ARCHITA RANA

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AREA OF RESEARCH

I work on carbonaceous aerosol; specifically optical and chemical properties of black carbon (BC) and brown carbon (BrC) aerosols in rural eastern Indo-Gangetic plains to understand source emissions and climate forcing. Along with that I also work on quantitative and qualitative analysis its chromophoric composition.

Under the Supervision of **Dr. Sayantan Sarkar,** School of Engineering, IIT Mandi and Co- supervision of **Dr. Manoj Kumar Jaiswal**, IISER Kolkata

ACADEMIC BACKGROUND

2017-till date	Integrated MS-PhD	Department of Earth Sciences, Indian Institute of Science Education and Research Kolkata, India	8.67
2016-2017	PG Diploma in Environment and Sustainable Development	Indira Gandhi National Open University (IGNOU), Delhi	60%
2013-2016	B.Sc. (Hons.) Geology	Hansraj College, University of Delhi, Delhi	74.00%
2013	Senior Secondary Examination (12^{th})	Central Board of Secondary Education, Delhi	87.40%
2011	Secondary Examination (10th)	Central Board of Secondary Education, Delhi	9.4

TEACHING ASSOCIATESHIP

Internal:
ES1101: Earth and Planetary Sciences (1st year BS-MS core course)
ES2202: Introduction of Environmental Sciences (2nd year BS-MS core course)
ES2102: Hydrology and Geodynamics (2nd year BS-MS core course)
External:
2021-22- NPTEL course: Research methodology (Assignment checking)
2022-23 - NPTEL course noc22_ce102: Environmental geomechanics
NPTEL course noc23_ce14: Air pollution and control

COURSES TAKEN IN PHD

None (116 credits of coursework were completed during the first 3 years of the IPhD program).

RESEARCH INTERESTS

- Optical and chemical properties of black and brown carbon aerosol with emphasis on nitroaromatic chromophores.
- Aerosol climate forcing
- Reconstruction of historical pollutant deposition profiles in lake sediments

AWARDS AND ACHIEVEMENTS

- **Prime Minister Research Fellowship (PMRF)** in May 2020 – June 2022 for Ph.D. by Ministry of

Education, Government of India (GOI).

- **Global Engagement Fund award** of University College London (UCL), for collaborative research at UCL during 18th January to 2nd February 2020 with Professor Neil Rose on reconstructing historical pollutant deposition profiles using lake sediment archives.
- Registration support under the **Special Registration Support Program for 36th International Geological Congress** postponed due to COVID-19; new dates will be announced soon.

RESEARCH EXPERIENCE

1. "Brown carbon (BrC) aerosols and its chromophoric composition in the Indo-Gangetic Plain" with Dr. Sayantan Sarkar, Assistant Professor, School of Engineering, IIT Mandi. (2017-till date)
2. "Brown carbon and HULIS in the Arctic" with Dr. Sayantan Sarkar, along with scientists from NCPOR Goa and IITM Pune as collaborators. (September-October 2019)
3. "Hydrogeological and Geomorphological mapping of Jammu region using Aster GDEM and Landsat" with Dr. Vinay Sinha, Associate Professor, Department of Natural Resources, TERI University. (June 2015-July 2016)

PUBLICATIONS

Peer-Reviewed Articles

1. Dey, S., Mukherjee, A., Polana, A. J., **Rana, A.,** Mao, J., Jia, S., Yadav, A. K., Khillare, P. S, Sarkar, S., 2020. Brown carbon aerosols in the Indo-Gangetic Plain outflow: insights from excitation emission matrix (EEM) fluorescence spectroscopy**. Environ. Sci.: Processes Impacts**, 23, 745–755. https://doi.org/10.1039/D1EM00050K
2. Mukherjee, A., Dey, S., **Rana, A.,** Jia, S., Banerjee, S., Sarkar, S., 2020. Source and atmospheric processing of brown carbon and HULIS in Indo-Gangetic Plain: Insights from compositional analysis. **Environ. Pollut.,** 267, 115440. https://doi.org/10.1016/j.envpol.2020.115440
3. **Rana, A.,** Dey, S., Rawat, P., Mukherjee, A., Mao, J., Jia, S., Khillare, P. S., Yadav, A. K., Sarkar, S., 2020. Optical properties of aerosol brown carbon (BrC) in the eastern Indo-Gangetic Plain. **Sci. Total Environ.** 716, 137102. https://doi.org/10.1016/j.scitotenv.2020.137102
4. Kolakkandi, V., Sharma, B., **Rana, A.,** Dey, S., Rawat, P., Sarkar, S., 2020. Spatially resolved distribution, sources and health risks of heavy metals in size-fractionated road dust from 57 sites across megacity Kolkata, India. **Sci. Total Environ.** 705, 135805. https://doi.org/10.1016/j.scitotenv.2019.135805
5. **Rana, A.,** Jia, S., Sarkar, S., 2019. Black carbon aerosol in India: A comprehensive review of current status and future prospects. **Atmos. Res.** 218, 207-230. https://doi.org/10.1016/j.atmosres.2018.12.002

Papers under review

6. **Rana, A.,** Rawat, P., and Sarkar, S., 2023. Sources, transport pathways and radiative effects of BC aerosol during 2018-2020 at a receptor site in the eastern Indo-Gangetic Plain. (Under review in Atmospheric Environment)

Book Chapters

1. **Rana, A.,** Dey, S., Sarkar, S., 2021. Optical properties of brown carbon (BrC) in aerosols and surface snow at Ny- Ålesund during the polar summer. In **Understanding Present and Past Arctic Environments: An Integrated Approach from Climate Change Perspectives, ISBN: 9780128228692.**
2. **Rana, A.,** Sarkar, S., 2019**.** First Measurements of Aerosol Climate Forcing Agents in Rural West

Bengal. In **Environmental issues: Approaches and practices,** ISBN: 978-81-939266-1-1.

Conference Papers/Posters

1. **Rana, A.,** Dey, S., Sarkar, S., 2020. Optical properties of atmospheric brown carbon (BrC) for photochemical and biomass burning-dominated aerosol regimes in India. **36th International Geological Congress (IGC),** (Postponed due to COVID-19), New Delhi, India.
2. **Rana, A.,** Sarkar, S., 2018. Summer-time black and brown carbon (BC and BrC) in the eastern Indo-Gangetic plains, oral presentation at **Indian Aerosol Science & Technology Association (IASTA 2018) conference during 26-28 November 2018 at Indian Institute of Technology (IIT), Delhi.**

WORKSHOP ATTENDED

1. Participated in **International Workshop on Cloud Dynamics, Microphysics and Small-scale Simulation** during 13 - 17 August 2018 organized by Indian Institute of Tropical Meteorology (IITM), Pune.
2. International workshop on **Land-Ocean-Atmosphere interaction, greenhouse gases and coastal processes (LOA**) 2018 conducted at IISER Kolkata during 24 July – 5 August 2018.
3. **Global Initiative of Academic Networks (GIAN)** course on science communication by Prof. Lewis Dartnell from 22 - 26 July 2019 in IISER Kolkata.

INSTRUMENTATION EXPERIENCE

Mass spectroscopy [GC-MS and HPLC-MS], Transmission and Reflected Light Microscopy, Aethalometer (AE- 33), $PM_{2.5}$ sampler, UV-vis spectroscopy, Fluorescence spectroscopy, Attenuated Total Reflection Fourier Transform Infrared (ATR FTIR) Spectroscopy, Wavelength Dispersive X-Ray Fluorescence (WD-XRF), Nuclear magnetic resonance (NMR).

SOFTWARE AND TOOLBOX USED

OriginPro, MATLAB, ArcGIS, SBDART, HYSPLIT, drEEM toolbox, PARAFAC model

FIELD STUDIES

February - March 2020	Mandi, Himachal Pradesh, India	Indoor pollution sampling	IISER Kolkata
September - October 2019	Ny-Alesund, Svalbard, Norway	Brown carbon and HULIS in Arctic	IISER Kolkata and NCPOR Goa
December 2018	Chandipur, Orissa, India	Sedimentology	IISER Kolkata
January 2018	Ghatshila region, Jharkhand, India	Reconstruction of the structural deformation history of the region	IISER Kolkata
December 2017	Gurudomgmar lake, Sikkim, India	Preliminary survey for limnological studies.	IISER Kolkata
December 2015-January 2016	Mandi, Himachal Pradesh, India	Structural Sedimentological features	Hansraj College, Delhi University
December 2014-January 2015	Jammu, India	Paleontological, structural, sedimentological features and stratigraphy of Siwaliks (Outer Himalaya)	Hansraj College, Delhi University

EXTRA-CURRICULAR

- Participated in university-level competition themed as “Meeting the Challenges of India”
- Participated in “Pink Chain Campaign” for cancer awareness.
- Participated in “Protolith (2015)”, Geological festival of IIT Bombay.
- Participated in Fevicryl Painting workshop at IISER Kolkata.
- Worked as Ed-Volunteer in Make a difference NGO.
- Stood first in spray painting in INQUIVESTA at IISER Kolkata.

Environmental Issues: Approaches and Practices (2019), 1:32-39
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First Measurements of Aerosol Climate Forcing Agents in Rural West Bengal

Archita Rana • Sayantan Sarkar*

Abstract This study reports the first measurements of aerosol climate forcing agents (black and brown carbon; BC and BrC) from a rural location in West Bengal. To this end, time-resolved measurements of aerosol optical properties were carried out at Mohanpur, West Bengal using a 7-wavelength Aethalometer during summer 2018. These were supplemented by time-integrated fine-mode aerosol ($PM_{2.5}$) samples, and analysis of optical properties of their aqueous and organic extracts. The daily averaged BC varied from 0.9-7.5 µg m^{-3} (mean: 3.6±2.0 µg m^{-3}), and its diurnal profile exhibited early morning (0700-0800 h) peaks characterized by high fossil fuel BC, and late evening (1900-2100 h) peaks from residential fuel use reflected by enhanced biomass burning (BB-BC). The contribution of BB-BC to BC_{total} was 17% for the study period. The diurnal profile of BrC absorption ($b_{abs(BrC)}$) tracked the BC-BB fraction with a concurrent peak during 1900-2100 h, suggesting co-emission. Overall, BrC contributed 15% and 18%, respectively, to total and BC-associated light absorption at 370 nm. Aqueous and organic extracts of summertime aerosol showed strong wavelength-dependence with averaged BrC_{AE} values of 7.2 and 6.2, respectively, confirming a substantial presence of both aqueous- and organic-soluble BrC chromophores. Fluorescence spectra for aqueous extracts showed a strong peak at ~420 nm, possibly indicating the presence of poly-conjugated humic-like substances (HULIS), while that for organic extracts exhibited a broader and more intense peak suggesting water-insoluble BrC chromophores. Overall, this study established for the first time that BrC is a significant component of light absorbing aerosol in rural West Bengal.

Keywords Angstrom exponent, Carbonaceous aerosols, Concentration-weighted trajectory (CWT), India, Optical properties

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INTRODUCTION

Among aerosol chemical constituents, black carbon (BC) is the most potent climate forcing agent (radiative forcing estimate: +1.1 W m^{-2}; Bond et al., 2013) with pronounced effects on atmospheric stability, large scale circulation, monsoon patterns and snow albedo (Tiwari et al., 2013 and references therein). In India, large internal heterogeneities exist for BC

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Review article

Black carbon aerosol in India: A comprehensive review of current status and future prospects

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ABSTRACT

India is currently the second-largest emitter of black carbon (BC) in the world, with emissions projected to rise steadily in the coming decades. In view of the large variations associated with BC emission inventories in this region, model outputs of BC mass and radiative forcing (RF) need to be validated against long-term regionally-representative atmospheric measurements. Such measurements are highly scattered spatially as well as temporally in India, and a systematic evaluation of BC data is non-existent so far. To address this issue, we present here a comprehensive review of BC measurements in India from a survey of > 140 studies spanning 2002–2018. In addition to summarizing baseline BC levels in urban, semi-urban, rural and remote locations, we report impacts of anomalous environmental and/or emission conditions, e.g., truck/general strikes, firework events, fog/haze episodes, large-scale biomass burning events, etc. We also present a discussion on major BC sources and climate impacts (in terms of direct RF) in major land-use categories, mitigation strategies currently employed on a national scale, and recent advances in measuring brown carbon (BrC) in India. We identify key areas for improvement, such as – i) the need for long-term BC monitoring networks, especially in regions where estimated emissions are high but measurement coverage is low; ii) the general lack of understanding, despite some recent reports, of BC aerosol mixing states, aging and direct climate effects in the Indian context; iii) the need to shift from qualitative approaches of BC source apportionment to robust quantitative measures; and iv) the prospects for coupled chemical-optical characterization of BrC for a better understanding of its sources and climate effects. We list potential research directions for the scientific community to address these knowledge gaps. We also believe that this review will be beneficial to policymakers for prioritizing BC mitigation efforts.

1. Introduction

Atmospheric fine mode aerosols play an important role in the earth's energy balance by scattering and absorbing solar radiation, and by modifying cloud characteristics, snow albedo and precipitation. Among aerosol chemical constituents, black carbon (BC) is the most potent climate forcing agent with a radiative forcing (RF) estimate of +1.1 (+0.17 to +2.1) W m^{-2} (Bond et al., 2013), which is around ~65% of that of CO_2. Aerosol BC is released from the incomplete combustion of fossil fuels, bio-fuels and biomass, and is known to exert considerable influence on regional precipitation and surface cooling (Menon et al., 2002), northern hemispheric tropical expansion (Allen et al., 2012), Arabian Sea tropical cyclones (Evan et al., 2011) and the hydrological cycle in general (Ramanathan et al., 2001). Such effects are facilitated by its atmospheric residence time in the order of 6–10 days (US EPA, 2012) that supports regional and long-range transport from source regions followed by deposition. Owing to its limited atmospheric lifetime compared to greenhouse gases, there is broad scientific consensus in targeting BC mitigation as a short-term climate strategy (Jacobson, 2002; Ramanathan and Xu, 2010). In addition to climate impacts, exposure to BC aerosols have also been linked to adverse cardiovascular and respiratory effects in humans (WHO, 2012).

Due to the absence of long-term regionally representative atmospheric BC data, climate models use emission estimates derived from fuel consumption inventories as inputs for simulation of BC mass density and RF. This represents a major source of uncertainty in current BC RF estimates. Regional BC emission inventories have considerable variability owing to the choice of emission factors and technology diffusion scenarios, unreliability of fuel consumption estimates in the preindustrial and early-industrial era, and the general lack of historical

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Optical properties of aerosol brown carbon (BrC) in the eastern Indo-Gangetic Plain

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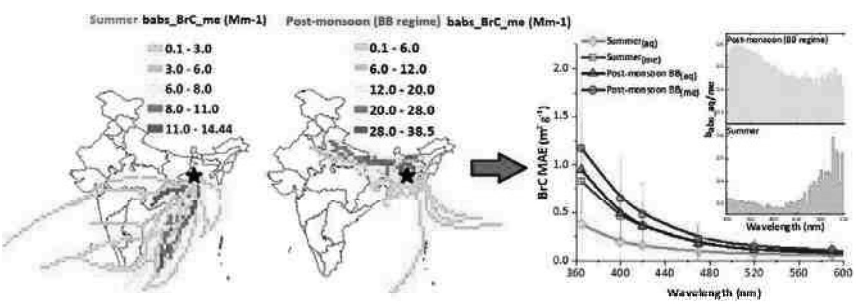
HIGHLIGHTS

- This study reported a coupled chemical-optical characterization of BrC in the Indo-Gangetic Plain.
- Absorption due to aqueous- and methanol-extractable BrC were enriched by factors of 3–5 during biomass burning periods.
- Humic-like substances and nitroaromatics mostly constituted BrC light absorption.
- Atmospheric aging of the biomass burning plume modified BrC optical properties.
- BrC was found to be a significant component of light-absorbing aerosol in this region.

GRAPHICAL ABSTRACT



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Nitroaromatic compounds
Mass absorption efficiency (MAE)
Radiative forcing

ABSTRACT

We report here measurements of aerosol black carbon (BC) and aqueous and methanol-extractable brown carbon (BrC_{aq} and BrC_{me}) from a receptor location in the eastern Indo-Gangetic Plain (IGP) under two aerosol regimes: the photochemistry-dominated summer and biomass burning (BB) dominated post-monsoon. We couple time-resolved measurements of BC and aerosol light absorption coefficients (b_{abs}) with time-integrated analysis of BrC UV–Vis and fluorescence characteristics, along with measurements of total and water-soluble organic carbon (OC and WSOC), and ionic species (NH_4^+, K^+, NO_3^-). In the BB regime, BC and its BB-derived fraction (BC_{BB}) increased by factors of 3–4 over summertime values. In comparison, $b_{abs\_365\_aq}$ and $b_{abs\_365\_me}$ (absorption coefficients of BrC_{aq} and BrC_{me} at 365 nm) increased by a factor of 5 (9.7 ± 7.8 vs 2.1 ± 1.4 Mm^{-1}) and 2.5 (17.2 ± 9.0 vs 6.9 ± 2.9 Mm^{-1}), respectively, in the BB period over summer, and were highly correlated ($r =$ 0.82–0.87; $p < 0.01$) with the BB-tracer nss—K^+. The wavelength dependence of b_{abs_BrC} (Ångstrom exponent: 5.9–6.2) and the presence of characteristic fluorescence peaks at 420–430 nm suggested presence of humic-like substances (HULIS) in the aged BB aerosol, while significant association between BrC_{aq} and NO_3^- ($r =$ 0.73; $p < 0.01$) possibly indicated formation of water-soluble nitroaromatic compounds. BrC_{aq} contributed 55% to total BrC absorption at 300–400 nm while that for the water-insoluble component (WI-BrC) increased from

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c0016 CHAPTER 16

Optical properties of brown carbon in aerosols and surface snow at Ny-Ålesund during the polar summer

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s0010 16.1 Introduction

p0010 As compared to mid-latitudes, the Arctic climate is more sensitive to emissions of light-absorbing aerosols such as black carbon (BC) with a warming estimate of 1.24K, which is comparable to a 10-fold increase in BC concentration at mid-latitudes (Stjern et al., 2017). Long-range transport events to the Arctic directed from Europe and Russia are more frequent and significant compared to those from Asia and North America and have contributed significantly to the Arctic temperature rise over the past century (AMAP Assessment, 2011). After the polar sunrise, the effect of photooxidation of aerosol and sea-to-air emissions of marine organics is common (Fu et al., 2015). Organic-rich particles significantly contribute to the total aerosol mass in the atmosphere over the Arctic after the polar sunrise (Willis et al., 2016). Overall, carbonaceous aerosols are known to be one of the major contributing factors to Arctic climate change due to their light absorption and scattering properties (Seinfeld and Pandis, 2012). Along with BC, the light-absorbing fraction of organic carbon, that is, brown carbon (BrC), has recently emerged as a species of interest. Light absorption by non-BC constituents can be as high as 25% of the total light absorption in Svalbard and mainland Norway (Doherty et al., 2010).

p0015 Optical properties of BrC depend heavily on its origin, that is, the relative importance of primary emissions versus secondary formation, and therefore, on the nature of atmospheric processing. Biomass burning (BB)

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