrode metals and building surfaces, soil, textiles and clothing. It may lead to climate change such as net cooling for refractive particles while some (soot) absorb energy and lead to warming and other change in timing and location of traditional rainfall pattern. Particulate sources include electric power plants, industrial facilities, automobiles, biomass burning and fossil fuels used in homes and factories for heating.

Air Quality Index (AQI) of the pollutants

The AQI of the pollutants were obtained in order to evaluate the health risks which the public are exposed to due to air pollution. The results of AQI data for the four locations are presented in Tables 4 and 5 for wet and dry seasons respectively. The health message for wet season ranged from good in Om to moderate in all the industrial areas with maximum being 80 and 23 as minimum, the AQI for the day was $PM_{2.5}$. Table 5 indicates the AQI for the day to be PM_{10} with health message varied from very unhealthy in $PM_{2.5}$ to hazardous in PM_{10} in all the study areas.

Nwaogazie and Zagha [23] reported that the AQI of all study areas in Port Harcourt, in exception of Bodostreet or new GRA, posed serious health risks to individuals who spent long hours and those sensitive groups such as asthmatics, children and elderly, people with heart or lung diseases were at highest risk [23]. Airborne particulate matter has negative effect to health [24] and has previously been estimated to cause between 3 and 7 million deaths every year, primarily by creating or worsening cardio-respiratory disease [25].

	$PM_{2.5}$	**PM_{10}**	**AQI for the day**	**Pollutant that characterize the AQI**	**Colour code**	**Category**
Rm	60	50	60	PM2.5	Yellow	Moderate
Og	80	46	80	PM2.5	Yellow	Moderate
El	73	62	73	PM2.5	Yellow	Moderate
Om	23	10	23	PM2.5	Green	Good

Table 4: Air Quality Index (AQI) for wet season.

	$PM_{2.5}$	**PM_{10}**	**AQI for the day**	**Pollutant that characterize the AQI**	**Colour code**	**Category**
Rm	273	>500	>500	PM10	Maroon	Hazardous
Og	250	>500	>500	PM10	Maroon	Hazardous
El	225	>500	>500	PM10	Maroon	Hazardous
Om	225	>500	>500	PM10	Maroon	Hazardous

Table 5: Air Quality Index (AQI) for dry season.

Conclusion

Results of our assessment of atmospheric particulate matter at the three emerging industrial sites indicated higher concentrations compared to our control for both $PM_{2.5}$ and PM_{10}. $PM_{2.5}$ and PM_{10} data from this study indicated seasonal variation with the dry season indicating concentrations higher than local acceptable limits of 150 μg/m^3 and 230 μg/m^3. The AQI of the three emerging industrial sites indicated a category for 'good' to 'moderate' for wet season while for dry season, they varied from 'very unhealthy' to 'hazardous' in all the sampling areas. The activities of some of the industries located at these emerging industrial sites may be contributing particulate matter of human health relevant sizes into the atmosphere. People with respiratory disease, such as asthma, may be affected if they are exposed to particulate matter at the emerging industrial sites. There should be regular monitoring of air quality at new industrial sites like the ones investigated in this study.

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