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SPATIOTEMPORAL ASSESSMENT OF AIR QUALITY IN SELECTED LGA IN RIVERS STATE

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Abstract - The pollution of ambient air has long been revealed as the most fatal form of environmental pollution. The levels of air pollution vary from one location to another and from time to time. This study investigated the spatiotemporal distribution of air pollutants in Port Harcourt metropolis. Nine points in the study area were purposefully sampled within two pick-periods (8 am and 4 pm), based on high industrial clusters, high vehicular traffic, and rising human population density. The concentrations of $PM_{2.5}$, PM_{10}, CO, SO_2, and NO_2 were measured using a hand-held Gas analyser; Aerocet-531 Met One Instrument, Drager X-am 5000. A handheld Germin-300 GPS device analyzer to record the GPS coordinates of the sampling points which aided the data processing, to develop spatial interpolation maps in ArcMap. The results of air quality parameters were above the WHO and FMEnv air quality standards. $PM_{2.5}$ and PM_{10} have a maximum value of 159.23 and 378.39 respectively which is higher than the WHO and FMEnv Standard limits for 24 hours exposure. The recorded exceedance is 68.5ppb, 28.7ppb and 113.7ppb for SO_2, NO_2, and CO respectively, in the wet season. Also, 71.1ppb, 15.31ppb and 58.9 ppb for SO_2, NO_2, and CO respectively in the dry season, are higher than WHO and FMEnv limited. Based on these, it is recommended that the populace of Port Harcourt city should limit their exposure, especially in the dry season.

Keyword: Ambient Air, Air Pollutants, Spatiotemporal Assessment, Air Quality Index.

I. INTRODUCTION

Air pollution occurs when excessive/harmful substances are introduced in the atmosphere which lowers the quality of air and affects the quality of life. The pollution of ambient air has long been revealed by WHO, as the most fatal form of environmental pollution. This is because of the increasing pollution levels as a result of urbanization, industrialization and population growth. National Ambient Air Quality Standards (NAAQS) for six principal pollutants which are called "criteria pollutants: Nitrogen dioxide (NO2) Carbon monoxide (CO), Sulphur Dioxide (SO2) Lead (Pb), Ozone (O3) and Particulate Matter (PM), concentrations in Lima Ohio using the US EPA recommended software. The study utilizes Geographic Information Systems (GIS) to visualize predicted concentrations of air pollutants for a desired geographic area and prepare maps to categorize the ambient air quality according to NAAQS and the World Health Organization (WHO) guidelines. Air pollution globally has received considerable attention from local and global communities. Many developed cities have established air quality monitoring stations except the underdeveloped cities in developing countries like Nigeria, but these stations tend to be scarcely distributed and do not provide sufficient tools for mapping atmospheric pollution since air quality is highly variable (Khare, 2012).

Vehicular emissions, legal/illegal refineries and use of generators have negatively affected air quality in Por Harcourt and environs. The Year, 2016 was the era of seasonal soot precipitation affecting surfaces and causing severe panic among residents. Air pollution contributes to an estimated 7 million deaths worldwide every year (WHO, 2010). Till the time of this study, there was still soot precipitation especially in the dry season of the year. Reoccurring seasonal soot precipitation in Port Harcourt motivated the two assessments (Akinfolarin, Boisa, & Obunwo, 2017).

The aim of the study is to assess the spatiotemporal variation of air quality parameters in selected locations of Port Harcourt. The aim is achieved using the underlisted objectives. To achieve the aim, the underlisted objectives were pursued: To assess the seasonal variation of air quality parameters in the study area. To analyse the spatial variability of air pollutant concentration in both wet and dry. To correlate the air quality index of both seasons within Port Harcourt to generate spatiotemporal maps. To visualize the spatial distributions of air pollutants within the studies including NO2, CO, PM10, PM2.5, and SO2.

Description of Study Area

Port Harcourt is the capital of Rivers State, Nigeria.

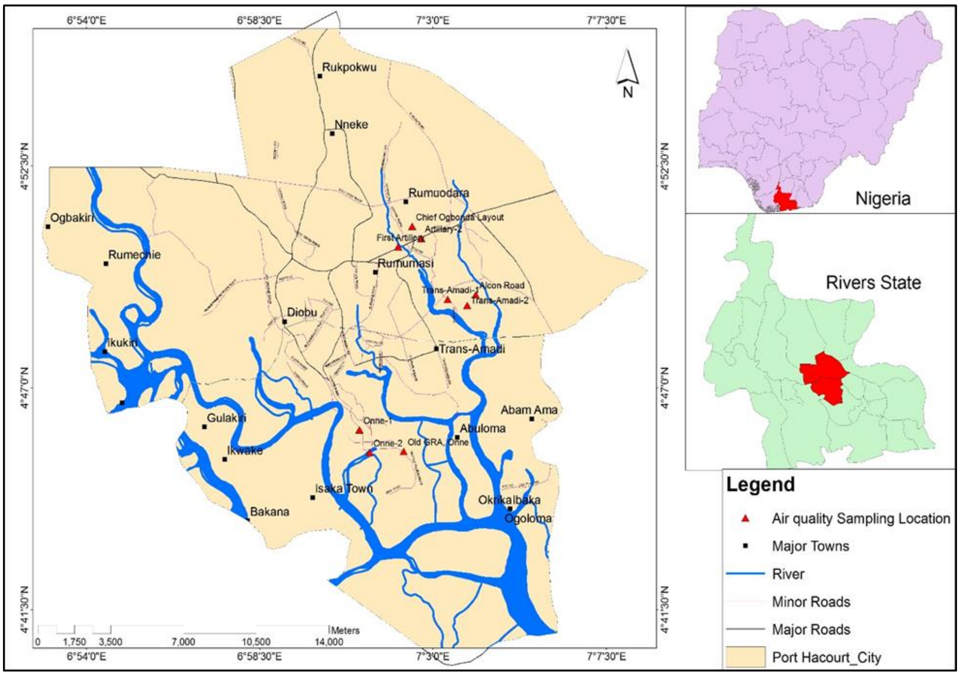

Figure 1: Map of the study area showing sampling locations

It lies along the Bonny River (an eastern distributary of the Niger River) 66km upstream from the Gulf of Guinea (Ugochukwu, 2008). Port Harcourt City due to the current urban expansion has extended and covered both Port Harcourt and Obio/Akpo LGA. The City lies within Latitude 4052'30"N to Longitude 6054'30" and Latitude 4041'30"N to longitude 705'30"E. Port Harcourt has an estimated population of 1,865,000 inhabitants (Okonkwo, Okpala, & Opara, 2014). Average temperatures are typically between 250 - 280 Celsius in the city.

A study on the wind energy potentials for a number of Nigerian cities shows that the annual wind speed ranges from 2.32 m/s for Port Harcourt (Okonkwo et al., 2014). The Deltas and estuaries, with their saline wetlands, have a total surface area of 858,000 hectares, while freshwaters cover about 3,221.500 hectares (Nwilo & Badejo, 2005). Other water bodies, including small reservoirs, fishponds and miscellaneous wetlands suitable for rice cultivation cover about 4,108,000 hectares (Kuruk, 2004).

II. TYPES AND SOURCES OF DATA

In-situ air pollutants were measured in the atmosphere within the study area. Parameters such as Carbon monoxide (CO), Nitrogen dioxide (NO2), Particulate matter (PM2.5 and < PM10), Sulphur oxides(SO2), were collected. Also, the GPS at the collection point of air quality data in the study area was recorded for further geospatial interpolation analysis using ArcMap 10.0.

The primary data of this study was acquired through field data gathering in the study area.

These include the in-situ measurements of the air quality parameters in the study area. The data was acquired at purposefully selected locations using hand-held Gas analyser; Drager X-am 5000 and a Handheld Germin-300 Global Positioning System (GPS) device to record the GPS coordinates of the sampling points. The concentrations of air quality parameters selected for this study which include PM2.5, PM10, CO, SO2, and NO2 were measured at the sampling locations using a hand-held Gas analyser; Aerocet-531 Met One Instrument. The sources of secondary data used include literature and climatic data acquired from published journals, gazettes, brochures, Internet and statistical publications of the Environmental Protection Institutions and Nigerian Metrological Agency. The air quality monitoring devices and the software used for geospatial analysis are two basic categories of tools used for this study.

The air quality monitoring devices include Garmin X300, a hand-held Global Positioning System. This was used in this study to determine the geo-reference coordinates of each sampling point for both the dry and wet season data acquired at in-situ from the study area (Jensen Steen Solvang, 1999; Kelly & Fussell, 2015). The Germin 300 GPS, Aerocet-531 device and Drager X-am 5000, handheld devices used for this study was calibrated before use for field measurements. The tools were calibrated. Aerocet-531; is a handheld battery-operated particle counter. It was used to monitor PM2.5 and PM10.

Drager X-am 5000, hand-held air-quality monitoring equipment was used in this study to measure Carbon monoxide, Nitrogen Oxides, and Sulphur dioxide (Zagha & Nwaogazie, 2015). The AQI was computed by using the pollutant concentration data and the linear interpolation equation (Equation 1):

$$I_p = \frac{I_H - I_L}{BP_H - BP_L} (C_p - BP_L) + I_L \quad \text{.......................... (1}$$

Where: I_p = the index of pollutant, p;
C_p = the rounded concentration of pollutant p;
BP_H= the breakpoint that is greater than or equal to Cp (upper limit);
BP_L= the breakpoint that is less than or equal to Cp (lower limit);
I_H= the AQI value corresponding to BPH; and
I_L= the AQI value corresponding to BPL.

Table 1.: AQI Values, Health Colour, and Concerns Codes.

Air Quality Index (AQI)	Levels	of Colors
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy	Orange
151-200	Unhealthy	Red
201-300	Very	Purple
301-500	Hazardous	Maroon

Source: www.airnow.gov

III. RESULTS AND DISCUSSION

Results

The entire analysis and results of the air quality of Port Harcourt and the Spatiotemporal comparison of wet and dry season data of air quality in the study area in 2018 are presented in this chapter. The results are displayed in maps below.

The mean values of air quality parameters were calculated using the MS Excel Spreadsheet. The results were subjected to Spatiotemporal analysis which was revealed in maps showing the spatial distribution of air quality parameter concentration in maps. Bar charts were developed with the air quality parameter data to compare the variation in the concentrations of wet and dry season air quality data and the different parameters assessed at the different sampling locations in the study area.

Atmospheric Weather Conditions

Average wind speed in Port Harcourt ranges from 1-6m/s and 0.5-2.m/s during the day and night, respectively, and can be higher during occasional periods of storms and squalls. Figure 4.1 and Figure 2 revealed the dominant wind directions in Port Harcourt for the most part of the year and the wind speed.

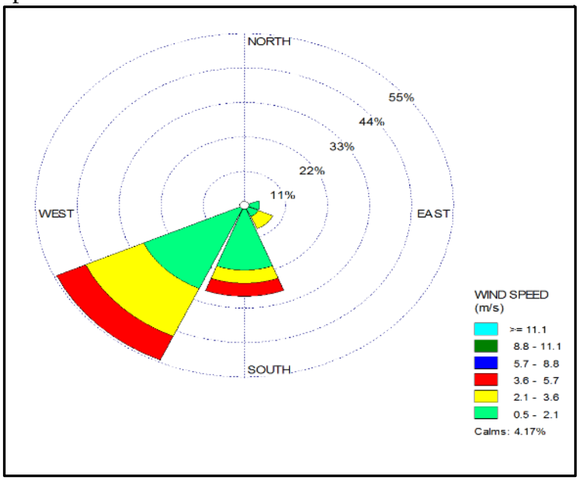

Figure 2: Diurnal wind rose pattern in Port Harcourt
Source: (Ede & Edokpa, 2017)

It has been determined that the atmospheric boundary layer stability conditions in Port Harcourt are very stable at night and unstable during the day (Edokpa & Ede, 2013).

The implication of these emissions concentrations around Port Harcourt is that ground-level concentrations will be low for sensitive receptors under unstable atmospheric conditions during the day and severe for sensitive receptors under stable conditions at night (Edokpa & Ede, 2013).

Spatiotemporal Analysis of PM_{10}.

The results obtained from the field monitoring of air quality in the study area in January and September

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2018 for both dry and wet seasons respectively, PM_{10} was subjected to spatial interpolation analysis using the Inverse Weighted model (IDW) tool in ArcGIS. It revealed that the concentration of PM_{10} was high in the city centre in both seasons.
Lower concentrations considered to be moderate by air quality index were observed in the residential estates within analyzer Trans-Amadi location (Northern/western part) of the city in the wet season. Lower concentration was also noticed towards the southern part of the city. Thus, this could be as a result of the variations in the activities in the area at different study periods (see Figure 3). For instance, nearly all industrial processes, as well as the burning of fossil fuels, release particulate matter into the atmosphere (Danish, 2013; Jaffe, 1968).

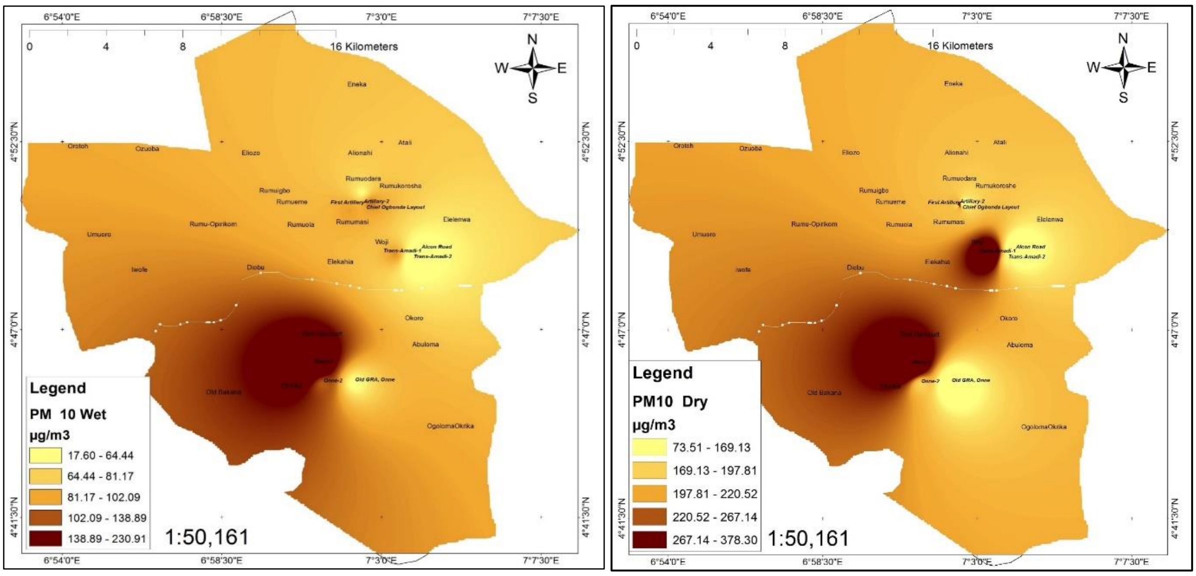

Figure 3: Spatiotemporal Variation of PM_{10} ($\mu g/m^3$)

In conclusion, the PM_{10} from Figure 3 revealed that Onne, Trans-Amadi, and Artillery were locations dictated to have a very high concentration above the WHO and FMEnv exposure limits. This concentration followed the same trend in the two seasons. The Spatiotemporal distribution followed the same trend of dispersion and this was further evaluated using a T-test statistical tool. Particulate matter encompasses the small solid or liquid substances that are released into the atmosphere through many activities.

Spatiotemporal Variation of $PM_{2.5}$

From figure 4 above, it was revealed that areas around Onne and Trans-Amadi have a very high concentration of $PM_{2.5}$. the range for the dry season was identified as 34.1 $\mu g/m^3$ to 159.07 $\mu g/m^3$ whereas these values generally reduced in the rainy season. The ranges for the rainy season are from 2.5 $\mu g/m^3$ to 80.4 $\mu g/m^3$. this shows that pollution is higher in dry season than the rainy season. This also seen in the seasonal precipitation of soot in the city. See figure 4 below for the spatial distribution in the study area.

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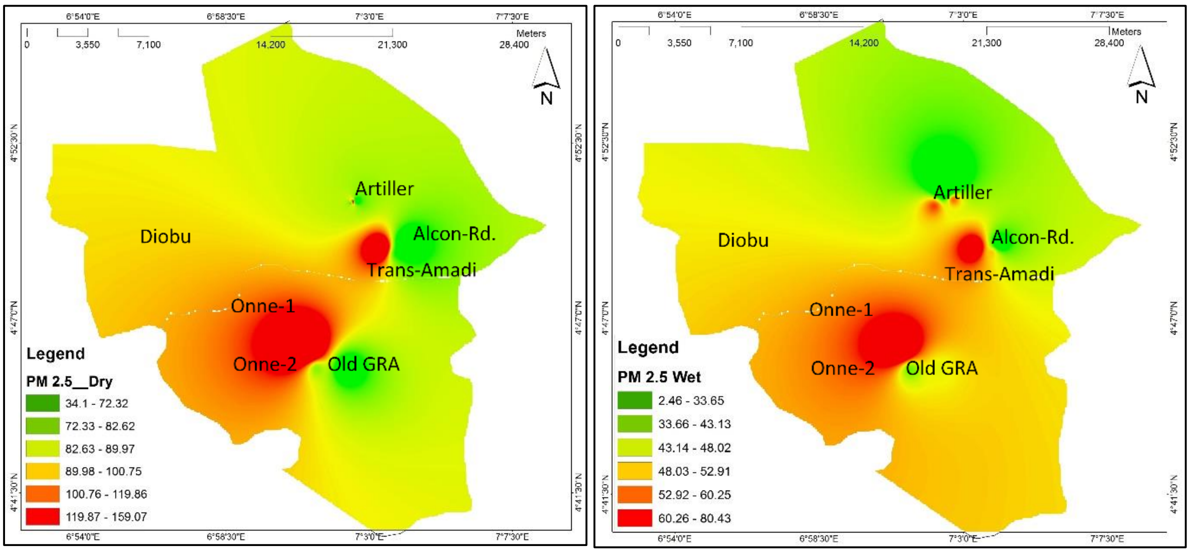

Figure 4: Spatiotemporal Variation of $PM_{2.5}$ ($\mu g/m^3$)

Also, on the other hand the areas that appeared lower in concentration are the second artillery point and the point within Alcon road in Woji and Old GRA. These areas have many vegetative covers as they are well planned with low economic activities.

Spatiotemporal Analysis of Nitrogen Dioxide (NO_2).

Fig. 5 shows the Spatiotemporal distribution of nitrogen dioxide concentration in the study location for both dry and wet monitoring seasons.

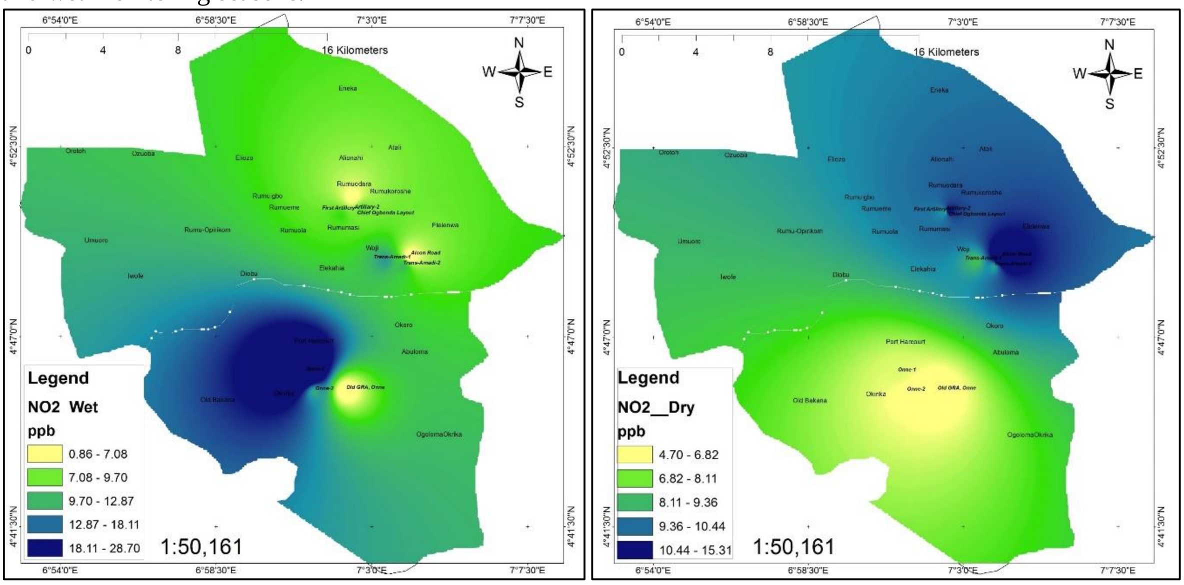

Figure 5: Spatiotemporal Variation of NO_2 (ppb)

The results of the IDW analysis revealed a high concentration of nitrogen dioxide in the Northern region, but lower concentration at both the city centre and southern parts of the study area.

The spatiotemporal distribution of the results revealed that the lowest value was recorded in the Old-GRA of the city for both seasons of the study, whereas in the dry season there are several factors that can possibly contribute to the increasing trend at these points in their study year such as its central location with the junction of major roads and a cluster of minor roads at the North. As regards the Southern part of the city is not the centre of the city and thus has fewer local vehicles and major oil and gas flaring as compared to other locations. Also, these areas that are lower in concentration was observed to be above FMEnv and WHO limits of exposure. Moreover, the data levels of nitrogen dioxide are consistently below the DPR and NAAQS air quality goals in the study region.

Spatiotemporal Analysis of Sulphur Dioxide (SO_2).

Figure 6 below shows the spatiotemporal distribution of concentration of the sulphur dioxide in the study area at the period of monitoring.

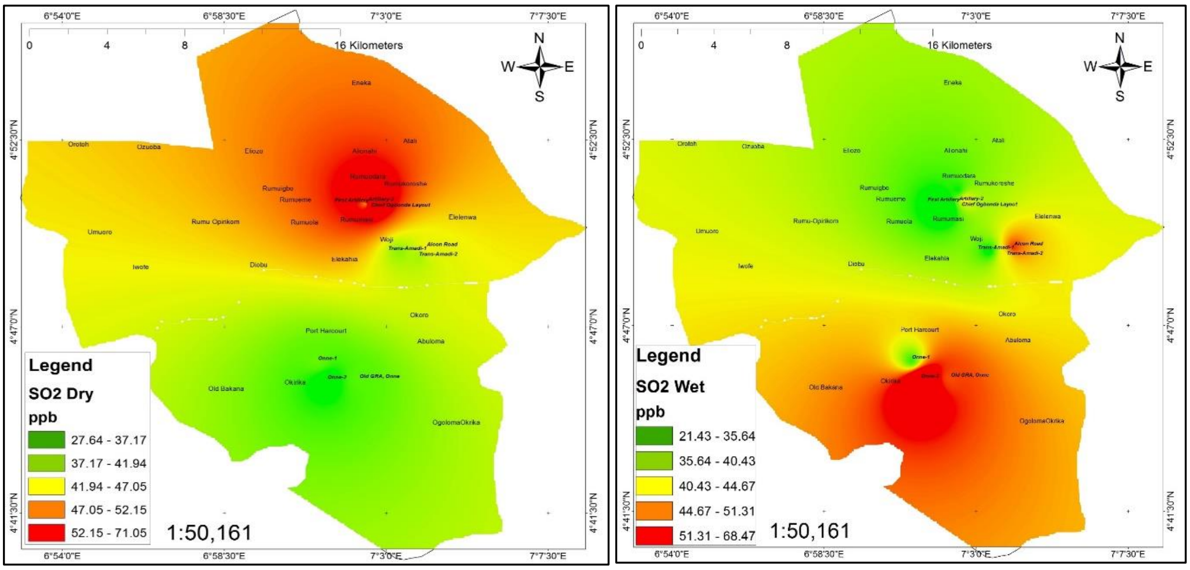

Figure 6: Spatiotemporal variation of SO_2 (ppb)

The SO_2 concentration observed from the sampling location was in the range of 21.43ppm to 68.47ppm for the wet season. While in the dry season it was discovered that the range was spatially distributed in the area from 27.64ppm to 71.05ppm. The highest concentration of SO_2 was discovered from the city centre towards the northern part of the study area. Based on the dry season survey, the reason for the high concentration value could be attributed to the surrounding activities in the neighbouring areas like illegal refining and flaring of gases. And traffic congestion was observed at the road intersections, where the long waiting time for vehicles was observed. Thus, the wetness of the area dilutes these gases during the raining season. Hence the concentration is reduced but above WHO and FMEnv exposure limits

Spatiotemporal Analysis of Carbon Monoxide (CO).

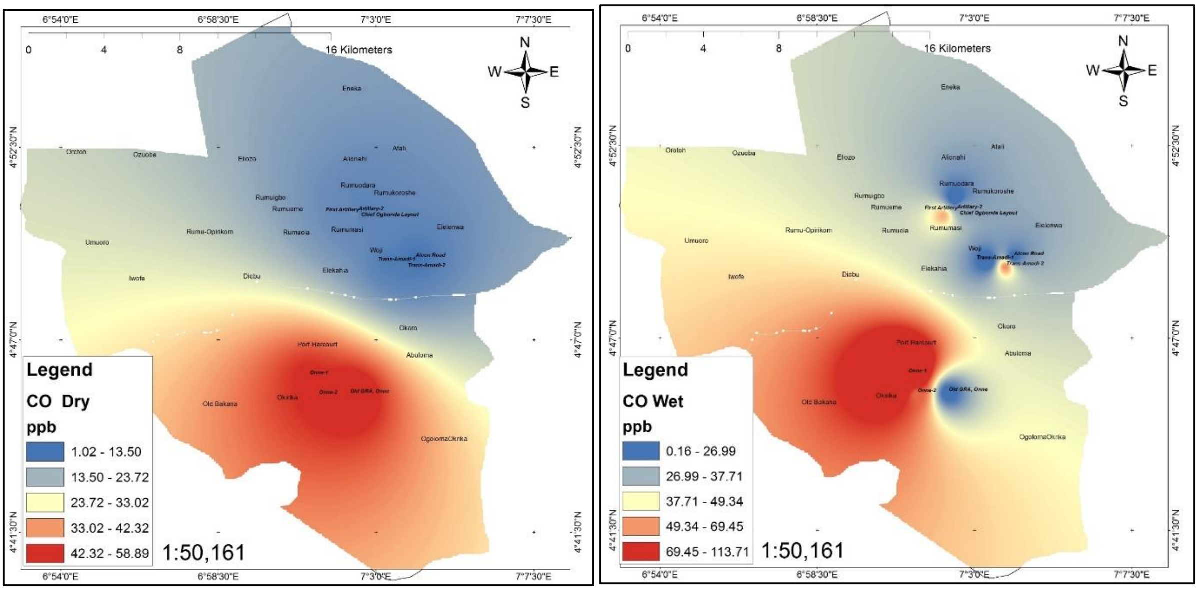

Figure 7: Spatiotemporal Variation of CO (ppb)

Figure 7 revealed the distribution CO in the study area for both dry and wet season in 2018. The result of the spatiotemporal analysis for the two study seasons followed the same trend revealing that the northern part of the city has the highest concentration of CO in the study area. Carbon monoxide was observed to be high in concentration within the Old GRA in the dry season with an average value of 58.89 ppb. This is above normal exposure in the study location. While in the wet season the concentration of CO reduced in comparison with the location with the highest concentration value in dry season result but a higher value was dictated at Onne. According to the field survey, the concentration of CO ranges from 0.98 to 114.3 ppb.

Air Quality Index Mapping of the Study Area

From the AQI model of PM 2.5 of both the rainy and dry season, it was discovered that all sampling locations exhibited unhealthy air quality.

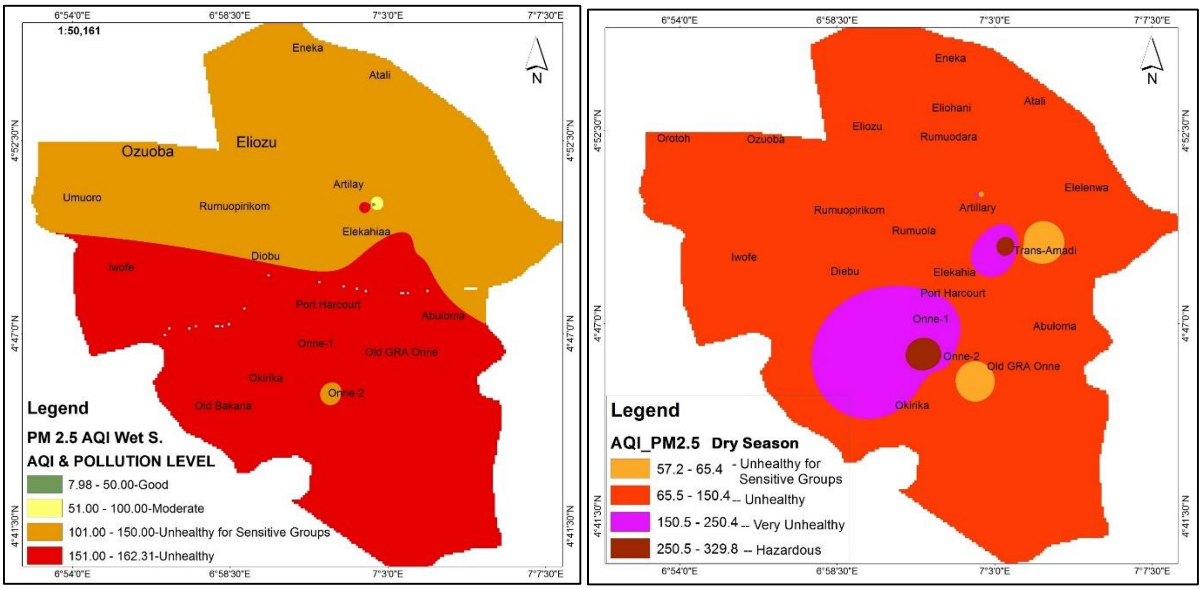

Figure 8: AQI Map of $PM_{2.5}$ of the study area for Wet and Dry Season.

However, the spatiotemporal AQI model revealed that air pollution in the dry season was hazardous and very unhealthy for sensitive locations in the study area. Locations like Trans-Amadi and Onne, exhibited very hazardous air pollution level with an AQI range of 250.5 to 329.8, while locations like Artillery was recorded to be very unhealthy with AQI range of 150.5 to 250.5.

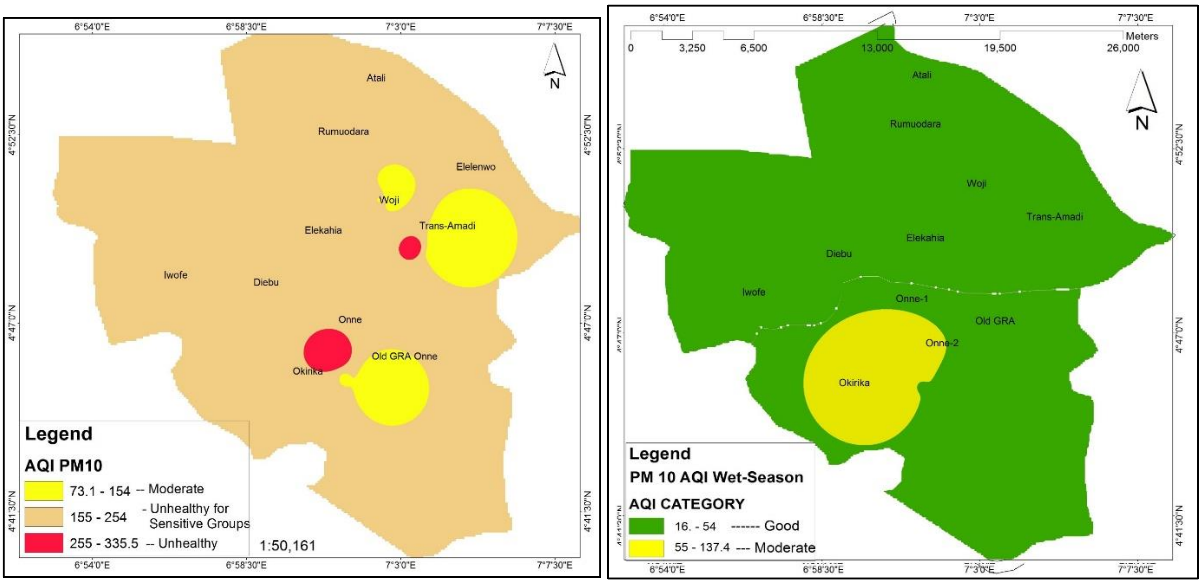

Figure 9: AQI Map of PM_{10} of the study area for Wet and Dry Season.

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There are implications of health concerns for different AQI values obtained from air quality assessment studies which help in the level of the cautionary measure raised for the public health concern in the study area. These health concerns include the following:

1. Good has minimal health impact based on the AQI value and ranges, but from 51 to 100 could cause minor breathing discomfort to sensitive people.
2. Moderate values of Air Quality Index values cause breathing discomfort to the people with lung, heart disease, children and older adults.
3. The rank classified as unhealthy for sensitive groups appears in the AQI category of 201 to 300 and it could cause breathing discomfort to people on prolonged exposure.
4. Very poor AQI values of 301 to 400 are classified unhealthy and could cause respiratory illness to the people on prolonged exposure.

4001 AQI values are classified as severe and are of hazardous effects. This could cause respiratory effects even on healthy people.

4.4 Statistical Analysis of Air Quality.

Table 2. displayed the correlation between all air quality parameters sampled in the study area. NO_2 was significantly correlated with SO_2 with correlation coefficient (r) = 0.6 at p = 0.05 (2-tailed). This implies that the independent variable can predict the dependent variable with 60% accuracy. But the relationship was directly proportional. Although there was a negative correlation between NO_2 and PM_{10}, $PM_{2.5}$, and CO. there was a positive significant correlation between PM_{10} and $PM_{2.5}$ with the correlation coefficient of 0.99 at P equal to 0.05. PM_{10} was significantly correlated with CO with a correlation coefficient (R) = 0.084 at 5 percent level of confidence. $PM_{2.5}$ was observed to have a significant correlation with CO with a correlation coefficient of 0.121 at a 5 percent level of confidence.

Table 2: Correlation of air quality parameters sampled in the study area

	NO2 (ppb) W	*SO2 (ppb)W*	*PM10 (µg/m3) W*	*PM2.5 (µg/m3) W*	*CO (ppb) W*
NO2 (ppb) D	1				
SO2 (ppb) D	0.602864	1			
PM10 (µg/m3) D	-0.47255	-0.22787	1		
PM2.5 (µg/m3) D	-0.49246	-0.22122	0.997397	1	
CO (ppb) D	-0.76917	-0.62634	0.084088	0.121793	1

Direction for interpretation

* Significance @ 10% i.e ≤ 0.1
** Significance @ 5% i.e ≤ 0.05
*** Significance @ 1% i.e ≤ 0.01
Each parameter with "d" is for dry season
Each parameter with "w" is for wet season

Table 3: Correlation between PM_{10} of Dry and Wet season

	PM10 (µg/m3) Wet	***PM10 (µg/m3) Dry***
PM10 (µg/m3) Wet	1	
PM10 (µg/m3) Dry	0.520148	1

There was a significant correlation between the PM_{10} of data acquired in Wet season and that of Dry Season with the correlation coefficient (R) of 0.5 at 0.05 level of confidence.

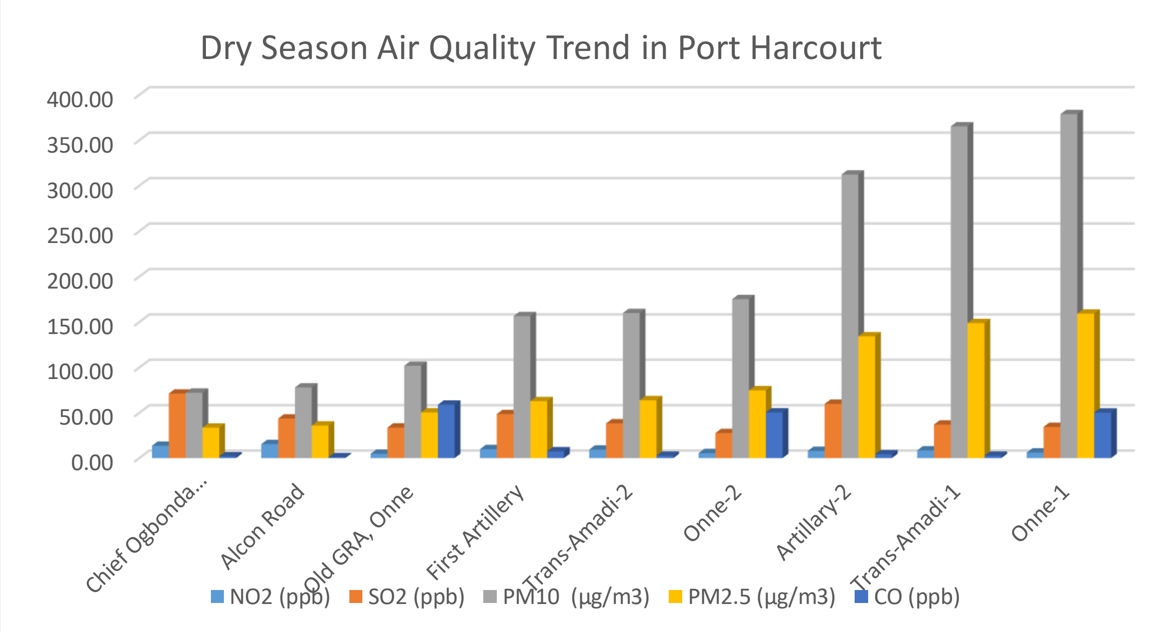

Figure 10A: Variation of Air Quality parameters in Dry Season.

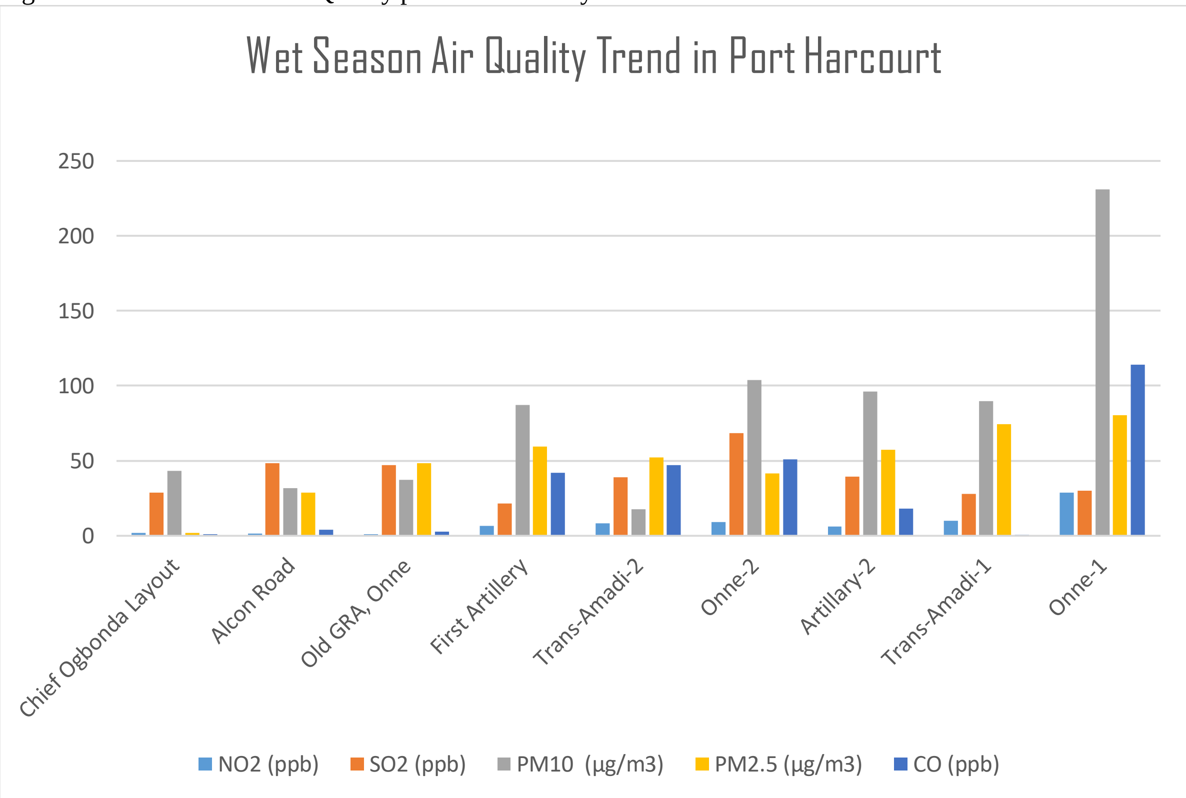

Figure 10B: Variation of Air Quality parameters in the Wet Season.

Figure 10A and Figure 10B revealed that air pollution exists in high concentrations in a busy location and lower in the location of low movement and fewer activities. This conclusion was drawn from the variations observed from the bar charts where areas of high commercial activities are noted to be very high in concentration and are above WHO and FMEnv standards. Generally, all the results of Air quality parameters are above the WHO and FMEnv Air Quality Standards. $PM_{2.5}$ and PM_{10} have a maximum value of 159.23 and 378.39 respectively which way higher than the WHO and FMEnv. Standard limits for 24hours exposure. Also, SO_2, NO_2, and CO recorded values higher than FMEnv. and WHO standards in most locations sampled and their spatiotemporal analysis showed a similar trend

of the spatial and temporal distribution of Air Quality parameters (Ibe, Njoku, & Opara, 2016).
It is noted that some parts of Onne have an Artisanal refinery which is usually set ablaze by police and this burning or explosion of hydrocarbon material from illegal or Artisanal refinery, gas flaring and excessive vehicular emission in and within the city surrounding causes the heavy carbon soot pollution in Port Harcourt.

IV. CONCLUSIONS AND RECOMMENDATIONS

In summary, the high emission values of Carbon monoxide and Suspended particulate matter was because of the regular explosion and vandalization of oil facilities in Port Harcourt and greatly from artisanal refinery operations within the city periphery. A greater percentage of the areas mapped for $PM_{2.5}$ revealed unhealthy. Geospatial interpolation suggested hotspots of air pollution resulting in exceedance recorded in the study. 68.5 (µg/m3), 28.7(µg/m3) and 113.7(µg/m3) for SO2, NO2, and CO respectively, in the wet season. Also, 71.1(µg/m3), 15.31 (µg/m3) and 58.9(µg/m3) for SO2, NO2, and CO respectively in the dry season. The concentrations of the monitored indices are higher in the dry season and lower in the rainy season. PM2.5 and PM10 have a maximum value of 159.23 and 378.39 respectively which is higher than the WHO Standard limits for 24 hours exposure. Based on the Spatiotemporal distribution of the discussed results, the major high pollutants are from the explosion of artisanal refinery operations in Port Harcourt. These activities occur within the creeks surrounding the city metropolis.

Port Harcourt being rated as one of the fastest-growing economic city, in Nigeria. Nigeria as a developing nation is experiencing increased energy demand and other environmental resources (Molina, 2010), the prevention of air degradation by means of controlling atmospheric emissions has become a necessary responsibility. Following the results discussed in the previous chapter and conclusions drawn from this study, the following recommendations are made:
There should be strengthened and regular monitoring of air quality within the city, also implementation, monitoring and improvement of standards to effectively check operational as well as illegal activities that have the potential for adverse environmental outcomes. Industrial operators should adopt a more pragmatic approach towards technological and procedural improvements aimed at environmental sustainability.
The general public sensitization should be encouraged and regular power supply should be done to enable the public to reduce the rate of using generating set for power supply in their neighbourhood to reduce the emission of carbon and other unfriendly gasses that pollute the atmosphere. Additionally, adequate preventive measures like air purifiers may be installed inhabitable spaces like homes and offices.

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