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Preliminary Air Quality Index Estimates of Particulates Concentration in Port Harcourt during Soot Incidents

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Abstract:- *Airborne soot of anthropogenic origin which is generating much apprehension for residents has been plaguing Port Harcourt recently. An assessment of air quality during that period was used to construct an air quality index (AQI). The AQI indicates how relatively clean or polluted the ambient air is, and what accompanying health effects might be of concern for sensitive receptors. Suspended particulate matter of size PM_{10} and $PM_{2.5}$ during the soot incidents of early 2017 were used to evaluate the prevalent ambient air quality of the area at eight locations for both night and day periods. The daily sampled results of the particulates between January and April was used in estimating the AQI adopting the Oak Ridge National Air Quality Index developed by the US Oak Ridge National Laboratory (ORNL). The results show that clean air existed at Igwuruta during the night and day, and at Trans-Amadi during the day as AQI was less than 25. It was however severe at Eleme (day & night), Woji (day), and Diobu Mile-one area (day) as AQI was greater than 100. Areas like Woji and Oyigbo witnessed moderate air pollution at night (AQI <76), Diobu Mile-one area witnessed heavy particulates pollution (76≥AQI ≤100). Other areas that witnessed low particulates pollution both day and night include Choba and Rumuobiakani. Efforts should be made by relevant stakeholders to ensure that residents are protected from the plague of airborne soot and its deposition on the city as the end of it is not yet in sight.*

Keywords: Soot (black carbon), Particulates, Air Quality Index, Air Pollution, Port Harcourt.

1. INTRODUCTION

With the upsurge of population and anthropogenic emissions in urban centres such as Port Harcourt, concerns linked to airborne particulates pollution have attracted much reaction than ever before. The challenge of air pollution in the city has worsened with the deposit of black carbon, clearly visible since the last quarter of 2016 [1]. This hazardous deposit which comes from anthropogenic activities shows that there is urgent information about variations in the boundary layer pollution level [2]. The study of ambient air particulates concentrations is a prime focus of air pollution studies due to the negative health effects triggered by these contaminants in urban areas especially during severe and persistent pollution episodes as witnessed in Port Harcourt in the last two years. It has been observed that urban air quality in major Nigerian cities is prone to airborne particulates pollution from diverse sources [3]. A recent study conducted in China has shown that a 10μg/m^3 increase in ambient concentration of PM_{10} reduces life expectancy by 0.64years [4]. As a consequence, the application of an effective scalable tool such as the air quality index (AQI) to deepen understanding of air quality measurements in metropolitan areas is of crucial importance. Principally, the AQI is defined as a rating scale for analysing daily mutual influence of air pollutants concentration measured or modelled within any given area. In this respect, there is a need to relate levels of pollutant contamination in the effective boundary layer to an index that extracts the quality distributive track of the influence of the pollutants on boundary layer dwellers. Regarding the health impact of air particulates, AQI is a necessary indicator that should be used to enlighten the populace to appreciate and understand effortlessly how negative or positive the ambient air quality affect their health [5]. It contributes to the explanation of data for any assessment by policy makers in order to mitigate any form of widespread environmental effects that might result from dangerous air pollution episodes.

2. MATERIALS AND METHODS

2.1 Description and Meteorology of Study Area

Port Harcourt is situated in the Niger Delta area within Latitudes 4° 46′ 38.7″N and Longitudes 7° 0′ 48.2″E. The area is located around the coastal zone subjugated by low setting coastal plains of sedimentary formations [6]. Port Harcourt has a humid equatorial monsoon climate influenced by its closeness to the Ocean. This influence from large water bodies exposes the area to continentality effects e.g. land and sea breeze [7]. The moist northward moving maritime air coming from the Atlantic Ocean and the dry continental air coming from the African landmass influences rainfall regime in which the Inter-tropical Convergence Zone (ITCZ) plays a controlling factor. As a result of the robust presence of the moist southwest wind, the area receives abundant rainfall amount of annual mean above 2300mm [8]. The rainy season commences with the

early rains in late February, which ceases in November with bi-modal peaks in July and September. Mean high and low temperature value of 32°C and 26°C are recorded in January and July, respectively and the average relative humidity for the area varies from 66%-96% throughout the year [9] with high and low peaks during the wet and dry seasons. Cloud cover pattern in the area is constantly enhanced with monthly average of over 6 oktas. Mean daily wind speed pattern range from 0-3m/s with lower and higher trend observed during the night and evening. The predominant wind direction for most times of the year is south-westerly with slight north-easterly variation in December/early January. According to [10], the boundary layer atmosphere in Port Harcourt is slightly unstable, moderately unstable and very stable during the day, transition periods and night time.

2.2 Application of Air Quality Index

The airborne particulates (PM_{10} and $PM_{2.5}$) ambient concentrations were monitored using a digital portable hand-held air detector (5 in 1 multi-function laser sensor, BRV8). The instrument was held at a height of 2m above ground level and the ambient air particulates concentration determined as shown on the visual display unit. The regularity of the observation was such that a location was randomly monitored one day in a week both day and night time (i.e., 7.00am-12noon; 12am-5am) for four months i.e., January-April, 2017. The mean level for the periods for the particulates were averaged and computed. Table 1 shows the mean concentrations values for the various sampled locations.

Table 1: Concentration values for Particulates

Sampled Location	PM_{10} Concentration ($\mu g/m^3$)		$PM_{2.5}$ Concentration ($\mu g/m^3$)	
	Day	Night	Day	Night
Rumubiakani	170	212	50	65
Trans Amadi	110	230	35	49
Woji	415	335	120	62
Choba	176	197	55	53
Diobu (Mile One)	380	340	106	102
Oyigbo	140	216	48	77
Igwuruta	70	95	25	40
Eleme	494	376	81	155

In order to relay the rank of ambient air quality and its effects on human health, grouping of the AQI values were classified as clean air, light air contamination, moderate air contamination, heavy air contamination, severe air contamination. The AQI developed by the US Oak Ridge National Laboratory (ORNL) was adopted for the assessment of air quality. This tool is a nonlinear index having exponentialfunction with coefficient with other nonlinear relationship. In this method,coefficient may be constant or may vary but the relationship contains at least one variable raised to a power and this index may be taken in several forms for assessment of air quality. The ORNL AQI also hasadvantage for the relative ranking of overall air quality status at different locations of the study area with different airpollutants parameter.

AQI for each period in the study area was estimated with the help of a mathematical equation developed by the OakRidge National Laboratory (ORNL), USA [5] as given below:

$$AQI = [5.7 \Sigma I_i]^{1.37}$$

where,

$I_i = X/X_s$

X = observed pollutants concentrations for PM_{10} and $PM_{2.5}$

X_s = pollutant standard at National hourly values of $70\mu g/m^3$ and $30\mu g/m^3$ for PM_{10} and $PM_{2.5}$, respectively.

I = pollutant, while 5.7 and 1.37 are constants.

The index scale is demarcated from 0 to 100 and further divided into 5 sub categories of air quality groups. This indexrating is shown in Table 2.

Table 2: The Adopted ORLN Air Quality Index

Index Value	Description
00 – 25	Clean air
26– 50	Light air contamination
51– 75	Moderate air contamination
76– 100	Heavy air contamination
AQI>100	Severe air contamination

3. RESULTS AND DISCUSSION

3.1 Air Quality Index Analysis

Table 3 presents the AQI status of sampled areas for the day and night times, respectively. Using the data of daily average PM_{10} and $PM_{2.5}$ ambient concentrations at the various sampled location conducted between January and April 2017, the AQI was determined. The AQI of the particulates were determined in order to assess the level of hazards the ambient air quality pose to the health of boundary layer dwellers. Results shows that the AQI for Eleme area during the day and night times is quite significant i.e., severe air contamination. Igwuruta which is north of Port Harcourt had clean air as AQI was below 26 both for day and night times. Areas like Woji and Diobu (Mile One) had moderate to severe air contamination from the airborne particulates. Eleme, Woji, Diobu and Trans-Amadi areas are hosts to industrial and intense human activities

which make them prone to constant vehicular movement and thus sustained emissions releases. When these local emissions combine with other sources, the atmosphere becomes laden pollutants. A satellite determination of emission concentrations has shown that areas like Eleme, Woji, and Diobu (MileOne) are vulnerable to significant amount of ambient particulate matter concentrations [1] while areas northwest of Port Harcourt are less susceptible. For impacted areas, the concentrations downwind of sources are minimal at 0100hr and higher for the hours of 0300 and 0700. It was emphasized that daily concentrations over the city were not uniform, varying according to changes in atmospheric stability and transport, microclimatic conditions and urban surface concentrations [1]. On the average, the atmosphere over Port Harcourt is very stable at night, slightly unstable at noon and more unstable at sunset [10]. These stability settings especially both during the day and night periods magnify pollutants concentrations. During the day, when the atmosphere is unstable at moderate wind speed (typical of Port Harcourt), emission concentrations are manifestly downwind close to sources. At night under very stable condition, emission concentrations downwind of sources can be higher at closer distances when emission sources are below inversion level and higher at farther downwind distances when emission sources are above inversion level [9]. These trends tend to explain the disparity of the AQI pattern for the respective sample areas.

Table 3: Air Quality Index (AQI) for Sampled Areas

Sampled Location	AQI (Day)	AQI (Night)	Indication (Day)	Indication (Night)
Rumubiakani (IPHC)	36	50	Light air contamination	Light air contamination
Trans Amadi (IPHC)	21	47	Clean air	Light air contamination
Woji (IPHC)	122	75	Severe air contamination	Moderate air contamination
Choba (OPHC)	39	42	Light air contamination	Light air contamination
Diobu -Mile One (IPHC)	106	96	Severe air contamination	Heavy air contamination
Oyigbo (OPHC)	30	56	Light air contamination	Moderate air contamination
Igwuruta (OPHC)	12	20	Clean air	Clean air
Eleme (OPHC)	122	130	Severe air contamination	Severe air contamination

*IPHC – Inside Port Harcourt Metropolis;
**OPHC – Outside Port Harcourt Metropolis

3.2 The Current Air Pollution Mitigation Challenge in Port Harcourt

The escalation of black soot emissions within and around the Port Harcourt boundary layer atmosphere will stimulate conceivable air quality challenges in the near future. At the beginning of soot emissions in Port Harcourt, several residents demonstrated their worries and protests as the black particles were found to have settled on sensitive receptors such as the home environment, schools, market places, cars as well as triggering respiratory problems particularly during the early morning hours. Residents purported that the soot emissions was supposed to have ensued from the burnings of petroleum based hydrocarbons within and outside boundaries of Port Harcourt city. The Nigerian economy is over 80% dependence on oil and gas revenue, although, it is an advantage for the nation to harness her natural resources and make life comfortable for the masses, procedural inputs to harness these resources for economic viability should attains its optimal productivity without negatively impacting on the environment [13]. The present trend in the area informs us that the oil and gas industries are not only taken unaware, but are sure to disagree with the public that their activities largely contribute to the magnitude of black soot emission impact. Port Harcourt has been a nucleus of emissions from various sources such as the legal and illegal refining of petroleum crude, modular refineries, automobiles, abattoirs, domestics etc. While boundary layer pollution has been part of the inhabitant's routine lives, residents now face a unique type of peril, which is the increased soot particles ravaging the lower atmosphere of the metropolis and beyond. The US Environmental Protection Agency (EPA) describes soot harming the human body as microscopic particles capable of penetrating deeply into the lungs and have been linked to a wide range of serious health effects, including premature death, heart attacks, and strokes, as well as acute bronchitis and aggravated asthma among children. Apart from bodily harm, soot emission causes other environmental problems such as haze and acidification of rivers. Haze is formed when sunlight interacts with soot particulates in the atmosphere and this reduces visibility. Therefore, it is the inhabitants of the environment that agonise the burden of the impacts.

It is noted that an increase in the level of industrialisation especially from a developing country like Nigeria has its advantages and disadvantages. Advantages in the sense that the rate of unemployment which is a major plague in Nigeria will be reduced with envisioned economic boost. A major disadvantage is that emissions from the cumulative industries will choke up the lower troposphere thereby enhancing climate change consequences. However, where the medium to high level stage of industrialisation is yet to be achieved in Nigeria, it is relatable that the current

trend of atmospheric pollution will be tripled when the near-peak of industrialisation is attained in the future. The most challenging issue in Nigeria is that necessary strategies, policies, plans and program including fundamental technicalities are not being enhanced or adequately implemented to protect the biosphere and ensure quality of the inhabitable environment. The essential needs for survival while taking undue advantage of the environment is at its optimum most especially with the oil and gas related processes in Nigeria. All stakeholders such as governments, oil and gas producing industries, host communities etc. are engrossed with the notion to harvest the monetary dividends of the resources rather than device the precise strategy to favour and sustain both humanity and the environment. To mitigate the challenges of negatively impacting the environment, policy makers in Nigeria must implement complementary policies that adequately address the needs of the habitable environment. Strategies must be such that positive benefits from harnessed natural resources outwit the negative impacts.

4. CONCLUSIONS

The Outcome of the AQI for airborne particulates i.e. $PM_{2.5}$ and PM_{10} for sampled locations within and around Port Harcourt during periods of intense soot emissions of early 2017 has been evaluated using the Oak Ridged National Air Quality Index model. Woji, Diobu and Eleme study locations indicated a 'moderate' to 'severe' AQI. The activities of some of the industries situated at these areas as well as other anthropogenic activities may have contributed to the high level of particulates contamination into the atmosphere. Areas such as Rumubiakani, Trans Amadi and Choba witnessed clean to light air contamination. However in Igwuruta, southwest of Port Harcourt, the air was cleaner for both day and night times signifying low risk area for respiratory diseases. Persons with respiratory conditions as well as children and the elderly may be adversely affected if they are exposed to airborne particulates in areas of severe and heavy air contamination such as Eleme, Diobu and Woji. There should be regular monitoring of air quality at vulnerable areas so as to mitigate adverse health effects of the dwellers.

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