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Air Quality Effect of Particulates Matter (PM) distribution during Dry and Wet Season in selected Parts of Port Harcourt Metropolis, Rivers State, Nigeria.

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Abstract:
Background *This study investigated the air quality impact of seasonal variations on the Particulates Matter distribution in parts of Port Harcourt metropolis.*
Materials and Methods*: The study was carried out using complete randomized block design in factorial experiment. Two (2) Factorials were used (with factor A as Season and B as Location). The experiment was conducted in dry and raining seasons along the 3 locations (Makoba-station 1, Elekahia-station 2 and Rivers State University-station 3). An aerostat SPM 531 particle A met -1 aerosol mass monitor was used to measure respirable particulate and total suspended particles; using photochemical filtration pump/filter glass as its measurement principle.*
Results*: The effect of factorial interaction of season and location on the distribution of suspended particulate matter in ambient air was highly significant (P<0.05), PM_1 was higher (10.2857 µg/m^3) at station 3 during the raining season and lower (5.50µg/m^3) during the dry season at station 3.$PM_{2.5}$ level was highest at station 2 during the dry season (47.33 µg/m^3), while $PM_{2.5}$ was low during the raining season also at station 2. PM_7 value was higher at station 2 (160.67 µg/m^3) during the dry season and low (11.57 µg/m^3) during the raining season at the same station.PM_{10} and TSP were also high during the dry season at station 2 with values of 234.67 µg/m^3 and 260.80 µg/m^3, respectively. The study revealed the presence of Particulates Matter in the environment and recorded a significant concentration of pollutants during the dry season for both urban, industrial and rural areas. Black soot-containing particles are also associated with adverse effects on street foods vendors, contaminating building materials and possible negative effects on human health. This is a sources of Public health concerns.-*

Key Word*: Seasonal Variations, Black Soot, Particulate Matters, Environment, Port Harcourt*

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I. Introduction

In the last three years the emergence of black carbon (soot) in the city of Port Harcourt and her neighboring communities such as Makoba, Bund-Ama, Ogbogoro, Rumulumeni, Aker base, Naval Base, Eagle Island, has become a worrisome episode. Soot is a cancer-causing particle in the atmosphere linked to oil exploration and gas flaring in the Niger Delta region of the country. Particle pollution—also known as particulate matter or particulates—is a complex but stable gaseous suspension of liquid droplets and solid particles in the earth's atmosphere. According to Jacqueline and Sara **[1].** ''Particle pollution is known to have many environmental effects from poor visibility to more serious consequences such as acid rain, which pollutes soil and water. Particles are commonly classified according to their size as either coarse or fine. Fine particles have a diameter of 2.5 µm ($PM_{2.5}$) or less, and coarse particles are 10 µm or less (PM_{10}). Particulate matter that has a diameter over 100 µm tends not to stay airborne long enough to be measured. Sources of particulate matter are often classified according to whether they originate from natural or anthropogenic sources. Natural sources include particles suspended in the atmosphere by volcanic eruptions, bush fires and pollen dispersal. Anthropogenic source is emissions from combustion of fuels, for example, vehicle exhaust. In Europe, anthropogenic sources have been identified as the main contributor to PM_{10} due to urbanization, high population density and areas of intensive industry.''

We are concerned with particulate matter arising from black soot. It is also a general term that covers pollutants derived from the incomplete or inefficient burning of fossil fuels or biomass – plants or plant-based materials used as source of energy, Shell Petroleum Development Company **[2].**The major sources of soot include

fuels like diesel used in transport and in electricity generators. For the Niger Delta, the sources include the aforementioned and include others such as gas flares, the burning of illegal refineries and crude oil, burning of oil spills by incompetent contractors and the burning of sundry wastes [2]**.** Bush burning can also be a source of soot in our environment. Many pundits have attributed the black soot to some Chinese companies making plastics, to others, Asphalt Company, Eleme Petro-Chemical to the refinery operations, burning of tyres by butchers, until recently, some school of thought have attributed the sources of the soot or Particulate matters to the activities of illegal refineries in the creeks of the Niger Delta. Also, Rivers State Government , through Ministry of environment [3] have attributed the black carbons to the activities of security operatives who in attempt to curtailed these illegal activities resorted to burning of illegal refineries and refined products usually stored in plastic containers and carried in wooden boats of various sizes. Thus increasing the releasing of the soot into the atmosphere. The impact on people, assets, exposed foods, water bodies, and plants is obvious. In addition to food handling as contributors of food infection, the environment, where these food are prepared is a major source of concerns. The seasonal variation, for instance during the dry season, when the road is full of dust and other particulate matters from the environmental activities such as heavy trucks movement will cause settlement of these dust particles on food samples and man as the eventual consumer become the receptor. At the petroleum depots, most mama-put and other women roasting plantain, yam, and potato, fish, frying of Akara, were found around these facilities. In the raining season, we have also seen deposits of soot's arising from the activities from the local refineries sites and the setting on fire some drums with diesels by to security monitoring team in early morning and later in the night. You wake up early in the morning to find the whole sky very cloudy and smoky with photochemical smog as though it is the onset of harmattan**.** The impact is relatively low as rain periodically act as a cleanser and eventually reduces deposits on food and materials alike. The wind of continental origin was found to have significant contribution to higher BC concentration in summer. Aerosol black carbon (BC), produced mainly due to incomplete combustion of fossil fuel or biomass, is amongst the strongest contributors to the radiative warming of the atmosphere[4, 5]**,** through its strong absorption over a wide wavelength range (from UV to IR). They can heat the air, alter atmospheric stability, large-scale circulations and cloud albedo by changing the hygroscopicity of cloud condensation nuclei. BC aerosols are inert in nature as a result of predominant sub-micron size and chemical structure, being in the fine size range (median diameters in the range 100–200 nm), they bear a long atmospheric residence time, thereby leading to deterioration of air quality and health hazards as easily respirable [6,7]**.** In addition, BC-containing particles are also associated with adverse effects such as decrease in crop yields, contaminating building materials and adversely impact terrestrial and aquatic ecosystems [8,9,10]. Since the incidence of BC, there were significant variances in the mean concentrations of particulate matter, total suspended particle, Nitrogen dioxide, Carbon Monoxide, and Methane during the wet transition and dry seasons respectively at 0.05 significant level between the urban and rural zones [11, 12,13,14,15.]

Air pollution has long been seen as a fact of city life. Today in Port Harcourt you wake up to see black smoke (soot's) covering the sky and black soot dropping on cars and curtain in homes. People breaths and inhale these smoke as part of the daily oxygen intake. It is worrisome, not to mention the deposits on ready to eat foods. You might, for example, shrug off the discovery of black particles in your nostrils after a day pounding the streets of Makoba, Rivers State University and Elekahia in Port Harcourt. But as soot particles collect unpleasantly in our noses, what is happening as they travel down our lungs? For people whose job it is to work outside primarily such as vehicle inspectors (VIO) arms of the Petroleum Tankers Drivers Union as it is the case at Aker base and Makoba, security agents at the gate of the University and various check points along Elekahia and particularly those who are on duties for over Eight (8) hours ensuring safety of human and vehicular movement, it poses a more serious concern for consideration. Others in this category are street cleaners, refuse workers, community police support officers, the Navy, Police and Army (Joint taskforce operation) helping to control traffic on Aba road gridlock, cycle couriers and others are all at increased risk according to scientists. British Safety Institute[16]**.** These street workers will usually have at least most of their meals on the road. As they are exposed to more danger, one will ask who is protecting these workers from air pollution. If not, what should we look to change? Hence this study.

According to the BSI**,**[16], every year about 29,000 deaths in the United Kingdom were attributed to inhaling particulates found in outdoor air pollution. On recent evidence, this may rise to around 40,000 when considering nitrogen dioxide exposure. The Royal College of Physicians (RCP) said in their 2016 report "Every Breath we take: the lifelong impact of Air Pollution debate has centered on diesel exhaust emissions''. Since the international Agency for Research on Cancer (IARC) classified these as carcinogenic in 2012[16]**.** PM_{10} are so minute that they can be inhaled, penetrate the lungs and cause serious health problems. One event which illustrates the effect of particle pollution on human health is the 1952 'Great Smog' in London. Particle pollution from coal burning hung over the city for four days due to cold temperatures and lack of wind. Approximately 4000 deaths were linked to this single event**,** [17]**.** As a result of events such as the Great Smog and obvious signs of climate change, many countries are now committed to international and national clean air legislation and air quality standards. These agreements require regular reporting of air quality including PM concentrations.

The impact of these environmental nuisance is more evident for hawkers who walk distances along the streets of PH to sell their goods and services for their daily living. These ones have complained of heavy black particles in their nostrils and observed black dirt's when bathing from hair entrapment, the feet of people who walk barefooted in their homes are observed to be dark and possibly stains the white beddings, when going to bed without washing of their feet. This was the testimony of a Royal father along the Elekahia axis of Port Harcourt (part of the study location), who literally showed me his dark feet and dark palms when he swabbed his palms across the window blind to fold in place. You can better imagine the fate of the street workers such as the Traffic wardens in Rivers State, Rivers State Traffic Management Authority (TIMARIV), Okada riders, Newspaper vendors, Taxi drivers, Keke riders, Tanker drivers, street sweepers, waste scavenger's , food hawkers, and many other road users trying to meet daily obligation. Students and primary education school children who trek long distances to schools are not spared of the exposure. Street traders who display their wares on the road, traders and marketers are equally affected as the soot covers clothing and articles of sales. The soot is affecting everyone in Port Harcourt. The effects on humans, animals and plants alike is better imagined. The economic costs of particulate pollution on a country can be significant. In the European Union in 2015, the cost of air pollution-related deaths was reported to be over US$1.4 trillion. In Israel, it is estimated that 2500 people die each year as a result of exposure to air pollutant**s**[18]. In New Zealand (population ~ 4.4 million), it was reported that, despite relatively low air pollution when compared with other members of the Organisation for Economic Co-operation and Development, during 2012, a total of 1370 deaths, 830 hospital admissions and 2.55 million restricted activity days were linked to PM pollution, Statistic New Zealand, **[19],** even low levels of PM_{10} have been found to significantly affect human health.

This is posing untold economic hardship to the poor people of Rivers State, as the cost of cleaning and maintaining of infrastructures is on the increase. The Impact on the health of the people may not be acute but chronic, especially with children born within the period of the soot episode. According to Anny, et al.[20]. Pollutants derived from vehicular exhaust are transported away from their sites of release by wind and diffusion. Once airborne, they mix both with pollutants from other sources and with materials of natural origin, and they may be chemically transformed into other species. Ultimately, atmospheric pollutants are removed from the air either by rain or by dry deposition to the earth's surface. Highly reactive chemicals may be transformed or removed within a few minutes; stable substances may persist for years. Meteorological conditions and physical structures can also profoundly influence atmospheric concentrations. Thus, individual exposure is determined by the location a person occupies in relation to emission sources, as well as by patterns of atmospheric transport, transformation, and dilution. Airborne pollutants that are inhaled may deposit onto surfaces of the respiratory tract. Deposited insoluble material is moved (either intra- or extracellularly) towards the pharynx by mucociliary action and then swallowed. Alternatively, particles may be sequestered for long periods within pulmonary tissue or in adjacent lymph nodes. Inhaled chemicals that dissolve in body fluids may pass from the respiratory tract into the bloodstream and circulate throughout the body. As a result, air pollutants may affect "extra pulmonary organs"[20].Similarly, Florence Kayemba[21] reported that with high levels of air pollution, such as soot and pre-existing respiratory and other health conditions in the Niger Delta, this might increase the risk that COVID-19 poses to the health of the population of the Niger Delta. The Stakeholders democratic Networks (SDN) Programme Manager, Florence Kayemba further observed that the people of the Niger Delta are already suffering from environmental, health, and livelihood impacts from decades of oil spill pollution, associated gas flaring and artisanal refining. According to Oyet et al [22], polycyclic aromatic hydrocarbons (PAHs) are a group of notorious ubiquitous environmental contaminants produced primarily as a result of incomplete combustion of fossil fuels, biofuels and vegetation fires. PAHs found in street vended foods is of public health concern to consumers and call for urgent attention for the review of the PAHs sources in food preparations, handling and storage in Port Harcourt metropolis.

The presence of Particulate Matters (PM) in the urban air is of a public health concern. The air pollution caused by PM, is known to have adverse effects on the environment and human health. It is well known that both short-term and long-term exposure to small particles, especially those with the diameter less than 10 micrometers (PM_{10} and $PM_{2.5}$) have negative effects on human health, causing cardiovascular and respiratory diseases [23]. The presence of PM has negative impact on the environment, reducing visibility. The main sources of PM in the urban areas include industrial activities, domestic heating with coal or oil and traffic sector, especially diesel vehicles.

In comparison, the US National Ambient Air Quality Standard sets a limit value of 15 $\mu g/m^3$ for $PM_{2.5}$. In 2013 the -Environmental Protection Agency [24] has lowered the allowable average concentration of certain PM with 20% respect to 2006 making it more drastic in comparison with the European standard. The new annual limit imposed for the $PM_{2.5}$ concentration is 12 $\mu g/m^3$ (primary) and 15 $\mu g/m^3$ (secondary),on annual mean, averaged over 3 years (*http://ec.europa.eu/environment/air/quality/standards.htm).Accessed 20th May, 2020.* Total Suspended Particulate (TSP) mean values varied from 15.4 to 68.1 ± 9.2 $\mu g/m^3$ with a maximum mean of 68.1 ± 9.2 $\mu g/m^3$ this value was measured inside the academic land use. The Total Suspended Particulate (TSP) mean concentration across the stations were also comparatively lower than the National permissible limit of 250.0$\mu g/m^3$

[25]. Air pollutants called particulate matter include dust, dirt; soot, smoke and liquid droplets directly emitted into the air by sources such as power plants, factories, cars and construction activities [26].

This study evaluated the impact level of seasonal variations on particulate matters distribution in the environment where we leave and carry out our businesses in Port Harcourt Metropolis

II. Material and Methods

Study Area

Port Harcourt lies along the Bonny River and located in the Niger Delta, South-South part of Nigeria. Port Harcourt city covers about 360 sqkm. Port Harcourt is the capital and largest city in River State, located between latitudes 4°46'38.71" N and longitudes 7°00'48.24" E. As at 2016, the Port Harcourt urban area has an estimated population of 1,865,000 inhabitants, up from 1,382,592 as of 2006. [27]. The Study was conducted in three selected parts of Port Harcourt metropolis, Rivers States, along the following sampling points: Station1-Makoba (Terminal and Depots Housing Oil and Gas, and slump environment), Station 2- Rivers State University gate (Academic and urban Environment) and Station 3-Elekahia (Urban- Industrial and Residential Area).[22]

Methods

Experimental Design

The whole study was done using complete randomized design in a factorial experiment. Two factorials were used (Factors A and B); factor A represented Season, B Location given as 2X3 factorials, as shown in Table 1.0

Table 1.0 Experimental Design: Season and Locations

Stations	***Seasons***
Makoba-1	Wet
Elekahia -2	Wet
Rivers State University-3	Wet
Makoba-1	Dry
Elekahia -2	Dry
Rivers State University-3	Dry

Suspended Particulate Matter

An aerostat SPM 531 particle A met -1 aerosol mass monitor was used to measure respirable particulate and total suspended particles; using photo-chemical filtration pump/filter glass as its measurement principle. Measurements were done by holding the sensor to a height of about two meters in the direction of the prevailing wind and readings recorded at stability by data acquisition system. Equipment was pre-calibrated before taking to the field. This experiment was carried out for 2 days and the mean cumulative average used for the analysis. Real-time monitoring of PM concentrations was achieved using optical instruments. These instruments measured either light scattering, light absorption or light extinction caused by particulate matter. The most commonly used instrument is an optical particle counter (OPC) which uses a light source, normally a laser diode, to illuminate particles and a photodetector to measure light scattered by those particles. Zero count test was performed hourly to ensure proper operation of the particulate counter using zero count filter (PNG3111).Measurements from this instrument was periodically verified and calibrated using data from gravimetric instrumentation [28]. The portable aerostat 531 particle A met -1 mass monitor was obtained from Rofnel Energy Services Limited located at Plot 2 Addison Close, Rumuagholu, Port Harcourt

Statistical analysis

The mean values were subjected to statistical calculations which were performed using IBM SPSS (Statistical Package for Social Sciences) version 21

III. Result

Results for the distribution of particulate matters in in ambient air from stations 1, 2 and 3 during the raining and dry season are shown in Table 2. PM_1, $PM_{2.5}$, PM_7, PM_{10}, and TSP ranged from 0.857 – 10.286µg/m^3, 4.290 – 47.33 µg/m^3,11.57-160.33µg/m^3, 13.86 – 234.67 µg/m^3, and 15.43 – 260.83 µg/m^3 respectively. High PM_1 of 10.286 µg/m^3 was noted at station 3 during the raining season, this was however not statistically different ($P>0.05$) from PM_1 values of 4.667 µg/m^3, 5.167 µg/m^3 and 5.50 µg/m^3 recorded from stations 1,2 and 3, respectively, during the dry season. All the values were below 25 µg/m^3 (WHO maximum allowable limit). $PM_{2.5}$, PM_7 and PM_{10} values at all the locations were significantly above 25 µg/m^3 (WHO maximum allowable limit) except stations 1 and 2 during the raining season. TSP values of 260.83 µg/m^3 recorded at Elekahia during the dry season was above the National limit of 250 µg/m^3.

Table 2. Suspended Particulate Matter in Ambient Air from Stations 1, 2 and 3 during the Raining and Dry Seasons

Season	Station	PM_1 (µg/m³)	$PM_{2.5}$ (µg/m³)	PM_7 (µg/m³)	PM_{10} (µg/m³)	TSP (µg/m³)
Raining	**1**	1.29^{b} ±1.604	8.14^{c} ±3.020	24.86^{c} ±6.960	31.86^{cd} ±9.260	37.86^{cd} ±12.820
	2	0.86^{b} ±0.378	4.29^{c} ±0.490	11.57^{c} ±1.510	13.86^{d} ±1.770	15.43^{d} ±1.900
	3	10.29^{a} ±7.342	26.43^{b} ±11.79	52.43^{bc} ±4.470	61.86^{cd} ±5.840	68.14^{cd} ±9.230
Dry	**1**	4.67^{ab} ±0.816	$35.83b^{ab}$ ±18.400	137.50^{ab} ±94.54	170.00^{ab} ±121.590	184.83^{ab} ±129.140
	2	5.17^{ab} ±1.722	47.33^{a} ±15.550	160.33^{a} ±98.020	234.67^{a} ±85.830	260.83^{a} ±95.950
	3	5.50^{ab} ±1.722	30.33^{ab} ±1.370	96.00^{abc} ±16.200	114.00^{bc} ±19.790	126.33^{bc} ±22.900
WHO Standard		25	25	50	50	-
National Standard		-	-	-	-	250
Detection Limit		1.0	1.0	1.0	1.0	1.0

Values are means ± standard deviation of six replications.
Mean values bearing different superscripts in the same column differ significantly ($p<0.05$).
Key: PM_1 = Particulate Matters
$PM_{2.5}$ = Particulate Matters
PM_7 = Particulate Matters
PM_{10} = Particulate Matters
TSP = Total Suspended Particulate
Station 1 = Makoba
Station 2 = Elekahia
Station 3 = Rivers |State University

The effect of factorial interaction of season and location on the distribution of suspended particulate matter in ambient air was statistically high, as shown in Figures 1, 2, 3, 4, and 5. Respectively. From Figure 1, PM_1 was higher (10.2857µg/m³) at station 3 throughout the raining period and lower (5.50µg/m³) all through the dry season at station 3.$PM_{2.5}$ level was highest at station 2 during the dry season (47.33 µg/m³), as shown in Figure 2. While $PM_{2.5}$ was low during the raining season also at station 2.From Figure 3, PM_7 value was higher at station 2 (160.33 µg/m³) during the dry season and low (11.57 µg/m³) during the raining season at the same station. PM_{10} and TSP were also high during the dry season at station 2 with values of 234.67 µg/m³ and 260.83 µg/m³, respectively. As shown in Figures 4, and 5 respectively.

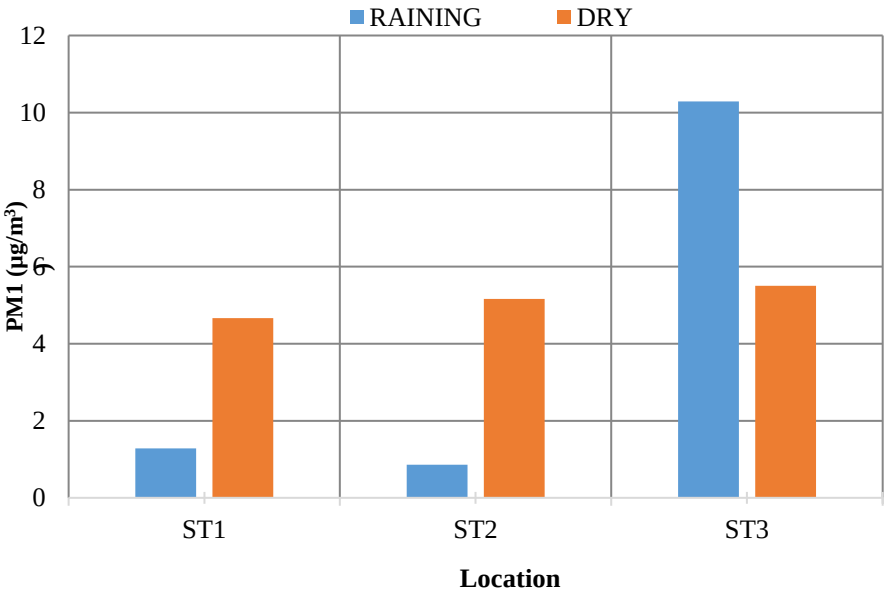

Figure 1. Effect of Seasonal Variation and Location on PM_1 Content of Ambient Air

Key: ST1 = Makobar
ST2 = Elekahia
ST3 = Rivers State University

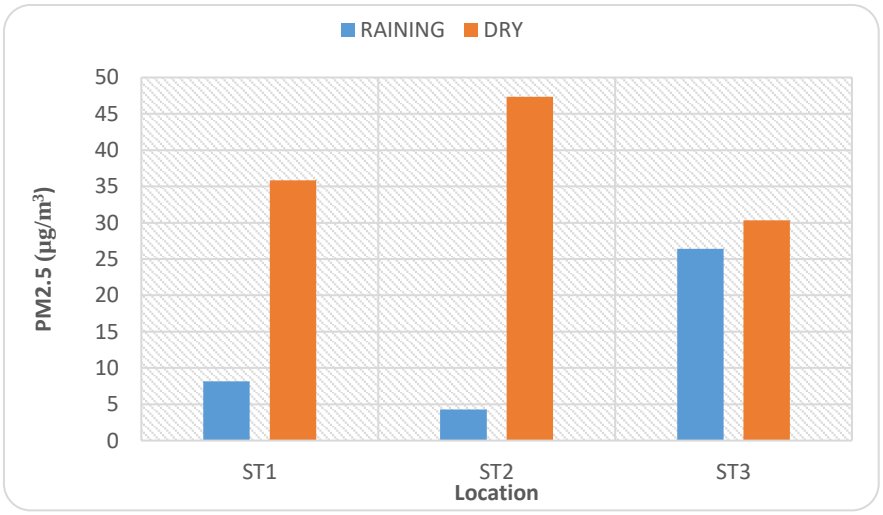

Figure 2. Effect of Seasonal Variation and Location on $PM_{2.5}$ Content of Ambient Air

Key: ST1 = Makobar
ST2 = Elekahia
ST3 = Rivers State University

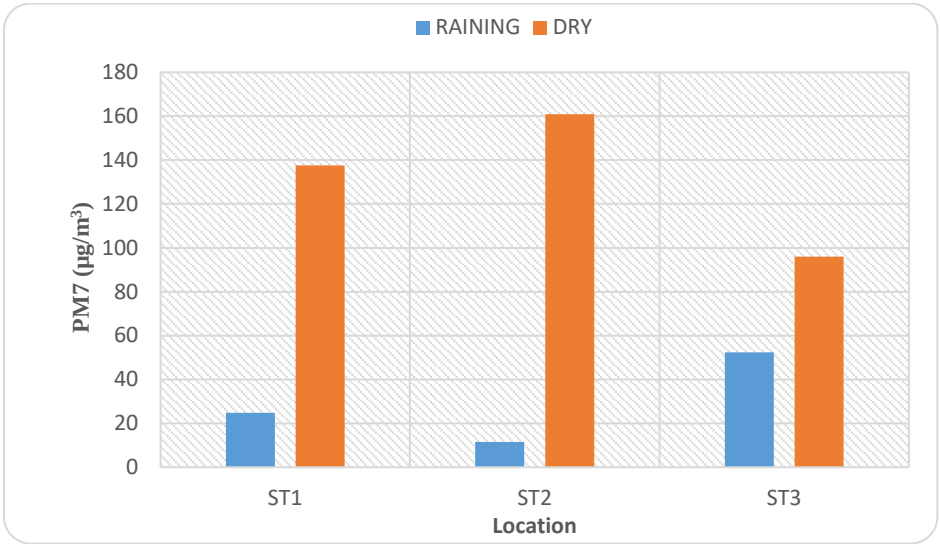

Figure 3. Effect of Seasonal Variation and Location on PM_7 Content of Ambient Air

Key: ST1 = Makobar
ST2 = Elekahia
ST3 = Rivers State University

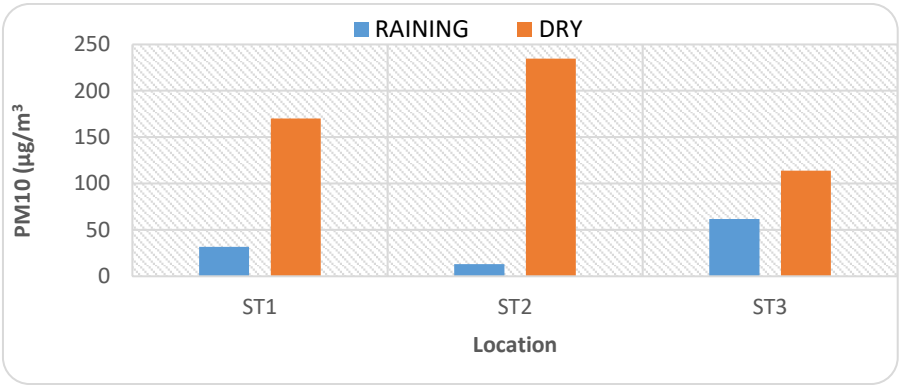

Figure 4. Effect of Seasonal Variation and Location on PM_{10} Content of Ambient Air

Key: ST1 = Makobar
ST2 = Elekahia
ST3 = Rivers State University

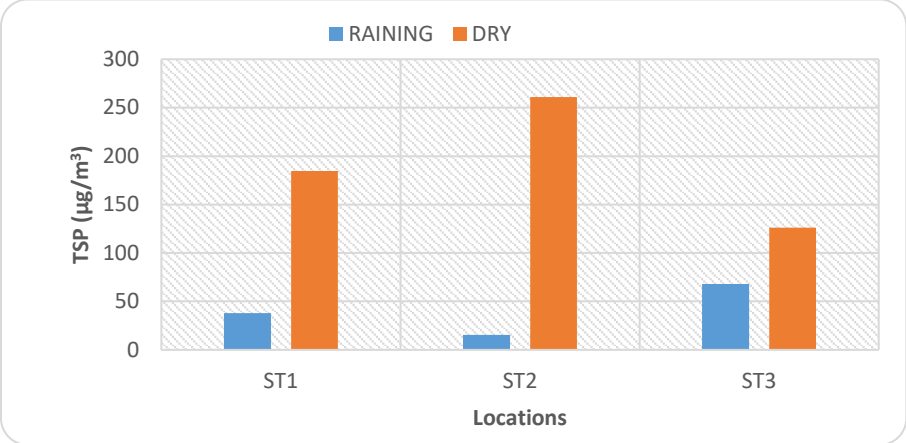

Figure 5. Effect of Seasonal Variation and Location on TSP Content of Ambient Air

Key: ST1 = Makobar
ST2 = Elekahia
ST3 = Rivers State University

IV. Discussion

This study was designed to examine the effects of Air quality on the particulate matter distribution during wet and dry seasons in parts of Port Harcourt metropolis.

Seasonal variations of Suspended Particulate Matter in Ambient Air from Stations 1, 2 and 3 during the Raining and Dry Seasons

Results for the distribution of respirable particulate matters in the ambient air within the study area from stations 1, 2 and 3 during the raining and dry season are shown in Table 2. PM_1, $PM_{2.5}$, PM_7, PM_{10}, and TSP ranged from 0.857 – 10.286µg/m^3, 4.290 – 47.33 µg/m^3, 11.57 – 160.33 µg/m^3, 13.86 – 234.67 µg/m^3 and 15.43 – 260.83 µg/m^3 respectively. High PM_1 of 10.286 µg/m^3 was noted at station 3 during the raining season, this was however, statistically different ($P<0.05$) from PM_1 values of 4.667 µg/m^3, 5.167 µg/m^3 and 5.50 µg/m^3 recorded from stations 1, 2 and 3, respectively, during the dry season. However, the values recorded in dry season were higher and statistically different (($P<0.05$) from the values in station 1 and 2 during the raining season except for station 3. We observed an abnormal high value of PM_1 during the raining season at station 3 (Rivers State University gate). PM_1 mean concentrations for wet and dry seasons varied from 5.50 to 10.3 ± 7.3 µg/m^3 across the study area. The mean values observed for the wet and dry seasons were generally low and falls within the WHO,[29] permissible limit of 25.0µg/m^3 for 24-hrs. However, for the TSP values of 260.83 µg/m^3 recorded at Elekahia during the dry season was above the National limit of 250 µg/m^3. Average time for stations 1-3 for PM_1, during the dry season, $PM_{2.5}$, PM_7 and PM_{10} values at all the locations were significantly above 25 - 50 µg/m^3 (WHO maximum allowable limit). However, during the raining season station1 $PM_{2.5}$, (8.14 µg/m^3), PM_7 (24.86 µg/m^3), PM_{10} (31.86 µg/m^3) were below the allowable limit. $PM_{2.5}$ mean concentrations during the wet and dry season sampling varied from 26.4 – 47.33 ± 15.5µg/m^3, for station 3 and 2 respectively with the highest mean value of this particle size recorded in the dry season. The concentration values observed for both seasons exceeded theWHO,[29] permissible limit of 25.0µg/m^3. It is important to note that the soot particle fall within the aerodynamic fractions of $PM_{2.5}$ and PM_1. Particulate matter less than two and one half microns ($PM_{2.5}$) or fine particulate matter consists of particles that are less than two and one half microns in diameter. This agrees with the work of Ede and Edokpa, [30] reported that in June, 2017, a part of Port Harcourt metropolis recorded a fire incident due to illegal refining of oil, which resulted to damage of assets worth millions of naira. This incident is one of the contributory source that would have propelled black soot into the lower atmosphere in addition to the various man made activities such as illegal refineries and bunkering activities in the creeks of Makobar. The decrease and increase in the values of PM during wet and the dry season is in collaboration with a similar study carried out by Udayasoorian et al, [31]that the variation of Black Carbon (BC) with the local meteorological parameters showed better association of the concentration of BC with temperatures during the summer season. The BC concentrations also showed better with wind speed in summer, thus indicating an increase in the ventilation coefficients, which led to the highest BC concentration in summer. On the other hand, a higher rain rate results in a higher aerosol deposition rate within a precipitating cloud, while during meagre rainfall, a steady increase in average BC level coupled with continued generation and longer lifetime is expected during dry months over the low-altitude

locations. It is seen for our meteorological features that 80% of rainfall occurs during the monsoon season, leading to strong wet removal of aerosols. In comparison to the dry deposition, heavy rainfall resulted in considerably decreased BC concentration, as rainfall is the effective scavenger of atmospheric aerosol."

The World Health Organization WHO**,** [32]air quality model of 2016 stated that about 92% of the world's population live in places where ambient air quality levels exceeds WHO limits. The interactive map for $PM_{2.5}$ revealed an ambient level for Port Harcourt (i.e. 36-69µg/m^3) were above both national and international standards. $PM_{2.5}$ can be directly emitted or secondarily formed in the atmosphere and is generated from various sources including the combustion of fuel, fires, industrial processes and vehicle emissions. $PM_{2.5}$ that is directly emitted as a solid or a liquid is defined as filterable particulate matter. Particulate matter that is released as a vapour and condenses to form a solid or liquid particle is known as condensable particulate matter. Additionally $PM_{2.5}$ can form in the presences of precursor emissions, such as nitrogen oxide and Sulphur dioxide [33].

PM_7 mean concentrations for the two study seasons' varied from 52.43µg/m^3 in the wet season at the University gate and 160.33 ± 98.020 µg/m^3at Elekahia in the dry season respectively. The dry season recorded the highest mean value, though both seasons had values above the international regulatory limits of 50.0 µg/m^3 stipulated by WHO**,** [29]. The results for the two seasons showed diurnal effects in particulate concentrations and distributions in the air basin around the study area for both fine and coarse particles. Inhaled particles can pass from the lungs into the bloodstream and affect the cardiovascular system. The effects of short-term (acute) exposure includes irregular heartbeat, nonfatal heart attacks while effects of long-term (chronic) exposure are aggravation of existing heart diseases, premature death of people with heart disease[34]**.** The implication of this study is that the university gate showed higher deposit of high particulate matter during both seasons.

PM_{10} mean values for the wet and dry season's varied from 61.9µg/m^3 in the wet season to 234.7 ± 85.830 µg/m^3 in the dry season. The maximum mean value of 234.7 ± 85.830 µg/m^3 in the dry season was high, the values for both seasons exceeded the WHO**,**[29] permissible limit of 50.0µg/m^3 for 24-hr average time, this points to the closeness of major sources of respirable particles around the study area during the data gathering exercise. The entire study area is controlled by two atmospheric dispersions and circulation patterns for instance the North Easterly wind or tropical continental air mass that is dominant around the study area in the dry season is characterized with high dust while the maritime air mass contains more moisture and is characterized by heavy and light precipitations which could serve as scavenger of particulates in the ambient air during the wet season. This agrees with the work of Anny *et al***.,**[20] that ultimately, atmospheric pollutants are removed from the air either by rain, moisture or by dry deposition to the earth's surface. Also, cold temperatures increase the likelihood of an inversion layer forming in many locations. An inversion exists where a layer of cool air at the earth's surface is covered by a higher layer of warmer air. An inversion prevents the upward movement of air from the layers below and traps PM near the ground. As a result, cold temperatures tend to coincide with high concentrations of PM. However, in some locations days with high temperatures, no clouds and stable atmospheric conditions result in high PM[35] . In other locations when the difference between daily maximum and minimum temperatures is large and the height of the Atmospheric boundary layer (ABL) mixing layer is low, high PM_{10} concentrations are observed[36]**.**The wind pattern shows that during the day, emission concentrations will be high near the source and low at farther distances. At dawn when soot deposits were very noticeable in Port Harcourt, particulates concentrations will be confined near the source area due to temperature inversion and move downwind of source below inversion layer due to lateral displacement of air. Lateral displacement of air is always prominent during stable atmospheric conditions. It has been determined that the atmospheric boundary layer stability conditions in Port Harcourt is very stable at night and unstable during the day [37].

High concentration of PM in the dry season could be attributed to the effects of (harmattan) and human activities around the stations. Air pollutants may be higher in the vicinity of specific sources of air pollution, such as roads construction sites, filling stations, power plants, (Heavy duty trucks carrying cements and petroleum products) and large stationary sources, protection of population working around such environment may require special measures. PM_{10} describes inhalable particles, with diameters that are generally 10 micrometers; the chemical properties vary depending on the sources of particles. Land usage can also influence PM_{10} concentrations, and therefore, land use type may be a useful explanatory variable. One study discovered spatial variations in PM_{10} with higher concentrations in commercial areas than in residential and industrial areas[38]**.** However, land use classifications are not common in PM models. Ede & Edokpa**,**[30] reported that Particulates emissions as observed from the HYSPLIT model platform indicates that emission sources south and southwest of Port Harcourt contributes vastly to the particulate load across the lower atmosphere of the city and its environs especially during night-time and early hours of dawn. The lower atmosphere is a dynamic energetic system that supports the sustenance of life; however, inhabitants of Port Harcourt are part of the millions of people predominantly in developing countries that live with detrimental air due to particulates emissions from vehicles, industries, illegal refineries and care free burning of hazardous substances such as spilled crude oil and gas flaring.

It is important to note that particulates are not one particular chemical substance but a classification of particles by size rather than chemical properties. Particles within the two size ranges behave differently in the

atmosphere. $PM_{2.5}$ or fine particles can remain airborne for long periods and travel hundreds of miles. Coarse particles or the subset of PM_{10} that is larger than 2.5μm, do not remain airborne as long and their spatial impact is typically limited because they tend to deposit on the ground downwind of emissions sources [39]. These agrees with the air quality monitoring study conducted by SPDC[2]in Port Harcourt (i.e. Shell I.A, R.A and Kidney Island), late 2016 and early 2017 which showed that average particulates concentrations ranged from 16.4-360 μg/m^3. In the SPDC[2] study it was PM_7 and PM_{10} that had the highest concentrations in the ranges of 72.1-103.3 μg/m^3; 91.2-209.6 μg/m^3 respectively.TSP values of 260.83 μg/m^3 recorded at Elekahia during the dry season was above the National limit of 250 μg/m^3. It was also shown that the TSP values of 15.43 μg/m^3 was recorded at the same station 2 (Elekahia) during the raining season, which was below the National Limit of 250 μg/m^3. In a similar air monitoring study conducted by SPDC[2] in Port Harcourt it was recorded that TSP had the highest concentrations in the ranges of 120.6-360 μg/m^3 during the same dry season. Similarly, the Rivers State Ministry of Environment Study[3] found TSP range of 62-270 μg/m^3, which agrees with the values of 260.83 μg/m^3 recorded at Elekahia during the dry season. Robert and Barry, [40] Revealed that there was the significant concentration of pollutants during the dry season for both urban and rural areas closely followed by that of the transitional period than the wet season.

Similarly, the National Academies of Sciences, Engineering, and Medicine NAP,[41] reported that Black Carbon(BC) affects man's health adversely through the inhalation of polluted air, the consumption of polluted water and/or food, and the skin's absorption of polluted air and water. Thus, the inhalation of air polluted with dust from coal mines, fossil fuels burning and from exhaust of internal-combustion engines resulting in the deposits and accumulation of harmful particles in the lungs affects man. The study recorded high values of $PM_{2.5}$, PM_7, $PM_{10,}$ and TSP, around the three locations during dry season and some selected stations in raining seasons, thus posing a health concerns for people resident within the area of study.

Effects of Seasonal variation and Location on Suspended Particulate Matter in Ambient Air

The effect of factorial interaction of season and location on the distribution of suspended particulate matter in ambient air was highly significant ($P<0.05$) statistically as shown in Figures 1. 2, 3, 4 and 5, which showed the effect of factorial interaction of season and location. Figure 1. Showed that $PM_{1.}$ Was higher (10.28μg/m^3) at station 3 during the raining season and lower (5.50μg/m^3) during the dry season at station 3. The Particulate matters recorded were below the National and WHO standards of 25.μg/m^3 and thus may pose no health concerns at the current stage.PM2.5level was highest at station 2 during the dry season (47.33 μg/m^3), and recorded a corresponding very low values (4.29 μg/m^3) at the same station during the raining season respectively as shown in figure 2. According to Figure 3. PM_7value was higher at station 2 (160.67 μg/m^3), during the dry season which was above the maximum allowable national standard (50.00 μg/m^3) limit and recorded low value (11.57 μg/m^3) during the raining season at the same station. PM_{10} and TSP were also high during the dry season at station 2 with values of 234.67 μg/m^3 and 260.80 μg/m^3, according to figures 4 and 5. Respectively. The high value of $PM_{2.5,}$ PM_7 ,PM_{10} and TSP during the dry season may be attributed to the high volume of dust present in the lower atmosphere and human activities such as vehicular movement, burning of fossil fuels and other anthropogenic sources and may be a source of concerns for occupational health practitioners.

This finding of low levels of PM during raining season is in collaboration with the work of Olszowski[42]that PM_{10} levels can be reduced by rain, snow, fog and ice. Rain scavenging, a phenomenon in which below-cloud particles are captured and removed from the atmosphere by raindrops, is considered to be one of the major factors controlling the removal of PM from the air. The degree to which PM is removed is dependent on rainfall duration and intensity. Conversely, the decrease of PM_1 , when compared with $PM_{2.5}$ during dry season is agreement with the work of Afzali et al**.,** [43]**,** who reported that high lunar radiation has also been shown to result in lower PM_{10}. When solar radiation is high, the surface of the earth is warmer; as a consequence the exchange of heat in the air results in turbulent eddies that disperse suspended particles. Also, the study have shown a relationship between raining and dry season in terms of PM concentrations. Similar study by Ul-Saufie et al**.** [44] reported a relationship between PM concentration and relative humidity also depends on other meteorological conditions. For example, if humidity is high and there is also intense rainfall (such as during a monsoon season), then humidity has a negative correlation with PM due to rain scavenging. If high humidity is not accompanied by rainfall but is accompanied by high temperatures, humidity has been found to contribute to higher PM_{10} concentrations. It has been suggested that when the relative humidity is over 55%, then PM_{10} concentrations are affected[44.]

According to Edokpa and Nwagbara**,** [37] recorded that a dare consequence of emissions concentrations in Port Harcourt will be low for sensitive receptors as a result of unstable atmospheric conditions during the day and high for sensitive receptors under stable conditions at night. Most petroleum activities are carried out in the Niger Delta region and therefore, the atmosphere plays a significant role in the problem of dispersion process of air pollutants and thus the Niger delta atmosphere act as a sink for emission collections**,** [45.]

Williams, [46] and WHO[32] reported that today some Nigerian cities such Kaduna, Aba, Onitsha and Port Harcourt were reported with the worst air quality in the world and ranked among cities of over 100,000 people with the poorest air quality in 2016. The implication of these high values of Particulate, according to WHO[32] that ambient air pollution was responsible for 4.2 million deaths in the world. Over 50% of humanity live in urban areas and WHO[32] through its Global Health Observatory (GHO) Data estimates that ambient air pollution cause about 16% of the lung cancer deaths, about 17% of ischemic heart disease and stroke, and about 26% of respiratory infection deaths. From various eye witness account, the dry season, especially very early hours of the morning present dark cloudy environment around Port Harcourt and with the tendency of high volume of black soot deposits on the floor of the house, the top roof of the exposed cars and every properties that are not air tight at Makoba and Rivers State University respectively due to their relative location to sources of illegal refineries and bunkering activities. For street workers such as vended food sellers, the tendency to surfer from the consequence of the inhalation of these particulate matters is better imagine than explained in this studies.

The effect of wind speed and direction on PM varies with the geographical characteristics of a location. Low wind speed can be associated with high PM[47], this is common in hilly or mountainous regions. Conversely, in coastal or desert regions, high wind speeds result in high PM_{10} concentrations due to salt or dust suspension. This is true for Makoba, Elekahia and Rivers State University as the concentration of PM is higher during the Harmattan period of dry season and particularly, for Elekahia the wind speed and wind direction may be accountable to the high PM due to the location off the coastal region into the heart of Port Harcourt metropolis and nearness to the Elekahia Market and also the bole zone, now a commercial center in outlook. In Europe, PM_{10} concentrations are significantly influenced by long-range transport contributions, which are independent of local emissions, so both wind direction and speed have a significant impact [48]. Similarly, the results of high PM distribution in Elekahia is in collaboration with the study of Chen et al., [49].In many countries and especially in urban areas, road transportation is considered to be the largest contributor to PM_{10}. Road vehicles not only emit exhaust but also re-suspend particulate matter. Where data on traffic are not available, CO and NO_x can be used as a proxy for exhaust emissions [50]

According to Oyet et al,[51] some of the contributors of these air pollutants include the quality of flared gas. The study also reported that 22.02% accounted for the generation and dispersal of particulates and incombustible materials (e.g. soot) into the atmosphere, which could possibly affect growth of plants. It was known that these clouds of chemicals could trap heat radiated from the earth (that would have otherwise escaped rapidly into space), thus making flora, and fauna more vulnerable to heat waves and droughts [52]. The 22.02% non-compliance of incombustible flare plum constitutes 20% light transmission through smoke and 80% smoke transmission through light [53]. Thus, pollution emissions (such as particulates and soot) are known to directly damage green foliage on which they settle, deteriorating air quality by causing breathing problems and lung illness and destroy laundry and other valuable property susceptible to dirt particles [52]. These 22.02% non-conformance could be due to carry over, operational upsets and station start-up. The 77.98% agreed with the radiation level for a gas flare, which is also a function of flame temperature, gas flow rate and flare stack geometrical design [51, 52].The TSP concentrations for wet season were low and within the National air quality standard, while the observed concentrations in the dry season showed violations (260.83 $\mu g/m^3$) at station 2 to the National standard. According to Williams,[46], implicated shoots presence as a major contributors to symptoms of some illnesses suffered by the inhabitants of Port Harcourt residents such as cough, catarrh, difficulty in breathing, asthmatic attack, fast breathing, and noisy breathing. The inhabitants of these locations are at risk of being susceptible to COVID-19 disease considering the symptoms upon manifestation. Thus, Weli et al, [54] recommended that Noise mask should be worn as a temporary and immediate measure to reduce exposure to the inhalation of PM_1 and $PM_{2.5.}$

V. Conclusion

During the dry season, $PM_{2.5}$, PM_7 and PM_{10} (26.43 to 234.67 $\mu g/m^3$) values at all the locations were significantly above 25-50 $\mu g/m^3$ (WHO and National maximum allowable limit), whilst, during the raining season, the PM were within the allowable limits except for the Rivers State University gate, with high vehicular activities. The study demonstrated the impact of wet and dry season on the concentrations of PM. The location of the facilities and nearness to the pollutant sources may be accountable for the concentrations of PM deposited at any particular location. The presence of SPM and its distribution within the three location of study is a major source of public health concerns as the PM concentration recorded is above the WHO and National maximum allowable limit. The presence of soot has been implicated as a major contributors to symptoms of some illnesses suffered by the inhabitants of Port Harcourt City such as cough, catarrh, difficulty in breathing, asthmatic attack, fast breathing, and noisy breathing. The inhabitants of these locations are at risk of being susceptible to COVID-19 disease considering the symptoms of the disease upon manifestation. The study revealed the presence of Particulates Matter in the environment and recorded a significant concentration of pollutants during the dry season for both urban, industrial and rural areas. Black soot-containing particles are also associated with adverse effects

on street foods vendors, contaminating building materials and possible negative effects on human health. This is a sources of Public health concerns. It is essential to have models that accurately estimate and predict PM concentrations for reporting and monitoring purposes. Further studies to be conducted to investigate the toxicity of these particulate matters in the environment of Port Harcourt as well as engagement in further studies to establish the direct impact of Black Carbon on humans, animals, plants and food sources and pathways around the study areas in Port Harcourt Metropolis. The presence of black soot in the Environment of Makoba, Elekahia and Rivers State University gate, all in Port Harcourt Metropolis is a call to declare a state of emergency for comprehensive air quality study in Port Harcourt and its environs. This call is necessary due to the current COVID-19 disease that is ravaging the country and Port Harcourt in Particular.

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