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FINE PARTICULATE CONCENTRATIONS IN THE AMBIENT ENVIRONMENT OF A MAJOR HAULAGE VEHICLE PARK

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ABSTRACT

The study was carried out to determine the levels of particulates in the airshed of major vehicular park and suggest appropriate ways of controlling the ambient particulate concentrations. The ambient fine mode particulate number concentrations were measured at five different designated points in the park using the Met-One mode GT-321 particulate air monitor. Measurements were conducted both in the wet and dry seasons. The Results showed that the averaged 8 hr daytime particulate concentrations for 0.3, 0.5 and 1.0µm PM within the park were of the range 1.19 x 10^8 - 2.52 x 10^8 particles/m^3 with an average of 2.25 x 10^8 particles/m3, 2.66 x 10^7 - 7.59 x 10^7 particles/m^3 with an average of 5.08 x 10^7 particle/m^3 and 3.17 x 10^6 - 9.82 x 10^6 particles/m^3 with average of 6.97 x 10^6 particles/m^3 respectively during the wet season and 1.22 x 10^8 - 1.73 x 10^8 particles/m^3 with an average of 1.41 x 10^8 particles/m^3, 1.58 x 10^7 - 3.99 x 10^7 particles/m^3 with an average of 2.94 x 10^7 particles/m^3 and 3.74 x 10^6 - 9.67 x 10^6 particles/m^3 with an average of 6.48 x 10^6 particles/m^3 respectively during the dry season. The Particulate Concentrations measured during the two seasons were within the maximum permitted limit of ISO Class 9 for PM1 required for a clean zone by International Standard Organization-ISO 146441. The study showed that vehicular activity could be one of the major contributors to ambient particulate concentration. Hence effective control measures such as cleaner technology, the use of catalytic converters, the use of alternative fuel and clean fuel and the implementation of emission standard should be employed in order to have an improved air quality based on ambient particulate concentration.

Keywords: *Ambient environment, fine particles, transport system, haulage vehicle park, meteorological parameters*

1. INTRODUCTION

Particulate matter (PM), a complex mixture of extremely small particles and liquid droplets found in the air (Libby, 2007) could pose serious challenge to both the environment and human health. Some particles are large or dark enough to be seen as soot, while some (including fine particles) are tiny and generally not visible to the naked eye. The fine mode particulate matter is of health concern because they can reach the deepest regions of the lungs. Pathogenesis by fine particles depends on the physical characteristics (size, shape, concentration, composition and aggregation effects) of the particles and host body defense systems (DEH, 2004; Maynard and Kuempel, 2005; Baveye, 2008). The Health effects include asthma, difficult or painful breathing, and chronic bronchitis, especially in children and the elderly (Donaldson *et al*., 1988; Bate, 1995; Atkinson *et al*., 1999; Pope III, 2000; Cacciola *et al*., 2002).

Transportation sector makes a vital contribution to the economy and plays a crucial role on daily activities in Nigeria like many other developing countries. However, it is becoming a significant source of air pollution and is currently one of the major emission sources in megacities with subsequent adverse effects on human health (Colvile *et al*., 2001). Although, road transport has the advantage of providing door-to-door transportation and convenience for man's daily life, its fuel requirement in combustion and emissions are much higher than other transport modes (Masjuki et al., 2004; Soylu, 2007). These emissions from road transport are serious threats to urban air quality and global warming (Saija and Romano, 2002).

Vehicular activities are one of the major primary fine particulate matter sources. They account for approximately 15 – 50 % of total fine aerosol mass in urban areas (Sheesley *et al*., 2007). Diesel-powered vehicles and engines contribute more than half of the mobile source particulate emissions (Ramachandran *et al*., 2005; Morawska *et al*., 2008).

The measurement of fine particle exposure can be determined in terms of size distribution, particle number concentration, surface area concentration and mass concentration (Cheng *et al*., 2008). Fine particulate matter contributes significantly to particle number concentration (PNC), but little to particle mass concentration (ECJRC, 2002) hence particle number concentration and surface area are more likely to be related in potential health effects than particle mass concentration. The mass concentration from fine particle is low and size-dependent particles can possibly impact on respiratory system areas through translocation and biological response (Oberdörster, 2000).

To examine the impacts of vehicular activities on ambient air quality in a haulage vehicle park, this study measured the particulate number concentrations from a major haulage vehicle park located at Ogere, Ogun State, Nigeria. This park is strategically located in transport corridor leading to Lagos and Ibadan which are emerging megacities in Nigeria. Its features have earlier been discussed (Fakinle et al., 2013). The information derived from this will assist in developing appropriate control measures for the abatement of particulate emission in haulage parks. It will also assist in legislating

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on ambient air quality standards around haulage vehicle parks, and also add to the data bank on aerial pollution in Nigeria.

2. METHODOLOGY

The study area (Fig. 1) has been earlier described in Fakinle *et al*, (2013). Fine mode particulate number concentrations were measured at five different locations designated within the park using the Met one Isokinetic particle air monitor (Met One model GT-321). Measurement with the isokinetic monitor was set to operate between 10.00 am - 18.00 pm at each of the sampling points throughout the months of July and December 2010 which are the months in rainy and dry season, respectively. The isokinetic monitor is a small and portable unit with self-contained power supply. The LCD display of the unit allows viewing of two discrete particle-counting channels in real time simultaneously. The sampling time is typically 5 minutes for all cases with logging interval of about 15 min. its battery can last about 24 hours between periods of recharge.

2.1. Meteorological Condition

The meteorological conditions of the site were measured using the Kestrel 4000 pocket weather tracker which is an easy weather monitoring device that instantly measures environmental condition accurately. It is set up to display the following meteorological parameters: relative humidity, temperature, wind speed, pressure and altitude. These measured parameters have also been reported earlier by Fakinle *et al*., 2012.

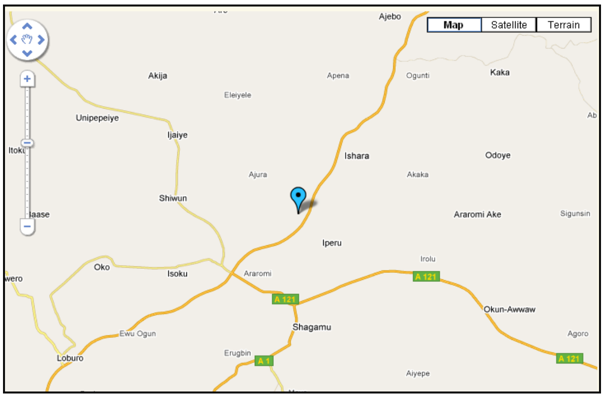

Fig. 1. Sampling Points at Ogere, Ogun State
Source: Google map (2010)

3. RESULTS AND DISCUSSION

Summarized in Table 1 and Table 2 are the 8-hr averaging period measured fine particulate number concentrations (particles/m^3) at the various sampling points. The concentrations ranged between 1.91 x 10^8 - 2.52 x 10^8 particles/m^{3}with an average of 2.25 x 10^8 particles/m^3, 2.66 x 10^7 - 7.59 x 10^7 particles/m^3 with an average of 5.08 x 10^7 particles/m^3, 3.17 x 10^6 - 9.82 x 10^6 particles/m^3 with an average of 6.97 x 10^6 particles/m^3 for particles with size fraction 0.3 µm, 0.5 µm, 1.0 µm respectively during the rainy season, while the ranges were 1.22 x 10^8 - 1.73 x 10^8 particles/m^3 with an average of 1.41 x 10^8 particles/m^3, 1.58 x 10^7 - 3.99 x 10^7 particles/m^3 with an average of 2.94 x 10^7 particles/m^3, 3.74 x 10^6 - 9.67 x 10^6 particles/m^3 with an average of 6.48 x 10^6 particles/m^3 respectively in the dry season. During the rainy season the minimum and maximum $PM_{0.3}$ concentrations were at S1 and S3 respectively, but for $PM_{0.5}$ the minimum and maximum concentration they were at S5 and S4 respectively while sampling points S5 and S4 had the minimum and maximum respectively for PM_1 respectively. In the dry season the minimum $PM_{0.3}$, was at sampling point S5 while $PM_{0.5}$ and PM_1 both had their minimum at S4. The maximum concentrations for all the size fractions were at sampling point S1.

In sampling locations S4 and S5 the minimum $PM_{0.5}$ and PM_1 for both seasons which could be attributed to lesser haulage vehicle activities compared to the other locations. However, in the dry season S1 which is located at the median of the dual carriageway experiencing higher traffic volumes as compared to other sampling locations had the maximum particle concentrations for all the size fractions. The maximum concentrations of all the size fractions at S1 during the season could be as a result of high traffic volume and activities.

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Table 1: Eight hour averaged ambient particulate number concentrations (Particle/m^3) in July, 2010 wet season

Location	Concentration Wet season		
	0.3 µm	0.5 µm	1.0 µm
Station 1	1.91 x 10^8	5.12 x 10^7	6.11 x 10^6
Station 2	2.23 x 10^8	4.38 x 10^7	6.89 x 10^6
Station3	2.52 x 10^8	5.65 x 10^7	8.86 x 10^6
Station 4	2.50 x 10^8	7.59 x 10^7	9.82 x 10^6
Station 5	2.10 x 10^8	2.66 x 10^7	3.17 x 10^6
Mean	2.25 x 10^8	5.08 x 10^7	6.97 x 10^6

Table 2: Eight hour averaged ambient particulate number concentrations (Particle/m^3) in December, 2010 dry season

Location	Concentration Dry Season		
	0.3 µm	0.5 µm	1.0 µm
Station 1	1.73 x 10^8	3.99 x 10^7	9.67 x 10^6
Station 2	1.37 x 10^8	3.32 x 10^7	7.38 x 10^6
Station 3	1.52 x 10^8	2.57 x 10^7	5.54 x 10^6
Station 4	1.22 x 10^8	1.58 x 10^7	3.74 x 10^6
Station 5	1.22 x 10^8	3.22 x 10^7	6.07 x 10^6
Mean	1.41 x 10^8	2.94 x 10^7	6.48 x 10^8

Using the ISO 14644-1 classification for airborne particulate cleanliness classes for clean rooms and zones as summarized in Table 4, all the sampling points breach the $PM_{0.3}$ standard during both rain and dry seasons as the concentrations at these points exceed the maximum ISO Class 6 permitted for a clean zone. For $PM_{0.5}$, sampling point S5 can be classified into Class 9 during the rainy season, while other sampling points breached the limit set for this faction. During the dry season, sampling points S2, S3, S4 and S5 can be classified into ISO Class 9 using $PM_{0.5}$. Also sampling points S1, S2 and S5 during the rainy season as well as sampling points S2, S3, S3, S4 and S5 during the dry season can be classified into Class 9 using PM_1. The result showed that Ogere road transport system has enormous PM loading in its ambient air which could be attributed to the influence of vehicular activities in the region.

In this study, result showed that particulate number concentrations of the fine particles ($PM_{0.3}$ and $PM_{0.5}$) were higher during the wet season as compared to the dry season. This observation could be linked to the variation in the meteorological conditions (Table 3) which were 64.21 %, 29 ^{0}C and 0.82 m s^{-1} for relative humidity, temperature and wind speed respectively during the rainy season, while those of the dry season were 51.41 %, 32.44 ^{0}C and 0.76 m s^{-1} respectively. Also vehicular count could be a contributing factor to the variation in the particulate concentrations in the airshed in both seasons. From the measured meteorological parameters, it was observed that the relative humidity during the wet season was higher compared to the dry season. High relative humidity accounts for the presence of moisture in the ambient air of the haulage park which could aid particles coagulation during the season, hence this could be the reason for higher concentrations of fine particle during the season compared to the dry season. Also from the overall mean of particulate in Table 2 the study area could be classified into ISO Class 9 during the dry season using $PM_{0.5}$. For PM_1 the study region could be classified into ISO Class 9 during the two seasons.

Table 3: Overall mean and Standard deviations of Meteorological parameters measured during the sampling period.

Season	Relative Humidity (RH %)	Temperature (°C)	Wind speed (m/s)
Rain	64.21 ± 7.38	29.00 ± 1.68	0.82 ± 0.26
Dry	51.41 ± 7.77	32.44 ± 1.36	0.76 ± 0.21

Table 4: Selected airborne particulate cleanliness classes for cleanrooms and clean zones

Classification Number(N)	Maximum concentration limits (particles / m³) for particles equal to and larger than the considered sizes shown below		
	0.3 µm	0.5 µm	1 µm
ISO Class 1			
ISO Class 2	10	4	
ISO Class 3	102	35	8
ISO Class 4	1020	352	83
ISO Class 5	10200	3520	832
ISO Class 6	102000	35200	8320
ISO Class 7		352000	83200
ISO Class 8		3520000	832000
ISO Class 9		35200000	8320000

Using these ISO Classifications for airborne particulate cleanliness, efforts need to be made at the haulage park to ensure that the particulates levels in the ambient environment of the park do not go beyond ISO Class 5.

The Particle number concentrations (PNCs) of the fine mode fractions (0.3µm, 0.5µm, 1.0µm) appeared to be in similar order of magnitude at each of the five sampling points. The average of the PNCs over the entire sampling duration indicated that 0.3µm, 0.5µm and 1.0µm constituted 80%, 18% and 2% respectively of the total PM during rainy season (Fig. 2) while 80%, 16% and 4% respectively during the dry season (Fig. 3). These particles could consist of soot since diesel combustion in the heavy trucks operating around the park was a major source of particulates (Dallaman *et al.*, 2014).

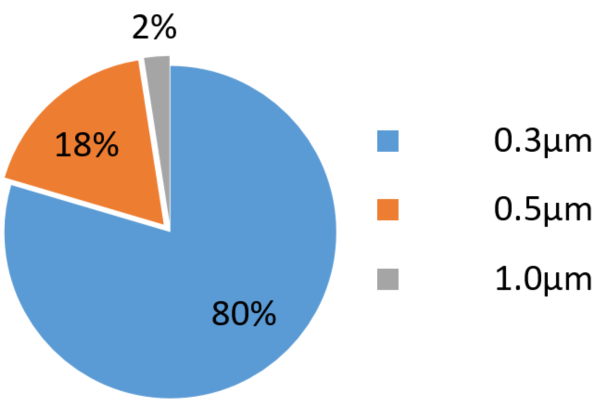

Fig. 2: Ambient Particle Concentration during Rainy Season.

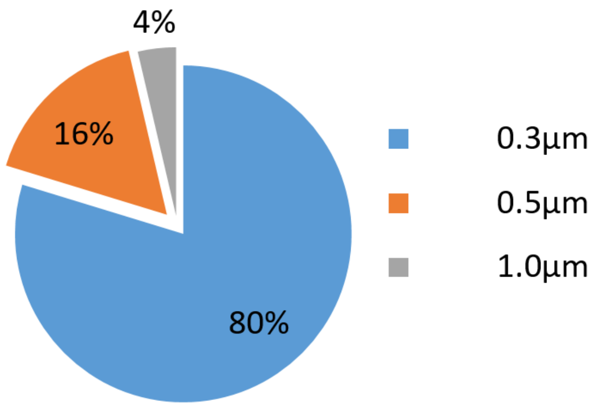

Fig. 3: Ambient Particle Concentration during Dry Season.

4. CONCLUSION

This work investigated the contribution of haulage vehicular activities to the air quality of Ogere's airshed based on PNC of fine mode particle. The particles with diameter of 0.3µm dominate the PNCs in the ambient air of the study area. The measured PNCs ranged between 1.91×10^8 - 2.52×10^8 particles/m³, 2.66×10^7 - 7.59×10^7 particles/m³, 3.17×10^6 - 9.82×10^6 particles/m³ for particles with size fraction 0.3 µm, 0.5 µm, 1.0 µm respectively during the month of July, 2010 rainy season, while the ranges were 1.22×10^8 - 1.73×10^8 particles/m³, 1.58×10^7 - 3.99×10^7 particles/m³, 3.74×10^6 - 9.67×10^6 particles/m³ respectively in the dry season in December, 2010. The percentage contributions of $PM_{0.3}$, $PM_{0.5}$ and PM_1 during the wet season were 80%, 18%, and 2% respectively, while that of the dry season were 80%, 16%, 4% respectively. Due to high concentration of the fine mode particle in the study area it is observed that the contribution of vehicular activities to the ambient air quality is significant hence it is imperative that control measure should be put in place in order to have an improved air quality. Control measure such as cleaner technology, the use of catalytic converters, the use of alternative fuel and clean fuel and the implementation of emission standard should be employed in order to control emission from vehicular activities.

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