CORRELATION OF METEOROLOGICAL PARAMETERS AND DUST PARTICLES USING SCATTER PLOT IN A RURAL COMMUNITY

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ABSTRACT

This study investigated the spatial distribution of repirable and inhalable suspended particulate matters and the influence of meteorological factors on the pollutants captured in a rural community. The respirable and inhalable suspended particulate matters were captured at five different locations using Portable Programmable SKC Air Check XR5000 High Volume Gravimetric Sampler Model. The meteorological parameters were captured using anemometer and hydro thermograph from May 2009 to October 2009. The mean concentration range of respirable suspended particulate matter was 104.17-208.33μg/m^3 and the inhalable suspended particulate matter was in the range of 104.17-225.69 μg/m^3. The spatial distribution of respirable and inhalable suspended particulate matter was significant and remarkable ($P<0.05$). The mean concentrations of the respirable and inhalable particulates were generally higher than the regulatory limits set by the United States National Ambient Air Quality Standards indicating poor air quality. The correlations of respirable and inhalable suspended particulate matter with wind speed and relative humidity were negative while it was positive with temperature.

Keywords: Respirable, Inhalable, Particulate, Scatter Plot, Meteorological Parameter, Rural Area

INTRODUCTION

The distinction between coarse or inhalable and fine or respirable particles is made due to the differences in sources, formation mechanisms, composition, atmospheric lifetimes, spatial distribution, indoor-outdoor ratios, temporal variability, in addition to size and health impacts (Wilson *et al.*, 1997).

Recently, problems caused by atmospheric particulate matter (PM) have received greater attention. Various health effects attributable to particulate matter have been documented (Brunekreef and Holgate, 2002; WHO, 1999). The most conclusive evidence has been provided by cohort and time series students that have linked elevated concentrations of PM to increased morbidity and mortality (Ediagbonya and Tobin, 2012; Samet *et al.*, 2000; Katsonyanni et al., 1997; Pope *et al.*, 1995). The majority of recent health studies suggested that fine particle ($PM_{2.5}$) or respirable particles arising mainly from man-made sources are more harmful than coarse or inhalable particles (Pope *et al.*, 2002; Hopke *et al.*, 2002; Laden *et al.*, 2002; Mar *et al.*, 2000; Schwartz *et al.*, 1996). Several efforts have also been specifically aimed at studying concentrations and potential health effects of the so-called ultra fine particles in the size range below 0.1μm (de Harrtog et al., 2003; Ruuskarien *et al.*, 2001; Peters et al., 1997). However some studies have also detected adverse health effects related to coarse or inhalable particle (Mar *et al.*, 2000).

There is a balance between the factor that leads to pollutant accumulation and the factor that leads to pollutant dispersion controls, temporal and spatial variation in concentration of pollutants (Fang *et al.*, 2000). Firstly, the concentration and other characteristics of suspended particulate matter are determined by the presence and the activity of the source. Once a formed particle changes its sizes and composition by condensation, evaporation, or by coagulating with other particles or by chemical reaction, the concentration in the atmosphere is either reduced or increased depending on the size of the particles. The smaller the particle sizes, the higher is the residence time in the atmosphere (Seinfelt and Pandis, 1998). Secondly, meteorological factors such as wind speed and direction, temperature, amount of precipitation and the height of the atmospheric boundary layer are most important factors governing the concentration variation of particulate matter in the atmosphere (Ediagbonya *et al.*, 2013; Pohjola *et al.*, 2000). The highest PM concentrations are often reported during stable meteorological condition such as inversion and low wind speed (Pohjola *et al.*, 2004). Particulate matter of thoracic size may be emitted from a number of sources, some of them are natural (e.g volcanoes and dust storms), while others may be man-made (power plants and industrial processes, vehicular traffic, domestic coal burning, industrial and municipal waste incinerators). The majority of these man-made sources are concentrated in limited area i.e. urbanized area, where population is also concentrated.

In industrial countries, the difference between mass concentration of total suspended particulate matter (TSP) and PM_{10} (inhalable particle) and between PM_{10} and $PM_{2.5}$ (respirable particle) is usually larger in urban and industrial areas than in rural area. This is due to the larger fractions of relatively small secondary particles in rural area, originating mainly from long range transport of air pollutants (Tarrason and Tsyro, 1998). Sedimentation and deposition of larger particles take place close to the emission sources. Thus, the proportion of $PM_{2.5}$ relative to TSP and PM_{10} is usually higher in rural areas. Typical contributions of sulphate, nitrate and ammonium particulate to the total $PM_{2.5}$ mass are about 40% in urban area and 50% in rural regions (Seinfelt and Pandis, 1998).

MATERIALS AND METHOD

Sampling was done in Obaretin in Ikpoba-Okha Local Government Area of Edo State in the Niger Delta Region of Nigeria (Fig. 1 and Table 1). The rural community is sparsely distributed with a population estimate of few thousands of inhabitants. The settlement is situated along the main road. Thick rubber plantations and industrial farms are located behind the community. The rural dwellers engage themselves in farming, hunting, rubber tapping and inter or intra-transportation due to the accessibility of the community to the main road. Also the people are engaged in cassava processing and smoking of fishes. Their major way of waste disposal is by burning. The main road that lead to the community is unpaved and very dusty. It follows therefore that the major human activities in this region that generate pollution are the particulate generated from motor bike and vehicle exhaust, bush burning and re-suspended particles from the unpaved road.

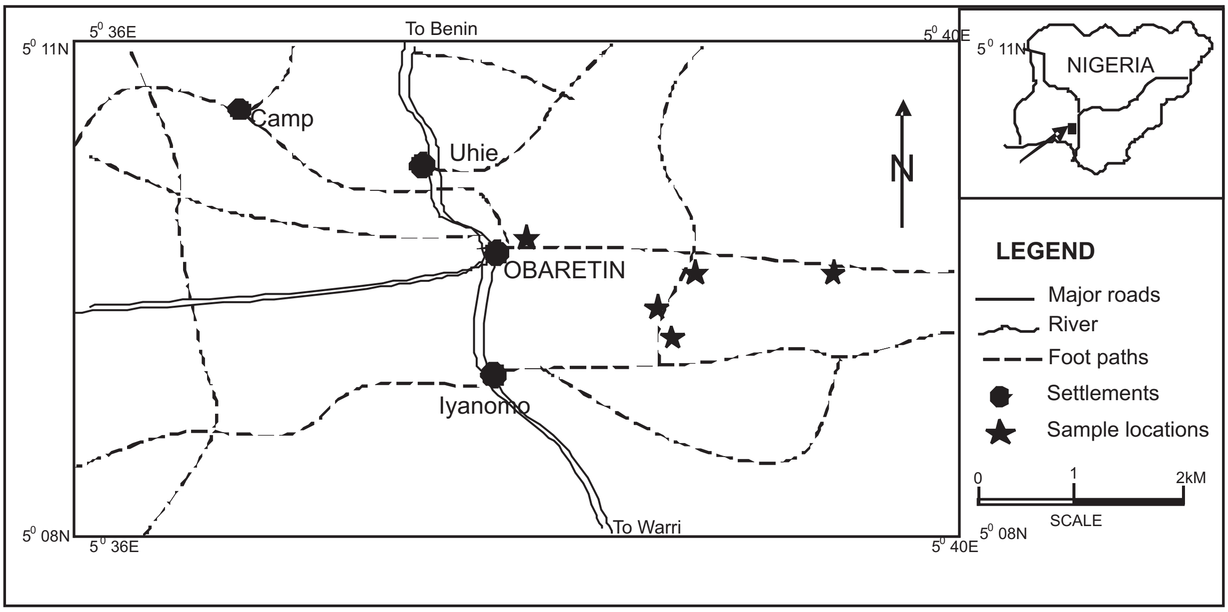

Fig. 1: Obaretin and Environs Showing the Sampled Locations.

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Table 1: Monitoring Sites and their Co-ordinates

Site No.	Site Code	Topographic Co-ordinates	Site Description
1	RH_A	N06°09' 43.3" E005° 38' 49.2"	Mud house detached, kitchen unceiled roof
2	RH_B	N06° 09'46.9" E005° 38'44.7"	Mud house detached, kitchen unceiled roof
3	RH_C	N06°09' 46.9" E005° 38' 48.1"	Mud house detached, kitchen unceiled roof
4	RH_D	N06° 09' 40.0" E005°38' 53.8"	Mud house detached, kitchen unceiled roof
5	RH_E	N06° 09' 35.8" E005° 38'30.4"	Mud house detached, kitchen unceiled roof

Ambient Air Sampling and Analytical Procedure

SKC Air check XR5000 High volume Gravimetric sampler Model 210-5000 serial No. 20537 and the I.O.M multi fraction dust sampler (Institute of Occupational Medicine) were used in this study. The sampling train was made of an air mover, a flow measuring device and a sample collection. A flow of air was created by the air mover which allowed the capture of contaminants in the air into the sample collection. The collection mechanism was made of cassette cover front plate, two-o-rings, cassette rear front and the sampler body which was connected to a vacuum pump with a Teflon tube. The inbuilt flow meter has a rating of 1000 ml/min to 5000 ml/min of air samples which was calibrated into 2000 ml/min (2 l.min). Before sampling, the unit was carefully calibrated against a standard meter to determine the quantity of air flows and all unloaded glass fiber filter and the foam were dried in the desiccator at room temperature. The respirable foam was affixed to 25 mm diameter filter for inhalable dust sampling with a flexible sample head to determine the respirable particle. The filter and cassette rear were pre-weighed to determine the initial respirable dust, while the filter, foam and whole cassette together were pre-weighed to determine the initial inhalable dust. After sampling, the filter, foam, with the whole cassette together were re-weighed to determine the inhalable fractions. The respirable fraction was determined by weighing the cassette rear and the filter only. These particles were collected at a flow rate of 21/min for eight hours and the sampler was placed between heights of 1.5-2 m to reflect the breathing zone of man. The difference between the final weight and the initial weight was the amount of respirable and inhalable dust collected (Shaw, 1987; UNEP / WHO, 1994).

The concentration in μg/m^3 was calculated using the equation below:

$$\frac{(\text{Final weight (mg)} - \text{ initial weight (mg)}) \times 1000}{\text{Flow rate (m}^3\text{min)} \times \text{sampling period (min)}}$$

To qualitatively estimate the possible impact of the airborne particulate on the health of neighbouring receptor, the toxicity potentials (TP) of respirable and inhalable suspended particulate matter (REPM &ISPM) were calculated by dividing the concentration for each sampling site with the daily average USEPA National Ambient Air Quality standard level concentrations of 155 and 65 μg/m^3 for inhalable and respirable particle (USEPA, 1980) respectively.

Meteorological Parameters

Air temperature and humidity were measured simultaneously four times a week during the particulate sampling by using RS Humidity/Temperature meter with resolution of 0.1% RH and 0.1°C (model RS 1364. RS Component Ltd UK). Wind speeds were also measured using LM-8000 Anemometer (Heatmiser uk) with resolution of 0.1 m/s.

RESULTS AND DISCUSSION

Tables 2 and 3 show that the concentrations of the respirable and inhalable particulate matters range between 104.17 and 208.33 μg/m^3 and 104.17 312.50 μg/m^3 respectively as against the regulatory limits of 65 μg/m^3 and 150 μg/m^3 respectively set by the United States National Ambient Air Quality (USNAAQ) Standards. The spatial variations in the data obtained were significant ($p< 0.05$) for both respirable and inhalable. The concentrations of the respirable fraction clearly exceeded the regulatory limit set by the United States National Ambient (USNA) Air Quality in all the sites (Table 2) while only sites 1, 2 and 4 had mean concentrations of inhalable particulates that are below the USNA Air Quality regulatory limits (Table 3). The highest mean concentration of respirable fraction captured was observed at site 5 while the lowest mean concentration was observed in site 2 (Table 2). The highest mean concentration of inhalable fraction captured was observed at site 5, a site close to an unpaved road, while the lowest mean concentration was observed at site 2. It is suspected that the generally high concentrations of both the respirable and inhalable particulates might be significantly due to the unpaved road very close to the sampled sites. Paved and unpaved roads are among the largest emitters of particulate matter in many areas (Ruellan and Cachier, 2001).

The variations in the concentrations of particulate matter at the various sites could also be attributed to factors such as burning of wood as source of fuel, bush burning as a pre-planting operation and burning of waste as means of waste disposal at different locations, wind speed, relative humidity, atmospheric stability as well as the local terrain.

Table 4 shows that the toxicity potential for respirable particulates ranges from 1.60 3.21 and 0.69 1.50 for inhalable particulates. By the United States Environmental Protection Agency (USEPA) Standards, toxicity potential values greater than 1 indicate potentially toxic deposition at a receptor location (USEPA, 1980). Using this threshold, sites 1-5 are potentially toxic for respirable particulates and sites 3 and 5 for inhalable particulates.

Table 5 contains the mean temperature, relative humidity and wind speed at the investigated sites. The mean ambient temperature ranges from 27.4 - 29.0°C, while the mean relative humidity ranges from 70.2 - 85.2% and the mean wind speed from 0.1- 0.3 m/s.

Table 2: The Range and Mean Concentration of Suspended Respirable Particulate Matter.

Site No.	Site Code	Range (µg/m^3)	Mean (µg/m^3)	Regulatory Limit
1	RH_A	104.17-208.33	121.53 ± 42.53	65 µg/m^3
2.	RH_B	104.17-104.17	104.17 ± 00.00	"
3.	RH_C	104.17-208.33	138.89 ± 53.79	"
4.	RH_D	104.17-104.17	104.17 ± 00.00	"
5.	RH_E	208.33-208.33	208.33 ± 00.00	"

Table 3: Range and Mean Concentration of Suspended Inhalable Particulate Matter.

Site No.	Site Code	Range (µg/m^3)	Mean (µg/m^3)	Regulatory Limit
1.	RH_A	104.17-208.33	138.89 ± 53.79	150 µg/m^3
2.	RH_B	104.17-104.17	104.17 ± 00.00	"
3.	RH_C	104.17-208.33	190.97 ± 42.52	"
4.	RH_D	104.17-208.33	138.89 ± 53.79	"
5.	RH_E	208.33-312.50	225.69 ± 52.54	"

Table 4: The Toxicity Potential for Respirable Particles and Inhalable Particles.

Site No.	Site Code	Respirable Particles	Inhalable Particles
1	RH_A	1.87	0.92
2	RH_B	1.60	0.69
3	RH_C	2.14	1.27
4	EH_D	1.60	0.92
5	RH_E	3.21	1.50

Table 5: Mean of the Ambient Temperature Relative Humidity and Wind Speed Between May 2009 and October 2009.

		Ambient Temperature (°C)		Relative Humility (%)		Windspeed (m/s)	
Site No.	Site Code	Range	Mean	Range (%)	Mean (%)	Range	Mean
1	RH_A	25.00 - 31.20	28.40	64.20 - 84.40	74.30	0.0 - 0.3	0.15
2	RH_B	26.80 - 30.00	27.50	70.60 - 80.20	75.40	0.0 - 0.4	0.20
3	RH_C	25.10 - 28.40	27.40	72.10 - 84.50	78.30	0.0 - 0.5	0.25
4	RH_D	26.90 - 29.00	28.00	80.20 - 90.30	85.25	0.0 - 0.6	0.30
5	RH_E	27.20 - 32.20	29.00	65.10 - 75.30	70.20	0.0 - 0.2	0.10

Correlation between Respirable and Inhalable Suspended Particulate Matter and Wind Speed.

The correlation between respirable and inhalable suspended particulates and wind speed are shown in Figures 2 and 3. The figures show that the concentrations of both suspended particulates generally decrease with increase in wind speed. The correlation coefficients are however relatively low at r = 0.69 and 0.40 respectively (see Figures 2 and 3). The effect of wind speed on pollutants is twofold: one effect is that wind speed will determine the travel time of a pollutant form a source to a receptor while the other effect is that it reduces the amount of pollutant in the wind ward direction.

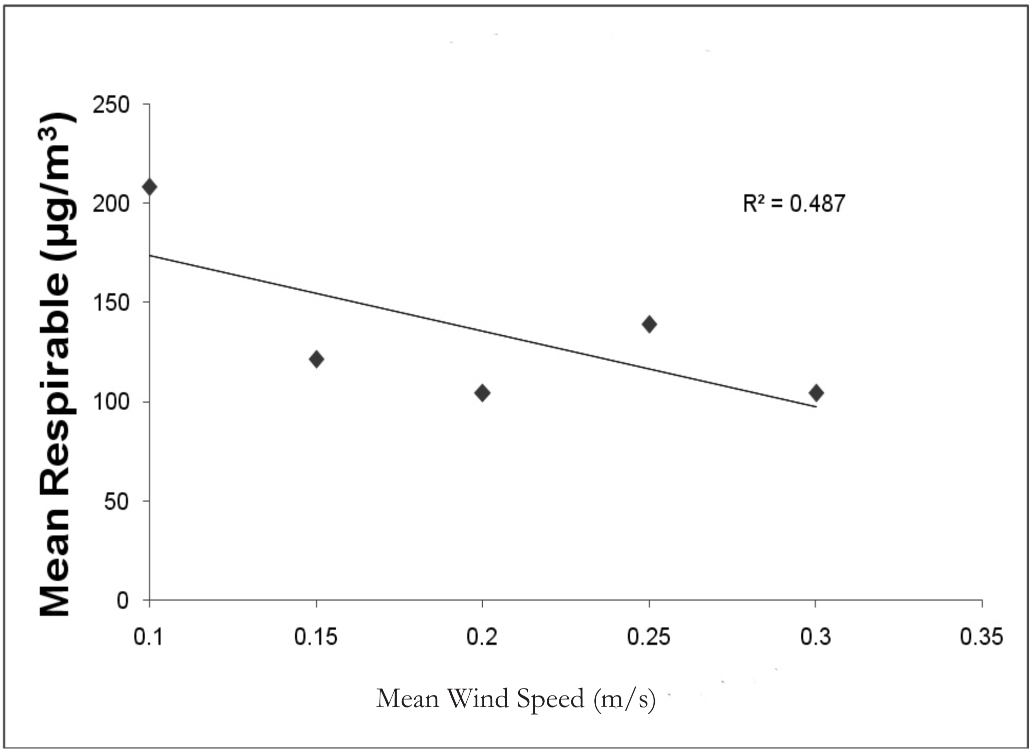

Fig. 2: Correlation of Mean Respirable Particle with Mean Wind Speed (Scatter Plot)

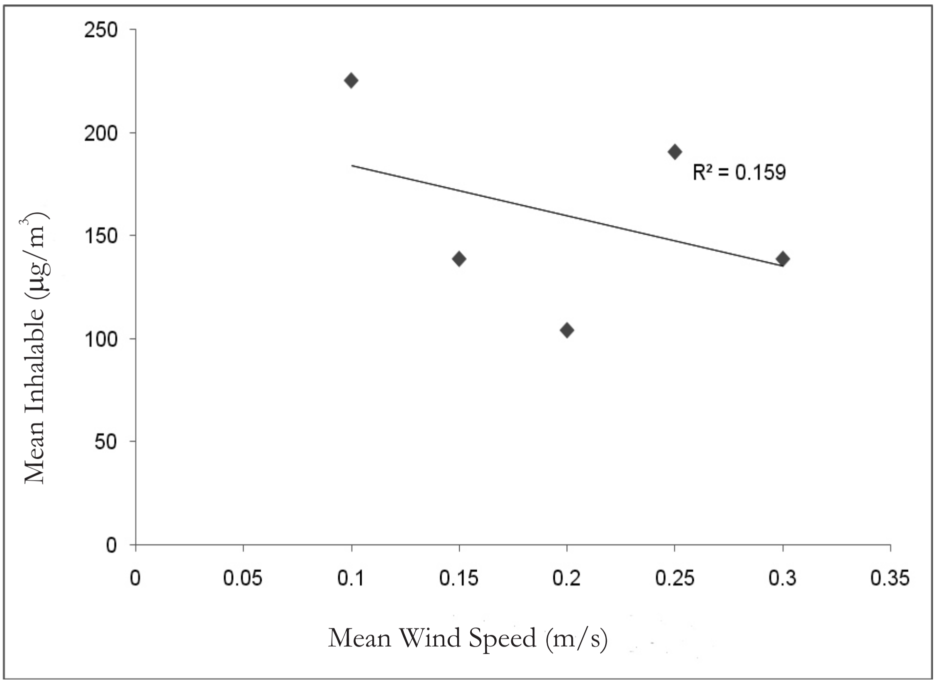

Fig. 3: Correlation of Mean Inhalable Particle with Mean Wind Speed (Scatter Plot)

Correlation between Respirable and Inhalable Suspended Particulate Matter and Relative Humidity.

Figures 4 and 5 show the correlation of the mean concentrations of respirable and inhalable particulates with mean relative humidity. The particulates generally show a decrease in concentration with increase in humidity. The correlation coefficients are however low at r = 0.68 and 0.40 respectively. Particulate matter is hygroscopic in nature. Generally, as the relative humidity increases, the PM decreases. The higher the relative humidity, the smaller the particulate in the atmosphere due to the adsorption of water vapour onto the particulate mater which may increase their settling rate and deposition.

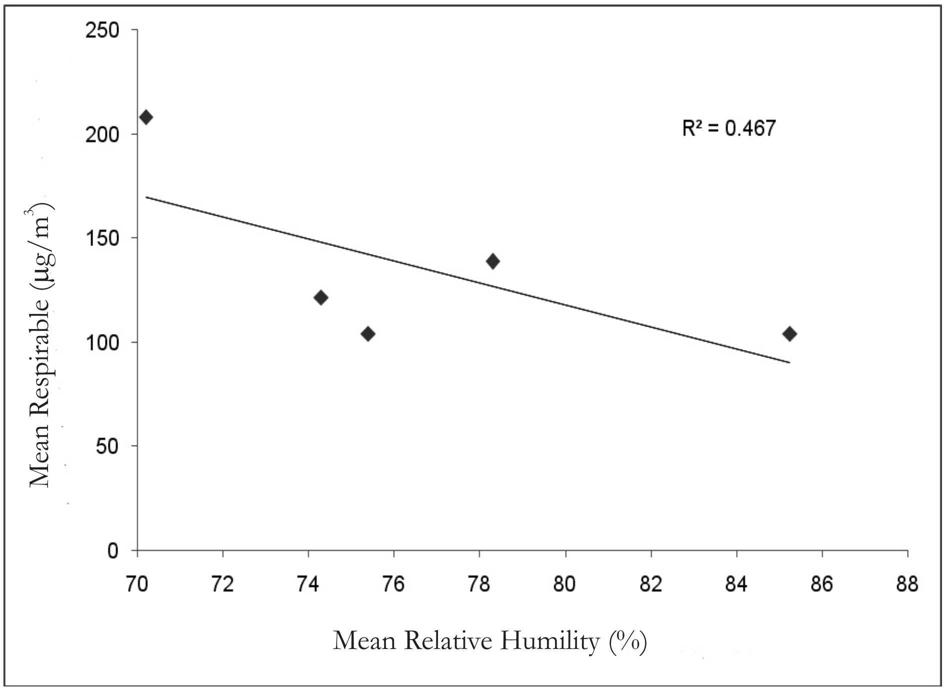

Fig.4: Correlation of Mean Respirable Particle with Mean Relative Humidty (Scatter Plot)

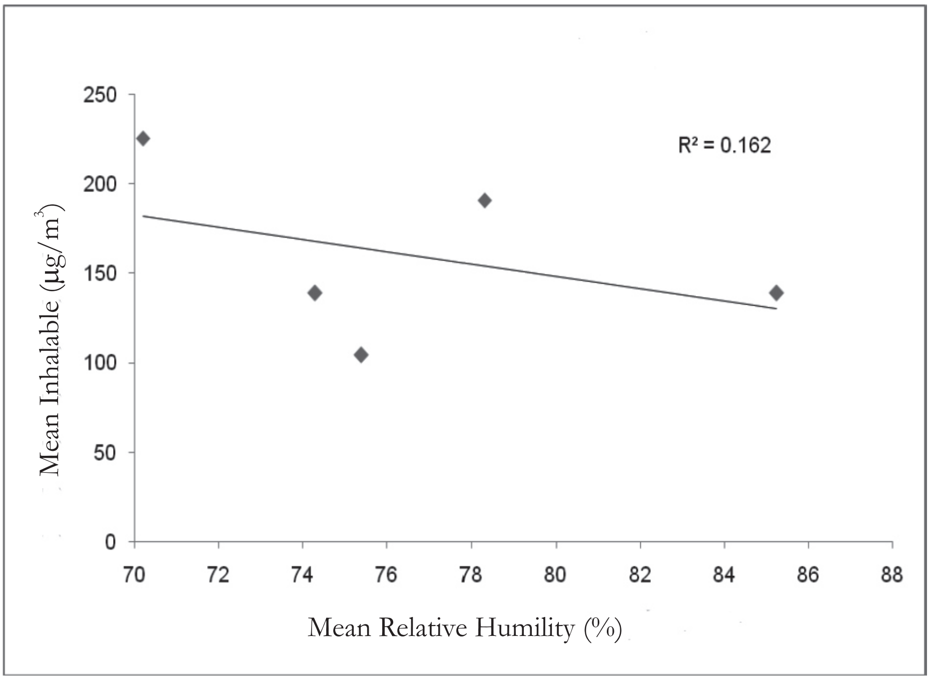

Fig. 5: Correlation of Mean Inhalable Particle with Mean Relative Humidity (Scatter Plot)

Correlation between Respirable and Inhalable Suspended Particulate Matter with Temperature.

Wind speed and relative humidity may not be sufficient to explain the variability in concentration of suspended particulate matter in the atmosphere hence the correlation of the atmospheric temperature with and respirable and inhalable suspended particulate matter. Figures 6 and 7 show the correlation of the mean concentrations of repirable and inhalable particulates with the mean temperature. The particulates generally show an increase in concentration with increase in temperature with correlation coefficients of r = 0.71 and 0.52 respectively. High temperature increases the reactivity of gaseous constituents in the atmosphere resulting in greater particulate production.

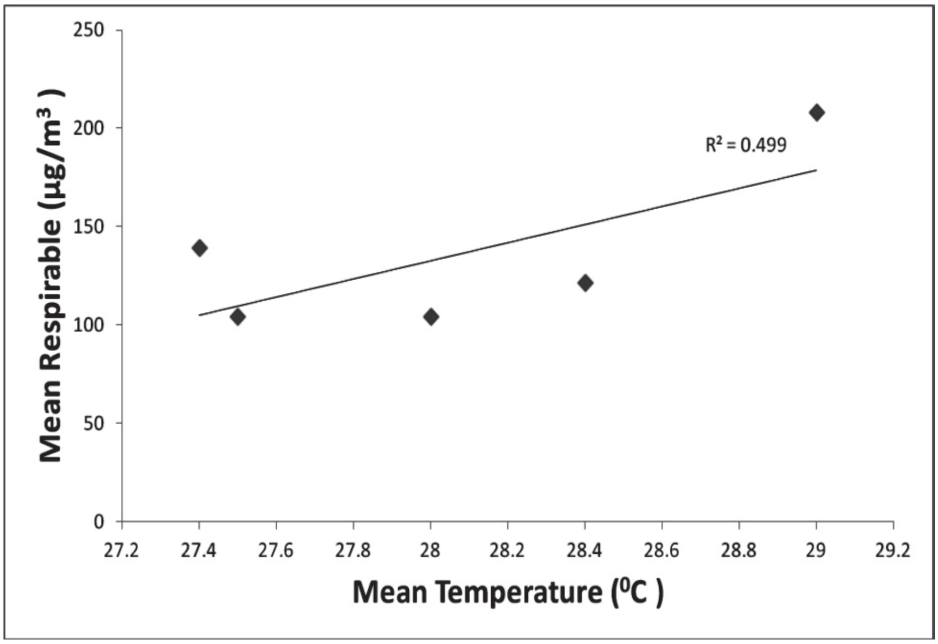

Fig 6: Correlation of Mean Respirable with Mean Temperature (Scatter Plot)

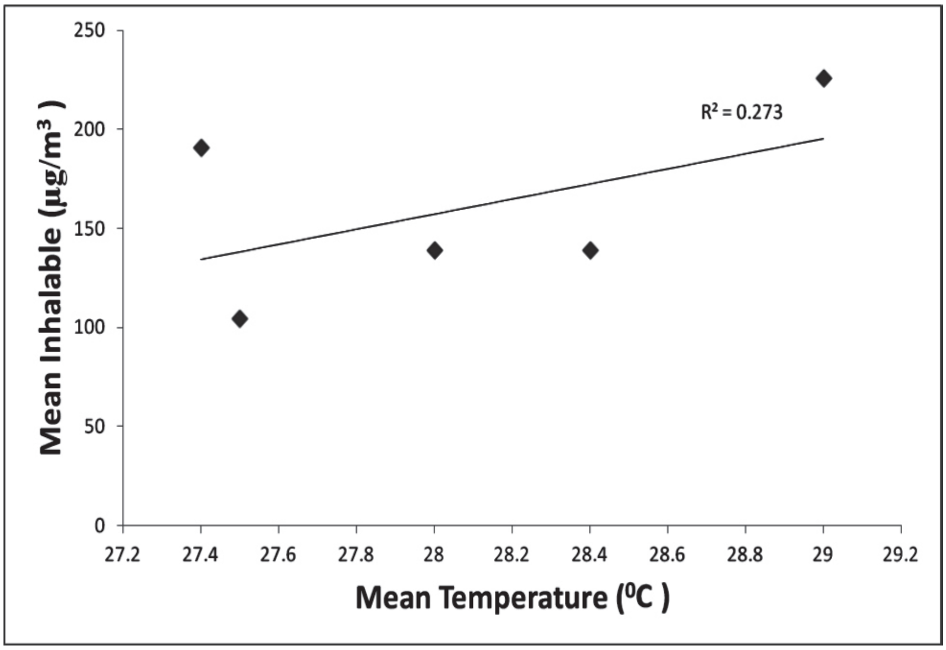

Fig 7: Correlation of Mean Inhalable with Mean Temperature (Scatter Plot)

CONCLUSION

The results obtained in this study showed that there was a spatial distribution of respirable and inhalable particle in the study area. The concentrations of the inhalable particulates are relatively higher than the concentrations of the respirable particulates. The mean concentrations of the respirable and inhalable particulates are generally higher than the regulatory limits set by the United States National Ambient Air Quality Standards indicating poor air quality. The poor air quality in the study area could be attributed to unpaved road network, indiscriminate bush burning, burning of waste and open space burning of wood. The concentrations of the particulates generally decrease with increase in wind speed and relative humidity but increase with increase in temperature.

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