Full Paper

AEROSOL COMPOSITIONS IN SOUTHEASTERN LAGOS, NIGERIA

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ABSTRACT

The continuous generation of aerosol from natural and anthropogenic sources in Southeastern Lagos, Nigeria necessitated characterization of the fine and coarse modes aerosol of the area. Aerosol concentration was measured using gravimetry method with a high volume sampler fitted with a two-fitter holder and adopting a sampling period of 6 hours. Aerosol samplings were carried out in both the wet and dry seasons. The exposed filters were digested, filtered, diluted and subjected to Buck model 205 atomic absorption spectrophotometer analysis for elemental metal compositions determination while the Technicon Auto-analyzer II was used to determine the ionic compositions. The estimated 24-hour concentrations of Particulate Matter less than 10 µm (PM_{10}) ranged between 319.78 and 750.87 µg/m^3 while that of particulate matter less than 2.5 µm ($PM_{2.5}$) ranged between 94.97 and 282.18 µg/m^3 throughout the wet and dry seasons. All the measured concentrations were above the 24-hour mean World Health Organization (WHO) and World Bank standards of 50 µg/m^3 and 80 µg/m^3, respectively. The measured Particulate Matter concentrations and its constituents in dry season were found to be higher compared with wet season. The obtained results will assist policy makers and environmental regulators in developing optimal control strategies of aerosol in the area.

Keyword: *Aerosol, natural source, anthropogenic source, optimal control*

1. INTRODUCTION

Health problems and environmental degradation have been attributed to air-borne particulate matter (EPA, 1996) and whenever suspended in the atmosphere, they play a major role in the reduction of atmospheric visibility. Particulates with less than 10 µm (PM_{10}) and those of diameter less than 2.5 µm ($PM_{2.5}$) are characterized by optimum sizes that scatter light with wavelength in the visible range. This is one of the reasons PM_{10} and $PM_{2.5}$ are acceptable measures for visibility degradation, even though they are more commonly used for assessing health effects (Pope et al. 1995). However, PM_{10}, a specific indicator for anthropogenic fine dust, represent the thoracic fraction of the ambient particles while $PM_{2.5}$ is its alveolar fraction of the ambient particles (ISO, 1995).

Yang et al. (2001) explored emission characterization of particulates and its particles-bound metal elements in the construction sites of Southeastern Taiwan between December, 1996 and May, 1997. The ambient air Total Suspended Particulates (TSP) concentration at the eight construction sites were between 107 and 3,990 µg/m^3 with an average of 625 µg/m^3. (Oluyemi, 1996) investigated elemental compositions of air particulates in Nigeria, collected from Ikeja (an industrial centre), Yaba (a commercial centre) and Ikoyi (a low population density area). The range of TSP obtained in this study were 66 – 379 µg/m^3, 44 – 288 µg/m^3 and 31 – 129 µg/m^3 for Ikeja, Yaba and Ikoyi, respectively. Earlier, Oluyemi et al. (1994) collected air particulate matter between July and October, 1990 at a site located close to an industrial estate in Lagos, Nigeria. The Author analyzed for 18 elements using wavelength dispersive X – ray fluorescence spectroscopy (XRF) and atomic absorption spectroscopy (AAS). Varimax rotated factor analysis results identified the main sources as soil, marine, traffic, regional sulphate and industrial in the coarse fraction while major sources in the fine fraction were identified to be soil, vehicle exhaust and sea salt. Oluwole et al. (1988) measured the mean suspended particulate matter (SPM) concentration for two cement factories at Shagamu and Ewekoro in Nigeria as 3313 µg/m^3 and 4079 µg/m^3 within packing plants, 90 – 174 µg/m^{3}for air – conditioned offices in non – operating area while 186 – 375 µg/m^3 was obtained for non air – conditioned, non – operating area offices. Adejumo et al. (1994) reported TSP concentration range of 139 – 9368 µg/m^3 and 51 – 2266 µg/m^3 for two cement factories in northern part of Nigeria. (Akeredolu, 1986); Asubiojo et al. (1993) and Oluwole et al. (1988) determined elemental concentration of aerosol samples at various locations in Nigeria. The TSP matter was found to be relatively high when compared with data obtained from Europe and America most especially during the harmattan season in Nigeria.

Trace metals in the atmospheric particulate matter are mainly from anthropogenic sources such as residential wood combustion, forest fires, combustion of coal and oil, waste incineration and metal smelting (Chow et al., 1992). In the fine particles size range, trace metals are mainly Pb, Zn, Cd, As, Sb, Ag, In, La and Mo (EPA, 1996) while coarse mode found to consist majorly of Ca, Al, Ti, Mg, Sc, La, Lu, Hf and Tu (Bernstein and Rahn, 1979; Klee, 1984). Aerosol that consists of both fine and coarse modes consists of Na, K, Fe, V, Cr, Co, Ni, Mn, Cu, Sc, Se, Ba, Cl, Ga, Cs, Eu, W and Au (EPA, 1996). (Owoade, 2006) measured PM_{10}, $PM_{2.5}$ and TSP concentrations to quantify elemental concentrations of heavy metals in the ambient air

of a scrap iron and steel smelter in Lagos, Nigeria between April, 2003 and March, 2004. The TSP mean values measured in the area were generally above the WHO guideline of 40 µg/m^3 and Federal Ministry of Environment (FMENV) Nigeria (250 µg/m^3 daily average) (Sonibare, 2009). Xie et al. (1999) reported an 11- year database of PM_{10} aerosols in arctic site in Canada while Mazeera et al. (2001) presented PM_{10} aerosol measurements at McMudo station in Antartica.

Marmur et al. (2007) determined local source compositions of particulate matter and their corresponding contributions from ambient measurement and estimates of sources contribution using global-optimization mechanism. Kim et al. (2003) developed and applied factor analysis technique to characterize and quantify sources contributing ambient particulate matter levels. This is because a profile derived from any one source at any time may not be representative due to variability in time and space. Jimenex et al. (2006) characterized air quality in Pullman, eastern Washington to examine community exposure to agricultural burning smoke and related short term health effects in the area. The Chemical Mass Balance (CMB) results in the area showed major contributions of $PM_{2.5}$ from soil (38%), vegetative burning (35%) and sulphate aerosol (20%) while much less contributions are from vehicles (2%) and cooking (1%). Cheng et al. (2004) collected $PM_{2.5}$ and $PM_{2.5-10}$ samples between August, 1998 and March, 1999 at Taichung, an urban and coaster area of Taiwan. He applied principal component analysis with varimax rotation and a chemical mass balance model to qualify and quantify respectively the source contributions to PM_{10}. It was found that the source of the PM_{10} in the area was mostly from vehicle emission followed by crustal materials, secondary aerosols, biomass burning, industrial emissions and marine spray. Hennigan et al. (2008) measured atmospheric gases and fine particles chemistry in the Mexico City Metropolitan Area (MCMA) at a site about 30km downwind of the city centre. The results provided an estimate of secondary organic aerosol evaporation losses and suggested that a significant fraction of about 35% of the fresh MCMA secondary organic aerosol (SOA) measured at the surface volatilized.

This work characterized the aerosol of Southeastern Lagos that has similar environmental features like Sydney brown haze of Australia, aerosol in South Paolo in South America and aerosol in Beijing and other cities in China. The result of the work will assist Lagos State Government and environmental policy makers in developing optimal control of aerosol in the area.

2. MATERIALS AND METHODS

2.1. Sampling Site/Study Area.

Lagos is known as the nation's economic, commercial and industry city and it accounts for 50% of manufacturing industries present in Nigeria (Abegunde, 1986; Oluwafemi, 2007). Southeastern Lagos is characterized by towns and villages comprising of Yaba, Ebute-metta, Iddo-Otto, Akoka, Maroko, Ijero, Oko-baba, Abule-Ijesha and Olaleye. The site of interest is located at the center of Okobaba which is characterized by about 327 sawmills and 34 burning points of sawdust between Ebute-metta and Oyingbo on the edge of the Lagoon (Plate 1).This study area is quite visible on the Third Mainland Bridge, a major link between the mainland and the island parts of the city which is surrounded by various species of freshwater and water fishes around the state's island and Atlantic coaster water (Abegunde, 1986).

2.2. Sampling and Measurements

Sampling and analysis of fine($dp < 2.5\ \mu m$) and coarse ($2.5\ \mu m < dp < 10\ \mu m$) particulate matter in Southeastern Lagos was carried out. A sampling inlet that comprises a two-filter holder for collection of particles less than 2.5 µm and between 2.5 and 10 µm, designed and tested by Hopke et al. (1997) was used. The coarse particles were collected on 8.0 µm pore size filter while fine particles ($dp < 2.5\ \mu m$) were collected on 0.4 µm pore size filter. A high volume sampler was used for the sampling. The gravimetric air sampling was conducted at two different monitoring stations at Oko-Baba area. There is Oko-Baba underbrigde which comprises 67 sawmills with one burning point of sawdust and Oko-Baba inside which is made up of 260 sawmills with 33 open burning points of sawdust. A sampling period of 6 hours was adopted. Two samplings per sampling location were conducted for 6 hours in each quarter of a year. A total number of 8 sampling locations were used. The aerosol particles were collected on pre-weighed filters and the final weights were determined after sampling. The mass difference divided by the volume of air sampled was used in estimating $PM_{2.5}$ and PM_{10} concentration. The mass and concentration of $PM_{2.5}$ and PM_{10} were estimated as:

$$PM_{10}(\mu g) = PM_{2.5}(\mu g) + 2.5\,\mu m < dp < 10\,\mu m(\mu g) \quad (1)$$

$$PM_{10}\left(\frac{\mu g}{m^3}\right) = PM_{2.5}\left(\frac{\mu g}{m^3}\right) + 2.5\ \mu m < dp < 10\ \mu m(\mu g/m^3) \quad (2)$$

A semi-microbalance with a minimum resolution of 0.01 µg was used to weigh the filter papers. The balance and the sampled filter papers were equilibrated for 24 hrs at a constant temperature which corresponds to room temperature at zero ventilation, before they are weighed. The filters were digested in HCl/HNO_3 solution, filtered and then diluted to 25 ml with distilled/deionized water Lee et al. (2003). The sampled solution was subjected to chemical composition analysis using wet chemical analysis method. Atomic Absorption Spectrometer (AAS) was used to determine the elemental metal compositions, while a Technicon Automated Analyzer II was used to determine the ionic species of the aerosol. The metallic and ionic compositions in the area were used to predict the characteristics of emission pollution in the study area.

2.2.1. *Analysis of metals and ionic species*

A total of 8 pairs of filter papers sampled were digested per each quarter of a year with each pair consists of 1 fine ($dp < 2.5\ \mu m$) and 1 coarse ($2.5\ \mu m < dp < 10\ \mu m$). Four pairs represent Oko-Baba inside (weekday and weekend samplings) while the remaining 4 pairs represent Oko-Baba under-bridge (weekday and weekend samplings). Buck Model 205 Atomic Absorption Spectrometer was used to measure the concentration of the elemental metals (Na, K, Ca, Mg, Ti, V, Cr, Fe, Mn, Ni, Cu, Zn, Pb, Se, Sr, Sn, Sb, Co, Br, Rb, As, La and Sc.) in solution, while Technicon Auto Analyzer II was used in measuring the ionic species which include some of the secondary pollutants (NH_4^+, SO_4^{2-}, NO_3^-, Cl^-, PO_4^{3-}) in solution.

The Buck Model 205 Atomic Absorption Spectrometer is a 2004 model that is versatile in determining almost all elemental metals while Technicon Auto Analyzer II has displaced the ion chromatographic method since Technicon Auto Analyzer II can even measure solution that is low in organic materials and soluble salts.

Buck model 205 atomic absorption spectrophotometer is designed to measure the concentration of elemental metals in solutions. It provides integrated measurement in absorbance or emission intensity as well as sample concentration in comparison to standard solution.

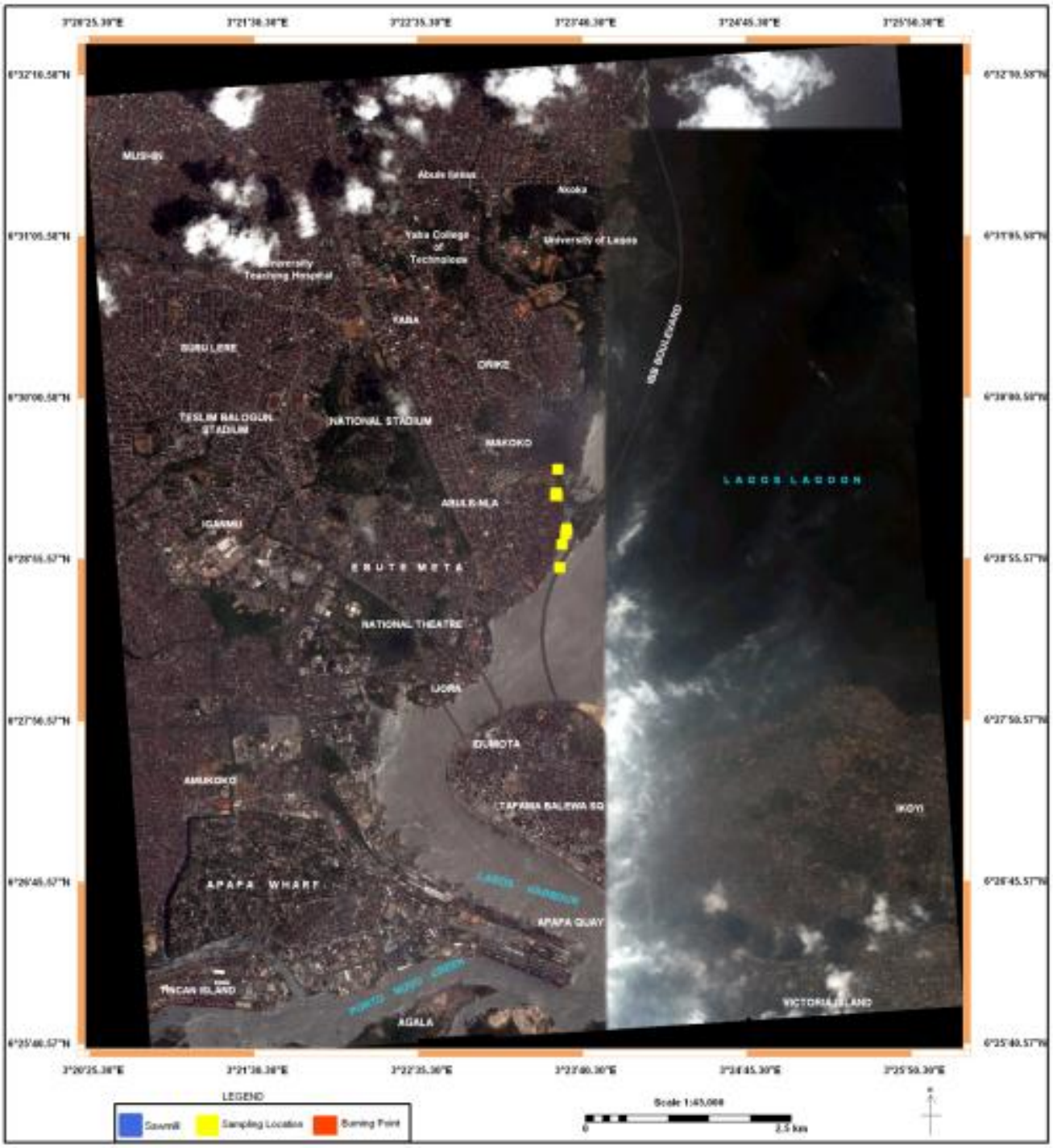

Plate 1: Study Area

The readings were integrated over a period of 0.5-10 s. Optional accessories allowed the user to print absorbance data and concentration in real time. The absorbance data were then collected using a laboratory recorder. Technicon auto analyzer II used to measure the ionic species in the solution is characterized by a tray containing 40 sample cups from which the sample is introduced into the auto analyzer in a pre-set sequence at a selected rate of speed (normally around 60 samples per hour). As the loaded sample tray rotates, a probe dips into each cup and aspirated a sample. The probe lifts out, introduces a small air segment and returns to the wash solution. The rate and ratio of sample/wash is controlled by a cam at the top of the sampler and can be changed. The recorder which is a single pen recorder moves at a speed fixed by a gear. The recorder can be checked by turning the switch on the colorimeter to zero on the chart. The organic and elemental carbon was analyzed using Thermal/Optical Carbon Analyzer as done by Lee et al. (2004).

3. RESULTS AND DISCUSSION

The results of the chemical analysis of the samples conducted in wet season (July, 2008; May, 2009) and dry season (October, 2008; February, 2009) are presented and discussed below.

3.1. Overall Concentration and Mass Distribution

The aerosol less than 10 µm (PM10) were measured to be in the range 395.07 – 927.93 µg/m3 for July, 2008 (wet season), 412.18 – 949.56 µg/m3 for May, 2009 (wet season), 417.26 – 994.93 µg/m3 for October, 2008 (dry season) and 653.38 – 985.50 µg/m3 for February, 2009 (dry season). In the wet season (July, 2008) at Oko-Baba inside, the average weekday particulate matter mass concentration was 885.65 µg/m3 while that of weekend was estimated to be 754.86 µg/m3. Also, in the wet season (May, 2009), the average weekday particulate matter mass concentration at Oko-Baba inside was 905.65 µg/m3, while that of weekend was measured to be 640 µg/m3. At Oko-Baba underbrigde where the burning points are lower when compared with that of Oko-Baba inside, the average weekday particulate mass concentrations were measured to be 700.62 and 727.69 µg/m3 in July, 2008 and May 2009, respectively while the weekend values were measured to be 404.79 and 420.37 µg/m3. Similarly, in October, 2008 (a dry season), at Oko-Baba inside, the average weekday and weekend particulate mass concentrations were measured to be 946.06 and 801.20µg/m3, respectively while that of Oko-Baba underbridge were measured to be 782.98 and 454.20 µg/m3 respectively. In another dry season (February, 2009), the average weekday and weekend particulate matter mass concentrations at Oko-Baba inside were measured to be 952.96 and 826.03 µg/m3, respectively. The corresponding values at Oko-Baba underbridge were 812.63 µg/m^3 for the weekday and 664.84 µg/m^3 for the weekend. In the result as shown in Table 1, the average estimated 24-hour PM_{10} concentration in wet season (July, 2008; May, 2009) and dry season (October, 2008; February, 2009) for the weekdays and weekends and that of control sample as shown in Table 2 are all above the WHO and World Bank Standards of 50 and 80 µg/m3, respectively.

The lower values at Oko-Baba underbridge at the two seasons were due to lower burning points in the area and as a result of fewer number of houses around the area which therefore reduces the emission from domestic heating in the area. However, in the two sampling sites, the average particulate matter concentrations are higher in dry season (October, 2008 and February, 2009) than wet season (July, 2008 and May, 2009) for both weekday and weekend since precipitation which occurs mostly in wet season is a major cleaning process for atmospheric aerosol. Also, rainfall increases soil moisture and hence reduces fugitive dust source emission. The higher values in weekday compared with weekend days may be attributed to higher traffic flow and hence higher re-suspension of large particles (road dust) from major traffic roads in the area.

3.2. Characterization of PM_{10} Metallic Elements

The average concentration of PM_{10} metallic ionic species measured in Oko-Baba inside and Oko-Baba underbridge of Southeastern Lagos was as summarized in Figs 1 – 4. Throughout the wet and dry seasons study, Ca, Na, Cu, La varied between 99.62 and 11.38 µg/m^3. The metallic concentrations of Mu, Fe, Cr, Co, Ni, Se, Vn, Ti, Sr, Sn, Pb and As are of the range 10.11 and 3.92 µg/m^3.

The higher values in wet season for most heavy metals may be as a result of higher atmospheric emissions from domestic cooking activities around the area. At the two sampling sites, the concentrations of metals and ions were higher in the weekdays than during the weekends. This was as a result of higher traffic flows, and other domestic cooking activities that are higher in the weekdays. NO_3^- and NH_4^+ concentrations were found to be higher in the wet season (July, 2008; May, 2009) when compared with the dry season (October, 2008; February, 2009) since NH_4NO_3 formation is enhanced at colder temperature and higher relative humidity.

Table 1: Average PM_{10} Concentration of Oko-Baba Area of Southeastern Lagos

Specific Place	Season	Weekday(µg/m^3)	Weekend (µg/m^3)
Oko-Baba Inside	Wet (July, 2008)	885.65(699.66)	754.86(602.14)
	Dry (October, 2008)	946.06 (747.63)	801.20 (632.95)
	Dry (February, 2009)	952.96 (750.87)	826.03 (640.37)
	Wet (May, 2009)	905.65 (704.32)	640.00 (498.26)
Oko-Baba Underbrigde	Wet (July, 2008)	700.62 (553.49)	404.79(319.78)
	Dry (October, 2008)	782.98 (618.55)	454.20 (358.82)
	Dry (February, 2009)	812.63 (631.17)	664.84 (513.32)
	Wet (May, 2009)	727.69 (569.13)	420.37 (323.93)

The bracket value is the estimated average 24-hour PM_{10} Concentrations.

Table 2: PM_{10} Concentration of the Control Sample

Season	PM_{10} concentration (µg/m^3)	24-hour PM_{10} Concentration (µg/m^3)
Wet (July, 2008)	135.58	107.11
Dry (October, 2008)	146.31	115.59
Dry (February, 2009)	148.51	117.34
Wet (May, 2009)	142.33	111.16

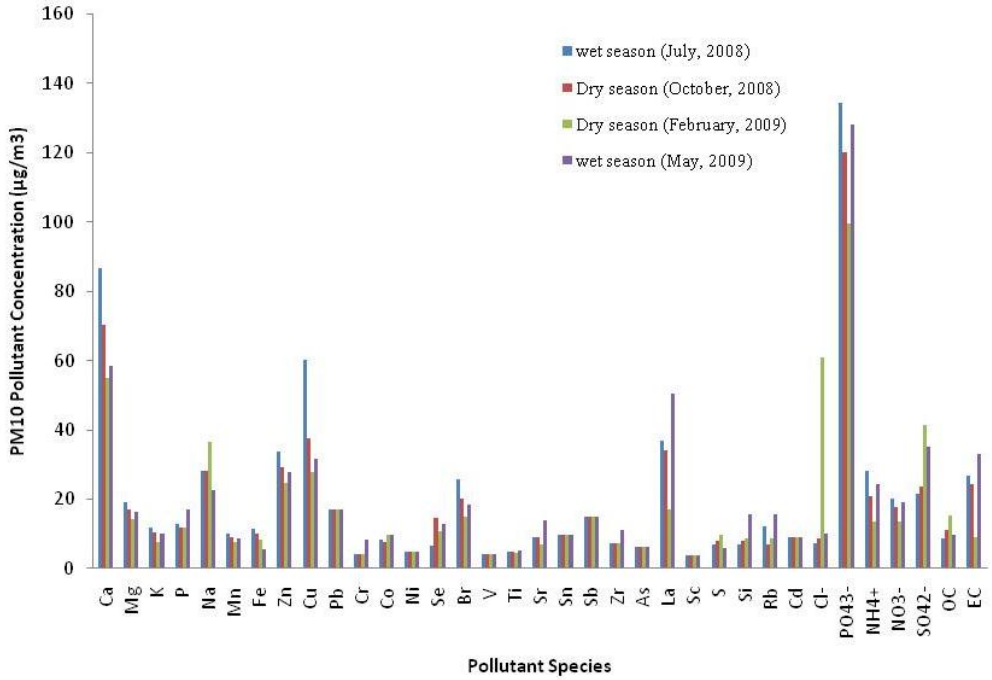

Fig. 1: Elemental/Ionic Concentrations from PM_{10} in Okobaba Inside (Weekend)

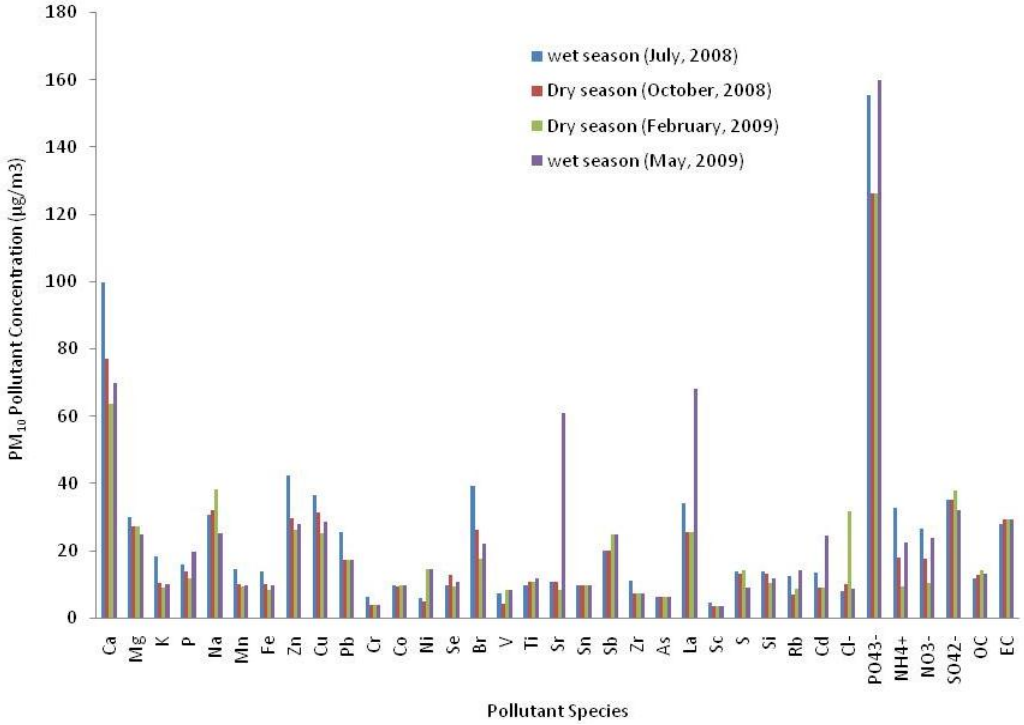

Fig. 2: Elemental/Ionic Concentrations from PM_{10} in Okobaba Inside (Weekday)

SO_4^{2-} concentrations were higher in the dry season than the wet season since the ambient temperature is relatively higher in the dry season. The increase of SO_4^{2-} with ambient temperature is as a result of the effect of solar radiation on the transformation of SO_2 to SO_4^{2-}. The oxidation rate of SO_2 is high when strong solar radiation occurs which is usually related to high ambient temperature. K^+ and Ca^{2+} were found to be higher in the wet season when compared with dry season. The increase of K^+ and Ca^{2+} with rainfall and wind speed can be related to higher wind speed which favours fugitive dust emission source which are made up of K^+ and Ca^{2+}. Cl^-, Na^+ and Mg^{2+} were observed to be higher in dry season when the rainfall was lower, temperature was higher, and the wind speed was higher.

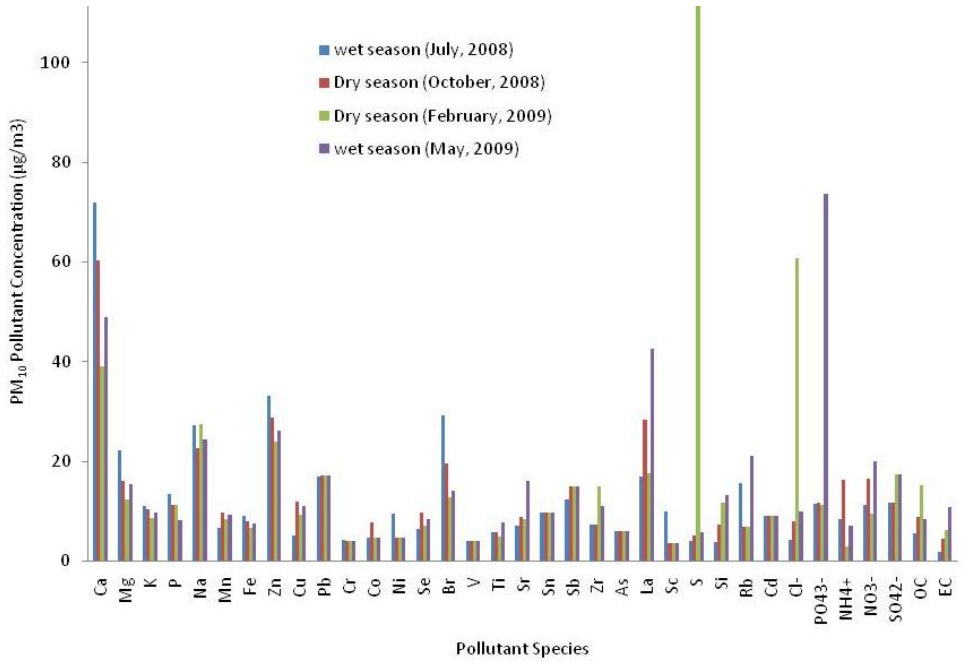

Fig. 3: Elemental/Ionic Concentrations from PM_{10} in Okobaba Underbridge (Weekend)

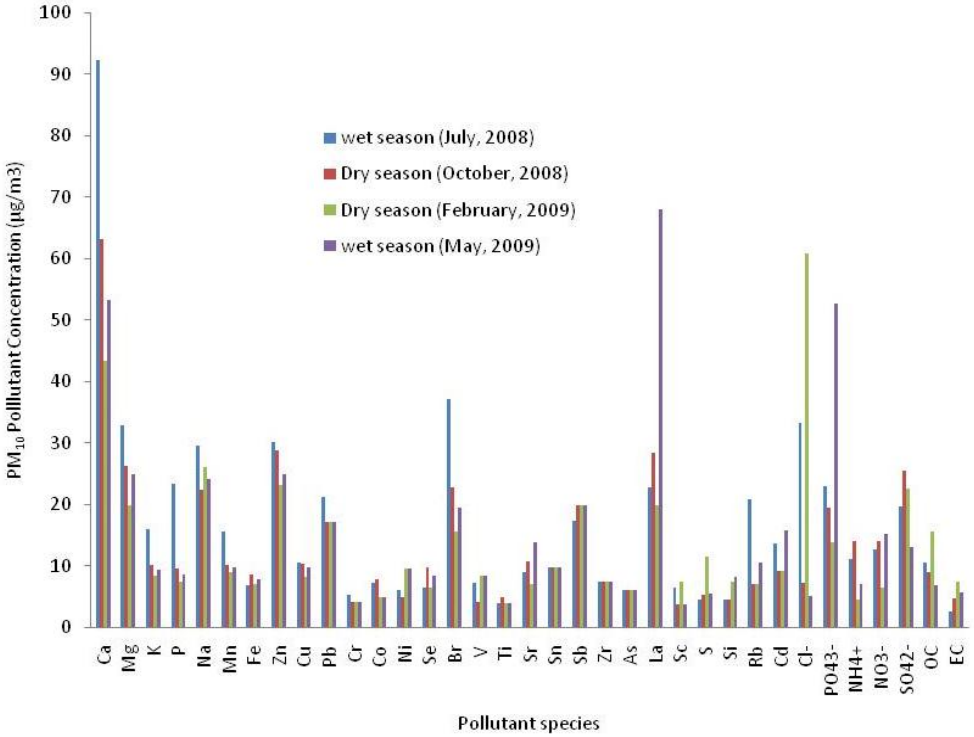

Fig. 4: Elemental/Ionic Concentrations from PM_{10} in Okobaba Underbridge (Weekday)

Higher wind speed causes an increase in marine source emission by blowing sea water into the ambient atmosphere. Ni^{2+}, a tracer of fuel oil burning emission was observed to be higher in weekdays for both Oko-Baba inside and Oko-Baba under-bridge as a result of higher traffic flows at the two sites in the weekdays.

3.3. Concentrations of Carbonaceous Species

The organic carbon (OC) and elemental carbon (EC) were measured to be between 1.95 and 27.92 µg/m^3 throughout the study. In the wet season (July, 2008), organic carbon (OC) in the fine particles was found to be higher in the weekday than at the weekend at Oko-Baba inside (6.62 µg/m^3 in weekend and 8.82 µg/m^3 in the weekday). The trend was the same in Oko-Baba underbridge (4.31 µg/m^3 in the weekend increasing to 7.35 µg/m^3 in weekday). In the coarse mode, OC concentrations follow the same increasing trend. The concentration of the OC in the coarse mode at Oko-Baba inside increased from 1.96 µg/m^3 in the weekend to 2.94 µg/m^3 in the weekday. At Oko-Baba underbridge, the OC concentration of 1.23 µg/m^3 in the weekend increased to 3.19 µg/m^3 in the weekday. The

EC concentration at Oko-Baba inside increased from 24.98 μg/m^3 in the weekend to 26.21 μg/m^3 in the weekday in the fine mode. However, there was a slight decrease in the EC concentration from 1.78 μg/m^3 in the weekend to 1.71 μg/m^3 in the weekday at Oko-Baba inside in the fine particles. At Oko-Baba underbridge, the OC concentration of 4.31 μg/m^3 in the weekend increased to 7.35 μg/m^3 in the weekday in the fine mode while the OC concentration in the coarse mode increased from 1.23 μg/m^3 in the weekend to 3.19 μg/m^3 in the weekday. Also, the EC concentration during the weekend of 1.23 μg/m^3 in the fine mode increased to 1.47 μg/m^3 in the weekday while that of the coarse mode increased from 0.72 μg/m^3 in the weekend to 0.98 μg/m^3 in the weekday.

Similarly, in the dry season (October, 2008), the OC concentration at the weekend of 8.33 μg/m^3 in the fine mode increased to 9.56 μg/m^3 in the weekday at Oko-Baba inside while that of the coarse mode increased from 2.94 to 3.19 μg/m^3. The EC concentration at the weekend of 21.32 μg/m^3 in the fine mode increased to 26.46 μg/m^3 in the weekday at Oko-Baba inside. However, the EC concentration of coarse mode in the same area in the weekend decreased from 2.94 to 2.70 μg/m^3. At Oko-Baba underbridge, the OC concentration at the weekend of 6.13 μg/m^3 in the fine mode increased to 6.25μg/m^3 in the weekday; while that of the coarse mode increased from 2.7 to 2.73 μg/m^3. The EC concentration of 3.43 μg/m^3 remained the same at Oko-Baba underbridge in the fine mode for both the weekend and the weekday while that of the coarse mode increased from 0.98 to 1.23 μg/m^3.

In another dry season (February, 2009), the OC concentration at the weekend of 9.07 μg/m^3 in the fine mode decreased slightly to 8.33 μg/m^3 in the weekday at Oko-Baba inside; while that of the coarse mode followed the same trend by decreasing from 6.33 to 5.90μg/m^3. Also, the EC concentration at the weekend of 4.80 μg/m^3 in the fine mode increased to 23.15 μg/m^3 at the weekday at Oko-Baba inside; while that of the coarse mode decreased slightly from 6.39 μg/m^3 at the weekend to 6.02 μg/m^3 in the weekday. At Oko-Baba underbridge, the OC concentration at the weekend of 8.15 μg/m^3 in the fine mode decreased to 6.39 μg/m^3 in the weekday; while that of the coarse mode increased from 7.10 to 7.13 μg/m^3. The EC concentration increased from 4.27 to 5.57 μg/m^3 in the weekday at Oko-Baba underbrigde in the fine mode while that of the coarse mode increased from 1.94 to 5.16 μg/m^3.

In another wet season (May, 2009) the OC concentration at the weekend of 5.90 μg/m^3 in the fine mode increased to 7.13 μg/m^3 in the weekday at Oko-Baba inside; while that of the coarse mode followed the same trend by decreasing from 3.95 to 5.90 μg/m^3. The weekend EC concentration of 16.13 μg/m^3 in the fine mode decreases slightly to 15.15 μg/m^3 in the weekday at Oko-Baba inside while that of the coarse mode decreased from 17.09 μg/m^3 in the weekend to 14.15 μg/m^3 in the weekday. At Oko-Baba underbrigde, the weekend OC concentration of 4.34 μg/m^3 in the fine mode decreased to 3.28 μg/m^3 in the weekday. The EC concentration decreased from 16.19 μg/m^3 in the weekend to 3.02 μg/m^3 in the weekday at Oko-Baba underbridge in the fine mode; while that of the coarse mode also decreased from 4.66 μg/m^3 to 2.55 μg/m^3.

Elemental and organic compounds (EC and OC) which are part of the tracers of fine particle burden in the atmosphere of urban and heavily industrialized locations were observed in Oko-Baba area of Southeastern Lagos to be composed of majorly $PM_{2.5}$. Hence the $PM_{2.5}$ to PM_{10} ratio throughout the area was measured to be: 0.60 – 0.94 (wet season; July, 2008), 0.69 – 0.91 (dry season; October 2008), 0.41 – 0.79 (dry season; February, 2009), 0.48 – 0.60 (wet season; May, 2009). This implies that 41 – 94 % of the particulate matter (PM_{10} values) of OC and EC are made up of $PM_{2.5\ in}$ Oko-Baba area of Southeastern Lagos. This is in agreement with past studies which showed that OC and EC are mainly in the fine particle size range Ho et al. (2003); Chow et al. (1996); Tunpin et al. (1990) and Hilderman et al. (1991).

At Oko-Baba inside, the ratio OC/EC which is often used to identify the presence of secondary organic aerosols in both wet and dry seasons was estimated to be ‹ 2, which implies that organic carbons measured in the area are formed from direct emissions of particles as pollutants. At Oko-Baba underbridge, the ratios of OC/EC were generally between 2 and 4, an indication of the presence of secondary organic compounds in the area (Ho et al. (2003); Chow et al. (1996).

3.4. $PM_{2.5}$ to PM_{10} ratio

The results showed that average mass concentration ratio of $PM_{2.5}$ / PM_{10} was 0.05-0.72 for the metallic species in the aerosol of Oko-Baba inside, and 0.13-0.80 for the ionic species. The $PM_{2.5}$ / PM_{10} for OC and EC were 0.41 - 0.78 and 0.49 - 0.93 respectively. Also, the average mass concentration ratio of $PM_{2.5}$ / PM_{10} for Oko-Baba underbridge for the metallic species in the aerosol were 0.06 - 0.58 and 0.09-0.80 for the ionic species while those of OC and EC were 0.41 - 0.78 and 0.52 - 0.78, respectively.

The average mass concentration ratios of $PM_{2.5}$ / PM_{10} at Oko-Baba area of Southeastern Lagos showed that its aerosol has their metallic concentration almost equally in the fine and coarse modes. This observation is the same in almost all the elemental and ionic species except in EC and OC where 41-94 % of the PM_{10} are in the $PM_{2.5}$ mode. The results also showed that most heavy metals have their $PM_{2.5}$ / PM_{10} ratio in the range 0.05 - 0.72. The results also indicated that majority of the metals were in the coarse mode except in some metals like Pb, Cr, Ni, V, Sn, Zr, As and Sc, Rs where metals in the fine and coarse modes are the same. SO_4^{2-}, NO_3^- and NH_4^+concentrations showed that about 13 – 80 % of the Particulate Matter were in the fine modes while the rest are in the coarse mode. This result is in agreement with most studies as reported by Ho et al. (2003) and Chow et al. (1996).

4. CONCLUSION

The estimated 24-hour PM_{10} concentration in wet season (July, 2008; May, 2009) and dry season (October, 2008; February, 2009) for Okobaba inside and Okobaba underbridge in the weekday and weekend are all above the WHO and World bank Standards of 50 μg/m^3 and 80 μg/m^3 respectively. However, the 6-hour PM_{10} concentrations measured and the estimated 24-hour PM_{10} concentrations in the dry season are relatively higher than the wet season.

The lower $PM_{2.5}$ and PM_{10} concentrations at Okobaba inside and Okobaba underbridge in wet season was due to higher precipitation which often clean aerosol in the wet season. Also, higher rainfall in the wet season increases soil moisture and hence reduces fugitive dust emission. Higher values of $PM_{2.5}$ and PM_{10} concentrations in weekdays compared with weekend days was due to higher traffic flows and higher re-suspension of particles from major traffic roads at Okobaba areas.

The higher concentrations of the heavy metals in wet season at Okobaba inside and underbridge was due to higher household cooking emission in wet season while higher concentrations of Cl^-, Na^+ and Mg in the dry season are as a result of lower rainfall, higher temperature and higher wind speed which favour marine source emission. Higher Ni and other heavy metals in weekdays are as a result of higher traffic flow. Higher SO_4^{2-} in dry season is as a result of higher ambient temperature and higher solar radiation which are attributes of dry season while higher NO_3^- and NH_4^+ in wet season can be due to colder temperature that favours NH_4NO_3 formation.

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