

An Assessment of Ground Level Criteria Pollutant Concentrations in Port Harcourt City, Nigeria

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Abstract

This study evaluates the ground level concentrations of main criteria pollutants emitted from prevalent emission sources at 10 sampled locations in Port Harcourt city for peak dry and early wet seasons. Assessments were done within 3 hours per dual diurnal section using approved standard methods and converted to a 1-hour mean for the morning and evening period of sampling i.e. 6-9am and 5-8pm. These periods are the rush hours of peak human/traffic movements across the city. Results shows that during the peak dry season in January, pollutants concentrations ranged between 0.05-0.39 mg/m³; 1.02-21.22 mg/m³; 3.1-31.3 µg/m³ and 15.2-257.7 µg/m³ for NO_x, CO, PM_{2.5} and PM₁₀ and for early wet season in April, it ranged between 0.06-0.28mg/m³; 1.02-22.67 mg/m³; 6.3-35.8µg/m³ and 14.2-201.4µg/m³ respectively. The air quality assessments show that NO_x and PM₁₀ were significant and above set limits for Nigeria (100-370% and 10-60%) during the dry season and sampled time frame except for the wet season when PM₁₀ was below set limit for most of the sampled locations due to downwash of the suspended particulate by early rains. The concentration of PM_{2.5} was generally below set limit across the sampled locations for Nigeria and WHO (based on target 1) standards. Ground level concentrations of NO_x and CO were above set limit for Nigeria at a sampled residential location during the morning rush hours while particulates were below set limits for the area. The air quality was best at Port Harcourt international airport as pollutant concentrations were generally below set limit. There is need for nonstop surveillance of ground level emission concentrations most especially around the city centre to guarantee the protection and well-being of the environment and the city dwellers.

Keywords: Air pollution; Boundary layer; Carbon monoxide; Oxides of nitrogen; Particulates; Port Harcourt

Introduction

Anthropogenic activities resulting from human's quest to generate returns for survival has alleviated the rate of pollutants emissions within the planetary boundary layer. At every moment various emission facilities releases pollutants into the local environment which affects the health and wellbeing of boundary layer dwellers [1]. Port Harcourt, a well-known city in Nigeria has been worst hit both in the past and recently due to multiple sources of emissions daily without any period of cessation. Exposures of living organisms including humans to these emissions can lead to short and long term injurious health effects [2], however, this does not seem to bother both the emitters and environmental regulators.

This lack of sensitivity to environmental pollution in Nigeria has been attributed to the very low level of awareness of the people and policy makers [3]. The most common air pollutants release within cities includes Suspended Particulate Matter of various sizes (SPM), Oxides of Nitrogen (NO_x), Sulphur Dioxides (SO_x), Carbon Monoxide (CO) etc., and these pollutants can be in form of solid particles, liquid droplets or gases [4]. Air pollutants can be primary or secondary and also classified according to space of their effects i.e. local, regional and global [5]. Primary pollutants' such as NO_x, CO, SPM, etc. are released from the original sources while secondary contaminants are those generated in the atmosphere by chemical reactions and include: ozone (O₃), other photochemical oxidants – Peroxyacetyl Nitrates (PAN), and oxidised hydrocarbons etc. According to the estimates by the World Health Organisation (WHO), about seven million fatalities have taken place due to the

effects of criteria air pollutants on people i.e. one in eight of overall death globally [6]. A WHO ambient air quality analysis released in September, 2016 has shown that over 90% of World's populace dwells in regions where the quality of inhaled air surpasses WHO acceptable limits. It was affirmed that the most affected locations are the developing nations such as Nigeria. It was also noted that about 3million fatalities take place yearly as a result of human exposure to air contaminants from the developing nations.

The variance between urban and rural atmosphere lies in the intensified loads of pollutants in the urban atmosphere due to the more amplified human activities [7]. Air pollution is the closest trait of urban climate system after the heat island phenomenon that has engaged the interest of researchers in recent the years [7]. However, the difference between these two urban influences is that air pollutants concentrations can be transported far from an urban centre to a rural area by atmospheric agents [8-10]. This study is centred on one of Nigeria's main business hub, Port Harcourt, known for its huge oil and gas exploration/servicing activities. In Port Harcourt, air pollution has increased vastly due to the continuous congestion of the city which led to increase in vehicular movements, various set of burnings from domestic homes; abattoirs; petroleum products as well as the popularly known 'black carbon' emissions locally referred to as black soot etc., all of which are stimulated by a very weak environmental enforcement values. Amid the foremost air pollutants of concern in the city are particulate matters, carbon monoxide, and oxides of nitrogen etc. Although carbon dioxide is a principal emission from these sources, it harms to health is not as pronounced as the criteria pollutants except in the case that it's build-up in the lower troposphere enhances global warming. The major sources of air pollutants in the Nigerian environment include emissions from vehicles, electricity generators and industries, road and building construction activities [11].

The Study Area

Port Harcourt is coastal area located in the Niger Delta part of Nigeria. It has a humid tropical monsoon climate classified as Am and located in the tropical rainforest zone [12]. By virtue of its closeness to the Ocean (around 40km), the domain is heavily impacted by south-westerly winds associated with rainfall with peaks in July and September [13,14]. According to Adejuwon (2012) [14], the annual rainfall average over 2300mm and last within eight to 10 months with high relative humidity. Uko and Tamunobereton-Ari, (2013) specified that the mean maximum and minimum temperatures during the dry season are within 31-33 °C and 21-23 °C respectively (mean: 32 °C and 22 °C). For the wet season, it is within 25-33 °C and 18-23 °C respectively (mean: 29 °C and 21 °C). High temperatures during both seasons are observed during the day and lowest at night. The prevailing wind direction is south-westerly during the rainy season and north-easterly

during December-January when the Harmattan wind bearing dust particles is dominant. Fagbenle (1990) [15] estimated the monthly mean daily solar radiation for Port Harcourt with a range of 12-13MJ/m²-day within July-September (July being the lowest at 12.6MJ/m²-day) and 14-17MJ/m²-day within October-May (February being the highest at 17.1MJ/m²-day). Mean sunshine hours per day range within seven to eight hours from December to February and within three to four hours from June to October [16]. Minimum wind speed is 0m/s while maximum speed range is up to 7m/s with a mean range of 3.6m/s [17]. Wind speed is generally high during the day and low during night time. It can be higher during occasional storms and squalls. Ngene et al., (2015) [18] indicated the elevation of Port Harcourt to be about 19m above sea level. Port Harcourt is an abode to oil and gas industries as well as other production factories. From the 2006 census, its population is about 1,382,592 [19] (NPC, 2006). Figure 1 shows the Map of Port Harcourt.

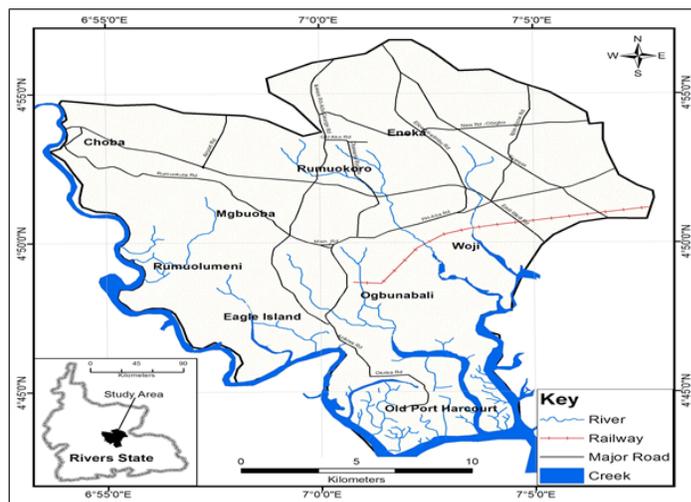


Figure 1: Map of Study Area.

Materials and Methods

This study was conducted in some selected locations within Port Harcourt metropolis and at the international Airport, a location about 15km away from the city Centre (Figure 2). The aim of the study was to examine the level of surface layer pollutants concentrations during the periods of peak human activities. These locations were chosen based on the anthropogenic activities that take place at the areas as well as the proximity to residential expanses. The major roads across these locations have high traffic density, while minor roads axes are minimal. In Port Harcourt metropolis the usage of generators for energy consumption within industrial and residential areas are rampant due to the epileptic power supply. Some selected locations were assessed to accommodate the emissions from the combined sources including other domestic activities. An assessment of some criteria air pollutants such as

Oxides of Nitrogen (NO_x), Carbon Monoxide (CO) and particulate matters of sizes PM₁₀ and PM_{2.5} was carried out using portable air quality measuring equipment. This equipment includes: Testo 350XL Gas Analyzer for NO_x, and CO which detects combustible gas as well as a digital hand-held air detector (5 in 1 multi-function laser sensor BRV8) for PM₁₀ and PM_{2.5}. The gas sampling method was by natural diffusion with accuracy of $\leq \pm 5\%$. The response time was less than 5 minute. Measurements were done within 3 hours per section and converted to a 1-hour mean. About 10 locations were sampled in January and April, 2017 during the morning and evening period i.e. 6-9am and 5-8pm. The essence of these sampling times is important because the rush hours with its peak within the sampled time frame. Sampling was done *in situ* with the calibrated equipment and each location was geo-referenced using a GPS device. The sampled locations as well as features are shown on Figure 2 and in Table 1.

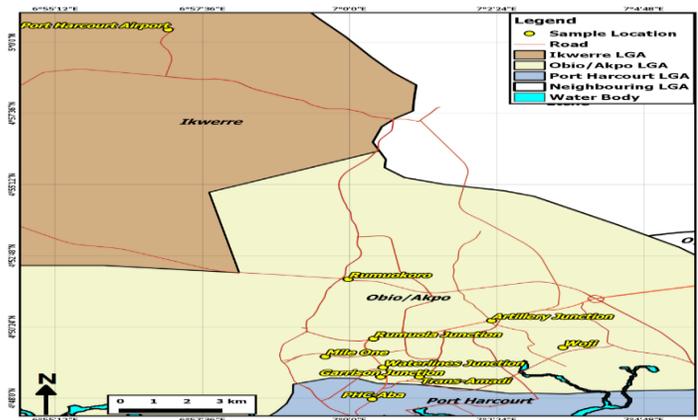


Figure 2: Map Showing Sampled Locations in Port Harcourt.

S/N	Sampled Location	Features
1	Port Harcourt-Aba Road	Stream of traffic area
2	Trans Amadi	Industrial area
3	Mile One	Heavy commercial and traffic area
4	Garrison Junction	Heavy traffic area
5	Rumuola Junction	Heavy traffic/commercial area
6	Artillery Junction	Heavy traffic/light commercial area
7	Rumuokoro	Heavy commercial area

8	Waterlines Area	Commercial area/stream of traffic
9	Woji	Residential area
10	Port Harcourt International Airport	Airline transport area

Source: Edokpa, 2018.

Table 1: Sampled Locations Characteristics.

Results

The result analysis for this study is shown in Table 2 and Table 3. The essence of this ambient measurement was to highlight the contributions of anthropogenic emission sources over the lower atmosphere in Port Harcourt. From Table 2 and Table 3 the shaded area indicates locations of emissions below the acceptable limits in Nigeria. During the dry season in January, emissions range between 0.05-0.39mg/m³; 1.02-21.22mg/m³; 3.1-31.3µg/m³ and 15.2-257.7µg/m³ for NO_x, CO, PM_{2.5} and PM₁₀ respectively. During the early wet season (April) emissions range between 0.06-0.28mg/m³; 1.02-22.67 mg/m³; 6.3-35.8µg/m³ and 14.2-201.4µg/m³ for NO_x, CO, PM_{2.5} and PM₁₀. It was observed from the results that there exists a close similarity trend between the sampled values for the pollutants for the morning and evening hours for both seasons. This shows the periods of rush hours that generate enhances high ground level pollutants concentrations across the sampled locations (Table 2 and Table 3). Results indicates Oxides of Nitrogen (NO_x) to be the most released pollutant above acceptable limit of Nigeria (by 100-370%) for both sampled seasons and times across all locations within the Port Harcourt metropolis except at the International Airport where it was generally below the set limit in Nigeria. Carbon monoxide concentrations indicate above (for Nigeria) and below limit rates for the sampled locations across seasons and times. This trend shows locations of higher vehicular and electricity generation activities within both the industrial, commercial and residential areas. However, at the airport, ground level CO concentration was below set limit and this can be attributable to the low level of human activities at the airport arena. Satellite observations alongside aircraft assessments as well as the GEOS-Chem model have been utilised by Marais et al., (2014) [20] to comprehend the pollution levels in Nigeria. The report indicated that observations of these pollutants such as nitrogen dioxide (NO₂), ozone (O₃), carbon monoxide (CO), methane (NH₄) etc. close to the source areas are very minimal. Additionally, the report revealed that CO, NO₂ had maximum concentrations in Central Nigeria from seasonal open fires between December to February, while NO₂ was widespread in the Niger Delta and Lagos region during the period under review. It was also emphasized that NO₂

was higher in the Sahel region (extreme north-eastern Nigeria) during the same period. According to Jaegle' et al., (2004) [21], this high rate in the Sahel region is due to the onset of rain that triggers the emissions of inorganic nitrogen from exposed top soils across massive expanses of the Sahel.

For both the dry and early wet seasons sampled across the locations, ambient measured values $PM_{2.5}$ was below acceptable limit in Nigeria. Also, it is shown that PM_{10} emissions were majorly below acceptable limit in Nigeria during the early wet season across the sampled locations and above the limit for Nigeria (by 10-60%) during the dry season at most of the locations sampled. These locations that had higher PM_{10} for the dry season are area of significant commercial and vehicular activities. The early wet season sample for PM_{10} indicates the down wash of the suspended particulates from the lower atmosphere by the early rains in Port Harcourt. As disclosed from a study conducted by Weli (2014) [22], it was observed that PM_{10} could range between 200-600 $\mu g/m^3$; 10-450 $\mu g/m^3$ and 70-590 $\mu g/m^3$ during the dry, wet and transition

periods across Port Harcourt. These values indicate a lower range assessment for PM_{10} concentration during the wet season. WHO (2016) [23] has noted mean ambient $PM_{2.5}$ to range between 16-35 $\mu g/m^3$ within the Niger Delta area and from 70 $\mu g/m^3$ and above in places like Kano and Maiduguri.

The distribution of particulate matter in the PM_{10} size range was observed for six years across 17 cities in Nigeria [24]. Findings show that the urban centres are characterised by high levels of the pollutant considered with an overall annual mean of 123.6 $\mu g/m^3$. Furthermore, outcomes also revealed that the concentrations were higher (8%) in the northern domain than in the southern end. Likewise, it was discovered that the mean concentrations in the urban areas were 136% greater than that of the rural centres. Monthly analysis of sampled areas in Nigeria shows that ambient PM_{10} concentrations were higher all year round with slight increase during the dry period than in the rainy period. The increase during dry period has been attributed to the deposition of particulates during the Harmattan season from the Northern Sahara Desert [24].

Sampled Areas	Coordinates	Mean Ground Level Emissions Concentration in January, 2017							
		NO_x (mg/m ³)		CO (mg/m ³)		$PM_{2.5}$ ($\mu g/m^3$)		PM_{10} ($\mu g/m^3$)	
		6-9am	5-8pm	6-9am	5-8pm	6-9am	5-8pm	6-9am	5-8pm
PHC-Aba Road	4o47I 58.24IIN 7o00I 22.11IIE	0.16	0.22	21.22	12.51	14.7	25.3	159.1	191.3
Trans-Amadi	4o48I 43.30IIN 7o01I 08.28IIE	0.17	0.13	10.23	7.18	17.2	18.2	143.6	128.9
Mile One	4o49I 24.22IIN 6o59I 36.12IIE	0.21	0.29	15.17	17.03	19.2	20.2	168.4	176.3
Garrison Junction	4o48I 43.30IIN 7o00I 30.35IIE	0.26	0.23	11.77	14.28	28.2	22.5	196.5	201.7
Rumuola Junction	4o50I 00.33IIN 7o00I 23.45IIE	0.29	0.32	19.21	15.78	26.3	21.1	220.5	258.7
Artillery Junction	4o50I 37.07IIN 7o02I 18.96IIE	0.37	0.39	8.13	20.29	21.1	19.8	210.1	239.4
Rumuokoro	4o52I 00.68IIN 6o59I 58.56IIE	0.29	0.27	12.09	11.33	27.1	31.4	176.4	207.1
Waterlines Junction	4o49I 02.18IIN 7o00I 32.67IIE	0.28	0.19	9.96	12.01	23.2	21.9	181.2	170.6
Port Harcourt Airport	5o00I 25.45IIN 6o57I 02.36IIE	0.05	0.05	1.12	1.02	4.1	3.1	15.2	17.2
Woji	4o49I 42.52IIN 7o03I 28.67IIE	0.17	0.14	13.61	8.15	16.1	11.3	111.4	134.7

	Mean	0.23	0.22	12.25	11.96	19.72	19.48	158.28	172.59
	FMEV, 1991	0.08mg/m ³ (1Hr)		10-11.8mg/m ³ (1Hr)		150µg/m ³ (1Hr)			
	WHO, 2017	0.2-0.5 mg/m ³ (1Hr)		30 mg/m ³ (1Hr)		PM10 (150µg/m ³ for 24Hr) and PM2.5 (75µg/m ³ for 24 Hr) Based on WHO interim target 1			
Source: Edokpa, 2018. *Green Coloured Areas – Below Ambient Set Limit. **Other Areas – Above Ambient Set Limit.									

Table 2: Mean Ground Level Emissions Concentration in January, 2017.

Sampled Areas	Coordinates	Mean Ground Level Emissions Concentration in April, 2017							
		NO _x (mg/m ³)		CO (mg/m ³)		PM _{2.5} (µg/m ³)		PM ₁₀ (µg/m ³)	
		6-9am	5-8pm	6-9am	5-8pm	6-9am	5-8pm	6-9am	5-8pm
PHC-Aba Road	4o47I 58.24IIN 7o00I 22.11IIE	0.12	0.14	6.21	8.34	21.8	25.2	98.6	113.2
Trans-Amadi	4o48I 43.30IIN 7o01I 08.28IIE	0.18	0.25	7.06	11.13	26.2	28.3	88.9	76.4
Mile One	4o49I 24.22IIN 6o59I 36.12IIE	0.17	0.16	11.93	10.44	21.7	28.2	91.1	201.4
Garrison Junction	4o48I 43.30IIN 7o00I 30.35IIE	0.15	0.17	15.79	17.54	26.3	24.2	125.4	80.6
Rumuola Junction	4o50I 00.33IIN 7o00I 23.45IIE	0.11	0.13	13.65	12.87	19.5	22.9	41.5	49.7
Artillery Junction	4o50I 37.07IIN 7o02I 18.96IIE	0.21	0.18	7.94	19.26	35.8	23.5	73.1	84.3
Rumuokoro	4o52I 00.68IIN 6o59I 58.56IIE	0.18	0.15	17.01	22.67	18.8	25.1	76.4	93.7
Waterlines Junction	4o49I 02.18IIN 7o00I 32.67IIE	0.12	0.14	10.87	16.12	16.9	20.7	49.6	52.5
Port Harcourt Airport	5o00I 25.45IIN 6o57I 02.36IIE	0.06	0.07	1.02	1.18	6.3	9.1	14.2	17.4
Woji	4o49I 42.52IIN 7o03I 28.67IIE	0.28	0.13	9.22	5.23	22.1	17.4	95.2	93.6
	Mean	0.16	0.15	10.07	12.48	21.54	22.46	75.4	86.28
	FMEV, 1991	0.08mg/m ³ (1Hr)		10-11.8mg/m ³ (1Hr)		150µg/m ³ (1Hr)			
	WHO, 2017	0.2-0.5 mg/m ³ (1Hr)		30 mg/m ³ (1Hr)		PM10 (150µg/m ³ for 24Hr) and PM2.5 (75µg/m ³ for 24 Hr) Based on WHO interim target 1			
Source: Edokpa, 2018. *Green Coloured Areas – Below Ambient Set Limit **Other Areas – Above Ambient Set Limit									

Table 3: Mean Ground Level Emissions Concentration in April, 2017.

Discussion

Bases and Implication for Ground Level Pollutants Concentrations in Port Harcourt

Regarding the accumulations of ground level pollutants concentration within the surface layer of Port Harcourt city which could lead to severe health concerns, the issues of air pollution has attained its utmost level over the years in Port Harcourt. The quality of the air within the city boundary layer is largely determined by anthropogenic sources and environmental regulators have been finding it very difficult to ensure full cooperation and control for the emissions spread. This arises as a result of the lack of effective mitigation measures in place. The emission enhancement pattern in the area's lower atmosphere is more of a planned one than fugitive or accidental. The black soot emissions from the burnings of petroleum product witnessed in the city has only heightened the negative impacts these pollutants will have on the city inhabitants. The consistent increasing population growth and the need to meet the demands of the economy have necessitated the growth of various trades and industries in city over the years. The oil and gas facilities located in the area as well others industries of close proximity to the city centre emits various kinds of pollutants. The consequence is that businesses are enticed to the area for access to oil and gas wealth with associated negative impacts such as polluting the boundary layer atmospheric environment. The modelling of pollutants concentrations, as well as the microclimatic impacts on the pollutants in the Niger Delta region, has been determined by (Sonibare and Ede, 2009; Ede et al., 2011; Edokpa and Ede, 2013; Ede and Edokpa, 2017) [8,9,25,26]. Activities associated with oil and gas production such as gas flaring; oil well, oil storage tanks and pipeline explosions; fugitive emissions from obsolete equipment's etc. all contribute to the concentrations of pollutants such as NO_x, SO_x, VOCs, CO, PM etc. in the lower atmosphere [27].

Large numbers of vehicles ply Nigerian roads and each one is a potential source of air pollution [28]. The implication is that most roads in metropolitan cities where prominent such as Port Harcourt are now congested leading to the corresponding loading of the atmosphere from the release of pollutants. The various opportunities contained in the city are accompanied with various forms of activities of which traffic usage is central. Where most roads are not in good condition or lacks the adequate capacity to contain the volume of increased vehicles (as obtainable in Nigeria), congestion is unavoidable. This type of trend enhances delays, hence, emission concentrations from the areas. Vehicles obtain their energy from the combustion of fuel gas [29]. During the process of combustion, exhaust gases are emitted into the environment. Mmom and Essiet (2014) [30] affirmed that automobiles traversing major urban regions in Nigeria are projected to account for 80% of all carbon monoxide, 50% of

hydrocarbons and about 40% of oxides of nitrogen. It has been noted that vehicular emissions in Nigeria are found higher mostly at mornings and evenings periods [29-31]. This is due to the gridlock caused during the peak hours in the morning, break time (during the afternoons) and evenings; another peak time when people are closing out for the day's activities. Mmom and Essiet (2014) [30] highlighted some factors that enhance the emission of pollutants from vehicles. This includes the number of vehicles, the age of vehicles, the mileage driven by the various vehicles and the technology used for emission technology. In a developing country like Nigeria, the availability of vehicles using emission technology depends on the purchasing power of the populace where about 70% are below poverty levels. In this regards, most prevalent vehicles in Nigeria will be used ones where age and enhanced emission technology are not favourable. Okolo (2014) [28] have recommended that used cars imported into Nigeria should have brand new engines and a total ban on the importation of used 2 stroke engines. The lack of consistent power supply in Nigeria has increased the usage of private electricity generation set from industrial, commercial and residential owners. This without doubt has contributed to ground level pollutants build-up. Burnings from domestic usages, abattoirs, biomass, petroleum products within the city area although not as frequent in magnitude as the major emission sources highlighted also contributes to ground level pollutants concentrations in the city.

It is therefore critical that government at all levels must initiate robust policies that will curb the threat of air pollution in order to avoid fatalities over time. The World Health Organization (2017) [32] has revealed that developing countries are being ravaged by poor air quality pattern and as a result, continuous loss of lives due to acute respiratory diseases. It is based on this perspective that all stakeholders presume that alleviating air emissions within any sensitive part of Nigeria will become strongly apprehensive than ever any moment if the existent attitude lingers. It is therefore vital that active actions and practicable resolutions be advanced by policy makers to protect the sensitive boundary layer expanse.

Factors that Influence the Ground Level Pollutant Concentrations in Port Harcourt

The meteorology of the lower troposphere has been acknowledged to be fully liable for air pollutants transport across boundaries [10]. Pollutants behaviour in the troposphere includes transportation, dilution, transformation and removal. The knowledge of the physical processes that lead to an observed concentration of pollutants to a given point is an important tool for the concentrations of ground level pollutant's dispersion at any point in time. The dispersion of air near the earth's surface is caused by atmospheric turbulence, or random fluctuation in wind velocity [33]. The wind direction determines the direction in which the pollutants will move across local terrain [34]. Wind

speed influences the emission rise and the rate of dilution. The turbulence of the atmosphere is by far the most important parameter affecting dilution of a pollutant [35]. As the atmosphere boundary layer becomes unstable the higher the dilution. Stability categories are determined for the various meteorological conditions, branded by wind velocity and solar radiation and cloud cover. The lower atmosphere over Port Harcourt surface layer is characterized by moderate wind speed with its major range between 0-3m/s [36]. This major wind speed rate ensures the prevalence of moderate mechanical turbulence generated by wind shear. The atmospheric stability of within the lower atmosphere in Port Harcourt is slightly unstable (PG class C) during the day time and more unstable (PG class B) during transition periods [37]. This means that surface layer emissions will be dispersed at a slower rate given a lower wind velocity during the day and at a modest rate due to somewhat increased mixing given a moderate wind velocity during transition periods. A critical time of high ground level pollutants concentrations in recent times within Port Harcourt city is during the night periods/early hours of dawn i.e. from 12am to 5am. This is due to the very stable boundary layer atmosphere of the city (Pasquill-Gifford stability class F) and the low boundary layer height which does not exceed 185m [36,37]. Nonetheless, this time of high ground level pollutant concentration most especially when black soot is in the air occur during very low human outdoor activities. The tendency for the surface layer during this period to be impacted with high emissions concentrations is significant as vertical mixing of ambient air is restricted due to temperature inversion. Since microclimatic conditions for any given region cannot be modified, it is vital to note that pollutants emissions reduction from sources is the only option required to lessen the impacts of climatic variables on emissions dispersion.

Conclusion

This study has been able to show the average level of criteria air pollutants released from the surface boundary layer in Port Harcourt for a dry and wet season sampling periods. The pollutants that surpass the Nigeria set limit in most sampled location were NO_x , CO and PM_{10} and the locations exceeded were areas of significant traffic and commercial activities. Locations of below limit at most periods were residential and the international airport in Port Harcourt was significant emissions activities are minimal. The main sources of air pollutants in Port Harcourt city include releases from automobiles, electricity generators, industries, construction activities etc. However, while vehicular emissions constitute the main source of ground level emissions around most commercial and domestic areas during the day, the black soot emission prevails during the night time/early hours of dawn. These emissions have a severe influence on municipal air quality and public health. Exposure of boundary layer dwellers to these air pollutants has been linked with amplified threat of upper

respiratory tract sicknesses such as persistent obstructive lung disease, asthma, cancer, increased chances of heart ailment, severe impairment to the central nervous system etc. The study revealed that the input of criteria air pollutants to the surface boundary layer of Port Harcourt City is sizable. In order to ensure that ground level pollutants concentrations does not continue to surpass set limits, policy makers must ensure that necessary checks are in place to reduce the emissions from the known emitters thereby preventing harm to the health of boundary layer dwellers.

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References

1. Olamide T, Sonibare J, Odunfa M, Ayeni A (2015) Modelling of Criteria Air Pollutant Emissions from Selected Nigeria Petroleum Refineries. *Journal of Power and Energy Engineering* 3: 31-45.
2. Fakinle BS, Oki AA, Sonibare JA (2018) Dispersion Modelling of Air Emissions from all Cement Plants in Nigeria. *International Journal of Mechanical Engineering and Technology* 9: 1155-1171.
3. Asubiojo O, Ede PN, Edokpa OD, Ayodeji O (2011) Aspect of Air Quality Status of Bonny Island Nigeria Attributed to an LNG Plant. *Energy and Environment* 22: 891-909.
4. Njoku KL, Rumide TJ, Akinola MO, Adesuyi AA, Jolaoso AO (2016) Ambient Air Quality Monitoring in Metropolitan City of Lagos, Nigeria. *J Appl Sci Environ Manage* 20: 178-185.
5. Ukemenam OS (2014) Causes and Consequences of Air Pollution in Nigeria. *South American Journal of Public Health* 2: 293-307.
6. Uwaegbulam C, Alao T, Muanya C (2015) Pollution threatens air quality. *Guardian Newspapers*, March 19.
7. Ayoade JO (2012) Introduction to Building and Urban Climatology. Ibadan: AgboAreo Publishers.
8. Ede PN, Edokpa OD, Ayodeji O (2011) Aspect of Air Quality Status of Bonny Island Nigeria Attributed to an LNG Plant. *Energy and Environment* 22: 891-909.
9. Edokpa OD, Ede PN (2013) Challenges of Associated Gas Flaring and Emission Propagation in Nigeria. *Academia Arena* 5: 28-35.
10. Oyem AA, Igbafe AI (2010) Analysis of the Atmospheric Aerosol Loading over Nigeria. *Environmental Research Journal* 4: 145-156.
11. Obanya HE, Amaeze NH, Togunde O, Otitolajo AA (2018) Air Pollution Monitoring Around Residential and Transportation Sector Locations in Lagos Mainland. *Journal of Health and Pollution* 8: 1-9.
12. Isikwue BC, Ameh ME, Utah EY (2013) Analysis of rainfall variability over some cities in Nigeria using Harmonic Analysis technique. *Nigerian Journal of Physics* 24: 16-24.
13. Umoh MD, Udo SO, Udoakah YN (2014) Estimating global solar radiation on horizontal surface from sunshine hours over Port Harcourt, Nigeria. *Journal of Electrical and Electronics Engineering Research* 6: 1-5.

14. Adejuwon JO (2012) Rainfall Seasonality in the Niger Delta Belt, Nigeria. *Journal of Geography and Regional Planning* 5: 51-60.
15. Fagbenle RL (1990) Estimation of Total Solar Radiation in Nigeria Using Meteorological Data. *Nigerian Journal of Renewable Energy* 1: 1-10.
16. Weather2 (2016) Country Overview for Nigeria. Available from: www.myweather2.com/city/city-Town/Nigeria
17. Amadi SO, Udo SO (2015) Analysis of Trends and Variation of Monthly Mean Wind Speed Data in Nigeria. *IOSR Journal of Applied Physics* 7: 31-41.
18. Ngene BU, Agunwanba JC, Tenebe IT, Emenike PC (2015) Evaluation of Spatial and Temporal Characteristics of Wind and Wind Resources: A Case Study of Some Nigerian Cities. *International Journal of Applied Engineering Research* 10: 40153-40158.
19. NPC (2006) Census Figures for 2006. National Population Commission, Abuja.
20. Marais EA, Jacob DJ, Wecht K, Lero C, Zhang L, et al. (2014) Anthropogenic emissions in Nigeria and implications for atmospheric ozone pollution: A view from space. *Atmospheric Environment* 99: 32-40.
21. Jaegle L, Martin RV, Chance K, Steinberger L, Kurosu TP, et al. (2004) Satellite mapping of rain-induced nitric oxide emissions from soils. *J Geophys Res* 109: 1-10.
22. Weli VE, Kobah E (2014) The Air Quality Implications of the SPDC-Bomu Manifold Fire Explosion in K-Dere, Gokana LGA of Rivers State, Nigeria. *Research Journal of Environmental and Earth Sciences* 6: 1-9.
23. WHO (2016) Global Ambient Air Pollution.
24. Efe SI (2008) Spatial distribution of particulate air pollution in Nigeria cities: implication for human health. *Journal of Environmental Health Research* 7: 107-116.
25. Sonibare JA, Ede PN (2009) Potential Impacts of Integrated Oil and Gas Plant on Ambient Air Quality. *Energy and Environment* 20: 331-345.
26. Ede PN, Edokpa OD (2017) Satellite Determination of Particulate Load over Port Harcourt during Black Soot Incidents. *Journal of Atmospheric Pollution* 5: 55-61.
27. Ede PN, Edokpa OD (2015) Regional Air Quality of the Nigeria's Niger Delta. *Open Journal of Air Pollution* 4: 7-15.
28. Okolo AI (2014) Vehicle Emission Control: A means to achieve clean air.
29. Oguntoke O, Yussuf AS (2008) Air Pollution Arising from Vehicular Emissions and the Associated Human Health Problems in Abeokuta Metropolis, Nigeria. *Asset Series A* 8: 119-132.
30. Mmom PC, Essiet U (2014) Spatial-Temporal Variations in Urban Vehicular Emissions in Uyo City, Akwa Ibom State, Nigeria. *Journal of Sustainable Development* 7: 272-281.
31. Okunola OJ, Uzairu A, Gimba CE, Ndukwe GI (2012) Assessment of Gaseous Pollutants along High Traffic Roads in Kano, Nigeria. *International Journal of Environment & Sustainability* 1: 1-15.
32. World Health Organization (2017) Evolution of WHO air quality guidelines: past, present and future. Copenhagen: WHO Regional Office for Europe.
33. Azeez MA (2002) Estimation of Air Pollutants from Oil Processing using Photochemical Model, An unpublished Master Thesis, Department of Geography, University of Port Harcourt, Port Harcourt.
34. Ede PN (2007) Advanced Meteorology: Lecture notes on Air pollution meteorology. Institute of Geosciences and Space Technology, Rivers State University of Science and Technology, Port Harcourt Pg No: 65.
35. Davis MI, Cornwell AD (1998) Introduction to Environmental Engineering, (3rd Edition). New York: McGraw – Hill.
36. Edokpa OD (2018) Atmospheric Stability Conditions of the Lower Atmosphere in Selected Cities in Nigeria. An Unpublished Ph.D. Thesis, Department of Geography and Environmental Management, University of Port Harcourt, Nigeria.
37. Edokpa OD, Nwagbara MO (2017) Atmospheric stability pattern over Port Harcourt, Nigeria. *Journal of Atmospheric Pollution* 5: 7-19.