

Characteristics of Brown Carbon Present in Ambient Aerosols Over Different Regions in India

A Thesis

submitted for the Award of Ph. D. degree of

MOHANLAL SUKHADIA UNIVERSITY

in the

Faculty of Sciences

By

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2018

DECLARATION

I, Mr. Rangu Venkata Satish Kumar, S/o R Tirupatha Chari, a resident of PRL, Ahmedabad-380009 hereby declare that the research work incorporated in the present thesis entitled "**Characteristics of Brown Carbon Present in Ambient Aerosols Over Different Regions in India**" is my work and is original. This work (in part or in full) has not been submitted to any University for the award of a degree or a diploma.

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I am satisfied with the analysis of data, interpretation of results and conclusions drawn. I recommend the submission of the thesis.

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**Dedicated to Nanna, Amma
and Grand Parents**

ACKNOWLEDGMENT

Well, it took a successful five long years to complete this thesis. In this regard, it gives me immense pleasure to acknowledge the people who contributed directly/indirectly to this thesis. Firstly, I would like to acknowledge my indebtedness, render and warmest thanks to my supervisor, Dr. Neeraj Rastogi, who made this work possible. I have been fortunate to have a supervisor like him who cared so much about my work, his friendly guidance; expert advice has been invaluable throughout all stages of the work. I am extremely obliged to Prof. M. M. Sarin for his critical comments, suggestions, and support. He always encouraged me to think and do something new, and discussions with him were still fruitful.

I thank Dr. Anil Bhardwaj, the Director, and Prof. P. Janardhan, the Dean, Physical Research Laboratory, for providing me with all the necessary facilities to carry out my thesis work.

In the chemistry lab, I would like to thank Dr. Ravi Bhushan for his constructive ideas and support. I will also thank Dr. Sudheer for his help in handling several instruments. I will also thank Dr. Sunil K. Singh and Dr. Rengarajan for his support. I am thankful to my seniors Dr. Prashant Rajputh, Dr. Srinivas Bikkina and Dr. Atinderpal for their constant support and help. I accord my thanks to all my colleagues Venkatesh, Damodar Rao, Kiran, Anil, Chandana, Mahesh, Upasana, Bhatuk, Shubh, Jaldhi, Sneha, Utsav, Chinmay, Preksha, Vineet, Satinder, Rupali, Nithesh, Muruganamtham, Jay, Harsh R, Naman, Romi, Rahul, Nirmal, Onam, Praveen, Ishita, Bankim, Lakan Singh, Mannan, Harsh O, Bivin, Ikshu, Anirbhan, Niharika, Nidhi, Prerana, Prasad, Krishna, Shekar, and Srinivas.

I thank Prof. J. S. Ray, Dr. R. D. Deshpande, Dr. M. G. Yadava, Dr. Sanjeev, Dr. Arvind Singh, Dr. A. D. Shukla, Prof. Ramachandran, Dr. Harish Ghadavi and Dr. Som Kumar Sharma for their interest in my work and interactions during the area seminars. The sincere criticism of my work by Academic Committee members is duly

acknowledged. I also would like to thank Dr. Lokesh Kumar Sahu for his help in scientific discussions and ideas.

I am glad to acknowledge, Dr. S. N Tripathi and his group members (Shamjad, Abhishek, Deepika, Navaneet, and Anil), Dr. Darshan Singh, Syam Kumar Kundu, Arup Borgohain, Nilamoni Barman, Dr. Dilip Ganguly and his group members (Pavan Vats, Sunil and Vijay) for their help in aerosol sampling.

I am highly indebted to my parents (Adi Lakshmi and Tirupatha Chari), grandparents late (Sitarama Swamy, Venktaravamma, and Viswarupa Chari), Krupavati, Sisters (Sunitha and Anitha), Uncles (Dr. Venkata Ramana, Rama Krishna, Srinivas and Bangaru) who always have been a source of inspiration and motivation to me. I want to thank Dr. Nikitha for her constant support to complete my thesis.

The time spent at PRL hostel with my close friends (Yasir, Rupa, Navpreet, Prahlad, Rukmani, Kuldeep, Kumar, Jabir, Ali, Chandan, and Santosh) will be an unforgettable moment of my life. Last five years gave me beautiful memories to remember. Finally, I thank all the persons who have, directly or indirectly, helped me during my Ph. D. Thesis

ABSTRACT

Brown carbon (BrC) is a part of organic carbon (OC) which efficiently absorbs light at near UV and visible region, and it is characterized by an absorption spectrum that smoothly increases from the visible to UV wavelengths. BrC immersed in cloud droplets can absorb light and facilitate evaporation/dispersion of clouds. It contributes ~35% of the direct radiative forcing warming caused by carbonaceous aerosols. However, to better assess the effects of BrC on air quality and climate, a proper understanding of its sources and characteristics on temporal and spatial scales is very important. In this study, we have characterized atmospheric BrC using both offline and online techniques. With an aim to understand the characteristics of BrC over different regions dominated by different emission sources and/or meteorological conditions, many regions (Patiala, Delhi, Kanpur, Ahmedabad, Shillong, and Port Blair) and sampling periods were selected for particulate matter smaller than 2.5 μm aerodynamic diameter (PM_{2.5}) sampling. Absorption coefficient at 365 nm is used as a general measure of water-soluble ($b_{\text{abs_365_Water}}$) and methanol soluble ($b_{\text{abs_365_Methanol}}$) BrC. Further, BrC characteristics were investigated concerning its sources, chemical composition, optical properties, and atmospheric evolution. Results from this study suggest that primary emissions from biomass burning (BB) and fossil fuel burning (FFB) are the major sources of highly absorbing BrC, and BB emits significant fraction of water-insoluble BrC. Further, secondary BrC and aged/oxygenated OA are found to be relatively less absorbing. BrC absorption decreases as the day progresses achieving a minimum during afternoon hours, which is ascribed to photo-bleaching/volatilization of BrC. It is also shown that BrC composition is not uniform throughout the day. Our observations suggest that BrC chromophores are a variable mixture of at least HULIS and nitrogen-containing organic compounds over the study regions. Mass absorption efficiency (MAE) of water-soluble and methanol-soluble BrC is found to be significant compare to that of elemental carbon over most of the study sites. These results have important implications in estimating regional radiation budget.

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LIST OF ABBREVIATIONS

AAE	Absorption Ångström Exponent
AOD	Aerosol Optical Depth
BB	Biomass Burning
BBOA	Biomass Burning Organic Aerosol
BC	Black Carbon
BrC	Brown Carbon
CCN	Cloud Condensation Nuclei
CO	Carbon Monoxide
EC	Elemental Carbon
FFB	Fossil Fuel Burning
FID	Flame Ionization Detector
HOA	Hydrocarbon like Organic Aerosol
HYSPLIT	Hybrid Single Particle Langrangian Integrated Trajectory
IGP	Indo-Gangetic Plain
IPCC	Intergovernmental Panel on Climate Change
KHP	Potassium Hydrogen Phthalate
MAE	Mass Absorption Efficiency
MODIS	Moderate Resolution Imaging Spectroradiometer

NDIR	Non Dispersive Infrared Detector
NIOSH	National Institute of Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NO	Nitrogen Oxide
NO ₂	Nitrogen Dioxide
OA	Organic Aerosol
OC	Organic Carbon
OM	Organic Matter
OPAC	Optical Properties of Aerosol and Clouds
PC	Pyrolyzed Carbon
PM	Particulate Matter
RH	Relative Humidity
SOA	Secondary Organic Aerosol
SVOOA	Semivolatile Oxygenated Organic Aerosol
TC	Total Carbon
TOC	Total Organic Carbon
TSP	Total Suspended Particulates
VOC	Volatile Organic Carbon
WSIS	Water Soluble Ionic Species
WSOC	Water Soluble Organic Carbon

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List of Publications:

1. A. Singh, N. Rastogi, A. Patel, **R. V. Satish**, D. Singh, Size-Segregated Characteristics of Carbonaceous Aerosols over the Northwestern Indo-Gangetic Plain: Year Round Temporal Behaviour. *Aerosol Air Qual. Res.* **2016**, *16* (7), 1615–1624 DOI: 10.4209/aaqr.2016.01.0023.
2. **R.V. Satish**, P.M. Shamjad, N.M. Thamban, S. N. Tripathi and N. Rastogi, Temporal Characteristics of Brown Carbon over the Central Indo-Gangetic Plain. *Environ. Sci. Technol.* **2017**, *acs.est.7b00734* DOI: 10.1021/acs.est.7b00734.
3. P. M Shamjad, **R. V. Satish**, N. M Thamban, N. Rastogi, Tripathi, S. N. Absorbing Refractive Index and Direct Radiative Forcing of Atmospheric Brown Carbon over Gangetic Plain. *ACS Earth Sp. Chem.* **2018**, *2* (1), 31–37 DOI: 10.1021/acsearthspacechem.7b00074.
4. N. Rastogi, A. Singh, **R. V. Satish**, Characteristics of sub-micron particles coming from a big firecrackers burning event: Implications to atmospheric pollution. *Atmos. Pollut. Res.*, 2018 (accepted, in press).
5. **R. V. Satish** and N. Rastogi, On the Use of Brown Carbon Spectra as a Tool to Understand Their Broader Composition and Characteristics: A Case Study from Crop-residue Burning Samples, 2018 (Under review)