CORRELATION BETWEEN PARTICULATE MATTER CONCENTRATIONS AND METEOROLOGICAL PARAMETERS AT A SITE IN ILE-IFE, NIGERIA.

***Owoade, O.K.; Olise, F.S.; Ogundele, L.T.; Fawole, O.G. and Olaniyi, H.B.**
Department of Physics, Obafemi Awolowo University, Ile-Ife, 22005, Nigeria
*Corresponding Author
Email Address: oowoade@oauife.edu.ng

ABSTRACT

Measurement of atmospheric particulate matter was carried out with a view to establish the potential influence of meteorological parameters such as wind speed, wind direction, air temperature, rainfall, relative humidity and global radiation on the mass concentration. Particulate matter (PM) in two size fractions (≤2.5 μm and 2.5-10 μm) were collected on nuclepore polycarbonate at the top of Physics building, Faculty of Science, Obafemi Awolowo University, Ile-Ife thrice a week between November 2009 and August 2010. A total of 162 samples were collected (81 for each PM fraction). Pearson correlation analysis was performed on mass concentration and daily average meteorological data obtained from Nigeria Micrometeorological Experiment (NIMEX), Obafemi Awolowo University, Ile-Ife. The results showed the temporal daily variation of PM with mean mass concentrations of 25.37 and 37.15 $\mu g/m^3$ for $PM_{2.5}$ and $PM_{2.5-10}$ respectively. Seasonal variation was observed which was characterized with high concentrations in dry season and low in rainy season. Air temperature did not significantly influence the $PM_{2.5}$ and $PM_{2.5-10}$ concentration, although weak correlation (r = 0.10 and 0.23) was obtained. $PM_{2.5}$ and $PM_{2.5-10}$ exhibited significant correlation (r = 0.12 and 0.25 respectively) with global radiation while negative correlations were observed for rainfall and relative humidity (r = -0.18 and -0.12; -0.22 and -0.15). $PM_{2.5}$ was negatively correlated (r = -0.05 and -0.41) while $PM_{2.5-10}$ was positively correlated (r = 0.36 and 0.20) with wind speed and direction respectively. An investigation into the clearness of the sky was carried using the Linke Turbidity factor, T_L. The values obtained for T_L ranged between 7.06 and 17.3 which is a clear indicator of a very turbid atmosphere, signifying an unclear and wet sky. INAA assay of the PM loadings detected fourteen elements (As, Br, Cu, K, La, Na, Sb, Sr, Zn, Ce, Co, Cr, Sc and Th) with Br, K, Na, Sr and Zn being dominant elements. The PM loadings are due to both local anthropogenic and long-range sources.

Keywords: REE, PM, Linke Turbidity Factor, Meteorological Variables, Correlation.

INTRODUCTION

The earth's atmosphere has served man as a means of sustaining air to breathe and as a medium for disposing waste from various activities. Pollutants such as dust, fumes, gas, mist, odour, smoke, or vapour occur in varying quantities, characteristics and residence time and have the potential to alter the state of the atmosphere (Flagan and Seinfeld, 1988). The actual composition of the atmosphere varies with geographical location, elevation and season of the year (Muhammad, 2007). Atmospheric accumulation of pollutants may also have significant impact on the climate and weather processes and modification. One of the most frequently encountered pollutants is particulate matter which consist of suspended mixture of solids and liquid droplets materials. Particulate Matter (PM) are introduced into the atmosphere from a variety of anthropogenic and natural sources (Miranda and Tomaz, 2008). The primary sources of the particulate matter are dust storms, fugitive dust from tilling, roadways and construction, windblown soils, forest fires, bush and wood burning and traffic exhaust while secondary sources involve chemical transformation of the primary pollutants through complex photochemical reactions and gas-to-particle conversion of precursors such as SO_2, NO_2 and Volatile Organic Compounds (VOCs) under favourable meteorological conditions (Fraser *et al.,* 1999). Incineration of domestic waste constitutes further sources to atmospheric particulate matter. In urban area, the principal sources of air pollution are from activities which involve generation of fuel and its utilisation to achieve services necessary for promoting good and enviable standard of living. The concentration of particulate matter varies and it is majorly influenced by weather pattern, wind speed and direction, relative humidity, precipitation and topography (Ghim, *et al.*, 2001). Study of large scale potential influence of meteorological conditions on atmospheric particulate matter requires the knowledge of physiochemical composition, sizes, distribution in time, space and atmospheric residence time of the particulates (IPCC, 2001). Meteorological conditions also determine the behaviour and fate of atmospheric particulates after been released from the source. Physical sizes depend on the

aerodynamics dimension of the particulates. Limited information is available on the interrelation of particulate matter and meteorological factors in Ile-Ife, the study area, as most available publications on particulate matter focus majorly on elemental composition. Hence, this study will provide a baseline information in the understanding of the interaction between particles whose diameter is less than 10 μm which includes, fine ($PM_{2.5}$) and coarse ($PM_{2.5-10}$) and meteorological conditions in the western region of Nigeria. Estimating the turbidity of a particular atmosphere gives a clear picture of the clearness of the atmosphere and by implication the range of visibility. Turbidity is the measure of atmospheric aerosol loadings which plays a very important part in climate modelling and climate change. Aerosols and water vapour are two main parameters that affect the transmission of solar radiation through the atmosphere (Chaabane et al., 2004).

EXPERIMENTAL

Sampling Location and Prevailing Meteorological Conditions.

The sampling location was the roof top of the Physics building at the Obafemi Awolowo University Campus, Ile-Ife, Nigeria. The choice of this location was considered most appropriate because of the open space and proximity to a meteorological base station. The sampling platform was 15 m above the ground and approximately 294 m above the sea level. It was carefully chosen to be away from the surrounding buildings so that free circulation of air was not hindered. It is located within the tropical rainforest zone on latitude 7.52 °N and longitude 4.52 °E.

There are two broad seasonal patterns, namely the dry season (November-April) and rainy season (May-October) experienced in the study area. The dry season features brief spells known locally the harmattan period when cold and dust laden North-east trade winds from the Sahara desert keep the atmosphere heavily loaded with dust for many days. The other periods is usually dry with high solar radiation and clear sky conditions, moderate air temperature and no precipitation. Between April and mid-October, the near surface flow is dominated by the South-Westerly winds originating from the Atlantic. The weather is mainly characterized by moderate to heavy rainfall and highly humid conditions. The presence of convective clouds is mainly responsible for the marked reduction of intensity of solar radiation during the rainy season (Ogunjobi *et al.,* 2002).

Figure 1 shows the googlemap of Obafemi Awolowo University campus with sampling location. There is no major industrial activity around the campus but the presence of particulate matter is due to anthropogenic activities such as vehicular emission, bush and waste burning and re-suspended soil dust. A highway passes about 2 km from the sampling location. A major source of PM at the location is the trajectory of dust plume from the Sahara desert area during the dry season.

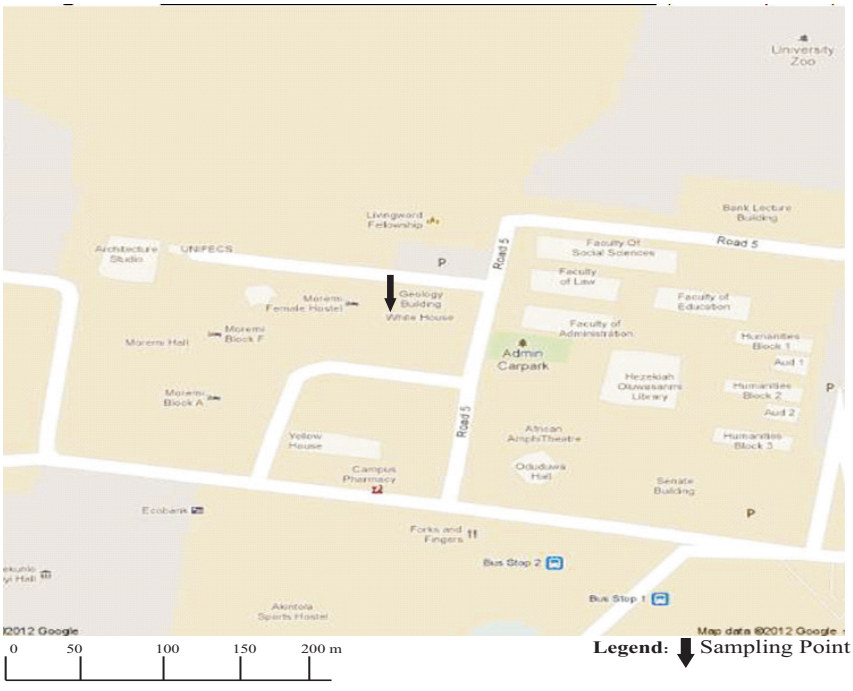

Figure 1: Google map of the Obafemi Awolowo University Campus, Ile-Ife, Nigeria showing the sampling point.

Sampling Procedure

The particulate matter samples were collected using Gent sampler (Meanhaut *et al.*, 1994; Hopke *et al.,* 1997). The sampler is equipped with stacked filter unit (SFU) carrying two 47 mm filters. Nucleopore polycarbonate filters of 8.0 and 0.4 ìm pore sizes were used as collecting media. Air was sampled at an average flow rate of 16 L/min with collection of particulate matter in the sizes segregation of coarse in the first stage and fine in the second stage (Parr *et al.*, 1996). The filter holder was placed at the height of about 1.6m on the roof top of the Physics building facing downward to avoid direct particle deposition on the filters.

A total of 162 samples were collected (81 for each particle fraction). 24 hours sampling was carried out thrice a week from November 2009 and August 2010. Before and after each sampling, the filters were weighed using an electronic micro-weighing balance of 1 μg sensitivity and then conditioned in a dessicator for at least 24 hours for weight stability. The mass concentration C, of particulate matter collected on each sampled filter in μgm^{-3} was obtained by dividing the difference between the filters weight before and after sampling, W_i and W_f, respectively by the total volume V of the air sampled.

$$C = \frac{W_f - W_i}{V} \quad \ldots\ldots\ldots\ldots (1)$$

Elemental Analysis.

Each filter was divided into two; and a half was rolled up and put into a thin foil of aluminium and irradiated for 5 hours at a thermal neutron flux of $9.11 \times 10^{12}\ cm^{-2}\ s^{-1}$ ($f = 73\pm2$; $\alpha = -0.019\pm0.0001$; $T_n(K) = 336\pm3$) in the Portuguese Research Reactor. After irradiation the sample was removed from the aluminium foil and transferred to a polyethylene container. For each irradiated sample, two gamma spectra were measured; one spectrum was measured 2-3 days after the irradiation and the other after 4 weeks. The k_0-INAA method was used and 1mm diameter wires of 0.1% AuAl alloy (Institute for Reference Materials and Measurements reference material 530) were co-irradiated as comparators.

Measurements were carried out using Compton Suppression System (six Ortec NaI(Tl) crystals around and one Ortec crystal on top, with detector and electronics from Canberra). Compton-suppressed spectra were acquired simultaneously with the regular ones. Elemental masses were calculated using the k_0-INAA method and the National Institute of Standards and Technology (NIST) standard 1633a-Coal Fly Ash, which was co-irradiated with the samples, was used as quality control. Blank Nuclepore filters were treated as regular samples. All measured species in the blank were very homogeneously distributed; therefore loaded filters concentrations were corrected by subtracting the filter blank contents. The INAA technique has been optimized for the irradiation and quantification of As, Br, Cd, Cr, Fe, Na, Sb, Sn and Zn (Mustra et al, 2003).

Atmospheric Turbidity.

Turbidity of the atmosphere implies the reduction of the transmittance of the clean and dry atmosphere often called, Rayleigh Atmosphere (Kasten, 1980). This can be estimated from irradiance measurements. The attenuation of solar irradiation caused by absorption by water vapour and scattering by aerosol can be determined by the Linke's turbidity factor, T_L (Linke F., 1922). T_L is given by:

$$TL = (0.9 + 9.4 \sin\gamma).1n\left(\frac{I_o}{I_\gamma}\right) \ldots\ldots\ldots\ldots\ldots (2)$$

Where γ is taken as 90^o for overhead sun at noon.

γ - Solar elevation angle

I_o - Extraterrestrial solar irradiance at normal incidence

$I_o = 1367\ W/m^2$ (Danny and Joseph, 2002)

I_γ = Irradiance at local noon.

DATA ANALYSIS

Observations of surface meteorological parameters: air temperature, relative humidity, wind speed, wind direction, rainfall and global radiation used in this study used in this study were acquired from an automated meteorological station at Obafemi Awolowo University campus, where routine measurements are continuously carried out. The station data were reduced to hourly and monthly average using data analysis software (*MicroCal. ORIGIN version 6.0*).

The Pearson correlation analyses were performed between particulate matter concentration and daily average values of meteorological parameters using the Statistical Package for Social Sciences, SSPP 17. The analyses gave coefficients which indicated the relationship between particulate matter concentration and meteorological parameters in the study area.

RESULTS AND DISCUSSION

Mass Concentration of Particulate Matter

Table 1 shows the descriptive statistics of daily mass concentration of $PM_{2.5}$ and $PM_{2.5-10}$ in the study area. The average mass concentration of $PM_{2.5}$ and $PM_{2.5-10}$ are 25.37 and 37.15 $\mu g/m^3$ respectively. Mass concentrations of $PM_{2.5}$ are in the range of 1.22 131.50 $\mu g/m^3$ with the median and standard deviation of 3.73 and 2.35 $\mu g/m^3$ respectively. The concentration of $PM_{2.5-10}$ ranged between 0.38 $\mu g/m^3$ and 350.32 $\mu g/m^3$ with median and standard deviation as 23.54 and 32.39 $\mu g/m^3$ respectively. A linear correlation between $PM_{2.5}$ and $PM_{2.5-10}$ yielded 0.05 which indicates weak strength of relation and statistically not significant at the 0.05 level. This indicates the dominance one fraction of the particulate matter over the other in the sampling area.

Table 1: Descriptive Statistics of Daily Mass Concentrations of $PM_{2.5}$ and $PM_{2.5-10}$ (November 2009 to August 2010).

Parameters	$PM_{2.5-10}$ ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)
Mean	37.15	25.37
Median	23.54	3.73
Standard Deviation	32.39	2.35
Maximum	350.31	131.50
Minimum	0.38	1.22
No. of Samples	81	81

The time series plot of $PM_{2.5}$ (fine) and $PM_{2.5-10}$ (coarse) presented in Figure 2.0 shows temporal (daily) variation of mass concentration over the sampling period. The time series plot shows a crowded pattern with several peaks. $PM_{2.5}$ exhibits a higher concentration compared to $PM_{2.510}$ from November, 2009 to February, 2010. Higher $PM_{2.5}$ mass concentration suggests that the major sources of particulates are from fossil fuel burning, vehicular emission, bush burning, forest fire and other forms of combustion process and natural sources such as harmattan (Ogugbuaja and Barsisa, 2001; Dimari *et al.*, 2008). $PM_{2.510}$ concentration shows a relatively uniform trend from November, 2009 to February, 2010. This may be attributed to the fact that $PM_{2.510}$ undergoes dry deposition and exhibits less residence time in air compared to $PM_{2.5}$ (Tai *et al.,* 2010). $PM_{2.5-10}$ was exceptionally high in the month of March, mass concentration ranges between 245.36 and 350.31 $\mu g/m^3$ on 19 and 21 March 2010 when the atmosphere was laden with dust due to occurrence of an unusual haze. Infact the dust haze occurred from 16th 29th March, 2010. This was in agreement with Zhao *et al.* 2010, which reported haze in Xiamen, a Coastal City in China. The $PM_{2.5}$ and $PM_{2.5-10}$ mass concentration from the month of April to August shows relatively little variation and clusters around the lower value. This may be attributed to the effect of precipitation scavenging process that result in the removal mechanism of the particulate from the atmosphere (Czarnecka *et al.*, 2007). Dust storms transported from arid region reaching the study area by north-easterly wind and atmospheric circulation contributes significantly to $PM_{2.5-10}$ mass concentration. Generally, each season has it's own unique meteorological conditions that affect the concentration of the particulate matter in the study area (Giri *et al.,* 2008).

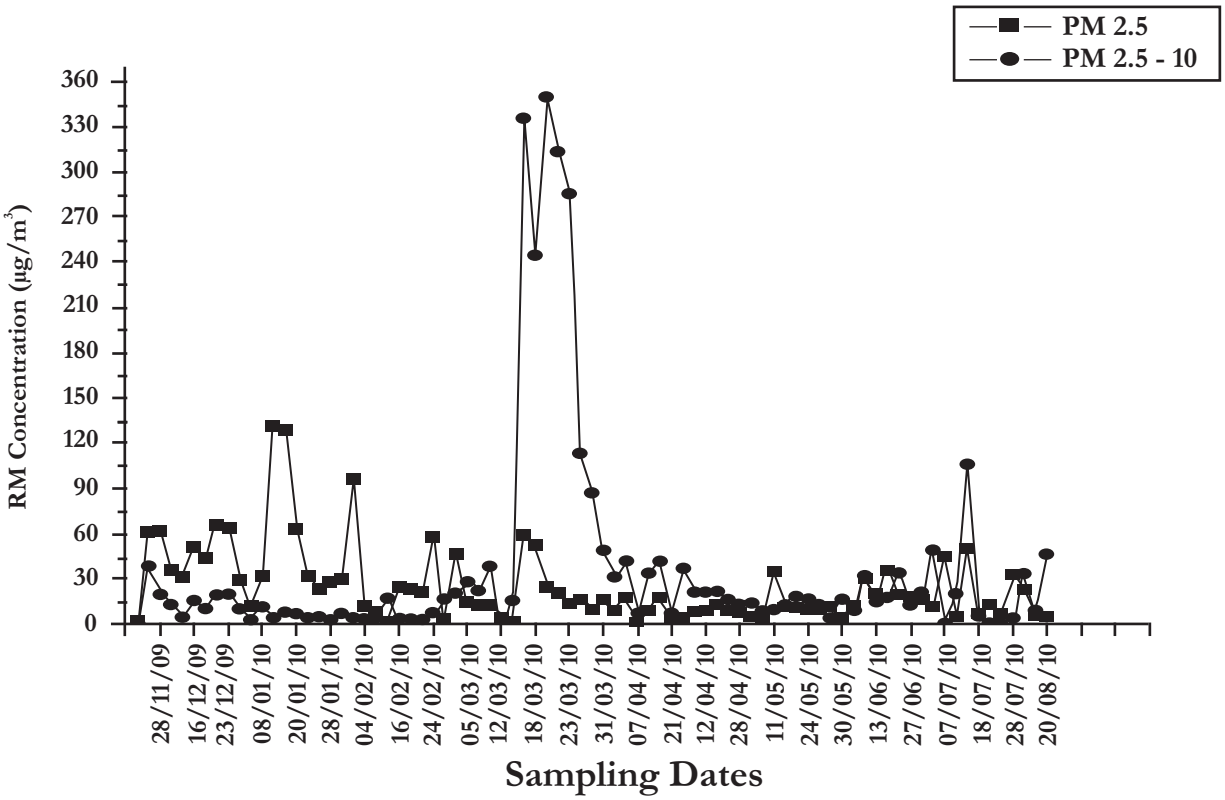

Figure 2: Daily Variation of Concentration of Particulate Matter in µg/m^3

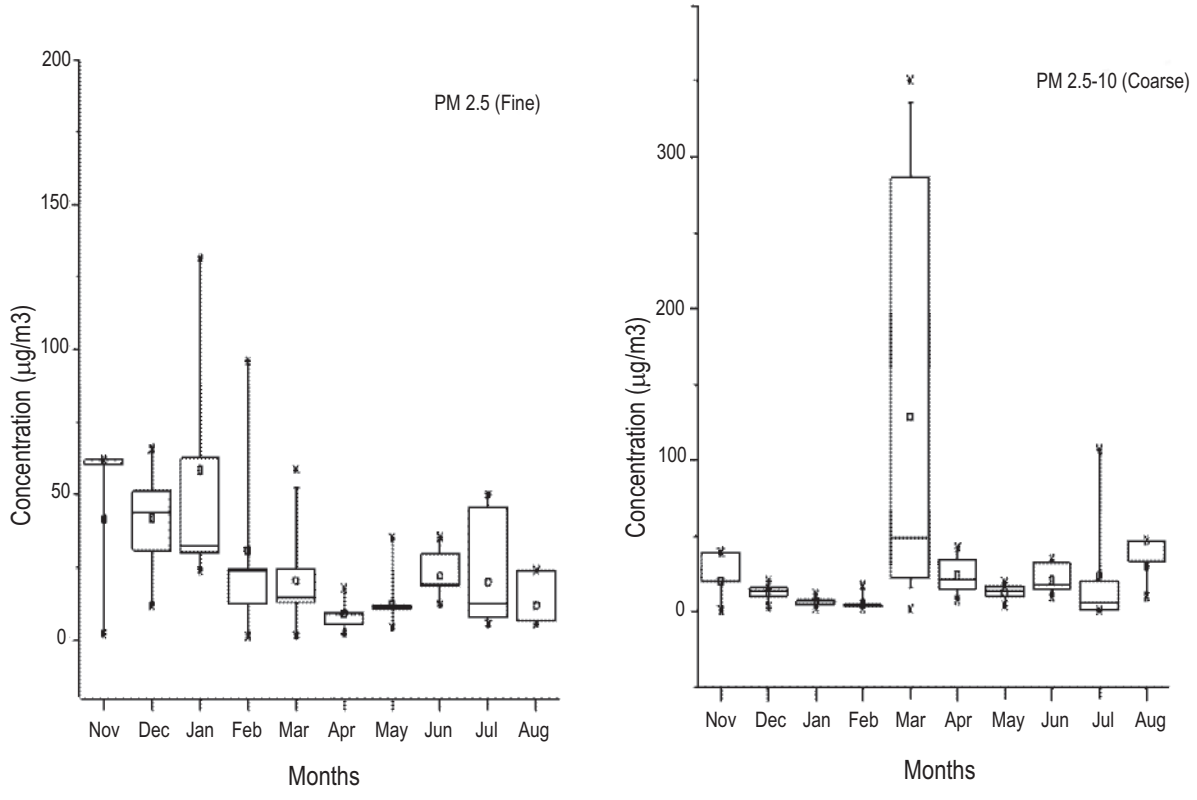

Figure 3a and b: Box-Whisker Plot for monthly mass concentration at top of $PM_{2.5}$ and $PM_{2.5-10}$.

The monthly variations of the mass concentration of fine and coarse particulate are presented using Box- Whisker plots in Figure 3a and b respectively. The plots of coarse and fine show higher mass concentration during the dry season (November to February) and comparatively lower concentration of particulate matter during rainy season (April to August). Jo and Park, 2005; Gupta and Kumar (2006); Kothai *et al.,* (2008) reported similar pattern of particulate mass concentration variation.

Table 2: Monthly Mean Mass Concentration of $PM_{2.5}$, $PM_{2.5-10}$ and Meteorological Parameters from November 2009 to August 2010 at Ile-Ife.

Months	$PM_{2.5}$ ($\mu g/m^3$)	$PM_{2.5-10}$ ($\mu g/m^3$)	Wind speed (m/s)	Wind Direction (°)	Air Temperature (°C)	Relative Humidity (%)	Rainfall (mm)	Global Radiation (W/m^2)
November '09	63.64	37.67	0.7	79.6	26.2	65.0	0.0	221.9
December '09	48.31	17.96	0.8	95.3	27.3	70.6	0.0	186.7
January '10	58.27	9.24	0.7	93.2	26.5	70.3	0.0	170.2
February '10	27.15	6.00	1.0	166.2	28.1	66.7	0.0	190.5
March '10	23.08	102.30	1.0	216.9	28.0	71.3	0.0	190.2
April '10	9.86	26.05	0.8	210.4	27.0	78.4	218.0	196.8
May '10	12.08	13.39	0.9	239.9	25.6	84.6	456.2	92.4
June '10	19.01	18.61	0.9	251.0	24.4	85.4	353.2	80.1
July '10	19.55	24.26	0.8	254.9	24.0	87.2	282.6	86.6
August '10	28.41	19.03	1.0	241.5	24.2	86.1	0.1	163.0

Table 2 shows the monthly average mass concentration of $PM_{2.5}$, $PM_{2.5-10}$ and meteorological data. PM mass concentration shows a pattern of variation with high concentration in dry season (November March) and low in the rainy season (April- August). The average wind speed observed during the study period ranged from 0.67 to 0.97 m/s and it's directions were predominantly North-east and South-east in November through December and January to February respectively, while from April through August, South-westerly wind prevailed. The monthly average temperature ranged from 23 °C to 28 °C which shows a short term variation. Relative humidity ranged between 65% and 87% with the lowest value typically recorded in November and highest value July. The cumulative rainfall value was minimal in the dry season and increased gradually until maximum value of 456.2 mm in May 2010 and gradually decreased to 0.6 mm in August 2010. Solar radiation shows a steady variation all through November 2009 with the highest value of 221 W/m^2 in April 2010 and lowest value of 86 W/m^2 in June. $PM_{2.5}$ was higher in November to January due to more re-suspended soil dust and harmattan occurrence. $PM_{2.5-10}$ had exceptionally high concentration in March due to the occurrence of the atmospheric haze where the atmosphere was laden with dust during the sampling period.

Table 3: Correlation Matrix of $PM_{2.5}$, and $PM_{2.5\text{-}10}$ Mass Concentration with Meteorological Parameters (N = 81) at Ile-Ife.

		Fine ($\mu g/m^3$)	Coarse ($\mu g/m^3$)	WIND sp	WIND d	AIR TEMP	REL HUM	RAINFALL	GLO RAD
Fine($\mu g/m^3$)	Pearson Correlation	1	0.057	-0.058	-0.414**	0.104	-0.190	-0.220*	0.122
	Sig. (2-tailed)		0.611	0.608	0.000	0.358	0.089	0.048	0.276
Coarse($\mu g/m^3$)	Pearson Correlation	0.057	1	0.361**	0.200	0.232*	-0.121	-0.153	0.251*
	Sig. (2-tailed)	0.611		0.001	0.073	0.037	0.283	0.172	0.024
WIND sp	Pearson Correlation	-0.058	0.361**	1	0.298**	0.152	0.042	-0.100	0.109
	Sig. (2-tailed)	0.608	0.001		0.007	0.175	0.710	0.373	0.331
WIND d	Pearson Correlation	-0.414**	0.200	0.298**	1	-0.285**	0.672**	0.454**	-0.446**
	Sig. (2-tailed)	0.000	0.073	0.007		0.010	0.000	0.000	0.000
AIR TEMP	Pearson Correlation	0.104	0.232*	0.152	-0.285**	1	-0.590**	-0.409**	0.709**
	Sig. (2-tailed)	0.358	0.037	.175	.010		0.000	0.000	0.000
REL HUM	Pearson Correlation	-0.190	-0.121	0.042	0.672**	-0.590**	1	0.464**	-0.650**
	Sig. (2-tailed)	0.089	0.283	0.710	0.000	0.000		0.000	0.000
RAINFALL	Pearson Correlation	-0.220*	-0.153	-0.100	0.454**	-0.409**	0.464**	1	-0.686**
	Sig. (2-tailed)	0.048	0.172	0.373	0.000	0.000	0.000		0.000
GLO RAD	Pearson Correlation	0.122	0.251*	0.109	-0.446**	0.709**	-0.650**	-0.686**	1
	Sig. (2-tailed)	0.276	0.024	0.331	0.000	0.000	0.000	0.000	

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

Table 3 shows the result of the correlation matrix of PM concentration and meteorological parameters. From the Table, it was observed that positive and negative correlations were obtained between $PM_{2.5}$, $PM_{2.5\text{-}10}$ and meteorological parameters. $PM_{2.5}$ was negatively correlated with rainfall and relative humidity but statistically significant with rainfall at 0.05 confidence level. The negative correlation coefficients obtained might be due to washout process as rain exhibit wet deposition effect on particulate matter. Rainfall removes atmospheric particulates and moisture restricts the possibility of resuspended soil particulate by making the soil humid (Jaenicke, 1993; Misra *et al.,* 2008), hence decrease in the mass concentration of the atmospheric particulate. Wind speed yielded negative correlation with $PM_{2.5}$ but positive and statistically significant at 0.01 confidence level with $PM_{2.5\text{-}10}$. Wind speed plays a leading role in cleansing atmosphere of fine particulates compare to coarse. Windspeed affects the turbulence near the ground. The greater the wind speed, the greater the dispersion of particulates, the greater the dilution effects and transport of the particulate hence the lower the mass concentration (Oren, 2001; Mkoma and Mjemah, 2011). Wind direction exhibited moderately negative correlation with $PM_{2.5}$ and positively low with $PM_{2.5\text{-}10}$. Apart from wind speed, wind direction plays influencing roles by transporting particulate matter from different neighbouring regions to the sampling location contributing significantly to the variation in concentration of the particulate matter (Guerra *et al.,* 2006).

Flat topography of the study area experiences horizontally homogenous wind flow which does not allow accumulation of particulate matter. $PM_{2.5}$ and $PM_{2.5\text{-}10}$ weakly and positively correlation coefficients with air temperature though a significant relation exists with $PM_{2.5\text{-}10}$. The influence of temperature over PM is attributed to the fact that more favourable atmospheric dispersion conditions occurred under a warm air than cold air masses. $PM_{2.5}$ and $PM_{2.5\text{-}10}$ yeilded a weakly positively correlation with global radiation but statistically significant at 0.05 level occurred with $PM_{2.5\text{-}10}$. The may be attributed to the fact that Global radiation drives photochemical reactions in the atmosphere leading to formation of secondary particulate matter. Short-wave radiation is considerably modified as it moves across the polluted atmosphere being reduced by 2-10% and the reduction depends on the seasonal variation in particulate matter concentration (Prèndez *et al.,* 1995).

Elemental Concentrations of Airborne Particulate Loadings.

Instrumental Neutron Activation Analysis (INAA) detected fourteen (14) elements; As, Br, Cu, K, La, Na, Sb, Sr, Zn, Ce, Co, Cr, Sc and Th. This includes metals, non-metals, Lanthanides and rare earth elements (REE). The term 'rare earth elements' refers to the elements Y, La and the Lanthanides (Ce - Lu) (Cotton et al., 1999). The Lanthanides and REEs were detected in ultra-trace concentrations. The high concentration of Zn and Br can be attributed to Vehicular emission as well as tyre and brake wear in automobiles. REEs are generally due to petrochemical industries and entrainment of crustal materials (Pranav et al., 2006). Studies have also established a relationship between REE and uranium bearing ores and rocks (Ahmad et al., 1980). K is due primarily to biomass burning and Cr and Cu are typical particulate from an iron smelting factory (Owoade et al., 2009). The sources of these particulates are both local and long-range. The REEs and Na may have been due to harmattan dust from the Sahara in Northern Africa (Adepetu et al., 1988) while K, Br and Zn could be attributed to local sources.

Table 4: Elemental Concentrations of Fine and Coarse PM Fractions.

	Fine ($PM_{2.5}$) μg/g			Coarse ($PM_{2.5-10}$) μg/g		
	MEAN (Uncert.)	MIN	MAX	MEAN (Uncert.)	MIN	MAX
As	0.014 (0.003)	0.0005	0.096	0.032 (0.006)	0.0001	0.153
Br	1.092 (0.027)	0.0715	5.681	0.815 (0.020)	0.0061	4.137
Cu	0.313 (0.047)	0.0002	3.304	3.824 (0.574)	0.0020	42.603
K	61.024 (6.10))	0.8213	664.324	54.810 (5.481)	0.5815	286.320
La	0.043 (0.003)	0.0009	0.557	0.134 (0.011)	0.0003	0.724
Na	9.566 (0.191)	0.4548	48.184	73.871(1.477)	1.1362	766.470
Sb	0.036 (0.002)	0.0014	0.253	0.023 (0.001)	0.0005	0.121
Sr	128.53 (15.424)	9.7986	886.737	2066.93(248.03)	26.3945	6833.294
Zn	1.368 (0.096)	0.0775	5.209	4.051 (0.284)	0.0225	29.877
Ce	0.120 (0.026)	0.0029	1.201	0.297 (0.065)	0.0018	1.883
Co	0.015 (0.001)	0.0003	0.163	0.030 (0.002)	0.0001	0.223
Cr	0.398 (0.04)	0.0454	1.851	0.847 (0.085)	0.0037	4.714
Sc	0.012 (0.001)	0.0004	0.124	0.035 (0.004)	0.0009	0.162
Th	0.014(0.001)	0.0003	0.127	0.031(0.003)	0.0005	0.147

Temporal Variation of Linke Turbidity Factor, T_L at Ile-Ife.

Table 5: Monthly Averages of Linke Turbidity Factor, T_L and Airborne PM Loadings.

Month	Average Linke Turbidity factor,T_L	Concentration of $PM_{2.5}$ (FINE)	Concentration of $PM_{2.5-10}$ (Coarse)	Concentration of PM_{10}
January	8.81	58.53	6.22	64.75
February	7.13	30.68	5.72	36.40
March 19th	5.87	52.80	245.36	298.16
March 21st	9.09	24.36	350.32	374.68
March 22nd	8.62	20.72	313.95	334.68
March 23rd	7.24	13.57	286.26	299.83
March 25th	9.93	16.18	113.73	129.91
March 28th	5.89	9.77	87.77	97
March	8.05	20.41	128.45	148.86
April	7.06	8.97	23.18	32.15
May	7.77	12.38	12.57	24.96
June	11.95	21.91	20.56	42.47
July	17.30	21.60	23.56	45.15
August	7.94	11.96	29.75	41.71

March 19th 22nd covered essentially the period when harmattan dust spell occurred. It was noticed that there was Southward progression of inter-tropical discontinuity (ITD) line reaching as far as latitude 7.2 ^{0}N on the 20th of March. Visibility dropped sharply from about 15 km on the 19th to less than 1 km between 19th and 22nd of March. The concentrations of $PM_{2.5}$ and $PM_{2.5-10}$ measured close to the surface were found to be very high ranging as high as 52.8 and 350.3 μg/m^3 respectively.

Table 5 shows the trend of variation Linke Turbidity Factor, T_L and the two fractions of PM sampled. The highest value of 27.39 was obtained for T_L in July while the least value of 2.88 was obtained in May. The range of highest value obtained in the months of June and July will be due partly to the PM concentration and the high concentration of water vapour in the atmosphere at that time of the year.

CONCLUSION

The study concluded that meteorological parameters play a major role in day-to-day variations of the mass concentration of $PM_{2.5}$ and $PM_{2.5-10}$. Highest mass concentration of particulate matter was observed in March (dry season) due to atmospheric haze and lowest in July (rainy season) due to washout process by rainfall. The results of the linear correlation analysis between $PM_{2.5}$ and $PM_{2.5-10}$ mass concentration and meteorological parameters such as wind speed air temperature, relative humidity and global radiation were weak. It was also concluded that meteorological factors such as rainfall, global radiation, air temperature and relative humidity play significant role in the particulate matter loadings in the study. The high T_L values for the months of January through April are predominantly due to high PM loading while the very high values of June and July are due to the combine effects of PM loadings and water vapour.

The sources of the fourteen elements detected by INAA could be attributed to both local and long-range. The local sources are anthropogenic: Biomass burning, vehicular emission and automobile-related particulates. The long-range PM are probably from a source rich in Uranium which is probably the Sahara desert.

ACKNOWLEDGEMENT.

The authors gratefully thank Prof. O.O. Jegede and other members of the Nigeria Micrometeorological Experiment (NIMEX), Obafemi Awolowo University, Ile-Ife for providing atmospheric data used in this work. The author also appreciates Instituto Technologico e Nuclear (ITN) Portugal, for a research visit granted one of them (Dr. F.S. Olise).

REFERENCES

Adepetu J.A., Asubiojo O.I., Iskander F.Y. and Bauer T.L. 1988. Elemental Composition of Nigerian Harmattan Dust. *Journal of Radioanalytical and Nuclear Chemistry, Articles*. 121(1): 141-147.

Angstrom A. 1961. Techniques of determining the turbidity of the atmosphere. Tellus, 13:21423.

Chaabane M., Masmoudi M., Medhioub K. 2004. Determination of Linke turbidity factor from solar radiation measurement in northern Tunisia. *Renewable Energy* 29: 20652076

Cotton F., Wilkinson, G., Murillo, C. and Bochmann, M. 1999. Advanced inorganic Chemistry. Wiley, New York.

Czarnecka M., Kalbarczyk R. and Kalbarczyk E. 2007. Variability in particulate matter Concentrations versus Precipitation in Pomerania region. *Polish Journal of Natural Science* 22: 645-659.

Danny H.W.L and Joseph C.L. 2002. A study of atmospheric turbidity for Hong Kong. *Renewable Energy* 25:113.

Dimari G. A., Hati S. S., Waziri M., and Maiteria O. N. 2008. Pollution Synergy from Particulate Matter Sources: The Harmattan, Fugitive Dust and Combustion Emissions in Maiduguri Metropolis, Nigeria. *European Journal of Scientific Research*. 23(3): 465-473.

Flagan R.C. and Seinfeld J.H. 1988. F*undamentals* of *air pollution engineering,* Prentice Hall, New Jersey.

Fraser M.P., Cass, G.R. and Simoneit, B. R. T. 1999. Particulate Organic Compound Emitted from Motor Vechicle Exhaust and in the Urban Atmosphere. *Atmospheric Environment* 33: 2715-2724.

Ghim Y. S., Oh H. S. and Chang Y. S. 2001. Meteorological effects on evolution high ozone episodes in greater Seoul area. *Journal of Air Waste Management.* 51: 185-202.

Giri D., Krishna Murthy V. and Adhikary, P. R. 2008. International Journal of Environmental Research. 2(1): 49-60.

Guerra S. A., Lane D. D., Marotz G. A., Carter R. E., Hohl C. M. and Baldauf R. W. 2006. Effects of wind direction on coarse and fine particulate matter concentrations in southeast Kansas. *Journal of the Air and Waste Management Association*. 56: 1525-1

Gupta I. and Kumar R. 2006. Trends of Particulate Matter in Four Cities in India. Atmospheric Environment, 40: 2552-2566.

Hopke P. K., Xie Y., Raunemaa T., Biegalski S., Landdsberger S., Maenhaut W., Artaxo P., and Cohen D. 1997. Characterization of Gent Stacked Filter Unit PM_{10} Sampler. *Aerosol Science and Technology* 27: 726-735.

IPCC 2001. The Third Assessment Report of Working Group I of the Intergovernmental Panel on Climate Change: Technical Summary, edited by Albritton D.L. and Meira Filho L.G., Cambridge University Press, New York.

Jaenicke R. 1993. Tropospheric Aerosols. *International Journal of Geophysical Services*.54: 1-31.

Jo W. K. and Park J. H. 2005. Analysis of Roadside Inhalable Particulate Matter (PM_{10}) in Major Korean Cities. *Environmental Management*. 36: 826-841.

Kothai P., Saradhi I.V., Prathibha P., Hopke P. K., Pandit G. G., and Puranik V. D. 2008. Source Apportionment of Coarse and Fine Particulate Matter at Navi Mumbai, India. *Aerosol and Air Quality Research*, 8(4): 423-436.

Linke F. 1922. Transmissions-Koeffizient und Tru¨bungsfaktor. Beitr Phys Fr Atmos 10:91103.

Maenhaut W., Francois F. and Cafmeyer J. 1994. The "Gent" Stacked Filter Unit (SFU) Sampler for the Collection of Aerosols in Two Size Fractions: Description and Instruction for Installation and Use. Applied Research on Air Pollution Using Nuclear-related Analytical Techniques, Report on the first Research Co-ordination Meeting, Viennam Austria, 30 March - 2 April 1993, NAHRES-19, IAEA, Vienna, 249-263.

Miranda F. and Tomaz E. 2008. Characterization of Urban Aerosol in Campinas, Sao Paulo, Brazil. *Atmospheric Research* 87: 147-157.

Misra A. Jayaram A. and Ganguly D. 2008. Validation of MODIS Derived Aerosol Optical Depth over Western India. *Journal of Geophysical Research*. 113:D04203.

Mkoma S. L. and Mjemah I. C. 2011. Influence of Meteorology on the Ambient Air Quality in Morogoro, Tanzania. *International*

Journal of Environmental Sciences 1(6): 1107-1115.

Muhammad A. E., Hassain I., Noorbatcha A. I., and Zen I. H. 2007. The effect of Climate and waste composition on leachate and Emission of Gas: A case study in Malaysian Context. Proceeding of The International Conference on Solid Waste Management, Chennii, India, 437-443.

Ogugbuaja V. O and Barsisa L. Z. 2001. Atmospheric Pollution in North-East Nigeria: Measurement and Analysis of Suspended Particulate Matter. *Bulletin of the Chemical Society of Ethiopia*. 15(12): 109-117.

Ogunjobi K. O., Kim J. Y., Adedokun J. A., Ryu S. Y., and Kim J. E. 2002. Analysis of sky condition using solar radiation data at Kwangju and Seoul, South Korea and and Ile-Ife, Nigeria. *Theoretical and Appllied Climatology* 72: 265-272.

Oren, C. N. 2001. Air Pollution. Access Science, McGraw-Hill Companies. Http://www.accessscience.com.

Owoade O.K., Olise F. S., Obioh I. B., Olaniyi H. B., Ferrero L. and Bolzacchini E. 2009. EDXRF elemental assay of airborne particulates: A case study of an iron and steel smelting industry, Lagos, Nigeria. *Scientific Research and Essay*, 4(11): 1342-1347.

Parr R. M, Stone S. F, and Zeizer R. 1996. Environmental Protection: Nuclear Analytical Techniques in air pollution monitoring and Research. International Atomic Energy Agency Bulletin.

Pranav K., Shankararaman C. and Matthew P.F. 2006. Lanthanum and lanthanides in the atmosphere fine particles and their apportionment to refinery and petrochemical operations in Houston, TX. *Atmospheric Environment* 40: 508-520.

Prèndez M. M., Egido, M., Tomas, C., Seco J., Calvo, A., and Romero H. 1995. Correlation between Solar Radiation and Total Suspended Particulate Matter in Santiago, Chile Preliminary Results. *Atmospheric Environment*. 29(13): 1543-1551.

Tai A. P. K., Mickley L. J., and Jacob D. J. 2010. Correlations between fine particulate matter ($PM_{2.5}$) and meteorological variables in United States: Implication for the sensitivity of $PM_{2.5}$ to climate change. *Atmospheric Environment* 44: 3976-3984.

Zhao J., Fuwang Z., Ya X., Jinsheng C., Liqian Y., Xuesong S. and Xu L. 2011. Chemical Characteristics of Particulate Matter during a Heavy Dust Episode in a Coastal City, Xiamen. *Aerosol and Air Quality Research*. 11: 299308.