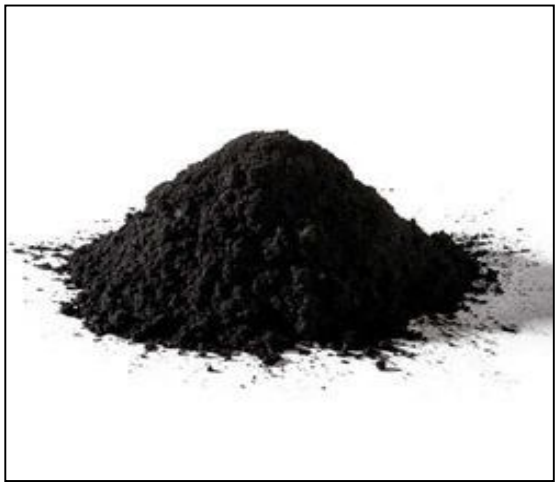
Weekly Science Research Journal
ISSN 2321-7871

Impact Factor : 2.4210 (UIF) [Yr.2014]
Volume - 3 | Issue - 4 | 6 Aug - 2015

STUDY OF BLACK CARBON AEROSOL OVER RAJKOT: A SEMIARID LOCATION OF SAURASHTRA

Nilesh H. Manani
Department of Physics, M. M. Science College, Morbi, Gujarat.



ABSTRACT

Black carbon aerosol measurements were carried out during December 2008, at Department of Physics, Saurashtra University, Rajkot as a representative of semiarid location of Saurashtra region. Diurnal variation of Black carbon aerosol (BC) is associated with changes in boundary layer mixing and anthropogenic activities. Concentration of BC in ambient air in this location is comparable to those measured in other cities of India. It has been also observed that this concentration of BC is much higher than that as reported for the other continents of similar locations in Europe, USA and Asia. BC concentration is found high in absolute terms (5–18μg m^{-3}) and mass fraction (~10%).Impact to regional climate may be large surface cooling and lower atmospheric heating.

KEY WORDS: Aerosol Black Carbon, BC Mass Concentration.

1. INTRODUCTION

The optically absorbing component of carbonaceous aerosol is Black carbon aerosol (BC). It has become a great interest in recent times, because it is a strong absorber of the solar radiation in the visible and near-infrared wavelengths.HaywoodandRamaswamy (1998) reported that BC has potential to alter the radiation budget.Jacobson (2001) reported that estimates of the global mean clear sky radiative forcing at the top of the atmosphere due to BC is between +0.4 to +0.8 Wm^{-2}.This positive forcing represents a considerable amount of heating of the lower atmosphere and has been conjectured as a potential factor causing global warming. To understand radiative effect of BC aerosols, several international experiments such as Indian Ocean Experiment (INDOEX), Tropospheric Aerosol Radiative Forcing Observational Experiment (TARFOX), Aerosol Characterization Experiments (ACE-1 and ACE-2) and Smoke, Clouds, Aerosol, Radiation-Brazil (SCAR-B) have been carried out. In India, BC concentration is being monitored at very few locations, Trivandrum, Bangaloreand Hyderabad in Southern part of India as shown in figure-1. Recently, Di Girolamo et al. (2004) have shown very high aerosol optical depth during winter season retrieved from Multi-angle Imaging Spectroradiometer (MISR) in the Northern India; although it is lower compared to the ground-based point measurements as it is spatial average over a large area. In this paper, Ihave presented the results of surface measurements of BC aerosols during December 2008. Diurnal variation of BC is discussed along with the associated variations in local meteorological parameters. Finally, the impact of BC aerosols climate has been discussed.

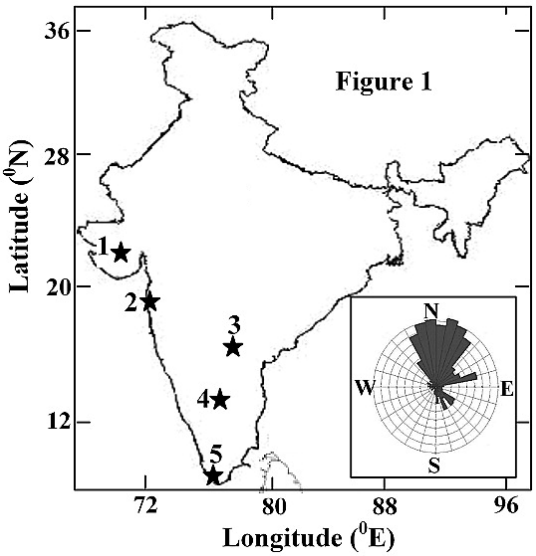


Figure-1: Location of the study area where BC concentration has been measured along with other urban stations in India with which my observation has been compared. The frequency distribution of wind direction during December 2008 at Rajkot has beendisplay in the corner of the above figure showing dominantly northerly wind.

Here, **1-Rajkot, 2-Mumbai, 3-Hyderabad, 4-Bangalore and 5- Trivandrum**

2. SITE LOCATION AND SYNOPTIC METEOROLOGY

For monitoring of BC aerosols, an Aethalometer (model AE-21, Magee Scientific, USA) has been deployed at the Department of Physics, Saurashtra University, Rajkot as a part of the ISRO-GBP Project in the month of December 2008. The campus is outskirt of the city (Fig-1), where the major sources of black carbon are transported from automobiles, power plants and other industries and biomass burning (particularly in the winter season) near the campus.The wind during the month of December was weak (1to 4 km hr^{-1}), variable but mostly northerly (Fig-1). The relative humidity (RH) was very high, especially during the nighttime (>85%), whereas during the daytime, it comes down to ~55% as shown in Fig-2.The temperature varied in the range of 9.5 to 22.5°C.

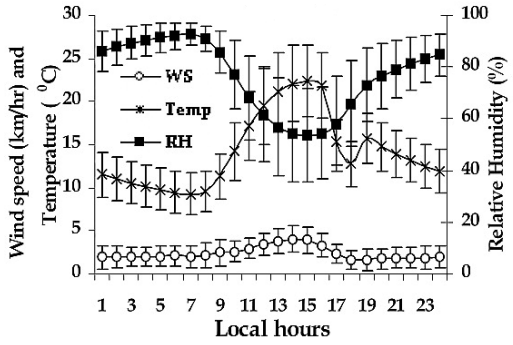


Figure-2: Day-to-day variation of Wind speed, Temperature and Relative Humidity

Monthly mean diurnal variations of wind speed (WS), temperature (Temp) and relative humidity (RH) for December 2008 with the standard deviation of each point shown as vertical bars.

3. EXPERIMENTAL DETAILS

Simultaneous measurements of BC concentration (M_b), total aerosol mass concentration (M_T) and meteorological parameters were carried out at ~10 m above local ground levelusing an Aethalometer (AE-21), 10 channel Quartz Crystal Microbalance (QCM) impactor (PC-2 of California Measurements Inc., USA) and automatic weather station respectively. The Aethalometer was operated at a flow rate of 3 liters/min and at an average time of 5 min. It uses a continuous filtration and optical transmission technique to measure the concentration of BC in near real time and aspirates ambient using its inlet tube and its pump. BC mass concentration is estimated by measuring the change in the transmittance of a quartz filter tape, on to which the particles impinge. The uncertainty in BC concentration is ~10% [Babu and Moorthy, 2002] and the specific absorption coefficient used is 16 m^2 g^{-1}. Measurements by QCM were made at hourly intervals for the whole month of December with the sampling duration of 6 min at RH < 75% in the size range 0.05 to >25 μm over 10 size bins. Stage 1 collects all particles with diameter >25 μm, whose monthly concentration is very low (3.08 μg m^{-3}) compared to other size bins; hence no geometric mean diameter is assigned to that size bin. As M_T is directly proportional to the change in the frequency difference of the sensing and the reference crystal, the short-term stability of the crystal oscillator during the sampling time of 6 min is of more importance than long-term drift. The uncertainty in QCM measurements is ~15–20% for M_T < 10 μg m^{-3} and the error is much less for higher M_T.

4. RESULTS AND DISCUSSION

Daily average values show significantly high values of BC in the range of 6–20 μg m^{-3}. No measurements were made on three days during 22–24 December due to unavailability of tape. Monthly mean diurnal variation of BC is shown in Figure 3 with two maxima peaks during morning 07:00–09:00 local time (LT) and evening 19:00–21:00 LT. BC shows higher variability during the nighttime and the early morning hours when values as high as up to 50 μg m^{-3} has been observed. BC concentration starts rising gradually after the sunrise and attains a peak at 09:00 LT. The diurnal trends of the temperature and relative humidity are opposite and out of phase, which is quite obvious, but the variability is much higher during the daytime. The high concentration of BC in morning hours, higher than the corresponding late evening values, is mainly because of two reasons. First, increased anthropogenic activities such as biomass burning for heating purpose and commencement of the industrial activities during the morning hours emit more BC and secondly, due to fumigation effect, when the pollutants are being brought near the surface from the residual nocturnal boundary layer [Stull, 1998]. The magnitude of the fumigation effect is however less than that observed at coastal stations, where the effect is enhanced by the land/sea breeze activity. During daytime increased mixing within the turbulent boundary layer as temperature increases leads to fast dispersion of BC aided by relatively higher wind speed (2–4 km hr^{-1}), thus reducing its near surface concentration. In the evening, boundary layer mixing again decreases due to inversion and as a result BC gets trapped near the surface and attains maximum value around 19:00–21:00 LT. As the night progresses, the anthropogenic activities and the industrial emission get reduced, as a result BC concentration decreases.

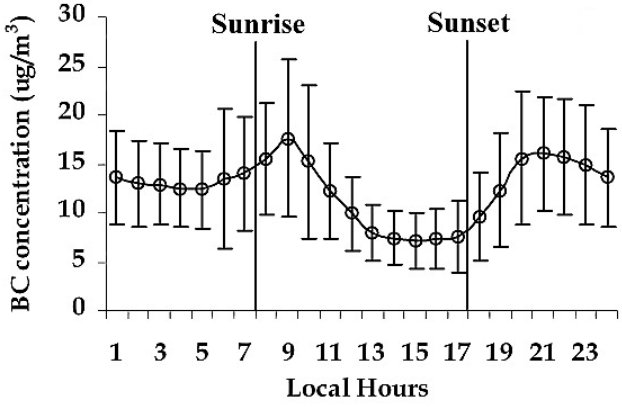


Figure-3: Day-to-day variation of BC concentration over observation site Rajkot

Monthly mean diurnal variation of BC. The error bars represent the standard deviation from the mean for respective days. BC in Rajkot shows much higher values (factor of two to five) than other urban or near city locations of Europe, USA and Asia (Korea) but lower than that reported in Hyderabad. BC in Rajkot is also higher than that in Trivandrum (coastal) and Bangalore (urban) in Southern India. Although BC in present study was measured in Rajkot, which is characterized as near city location; still BC values are comparable or higher than those found in urban or street locations of Europe. The reason for this could be the transport of BC from the city and a busy Ring Road, which is 2 km from the measurement site.The mass fraction of BC (F_{BC}) is important in estimating its impact on aerosol radiative forcing. During INDOEX, Satheesh et al. [1999] have estimated that a 6% BC fraction to total aerosol mass contributed ~11% to the aerosol optical depth; 35% to aerosol radiative forcing and 50% to aerosol atmospheric forcing [Podgornyetal., 2000]. F_{BC} was computed from the simultaneous measurements of M_T and M_b. Due to operational constraint during nighttime, when RH becomes greater than 75%, QCM was not operated during the nighttime throughout the month. Therefore I have used daytime average values of M_b and M_T and computed the F_{BC} from the ratio M_b/M_T. Thevalues of daytime mean of F_{BC} during December are in the range of 7–15%. The uncertainties in the measurements of M_b and M_T give an overall uncertainty of ~14% to F_{BC} [Babu and Moorthy, 2002]. The values of F_{BC} in Rajkot is higher than the values reported in Trivandrum but comparable to F_{BC} in Mumbai during INDOEX [Venkataraman et al., 2002], Bangalore [Babu et al., 2002] and in INDOEX program [Satheesh et al., 1999]. Such high F_{BC} could affect the climate more significantly over the land as the surface reflectance of land is much higher compared to that of ocean.Daytime average BC mass fraction with the error bars representing the uncertainties in the measurements.

5. CONCLUSIONS

1. Daily average BC was found to be between 5–18 μgm^{-3} with values as high as ~40 $\mu g\ m^{-3}$ during morning hours. BC concentration observed in Rajkot is comparable to those measured in other cities of India but much higher than in similar locations of Europe, USA and Asia.
2. The BC mass fraction was estimated from composite mass and BC mass was found to vary between 7–15%.

ACKNOWLEDGMENTS

This work is carried out under ISRO-GBP-Project. I am also thankful to Professor K. N. Iyer and Professor H. P. Joshi for providing me data for the present study. Thanks are due to two anonymous reviewers.

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