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ENVIRONMENTAL CHEMISTRY, POLLUTION & WASTE MANAGEMENT | RESEARCH ARTICLE

Air quality index pattern of particulate around a haulage vehicle park

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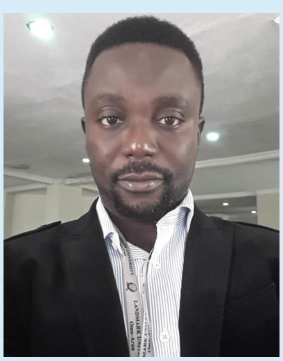
Abstract: This study investigated the air quality index patterns for $PM_{2.5}$ and PM_{10} in the airshed of a haulage vehicle park located around a major highway connecting Lagos, the commercial centre of Nigeria to its other parts. Measurements of $PM_{2.5}$ and PM_{10} were done at five different sub-parks using the aerosol mass monitor GT-331 by Met one instrument. The measured concentrations ranged between 16.07–29.95 μg m^{-3} and 125.95–433.08 μg m^{-3} for $PM_{2.5}$ and PM_{10}, respectively. The air quality index (AQI) within the park with respect to $PM_{2.5}$ could be described as moderate but unhealthy within at least two sub parks when PM_{10} is considered; hence, the health of vulnerable people could be at risk. This study establishes that vehicular activities at the park could have significant impact on the park's ambient air quality, thus calls for appropriate regulatory measure to protect commuters plying the major highway around the park.

Subjects: Chemical Engineering; Earth Sciences; Environmental Studies & Management

Keywords: $PM_{2.5}$; PM_{10}; vehicular activities; breakpoint; air quality index; haulage park



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PUBLIC INTEREST STATEMENT

This study investigated the air quality index patterns for $PM_{2.5}$ and PM_{10} in the airshed of a haulage vehicle park located around a major highway connecting Lagos, the commercial centre of Nigeria to its other parts. It showed that vehicular activities are contributory factor to impaired air quality, also it showed that ambient particulate levels are high enough to pose serious health concerns to human health, especially people with history of respiratory diseases.

1. Introduction

Air pollution is one of the most challenging problems of today's world as the atmosphere is getting polluted due to gaseous and particulates emissions from different anthropogenic sources such as industrial, domestic and vehicular activities (Koku & Osuntogun, 2007; Shukla, Misra, Sundar, & Naresh, 2008; Udia, 2005). In megacities of the world, vehicular activities are major sources of air pollution (Sharma, Kharol, & Badarinath, 2010). Emissions from mobile sources contribute to air pollution with deleterious impact on plants, human health and climate (Ndoke & Jimoh, 2000). Emissions from vehicular activities contain a wide variety of pollutants which are carbon monoxide (CO), oxides of nitrogen (NOx), particulate matter (PM) and volatile organic compounds (VOCs) which have a long-term impacts on air quality (Abam & Unachukwa, 2009; Han & Naeher, 2006; Sharma et al., 2010). PM has been linked with negative health effects (Abbas, Ahmadi, Ghanbari, & Moghaddamnia, 2007; Fridell, Steen, & Peterson, 2008; Ramanathan & Carmichael, 2008; Sacks et al., 2010) increased mortality, hospital admission and various cardiovascular and respiratory diseases (Aina, Sridhar, & Olawuyi, 2005; Pope, Brook, Burnett, & Dockery, 2011). The finer the particles are, the more difficult to control and deeper they penetrate into the human respiratory system to exert harmful effects (Donaldson, Li, & MacNee, 1998; Ferin, Oberdörster, & Penney, 1992).

The air quality index (AQI) is an index for reporting daily air quality. It informs the public on how clean or unhealthy the ambient air is with all the associated health effects which might be of concern (Sonibare, Adebiyi, Obanijesu, & Okelana, 2010). The focus of the AQI is the heath effect that can be experienced within a few hours or days after breathing unhealthy air. It has been established for six major pollutants which are ground-level ozone, PM, carbon monoxide, sulphur dioxide, volatile organic compound and nitrogen dioxide. For each of these pollutants US EPA has an established national air quality standard to protect public health. The computation of AQI requires an air pollutant concentration from a study (EPA, 2006). Table 1 summarizes the AQI, descriptor and colour codes, while Table 2 summarizes health effects for AQI values above 100.

Table 1. The six AQI categories

Air quality index values (range)	Descriptor	Colour code
0–50	Good	Green
51–100	Moderate	Yellow
101–150	Unhealthy sensitive groups	Orange
151–200	Unhealthy	Red
201–300	Very unhealthy	Purple
301 and above	Hazardous	Maroon

Source: EPA (2006); Sonibare et al. (2010).

Table 2. Specific sensitive groups to pollutant

Pollutant index above 100	Sensitive groups
Ozone	People with lung disease, children, older adults and people who are active outdoors are the groups most at risk
$PM_{2.5}$	People with heart or lung disease, older adults and children are the groups most at risk
PM_{10}	People with heart or lung disease, older adults and children and the groups most at risk
CO	People with heart disease are the group most at risk
SO_2	People with asthma are the group most at risk

Source: EPA (2006).

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In the study, the air quality index (AQI) around a haulage vehicle park was investigated using PM with aerodynamic diameter of 2.5 μm and 10 μm ($PM_{2.5}$ and PM_{10}, respectively) as indicators. This will guide in setting emission standards for these PM fractions in Nigeria since till date the national air quality regulation only takes care of total suspended PM.

2. Methodology

2.1. Study area description

The study area was a haulage vehicle park located in Ogere, Ogun State, Nigeria. It is located at latitude 6° 55′ 0″ North and longitude 3° 38′ 0″ East. Ogere is characterized by two types of landforms; sparsely distributed low hills and knolls of granite, other rocks of the basement complex and a flat topography. Two main climate conditions exit, the rainy season lasting between April and October with an interruption in August, while the dry season runs through November till February. The park (0.6 km^2) is located along Lagos–Ibadan express way in Nigeria, a dual carriage road. The park is located between 56 and 59 kilometres from Lagos on the express way. The presence of the park has led to an increase in commercial activities and an increase in the population of the studied area. Five sampling points which are representative of the park and the residential environments within the park were chosen for the study (Figure 1).

2.2. Sampling $PM_{2.5}$ and PM_{10}

PM with aerodynamic diameter of 2.5 μm and 10 μm ($PM_{2.5}$ and PM_{10}, respectively) were measured at five designated locations within the park and its environs using the GT-331 particle dust monitor. It is a unit of equipment from Met-One instruments, handheld, battery-operated and completely portable units measuring five mass ranges of particulate: PM_1, $PM_{2.5}$, PM_7, PM_{10} and total suspended solids (TSS). It has a concentration range of 0–1 mg m^{-3}, a sampling time of 5 min, a flow rate of 2.83 l/min and measures in μg m^{-3}. To measure, it is switched on in the environment of interest and the measured concentration is read directly on the LCD display. During this field study, the dust monitor was positioned 1 m above ground level in order to prevent measurement of fugitive dust mobilized by tides. Measurement was carried out during the dry season at each of the designated location for three different days consecutively at an averaging time of 8 h per day. The measured concentrations were extrapolated to obtain their 24-h averaging time concentrations using the atmospheric stability formula (Bashar, Kamel, & Khaldoun, 2009) given in Equation (1).

$$C_0 = C_1 \times F \tag{1}$$

where C_0 = The concentration at the averaging period t_0, C_1 = The concentration at the averaging period t_1, F = Factor to convert from the averaging period t_1 to the averaging period $t_0 = \left(\frac{t_1}{t_0}\right)^n$ $n = 0.28$, the stability dependent exponent.

Figure 1. Map of the study area.

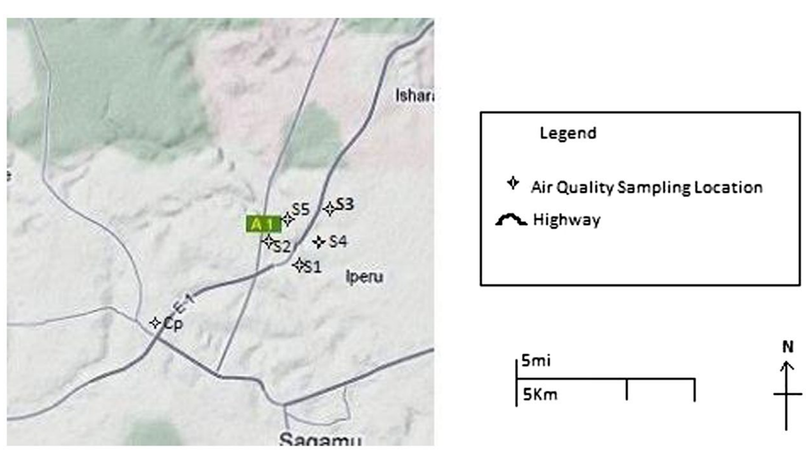

Table 3. Air quality index for pollutant

Breaking points $PM_{2.5}$ (μg m^{-3})	Breaking points PM_{10} (μg m^{-3})	AQI	AQI ratings
0.0–12.0	0–54	0–50	A
12.1–35.4	55–154	51–100	B
35.5–55.4	155–254	101–150	C
55.5–150.4	255–354	151–200	D
150.5–250.4	355–424	201–300	E
250.5–350.4	425–504	301–400	F
350.5–500	505–604	401–500	G

Source: EPA (2012).

2.3. Air quality index

The AQI around the haulage park was calculated using the EPA (2006) method in Equation (2).

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}}\left(C_p - BP_{Lo}\right) + I_{Lo} \tag{2}$$

where I_p = The index for pollutant *p*, C_p = The rounded concentration of pollutant *p*, BP_{Hi} = The breakpoint that is greater than or equal to C_p as given in Table 3, BP_{Lo} = The breakpoint that is less than or equal to C_p as given in Table 3, I_{Hi} = The AQI value corresponding to BP_{Hi}, I_{Lo} = The AQI value corresponding to BP_{Lo}.

3. Results and discussion

The mean 8-h measured ambient $PM_{2.5}$ and PM_{10} concentrations were 16.07–29.95 μg m^{-3} (Table 4) and 125.95–433.08 μg m^{-3} (Table 5), respectively, which on extrapolation to 24-h averaging period became 11.81–22.02 μg m^{-3} for $PM_{2.5}$ (Table 6) and 92.60–318.4 μg m^{-3} for PM_{10} (Table 7). The mean minimum and maximum $PM_{2.5}$ and PM_{10} were at S2 and S1, respectively. Sampling point S2 where the mean minimum concentration of PM_{10} was recorded also had the least 8-h daily concentration for day 1 and day 3 and these could be attributed to lesser haulage vehicles as compared to other sampling points. Sampling point S1 had the highest value for 8-h daily concentration all through the 3 consecutive days and this could be attributed to its being located on the middle of the dual carriageway where there were higher volumes of traffic as compared to other sampling points. Sampling points S2, S5 and S4 are sub-parks within the haulage vehicle park with varying number of vehicles.

The ambient temperature, wind speed and relative humidity during the field campaign were ranged 28.4–35.7°C with average of 32.3°C, 0.3–1.0 m s^{-1} with average of 0.8 m s^{-1} and 34.5–68.4% with average of 52.2%, respectively. The fairly moderate wind speed and temperature could aid in re-suspension of particulate from the dried unpaved floor of the studied region. Also, relative humidity could aid in the retention of these particulates in the air shed of the host environment. Likewise, the flat topography of the terrain has little or no effect on the air quality of the study area in terms of particulate concentration.

When compared with standards, the 24-h extrapolated ambient concentrations of $PM_{2.5}$ were within the guidelines of 35 μg m^{-3} and 25 μg m^{-3} by environmental protection agency (EPA) and World Health Organization, respectively, in all the sampling points. The extrapolated values of PM_{10} exceeded the accepted value of 50 μg m^{-3} by WHO (2005) in all the sampling locations, while the EPA 150 μg m^{-3} for PM_{10} was breached only at S1 and S4. The high level of particulates in S1 and S4 could be attributed to the high level of the haulage vehicular activities at these points compared to other sampling points.

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Table 4. Measured 8-h averaging period concentration of $PM_{2.5}$

Designated sampling point	Day 1 (μg m^{-3})	Day 2 (μg m^{-3})	Day 3 (μg m^{-3})	Average (μg m^{-3})
S1	27.9	29.26	32.69	29.95
S2	15.7	20.87	11.63	16.07
S3	12.59	32.32	19.51	21.47
S4	15.76	30.34	19.55	21.88
S5	14.78	18.71	16.59	16.69

Table 5. Measured 8-h averaging period concentration of PM_{10}

Designated sampling point	Day 1 (μg m^{-3})	Day 2 (μg m^{-3})	Day 3 (μg m^{-3})	Average (μg m^{-3})
S1	503.17	557.58	238.49	433.08
S2	124.29	147.48	106.07	125.95
S3	139.58	210.95	177.17	175.9
S4	280.5	257.44	199.42	245.79
S5	141.87	126.92	126.41	131.73

Table 6. Extrapolated 24-h averaging period $PM_{2.5}$ from the measured levels

Designated sampling point	Day 1 (μg m^{-3})	Day 2 (μg m^{-3})	Day 3 (μg m^{-3})	Average (μg m^{-3})
S1	20.51	21.51	24.03	22.02
S2	11.54	15.34	8.55	11.81
S3	9.26	23.76	14.34	15.79
S4	11.59	22.31	14.37	16.09
S5	10.87	13.76	12.20	12.28

Table 7. Extrapolated 24-h averaging period PM_{10} from the measured levels

Designated sampling point	Day 1 (μg m^{-3})	Day 2 (μg m^{-3})	Day 3 (μg m^{-3})	Average (μg m^{-3})
S1	369.93	409.93	175.34	318.4
S2	91.38	108.43	77.98	92.60
S3	102.62	155.09	130.26	129.32
S4	206.22	189.27	146.61	180.70
S5	104.30	93.31	92.94	96.85

Table 8. AQI rating for the airshed of the study area

Sampling point	AQI ($PM_{2.5}$)	AQI rating ($PM_{2.5}$)	AQI (PM_{10})	AQI rating (PM_{10})
S1	71.86	*B*	182.38	*D*
S2	49.21	*A*	69.61	*B*
S3	58.76	*B*	87.78	*B*
S4	59.39	*B*	113.72	*C*
S5	51.38	*B*	71.71	*B*

Summarized in Table 8 are the AQI and AQI ratings at each of the sampling locations for $PM_{2.5}$ and PM_{10}. AQI is an indicator of air quality based on the pollution levels for the criteria air pollutant that have adverse effects on human health and the environment. The air quality with respect to $PM_{2.5}$ could largely be described as moderate though a good AQI rating was obtained at S2. The ambient air quality at sampling points S1 and S4 were unhealthy due to the level of PM_{10} in their airshed, while the air quality in S2, S3 and S5 are moderate due to less vehicular activities in these areas.

4. Conclusion

This study investigated the air quality index patterns for $PM_{2.5}$ and PM_{10} in the airshed of a haulage vehicle park located around a major highway connecting Lagos, the commercial centre of Nigeria to its other parts. Measurements of $PM_{2.5}$ and PM_{10} were done at five different sub-parks using the aerosol mass monitor GT-331 by Met-one instrument. For the purpose of assessment, the 24-h concentrations of the measured particulates were extrapolated. The result observed from this study shows that ambient particulate levels are high enough to pose serious health concerns to human health, especially people with history of respiratory diseases. The 24-h values of PM_{10} exceeded the accepted value of 50 μg m^{-3} by WHO in all the sampling locations, while the EPA 150 μg m^{-3} for PM_{10} was breached at two locations. Going by the AQI pattern for this area, the study concluded that it is imperative that Nigeria sets ambient standard for $PM_{2.5}$ and PM_{10} as the size fractions poses deleterious effects to human, vegetation and the environment.

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