International Journal of Environment and Pollution Research
Vol.11, No.1 pp.24-42, 2023
Print ISSN: 2056-7537(print)
Online ISSN: 2056-7545(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Assessment of Air Quality Parameters in Selected Road Intersections in Port Harcourt, Nigeria: A Case Study of their Potential Impacts on Terrestrial and Aquatic Environment

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doi: https://doi.org/10.37745/ijepr.13/vol11n12442 Published Februarys 18, 2023

Citation: Akankali J. A., Chukwuma B., Ambrose I. S., Unyime U. S. (2023) Assessment of Air Quality Parameters in Selected Road Intersections in Port Harcourt, Nigeria: A Case Study of their Potential Impacts on Terrestrial and Aquatic Environment, *International Journal of Environment and Pollution Research*, Vol.11, No.1 pp.24-42

ABSTRACT: *Selected air quality parameters (SO_2, NO_2, CO, $PM_{2.5}$ and PM_{10}) concentrations were measured at selected road intersections within the study area. SO_2, NO_2, CO, $PM_{2.5}$ and PM_{10} were found to be above permissible limits of Federal Ministry of Environment (FME) and WHO, while CO was within the limit at all sampling stations. The result of the statistical analysis showed that the P-value was less than 0.05 (level of significance) in $PM_{2.5}$ and PM_{10} parameters, which imply that these air quality parameters were significantly different from the FME limits. Similarly, NO_2 and SO_2 results showed significant differences when compared with FME standards. Generally, the results showed that the concentration the assessed pollutants were significantly higher than the recommended Nigeria FME limits. Thus, they constitute potential sources of health hazards to humans and aquatic flora and fauna within the water bodies in the study area. Routine monitoring of these air quality parameters and advocacy on their impacts on terrestrial and aquatic environment cum organisms amongst others, were recommended as a way of reducing air pollution within the study area.*

KEY WORDS: air, quality, impacts, terrestrial, aquatic, environment

INTRODUCTION

Air pollution is fast becoming an increasingly dreadful issue in many cities across the world. Air quality is a yardstick of how clean or polluted the air is. Monitoring air quality is important because polluted air can be bad for our health and the health of the environment. Air pollution can be described as any atmospheric substances in form of gases or particulate and particles of biological origin present in concentrations harmful to man and the environment. Pollution is a global health hazard with serious public health implications, particularly for children and elders. Air pollution is one of the most severe problems facing both developing and developed countries. Most of the cities in developing countries experience outdoor air pollution impact due to industrial emissions and lack of maintenance of vehicles (Chauhan and Pawar, 2010). Urban areas have experienced deterioration in air quality and an increase in health and environmental impacts. Several scientific studies have confirmed that a large number of premature deaths, so also respiratory and cardiovascular diseases, are caused by air pollution (Bahino *et al*., 2018).

Alvarez *et al*. (2020) found the health-related consequences of air pollution (especially particulate matter—referred to as $PM_{2.5}$ and PM_{10} when the particle diameters measure less than 2.5 or 10 micrometers, respectively—can affect both respiratory and cardiovascular health through conditions, such as chronic obstructive pulmonary disease, myocardial infarction, stroke, and cancer) to have been well established over recent years. Gaseous air pollutants that are expelled through anthropogenic activities, namely nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), and volatile organic compounds (VOC), have also been shown to increase cardiovascular and respiratory mortality and morbidity (Newell *et al*., 2017; Cheng *et al*., 2018); these air pollutants further harm human health by affecting the environment through acid rain (Adon *et al*., 2016).

According to Akimoto (2015), the atmospheric lifetime of CO can take average of one to two months to allow intercontinental transport and hemispheric air pollution. A significant portion of CO pollution is from automobiles and biomass burning (Omasa *et al*., 2012). Global pollution by CO is worrisome because of its effect on the oxidizing capacity of the atmosphere (Akimoto, 2015). From 1968 to 1998, the US Centers for Disease Control reported that non–fire-related CO poisoning caused or contributed to 116,703 deaths, 70.6% of which were due to motor vehicle exhaust and 29% of which were unintentional (Koa *et al*., 2006). Although most accidental deaths are due to house fires and automobile exhaust, consumer products such as indoor heaters and stoves contribute to approximately 180 to 200 annual deaths (Mott *et al*., 2002). Unintentional deaths peak in the winter months, when heating systems are being used and windows are closed (Kao *et al*., 2006). A study done by Amancio and Nascimento (2012) suggested that SO_2 can cause cardiovascular disease due to increases in daily levels of SO_2 exposure. Under high SO_2 concentrations, crops greenhouses can be damaged within a few hours. Thus, if greenhouse SO_2 concentration is not managed well, it is potentially harmful for both crops and farmers (Lee *et al*., 2017).

As the urban population increases, an increasing amount of people are becoming susceptible to suffering from these health effects (Adon *et al*., 2016). A study that was conducted in Senegal, identified the links between poor air quality and conditions, like asthma and bronchitis, especially in urban regions (Toure *et al.*, 2020). Air pollution also leads to millions of preventable deaths each year, approximately 4.2 million in 2016 (WHO, 2020). According to Manisalidis *et al*. (2020), the bulk of environmental pollutants evolve from large-scale anthropogenic activities such as the use of industrial machinery, power-producing stations, combustion engines, and vehicular traffic. These activities are brought off at such a large scale posing as major contributing factors to air pollution, with vehicular traffic being responsible for approximately 80% of air pollution. Air pollution affects those living in large urban areas, where road emissions contribute the most to the degradation of air quality Kelishadi and Poursafa, 2010).

WHO (2021) estimated over 90 per cent of the world's population lives in places where air pollution levels exceed the maximum exposure limits recommended by it to abate critical consequences for human health. Yin *et a*l. (2020) reported of nearly 7 million premature deaths across the world attributable to air pollution in 2016. Juginovic *et al*. (2021) confirmed that one billion children the world over are exposed to high levels of air pollution in their homes. USGCRP (2009) confirmed air pollution to have various malign health effects in early human life, such as respiratory, cardiovascular, mental, and perinatal disorders, leading to infant mortality or chronic disease in adult age.

According to IMF (2017), the western African region has witnessed an economic rise estimated at 2.7% in 2017 with an expectation of 3.5% in 2018. Most of the economic activities of African countries (e.g. industries, trade, transport and real estate) are concentrated in cities, and this led to population explosion in cities due to a massive and significant migration of rural populations (Denis and Moriconi-Ebrard, 2009). This intense economic activity, associated with a rapid population growth, strong urbanization and the perpetual uncontrolled expansion of cities, causes increasingly significant anthropogenic emissions of gaseous and particulate pollutants. Hence, causes of significant deterioration of general air quality altering the health of populations and damage ecosystems (Norman *et al*., 2007).

Six common air pollutants of significance also known as criteria air pollutants was identified by the Clean Air Act (CAA) of 1970, namely particulate matter, carbon monoxide, nitrogen dioxide, sulphur dioxide, ozone and lead (Saxena and Sonwani, 2019). Exposures to common urban air pollutants have been linked to a wide range of adverse health outcomes, including respiratory and cardiovascular diseases, asthma exacerbation, reduced lung function and premature death (USEPA, 2009). For example it has been reported that air pollutants, such as sulphur can lead to excess levels of acid in lakes and streams, damages to trees, forest soils, atmospheric nitrogen that could reduce the biodiversity of plant communities and other aquatic organisms. Also, ozone damages tree leaves and negatively affects scenic vistas in protected natural areas, while mercury and other heavy metal compounds emitted as exhaust from fuel combustion can eventually accumulate in plants and animals, some of which are consumed by people (www.epa.gov/eco-reserach/ecosystems-and-quality)

Also Wik-users between (2005 and 2008) lucidly summarized the nexus on aquatic resources by highlighting an example with atmospheric carbon dioxide and their effects in two major ways;

“The first is to increase the growth of algae. The increased alga population eventually dies off creating algae "blooms" (large clumps of dead algae) which are unsightly and odorous. As they rot they reduce dissolved oxygen levels in the water which kills fish. As the blooms sink they cover the sea bottom impacting fish breeding areas and creating anoxic areas. There is a third algae bloom problem, the blooms carry trace metals (eg iron) out of the upper reaches of the sea where it is required for plant life”

“Secondly the dissolved carbon dioxide decreases he pH of the sea water making it acidic. The acidic water dissolves coral and the shells of mollusks. NOx and SOx These are the components of air pollution causing acid rain. In water they can decrease the pH creating problems similar to those noted for the acidic impacts of carbon dioxide,. However, the pH can become very low and create other problems for the health of aquatic organisms and their breeding success. In addition the acidic water can dissolve heavy metals from rocks and silt which are toxic in their own right. Particulate matter

Many industrial operations emit particulate matter into the air which land in water directly or be washed down by rain or snow. These particulates can contain toxic components like metals and organic compounds (PAHs) which can impact fish and other organisms as well as the suitability of the water as a potable water source”.

Form the preceding description of the impacts of air pollutants on the aquatic environment, it is obvious that Port Harcourt metropolis located within the Niger Delta region of Nigeria, which is essentially a wetland, with air pollutant emissions, replete within it, due to intensive hydrocarbon exploration activities, as it is typical of most urban Niger Delta cosmopolitan cities within the Niger Delta; have obvious impacts on aquatic resources (rivers, lakes, swamps, creeks and coastal marine water bodies) that abound within the region.

This study therefore, was focused on the measuring selected five criteria air pollutants at selected junctions of Port Harcourt comprising Garrison, Artillery 1 and 2, Rumuokoro, Waterlines-Ikoku and Rumuokwurushi-Elimgbu. The main objectives of the study are to investigate the concentrations of the five criteria pollutants and to model the spatial distribution patterns of the air contaminants and the relationships with regulatory standard limits. Thus, the results form an empirical basis to ascertain the extent to which the concentration of these criteria air pollutants within Port Harcourt metropolis deviates from the regulatory standards and the inferred impacts they should have on both the terrestrial and aquatic resources cum human life.

METHODOLOGY

Climate and Meteorology of the Study Area

The study area located in Port Harcourt Metropolis, Nigeria, lies within Latitudes 4°47’38.658”N and 4°48’29.404’N and Longitudes 006°58’37.661’E and 006°59’34.515”E of the Greenwich Meridian (GM). The metropolis and environs of Port Harcourt extend to the fringes of Etche, Okirika, Degema Ikwere, Eleme, Emohua and Oyibo LGAs respectively.

The area is located within the Niger Delta coastal zone made up of the sedimentary formation. As a coastal city, the equatorial monsoon climate influences its atmospheric characteristics due to its nearness to the Atlantic Ocean. Both the maritime and continental air masses control the rainfall and temperature pattern of the city (Chiadikobi *et al*., 2011). Also, as a city located within the Inter-Tropical Convergence Zone (ITCZ) in the African continent, it is affected with the warm humid maritime tropical air mass with its south-western winds and the hot and dry continental air mass from the north-easterly winds. The moist south-west wind in the area generates heavy rainfall volumes ranging from 2000 mm to 2500 mm with the peak period from April to September and in some years extends to October (Fasote, 2007). From April, relative humidity increases, peaking in July to September and dropping steadily and continuously till March with the lowest trough in January (Elenwo, 2015). In a year cycle, temperature peaks in January to March and relative humidity drops continuously within the months. The urban warming that affects human comfort is a function of air temperature during the dry season, relative humidity during the wet season and wind flow systems in the dry season (Figueroa and Mazzeo, 1998). Average peak temperature is 32°C and the lowest 26°C are usually observed in January and July respectively (Edokpa and Nwagbara, 2017). The humidity is high with the mean annual figure at 85% with high and low peaks during the wet and dry seasons respectively (Chiadikobi *et al*., 2011). Cloud cover pattern in the area is continuously improved with a monthly average of over 6 oktas (Edokpa and Nwagbara, 2017) due to the massive water vapour that rises to the atmosphere as a result of adjacent water bodies. Cloud cover is highest during the wet season and lowest during the dry months respectively. The average daily sunshine was less than 3 hours as observed in July and about 4-5 hours in January and December respectively (Mmom and Fred-Nwagwu, 2013). For the wind speed pattern, mean monthly range is between 0-3 m/s (Utang and Wilcox, 2009) with high and low trends observed during the nocturnal hours. Urban warming is influenced by these climatic parameters operating in Port Harcourt Metropolis and Environs, Rivers State, Nigeria.

The study was carried out at 29 different points across Port Harcourt City. The location map of the study area is Figure 1.

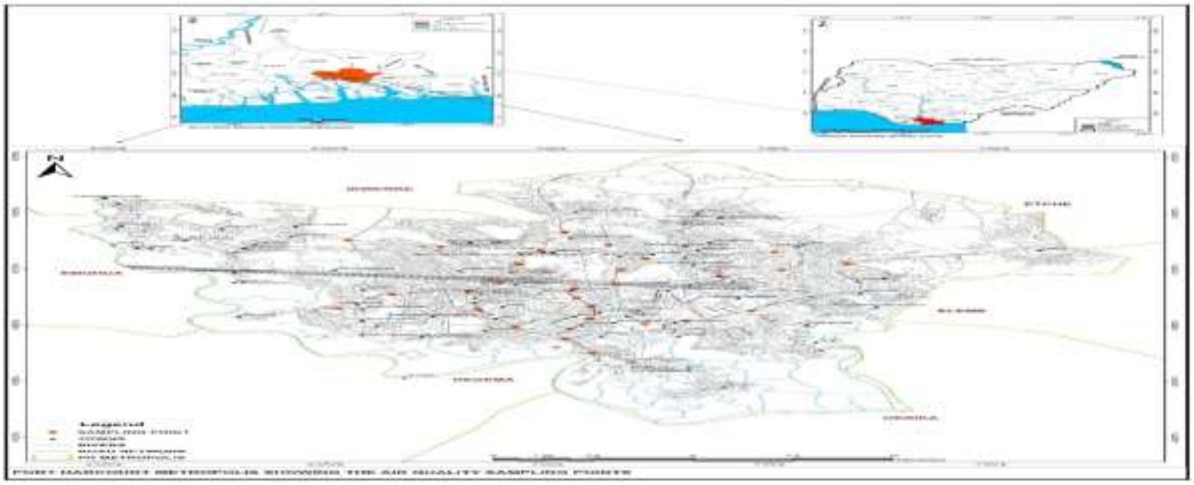

Figure 1: Map of PortHarcourt City Showing the Air Quality Sampling Points

Air Quality Measurements

The stdy areas were 5 selected junctions/sampling points comprising Garrison, Artillery 1 and 2, Rumuokoro, Waterlines-Ikoku and Rumuokwurushi-Elimgbu junctions. The pieces of equipment used for the analysis of criteria air pollutants (such as NO_2, SO_2, CO, $PM_{2.5}$ and PM_{10}) were well calibrated, highly sensitive digital portable meters (Gasman) held at arm's length at a height of 1.5 m (Figure 2). 29 stations were established and duly marked with GPS device (Table 4).

The Gasman is an intrinsically safe portable gas detector, designed to warn the user of dangerous conditions in the immediate vicinity. The rugged design allows the instrument to be used in almost any application. There are three versions of the Gasman, each suitable for specific applications. Gasman TO is designed to monitor for the presence of specific toxic gases and was used for this study. The parameters determined and equipments (Table 1) used were: Sulphur dioxide (SO_2) – (SO_2 gas monitor Gasman model 19648H); Nitrogen dioxide (NO_2) – (NO_2 gas monitor, Gasman), Carbon monoxide (CO) – (CO gas monitor, Gasman), $PM_{2.5}$ and PM_{10}.

Table 1: Method used in Determining the Gaseous Emissions

Parameter	Equipment	Range	Alarm levels
Sulphur dioxide (SO_2)	SO_2 gas monitor Gasman 19648H	0-10ppm	2.0ppm
Nitrogen dioxide (NO_2)	NO_2 gas monitor Gasman 19831N	0-10ppm	3.0ppm
Carbon monoxide (CO)	CO gas monitor Gasman 19252H	0-500ppm	50ppm

Figure 2: Sampling of Air Quality of the Study Area

Description of Air Ae Steward: Air Quality Monitor for $PM_{2.5}$, PM_{10}

This all-in-1 multi functions indoor air quality meter is capable of measuring the inhalable particles in 2.5 and 10 micrometers, Formaldehyde (CH_2O), Total volatile organic compounds (TVOC), air temperature and relative humidity. It engages the high quality sensing elements to provide precise and reliable readouts. Four (4) levels of LED signal indicators on the front panel are equipped to present the condition of air quality in accordance to the level of measurements, along with high frequency audible alarm. It certainly provides a good indication of how healthy of your environment you are living in.

Table 2: Procedure for Measurement of $PM_{2.5}$, PM_{10} and TVOC

Switch Machine	Long Press boot
Detection of lock	Push the switch machine work short lock detector testing data: $PM_{2.5}$ and PM_{10}/ µg/m^3 character and experiment/TVOC/mg/m^3 character and experiment/TVOC/mg/m^3 character twinkle recognition, then according to solution of zobah.
Alarm Sound	The press of a key open display shows close don't show
Display of the transformation	More than 3 seconds long press button convert $PM_{2.5}$/PM_{10} and formaldehyde/TVOC display page.
Backlight	The press of a key to open or close backlight, open display 5 minutes the backlight will be automatically closed.
Power saving mode	Press key 2 consecutive times manually close the backlight, instrument to enter power setting mode.
Set the time	Press select to adjust the year-month-day-time, press the + or – key
An experiment/TVOC data reset	Experiment formaldehyde/TVOC data reset long press + Experiment, more than 3 seconds formaldehyde/TVOC data reset new direction
$PM_{2.5}$ and PM_{10} data reset	$PM_{2.5}$ and PM_{10} data reset button for 3 seconds long above zero for a new test
Calibration to restore the factory pattern	Long press the + key instrument into more than 10 seconds, 120 seconds timing calibration status, sensor will restore the factory pattern

RESULTS AND DISCUSSION

Results

Dispersion of Criteria Pollutants at Garrison, Artillery 1 and 2 and Rumuokoro Junctions

The results of gaseous air quality analysis (Table 3) revealed that criteria pollutants such as NO_2, SO_2, $PM_{2.5}$ and PM_{10} exceeded WHO acceptable levels except carbon monoxide (CO). These gases have been estimated to be responsible for respiratory infection. The presence of these gases have adverse effects on public health, vegetation and acid rain precipitation causing metal corrosion, increase in soil acidity and many others.

According to the Figure 2, the least concentration of CO (9.079 - 10.203 ppm) was measured in Artillery. Trans-Amadi, Okuruame, Elekahia, Rumuepirikon, Nkpolu, Port Harcourt, Douglas and other southern settlements recorded CO concentration ranging from 12.453 - 13.576 ppm. Other settlements such as Elimbu, Choba, Alakahia, Rumuekini, Ozuoba, Ogbogoro, Nneke, etc. recorded concentration ranging from 14.701 - 15.824 ppm. The highest concentrations of CO (15.825 - 16.949) were observed only in Rukpokwu, Rumuodara and northern part of Rumuokoro. In Figure 3, the highest concentrations of SO_2 (0.384 - 0.426 ppm) were recorded in Rumukalagbor and Rumuogba, followed by Elekahia, Rumuodara, Umuorolu, Orogbum, Ogbunabali, etc. with the concentrations ranging from 0.343 - 0.384. The least concentrations were measured in Rumuokoro and Rumuigbo settlements. In Figure 4 below, the highest concentrations of NO_2 were recorded in Artillery especially in points AQ_6, AQ_8, AQ_{10} and AQ_{11}, followed by AQ_{13} and AQ_{14} in Rumuokoro while only AQ_3 in Garrison where the highest concentration was recorded. NO_2 concentrations ranging from 0.318 - 0.344 ppm were observed to be dominant in the study area especially in Diobu, Rumuokalagbor, Elekhia, Rumuorolu, Ogigba, Trans-Amadi, etc. However, places like Umuorolu, Ogbogoro, Rumu-Oparala, Mgbuoba, etc. recorded NO_2 concentration ranging from 0.29 - 0.317 ppm.

$PM_{2.5}$ had the lowest concentrations recorded in Artillery and its immediate surroundings at the range of 49.76 - 52.65 $\mu g/m^3$. Settlements like Okuruama, Trans-Amadi, Elekahia, Oroakwo, Orogbum recorded concentrations between 57.01 and 58.45 $\mu g/m^3$. On the other hand, Ozuoba, Choba, Alakahia, Rumuigbo, Rumuokwuta and Elimbu recorded 55.56 - 57.00 $\mu g/m^3$ concentrations of $PM_{2.5}$ (Figure 5). In Figure 6, PM_{10} had uniform concentrations ranging from 106.48 - 120.36 $\mu g/m^3$ across the study area except for Old GRA, Douglas, Abo-Ama and Rumuebekwe where the concentration ranges from 92.58 - 106.67 $\mu g/m^3$. However, less than 4 % of the study area (Eligbolo, Rumuokoro) recorded highest concentrations of PM_{10} ranging from 120.37 - 134.26 $\mu g/m^3$.

Fig. 3: Map shows spatial dispersion of Carbon monoxide (CO)

Fig. 4: Map indicates spatial dispersion of sulphur dioxide (SO_2)

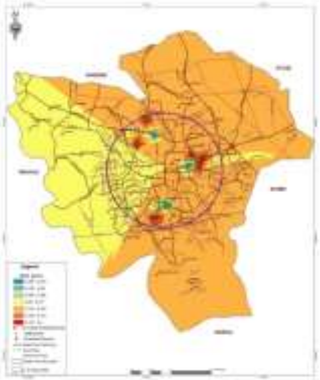

Fig. 5: Map shows spatial dispersion of nitrogen dioxide (NO_2)

Fig. 6: Map indicates spatial dispersion of $PM_{2.5}$

Fig. 7: Map showing spatial dispersion of PM_{10}

Dispersion of Criteria Pollutants at Waterlines-Ikoku Junction

In Figure 7, the least concentration of CO (3.0 to 3.5 ppm) was recorded in AQ_{23} while the peak dispersion was captured around AQ_{18} and AQ_{19} ranging from 6.0 to 7.0 ppm. However, CO is within the FMENV limit of 10.0 – 20.0 ppm. Long term exposure of CO, no matter the concentration, could result in adverse impact on human health which could lead to instant death.

The concentration of SO_2 was the highest (0.334-0.400 ppm) in AQ_{18} and its surroundings AQ_{17}. This was seconded by AQ_{20} and AQ_{21} with a concentration ranging from 0.234-0.3000 ppm. The least concentration was found in AQ_{23} with a concentration of 0.1 ppm (Figure 8). The recorded levels of SO_2 were above the FMENV regulatory limits of 0.01ppm – 0.1ppm for daily average of 8-hourly values in Nigeria. Almost every activity at the study area had the potential to generate considerable amounts of sulfur dioxide. As depicted in the Figure 9, NO_2 recorded highest concentrations in AQ_{19} and AQ_{22} ranging from 0.191 to 0.200 ppm while the least concentration (0.100 to 0.130 ppm) was recorded in AQ_{21} and AQ_{23}. Moderate level of NO_2 was recorded in AQ_{17}, AQ_{18} and AQ_{20} ranging from 0.161 to 0.170 ppm. However, the recorded values were all above the Federal Ministry of Environment's limits of 0.04 - 0.06 ppm. Generators, vehicular traffic, industrial boilers, etc contributed to the emissions of this gaseous pollutant. $PM_{2.5}$ recorded the highest concentration in AQ_{19}, AQ_{20} and AQ_{21} and its immediate surroundings at the range of 83 to 91 µg/m^3. The lowest dispersion was captured in AQ_{17}, AQ_{22} and AQ_{23} ranging from 67 to 74 µg/m^3 (Figure 10). PM_{10} recorded maximum concentration of 141 to 158 µg/m^3 in AQ_{20} and AQ_{21} and lowest in AQ_{22} and AQ_{23} ranging from 102 to 112 µg/m^3. The modest level of PM_{10} was captured in AQ_{18} and its environ which ranged from 120 to 125 µg/m^3 (Figure 11).

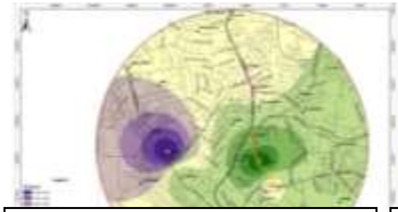

Figure 8: Air quality dispersion model of

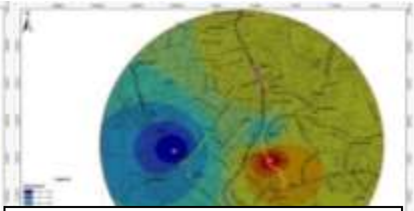

Figure 9: Air quality dispersion model of sulphur dioxide

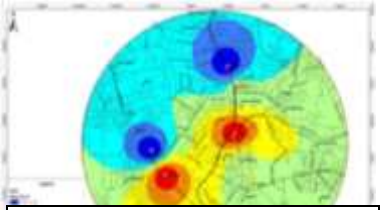

Figure 10: Air quality dispersion model of nitrogen dioxide

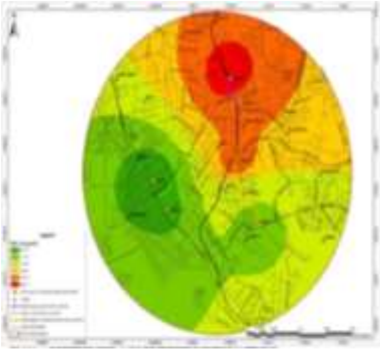

Figure 11: Air quality dispersion model of $PM_{2.5}$

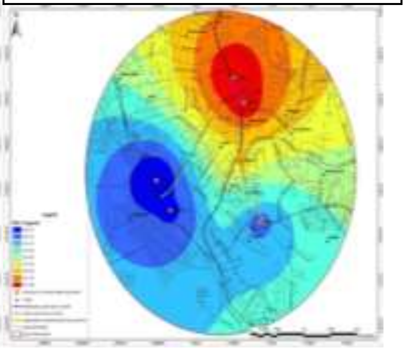

Figure 12: Air quality dispersion model of PM_{10}

Dispersion of Criteria Pollutants at Rumuokwurushi-Elimgbu Junction

In the model (Figure 12), the peak concentration of CO ranged from 4.890 to 6.00 ppm captured near the East-West Road junction. Other parts recorded low concentration. As observed in the model, areas toward north axis of the junction (close to Atali and school road) recorded highest level of SO_2 concentration while the lowest was captured southward (Figure 13). In Figure 14, the concentration of NO_2 was only observed to be high along the East-West Road junction (0.1-0.2ppm). Other parts of the route experienced the lowest concentrations of NO_2. The central point along East-West Road recorded the lowest concentration of $PM_{2.5}$ ranging from 44.00 to 49.78 µg/m^3. The concentration increased in both southern and northern directions ranging from 61.34 to 69.99 µg/m^3 (Figure 15). Hence, the $PM_{2.5}$ concentrations of the study area ranged from 44.0 to 70.0 ppm with the mean of 55.00±10.98. In Figure 16, the highest concentration of PM_{10} was recorded southward ranging from 108.67 to 125.99 µg/m^3. The least concentration was observed north of the study area ranging from 74.00 to 91.33 µg/m^3). However, the PM_{10} concentrations of the study area ranged from 74.0 to 126.0 ppm with the mean of 90.2±21.59.

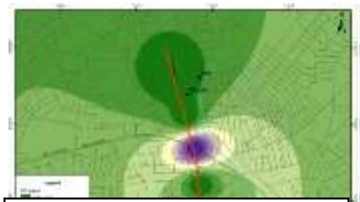

Fig. 13: Air Quality Dispersion Model of Carbon monoxide

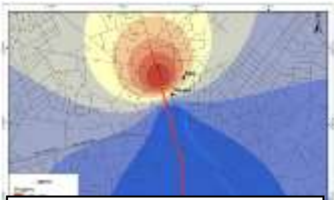

Fig. 14: Air Quality Dispersion Model of Sulphur Dioxide

Fig. 15: Air Quality Dispersion Model of Nitrogen Dioxide

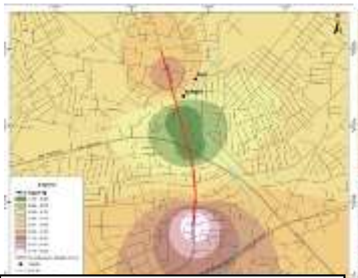

Fig. 16: Air Quality Dispersion Model of Particulate Matter ($PM_{2.5}$)

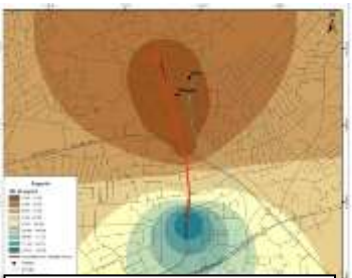

Fig. 17: Air Quality Dispersion Model of Particulate Matter (PM_{10})

Assessing the variability in Air Quality Dispersion

t-test was used in assessing the variation in the dispersion of the selected parameters with respect to the FME limits. The result is presented in Table 3.

Table 3: Variation Analysis of Selected Air Parameters.

S/N	Parameter	Test value	Mean	T	df	Sig. (2-tailed)	Remark
1	NO_2 (ppm)	0.04-0.06	0.2345	7.808	28	0.000	H_o rejected
2	SO_2 (ppm)	0.01-0.1	0.2966	8.352	28	0.000	H_o rejected
3	CO (ppm)	10.0-2.0	9.627	-0.41	28	0.686	H_o accepted
4	$PM_{2.5}$ (µg/m^3)	250	61.3793	-73.56	28	0.000	H_o rejected
5	PM_{10} (µg/m^3)	250	111.14	-26.27	28	0.000	H_o rejected

The result of the analysis showed that the P-value was less than 0.05 (level of significance) in $PM_{2.5}$ and PM_{10} parameters which implied that these air parameters were significantly different from the FME limit. In this case, the air quality was observed to be less than the FME standard which can authoritatively be concluded that there exist a significant different between these parameters and FME limit in Port Harcourt City. Similarly, NO_2 and SO_2 also recorded a significant difference when compared with FME standard. However, a critical analysis showed that the concentrations of these parameters were significantly higher than the FME limit. In the case of CO, the average concentration was observed slightly lower than FME limits with a mean difference of 0.373 which was an indication that the variation between CO and FME limit were statistically insignificant.

Table 4: Air Quality Measurements at the Selected Junctions of Port Harcourt City, Nigeria

Sample code	NO_2 (ppm)	SO_2 (ppm)	CO (ppm)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)
Garrison Junction					
AQ_1	0.3	0.4	12.0	50	89
AQ_2	0.3	0.5	15.0	53	104
AQ_3	0.4	0.3	13.0	64	121
AQ_4	0.3	0.4	12.0	61	138
AQ_5	0.2	0.4	12.0	68	141
Mean±SD	**0.3±0.07**	**0.4±0.07**	**12.8±1.3**	**59.2±7.53**	**118.6±22.21**
Range	**0.2-04**	**0.3-0.5**	**12.0-15.0**	**53-68**	**104-141**
Artillery 1 and 2					
AQ_6	0.4	0.3	13.0	48	84
AQ_7	0.2	0.2	9.0	45	78
AQ_8	0.4	0.5	17.0	47	87
AQ_9	0.3	0.5	14.0	52	92
AQ_{10}	0.4	0.3	14.0	57	102
AQ_{11}	0.4	0.4	15.0	46	82
Mean±SD	**0.35±0.08**	**0.367±0.12**	**13.667±2.66**	**49.167±4.54**	**87.5±8.53**
Range	**0.2-0.4**	**0.2-0.5**	**9.0-17.0**	**45-57**	**78-102**
Rumuokoro Junction					
AQ_{12}	0.3	0.4	15.0	45	77
AQ_{13}	0.4	0.3	16.0	54	97
AQ_{14}	0.4	0.4	14.0	56	112
AQ_{15}	0.3	0.5	15.0	63	143
AQ_{16}	0.2	0.4	15.0	71	177
Mean±SD	**0.32±0.08**	**0.4±0.07**	**15.0±0.71**	**57.8±9.78**	**121.2±39.41**
Range	**0.2-0.4**	**0.3-0.5**	**14-15**	**45-71**	**77-177**
FME limits	**0.04-0.06**	**0.01-0.1**	**10.0-20.0**	**-**	**-**

Table 4…/Contd

Sample Code	NO_2 (ppm)	SO_2 (ppm)	CO (ppm)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)
Waterline-Ikoku Junction					
AQ_{17}	0.1	0.2	5.0	91	158
AQ_{18}	0.2	0.3	7.0	82	146
AQ_{19}	0.1	0.2	3.0	78	124
AQ_{20}	0.1	0.2	5.0	82	132
AQ_{21}	0.1	0.2	5.0	88	153
AQ_{22}	0.2	0.2	4.0	76	121
AQ_{23}	0.1	0.1	3.0	67	102
Mean±SD	**0.129±0.05**	**0.2±0.06**	**4.571±1.4**	**80.571±7.96**	**133.71±19.91**
Range	**0.1-0.2**	**0.1-0.3**	**3.0-7.0**	**67-91**	**102-158**
Rumuokwurushi-Elimgbu Junction					
AQ_{24}	0.1	0.1	4.0	61	78
AQ_{25}	0.1	0.2	4.0	44	74
AQ_{26}	0.2	0.2	6.0	45	78
AQ_{27}	0.1	0.2	4.0	55	95
AQ_{28}	0.1	0.2	5.0	70	126
AQ_{29}	0.1	0.1	3.0	61	112
Mean/SD	**0.12±0.04**	**0.18±0.04**	**4.6±0.89**	**55.00±10.98**	**90.2±21.59**
Range	**0.1-0.2**	**0.1-0.2**	**4.0-6.0**	**44-70**	**74-126**
FME Limit (1991)	**0.04-0.06**	**0.01-0.1**	**10.0-2.0**	**250**	**250**

DISCUSSION

The poor traffic flow and congestions are major problems sighted in Port Harcourt city due to obstructions and increased vehicular population. A study by Kayode (2015), stated that elongated traffic jams are observed in many parts of the city and it appears that the road traffic management strategies and officials are incapable of solving it. Most vehicles in the PH City are driven by fossil fuel which seriously caused ambient air quality degradation, environmental impact and public health problems. The increase in vehicles population in the Port Harcourt city is associated with increase in business and economic activities. Studies have shown that the effect of polluted air from exhaust emissions from increased vehicles, poor integrity automobiles and congestion culminates to public health and climate change (Johnson and Hyelda, 2013). Greenhouse gases such as CO and SO_2 rises, leads to global warming, ultimately resulting in climate change. The climate change phenomenon essentially triggers sporadic terrestrial and aquatic temperature increase, leading to exacerbation of deforestation due to enhanced wildfire and heavy flooding as is currently being experienced globally. Both of this phenomenon adversely affects both the flora and fauna of both the terrestrial and aquatic environment of the Niger Delta region, within which Port Harcourt city is located.

Criteria pollutants (SO_2, NO_2, CO, $PM_{2.5}$ and PM_{10}) were above permissible limits of FMENV and WHO, except CO that was within the limit at all sampling stations. Arc GIS Version 10.8 was used to model the spatial distribution patterns of the air contaminants and the dispersion model developed has revealed that criteria pollutants from the Port Harcourt City was high and may be serious public health and environmental concern. The results of criteria pollutants showed that the air quality of the study area had been polluted. According to Saxena and Sonwani (2019), the uncontrolled use of fossil fuels in industries and transport sectors has become the dominant source of criteria air pollutants. Yin *et al*. (2020) reported long-term exposure to $PM_{2.5}$ is understood to have deleterious effects on public health. Similarly, Thurston *et al*. (2017) affirmed Long-term exposure to PM has damaging effect on human health. A study by Filippini *et al*. (2015), found childhood leukemia associated with higher traffic density. Chen *et al*. (2021) showed that $PM_{2.5}$, regardless of decrease in concentration is more harmful to human health than ozone. As previously reported (Bahino *et al*., 2018), atmospheric pollution of the Port Harcourt City is majorly ascribed to anthropogenic activities. Human activities are responsible for the main sources of gaseous and particulate pollutants emissions into the air and their concentrations measured in the atmosphere. NO_2, SO_2, CO, $PM_{2.5}$ and PM_{10} gases obtained from this study were present at relatively higher concentrations at all the stations as supported by Bahino *et al*. (2018). Particulate matter such as sooth is particularly implicated in heavy metal pollution of surface and soil capillary water. In surface waters and in severe cases as is currently obtainable within the Niger Delta region, where the city of this study is located, atmospheric particulate matter pollutants constitute sources of introduction of significant amounts of heavy metals into water. This happens when the sooths generated from partial combustion of hydrocarbon products from illegal refining activities gets dissolved in water. Such particulate matters also constitute sources of nuisance for surface waters, thereby reducing their aesthetics and recreational values (Elenwo and Akankali, 2015) Effects of pollution……….

According to Val *et al*. (2013), environmental changes, including air pollution, have significantly increased the burden of cancer in western Africa in recent years. Ghorani-Azam *et al*. (2016) noted NO_2 exposures at 2.0–5.0 ppm to have been shown to affect T-lymphocytes, and natural killer cells. According to Lindell and Weaver (2009), mild exposures of CO result in headache, myalgia, dizziness, or neuropsychological impairment, while severe exposures to carbon monoxide result in confusion, loss of consciousness, or death. Studies done by Yang *et al*. (2018) have reported increased risks of stillbirth with exposure to NO_2. Lertxundi *et al*. (2015) found that prenatal exposure to NO_2 was associated with significant decreases in cognitive development and motor development in children at the age of 15 months. A recent study by Robledo *et al*. (2015) showed that maternal exposure to SO_2 in the months before pregnancy is associated with an increased risk for gestational diabetes mellitus, a condition that is associated with adverse birth outcomes and risks to maternal health. Studies also indicate that exposure to SO_2 before pregnancy may play a role in the formation of orofacial clefts (Zhu *et al*., 2015).

Some studies have reported associations between exposure to air pollutants and dementia (Rit *et al*., 2016; Kiouourtoglou *et al*., 2016).

According to Lee *et al*. (2017), high level of SO_2 can affect photosynthesis and physiological processes relating to stomatal responses because stomata cannot close properly when the plant is under environmental stress. They further cited SO_2 to affect carbon allocation, and chlorophyll contents, which affect plant growth and productivity and also the cell membrane structure and change membrane permeability. Manisalidis *et al*. (2020) found high levels of nitrogen dioxide as being deleterious to crops and vegetation reducing crop yield and plant growth efficiency. Moreover, NO_2 can reduce visibility and discolor fabrics. Lavanya *et al*. (2014) reported acid rain formed in the air destroys fish life in lakes and streams, which disturbs aquatic ecosystem. Acid rain is a high precursor of aquatic medium acidity, which disrupts the P_H of both soil and water when it is significant. P_H is a critical water quality parameter that must be within the range of between 6-8 for optimal physiological processes functionality of most aquatic organisms, particularly fish. In fact, in extreme cases of either acidity or alkalinity, aquatic organisms could become highly susceptible to mortality.

CONCLUSION

This established that the atmosphere within the study area is significantly loaded with measured air quality apramеters. These air pollutants have the potential to cause human, terrestrial, aquatic flora and fauna adverse impacts. These findings provide a better understanding of the airborne pollutants present in human environments and a clue for assessing the infections, asthma, allergy, or other respiratory diseases resulting from exposure to airborne particles. Criteria pollutants such as NO_2, SO_2, CO, $PM_{2.5}$, PM_{10}, etc, have been detected in significant concentrations, except CO which fell within the regulatory limits and chronic exposure contributes to the risk of cardiovascular and respiratory diseases, as well as lung cancer. However, the high concentrations of NO_2, SO_2, $PM_{2.5}$ and PM_{10} is indicative of a serious potential impact these pollutants also have on the terrestrial and aquatic environment within the area of study.

Recommendations

Air pollution control is vital and should be on priority list of the governments. The policy makers and legislators must update all laws and regulations related to air pollutions. Coordination between different departments involved in air pollutions must be led by environmental protection organization. Government should ensure that the agency charged with the responsibilities for environmental protection is fully funded for administration, research, development, monitoring, and full control of the environment. Further research directly correlating directly the impacts of criteria air pollutants on various components of the terrestrial and aquatic environment should be conducted as a means within the study area.

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