Particle Counts and Size Distributions in Local Garri Processing Environment

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Abstract
Previous studies have linked morbidity and mortality of individuals to airborne particles resulting from anthropogenic sources. Fine particles (particles < 2.5 µm) are known to have harmful effects on human health and environment compared to the coarse particles (2.5 µm < d_p <10 µm). Sadly, developing countries experiencing rapid growth are characterized with inadequate environmental action and policy. Garri processing has been linked to contribute to ambient particulate matter pollution. The present study investigates the number and sizes of particulate emitted as a result of this anthropogenic activity. Continuous measurement of number concentration and size distributions of particles of diameters 0.3 µm, 0.5 µm, 1.0 µm, 2.0 µm and 5.0 µm were conducted, using a GT -321 particle counter for day and night cases November 2012 at four major local garri processing locations in the ancient city of Oyo, Nigeria. On the average, the total particle number concentration for the selected four locations were $2.3 \times 10^6 – 8.9 \times 10^6$; $0.085 \times 10^6 – 4.487 \times 10^6$; $0.073 \times 10^6 – 0.912 \times 10^6$; $0.022 \times 10^6 – 0.654 \times 10^6$; and $0.002 \times 10^6 – 0.155 \times 10^6$ for particle size 0.3µm, 0.5 µm, 1.0 µm, 2.0 µm and 5.0 µm respectively for day time readings and $1.021 \times 10^6 –8.793 \times 10^6$; $0.071 \times 10^6 – 3.323 \times 10^6$; $0.051 \times 10^6 – 1.903 \times 10^6$; $0.012 \times 10^6 – 0.278 \times 10^6$;and $0.003 \times 10^6 – 0.015 \times 10^6$ for particle size 0.3µm, 0.5 µm, 1.0 µm, 2.0 µm and 5.0 µm respectively for night time measurements. Daily cycle of particle numbers were obvious with high concentrations recorded during day time but lower level at night time which is consistent with the trend of the garri processing activity. The findings suggested that higher fraction of fine particles (0.3 - 2 µm) are produced and retained in the ambient air from this activity.
Keywords: Garri, number concentration, size distribution, particulate matter

1.0 Introduction

Antropogenic contribution of particulate matter and other gaseous pollutants increase the ambient loading of aerosols in air. Epidemiological studies have linked morbidity and mortality of individuals to exposure of particulate matter especially the fine particles, $PM_{2.5}$ and the coarse particles, PM_{10} (Brauer *et al*., 2001; Penttinen *et al*., 2001; WHO, 2003; Franklin *et al*., 2007; Bell *et al*., 2009; Ostro *et al*., 2009). Aside the health impacts, they affect visibility (Andreae and Merlet, 2001; Mahmoud, 2010), soil surfaces when deposited (Chow *et al*., 2002), and affect the earth's climate (MacCracken, 2008; Alleman *et al*., 2010). Studies have tend to investigate
ambient concentrations of pollutants resulting from some anthropogenic sources (Sonibare and Jimoda, 2009; Jimoda *et al*., 2011). However, the issue of air quality impact from some local manufacturing processses is yet t receive tangible attention from the policy makers and air quality researchers in the developing countries.

Cassava is one of the most important staple food crops grown in tropical Africa (IITA, 1990). It plays a major role in efforts to alleviate the African food crisis because of its efficient production of food energy, year-round availability, tolerance to extreme stress conditions, and suitability to present farming and food needs in Africa (Oyegbami *et al.,* 2010). Sanni and Olubamiwa (2004) and IITA (1990) estimated that over 70% of cassava yield in Nigeria is processed into 7- 10 million tonnes of garri (cassava flour) annually (FAO, 2004). People engage in the local processing of the product in many towns of southwestern Nigeria (Adebayo, 2009; Adejumo and Raji, 2010; Makanjuola *et al*., 2012). Oyo town is known for its high garri processing capability. It provides a high percentage of garri consumed in the adjourning towns and cities.

The processing of cassava to garri after harvesting in Oyo town is intensive during the dry season, which may contribute significantly to the ambient air pollution. Open frying is the most common method used by garri processors. Such frying often takes place in large extended pots supported by muds. Fire woods which are in plentiful supply are used majorly to supply the required heat for the processing. This study focuses on emissions from open burning of agricultural biomass such as cassava peels and firewood involved in garri processing. This is for the assessment of the number concentration of particulate matter of different sizes resulting from garri processing.

2.0 Materials and Methods

2.1 Sampling Area

Oyo is a town in Southwestern Nigeria. It is located in the region of Oyo State with latitude and longitude values of 7° 47' 26" N and 3° 56' 15" E respectively. Its population ranges between 250000 and 500000. It has an equatorial climate notably with dry and wet season, average daily temperature ranging between 25°C (77°F) and 35°C (95°F). The measurement and samplings were done at various stations namely Irepo (G1), Sabo (G2), Ajonibadi (G3) , Ajegunle (G4) and G_c (a residential area) ischosen as the control location as shown in Figure 1. The sampling stations (G1, G2, G3 and G4) are characterized by numerous cassava processing sheds, where cassava is being peeled, ground and fried. At the sampling sites, the particle concentrations were measured at about 1 m above the ground overlooking the locations where continuous burning takes place. There are no tall buildings or structures nearby to stop free flow of ambient air for quality readings of particle concentration.

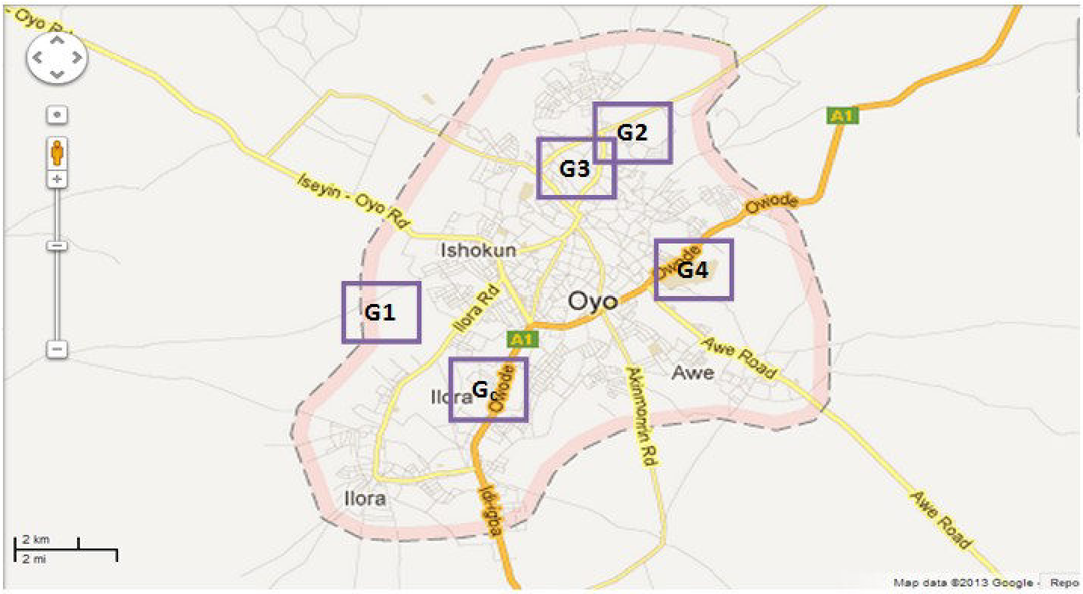

Figure 1: The study locations in Oyo, Southwestern Nigeria (Google Maps, 2013)

2.2 Particulate Matter Number and Size Characterization

Particulate matter (PM) was measured with GT-321 Particle Counter, an equipment from Met One Instruments. It is handheld, battery operated and completely portable unit measuring five number ranges of Total Suspended Particles: $PM_{0.3}$, $PM_{0.5}$, PM_1, PM_2, and PM_5. It has a sampling period of 2 minutes and a flow rate of 2.83 l/min. To measure, it is placed at 1 m above the ground level, switched on in the environment of interest and the measured concentration read directly on the screen after particle capturing. Measured concentrations were compared with the International Standard Organisation standard (ISO 14644) for airborne particulates for cleanrooms and clean zones (Table 1).

Table 1: Selected 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	0.5 µm	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	2370	1020	352	83	
ISO Class 5	100000	23700	10200	3520	832	29
ISO Class 6	1000000	237000	102000	35200	8320	293
ISO Class 7				352000	83200	2930
ISO Class 8				3520000	832000	29300
ISO Class 9				35200000	8320000	293000

Source: ISO (2004)

3.0 Results and Discussion

3.1 Particulate Matter size distribution and number concentration

On the average, the total particle number concentration for the four selected garri processing locations G1, G2, G3 and G4 range between 2.3 x 10^6 and 8.9 × 10^6 ; 0.085 x 10^6 - 4.487 x 10^6; 0.073 x 10^6 - 0.912 x 10^6; 0.022 x 10^6 - 0.654 x 10^6; and 0.002 x 10^6 - 0.155 x 10^6 for particle size 0.3µm, 0.5 µm, 1.0 µm, 2.0 µm and 5.0 µm respectively for day time readings and 1.021 x 10^6 - 8.793 x 10^6; 0.071 x 10^6 - 3.323 x 10^6; 0.051 x 10^6 - 1.903 x 10^6; 0.012 x 10^6 - 0.278 x 10^6; and 0.003 x 10^6 - 0.015 x 10^6 for particle size 0.3µm, 0.5 µm, 1.0 µm, 2.0 µm and 5.0 µm respectively for night time readings. In all the locations, it was noticed that the particulate matter size of 0.3 µm ($PM_{0.3}$) has the concentrations far above other particulates ($PM_{0.5}$, PM_1, PM_2 and PM_5) measured. Figures 2 – 5 show the percentage contribution of each particulate matter size to the overall particulate matter number concentration in each processing location. For the control location,
$PM_{0.3}$ contributed the highest percentages ranging from between 71% and 87%. It is followed by $PM_{0.5}$ with contribution of between 8% and 22%. The least contributor is the PM_5 with less than 1% contribution in all the study locations. Figure 6 indicated that G4 is the highest contributor of TSP into the air followed by G3, G2 and then G1. This is consistent with the trend and number of active processing point in each location. G4 has the highest number of frying point. It has about 198 points with an estimated firewood usage of 148.5 tonnes/day. G3 has 50 frying points with an estimated firewood usage of 35.75 tonnes/day, G2 with 47 points with about 35.25 tonnes of firewood used per day and G1with 21 frying points with about 15.75 tonnes of firewood used per day.

3.2 Comparison with Standard

The measured particulate number concentration were compared with the ISO 14644 standards (Table 1) for particles sizes 0.3 µm, 0.5 µm, 1.0 µm, and 5.0 µm. PM_2 does not have a ISO 14644 standard. Averaged measured concentration for particulate size 0.3 µm which is the most harmful of all the sizes measured were above the highest ISO class 6 of maximum concentration limit of 102000 particles/m^3. However, particle sizes 0.5 µm, 1.0 µm, and 5.0 µm measured fall within the ISO class 8 which has the maximum concentration limit of 3520000 particles/m^3, 832000 particles/m^3 , and 29300 particles/m^3 respectively (Tables 2 and 3). For the control location Gc, $PM_{0.3}$ also exceeds the ISO 14644 limit of 102000 particles/m^3. However, $PM_{0.5}$ and PM_1, fall in class 7, and PM 5 falls in class 7 and 8 for night and day time readings respectively.

Table 2: Measured Day time Particulate Matter Number Mean Concentration measured during study

Sampling Location	Mean Concentration (particles/m^3)				
	$PM_{0.3}$	$PM_{0.5}$	$PM_{1.0}$	$PM_{2.0}$	$PM_{5.0}$
G1	4343034	233923	176066	65053	10605
G2	5819408	608306	159190	106951	7268
G3	5921870	609490	118105	91514	8290
G4	7271768	2192791	440351	165325	6620
Gc	1973544	213655	71331	34022	3503

Table 3: Measured Night time Particulate Matter Number Mean Concentration measured during study

Sampling Location	Mean Concentration (particles/m^3)				
	$PM_{0.3}$	$PM_{0.5}$	$PM_{1.0}$	$PM_{2.0}$	$PM_{5.0}$
G1	4355117	1413703	498491	69065	7130
G2	5517710	1052906	150855	76278	7714
G3	6161774	1049619	418660	92725	8823
G4	4355117	1413703	498491	69065	7130
Gc	1936261	212435	52357	21830	1752

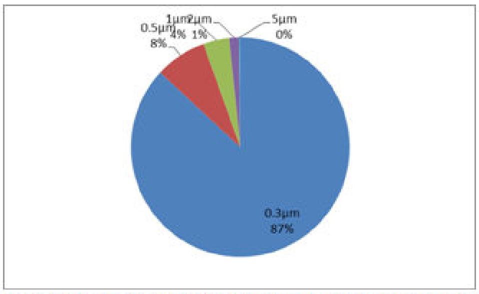

Figure 2: Percentage Contribution of PM sizes at G1

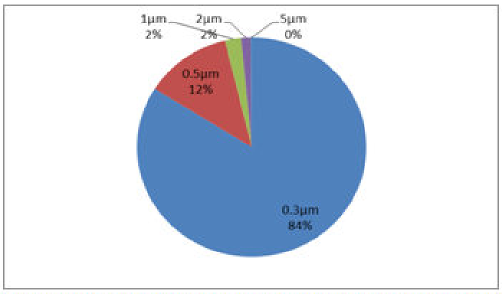

Figure 3: Percentage Contribution of PM sizes at G2

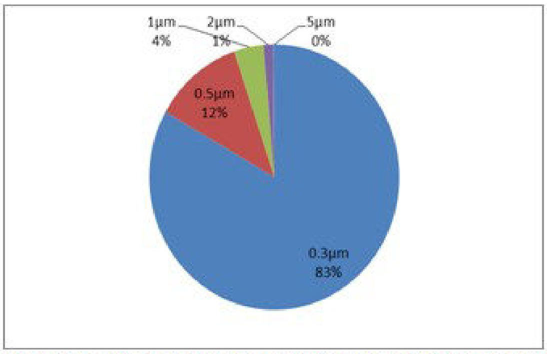

Figure 4: Percentage Contribution of PM sizes at G3

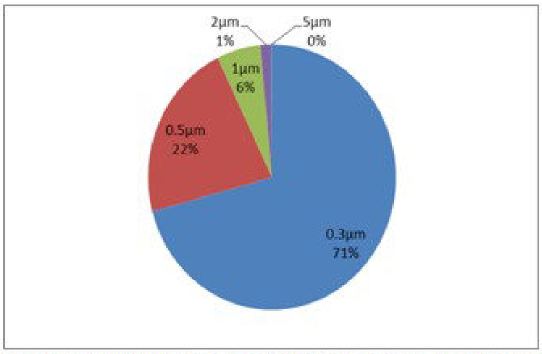

Figure 5: Percentage Contribution of PM sizes at G4

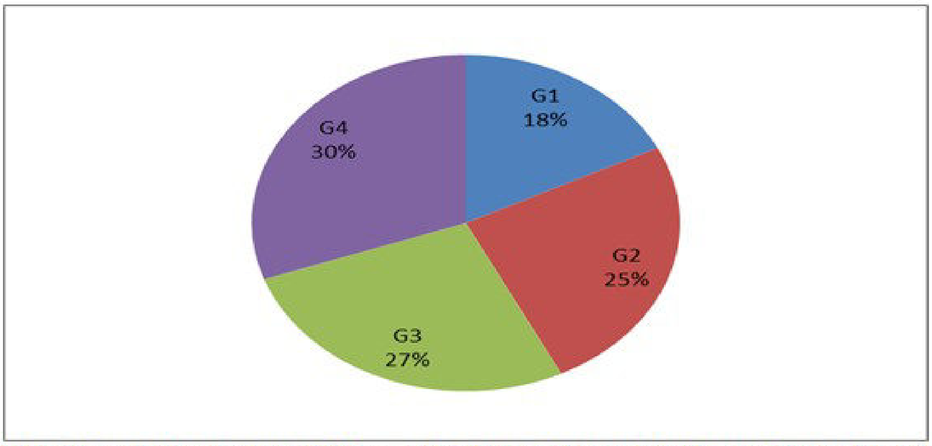

Figure 6: Overall contribution of $PM_{0.3}$ – PM_5 to the ambient air pollution due to the activity

3.3 Daily cycle for particulate matter

The daily cylces for the measured particulate matter number concentration were shown in figures 7 - 14 for the four locations considered in this study. The maximum concentrations were measured on a high activity day (day 4) which is a Monday. Higher concentrations were observed during the day time compared to the night-time measurements. The results signify that the concentration changes are consistent with the trend of activity as it is expected. Fine particulates has the highest concentration because they are lighter in weight and are not easily deposited compared to the higher diameter particulates. This conforms with the assumption of the previous studies (Al - Rajhi *et al*, 1996, Masmoudi *et al.,* 2002; Pryor, 2006; Piazzola *et al*., 2010; Kozawa *et al*., 2012; Fang *et al.*, 2012) that deposition is size dependent. The higher the diameter of the particle, the more the tendency of it being deposited. Premised on this fact, it is assumed that a higher percentage of particles emitted from the activity, most especially the smallest ($PM_{0.3}$) will be retained in the air for a very long period as reflected in the night time concentrations.

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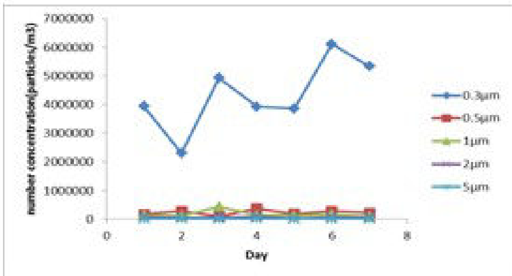

Figure 7: Day Time Number Concentration against Day for G1

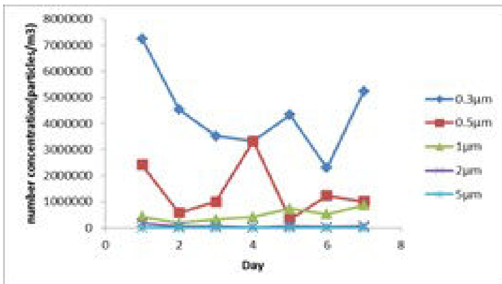

Figure 8: Night Time Number Concentration against Day for G1

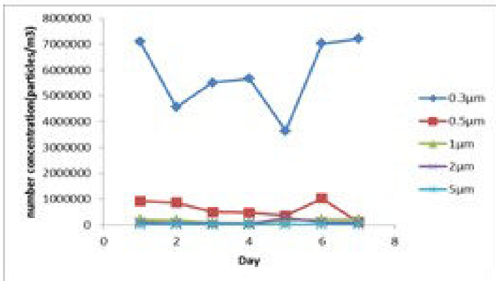

Figure 9: Day Time Number Concentration against Day for G2

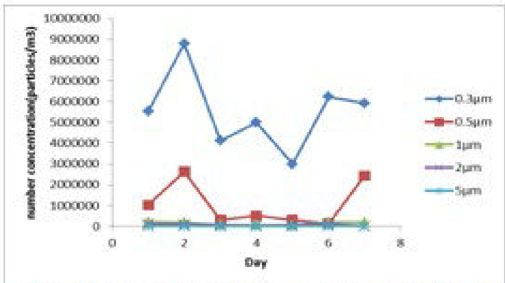

Figure 10: Night Time Number Concentration against Day for G2

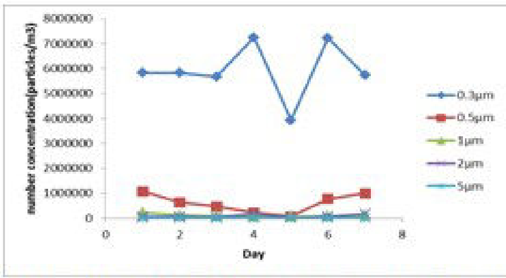

Figure 11: Day Time Number Concentration against Day for G3

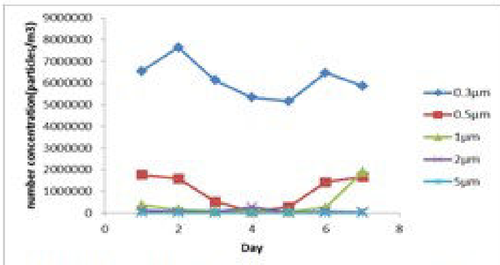

Figure 12: Night Time Number Concentration against Day for G3

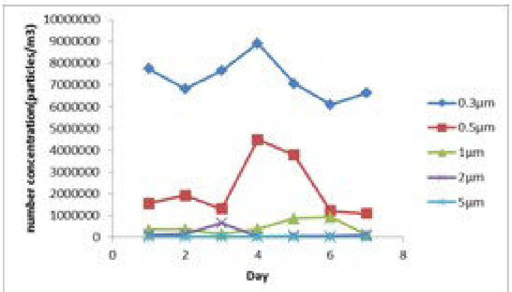

Figure 13: Day Time Number Concentration against Day for G4

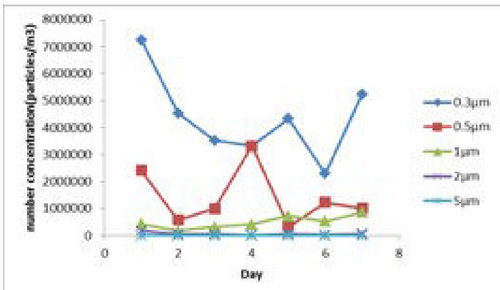

Figure 14: Night Time Number Concentration against Day for G4

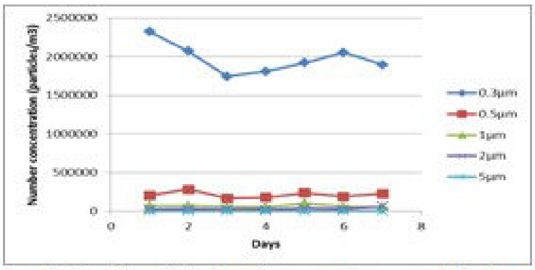

Figure 15: Day Time Number Concentration against Day for Gc

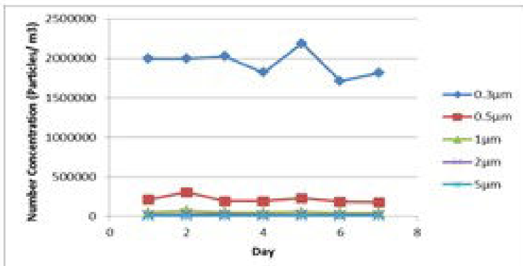

Figure 16: Night Time Number Concentration against Day for Gc

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4.0 Conclusion

Particulate number concentration and their respective size distributions were measured over a period of seven days for five different particulate sizes in four different garri local processing locations. It can be said that data generated or measured at these sites should reasonably represent the ambient air quality in the domains. The finest fraction and the most harmful of the particulates measured (0.3 µm) in the locations have the highest concentrations and exceeded the maximum allowable limit of ISO 14644 standards. This suggests that most of the pollutants emitted from the activity are retained in the ambient air for long hours especially the fine particulate fractions. It is therefore imperative that the policy makers and all the authorities concerned need to find lasting solutions through the provision of kilns and industrial stoves to reduce/eliminate the use of firewood. Efforts should also be geared towards the industrial drying and conversion of cassava peels to animal feeds as against burning them. Future researches should tend to investigate the elemental composition of the particulate matter emitted from the activity and other gaseous pollutants that may arise especially methane.

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