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EVALUATION OF PARTICULATE MATTER ($PM_{2.5}$) IN RECLAMATION ROAD AMBIENT AIR IN PORT HARCOURT.

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Abstract

Residents of Rivers State largely assume that the ambient air may have been polluted by soot, and the growing awareness of air quality amongst researchers and international organizations has been documented on different air quality parameters, putting particulate matter ($PM_{2.5}$) pollution at the forefront. The ambient air quality in the industrial area of Reclamation Road in Port Harcourt was therefore evaluated by taking in-situ measurements at eight (8) studied points in the outdoor environment for three (3) days each in the dry and wet seasons, through the use of air quality monitoring equipment. The concentrations of particulate matter ($PM_{2.5}$) at the eight (8) studied points were determined, following standard analytical sampling methods. The results showed substantial concentrations of $PM_{2.5}$ with the highest mean values of 202.51±133.45 and 106.00±2.83 μg/m^3 at the Maccobar jetty studied site during dry and wet seasons, respectively. The mean concentrations of $PM_{2.5}$ across all eight (8) studied points were found to be higher than the World Health Organization guideline value of 25 μg/m^3. Presently, in Nigeria, the National Environmental (air quality control) Regulations, 2014 do not have any guideline limit value for $PM_{2.5.}$ Residents and workers of industries around the Reclamation Road should therefore ensure that the anthropogenic activities that release particulate matter into the environment are well regulated, and $PM_{2.5}$ reduction strategies put in place for real-time monitoring.

Keywords: Evaluation, Particulate matter, Reclamation road, Ambient air, Port Harcourt

Introduction

Both outdoor and indoor air pollution has become a serious global enigma and are mainly associated with diverse environmental and human health problems. The degree of risks associated with atmospheric air parameters including fine particulate matter is a function of the particle sizes, a load of pollutants and chemical composition, which results in the total air quality in an environment (Oghenovo et al., 2019). WHO (2016) reported that out of every 100,000 individuals, the air pollution mortality rate is about 307.4 people in Nigeria, with $PM_{2.5}$ pollutant mean concentrations of 46.3 μg/m^3, about 4.5 times more than the outdoor air quality guideline values. The collective impacts of indoor and outdoor air pollution result in an estimated seven million untimely deaths annually, majorly due to amplified mortality from heart and respiratory-related organ diseases. The hygienic airborne ecosystem is amongst the fundamental requirements for the existence of safe biota and healthy human health. Particulate matter (PM) belongs to complex mixtures comprised of solid and liquid particles suspended in the atmosphere (Long & Valberg, 2017). PM is a major constituent in both outdoor and indoor air. Particulates are the utmost air quality parameters (AQP) in the Nigerian ecosystem and as such the studies of background reference of particulate matter (PM) have been given more consideration than any other type of air quality parameters. It has been reported that several cities within and outside of Nigeria were identified with the presence of high levels of air quality parameters and particulate matter (Obioh et al., 2005). Particulate matter is a very critical air pollutant that results in the death of living organisms across the world. It has been reported in developing countries that biota exposure to PM emissions causes a range of human health concerns in those nations. Several gaseous contaminants and particulates are well-known to originate from anthropogenic and natural sources that are potentially hazardous to human health and the environment (Rudel & Perovich, 2009).

PM is commonly produced from the combustion of wood, and fuels in automobiles, power plants, and stoves (Yadav et al., 2022). Gaseous pollutants are emitted to form PM from anthropogenic and natural activities in the atmosphere, which directly or indirectly contribute to PM emissions (Liu et al., 2009). Consequently, the $PM_{2.5}$ formed is influenced by other risk factors such as smoking, use of pesticides, waste generation and disposal, road vehicles, industrial activities, and socio-economic factors. WHO (2016) reported that fine particles ($PM_{2.5}$) are known to be an essential indicator of particulate-related human health risks. The pollution of PM has become both an environmental and human health problem with resultant effects on atmospheric conditions, and terrestrial and aquatic ecosystems. Particulates are categorized following their aerodynamic diameter and range from coarse (> 2.5 µm - 10 µm) to ultrafine (< 2.5 µm) particles and $PM_{2.5}$ commonly known as fine particulates with a diameter less than 2.5 µm can penetrate the respiratory tract (WHO, 2016). The PM diameter determines where the particulates could be deposited in the body of humans. Sioutas et al. (2005) reported that emerging evidence advocates that exposure to ultrafine particles less in diameter than 0.1 µm poses human health risks that may not be documented by any guideline. Consequently, $PM_{2.5}$ could comprise a multifarious mixture of various pollutants such as carbon black, nitrates, soot, sulphates, and organic and metal compounds. Coarse–particles that are inhalable larger than 2.5 micrometres, however, equivalent to or less than 10 µm in diameter. PM that is ultra-fine particles is commonly equivalent to or less than 0.1 µm in diameter. It has been reported that fine particles ≤ 2.5 µm can penetrate as remotely deep as the alveoli in animals (WHO, 2016). Bigger particles tend to be detached by natural respiratory mechanisms such as sneezing and coughing, but smaller particles tend to settle on the respiratory pathways (Sioutas et al., 2005). Particulate matter (PM) in the atmospheric environment is intensely related to adverse biota and human health consequences and characterizes a wide-ranging physical and chemical size substances from different sources as well as various effects (Michael, 2011). PM could be primarily characterised as distinct substances existing in solid or liquid states at different concentrations and sizes. PM belongs to a complex pollutant category, with atmospheric changes, source characteristics and human health outcomes that differ in size particles and chemical configuration. $PM_{2.5}$ is known as fine particles that are commonly equivalent to or less than 2.5 µm in diameter. Fine particles are formed predominantly from the processes of combustion and alterations of emission of airborne gases such as TVOCs, NO_x and SO_x. The increasing level of air quality parameters and pollution of PM could be mostly attributable to natural and anthropogenic processes such as industrialization, urbanization, and combustion of biomass in the environment (Taiwo et al., 2015).

Given the impacts of air pollution, globally, airborne PM is known as the most important marker for determining the quality of air (Singh & Sharma, 2011). The study of the sources of high PM levels is very important to contribute to knowledge on ambient air quality reduction strategy with the required data for local and international regulation (Jeong et al., 2011). In Nigeria, PM is among the air quality parameters upsetting the quality of air, and this is similar to other nations of the world (Farao et al., 2014). The environmental and human health risks are not more unlikely where a mixture of $PM_{2.5}$ pollutants and other harmful risk influencers including noise, vibrations, temperature, odours, wind direction and speed can cause severe problems and harm to biota, especially in highly populated environments (Bo et al., 2016). Unlike other air pollutants, PM differs significantly concerning their size and mass, toxicity, chemical composition, physical state (solid and liquid), and behavioural transformation in the atmosphere. It has been reported that more than 3.3 million deaths globally were directly attributed to the pollution of particulate matter (WHO, 2012). The environmental and human health effects associated with the particulates are categorized into short-term and long-term effects. Long-term effects of $PM_{2.5}$ exposure have been associated with cardiovascular-related diseases, high mortality rates, and emergency visits to the hospital for people with underlying ailments (Fajersztajn et al., 2017, Pan et al., 2018). The health effects of short-term exposure to $PM_{2.5}$ such as headaches, fatigue, dizziness, and irritation of the eyes, nose and throat could be noticeable immediately following a single exposure. For pregnant women, children and people with ailments such as respiratory tract problems, exposure can start showing instant symptoms, and as such aggravation of the conditions may be experienced. Ensuring that people with underlying ailments are not exposed to the sources of PM pollution is one of the best preventive and control measures. Previously existing health conditions such as age and individual sensitivity are risk factors that may contribute to the instant effect of PM pollution (Pan et al., 2018). Furthermore, heart diseases, respiratory diseases, and cancer are some of the human health effects which become noticeable following some years of repeated and prolonged risk exposure which may be very detrimental and fatal (Gharaibeh et al., 2010).

Aim and Objectives of the study

This study aimed to evaluate the particulate matter ($PM_{2.5}$) in Reclamation road ambient air in Port Harcourt, Rivers State, Nigeria. The objective is to generate reliable scientific data on the level of pollution status of the industrial area to prevent undesirable environmental and human health effects.

Materials and methods

Study area: This study was carried out at Reclamation road located in Port Harcourt City Local Government Area of Rivers State, Nigeria. The reclamation road area is one of the most industrialized parts of Port Harcourt Town where several companies including refined petroleum products storage tank farms, gas storage plants and chemical industries are located, with potential impacts on the ambient air. The choice of Reclamation road industrial location as the studied area was necessitated by the presence of industries within and around the area. Sampling point elevation and coordinates were measured using Garmin 76s global positioning system (GPS) as presented in Table 1. The sampling points were sited and positioned at about 5.0 – 8.0 m away from the edge of the access road in the direction of downwind.

Table 1: Coordinates of sampling points at Reclamation road studied location

Sampling points	Sampling codes	Coordinates
Maccobar jetty	RR1	04°45'33.5"N, 007°00'18.6"E
Naval base	RR2	04°45'26.9"N, 007°00'19.3"E
Otobo junction	RR3	04°45'31.8"N, 007°00'30.9"E
Sungas area	RR4	04°45'34.3"N, 007°00'37.3"E
Ibeto road	RR5	04°45'21.9"N, 007°00'39.2"E
Bundu ama	RR6	04°45'54.8"N, 007°00'26.7"E
Governor street	RR6	04°45'18.1"N, 007°00'33.6"E
Stella Maris	RR7	04°45'46.6"N, 007°00'42.6"E

Note: RR is an acronym for Reclamation Road in Port Harcourt

Sample collection: The levels of $PM_{2.5}$ were monitored in situ at eight (8) different studied points along Reclamation road with the use of air quality equipment (Diemien DM 106 model) for three (3) days each during dry and wet seasons, respectively. Meteorological parameters (noise, temperature, relative humidity, wind direction and speed) were measured using a sound level field meter, thermometer, hygrometer, and anemometer. Sampling starts at 06:00 am and was completed by 18: 00 pm daily. The data were instantaneously generated on sites using the air quality monitors.

Operational procedure for Diemien DM 106 aerosol mass monitor: The monitoring equipment was hand-held at 1.5 m directly high above the ground level. The boot nob was pressed and hand-held for approximately three seconds, to switch on or off the instrument for air quality monitoring of HCHO/TVOC mg/m^3 and $PM_{2.5}$ /PM_{10} µg/m^3 atmosphere, twinkled detection, with the whole parameters on the LED display unit reading 0000. Otherwise, the + push button was pressed-long till the display unit read 0000 to reset. This monitoring instrument first read the $PM_{2.5}$ /PM_{10}, temperature, and RH parameters and afterwards, three seconds of press-long on the + push button the $PM_{2.5}$ /PM_{10} displaying unit was converted to HCHO/TVOC display unit and detailed results on the LED displayed. The instrument alarm light hoots red for severe air pollution levels, yellow for pollution, and green for optima.

Results

Seasonal concentrations of particulate matter ($PM_{2.5}$): The results obtained showed the mean concentrations of $PM_{2.5}$ during the dry season were higher than the values during the wet season as presented in Table 2. The results indicated that the mean concentrations of $PM_{2.5}$ during the dry and wet seasons are 202.51±133.45 and 106.00±2.83 µg/m^3, 161.27±81.40 and 53.00±4.24 µg/m^3, 199.33±125.57 and 76.50±2.12 µg/m^3, 202.48±131.56 and 85.00±4.24 µg/m^3, 111.44±10.51 and 63.00±1.41 µg/m^3, 189.32±111.56 and 49.50±0.71 µg/m^3, 136.09±45.38 and 42.50±0.71 µg/m^3, and 147.92±65.44 and 42.50±2.12 µg/m^3 at RR1, RR2, RR3, RR4, RR5, RR6, RR7 and RR8 studied points, respectively. The mean concentrations of all the studied points along the

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Reclamation road during dry and wet seasons are above the national and international standards (25 µg/m^3) set by FEPA (1991), WHO (2006) and United States Environmental Protection Agency (2009) as presented in Figure 3.1. The sources of particulates within and around the Reclamation Road may be attributed to different anthropogenic activities in the area. The levels of $PM_{2.5}$ were observed to be highest at the Maccobar jetty area where there are both residential houses using wood and kerosene for cooking, and industrial activities such as illegal bunkering exist. This could pose serious potential human health and environmental risks in the area.

Levels of meteorological parameters: The meteorological parameters measured in the studied points during dry and wet seasons were noise, temperature, relative humidity and wind direction and speed. The noise level ranges were 56.50 – 82.35 (dB)A and 51.50 – 81.75 (dB)A during dry and wet seasons, respectively. The temperature range was between 30.33 °C – 38.43 °C, and relative humidity was between 55.74 % – 56.08 %. The wind speed range was 1.93 – 1.94 m/s, and the wind direction was south-westerly.

Table 2: Seasonal concentrations (mean±SD, µg/m^3) of $PM_{2.5}$ at Reclamation road

Sampling points	Codes	Dry season	Wet season
Maccobar jetty	RR1	202.51±133.45	106.00±2.83
Naval base	RR2	161.27±81.40	53.00±4.24
Otobo junction	RR3	199.33±125.57	76.50±2.12
Sungas Area	RR4	202.48±131.56	85.00±4.24
Ibeto road	RR5	111.44±10.51	63.00±1.41
Bundu Ama	RR6	189.32±111.56	49.50±0.71
Governor street	RR7	136.09±45.38	42.50±0.71
Stella maris	RR8	147.92±65.44	42.50±2.12

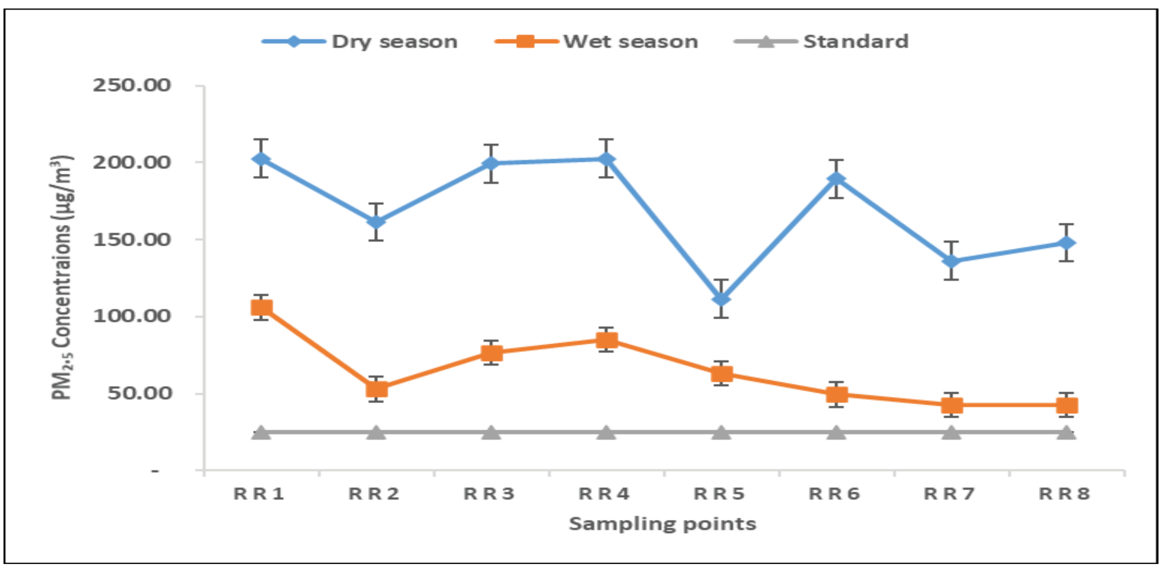

Figure 1: Comparing the mean concentrations (mean±S.D) in the studied sites against the recommended standard.

Seasonal toxicity potential assessment (TPA): The degree of toxicity of the measured levels of concentration was evaluated utilizing a calculated index known as the toxicity potential (TP), which indicates the potential risk of a pollutant unit available in the environment. The toxicity potential (TP) using the measured concentrations of $PM_{2.5}$ has been accurately estimated. Toxicity potential has been calculated as represented in equation (1) below. Preferably, the value of TP should be ≤ 1.

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$$\text{Toxicity potential (TP)} = \frac{C_p}{S_p} \quad (1)$$

Where C_p is the measured concentration of air pollutants and S_p is the standard of air pollutants (Ayodele et al., 2016).

The seasonal toxicity potential assessment based on the concentrations of $PM_{2.5}$ is presented in Figure 2. The TPA for $PM_{2.5}$ during the dry and wet seasons at RR1 – RR8 were (8.02, 4.24), (6.45, 2.12), (7.97, 3.06), (8.10, 3.40), (4.46, 2.52), (7.57, 1.98), (5.44, 1.70) and (5.92, 1.70), respectively. The TPA values of $PM_{2.5}$ were observed to be higher both in dry and wet seasons in comparison with the concentrations obtained. Generally, the values of TPA for all studied points were greater than 1, which shows high concentrations of $PM_{2.5}$ toxicity. This indicates that the residents and workers around the Reclamation road area are at higher risk of exposure and toxicity to $PM_{2.5}$ during dry and wet seasons of the year. This could be attributed to the presence of black soot in the environment in the city of Port Harcourt. The air quality around Reclamation road is determined by a combination of different air pollutants from various sources and is influenced by illegal oil bunkering activities, gas plants, oil drilling storage facilities, refined petroleum product storage depots, and the use of wood and fuels by the residents. Consequently, since most anthropogenic activities are not controlled, regulated, or monitored, the potential human health and environmental impacts should be a thing of concern to all stakeholders.

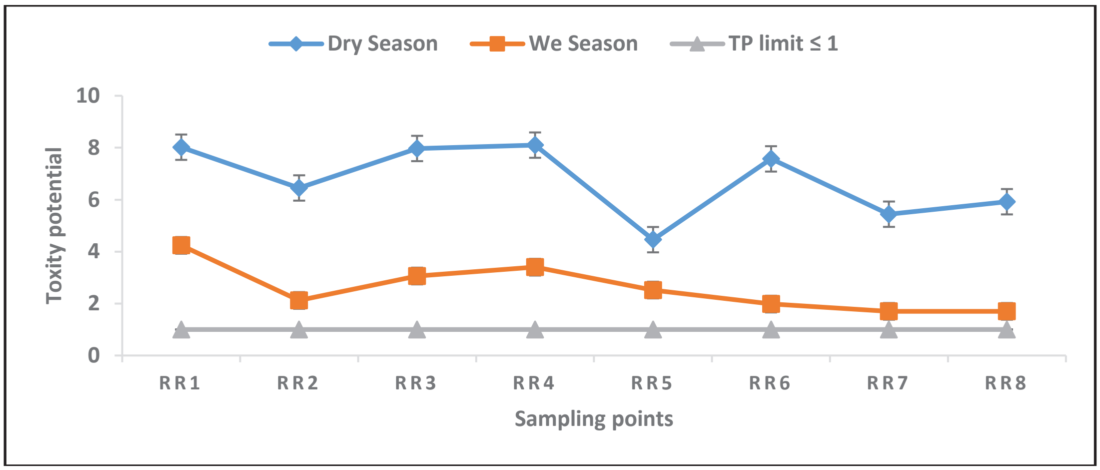

Figure 2: Toxicity potential of $PM_{2.5}$ at Reclamation road studied point.

Discussion of findings

The concentrations of $PM_{2.5}$ across the studied points along the Reclamation road during dry and wet seasons were above the national and international standards (25 µg/m^3) set by FEPA (1991) and WHO (2006). In comparing the findings in this study with other investigative studies, Achilleos et al. (2019) reported the conformity limits for twenty–four hours mean and annual mean of $PM_{2.5}$ as 25 µg/m^3 and 50 µg/m^3, respectively, as national ambient air quality standards (NAAQS) set by the World Health Organization (WHO, 2006). The results obtained in this study were similar to other studies. For example, Yadav et al. (2022) showed how controlled anthropogenic activities can reduce the pollution of municipalities by particulate matter. The anthropogenic activities in this studied location are not restricted to reducing the levels of particulates in the ambient air. Obioh et al. (2013) documented 20–102 µg/m^3 of $PM_{2.5}$ in atmospheric megacities such as Port Harcourt, Kano, Lagos, Abuja, Aba, and Maiduguri. Onabowale and Owoade (2015) evaluated the PM of residential air indoors and outdoors in Ibadan, and 22.20–50.0 µg/m^3 of $PM_{2.5}$ was recorded indoors. The mean concentrations of 202.51±133.45 mg/m^3 and 106.00 ±2.83 mg/m^3 were obtained at Maccobar jetty of the Reclamation road studied site during the dry and wet seasons, respectively. The immediate environment within the Reclamation road is characterized by high commercial and mixed land use which serve as a mechanism for particulate generation and dispersion into the ambient air stream. The sources of particulates within and around the Reclamation road may be attributed to different anthropogenic activities in the area.

Conclusion

The air quality within and around the Reclamation road environment in Port Harcourt, Rivers State, Nigeria was measured. The results obtained showed an increased concentration of $PM_{2.5}$ at all the studied points, and this indicates a high potential risk to the residents and workers of companies around the areas. Children and women are potentially the most affected by $PM_{2.5}$. The flashpoint for higher concentrations of $PM_{2.5}$ was identified to be the Maccobar jetty, bitumen storage and blending plant, LPG storage plant and petroleum product storage depots, and other anthropogenic activities as a result of biomass combustion. The worsening condition of air quality and the increasing levels of air pollution associated with $PM_{2.5}$ have hitherto been observed to cause both non-respiratory and respiratory ailments due to exposure to a particulate-burdened environment. Consequently, the air quality at Reclamation road studied points could in the long run aggravate respiratory and cardiovascular ailments. Following the results obtained, the concentrations of $PM_{2.5}$ are significantly high and may potentially cause a high risk to residents' health and well-being. Given this, it is recommended that the right types of air quality monitors are installed across the $PM_{2.5}$ sources to ensure that air quality monitoring programs are effectively conducted to protect the lives of residents and workers against increasing pollution levels.

Recommendations

1. The environmental monitors were not stationed for in-situ measurement over a long period, hence, should be mounted in the studied sites permanently for a year to determine real-time seasonal concentrations of the air quality parameters.
2. To effectively establish the comparison in levels of air quality parameters, the adjoining locations based on the dispersal of air quality parameters over a wider environment should be sampled, hence, such locations should be considered in further research work using other statistical tools. The number of sampling points across the studied locations should be increased to have a wider picture of the actual station of the studied areas.
3. A national guideline limit value for $PM_{2.5}$ should be established in Nigeria to address the peculiar environment.

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