CHEMICAL CHARACTERISTICS OF PARTICULATE MATTER OVER NORTHERN INDIA: SPATIOTEMPORAL VARIATION

Manoj K. Srivastava, S. K. Sharma, T. K. Mandal, A. Chatterjee, Saraswati, Mohit Saxena, B. P. Singh, R. K. Singh, S. Jain, A. Adak and S. K. Ghosh

Department of Geophysics, Banaras Hindu University, Varanasi-221 005, India

CSIR-National Physical Laboratory, Dr. K S Krishnan Road, New Delhi-110 012, India

Centre for Astroparticle Physics and Space Sciences, Bose Institute, Kolkata-700091, India

e-mail: mksriv@gmail.com

Banaras Hindu University India

ICIMOD

Second Atmospheric Chemistry and Asian Monsoon Workshop (2nd ACAM)

June 8-10, 2015, Bangkok, Thailand

Introduction to the topic:

- The Indo Gangetic plain (IGP), the major source region of pollutants, has important contribution from regional anthropogenic activities that are governed by a number of factors like climate, human pressure, economics and technologies.
- Ambient aerosols consist of mineral dust, metals, sea salts as well as organic (OC, EC) and inorganic pollutants with highly variable contributions.
- All these processes affect the C and N pools and their bio-geochemical cycles.
- Studies suggest that carbonaceous aerosol contribute ~30-35% of the total suspended particulate mass over IGP during wintertime, whereas contribution of WSIC is of the order of 15-20%.
- In view of the importance, the present study has been carried out for stable isotopes of C and N (δ13C and δ15N) over IGP, India for its representative east (Kolkata), central (Varanasi) and west (Delhi) stations (Figure 1) for the year 2011.

Sites description:

•The description of the study sites (Figure 1) is given below:

Delhi: PM_{10} samples were collected at sampling site of the New Delhi (28 38′N, 77 10′E; 218 m amsl). This location show high pollution and high population.

•*Varanasi*: PM_{10} samples were collected at Varanasi (25 18′N, 83 03′E; 129m amsl). This location is a representative station in the middle Ganges valley of North India, in the Eastern part of the state of Uttar Pradesh.

Figure 1: Map of India showing Indo-Gangetic Plain and observational locations: Delhi, Varanasi and Kolkata

•*Kolkata*: PM_{10} samples were collected Kolkata (22 33′N and 88 20′E; 9m amsl). Kolkata is the second most populous city of India after Mumbai. The city is bounded to the west and north-west by Hooghly river spread along 80 km.

Methods:

Stable isotopic compositions ($\delta^{13}C$ and $\delta^{15}N$ values) of PM_{10} were determined by using Delta V plus GC/irMS (Thermo) in a continuous flow mode. TC and TN contents in sample are also calculated from the calibration curve made of four ACA standards ranging from 1–4 µmol for N and 6–24 µmol for C.

Analysis of OC and EC on ambient PM_{10} samples have been carried out by OC/EC carbon analyzer (Model: DRI 2001A; Make: Atmoslytic Inc., Calabasas, CA, USA) following the USEPA Method 'Improve Protocol' with negative pyrolysis areas zeroed.

Possible transport pathways of PM_{10} from their potential sources of origins has been identified by 5 days backward trajectory calculated using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model using GDAS meteorological data.

Results:

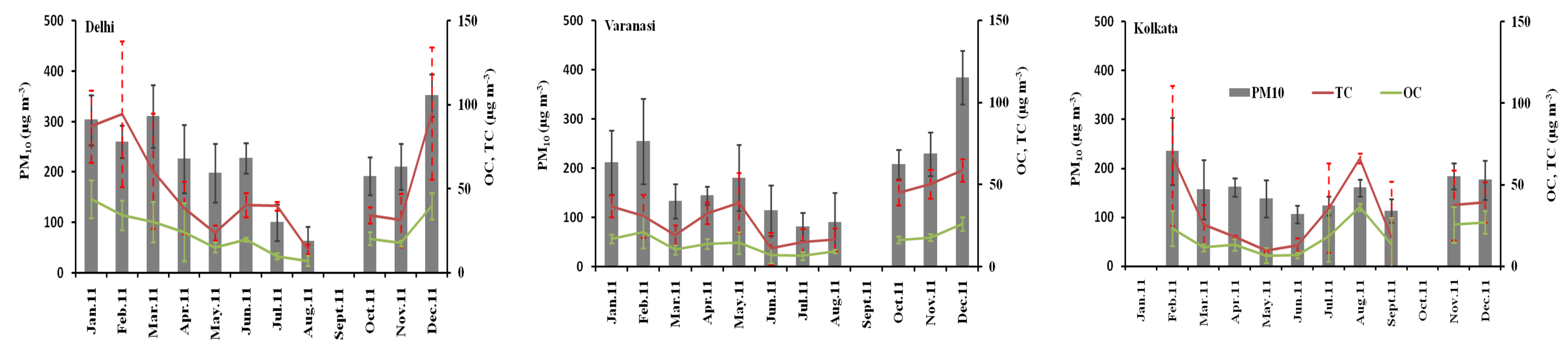

Figure 2 : Monthly variation in concentrations of PM_{10}, OC and TC over IGP, Northern India

Figure 2 shows the monthly variation in PM_{10} mass concentration along with TC and OC over Delhi (Left Panel), Varanasi (Central Panel) and Kolkata (Right Panel) of IGP, India during the study period. The average daily mass concentration of PM_{10} over Delhi, Varanasi and Kolkata were between 51.1 – 376.3 µg m^{-3}, 48.3 – 387.3 µg m^{-3}, and 92.9 – 312.4 µg m^{-3}, respectively during January–December 2011. Higher monthly concentration of PM_{10} was recorded as 333.6 µg m^{-3} and 366.6 µg m^{-3} over Delhi and Varanasi, respectively, in December 2011, whereas higher monthly PM_{10} mass concentration was recorded as 244.3 µg m^{-3} over Kolkata during February 2011.

The average elemental concentrations of total carbon, total nitrogen (TC and TN) and isotopic ratios of $\delta^{13}C$ & $\delta^{15}N$ along with $\delta^{13}OC$ & OC of PM_{10} mass over Delhi, Varanasi and Kolkata of IGP, India are summarized in Table 1. The average concentrations of TC and TN of PM_{10} were recorded as 52.9 33.6 µg m^{-3} and 14.9 10.8 µg m^{-3} over Delhi, whereas $\delta^{13}C$ and $\delta^{15}N$ of PM_{10} vary in a narrow range of –25.5 0.5‰ – 9.6 2.8‰, respectively. The TC/TN ratio of PM_{10} over Delhi ranges from 4.8 – 20.2 with an average value of 9.8 3.7 (Table 1). The average elemental concentrations of $\delta^{13}OC$ and OC of PM_{10} over Delhi were recorded as –25.5 0.4‰ and 25.3 19.3 µg m^{-3}, respectively (Table 1). The average value of $\delta^{13}C$ and $\delta^{15}N$ of PM_{10} was recorded as –25.4 0.8‰ and 6.8 2.4‰ respectively, over Varanasi with a range of –26.4 to –23.3‰ and 2.8 to 11.0‰ respectively. The average concentrations of $\delta^{13}OC$ and OC of PM_{10} were recorded as –25.3 0.7‰ and 11.6 7.6 µg m^{-3}, respectively over Varanasi (Table 1).

Table 1: Annual average elemental concentrations of total C & N, and their isotopes $\delta^{13}C$, $\delta^{15}N$ with TC/TN ratios of PM_{10} collected over IGP India

Parameters	Delhi (*n = 20*)		Varanasi (*n = 20*)		Kolkata (*n = 18*)	
	Range	Average	Range	Average	Range	Average
$\delta^{13}C$	-26.38 – -24.79	–25.52 0.48	-26.38 – -23.28	–25.41 0.82	-26.59 – -24.92	–25.99 0.42
$\delta^{15}N$	3.30 – 14.32	9.62 2.75	2.81 – 11.01	6.78 2.42	2.76 – 11.51	7.40 2.71
µg C m^{-3} (TC)	13.14 – 125.91	52.97 33.62	9.32 – 51.92	27.06 13.23	9.03 – 98.15	32.57 24.85
µg N m^{-3} (TN)	1.52 – 42.25	14.92 10.83	2.28 – 36.56	9.84 9.68	1.42 – 25.92	9.27 8.24
TC/TN	4.84 – 20.19	9.82 3.71	2.05 – 16.33	9.18 3.98	4.40 – 25.93	11.05 5.74
δ^{13} OC	-26.59 – -24.92	–25.49 0.39	-26.29 – -24.61	–25.30 0.65	-27.34 – -25.01	–26.05 0.65
µg OC m^{-3}	3.25 – 61.13	25.33 19.27	4.32 – 39.92	11.54 7.64	6.06 – 66.93	23.36 19.68

Figure 3 shows scatter plot between OC and EC during the study period for Delhi (r^2= 0.78), Varanasi (r^2= 0.88) and Kolkata (r^2= 0.81). Such high regression has been attributed to biomass burning emissions, e.g. vehicular traffic, biomass burning etc., as major sources of PM over IGP India. In the present case, positive correlation between $\delta^{13}C$ and TC values was seen over Delhi (r^2 = 0.268), Varanasi (r^2 = 0.168) and Kolkata (r^2 = 0.453), which suggest presence of inorganic C in regional ambient air.

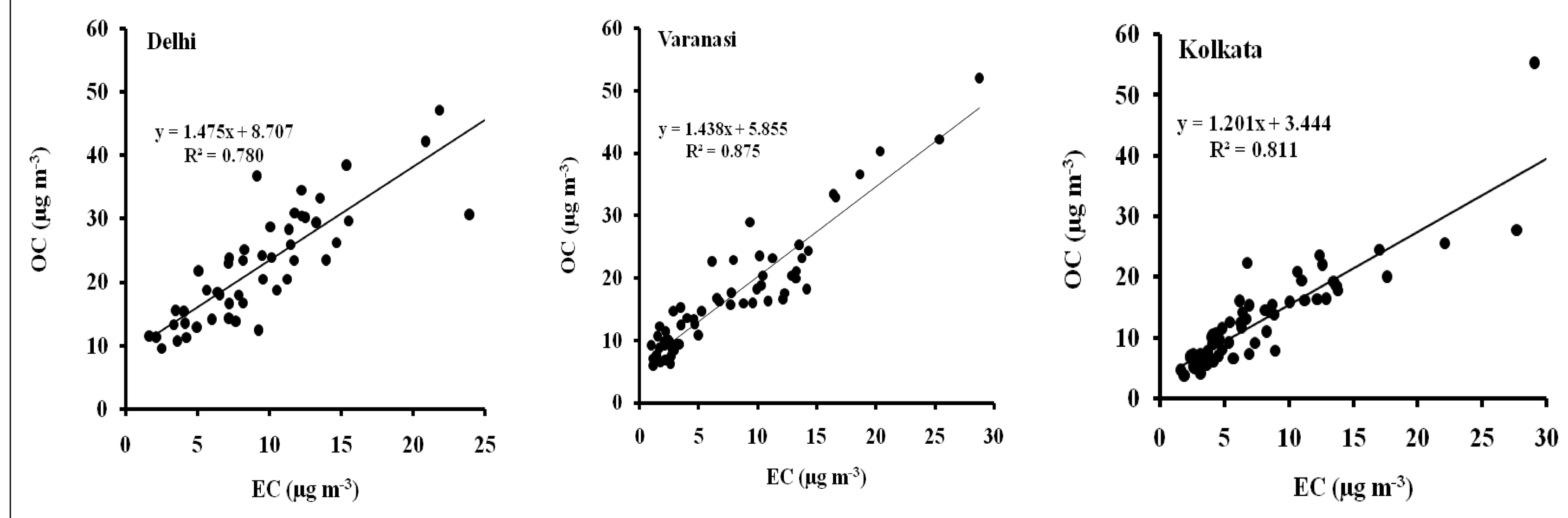

Figure 3: Scatter plot of OC and EC of PM_{10} over Delhi, Varanasi and Kolkata of IGP India

Back Trajectory (HYSPLIT) (Figure 4) shows the air mass parcel from long range transport at the receptor sites. During the study, the approaching air mass at the receptor site Delhi (Figure 4a) was mainly of continental type and transported from the IGP, Pakistan, Afghanistan and its surrounding areas. In another study, we found similar trajectories for Delhi during winter season, but for another year.

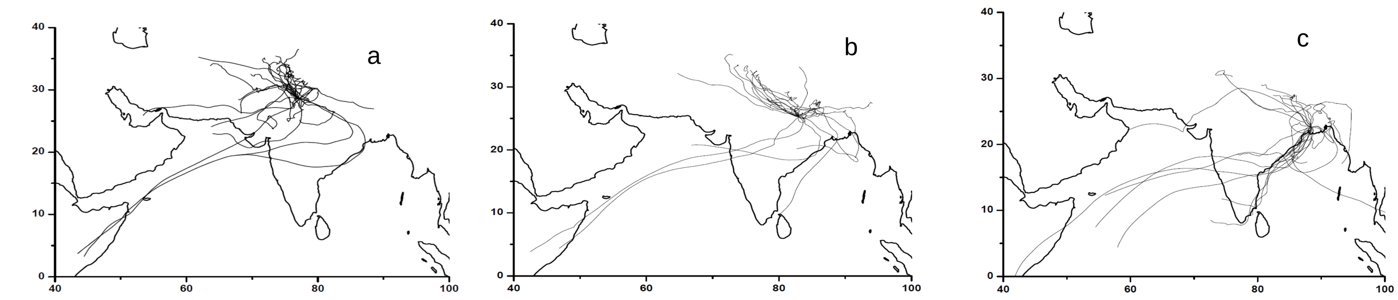

Figure 4: Air parcel back trajectories over (a) Delhi, (b) Varanasi and (c) Kolkata during 2011

The approaching air mass at the receptor site Varanasi (Figure 4b) was mainly from IGP and surrounding area, whereas at Kolkata (Figure 4c), it was found approaching from IGP, Bay of Bengal, Arabian sea, and coastal sites of West Bengal, Orissa and Andhara Pradesh. IGP, central, east coast and south Indian are reported for its high emission of BC aerosols due to extensive use of biomass fuels, particularly wood.

Conclusions:

The study of simultaneous observation of PM_{10} at three locations viz., Delhi (upper IGP), Varanasi (middle IGP) and Kolkata (lower IGP) and its chemical properties (OC, EC, and WSIC) for the year 2011 provides following points:

- The average mass concentration of PM_{10} was observed higher (205.7 µg m^{-3}) at Delhi. Average value of PM_{10} over IGP was recorded as 152.8 29.7 µg m^{-3} with a range of 28.8–392.1 µg m^{-3} during study. The maximum average concentration of OC has been recorded at Delhi (23.57 µg m^{-3}) and minimum at Kolkata (12.74 µg m^{-3}).
- The analysis of OC and EC also attributed the combined effects of traffic emission, biomass burning, wood burning and crop residue burning of PM_{10} mass over Delhi, Varanasi and Kolkata of IGP, India.
- Demographic variation, local anthropogenic loading as well as advection from associated areas and long distance might have influenced the mass concentration of PM_{10} and their chemical characteristics. Further analysis using receptor models applying available data on chemical properties as an input, source apportionment study, particularly the contribution of different sectors to the mass concentration of PM_{10} may be quantitatively determined.

Acknowledgements:

Authors are thankful to ISRO-ARFI and Council of Scientific and Industrial Research (CSIR), New Delhi for providing financial support for the study. The authors are thankful to the Director, CSIR-NPL, New Delhi and Head, Radio and Atmospheric Sciences Division, NPL, New Delhi for their encouragement. Author MKS is thankful to ICIMOD for financial support for participation in 2nd ACAM.