IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 8, Issue 2 Ver. I (Mar. - Apr. 2016), PP 32-38
www.iosrjournals

Fine Particulate Distribution and Assessment in Nasarawa State – Nigeria

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Abstract: *The purpose of this work is to analyze fine particulate matter (PM_{10}) distribution in the ambient air of some major towns in Nasarawa State-North central Nigeria using a high volume respirable dust sampler (APM 460 NL) model, also the meteorological parameters of the State have been correlated with the measured values. Ambient air laden with suspended particulates enter the APM 460 NL system through the inlet pipe, which separates the air into fine and coarse particles. The PM_{10} concentrations were analyzed to obtain the monthly average PM_{10} concentration and monthly maximum concentration. The results show that Nasarawa State towns of Karu and Lafia have fine particulates loading in the ambient air more than the recommended standard set by NAAQS and WHO. Variation trends of pollution levels were also identified. The fine particulate matter PM_{10} average concentrations in the ambient air of Nasarawa State towns had average values increase in the range of 4.0 – 18.0μg/m^3 per month. The level of monthly increase of maximum average concentrations also had readings in the range of 8.0 – 20.0 μg/m^3 per month. These values were compared with the NAAQS to obtain the toxicity potential for all the study towns in the State. It is shown that there are considerably very strong correlations between PM_{10} monthly average concentrations and PM_{10} monthly maximum average concentrations over 24-hour period in the ambient air: the linear correlation coefficient is between 0.7 – 1.0. The created frequency distributions of fine particulate matter PM_{10} concentrations allow assessing the probabilities of development of hazardous pollution situations in the state.*
Keywords*: particle size, toxicity potential, fine particle distribution and statistical analysis*

I. Introduction

Suspended particulate matter is a major air pollutant in Nigeria. In most of the cities the levels of particulate loading in ambient air have been above the permissible limits (Ukpebor *et al*., 2010; Obioh *et al*., 2005; U S EPA, 1999). Emphasis is being laid on the study of emission and dispersion of particulate matter in the atmosphere (Telesca and Lovallo, 2011).The particulate matters behavior, size and their dispersion in the atmosphere is the same manner as gases.They are pernicious to health especially if they originate from urban source and hence contain a number of toxic and carcinogenic chemicals. These Chemical compounds that exist in the ambient air affect human health significantly. The nature of this effect depends on the physical and chemical properties of these compounds, their concentration in the air and time of exposure.

The main reason of air pollution is human economic activities, especially industry, transportation, energetics and agriculture (Agu, 2014).

The effect of seasonal phenomena on soil and automobile related fine (respirable and coarse (inhalable) particle has been reported from different regions around the world (Rodriquez *et al*., 2001;Ediagbonya *et al*., 2013; Owega *et al*., 2004; Dorderic *et al*., 2004).

In order to comprehend the processes responsible for the spatial and temporal distribution of aerosols, in depth analysis of local regional meteorology, especially wind speed, wind direction and temperature are required (Zelenka, 1997; Hien *et al*., 2002; Laakso *et al*., 2003).

It has been demonstrated that the component in particulate matter can induce bulky DNA adducts and oxidative bases that may induce mutations. Indeed, a plethora of evidence have demonstrated that ambient pollutants are able to induce DNA adducts, mutations and tumors in animals models (Reymao *et al.*, 1997; Ukuo and Ndiokwere, 2005).

Health effects of particulate matter are determined by their size distribution, bulk chemical, microbiological concentration and composition (Agu, 2014; Hare, 2013).

However plethora respirable particles ($PM_{2.5}$ and PM_{10}) concentration have been shown to have insidious effect on the respiratory and cardiac health of humans, attenuate visibility and also affects the structural integrity of plant (Jimoda, 2012).The study of pollution conditions allows to design actions for reducing the ambient air pollution and also to evaluate the efficiency of the measures applied.

Thus the objective of this study is to assess the distribution of fine particulate PM_{10} pollution levels over time and space and thus determine the toxicity potential to people's health.

II. Materials And Methods

2.1 Sampler and analytical procedure

In this study, the sampling tool employed was the high Volume respirable dust sampler (APM 460 NL) model. This sampling unit consists of an inlet pipe with an in built flow rate meter and a filter adaptor assembly connected to the sampling pump by a cyclone. Airborne particulate matter was collected on a Whatman glass fiber filter papers (GF/A) 8 by 10 inches. The inbuilt gas flow meter has a rating of 0.9 to 1.2 M^3/min of air samples. Before sampling, all unloaded glass fiber filters were dried in a desiccator at room temperature and their initial weights were taken.

The particulates were collected on the pre-weighed filter papers after exposure for eight hours and then dried again in desiccators and re-weighed to determine the final weight.

The concentration of the fine particulates in the air was determined from the difference in weight of the filter paper after and before sampling divided by the volume of air sampled (Ugwuanyi and Sombo, 2005).

The sampler was placed at a height of 1.5 meter above ground level to reflect the breathing zone of human.

Fine particulate PM_{10} concentration is calculated as

$$\text{Con } (\mu g m^{-3}) = \frac{(Final - initial\ )mass\ of\ filter\ paper}{Volume\ of\ air\ sampled} \text{ x } 10^6 \quad \text{or}$$

$$\text{Con } (\mu g m^{-3}) = \frac{w2-w1}{V}\ X\ 10^6 \qquad (1)$$

Where v = Φ x t

Φ = average flow rate in m^3/min and t is sampled time in minutes, 10^6 is conversion factor from grams to micrograms. Because of the proximity of residential houses to the PM_{10} sources and human exposure, the probability of human effect exists. Thus toxicity potential (TP) are computed as

$$T\,P = \frac{observed\ mean\ mass\ of\ PM_{10}\ Concentration}{Permissible\ limit\ set\ by\ NAAQS} \qquad (2)$$

T P > 1 is harmful to human (Ediagbonya *et al*., 2013).

2.2 Study Area

The study area covers five major towns which are Lafia, Akwanga, Keffi, Karu and Nassarawa (all in Nassarawa State- Nigeria). The area is approximately 11120 km^2 and is located within latitude (7.6^0-8.3^0) N and longitude (7.5^0-8.31^0) E. The approximate population of the area is 932,118 according to 2006 census figure (NPC, 2006). The climate condition is tropical, characterized by wet and dry seasons. The wet season set in between April and October while the dry season is between November and March (Strachler and Straler, 1977).

The major human activities in these towns that generate cumbersome pollution are the particulate generate from bike, vehicular exhaust, local manufacturing industries, bush /refuse burning and resuspended particle from the untarred roads.

Fig. 1 is the map of Nasarawa State showing the study towns.

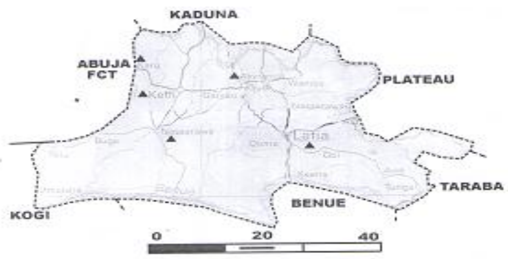

Figure1. Map Of Nasarawa State Showing The Study Towns

2.3 Sampling site selection

Four sites were selected in each of the five towns for study as shown in Table 1.

Table 1. Sampling Town /Sites and coordinates.

/N	Town	Site Names	Coordinates: Lat. Long.
1	Lafia	Rice mill, Doma road junction, Main market and GRA Road construction site	8.3N 8.31E
2	Akwanga	Akwanga motor park, Jos/Keffi roundabout, Main Market and Lafia road	8.55N 8.23E
3	Keffi	Angwan Waje, Total roundabout, Abuja/Kachia Junction and Keffi Main market	8.51N 7.52E
4	Karu	Karu International Market, New Karu junction, Abuja Express Way and Mararaba Stone crushing Site (Aso road)	9.03N 7.60E
5	Nasarawa	Central Motor Park, Toto junction, Main market and Bread backing factory	7.59N 7.49E

The four sites where chosen in the 'heart' of the selected towns based on human activities, high population density and traffic volume as carefully observed by the researcher.

III. Results And Discussions

Table 2 Gross Mean Concentrations of the Study towns and the Toxicity potential

Study Town	**Monthly concentration(μg/m^3)**				**$\frac{1}{3}$ annual mean (μg/m^3)**	**Toxicity potential**	**Regulatory limit set by NAAQS**
	SEPT	OCT	NOV	DEC			65.0μg/m^3
Lafia	55.556	48.157	66.170	124.434	73.579	1.132	
Akwanga	43.516	61.303	57.870	65.789	57.120	0.879	
Keffi	56.155	27.027	65.734	71.217	55.033	0.847	
Karu	70.099	69.615	70.199	103.226	79.035	1.216	
Nasarawa	38.363	31.153	34.435	57.624	40.394	0.621	

Source: Field survey, 2015

Table 3 Maximum Monthly Mean Concentrations in the Study Towns.

Study towns	**Maximum Monthly Concentration (μg/m^3)**				**Mean (μg/m^3)**
	SEPT.	OCT.	NOV.	DEC.	
Lafia	83.333	61.027	105.311	160.256	102.482
Akwanga	59.524	111.350	84.635	83.333	84.711
Keffi	86.610	60.185	80.492	88.768	79.014
Karu	92.844	89.286	100.000	130.762	103.200
Nasarawa	49.242	47.619	54.451	84.325	58.909

Source: Field survey, 2015

Table 2 and 3 are monthly mean of the entire sampled sites for each of the study town.

Table 4 Weekly Mean Meteorological Data

Month/Year	**Wind speed(m/s)**	**Wind direction (Degrees)**	**Temperature (Degree Celsius)**
SEPT./2015	0.79	151.9	25.4
	0.77	165.5	26.1
	0.79	168.5	25.5
	0.90	152.7	26.2
Mean Value	**0.813**	**159.650**	**25.800**
OCT./2015	0.70	162.4	26.4
	0.90	138.6	27.0
	0.91	133.2	27.3
	1.01	141.9	27.1
Mean Value	**0.880**	**144.025**	**26.950**
NOV./2015	0.80	139.3	27.2
	0.90	139.0	27.4
	0.91	112.8	26.4
	1.00	110.5	27.3
Mean Value	**0.903**	**125.400**	**27.075**
DEC./2015	1.40	185.3	25.7
	1.40	185.7	25.3

	1.41	184.6	24.7
Mean Value	1.60 **1.453**	214.3 **192.475**	24.9 **25.150**

Source: NADP Headquarters' Automatic weather stations report, Lafia- Nasarawa State.

Table 5 Statistical Characteristics of Fine Particulate Matter PM_{10} Concentrations in Nasarawa State.

Statistical Characteristics/City		**LAF.**	**AKW.**	**KEF.**	**KAR.**	**NAS.**
$C_{MA, \mu g/m^3}$	Minimum	48.2	43.5	27.0	69.6	31.2
	Average	73.6	57.1	55.0	78.3	40.4
	Median	60.9	59.6	61.0	70.2	36.4
	Maximum	124.4	65.8	71.2	103.2	57.6
$C_{MM, \mu g/m^3}$	Minimum	61.0	59.5	60.2	89.3	47.6
	Average	102.5	84.7	79.0	103.2	58.9
	Median	94.3	84.0	83.6	96.4	51.9
	Maximum	160.3	111.4	88.8	130.8	84.3
No of times exceeding LV_{24}	Minimum	1	0	0	1	0
	Average	2	1	2	4	0
	Median	2	1	2	3	0
	Maximum	3	3	3	4	1

The mean concentrations of fine particulate matter PM_{10} obtained in Nasarawa State are analyzed statistically with the characteristics presented in table 5. Where,

C_{MA} = monthly average concentration

C_{MM} = monthly maximum concentration

LV_{24} = monthly number of times when the pollution level limit value

(65 $_{\mu g/m^3}$) was exceeded in the ambient air.

C_{MA} is based on mean concentration in Table 2. The monthly maximum pollutant concentrations in the air C_{MM} are calculated on the basis of average measured maximum concentrations in a month as in Table 3.

The monthly number of times when the pollution limit value (LV) was exceeded has been computed based on monthly mean of daily values from the entire results.

The mean values of the changes in fine particulates matter monthly concentrations $C_{MA,}$ monthly maximum concentration $C_{MM,}$ and the number of times when the limit values where exceeded (Table 5) were computed. In September to December, 2015, the maximum value of fine particulate matter PM_{10} monthly average concentrations $C_{MA,}$ was 124.4µg/m^3 in Lafia followed by 103.2 µg/m^3 in Karu then that of Keffi, Akwanga and Nasarawa readings were in decreasing order.

Maximum average value of 160.3 µg/m^3 of PM_{10} was obtained in Lafia and 130.8 µg/m^3 was obtained in Karu; these values exceed the permissible limit. Also on the basis of four month gross mean concentration from Table 5, it is observed that Karu has the highest concentration of 78.285 µg/m^3 followed by Lafia with 73.579 µg/m^3, the values also exceed the permissible limit of 65 µg/m^3 for respirable fine particulates set by National Ambient Air Quality Standards NAAQS with a toxicity potential of 1.22 and 1.13 respectively. This may be attributed to high traffic congestion in Karu as a result of its proximity to FCT Abuja and numerous local industries like bread baking factories, rice mill factories, stone crushing areas etc., and other factors like incineration of solid waste, gas flaring biomass burning and resuspended dust among others. For the case of Lafia, one would attribute the higher concentration of fine particulates matter to the massive ongoing roads construction project in the town, the presence of local industries like rice mill, timber processing factory, Bukan-Sidi long roofing aluminum factory and other activities like burning tires for street protest or for roasting slaughtered cows, goats and lambs, biomass burning and incinerate of waste. The gross mean concentration of PM_{10} recorded in Akwanga, keffi and Nasarawa shows results with toxicity potential values of 0.88 for Akwanga, 0.85 for Keffi and 0.62 for Nasarawa towns. Figure 2 and 3 are PM_{10} distribution of monthly average concentrations and maximum average concentrations in the study towns of Nasarawa State from September – December, 2015

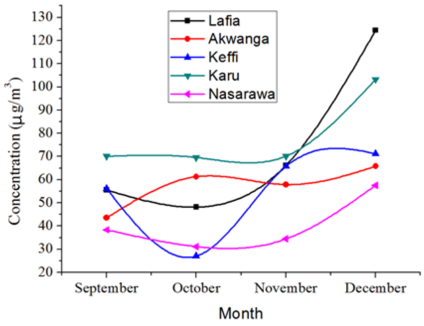

Figure 2. PM_{10} Monthly Average concentrations and the study town

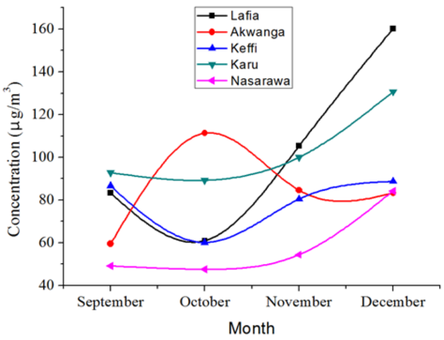

Figure 3. PM_{10} Monthly Maximum Average concentrations and the study towns

From Tables 2 and 3, we observed that in November and December (dry season) peak values of PM_{10} concentrations were high. This is possible because rain is reduced and resuspension is enhanced and washout is also reduced.

In addition, it appears that the fine particulate monthly average concentrations show an increasing trend as we move from wet season to dry season in the state. This increase is described by a linear regression model

$$C = a.n + b \quad (3)$$

Where n is the serial number of the month of the research work beginning from September to December.

The parameters of the regression model characterizing the change in monthly average concentrations and monthly maximum concentrations are computed as follows:

$$a = \frac{4\sum nC_{MA} - \sum n \sum C_{MA}}{4\sum_n 2 - (\sum n)2} \text{ and}$$

$$b = \bar{C}_{MA} - a.\,\bar{n} \quad (4)$$

With replacement of C_{MA} with C_{MM} as the case may be we obtained the regression parameters for all the study towns.

Also the correlation between PM_{10} monthly average concentrations C_{MA} and monthly maximum average concentrations C_{MM} are very strong. The strength and direction of the regression model is described by the coefficient

$$R = \frac{i\sum C_{MA}C_{MM} - \sum C_{MA}\sum C_{MM}}{\sqrt{[i\sum C_{MA}2 - \sum(C_{MA})2]\,[i\sum C_{MM}2 - \sum(C_{MM})2]}} \quad (5)$$

Where i is the number of pairs of data.

Table 5. Linear Regression Models of the change of Fine Particulate Matter PM_{10} monthly average concentrations C_{MA} and monthly maximum average concentrations C_{MM} in the ambient air in Lafia, Akwanga, Keffi, Karu and Nasarawa during the months of September – December, 2015.

Town	**Monthly average ($\mu g/m^3$)**	**Monthly maximum average ($\mu g/m^3$)**	**Correlation coefficient (R)**
Lafia	C_{MA} = 22.46n + 17.42	C_{MM} = 27.51n + 33.72	0.97
Akwanga	C_{MA} = 6.34n + 41.27	C_{MM} = 4.47n + 73.53	0.72
Keffi	C_{MA} = 8.39n + 34.06	C_{MM} = 2.68n + 72.32	0.92
ssKaru	C_{MA}= 10.00n + 25.13	C_{MM}= 12.45n + 72.11	0.97
Nasarawa	C_{MA} =6.11n + 25.13	C_{MM}=11.21n + 30.89	0.96

-

From table 5, we see that the correlation between average and maximum concentrations is strongest and the same for Lafia and Karu town R (5) is 0.97, followed by Nasarawa town where R is 0.96. For the case of Akwanga town where the relation is the weakest R is 0.72.

Since the fine particulates pollution levels are formed as a result of several random processes, they can be look upon from statistical point of view. By dividing the values of daily average concentrations into intervals of 20µg/m^3, the relative frequency distribution of the existing average concentrations can be found (Figure 5). It can be seen that the most probable daily average concentrations in the observed towns is 40 - 80µg/m3. In the case of Karu and Nasarawa the maximum frequency distribution is sharper; why in Lafia and Keffi the distribution is more even. Significant decrease occurs after the concentration of 80µg/m^3 in frequency percentages which means daily concentration values above 100 µg/m^3 are rare in all the study towns. These distributions can be attributed to size of the cities, location of monitoring stations in relation to location of factories and meteorological conditions (especially wind speed and wind direction)

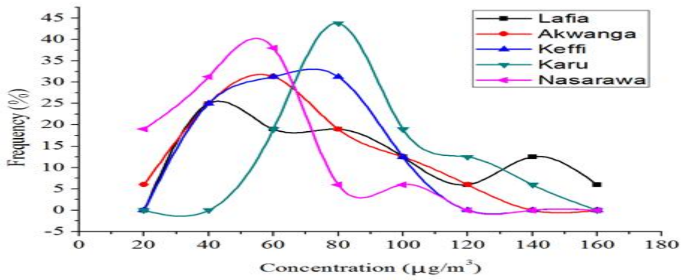

Figure 4. Frequency Distribution of PM_{10} daily mean concentration values of the study towns in intervals of 20 µg/m^3

IV. Conclusion

The results of this study shows that the captured PM_{10} exceeded set standards of 65 and 50 µg/m^3 by NAAQS and WHO respectively, especially in Karu and Lafia town. The fine particulates matter PM_{10} average concentrations analysis indicated that the ambient air of Nasarawa State towns increases on the average by 4.0 – 18.0 µg/m^3 per month. The increase of air pollution levels in terms of maximum concentrations have been possible due to numerous unpaved roads, lack of modern technology appliances in local industries present in the state, high traffic congestion and noncompliance with environmental protection guidelines. The result shows a strong correlation between the PM_{10} average concentrations and monthly maximum average concentrations in the ambient air; with linear correlation coefficient between 0.7 – 1.0.

Therefore we do recommend that Houses, Schools, Offices, Restaurants and playgrounds should not be sited on busy streets.

Acknowledgement

We gratefully acknowledge the support of Dr. (Mrs) B.C. Isikwue and Dr. Sombo, T. for their immeasurable material assistance.

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