Contributions Of Black Carbon Concentration To Atmospheric Particulate Matter Levels In Navrongo Senior High School. October, 2010-March, 2011.

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ABSTRACT: The objective of this research was to assess the black carbon concentration in air borne particulate matter in ambient air due to the use of biomass for cooking in the Navrongo Senior High School. The Gent air sampler was used to sample airborne particulate matter in the Navrongo Senior High School. These particulates were collected on nuclepore polycarbonate filters for a period of six months. In addition to determination of particulate mass in the two fractions by gravimetric method, the aerosol filters were also analyzed for black carbon (BC) concentration levels using the black smoke reflectometer method. The average fine fraction mass concentration determined was 134.59µgm^{-3} (with a minimum of 9.28µgm^{-3} and a maximum of 338.11µgm^{-3}) and that of coarse fraction (CF) was 355.04µgm^{-3} (with a minimum of 61.73µgm^{-3} and a maximum of 1117.43µgm^{-3}). The black carbon concentration in fine, average was 7.62µgm^{-3} (with a minimum of 1.68µgm^{-3} and a maximum of 35.35µgm^{-3}) and that of the coarse was 6.92µgm^{-3} (with a minimum of 1.76µgm^{-3} and a maximum of 22.61µgm^{-3}). The results of this research were compared to other works in the country. It was however realized that the values of this research were about twice as much as the other works. This was due to the fact that biomass burning is generally used for cooking in the study area which is usual of Northern Ghana and so produces a lot of black carbon as compared to the other area which are semi-urban areas in the southern part of the country. The values obtained for coarse to fine particulate matter ratio suggest that, the particulates were not only largely made up of combustion generated carbonaceous particles but also particulate matter emissions from natural activities.

Keywords: Biomass, Black carbon, Gent sampler, Gravimetric, Navrongo.

1.0 INTRODUCTION

Atmospheric pollution from anthropogenic activities is not only a local issue but it is also a regional as well as global problem. During the last decade, a greater awareness has been created in the general public and governments as to the impact of pollutants on the quality of human life and in general the ecosystems. As a result, rapid progress is being made in different regions of the industrialized world to develop a better understanding on the issues related to various aspects of the environment and its pollution including air pollution (Bilkis et al, 2010). Atmospheric aerosols stimulate strong research interest primarily due to their importance in influencing climate, restricting visibility and causing deleterious effects on human health. They play both direct and indirect roles in various atmospheric phenomena (Charlson et al, 1992). The direct effect includes the absorption or scattering of the solar irradiance by aerosols and indirect influence pertains to the modification of the cloud microphysical properties (Toon, 2000). Air, an invisible gas made up of a mixture of mainly nitrogen and oxygen is one of the fundamental basics of life for humans, animals and plants. The quality of the air we breathe is therefore essential for our health. It is becoming increasingly important to keep it clean for the future, as lots of contaminants such as smoke, dust and gases are discharged into the atmosphere.

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Air pollution occurs when contaminants are released into the air, in amounts that could be harmful to people and animals, or could damage plants (Sam-Quarcoo et al, 2012). Black carbon (BC), the optically absorbing part of carbonaceous aerosols, is the major anthropogenic component of atmospheric aerosol system, which has significantly different optical and radiative properties, as compared to the other normal constituents (Badarinath et al, 2009). BC acts as an indicator of airmass affected by anthropogenic pollution (Penner, 1995). Current estimates of total global emission are approximately 8 Tg C yr−1 (IPCC, 2007). The chief sources of BC are the burning of biomass and fossil fuels, the automobile and aircraft emissions and forest fires. Cooking is the most consume activity of energy for households. Kerosene fuel, charcoal and firewood are the most used cooking fuel in the northern part of the country. Their use incorporated with varying kitchen models in the households lead to complex problem for indoor air pollution. This prompted the need for the research as little work has been done in the north. The objective of this research was to assess the black carbon concentration in air borne particulate matter in ambient air due to the use of biomass for cooking in the Navrongo Senior High School.

Study Area

Navrongo is the capital of the Kassena-Nankana East District of the Upper East Region of northern Ghana. It is located at 10°53′5″N latitude and 1°5′25″W longitude (Figure 1). The terrain is flat and the ecology is typical of the Sahel-arid grassland. The area experiences Harmattan season from November to February, hot season from March to May and rainy season from June to November. The temperature may fall to as low as 17 degrees Celsius during the harmattan with the air being dry and dusty and as hot as 45 degrees Celsius in the hot season. The rainy season has short storms accompanied with thunder and lighting. The first ever solar plant with a capacity of 2 megawatt in Ghana is located in Navrongo. It has a 2012 settlement population of 27,306 people with varying sources of atmospheric pollution from a mix of ethnical and modern which is the major sector contributing to the air pollution. The usual practice of open fireplaces to confront the low temperatures in the study area by local people during the harmattan days and for cooking adds to the air pollution on a large scale.

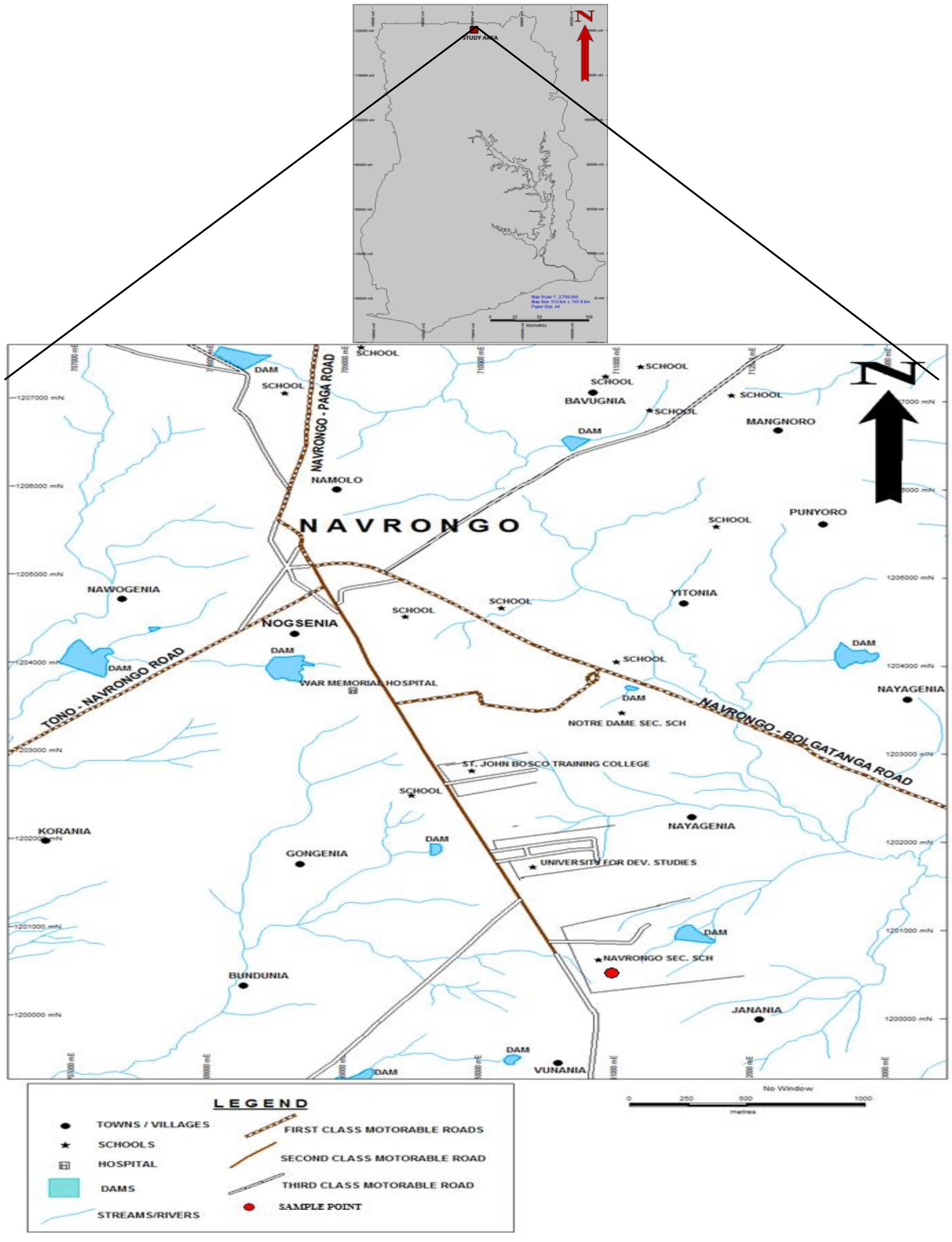

Figure 1: *A map showing the location of study area*

2.0 EXPERIMENTAL WORK

a) Site Selection

Airborne particulates were sampled in Navrongo Senior High School of the Kassena-Nankana East District of the Upper East Region using the Gent sampler. Generally, the northern part of Ghana is well noted for the use of biomass in cooking and burning. The sampling was done at the Navrongo Senior High School which has a big kitchen where wood and charcoal is used for cooking. The cooking is done under a shed in the kitchen which is enclosed. Cooking is usually done from 7:00 am to 3:30 pm for the seven days of the week until school goes on vacation. The sampler was placed in an enclosed yard in the kitchen about 15 m from the cooking shed.

b) Sample Collection

The sampler was operated at a flow rate of 18 L/min. The sampling covered the 24 hours of the day with intermittent breaks given a total sampling period of 12 hours on each sampling day. The intermittent breaks were necessary to avoid overloading the filters. The sampling duration and the average flow rate were recorded on each sampling day. The sampling covered a period of six months (October, 2010 to March, 2011). The unloaded and loaded filters were conditioned in a desiccator for at least 24 hrs and the weighing was done in a temperature and relative humidity controlled environment.

Gravimetric Analysis
Gravimetric analysis determines the mass concentration of ambient air particulates. The weighing of the Nuclepore polycarbonate filters were done before and after sampling in a temperature and relative humidity controlled environment after the filters are conditioned in a desiccator. The difference between the two masses taken represents the net mass of the particulates. The total volume of air sampled was determined from the volumetric flow rate (l/min) and sampling time (in hours). The concentrations of coarse and fine particulates in ambient air were computed as total mass of collected particles divided by the volume of air sampled in actual conditions. The mass concentrations were expressed in micrograms per actual cubic metre ($\mu g/m^3$).

The equation which governed the gravimetric analysis was:

$$C_{PM} = \frac{m}{V} \quad \text{....................................... (1)}$$

Where: C_{PM} = Particulate Matter Mass Concentration
m = net mass of the particulate matter collected on the sample filter
V = the volume of air sampled

Black Carbon Concentration
The black carbon concentration was determined using the Smoke Stain Reflectometer (SSR). It consists of an LCD display meter unit and a measuring head, which is connected to the unit. The unit also carries the main switch (at the back of the meter), coarse and fine sensitivity controls and the zero control. The Reflectometer was placed on a flat table with the LCD digital display faced forward. The zero control was adjusted clockwise and anti-clockwise until the display unit showed a value of '0.00'. The measuring head was then connected to the meter and allowed to warm up for about 10 to 15 minutes. The measuring head was then placed in the circular mask. The white and grey tile standard test was then taken as the circular mask was placed on them. Readings from the meter were taken and the coarse and fine controls adjusted until a value of '100.00' was obtained for the white tile. The circular mask was then moved over to the grey tile and the readings on the meter noted which agreed with the value on the cover glass of the tile, thus between 32 and 36. The above action was repeated several times until constant values were obtained on both tiles. A blank filter was then placed on the white tile with the shiny side faced up. The circular mask was then placed on the blank filter and the reading was taken. The fine and coarse controls were continuously adjusted until the value was exactly'100.00'.

Measurement of Smoke Particulates
The aerosol loaded filters were placed on the white tile with the loaded side up and centred on it. The circular mask was placed carefully and gently on the loaded area of the filters. The readings were taken from each filter with the mask placed at different positions. The reflectance was noted and the readings recorded. After measurement of about 10 filters, rechecks were made to make sure that blank filter reads '100.00' otherwise the coarse and fine controls were adjusted until a reading of '100.00' was obtained and then the previous filter or two was measured again, to correct for errors.

Calculation of the ambient concentration of black smoke
The Reflectometer reading, together with the measured volume of air sampled was used to calculate the ambient concentration of black smoke using the following equation (Cohen and Taha, 2000):

$$M = (D*A)/V \text{.................................. (2)}$$

Where M is the mass concentration of black carbon particulates in the atmosphere ($\mu g/cm^3$), D is the area density of particles on the filter ($\mu g/cm^2$), A is the filter collection area (cm^2), and

$$V = (60Ft/1000) \text{.............................. (3)}$$

Which is the volume of air sampled (m^3) using a pump flow rate of F (L/min) for a sampling time of t (hours). The area density was determined using the following equation:

$$EC_R\ (\mu g/\ cm^2) = \{100/\ (2F\varepsilon)\}\ \ln\ [R_0/R] \text{......(4)}$$

Where ε is the mass absorption coefficient for EC_R (m^2/g) at a given wavelength, F is a correction factor of order 1.00 to account for the fact that sulphates, nitrates and other possible factors like shadowing and filter loading have been ignored, R_0 and R are the pre and post-reflection intensity measurements at a given wavelength respectively. Maenhaut (1996) defines an equivalent experimentally determined expression for EC_R using white light reflectance measurements on 47 mm Nuclepore filters with ε= 5.27 m^2/g and F = 1.00 and a small positive offset of 0.0523 $\mu g/cm^2$ when R_0=R.

Quality Considerations
In this study, Quality Assurance (QA) and Quality Control (QC) activity covers two main areas, that is, site audits and Reflectometer calibration. The site audits ensured that the quality of sampling is maintained. The main operational features of site audits relevant to the measurement of particulates are: checking of sampler flow rate and leak check of tube. Reflectometer calibrations also ensure the consistency and accuracy of the reflectometry measurements. Due to handling and limits of the measuring equipments, each measurement contains a degree of uncertainty. The major sources of error concerning the sampling and analysis of particulate matter samples include (1) contamination of samples, (2) loss of collected aerosol species during sampling or after sampling, (3) sample handling, transport and storage, and (4) errors in data

handling. In order to control and minimize the overall uncertainty caused by these factors, the sampling of particulate matter and weighing of filters were carried out according to a standard operation procedure to assure high quality of sample processing. The Smoke Stain Reflectometer is calibrated by the manufacturer. For the calibration parameters provided by the manufacturer to be used, reflected light by a blank filter (this is set to 100.0) and a totally black filter (set to 0.0) are obtained before evaluating the sample filter. After every series of five sample filters reading taken, the mask, standard plate and tweezers are cleaned and calibration parameter re-set to 0.0 for a white filter and 100.0 for a totally black filter to ensure comparable and reproducible results. Raw data were first entered on printed field forms and subsequently, typed into computer files which were checked for possible typing errors.

3.0 RESULTS AND DISCUSSIONS

During the period of the research, the total atmospheric particulate matter (μgm^{-3}) of fine ($PM_{2.5}$) and coarse fraction (CF) collected on the filters varied from day to day. Table 1 gives the mean mass concentrations of fine and coarse fractions, black carbon concentration, (Figure: 2) and the percentage black carbon concentration in the two size fractions together with their standard deviations and ranges. The standard deviations are not "true" deviations which expresses fluctuations in experimental conditions for the analytical methods. Instead, they are combinations of these and the variations that occur due to changing weather conditions and human activities from one day to another. The maximum and minimum values of these parameters are provided in table 1.

Table 1: *Mass Concentrations (μgm^{-3}), and Black Carbon (BC) Concentrations (μgm^{-3}).*

Property in μgm^{-3}	Mean	Maximum	Minimum	Standard Dev.
Fine	134.59	338.11	9.28	93.34
Coarse	355.04	1117.43	61.73	233.74
BC in fine	7.29	35.35	1.68	4.81
BC in coarse	6.92	22.61	1.76	4.12
%BC in fine	7.92	55.18	1.02	10.31
%BC in coarse	2.46	5.14	0.96	0.89

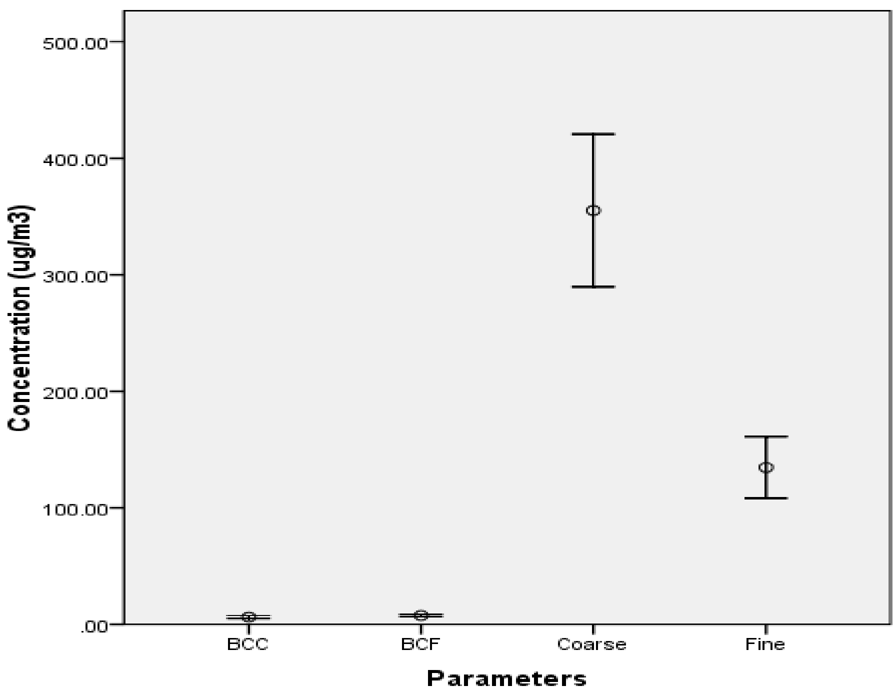

Figure 2: *Standard error bars presenting statistical summaries of the data at the study area.*

The coarse fraction mass concentration is relatively higher than the fine ($PM_{2.5}$) fraction. The daily variations of fine and the black carbon concentrations in the fine and coarse particulates are shown in figures 3 – 4 below.

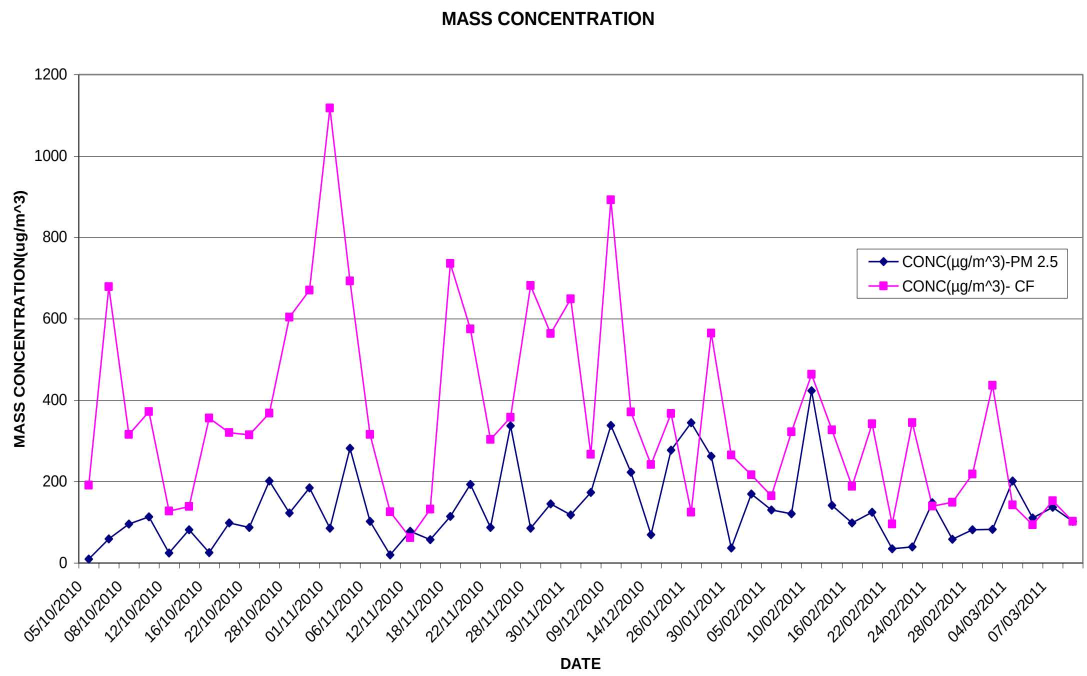

Figure 3: *Fine and Coarse Mass Concentrations*

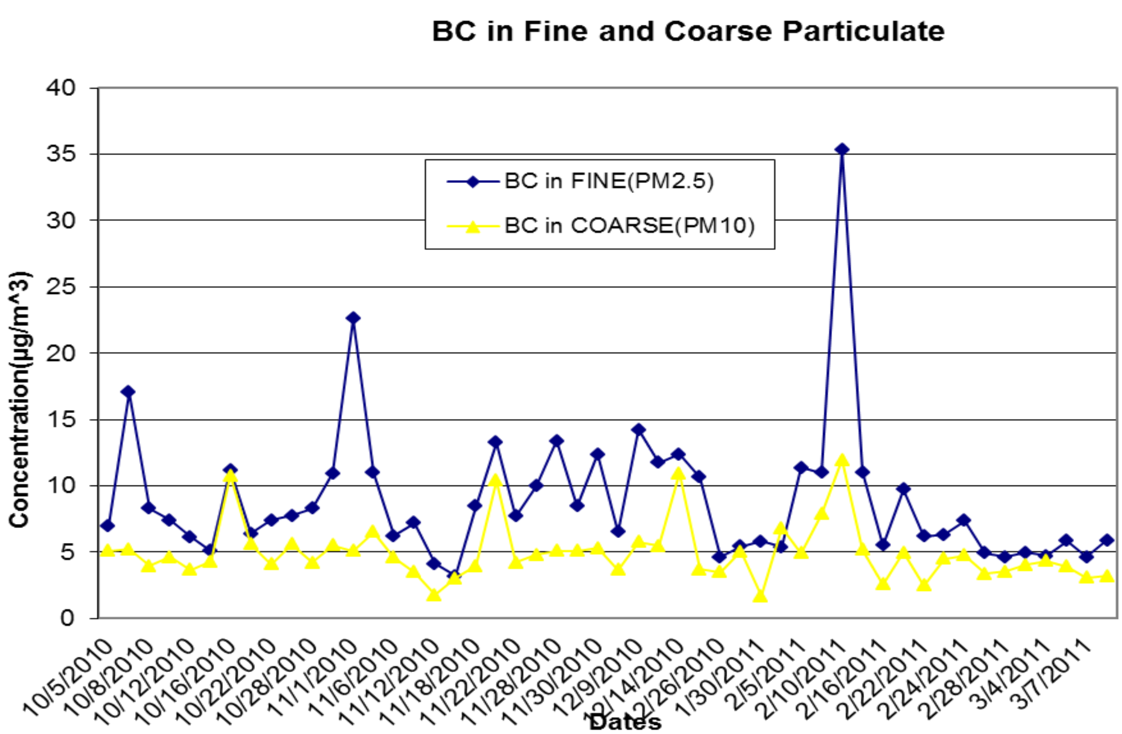

Figure 4: *Black carbon concentration in the coarse and fine particulates.*

It can be seen from the figures above that on some specific days the concentrations are very high, this is due to the changes in the harmattan conditions. This made much particulate matter to be sucked by the sampler and that also accounted for the wide standard deviations. Also from figure 3, it can be realised that on a few occasions the fine concentrations are higher than that of the coarse, this is due to the fact that the smoke particles were quite higher on those days. Comparing the result of the Black carbon Concentration analysis from this work with some selection from literature as in Table 2 below revealed that both fine and Coarse Fraction mean values are very high.

Table 2: *Comparison of BC means with some selection from literature*

Place	Concentration(µgm^{-3})		% BC in PM		Reference
	Fine	Coarse	Fine	Coarse	
Ashaiman	2.82	3.98	18.40	4.86	Sam-Quarcoo et al,2008
Kwabenya(All Data)	1.65	1.65	5.45	1.09	Aboh (2010)
" 05/06 Harmattan	0.70	0.57	6.61	0.64	"
" 05/06 Rainy	1.92	0.67	10.85	1.57	"
" 06/07 Harmattan	2.44	5.30	2.84	1.12	"
Navrongo Sec. Sch.	7.29	6.98	7.92	2.46	This work

Table 2 above shows that the BC concentration levels obtained in this work are higher as compared to that of Ashaiman and Kwabenya which are semi-urban areas in the Greater Accra Region. The higher concentrations of 7.29 µgm^{-3}and 6.98 µgm^{-3} for fine and coarse respectively from this work relative to the other works can be due to the fact that the measurements were taken from a kitchen where burning wood fire is used for cooking. This shows that BC is a good fingerprint of biomass burning emissions. WHO has a 24 hr standard of 50µg/m^3 for the coarse particulates and 25µg/m^3 for the fine particulates. But from this research an average of 355.04µg/m^3 was obtained for the coarse particulates and 134.8µg/m^3 was obtained for the fine particulates. This indicates that the results of this research were much higher than that of the WHO standards. Ofosu et al. (2009) reported a monthly variation of particulate levels at Ashaiman, a semi-urban area near Tema in Ghana, with a 109.56µg/m^3 as the mean for the coarse particulates and 23.95µg/m^3 for the fine particulates. These values are lower than the results from the Navrongo Senior High School. The difference in mean values from the Navrongo Senior High School could be due to the fact that the area is characterised by local pollution such as open burning, domestic wood, charcoal burning and dust emissions. According to the World Health Organization (WHO, 2005) report, the evidence of the association between airborne particulate matter and public health outcomes is consistent in showing adverse health effects at exposures experienced by urban populations in cities throughout the world, in both developed and developing countries. The risk for various outcomes has been shown to increase with exposure and there is little evidence for a threshold below which no adverse health effects would be anticipated.

Table 3 *shows the concentration ratios of fine to coarse particulates and the division of the mass concentrations by their respective black carbon concentration.*

Property(µgm^{-3})	**Mean**	**Maximum**	**Minimum**	**Standard Dev.**
Fine/Coarse	0.51	2.77	0.04	0.47
BC/Fine	0.08	0.55	0.01	0.10
BC/Coarse	0.03	0.05	0.01	0.01

Maximum coarse to fine ratios are often associated with local pollution episodes that are associated to combustion sources (Marcazzan et al. 2002) and the Navrongo Senior High School is especially prone to experience local pollution episodes because, the area is characterized by a lot of open burning, household wood and charcoal burning. It follows from these percentage values that black carbon constitutes a greater fraction if not dominated in the fine particulate matter. Fine fraction contains most of the respirable particulate matter and mostly generated by combustion activities. The ratios of coarse to fine concentrations of the particulates and the percentages of black carbon in the coarse and fine particulates are presented in Figure. 5 and 6 below:

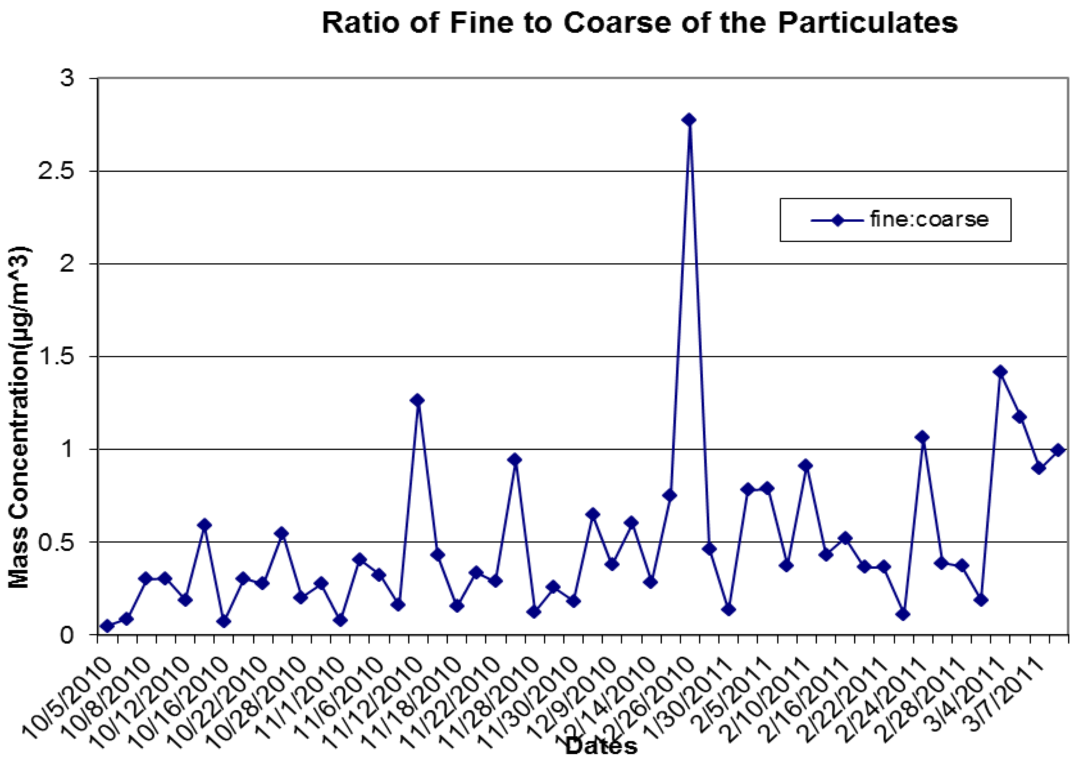

Figure 5: *Ratios of fine to coarse particulates*

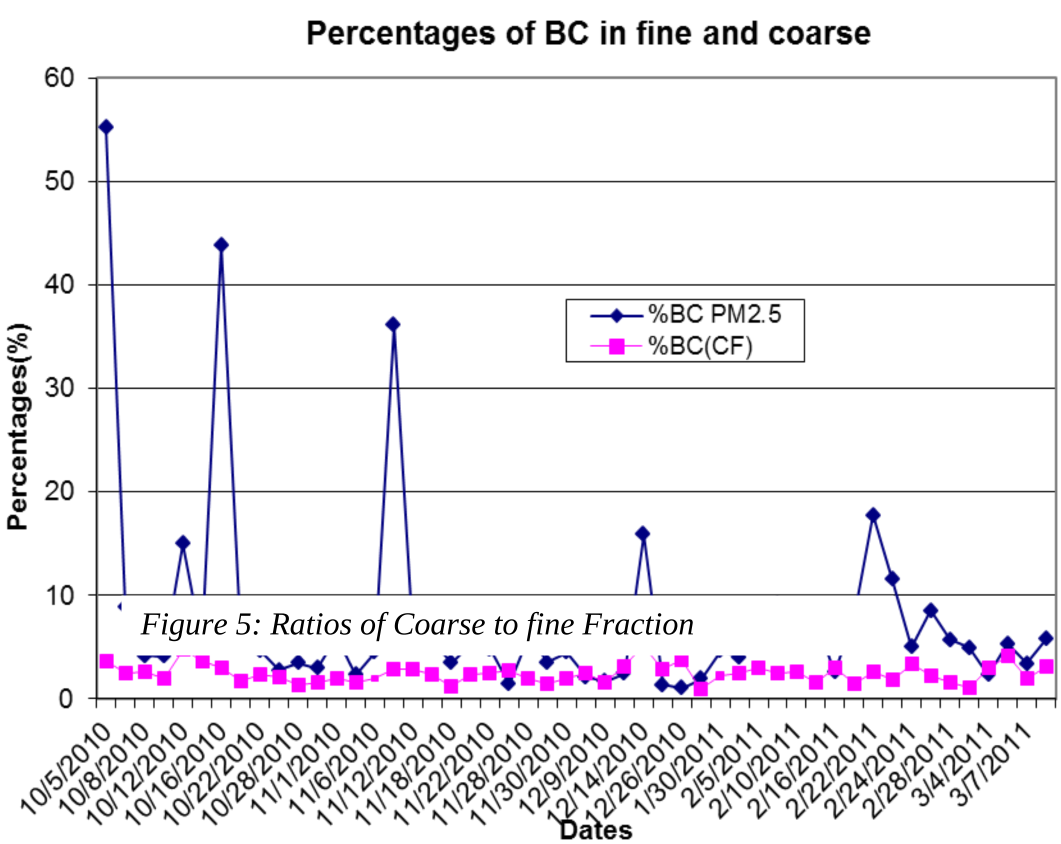

Figure 6: *A graph of percentages of BC in fine and BC in coarse*

4.0 CONCLUSION

This work involved the assessment of black carbon concentration in air borne particulate matter in ambient air due to the use of biomass for cooking in the Navrongo Senior High School. The gent sampler and nuclepore filters were used to sample both fine and coarse particulates. The mean values of 134.59µgm^{-3} and 355.04µgm^{-3} for the fine and coarse air borne particulate matter from the research are higher than that of the World Health Organisation standards and this indicates that the area produces large amount of pollution. There is therefore the need for modeling of the air borne particulate matter samples to identify the sources and quantities of those sources. A low mean value of 0.51µgm^{-3} for the fine to coarse ratio and a high mean value of 355.04 for the coarse fraction, suggest that most of the particulates were from the coarse mode. The percentage of black carbon in the fine particulates was found to be 7.92% while that of the black carbon in the coarse particulates was found to be 2.46%. This shows that the black carbon content was relatively high in the fine particulates than in the coarse particulates; this is due to the fact that carbonaceous particulates are mostly of fine particulates and high concentrations of the black carbon posses a lot of effects not only to the people but also to the environment. The results of the Atmospheric Particulate Matter were also higher than that of the World Health Organisation standards

5.0 REFERENCE

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