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Comparison of Cohen, British and Gagel Method of Approach to the Determination of Black Carbon in Nucleapore and Teflon Filters Using the M43D Smokestain Reflectometer

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ABSTRACT

The Objective of this project is to compare the three methods of analyzing Black Carbon in the atmosphere that is British, Cohen and Gagel method. Samples were collected from Ashaiman and Kwabenya in the Greater Accra Region and analysed using mention method. It was observed that there is a good correlation between the Cohen and British method. This is because in most all areas where the Cohen method measures high values for the elemental carbon concentrations; the British method also does the same and the vice versa. This pattern has been observed for both methods in the separate analysis carried out on samples from both site. The Gagel method however, displayed results which did not compare in pattern to either the British or the Cohen methods.

Introduction

Elemental carbon is essentially a primary pollutant (Seinfeld and Pandis, 1998) emitted during incomplete combustion of fossil and biomass carbonaceous fuels. In urban areas, diesel emissions are one of the major sources for elemental carbon, which is often used as a marker for urban pollution (Salma et al., 2004); furthermore, its temporal pattern could be related to traffic intensity (Ruellan and Cachier, 2001).

It is more often called Black Carbon (BC) because of its colour. It has a graphitic-like structure with the presence of some functional groups containing elements such as oxygen, sulphur, hydrogen and nitrogen, which are able to enhance catalytic processes. When carbon to oxygen ratio during the combustion process is less than 1, then it is referred to as soot. Indeed soot, that represents the dark component of the carbonaceous aerosol, is a very complex mixture of both elemental carbon and highly polymerized organic substances.

The large concern on elemental carbon (EC) concentrations in particulate matter samples is due to the adverse health effects (Summerhays, 1991; Oberdorster and YU, 1990) and soiling of surfaces. At a global scale, EC might also play a role in radiative forcing effects, as it is the dominant light-absorbing component of atmospheric aerosols.

Since Black Carbon is the dominant light-absorbing substance in the atmosphere, it is possible to estimate Elemental Carbon (EC) concentrations in the atmosphere as Black Smoke (BS) by measuring light absorption or reflectance as Particulate Matter (PM) collected on filter media. This analytical method employed in this work is termed Reflectometric Method of determining Black Carbon concentrations using Smoke Stain Reflectometer. The darkness of the particulate on the filter paper is consequently an indication of the amount of Element Carbon on the filter and is often referred to as Black Smoke. The reflectometer reads on a scale of 0 (black) to 100 (white). Using the British and Cohen method but that of Gagel . Measuring the reflected light emitted by a white filter (this is set to 8.0) and a totally black filter (set to 0.4), this enables the calibration parameters of the manufacturer's to be used. Several studies have reported that black Smoke, derived from absorbance coefficients, is well correlated with the concentration of elemental Carbon or Soot and can be recommended as a valid and cheap indicator in studies on combustion-related air pollution and health (Cyrys et al , 2003; Gotschi et al, 2002; Janssen et al, 2001, Kinney et al , 2000.)

The main Objective of this project is to compare the three methods of analyzing Black Carbon and also to ascertain the level of atmospheric Black Carbon pollution within Kwabenya and Ashaiman.

Materials and Methods

Sampling Equipments and Methods

The Gent dichotone sampler was used to collect aerosols samples on Teflon filters. The PM fraction for particles above the desired size range, determined in terms of aerodynamic diameter, were collected on impactor plates impregnated with Apiezon grease, which are cleaned and saturated on occasional basis in order to prevent particle bounce. Teflon filters conditioned for five days before weighing were used. The pore size of Teflon used for the PM2.5 fraction is 0.45 µm and PM10 is 8 µm for the pore size and 47 mm in diameter. The filters were weighed before and after sampling using a Sartorius MC-5 micro-gramme sensitive balance in a temperature- and relative humidity-controlled environment. The sampling in this work was done for approximately 24 hours and at a flow rate of approximately 17. L/min.

Measurement of reflectance

With the measuring head tightly attached to the mask, the sample filter is removed from the Petri dish using tweezers and located centrally on the white standard. The reflectance reading

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is measured from the meter reading on the SSR. Four additional measurements using the same sample filter is taken. After every series of five sample filters reading taken, the mask, standard plate and tweezers are cleaned and calibration parameter re-set to 8.0 for a white filter and 0.4 for a totally black filter.to ensure comparable and reproducible results and the instrument switched on to warm for more than 15 minutes. The measuring head inserted in the mask is then connected to the SSR central unit after adjusting the LCD meter reading to zero using the zero knobs in the front panel of the SSR. Locating the measuring head over the white standard, the reflectance reading is adjusted to100.0 by using coarse and fine knobs in the front panel.

For linearity check, the measuring head is moved over the grey standard to ensure that the reading is within the limits given for the standard plate in the manufacturer's manual (34-36).

Mass concentration of elemental carbon calculation using Cohen's Model, British Model and Gagel Model is explained below.

Cohen's Model

The area density, D (or EC_R (µg/cm²)

EC_R (µg/cm²) = {100/ (2Fε)} In $[R_0/R]$

The equivalent experimentally-determined expression defined by Maenhaut for element carbon (reflectance) using white light reflectance measurements no 47 mm Nucleapore filters, ε = 5.27m²/g and F = 1.00.

The volume of air sampled (V) and the filter collection area (A) known, the mass concentration (M) can be easily determined using the following equation:

$$M = (D*A)/V$$

British Model

For lighter stain with reflectometer reading of 40 to 99 the following formula is used:

C = F / V(91679.22 – 3332.0460R + 49.618884R2 – 0.35329778R3 + 0.0009863435R4)

Where:

V = Volume of air

R = reflectometer reading

F = a factor relating to the sampler clamp size, as follows:

0.288 for ½ inch clamp

1.000 for 1 inch clamp

C = Concentration in micrograms per cubic meter.

3.680 for 2 inch clamp

12.80 for 4 inch clamp

For darker stains with reflectometer readings of 40 to 20 the formular used are:

C = F/ V (214245.1 – 15130.512R + 508.181R2 – 8.831144R3 + 0.0628057R4)

For stains with reflectometer readings of less than 20 this formular gives only an approximation to the concentration, the result being well below the true value. Reflectometer readings of less than 10 are impossible to assess accurately and hence the results are calculated as if the reading had been 10, which gives a minimum value.

Gagel Model

The output voltage is converted to a measure of blackness known as "black smoke number", RZ is determined from the three output voltage obtained, that is from the aerosol filter to be evaluated, the totally white filter and the totally black filter. The equation relating the output voltage to the black smoke number is:

$RZ=RZ_{max}(U_{RZ0} – U_{RZ})/(U_{RZ0} – U_{RZmax}))$

Where

U_{RZ0} = output voltage with blank (white) filter (which is set to 8.0 V according to the instructions manual)

U_{RZmax} = output voltage with totally black filter (set to 0.4 V)

U_{RZ} = output voltage with actual filter to be evaluated

The RZ is then related to the concentration of black aerosol using the Lambert-Beer's law. This relation is given by:

$C_R = - (RM_1/V)In(1 – ((RZ – RZ_0)/(kRZ_{max})))$

where

C_R = the black carbon concentration

V = the sampled air volume

RM_1 = the black carbon mass in a single dust layer on the filter (

11.2)

RZ_0 = the black smoke number for a white (blank) filter (0.43)

RZ = the black smoke number for the actual filter

RZ_{max} = the black smoke number for a black filter - (constant = 1.2) (9)

k = calibration constant. (= ½ or 0.5 for smoke stain reflectometer M43D) (0.95)

The C_R is multiplied by ½ area of filter (C_R x 0.5 area of filter = C_Rf). This is further multiplied by normalized volume of air sampled (C_Rf x 24/sampled volume)

Validation

The Smoke Stain Reflectometer is calibrated by the manufacturer. For the calibration parameters provided by the manufacturer to be used, reflected light by a white filter (this is set to 8.0) and a totally black filter (set to 0.4) are obtained before evaluating the sample filter.

Results and Discussion

Maximum ratios are often associated with local pollution episodes that are associated to combustion sources (Marcazzan et al. 2002) Ashaiman is prone to local pollution episodes because, the town is characterized by a lot of open burning, household wood and charcoal burning and local traffic. From the graph it can be observed that there is a good correlation between the Cohen and British method. This is because in most all areas where the Cohen method measures high values for the elemental carbon concentrations; the British method also does the same and the vice versa.

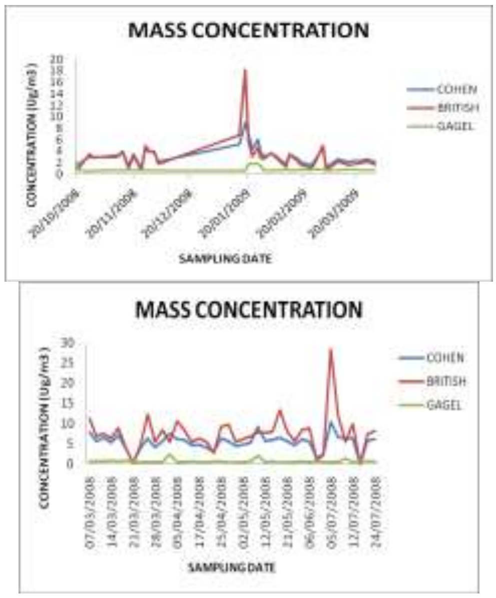

Figure1a & b graph of mass concentration on the various sampling days at Kwabenya and Ashiaman

Conclusion

This pattern has been observed for both methods in the separate analysis carried out on samples from Kwabenya and Ashaiman. The Gagel method however, displayed varied results which did not compare in pattern to either the British or the Cohen methods.

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