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Evaluation of the Concentration of Particulate Matter along Ibadan-Ilorin Highway of Nigeria

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Abstract

This paper examined the impact of particulate matter (PM) along the Ibadan-Ilorin highway of Nigeria. The study was conducted in Ogbomoso-section of Ibadan-Ilorin highway of Nigeria at three different locations for the wet and dry seasons. The GT-321 particle counter was used to measure the PM. It has five selectable size ranges of 0.3, 0.5, 1.0, 2.0, and 5.0 micron. The result of investigation showed that $PM_{0.3}$ had highest percentage concentration values (87 – 96%) in all the selected location and in both seasons. The results of the research work showed that selected location and season had impact on the emission rate of the particle. All the selected sizes of PM had values more than ISO classes 1 -7 maximum concentrations limit. The study concludes that transport-related pollution is indeed significant within the study area with possible severe health consequences.

Key words: Particulate matter, Particle number, seasons and site location

Introduction

In many urban areas, increased vehicle usage has resulted in a detrimental effect on air quality (Ling *et al.*, 2005). Road vehicles have long been identified as major contributors to the urban air pollution burden (Park *et al*., 2004). Traffic-related air pollution is most severe in urban areas and particularly city centres, where large traffic volumes and congestion commonly result in a significant degradation of the air quality in these areas. This problem is compounded by the fact that these are also centres of human activity (Tsai and Chen, 2004).

The emissions from a motor vehicle vary under different driving conditions (Tong *et al*., 2000; Frey *et al*., 2003). One of the specific driving modes is the idle condition. A motor vehicle may have over 25% of its time spent in the idle mode (Tong *et al.*, 1999). Idling emission is considered more harmful because the pollutants cannot be dispersed by the wake created by a moving vehicle. A specific idle mode is the park-and-wait mode in which the motor vehicle is parked along the street or in a terminal with the engine switched on. It is believed that, due to poor combustion conditions inside the engine cylinder when it is operating at idle and the poor dispersion condition when the vehicle is not moving, pollutant concentration will be high around the vehicle (Ning *et al*, 2005). This will pose a threat to the commuters and those waiting for the vehicles. In Hong Kong for example, due to the close proximity of the traffic to the commuters and shops on both sides of the road, the government has to urge the vehicle operators to switch off the engine while waiting (Ning *et al*, 2005).

Efe (2008) in his study examined distribution of ambient particulate pollution and its possible health implications in Nigerian cities. A total of 102 high-volume (HV) samplers were used in 17 Nigerian cities to draw a known volume of ambient air at a constant flow rate through a size selective inlet and through filters for a six-year period (2001-2006). Particles in the PM_{10} size range were then collected on the filter during a 24-hour sampling period to get a daily average ambient PM_{10}. The data were subjected to paired t-test, ANOVA and multiple regression statistical analyses. The results showed that the urban corridors of over 70% of Nigerian cities are sites with a high rate of daily mean/annual mean ambient PM_{10} of over 120µg/m^3, while < 30% of Nigerian urban centres had mean annual ambient PM_{10} value of 119.2µg/m^3.

A study of the impacts of urban road transportation on the ambient air was conducted by Koku and Osuntogun, (1999) in three cities of Nigeria: Lagos, Ibadan and Ado – Ekiti all in South-west region of Nigeria. Air quality indicators namely CO, SO_2, NO_2, and total suspended particulates (TSP) were determined. The highest levels obtained for the air pollution indicators in Lagos were CO-233ppm at Idumota, SO_2-2.9ppm at Idumota, NO_2-1.5ppm at Iyana–Ipaja and total particulates 852cpm at Oshodi bustop. At Ibadan, the CO and SO_2 levels at 271 and 1.44ppm were highest at Mokola round about while NO_2, at 1.0ppm was highest at Bere round about. In Ado-Ekiti the highest level obtained were CO-317ppm at Oke Isha, NO_2 -0.6ppm at Ijigbo Junction and SO_2-0.8ppm at Old Garage Junction. The obtained results of CO, SO_2, NO_2, and particulate counts per minute were found by Koku and Osuntogun (1999), to be higher than FEPA limits.

Scientific research has shown that prolonged exposure to these pollutants above a specific level may be harmful to human health (Anna and Nikolaos, 2008). The individual effects vary from one to another, and it is especially harmful to the young children and the elderly, and those with existing respiratory problems. Children are at risk because their lungs are not fully developed; they breath faster, and they spend lots of time outdoors (Kenneth *et al.,* 1999).

Among all the air pollutants in ambient air, PM affects more people than any other pollutants (Pope and Dockery, 2006). The adverse effects of PM on human health occur at levels of exposure currently being experienced by most urban and rural inhabitants in both developed and developing countries. The major constituents of PM are sulphates, nitrates, ammonia, sodium chloride, carbon, mineral dust, and water. PM consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in air. Particles are identified according to their aerodynamic diameters as either PM_{10}, or $PM_{2.5}$ (aerodynamic diameters equal to or smaller than 2.5µm). The latter are considered as more detrimental because, when inhaled, they may reach the peripheral regions of bronchioles and interfere with gas exchange inside the lungs (Liu and Frey, 2011; Bari *et al.*, 2003).
This paper therefore aimed at determining the impact of selected sizes of particulate matter along the major highway. Table 1 shows the Organization of International Standards (ISO) for number concentration of particulate matter (PM) of different sizes.

Table 1: Standards for Airborne Particulate Cleanliness Classes for Clean Rooms and Zones

ISO Classification Number (N)	**Maximum Concentrations Limits (particles/m^3)**					
	0.1 µm	0.2 µm	0.3 µm	0.5µm	1.0 µm	5.0 µm
ISO Class 1	10	2				
ISO Class 2	100	24	10	4		
ISO Class 3	1000	237	102	35	8	
ISO Class 4	10000	23700	1020	352	83	
ISO Class 5	100000	237000	10200	3520	830	29
ISO Class 6	1000000	2370000	102000	35200	8300	293
ISO Class 7				352000	83000	2930
ISO Class 8				3520000	830000	29300
ISO Class 9				35200000	8300000	293000

Source: Organization of International Standard (ISO-2004)

Materials and Methods

The Study Area/Sampling Site

The study was conducted in the city of Ogbomoso, a pre-colonial urban centre and the second largest city, both in terms of population and spatial extent, in Oyo State, Nigeria. The city is located approximately 100km north of Ibadan, the Oyo State capital, and roughly 80 km from both Ilorin and Osogbo, respectively the Kwara and Osun State capitals (Adeboyejo and Abolade, 2007). It is one of the main gateways to the northern regions of Nigerian from the Yoruba land, and is bounded by the

river Ora to the east, there are no major physical barriers towards the north and south along the Ibadan-Ilorin Road. Figure 1 is a geo-reference map showing the three locations that were selected for particle counts. The locations are Idi-oro, General and Aroje along Ibadan – Ilorin highway. These sites are along the road sides and associated with movement of motorcycles, cars, buses and trucks/trailers.

Measurement

In this study, particle counts were obtained using a handheld airborne particle counting device (GT-321, Washington Boulevard). The GT-321 is designed to be a small, easy to use and completely portable hand-held particle counter that can provide fast and accurate measurement of particulate contamination in particles per cubic foot. It has 5 selectable size ranges of 0.3, 0.5, 1, 2, and 5 microns. The counter contains a laser diode-based sensor, NiCd battery pack, vacuum pump, microprocessor electronics, LCD display and user input keys all in one small package. The accuracy of the GT-321 is certified according to ASTM and JIS standards and comparable to larger more expensive bench top particle counters. The fast 6-second response of the GT-321 makes it especially useful for troubleshooting contamination problems and tracing contamination leaks to the source. The laser diode-based sensor inside the GT-321 utilizes a specially designed elliptical mirror for high light collection efficiency and improved signal to noise. Precision optics collimates the laser beam into a thin, very intense beam resulting in increased signal and a high concentration limit of 3,000,000 particles per cubic foot. This high concentration limit allows the GT-321 to be used for indoor and outdoor aerosol particulate measurement. Particle counts were conducted for weekdays and weekends along the selected section of the road in the wet and dry seasons (May, July, October and December, 2011). Meteorological parameters such as temperature, humidity, wind speed, pressure and altitude values were also measured.

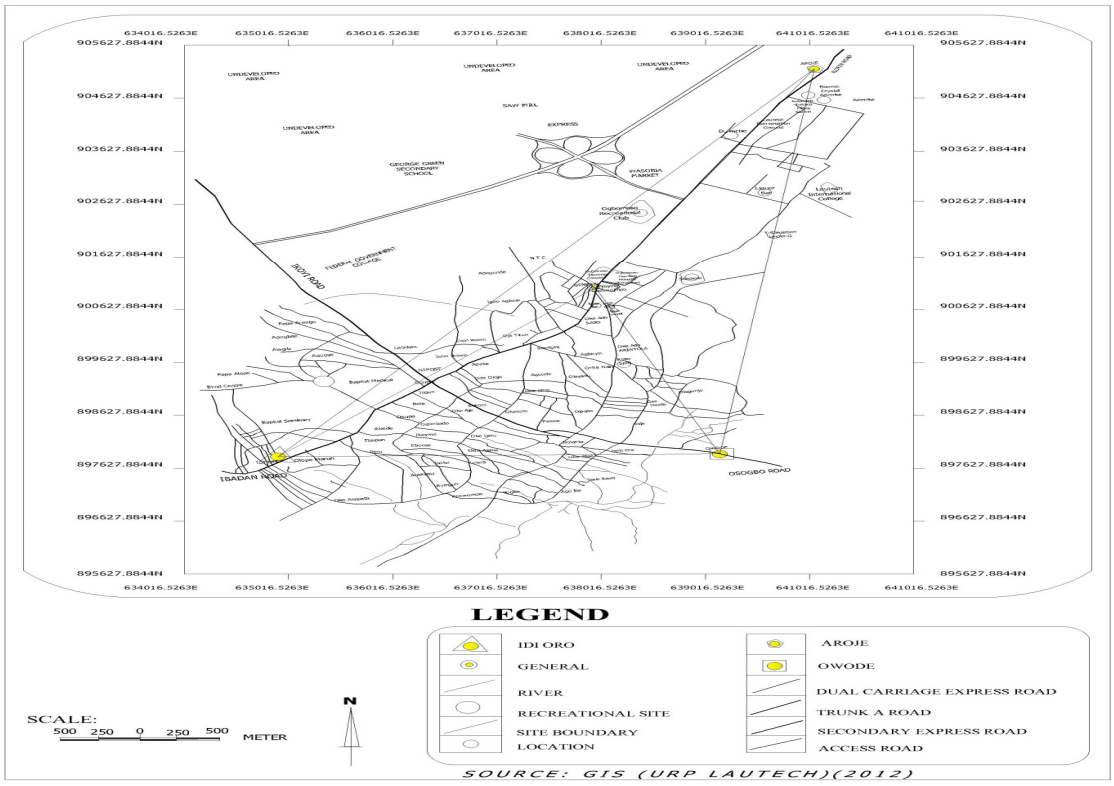

Figure 1: Geo-referenced Map of Ogbomoso Road Network Showing Sampling Locations

Results and Discussion

Particulate Matter (PM) number concentration measured (particles/m^3)

The number concentrations of the vehicular emissions of $PM_{0.3}$, $PM_{0.5}$, $PM_{1.0}$, $PM_{2.0}$, and $PM_{5.0}$ are summarized in Table 2 – 5 and the equivalent percentages are shown in Figures 2 – 5 for both the wet and dry seasons along the highway.

The variation of PM concentration with particle size

The results from Table 2 – 5 showed that concentration of PM generally decrease as particle size increased in all selected locations. The PM distribution in percentages as presented in Figure 2 – 5 showed that 0.3micron had highest percentage of 96% in October while 0.5micron had 10% as its highest percentage in December. A comparison of mean number concentrations of PM of 0.5 µm – 5.0 µm readings with permissible limit showed that both the wet and dry seasons' readings exceeded classes 1 – 7 of ISO standards.

It has been reported that among all the air pollutants in ambient air, PM affects more people than any other pollutants (Pope and Dockery, 2006). $PM_{0.1 - 2.5}$ were considered as more detrimental because when inhaled they may reach the peripheral regions of bronchioles and interfere with gas exchange inside the lungs (Liu and Frey, 2011; Bari *et al*., 2003). Summarily, it can be seen that the lower the particle size the higher the emission rates and vice - versa.

Table 2: PM Number Concentrations (particle/m^3 x10^5) in May

Location	0.3µm	0.5µm	1.0µm	2.0µm	5.0µm
Idi-oro	26.77	2.37	0.23	0.12	0.01
General	22.29	4.31	0.83	0.39	0.05
Aroje	30.58	3.82	0.77	0.36	0.03
Min	22.29	2.37	0.23	0.12	0.01
Max	30.58	4.31	0.83	0.39	0.05
Mean	26.55	3.50	0.61	0.29	0.03
STD	4.15	1.01	0.33	0.15	0.02

Table 3: PM Number Concentrations (particle/m^3 x10^5) in July

Location	0.3µm	0.5µm	1.0µm	2.0µm	5.0µm
Idi-oro	84.11	4.24	0.42	0.32	0.14
General	69.51	7.71	1.54	1.03	0.42
Aroje	51.62	4.37	1.66	0.78	0.05
Min	51.62	4.24	0.42	0.32	0.05
Max	84.11	7.71	1.66	1.03	0.42
Mean	68.41	5.44	1.21	0.71	0.20
STD	16.27	1.97	0.68	0.36	0.19

Table 4: PM Number Concentrations (particle/m^3 x10^5) in October

Location	0.3µm	0.5µm	1.0µm	2.0µm	5.0µm
Idi-oro	79.39	2.98	0.32	0.15	0.01
General	65.61	5.41	1.1	0.47	0.09
Aroje	67.34	3.5	0.66	0.28	0.06
Min	65.61	2.98	0.32	0.15	0.01
Max	79.39	5.41	1.1	0.47	0.09
Mean	70.78	3.96	0.69	0.30	0.05
STD	7.51	1.28	0.39	0.16	0.04

Table 5: PM Number Concentrations (particle/m^3 x10^5) in December

Location	0.3µm	0.5µm	1.0µm	2.0µm	5.0µm
Idi-oro x10^5	50.93	5.72	1.32	0.55	0.1
General x10^5	42.17	10.53	4.91	1.78	0.31
Aroje x10^5	44.96	12.17	4.79	2.11	0.22
Min	42.17	5.72	1.32	0.55	0.1
Max	50.93	12.17	4.91	2.11	0.31
Mean	46.02	9.47	3.67	1.48	0.21
STD	4.48	3.35	2.04	0.82	0.11

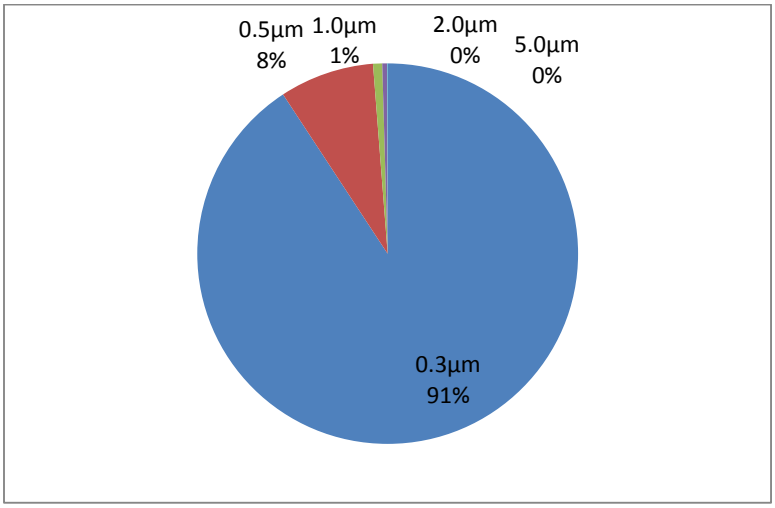

Figure 2: PM Distribution Percentages in May

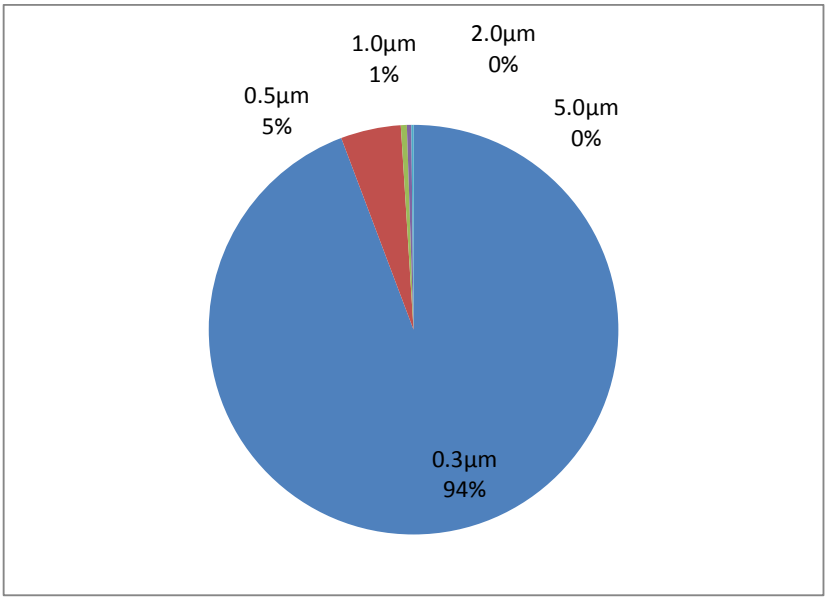

Figure 3: PM Distribution Percentages in July

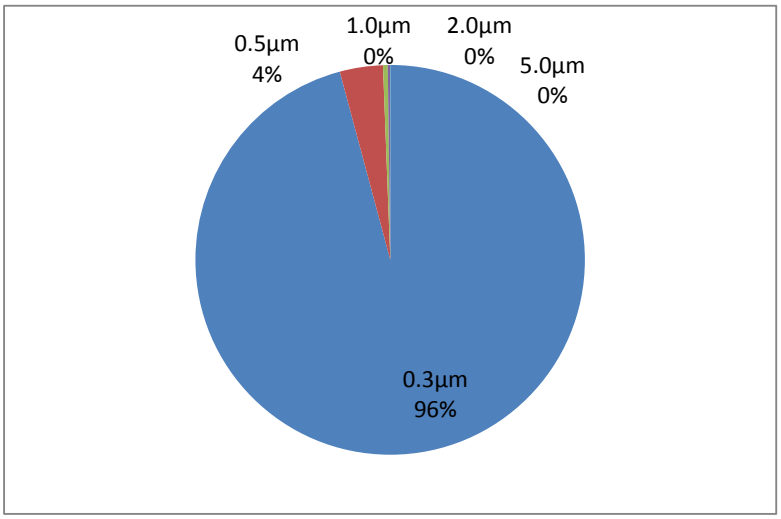

Figure 4: PM Distribution Percentages in October

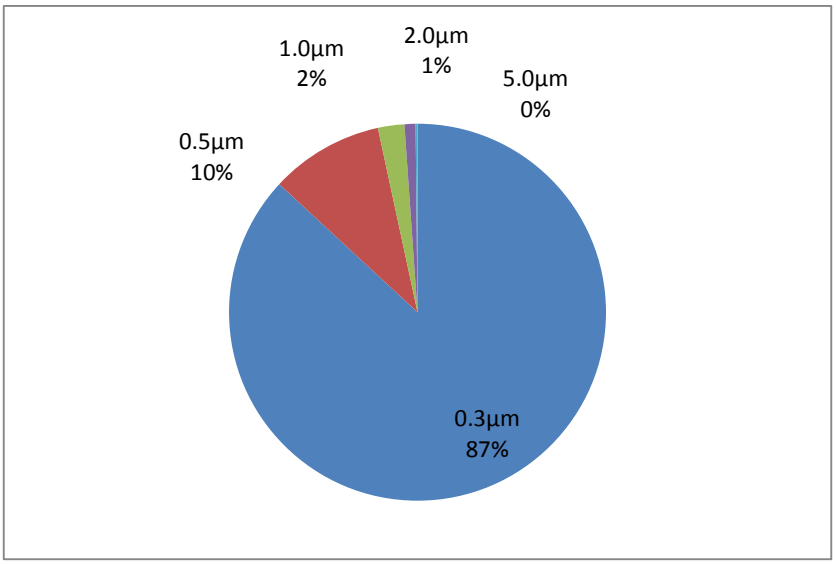

Figure 5: PM Distribution Percentages in December

The variation of PM concentration with location

The results obtained also showed that the selected locations had impact on the PM concentrations. Idi-oro had the highest concentration values in July, October and December than any other location for 0.3 micron because the location is the entrance to the city which is occupied with a lot of vehicles coming from different cities. The results also show that some locations favour particular size of particle than the other. Therefore, the type of vehicle and traffic count in a location will determine the PM concentration.

The variation of PM concentration with time

The results of PM concentration showed that time also had impact on its values. Since the research work was carried out in both the wet and dry seasons. The results of dry season (October and December) had the highest mean concentration values for all selected particle sizes because of the dry season coupled with harmattan. 0.3 micron had highest mean concentration in October while the rest of particle sizes had their highest values in December.

Conclusion

This work aims at determining the concentrations of PM along Ibadan-Ilorin highway of Nigeria at different locations in both wet and dry seasons. From the results of measurement conducted, it is concluded that:

i. There are three factors that affect the emission rate.
ii. Vehicular emissions have been identified to contribute significantly to the PM level of the ambient air

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