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Research Article

Seasonal and Diurnal Variation of Black Carbon Aerosols over Delhi and their Interrelationship with $PM_{2.5}$ and Meteorological Parameters

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Abstract

Due to industrial, vehicular and residential emission in Delhi, concentration of Black carbon (BC) emitted is substantially high. Black carbon plays a major role in altering the earth's climate and leads to adverse human health. The current research estimates the concentration of Black Carbon, a light absorbing carbonaceous aerosol at four locations of Delhi during 2017. The intra-seasonal variation indicated that the average BC surface mass concentration was highest during winters around 26.27 ± 3.28µg/m^3 followed by post-monsoon and pre-monsoon season. As per the diurnal variation, minimum BC concentration was found during the daytime between 12:00-17:00hrs due to enhancements in the MLH and increased convective activity. The BC mass concentration exhibit positive correlation with $PM_{2.5}$. This study will add significant value to the current BC research literature.

Keywords: Black Carbon, Diurnal variation, $PM_{2.5}$, Seasonal variation

Introduction

Atmospheric particulate matter (PM) is known to substantially affect atmospheric chemistry, ambient air quality and visibility as well as radiation budget of earth. Various research studies have reported that aerosols, specifically fine mode particles can have serious detrimental impact on human health especially causing cardiovascular and respiratory disorders.[10]

Black carbon (BC) is an anthropogenic aerosol that heats the atmosphere by absorption of sunlight[6] and is an important constituent of fine mode particulates, which are often released as a product of incompletecombustion.[7] Fossil fuels burning, vehicles exhaust, incineration of biomass, crop burning and forest fires are the most important sources of BC.[1] Due to high BC absorption over large wavelength range, it can significantly compensate the aerosol scattering effect.[5]

As the metro cities such as Delhi are expanding in their size as well as population, the demand for motorized vehicles (source of pollutants like $PM_{2.5}$ and BC) is raising for personal use and public transport department . This in turn has a detrimental impact on the environment as well as infrastructure of the city. In the year 2010, the Central Pollution Control Board (CPCB) developed a Comprehensive Environmental Pollution Index (CEPI) to estimate the level of air, water and soil pollution at the various industrial clusters. The study identified 43 clusters with the rating of more than 70 on the scale of 100, and near capital region areas of Faridabad and Ghaziabad was included in these.[4]

High in carbonaceous aerosols, $PM_{2.5}$ has critical effects on the atmosphere. Black carbon plays a crucial role in the climate system, but in most of the world's regions it accounts for less than 5% of atmospheric aerosol.[12]

The purpose of this study is to report findings from spatial, hourly, monthly and seasonal BC averages during 2017 in Delhi and its variations related to meteorology and emission.

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Methods

Delhi (28°350 N, 77°120 E, 217 m mean sea level) is the largest city by area and second largest by population in India.[8]

Weather Details during the period of observation (January-December 2017) are represented in Figure 1. Figure 1 shows a variation in the values such as monthly average temperature, relative humidity, wind speed (WS) and wind direction. The average monthly temperature is at its lowest in January month, and it gradually rises to its peak in May. The pre-monsoon dust storms as well as irregular rainfall reduce the temperature to some extent in June and it further falls in monsoon and winter seasons.

The average relative humidity was highest in 2017 in July and August and the lowest in April. The average wind speed was maximum in April. Wind direction is usually from southwest to northeast.

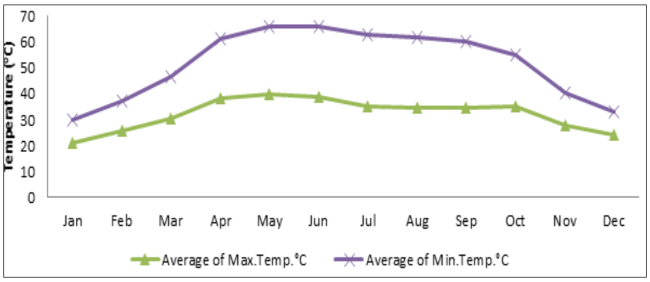

Figure 1(A).Monthly average temperature during 2017

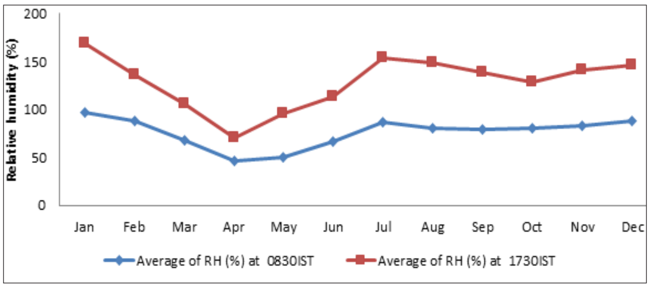

Figure 1(B).Monthly relative humidity during 2017

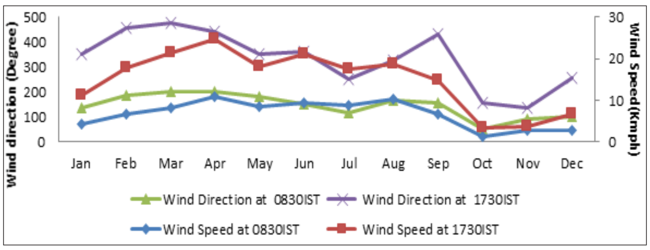

Figure 1(C).Monthly wind speed and wind direction during 2017

Measurements and Instrumentation

An estimation of black carbon has been done with the help of Aethalometer (Model-AE51). The meteorological parameters such as wind speed, direction of wind, relative humidity, temperature, pressure and visibility at Safdarjung, Delhi location has been provided by India Meteorological Department. Safdarjung is located in South Delhi region has an amalgamation of commercial as well as residential activities, and hence can be easily compared with other locations in Delhi. $PM_{2.5}$ data has been provided by Central Pollution Control Board (CPCB) through Continuous Ambient Air Quality Monitoring System (CAAQMS) for locations. The monitoring was done during winter (January), pre-monsoon (June) and post-monsoon (October) seasons at four locations of Delhi (Janakpuri, Pitampura, Arjunnagar and Sirifort) in 2017. Black carbon readings were taken for 8 hours each day from 10:00-18:00 hrs.

Estimation of BC Mass Concentration

The mass concentration of black carbon (BC) was estimated with the help of Aethalometer (Model-AE51) at 880nm. BC is the key absorber of light at this wavelength. An aethalometer measures the BC levels by measuring the variation in attenuation (ATN) of light. The instrument measures attenuation of light due to the collection of particles on the Quartz filter tickets. The attenuation is calculated by knowing the difference between light transmission through the particle rich sample spot and through the particle free reference spot in the filter. As air passes through the filter strip, the instrument collects air sample. Later, with the rise in the BC concentration level on filter strip, the attenuation also peaks. When this attenuation value obtained is divided by total air volume passing through the filter strip, the BC concentration levels can be obtained. The air is aspirated with the help of an inlet which is connected to a pump. The same air then passes through the filter tape which allows particles to be deposited, and this helps in recording the transmittance of light which is shown as BC mass concentration. In the current research, the concentrations are measured in a gap of 5 minutes for 8 hours during day time. The instrument worked at a flow of 100mlpm.

Results and Discussion

Seasonal Variation of BC

Average BC mass concentration during winter was 23.18 $\mu g/m^3$ followed by 15.45 $\mu g/m^3$ during post monsoon and 12.43 $\mu g/m^3$ during pre monsoon. Winters are very important in Delhi. In winter, this may be mainly due to the formation of an inversion layer and low mixing layer height, which increases the BC concentration, whereas in summer high convective activity and relatively high WS are responsible for the dispersal of aerosols and hence the comparatively low BC concentration. Moreover, dense smog formation during winter months has also been witnessed in Delhi, the reason of which may be vehicular pollution as well as the prevailing meteorological conditions particularly in the months of December and January. From Figure 2, it is clear that at all the four locations of Delhi, BC mass concentration was highest during winters, followed by post-monsoon and lowest during pre-monsoon. This scenario is mainly attributed to mixing height and rainfall dynamics. Janakpuri was found to be the most polluted, as this area

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is densely populated with high vehicular activities and is surrounded by small scale industries nearby.

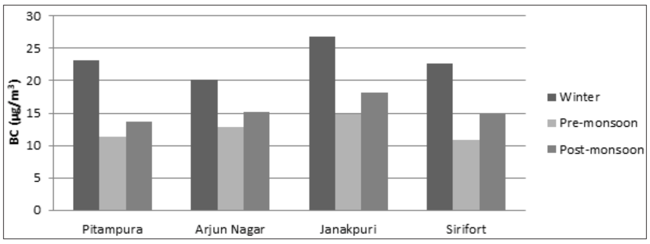

Figure 2.Seasonal variation of BC at different locations of Delhi

Diurnal Variation of Black Carbon

The daytime variance of BC showed high-pitches in the morning and evening hours. The morning and evening peaks in BC concentration are due to the combined effects of turbulent dispersion processes in mixed layers and the establishment of local man-made activities, especially the traffic load. The minimum BC concentration is detected during the day (11: 00-18: 00) due to improvements in MLH and increased convection in the atmosphere. Morning and evening times varied from day to day and were also dependent on the seasons with sunrise and sunset.[2]

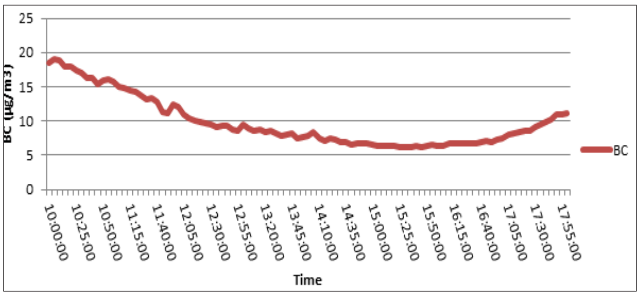

Figure 3.Diurnal variation of BC during day time

Relationship between BC mass Concentration and Meteorological Parameters

Fig 4(a) to Fig 4(A) and Fig 4(b) to Fig 4(B) shows the correlation between BC mass concentration and wind speed. Both show an inverse relationship, as increasing wind speed reduces the surface mass concentration of black carbon. Figure 4 (b) shows the negative correlation between the BC mass concentration and the temperature at which the surface mass concentration of black carbon decreases with increasing temperature. There is a positive correlation between the BC mass concentration and the relative humidity, as the relative concentration of carbon increases with increase in relative humidity.

$PM_{2.5}$ and Black Carbon

Black carbon is a constituent of particulate matter ($PM_{2.5}$) and impairs human health. BC fractions and $PM_{2.5}$ mass from January to December, 2017 are shown in Figure 5. November and December had the highest average $PM_{2.5}$ and BC respectively, with the minimum of the BC and $PM_{2.5}$ mass during monsoon months (July and August), whereas the lowest BC/$PM_{2.5}$ fraction was found in winter. The BC load of $PM_{2.5}$ is affected by pollution sources and weather conditions.[3] The rise in BC / $PM_{2.5}$ ratio in monsoon and winter may be affected by burning of surrounding crops and increased biomass combustion during this period.

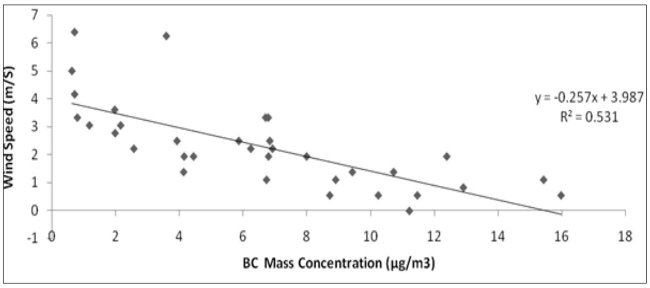

Figure 4(A).Variation of BC mass concentration with wind speed

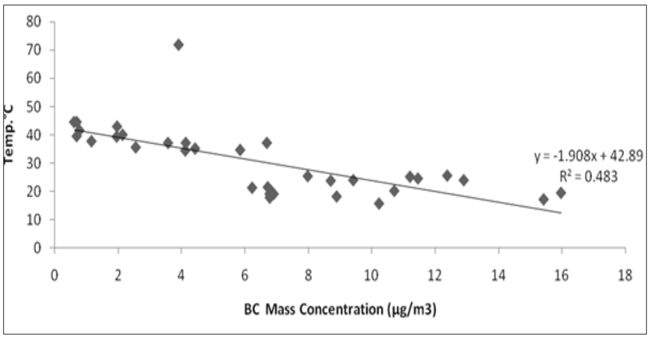

Figure 4(B).Variation of BC mass concentration with temperature

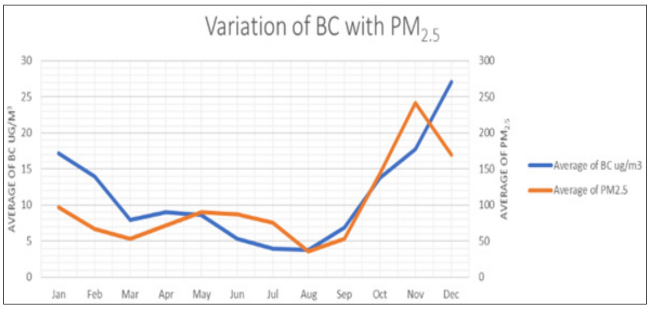

Figure 5.The monthly variation of $PM_{2.5}$ and BC mass concentration during 2017

Conclusion

BC shows distinct seasonal diurnal and seasonal variations and average values were comparable to concentrations reported for urban areas. BC Concentrations peaks were higher during busy traffic hours and lower boundary layer heights. BC and $PM_{2.5}$ showed the similar variations throughout the year and can be explained by their ratios that BC falls mainly within the size range of $PM_{2.5.}$ BC mass concentration was reported to be highest during cooler months and lowest during hotter periods owing to boundary layer mechanisms and pollution sources. BC concentration showed a clear inverse relationship with wind speed and temperature and exhibits a positive relationship with relative humidity.

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Conflict of Interest: None

References

1. Babu SS, Moorthy KK. Aerosol black carbon over a tropical coastal station in India. *Geophys Res Lett* 2002; 29(23): 1-4.
2. Bano T, Sinha S, Gupta NC, et al. Variation in aerosol black carbon concentration and its emission estimates at the mega-city Delhi. *Int J Remote Sens* 2011; 32: 6749-64.
3. Cao JJ, Zhu CS, Chow JC et al. Black carbon relationships with emissions and meteorology in Xi'an, China. *Atmospheric Research* 2009; 94: 194-202.
4. Guttikunda S. Air pollution in Delhi. *Economic and Political Weekly* 2012; 47: 24-7.
5. Haywood JM, Shine KP. Multi-spectral calculations of the radiative forcing of tropospheric sulphate and soot aerosols using a column model. *Q J R Meteorol Soc* 1997; 123: 1907-30.
6. Jacobson MZ. Strong radiative heating due to the mixing state of black carbon in atmospheric aerosols. *Nature* 2001; 409: 695-7.
7. Koelmans AA, Jonker MT, Cornelissen G et al. Black carbon: the reverse of its dark side. *Chemosphere* 2006; 63: 365-77.
8. Marrapu P, Cheng Y, Beig G, et al. Air quality in Delhi during the Commonwealth Games. *Atmos. Chem. Phys.* 2014; 14: 10619-30.
9. Salwachter AR, Freischlag JA, Sawyer RG. The training needs and priorities of male and female surgeons and their trainees. *J Am Coll Surg* 2005; 201: 199-205.
10. Sharma SK, Mandal TK, Jain S et al. Source Apportionment of PM2.5 in Delhi, India using PMF Model. *Bull Environ Contam Toxicol* 2016; 97: 286-93.
11. Tiwari S, Shrivastava A, Bisht D et al. Assessment of carbonaceous aerosol over Delhi in the Indo-Gangetic Basin: characterization, sources and temporal variability. *Nat Hazards* 2013; 65: 1745-64.
12. Wang ZL, Zhang H, Zhang XY. Simultaneous reductions in emissions of black carbon and co-emitted species will weaken the aerosol net cooling effect. *Atmos Chem Phys* 2015; 15: 3671-85.

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