Article

Spatio-temporal distribution of inhalable and respirable particulate matter in rural atmosphere of Nigeria

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Abstract

A complete description of particle pollution of the air at a particular site encompasses the physical characterization of the aerosol, including the total size distribution and that with respect to chemical composition as well as the variation of these quantities with respect to time. The particulate matter in this region was captured at five different locations using SKC Air Check XR 5000 High Volume Gravimetric Sampler and a respirable foam using I.O.M. (Institute of Occupational Medicine) Edinburg Multi dust sampler. The study was done between the months of December 2008 - October 2009. The spatial variations were significant and remarkable. The correlation of the inhalable fraction and respirable was significantly high ($P<0.01$).

Keywords seasonal variation; respirable particle; inhalable particle.

1 Introduction

Suspended particulate matter is a major air pollutant in Nigeria. In most of the cities the level of particulate loading in ambient air have been above the permissible limits (Ukuo et al, 2002; Ukpebor et al, 2010; Obioh et al, 2005). 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 dispersed 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.

The effect of seasonal phenomena on soil related fine (respirable and coarse (inhalable) particle has been reported from different regions around the world (Rodriquez et al, 2001; Quaerol, 1998; Pio et al, 1996; 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, specially wind speed, atmospheric stability, wind direction and turbulence are required (Zelenka, 1997; Hien et al, 2002; Laakso et al, 2003).

The purpose of this study is to determine the spatial and temporal variation of the particulate matter the toxicity potential of the particulate matter and to capture the meteorological parameters.

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 (Ichinose et al, 1997; Reymao, et al, 1997).

Health effects of particulate matter are determined by their size distribution, bulk chemical microbiological concentration and composition (Hetland et al, 2004; Griffin et al, 2001).

However plethora respirable particle ($PM_{2.5}$) concentration have been shown to have insidious effect on the respiratory and cardiac health of humans (Dockery et al, 1993; Gwyno et al, 2000; Pope et al, 2002) attenuate visibility and also affects the structural integrity of plant (Chameides et al, 1999; Bergin et al, 2001).

2 Materials and Methods

2.1 Sampling site

Sampling was done in Obaretin in Ikpoba-Okha L.G.A Edo State in Niger Delta region of Nigeria (Fig. 1; Table 1). The rural community is sparsely distributed with a population estimate of few thousand of inhabitant, the settlement is situated along the main road i.e Nodal Settlement. There are thick rubber plantations and industrial farms all located behind the community.

The rural dwellers engage themselves in farming, hunting, rubber tapping and rural or intra-transportation due to the accessibility of the community to the main road. Also the people engage in cassava processing, smoking of fishes, and their major way of waste disposal is by burning. The main road that led to the community is untarred. Other human activities in this locality include paving of roads and different artisans. All these activities afore-mentioned are veritable generator of particulates to the environment.

The major human activities in this region that generate cumbersome pollution are the particulate generate from bike, vehicular exhaust, bush burning and resuspended particle from the untarred road.

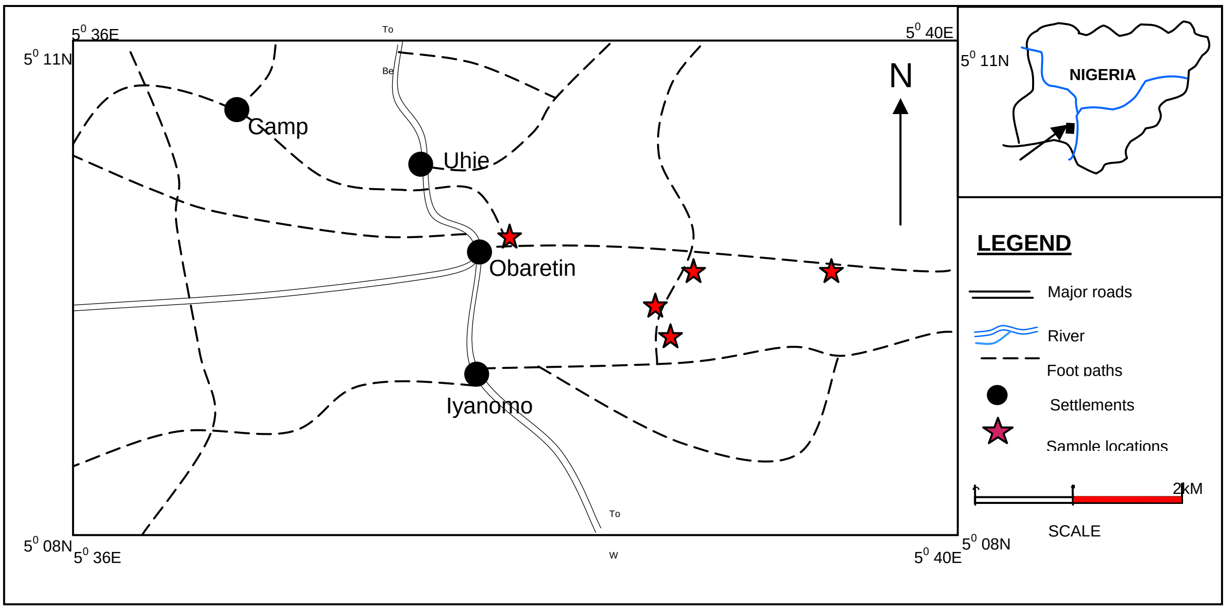

Fig. 1 Map of Obaretin and environs showing the sampled locations

Table 1 Monitoring sites and their co-ordinates

S/N	Site Code	Co-Ordinates	Site Descriptions
1	RH_A	N06^{0}09$^{'}$ 43.3$^{''}$ E005^O 38’ 49.2$^{''}$	Mud house detached, kitchen unceiled roof
2	RH_B	N06^O 09$^{'}$46.9$^{''}$ E005^O 38’44.7$^{''}$	Mud house detached, kitchen unceiled roof
3	RH_C	N06^{o}09$^{'}$ 46.9$^{''}$ E005^O 38’ 48.1$^{''}$	Mud house detached, kitchen unceiled roof
4	RH_D	N06^O 09$^{'}$ 40.0$^{''}$ E005^{O}38’ 53.8$^{''}$	Mud house detached, kitchen unceiled roof
5	RH_E	N06^O 09$^{'}$ 35.8$^{''}$ E005^O 38’30.4$^{''}$	Mud house detached, kitchen unceiled roof

2.2 Sampler and analytical procedure

In present study, we used the sampling tool, SKC Air Check XR 5000 high Volume Gravimetric Sampler Model 210-5000 serial No. 20537. This sampling unit consists of a gas pump with an in built flow rate meter and a filter holder manifold connected to the sampling pump by a Teflon tube. Airborne particulate matter was collected on a Whatman glass fiber filter.

The inbuilt gas flow meter has a rating of 1000 to 5000 ml/mm of air samples. Before sampling, all unloaded glass fiber filters were dried in a desiccators at room temperature and their initial weights were taken. The particulates were collected on the pre-weighed filter by pumping 2000ml/min (2 L/min) volume of air through it for eight hours, after sampling, the loaded filters were again desiccated and re-weighed to determine the final weight.

The concentration of the total suspended particulates in the air was determined from the difference in weight of the filter paper after and before sampling the duration of the sampling and the flow rate (Shaw, 1987; UNEP/WHO, 1994). The sampler was placed at heights of 1.5 m above ground level to reflect the breathing zone of human.

Total suspended particulate (TSP) is calculated as

$$TSP\left(\mu g / m^3\right) = \frac{\text{Final weight (mg) - Initial weight (mg)}}{\text{Flow rate}\left(\text{m}^3/\text{min}\right)\times \text{sampling period (min)}}\times 1000$$

Because of the proximity of residential houses to the PM and human exposure. The probability of human effect exists. Thus toxicity potential (TP) are computed as

$$TP = \frac{\text{observed gross dust concentration}}{\text{Permissible limit set by NAAQS}}$$

3 Results and Discussion

This study was conducted to provide simultaneous information on the spatial and temporal variation of inhalable suspended particulate matter and respirable suspended particulate matter in rural air in a selected location in Obaretin (rural area).

Table 2 and 3 showed that during wet season, the mean ambient temperature was in the range of 27.4 – 29.00 ^{0}C, the relative humidity was in the range of 70.20 – 84.25 % and the mean wind speed was in the range of 0.10 – 0.30 m/s, while for dry season, the mean ambient temperature was in the range of 26.40 ^{0}C, the relative humidity was in the range of 70.00-72.60 % and the mean wind speed was in the range of 0.13-0.34 m/s.

In dry season, precipitation (rain) is reduced and resuspension is enhanced and washout is also reduced. The low rainfall period, the aging and recirculation of pollutant in air mass expounds the violation in the permissible limit during the dry season.

The wet season affects the inhalable fraction more than the respirable fraction; that is inhalable fraction washes away more than the respirable fraction. From the data generated, inhalable fraction showed a clear seasonal pattern during the dry and wet season over the respirable suspended particulate matter.

The ratio of the dry to wet season inhalable fraction ranged from 1-3 while the ratio of the dry to wet season respirable fraction ranged from 1-2.

Table 4 and 5 show the toxicity potential from inhalable fraction for both wet and dry season. The toxicity potential ranged from 0.97-3.00 for dry season while for wet season ranged from 0.93-1.540. The toxicity potential for inhalable fraction was higher than the toxicity potential for wet season. The exposure and the damaging effect of inhalable fraction is higher during the dry season when compare to the wet season.

Table 6 and 7 show the toxicity potential for respirable fraction for both dry and wet season. The toxicity potential for dry season ranged from 1.60-4.00 while the toxicity potential for wet season ranged from 1.60-3.20 the toxicity potential of respirable fraction is higher than of the toxicity potential of inhalable fraction. A toxicity potential greater than unity is harmful to human; as seen from this work the toxicity potentials for both inhalable and respirable exceeded unity except for residential house (during wet season in Inhalable) which was lesser than unity.

The concentration of inhalable fraction during the dry ranged from 145.83-437.50 μg/m^3 while in wet season it ranged from 104.17-225.67 μg/m^3. And the concentration of the respirable fraction during the dry ranges from 104.17-208.33 μg/m^3 while the wet concentration range from 104.17.208.17 μg/m^3.

Table 8 and Table 9 show the spatial and temporal variation of the particulate matter captured. Table 8 shows the concentration of inhalable suspended matter for both dry and wet season. The permissible limits for inhalable and respirable fractions are 150 μg/m^3 and 65 μg/m^3 respectively. At the five monitoring site during the dry season for both inhalable and respirable fraction were clearly exceeded excepts site D in inhalable fraction while in wet season, the inhalable and respirable fraction exceeded the permissible limit set by (NAAQS) except in sites A, B and C for inhalable fraction which fall within the purview of the permissible limit.

Table 2 Ambient temperature relative humidity and wind speed between December 2008 and April 2009 for the various sampling locations in Obaretin

		Ambient temperature (^OC)		Relative humidity (%)		Wind Speed ($^m/_s$)	
S/NO	**Site Code**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
1.	RHA	27.10 – 35.20	30.10	59.14 – 70.00	68.40	0.0 – 0.3	0.20
2.	RHB	28.10 – 33.10	30.00	66.20 – 72.60	69.20	0.0 – 0.4	0.25
3.	RHC	25.10 – 29.70	26.40	68.10 – 71.20	70.20	0.0 – 0.5	0.34
4.	RHD	25.00 – 28.00	26.50	66.40 – 70.00	69.80	0.0 – 0.6	0.30
5.	RHE	28.10 – 34.50	30.20	50.10 – 70.00	67.20	0.0 – 0.2	0.13

Table 3 Range and mean of ambient temperature, relative humidity and wind speed in Obaretin during wet season

		Ambient temperature (^OC)		Relative humidity (%)		Wind Speed ($^m/_s$)	
S/NO	**Site Code**	**Range**	**Mean**	**Range (%)**	**Mean (%)**	**Range**	**Mean**
1.	RHA	25.00 – 31.20	28.40	64.20 – 84.40	73.30	0.0 – 0.4	0.15
2.	RHB	26.80 – 30.00	27.50	70.60 – 80.20	74.40	0.0 – 0.3	0.20
3.	RHC	25.10 – 28.40	27.40	72.10 – 84.50	77.30	0.0 – 0.5	0.25
4.	RHD	26.90 – 29.00	28.00	80.20 – 90.30	84.25	0.0 – 0.6	0.30
5.	RHE	27.20 – 32.20	29.00	65.10 – 75.30	70.20	0.0 – 0.3	0.10

Table 4 Spatial variation of inhalable fraction measured in Obaretin

S/N	Sampling Site	Site Code	Max	Min	Mean	Standard Deviation
1.	Rural house A	RHA	416.67	104.17	179.93	105.11
2.	Rural house B	RHB	520.83	104.17	170.46	133.99
3.	Rural house C	RHC	208.33	104.17	189.39	42.13
4.	Rural house D	RHD	208.33	104.17	142.05	52.55
5.	Rural house E	RHE	520.83	208.23	321.95	127.21

Table 5 Temporal variations of the measured inhalable fraction

S/N	Sampling Site	Site Code	Dry Season Mean (μg/m^3)	Wet Season Mean (μg/m^3)	Dry/Wet Season Ratio	Regulatory Limit by NAAQS
1.	Rural house A	RHA	229.17	138.89	1.65	150μg/m^3
2.	Rural house B	RHB	250.00	104.17	2.40	
3.	Rural house C	RHC	208.33	190.97	1.09	
4.	Rural house D	RHD	145.83	138.89	1.05	
5.	Rural house E	RHE	437.50	225.67	1.94	

Table 6 Spatial variation of respirable fraction measured in Obaretin (μg/m$^{3)}$

S/N	Sampling Site	Site Code	Max	Min	Mean	Standard Deviation
1.	Rural house A	RHA	208.33	104.17	151.52	54.40
2.	Rural house B	RHB	208.33	104.17	123.11	42.13
3.	Rural house C	RHC	208.33	104.17	132.57	48.65
4.	Rural house D	RHD	104.17	104.17	104.17	1.49
5.	Rural house E	RHE	312.5	104.17	208.33	46.58

Table 7 Temporal variations of the measured respirable fraction

S/N	Sampling Site	Site Code	Dry Season Mean (μg/m^3)	Wet Season Mean (μg/m^3)	Dry/Wet Season Ratio	Regulatory Limit by NAAQS
1.	Rural house A	RHA	187.50	121.53	1.54	65μg/m^3
2.	Rural house B	RHB	145.83	104.17	1.40	
3.	Rural house C	RHC	166.67	138.89	1.20	
4.	Rural house D	RHD	104.17	104.17	1.00	
5.	Rural house E	RHE	208.33	208.17	1.00	

Table 8 The toxicity potential in suspended particulate matter for inhalable

S/N	Sampling Site	Site Code	Toxicity Potential for dry	Toxicity Potential for wet
1.	Rural house A	RHA	1.53	0.93
2.	Rural house B	RHB	1.67	0.69
3.	Rural house C	RHC	1.39	1.27
4.	Rural house D	RHD	0.97	0.93
5.	Rural house E	RHE	2.92	1.53

Table 9 The toxicity potential in suspended particulate matter for respirable

S/N	Sampling Site	Site Code	Toxicity Potential for dry	Toxicity Potential for wet
1.	Rural house A	RHA	2.88	1.87
2.	Rural house B	RHB	2.24	1.60
3.	Rural house C	RHC	2.56	2.14
4.	Rural house D	RHD	1.60	1.60
5.	Rural house E	RHE	3.21	3.20

Fig. 2 and 3 show the correlation of inhalable and respirable during wet and dry season. The linear relationship model showed that there was a strong positive linear relationship between inhalable and respirable.

Fig. 4 shows the seasonal trend from December 2008 to October 2009. From December 2008 to May 2009, there was a decrease in the mean concentration of inhalable and respirable fractions, while October had the lowest the concentration, this was as a result of torrential downpour during this month.

Fig. 5 and 6 are the GIS maps for inhalable and respirable respectively showing the concentration for the spatial and temporal variations.

The poor air quality in Obaretin is strongly associated with biomass burning, bush burning as preplanting operation traffic related emission and incinerate of waste. The spatial distribution was significant and remarkable ($P<0.05$).

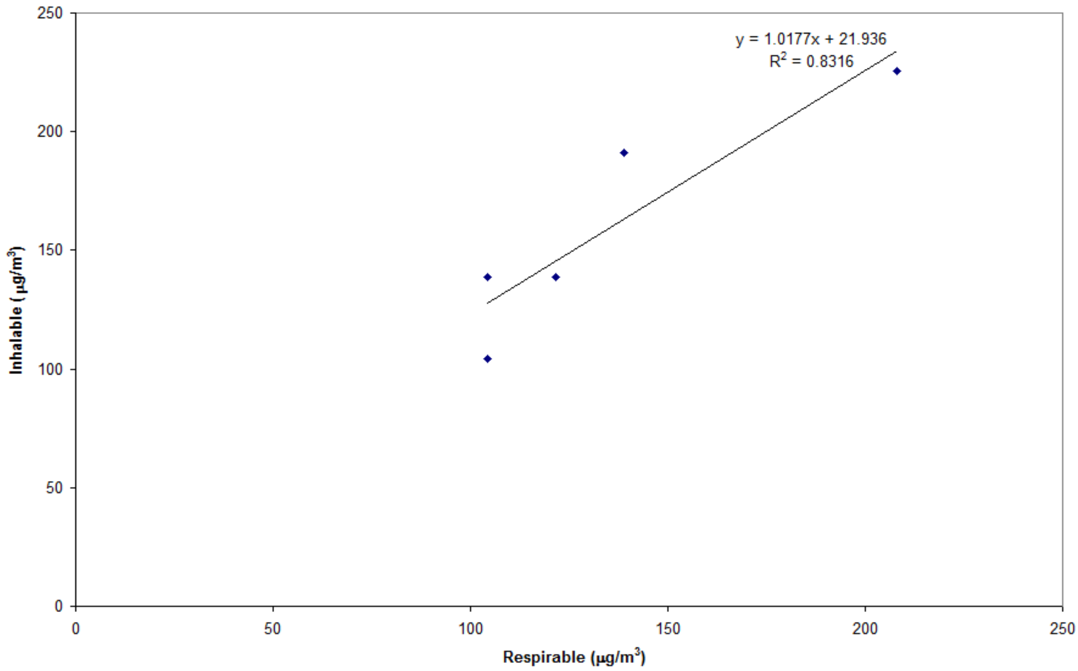

Fig. 2 The correlation of mean inhalable with mean respirable for obaretin wet season.

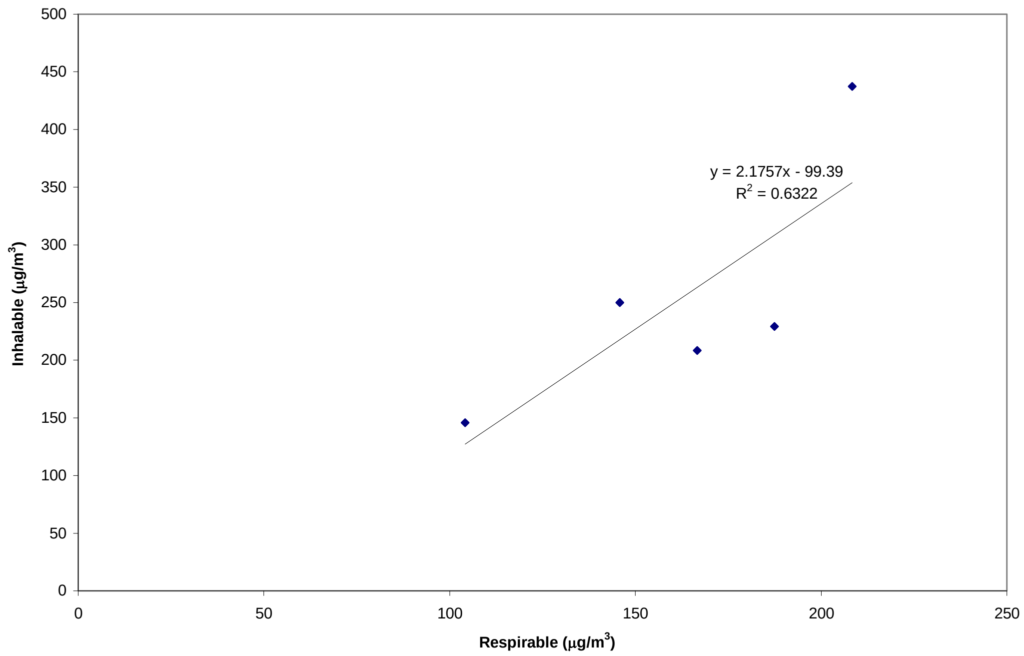

Fig. 3 The correlation of mean inhalable with mean respirable for obaretin dry season.

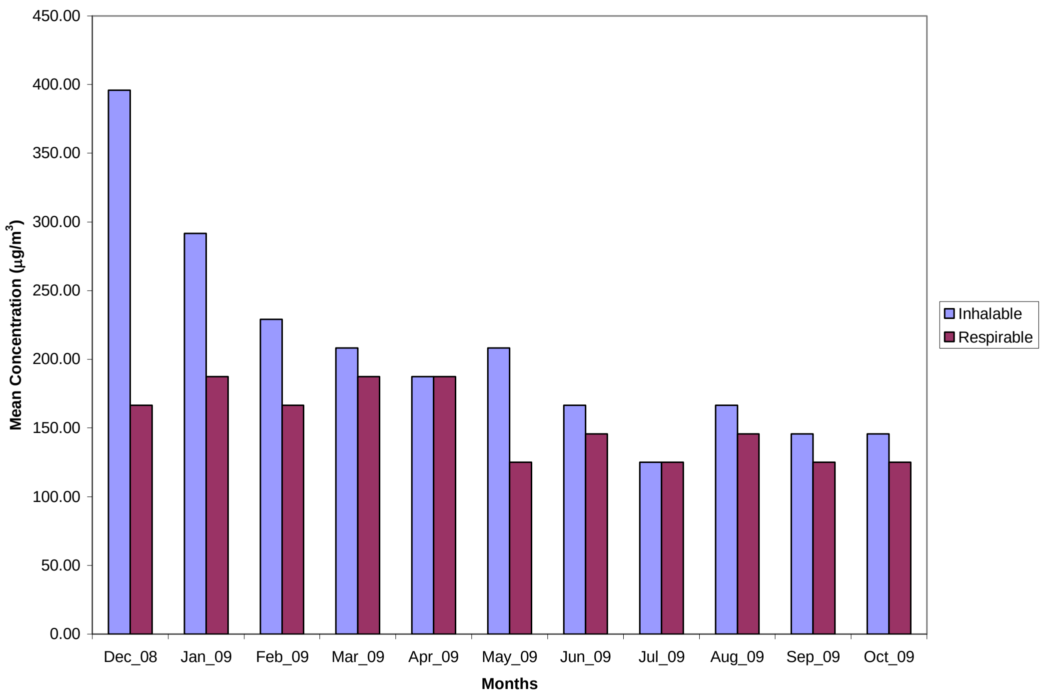

Fig. 4 Monthly concentration of mean concentration of inhalable and respirable.

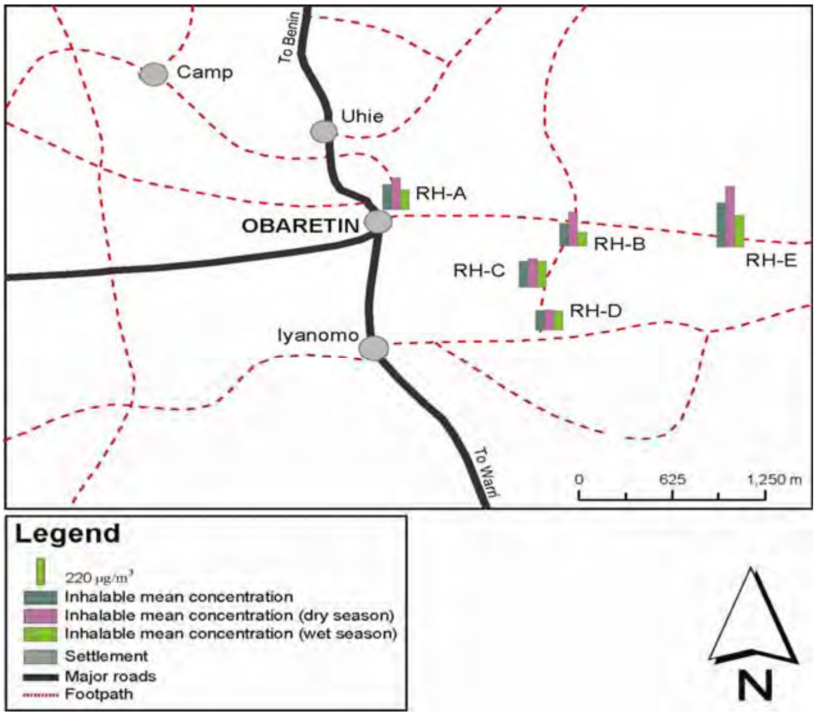

Fig. 5 GIS map for inhalable particle in obaretin.

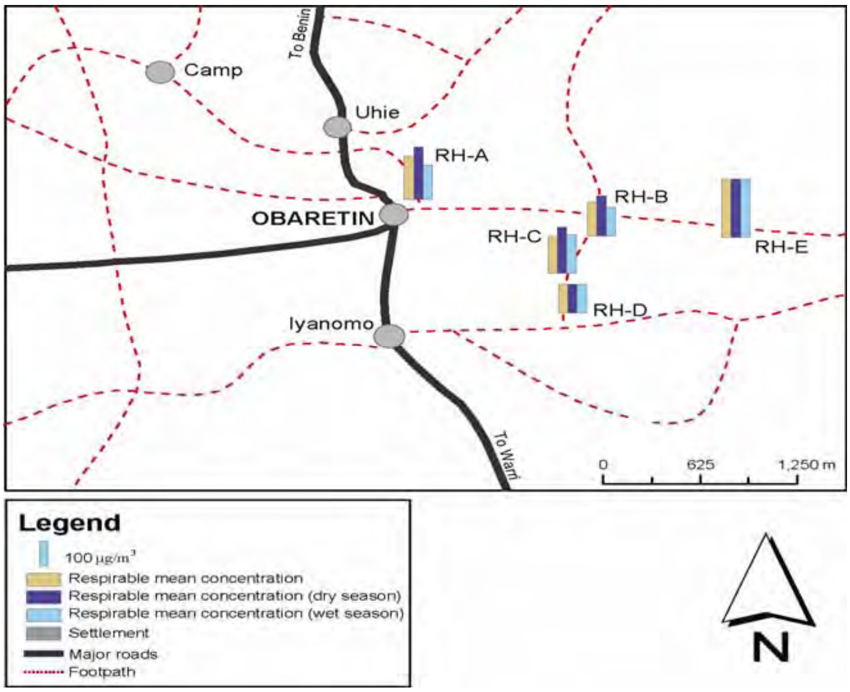

Fig. 6 GIS map of respirable particle in obaretin.

4 Conclusion

The air-borne particulate matter is a serious problem in Nigeria. This study has measured simultaneously the inhalable and respirable atmospheric particulate matter. The results show that the captured particulate matter exceeded set standard by (NAAQS).

The ratio of dry season to wet season inhalable particulate matter varied from 1.05 to 1.94 while respirable dry to wet varied from 1.00 to 1.54. The temporal variations are mainly due to meteorological factors such as, precipitation, wind speed, relative humidity and temperature.

The major sources of particulate matter are vehicular related emission, incineration of solid waste and gas flaring biomass burning and resuspended dust. The spatial distribution were significant and remarkable ($P<0.05$).

However, the since then has been a minute information on this subject matter it is hoped that the data generated will offer a sublime information for policy maker and other regulatory bodies in the country.

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