SOURCE APPORTIONMENT
OF AMBIENT AEROSOLS IN JAMMU

A Joint Initiative of

Central University of Jammu &

Jammu & Kashmir Pollution Control Committee

Source Apportionment of Ambient Aerosols in Non-Attainment City of Jammu

Joint Initiative

by

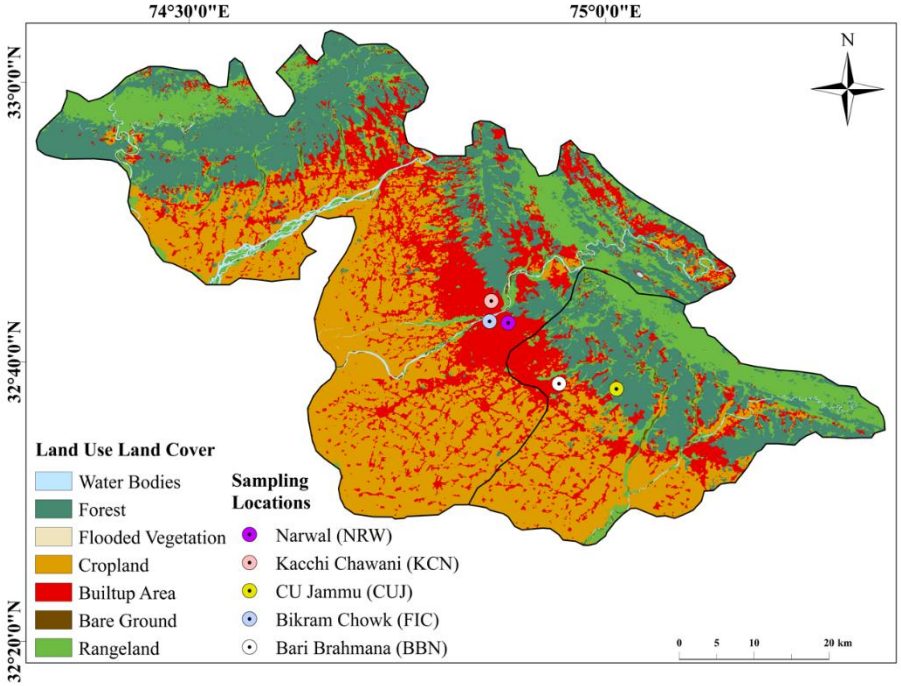
Central University of Jammu

and

Jammu & Kashmir Pollution Control Committee

Under the Project

"Source Apportionment of Ambient Aerosols and Carrying Capacity in Non-Attainment Cities of Jammu/Srinagar"



Principal Investigator:

Dr. Shweta Yadav

Associate Dean International Affairs & Assistant Professor,
Department of Environmental Sciences, Central University of Jammu,
Samba, Jammu & Kashmir– 181143, India

सत्यमेव जयते

Dheeraj Gupta, IAS
Addl Chief Secretary/
Financial Commissioner,
Forest, Ecology & Environment

Foreword

Clean air is a fundamental requirement for life and we are committed for achieving goals as envisioned under National Clean Air Programme, a nationwide initiative of Ministry of Environment, Forest and Climate Change, GoI. It gives me immense pleasure in extending commendation to the efforts of the Aerosol Research Group at Central University of Jammu on successful completion of study titled "Source Apportionment of Ambient Aerosols in Non-Attainment City of Jammu." This collaborative endeavor, undertaken in partnership between Central University of Jammu and Jammu & Kashmir Pollution Control Committee represents a significant milestone in our ongoing commitment towards achieving Clean Air Goals in the UT of Jammu & Kashmir.

Led by a dedicated group of researchers, supported by administration of UT of J&K and peer-reviewed by experts, this report will be instrumental in unraveling the complex dynamics of aerosols in non-attainment city of Jammu. Through systematic sampling, detailed chemical analysis, and overall robust methodology, the team has provided valuable insights into the sources and composition of ambient aerosols, paving the way for informed decision-making and targeted interventions.

I commend the dedication and perseverance of all the stakeholders from Central University of Jammu and Jammu & Kashmir Pollution Control Committee involved in this endeavor. Their collaborative spirit and tireless efforts have led to compilation of this study and also the establishment of Himalayan Aerosol Research Instrumentation (HARI) Facility.

I am immensely proud to be associated with this initiative and I look forward to designing of location specific interventions for seeking sustainable solutions to the problem of air pollution. I am confident that the findings and recommendations of this project will serve as a guiding light for future endeavors for air quality management and inspire further collaborative efforts towards capacity building in the region.

I congratulate Prof. Sanjeev Jain, Vice Chancellor, Central University of Jammu and Sh. Vasu Yadav, Chairman, Jammu & Kashmir Pollution Control Committee for this milestone achievement.

(DHEERAJ GUPTA)

प्रो०. संजीव जैन
कुलपति
Prof. Sanjeev Jain
Vice Chancellor

जम्मू केंद्रीय विश्वविद्यालय
Central University of Jammu
टेलिफैक्स/Tele-Fax : 01923-249634 (O)
Mob. : 9622443344
ई-मेल/ E-mail : vc@cujammu.ac.in
sj.vc@cujammu.ac.in

Foreword

I am delighted to note the completion of the study titled "Source Apportionment of Ambient Aerosols in Non-Attainment City of Jammu." This collaborative initiative, undertaken in partnership with the Jammu and Kashmir Pollution Control Committee (JKPCC), exemplifies our commitment to advancing scientific research and addressing pressing environmental issues.

As an Institute of Repute under the National Clean Air Programme, the Central University of Jammu is dedicated to capacity building in terms of establishing high-end laboratories, executing national and international projects and contributing in knowledge creation and dissemination. We have demonstrated excellence in the field of Atmospheric Science and Climate Change through research and innovation. The establishment of the Himalayan Aerosol Research Instrumentation (HARI) Facility in our campus, in collaboration with the Jammu & Kashmir Pollution Control Committee, highlights our dedication for conducting cutting-edge research on different dimensions of aerosols.

The study of source apportionment of ambient aerosols is crucial for understanding the complex dynamics of aerosols and its implications. This project represents a significant step forward in our collective efforts to identify and mitigate the sources of air pollution in the non-attainment city of Jammu.

I am especially thankful to Shri Manoj Sinha Ji, Honourable Lieutenant Governor of UT of J&K for his continued guidance and support. I also thank Forest, Ecology and Environment Department, UT of J&K and JKPCC for keeping confidence in our efforts. Together, we are making significant strides towards a cleaner and healthier environment for the UT of Jammu & Kashmir. I congratulate the Aerosol Research Group at Central University of Jammu and all other stakeholders for their commendable efforts in this project. Their dedication and expertise have contributed significantly to our understanding of air quality issues in non-attainment city of Jammu. Together, we are making significant strides towards a cleaner and healthier environment for the UT of Jammu & Kashmir.

(Prof. Sanjeev Jain)

Vasu Yadav
Chairman
J&K Pollution Control Committee

FOREWORD

Adverse effects of air pollution on health, ecosystems, and economy are well documented. Whereas pollution from industrial and vehicular sources is extensively discussed and debated, pollution from numerous other sources is often ignored in public discourse. This has a bearing on the strategies and policies that are adopted to tackle air pollution.

Source apportionment studies help tailor pollution control measures to specific emission sources, leading to more effective and efficient mitigation strategies. By identifying the primary contributors to air pollution, interventions can be directed towards the most impactful sources. Understanding the sources of pollution enables policymakers to develop and enforce regulations that address the most significant contributors to air quality degradation.

Governments and regulatory agencies can use source apportionment data to incentivize the adoption of clean technologies and sustainable practices. Empowering communities with information about air pollution sources and their effects is pivotal for fostering public engagement and support for pollution control initiatives.

The Source Apportionment Study for Jammu city was assigned to the Central University of Jammu by Jammu and Kashmir Pollution Control Committee. Despite difficulties on account of COVID related disruptions during the fieldwork phase of the study, the Aerosol Research Group led by Dr. Shweta Yadav has done an excellent job in carrying out this study. In addition, by establishing the Himalayan Aerosol Research Instrumentation Facility (HARI), the Central University of Jammu has also laid the foundation for future research in the field of aerosols, air pollution and climate change.

Continued investment in source apportionment research, expanded monitoring networks, and enhanced data sharing are essential for advancing pollution control efforts. Collaboration among researchers, policymakers, regulators, and industry stakeholders is vital to drive effective solutions and achieve cleaner air for all.

(Vasu Yadav)

INDIAN INSTITUTE OF TECHNOLOGY
Department of Civil Engineering and Department of Sustainable Energy Engineering
KANPUR - 208016 INDIA

Dr. Sachchida N. Tripathi, FNA, FNAE, FNASc
Professor
Sir M. Visvesvaraya Chair
J.C. Bose National Fellow

Tel : +91-512-2597845 (O), 2598806 (R)
Mobile: +91-9415050540
Fax : +91-512-2597395/2590260
E-mail : snt@iitk.ac.in, sachchida.tripathi@gmail.com
URL : http://home.iitk.ac.in/~snt

FOREWORD

Air Pollution is an emerging global environmental threat. Recognizing the menace of air pollution in India, the Ministry of Environment, Forest & Climate Change launched the National Clean Air Program in 2019. The program rests on three pillars: science & data, institutions and capacity building and mitigation. As part of capacity creation, technical institutions, government laboratories and universities were brought under a rainbow alliance with respective pollution Control Boards to provide scientific and technical contributions towards clean air goals in cities where program is implemented.

I am extremely pleased to see the joint efforts of Central University of Jammu and Jammu and Kashmir Pollution Control Committee in successfully completing the source apportionment study of aerosols in the non-attainment city of Jammu. This study provides the comprehensive dataset on concentration, sources and chemical signatures of fine particulates and will surely help the policymakers in designing location specific interventions for achieving clean air goals. This study will also help researchers to understand the implications of fine particulates on human health and the Himalayan climate.

I also congratulate the Central University of Jammu and Jammu and Kashmir Pollution Control Committee for establishing the joint Himalayan Aerosol Research Instrumentation (HARI) Facility in the campus.

I am confident that these joint efforts will hugely benefit the scientific community as well as policymakers and will contribute in the well-being of people of the UT of Jammu & Kashmir.

Your Sincerely,

Sachida Nand Tripathi

Sachchida Nand Tripathi

Project Team

Principal Investigator

Dr. Shweta Yadav,
Associate Dean, International Affairs & Assistant Professor, Department of Environmental Sciences, Central University of Jammu, Samba – 181143, Jammu & Kashmir, India
Nodal faculty under National Clean Air Programme, MoEFCC, GoI

Co - Principal Investigator

Mr. B. M. Sharma, Member Secretary, Jammu & Kashmir Pollution Control Committee, Jammu & Kashmir, India; Presently Additional Principal Chief Conservator of Forests (PCCF), UT of Ladakh

Mentor

Prof. Sachchida Nand Tripathi,
Department of Civil Engineering, Department of Sustainable Energy Engineering, Indian Institute of Technology Kanpur, Kanpur – 208016, India and National Coordinator, National Knowledge Network, National Clean Air Programme, MoEFCC, GoI

Contributing Scientist

Dr. Yash Paul, Scientist B, Head Labs, Jammu & Kashmir Pollution Control Committee, Jammu & Kashmir, India

Collaborator

Dr. Ankit Tandon,
Assistant Professor, Department of Environmental Sciences, Central University of Jammu, Samba – 181143, Jammu & Kashmir, India

Team Members

Research Associates:	Mr. Vijay Kumar and Mr. Ashish Dogra
Junior Scientific Assistant:	Mr. Ajay Thakur
Sampler Operators:	Ms. Havleen Kaur, Ms. Diksha Sharma, Ms. Konika Sharma, Ms. Suksham Jamwal and Mr. Sajan Bandral
Editorial Team:	Mr. Ashish Dogra, Ms. Sarita Bamotra, Ms. Konika Sharma and Mr. Sajan Bandral

Reviewers

Prof. Shubha Verma,
Department of Civil Engineering, IIT Kharagpur, Kharagpur – 721302, India

Prof. Sagnik Dey,
CAS, IIT Delhi,
New Delhi – 110 016, India

Prof. Sachin S. Gunthe,
CACS, Department of Civil Engineering, IIT Madras, Chennai – 600036, India

Disclaimer

This report is the result of project on "*Source Apportionment of Ambient Aerosols in the Non-attainment City of Jammu*", funded by the Jammu and Kashmir Pollution Control Committee (JKPCC), UT of Jammu & Kashmir. Central University of Jammu (CUJ) has conducted this study in collaboration with JKPCC and the analysis has been done in the Himalayan Aerosol Research Instrumentation Facility, a joint facility of CUJ and JKPCC.

The information generated in this report is in line with the objectives stated in the project. The interpretations and conclusions presented in this report are based on the measurements conducted at five different locations in the Jammu region from June 2021 to May 2022. Due care has been taken to ensure the accuracy and validity of the information.

This report can be cited as: *Yadav et al., 2024. Report on "Source Apportionment of Ambient Aerosols in the Non-attainment City of Jammu" conducted by CUJ and funded by JKPCC.*

Acknowledgement

We would like to express our sincere gratitude to ***Shri Manoj Sinha ji,*** *Hon'ble Lieutenant Governor, UT of Jammu & Kashmir* for his blessings and motivation to all the accomplishments of *Aerosol Research Group at Central University of Jammu (CUJ).*

Our special thanks are due to ***Mr. Dheeraj Gupta***, *Additional Chief Secretary, UT of Jammu and Kashmir* for his generosity, kind support and encouragement in all the endeavours of *Aerosol Research Group at CUJ.*

We express our sincere gratitude to ***Prof. Sanjeev Jain***, *Hon'ble Vice Chancellor, Central University of Jammu* for his visionary leadership and unwavering support to all the activities of *Aerosol Research Group at CUJ.*

We thank ***Prof. Yashwant Singh*** *(Registrar, CUJ)* for supporting smooth execution of project.

We sincerely thank ***Prof. Sachchida Nand Tripathi*** *(IIT Kanpur)* for his mentorship and invaluable insights since the inception and throughout the execution of this project.

Special thanks are due to ***Sh. Vasu Yadav***, *Chairman, Jammu & Kashmir Pollution Control Committee (JKPCC)* for his kind support, guidance and encouragement in completing this study and for strengthening the collaborative efforts of *CUJ* and *JKPCC.* We also thank previous *Chairmen* of *JKPCC:* ***Sh. Ravi Kesar, Sh. Suresh Chugh*** and ***Dr. Neelu Gera*** for their support.

We also thank ***Sh. Ghansham Singh****, Member Secretary, JKPCC* and previous *Member Secretary JKPCC* ***Sh. K. Ramesh Kumar*** for their guidance and support. The vision and support of previous *Member Secretary*, *JKPCC* ***Sh. B.M. Sharma*** is highly acknowledged.

We thank ***Dr. Prashant Gargava*** *(Director, National Clean Air Programme)* for his valuable suggestions and guidance.

We also extend our sincere thanks to ***Prof. Ashok Aima****, Former Vice-Chancellor, CUJ* for his humble support for this project.

We express gratitude to the ***Ministry of Environment, Forest and Climate Change (MoEF&CC)*** for signing tripartite MoU with *CUJ* and *JKPCC* on 6^{th}*June, 2019.* This milestone agreement laid the foundation of collaboration between *CUJ* and *JKPCC.* We are thankful to *JKPCC* for sanctioning this project and signing another MoU on 5^{th}*February, 2020* to conduct SA study and establish ***Himalayan Aerosol Research Instrumentation (HARI)*** **facility** in *CUJ* campus.

We also thank the administrative and technical staff of *JKPCC* stationed at different sampling stations for extending their support during this project.

We appreciate the support of ***Prof. Deepak Pathania*** *(Dean, DRS),* ***Prof. Sunil Dhar*** *(Dean, SLS),* ***Prof. Richa Kothari*** *(Head, EVS) and all other faculty, administrative and technical colleagues at CUJ* for extending their support during this project.

We also express our sincere appreciation to our collaborator and faculty colleague ***Dr. Ankit Tandon*** for his invaluable contribution in this project and also for the analysis of Water Soluble Ionic Species at *Central University of Himachal Pradesh*.

We are thankful to ***Prof. Shubha Verma*** *(IIT Kharagpur),* ***Prof. Sagnik Dey*** *(IIT Delhi) and* ***Prof. Sachin S. Gunthe*** *(IIT Madras)* for taking out time to review this report and providing valuable comments for improvement. Special thanks to ***Prof. Sachin S. Gunthe*** for his encouragement throughout the study.

We sincerely thank the efforts of entire research team of *Aerosol Research Group* and all who have directly and indirectly contributed to the successful completion of this study.

Dr. Shweta Yadav (PI)

Table of Contents

Executive Summary

Located in the foothills of North-Western Himalayan region, Jammu has seen extensive expansion in industrial activity and commercial sector in the recent years. Expanding population and corresponding increase in the number of vehicles, construction activity and energy consumption has resulted in multiple environmental challenges for the city. In order to address the issues related to air pollution in the Union Territory of Jammu and Kashmir, Central University of Jammu (CUJ) entered into a tripartite Memorandum of Understanding (MoU) with the Jammu & Kashmir State Pollution Control Board (JKSPCB) and Ministry of Environment, Forest & Climate Change (MoEF&CC), GoI on 6th June, 2019. CUJ, being an Institute of Repute (IoR) under the National Clean Air Programme (NCAP), is serving as technical partner to Jammu & Kashmir Pollution Control Committee (JKPCC). Jammu city is one of the identified non-attainment cities across the country, in which the particulate air pollution is above the prescribed National Ambient Air Quality Standards (NAAQS) threshold. Understanding the sources and composition of aerosols is paramount for achieving the goal of clean air under NCAP. Accordingly, this comprehensive source apportionment (SA) study has been carried out to apportion the sources of ambient aerosols in Jammu city.

1. Sampling Locations

In this study, systematic sampling of fine aerosols i.e. $PM_{2.5}$ (particulate matter with aerodynamic diameter of 2.5 µm or less) was done at five sites over one year period in Jammu. As shown in Fig. ES1 and Fig. ES2, following five sampling sites with specific signatures were chosen:

i) Background Site [Central University of Jammu (CUJ) (32.63°N, 75.01°E)]: As this site is surrounded by forest area and has relatively less anthropogenic sources, it is considered as the background site.

ii) Industrial Site [Bari Brahmana (BBN) (32.64°N, 74.94°E)]: This site is located on the outskirts of Jammu city. As it is surrounded by industries, it is considered as the industrial site.

iii) Kerbside Site [Bikram Chowk (FIC) (32.71°N, 74.86°E)]: This road side site is situated along one of the busiest road junctions in Jammu city and is considered as the Kerbside Site.

iv) *Commercial site [Narwal (NRW) (32.71°N, 74.88°E)]:* This site is surrounded by commercial buildings and is considered as the Commercial Site.

v) Residential site [Kacchi Chawani (KCN) (32.73°N, 74.86°E)]: This site is situated in residential area and is considered as the Residential site.

All the sites were chosen carefully to have a complete picture of aerosol composition and its sources in Jammu with due consideration for essential requirements for continuous sampling and safety of the sampling stations. The aforementioned sampling sites, along with land use land cover variations across Jammu are represented in Fig. ES2. Four sites are situated around 400 metres above mean sea level (amsl) and, CUJ, the background site is situated at an elevation of ~ 540m amsl.

Fig. ES1. *Location of sampling sites in Jammu.*

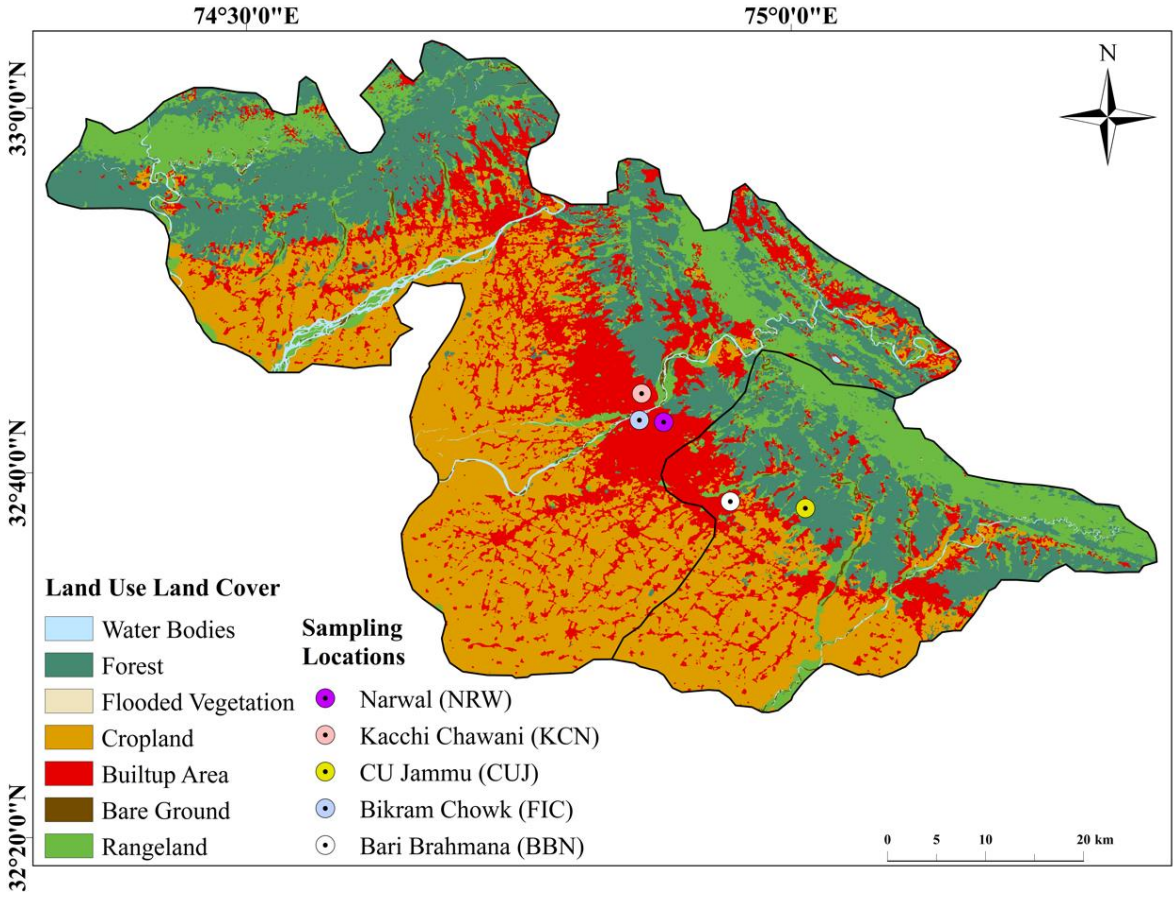


Fig. ES2. *Map showing sampling sites along with Land use Land cover details.*

2. Himalayan Aerosol Research Instrumentation (HARI) Facility

The Himalayan Aerosol Research Instrumentation Facility (HARI) is a joint facility of CUJ and JKPCC for conducting aerosol measurements and chemical analysis (Fig. ES3). The HARI facility has been established in CUJ campus and this facility is equipped with the following sophisticated instruments:

- Five Volumetric flow controlled (VFC) High Volume Air Samplers for ambient air sampling
- Inductively Coupled Plasma– Optical Emission Spectrometer (ICP-OES) for elemental analysis
- Microwave Digestion System (MDS) for sample digestion
- Thermal Optical Reflectance and Thermal Optical Transmittance (TOR/TOT) analyser for the study of carbonaceous aerosols.

Apart from this, the minor instruments available in HARI facility include:

- Five-digit electronic balance for gravimetric analysis
- Ultra-sonicator for sample preparation

- Hot air oven, Vacuum desiccators
- Chiller, refrigerator and temperature-controlled freezer (-20 °C).

Dust free clean room is used for sample handling and preparation in HARI facility and the uninterrupted electricity supply is ensured during sophisticated analysis.

Fig. ES3. *Snapshot of the Himalayan Aerosol Research Instrumentation (HARI) Facility laboratory.*

3. Objectives

Past investigations on source apportionment (SA) of aerosols in different regions of India have revealed significant variations in the contribution of pollution sources, even across the locations that were not so apart. Most city level SA studies from India have utilized chemical speciation datasets of $PM_{2.5}$, collected from multiple locations in a particular city/region. Consequently, mixed profiles were observed which are less precise for individual receptors and instead offer a more general representation of the entire spatial domain. Furthermore, review of SA studies conducted in India has revealed sparse data availability and less robust SA analysis. To provide deeper insight into the contributing sources of ambient aerosols and their potential effects on human health, climate and overall ecosystem, more comprehensive studies on physical and chemical characteristics of aerosols are required in India. Cities those are having sparse historical or baseline data are of great concern, and it is important to conduct robust SA studies at such locations. The comprehensive SA studies over these cities not only provide a better understanding of the sources, but also result in development of first of its kind $PM_{2.5}$ database for the city. The comprehension of the same further serves as a guide for researchers, policymakers, and air quality regulators for framing an effective air quality management strategy for any city. Based on the identified gaps, the following objectives were framed under this study:

- Source apportionment of ambient aerosols using multivariate statistical analysis based on major and trace elements, Water Soluble Ionic Species (WSIS), Organic Carbon (OC) and Elemental Carbon (EC).
- Assessment of monthly, seasonal, and annual variations in the mass, composition, and sources of ambient aerosols in Jammu.
- Investigation of the extent of contribution of the prominent sources to particulate matter in the region of study.

4. Steps and Work Plan for Source Apportionment Study

As shown in Fig. ES4, the source apportionment study involves three main steps: sampling, chemical analysis, and receptor modelling.

Step 1: Sampling

In the first step, an year long $PM_{2.5}$ sampling was performed every third day for 24 hours using High Volume Air Samplers installed at five distinct sampling sites (elaborated in *Section 1. Sampling Locations*). This sampling campaign was carried out continuously from June, 2021 to May, 2022 to capture monthly and seasonal variations in $PM_{2.5}$ concentration.

Step 2: Chemical Analysis

Following the sampling phase, chemical analysis of the collected $PM_{2.5}$ samples was performed. This analysis encompassed the determination of Carbonaceous Aerosols [Organic Carbon (OC) and Elemental Carbon (EC)] using Thermal Optical Reflectance and Thermal Optical Transmittance (TOR/TOT) analyser, Water Soluble Ionic Species (WSIS) using Ion Chromatography System, and Major and Trace Elements using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). This step provided insights into the chemical composition of the collected $PM_{2.5}$ samples.

Step 3: Receptor Modelling

In the final step, receptor modelling was employed to elucidate the sources of $PM_{2.5}$ over Jammu. This involved the investigation of concentration and uncertainty datasets of $PM_{2.5}$ and all chemical species obtained through chemical analysis. For SA, Positive Matrix Factorization (PMF), a robust receptor modelling technique was used. This model serves as a robust method to de-convolute environmental dataset matrices by integrating species' concentration profiles and factor contribution matrices. This approach facilitates a comprehensive understanding of the various sources/factors contributing to the overall $PM_{2.5}$

load. By identifying and quantifying these sources, actionable insights can be gained to formulate effective mitigation strategies and policies aimed at improving air quality.

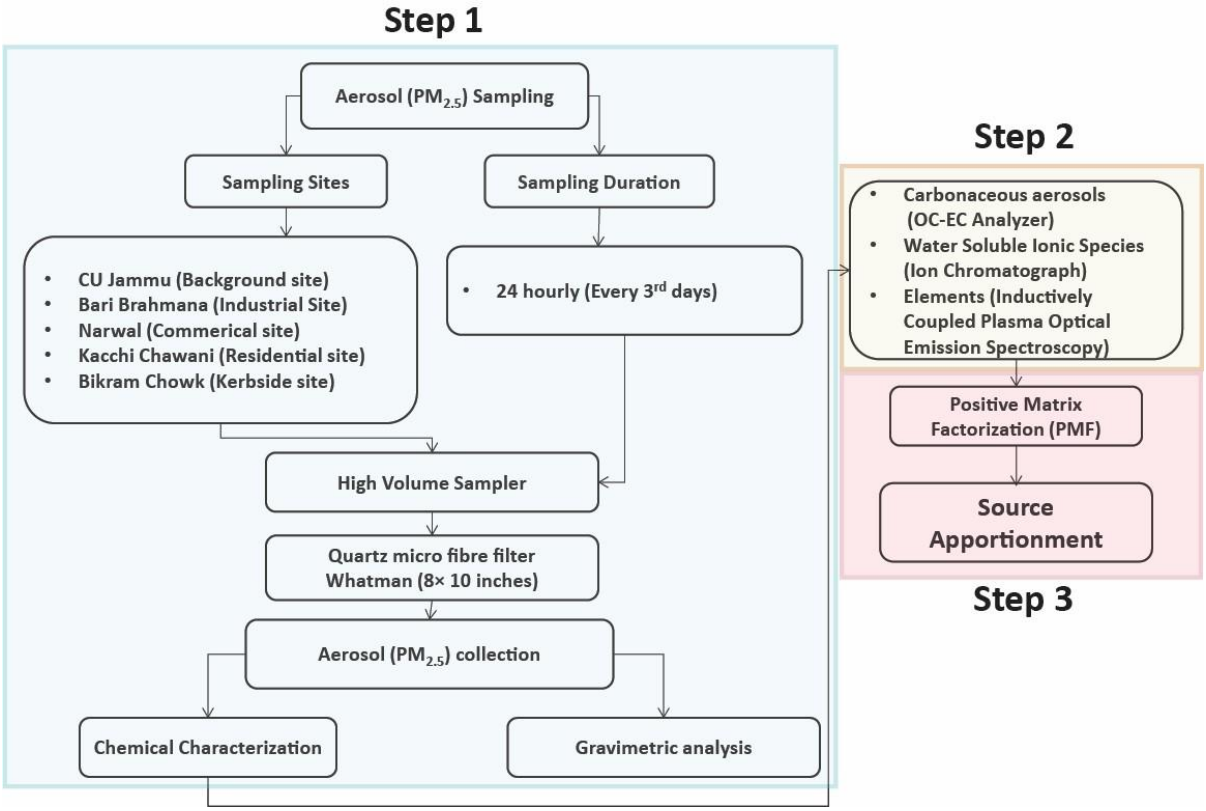


Fig. ES4. *Steps and work plan for source apportionment study.*

5. Meteorological Parameters in Jammu

Meteorological parameters viz. Temperature (T), Relative Humidity (RH), Planetary Boundary Layer (PBL), Wind Direction (WD), Wind Speed (WS), and Air Back Trajectories (ABTs) influence the fate of pollutants in the atmosphere by impacting their concentration in a certain area. Fig. ES5 shows the variations in meteorological parameters from June, 2021 to May, 2022 over Jammu. To study the seasonal variations observed in these parameters and their implications on aerosol concentration across the North-Western Himalayan (NWH) region, monthly dataset for the study period was extracted from European Centre for Medium-Range Weather Forecasts (ECMWF) product i.e. ERA5. Whereas, to represent the daily variations in these parameters, especially for the Jammu region, daily resolution dataset was extracted from the National Oceanic and Atmospheric Administration (NOAA) - Air Resource Laboratory (ARL). For the seasonal interpretation, the sampling year is divided into four major seasons, Summer Monsoon (June – July – August), Autumn (September –

October – November), Winter (December – January – February), and Spring (March – April – May).

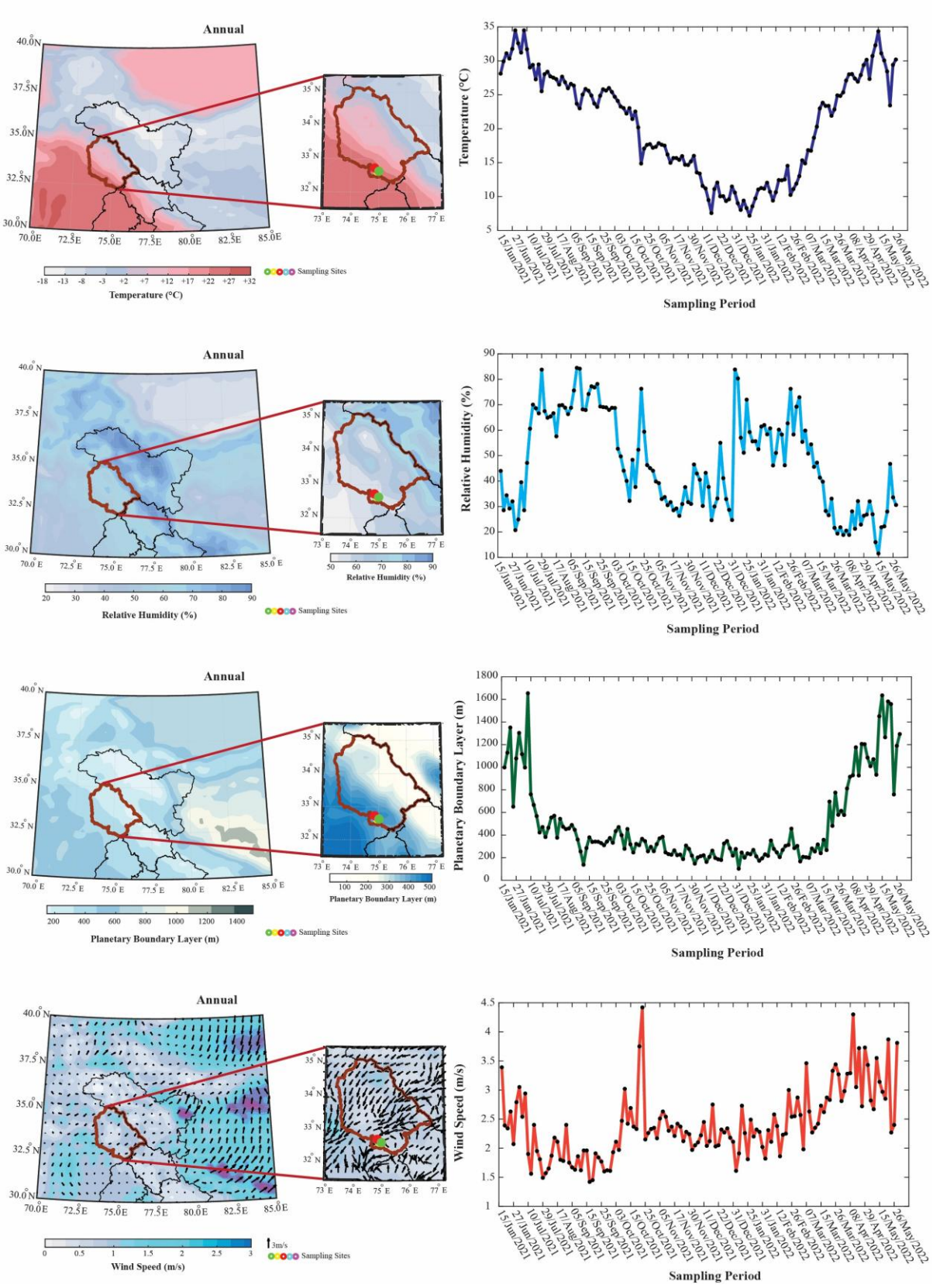


Fig. ES5. *Meteorological parameters in Jammu from June, 2021 to May, 2022.*

The maximum daily mean ambient T of Jammu during the study period was found to be 35 °C (29th June, 2021), while the minimum daily mean ambient T was observed as 7.2 °C (27th January, 2022). The daily mean RH varied from ~12% to ~85%, with seasonal variations suggesting high RH during summer monsoons (JJA) and low during springs (MAM). During the sampling campaign, maximum daily mean RH was recorded on 7th September, 2021, while minimum daily mean RH was recorded on 15th May, 2022. Interestingly, the study region was observed to have a year-long humid environment, except for few months during autumn and spring. Moreover, the daily and seasonal patterns of RH followed the inverse of T patterns. Similar to T, higher PBL was found during summer (JJA) and spring (MAM) season, while lower PBL was common during winter (DJF) season. Over the study region, maximum recorded daily mean PBL height was 1655m (7th July, 2021), while minimum daily mean PBL height was 103m (4th Jan, 2022). The surface winds across J&K region were mainly observed to be the Katabatic (downslope) winds coming from the mountains situated across the north-eastern part of Jammu and heads towards the south-western part. The surface daily mean WS during the study period ranged between 4.3 m/s (12th April, 2022) to 1.4 m/s (18th September, 2021) with an average speed of 2.4 m/s. On annual basis, it can be assumed that calm-to-low winds usually dominated over the Jammu region. On seasonal basis, MAM showed high WS, followed by JJA, SON, and DJF. During JJA, the ABT of 72 hours back in time at 50m above ground level (AGL) revealed air parcels may be coming from regional sources, while at 500m and 1000m AGL air parcels were observed to be coming from long range distance such as Indo-Gangetic Plains, Pakistan, or could be from Arabian Sea (contributing as sea salt in ambient $PM_{2.5}$ concentration) whereas, during MAM, most of the air parcels at varying AGLs were found to be transported from longer distant sources, this could be due to high T and PBL during this season, influencing vertical mixing of pollutants.

6. Fine Particulate Matter ($PM_{2.5}$) in Jammu

This study presents the first comprehensive dataset of $PM_{2.5}$ concentration and its associated chemical constituents across five distinct locations in the Jammu region. Fig. ES6 shows site wise annual average ambient concentration (μg/m^3) and seasonal distribution of $PM_{2.5}$. The annual average concentration of $PM_{2.5}$ along with (±) standard deviation was found to be 48.98±25.46 μg/m^3, which is above the National Ambient Air Quality Standards (NAAQS) threshold of 40 μg/m^3. The site-specific annual average concentrations were as follows: CUJ 44.33±25.02 μg/m^3, KCN 46.58±24.48 μg/m^3, NRW 47.94±19.76 μg/m^3, BBN 49.06±25.91

μg/m^3, and FIC 56.15±29.97 μg/m^3. Notably, FIC, located at a busy road intersection in a densely populated area, exhibited the highest $PM_{2.5}$ concentration. The monthly average concentration ranged from 32.82±14.83 μg/m^3 in September to a maximum of 82.92±38.26 μg/m^3 in December. Overall, the seasonal average $PM_{2.5}$ concentration was found to be the highest (72.33±33.36 μg/m^3) in the winter season. The observed lowest seasonal average $PM_{2.5}$ concentration (36.16±12.63 μg/m^3) in summer monsoon season can be attributed to the washout of the ambient pollutants from atmosphere due to high rainfall during this season. To scale the PBL effect, dilution correction factor (DCF) scaled $PM_{2.5}$ concentrations for each month were also calculated. The DCF scaled $PM_{2.5}$ concentration showed higher emissions in summer months.

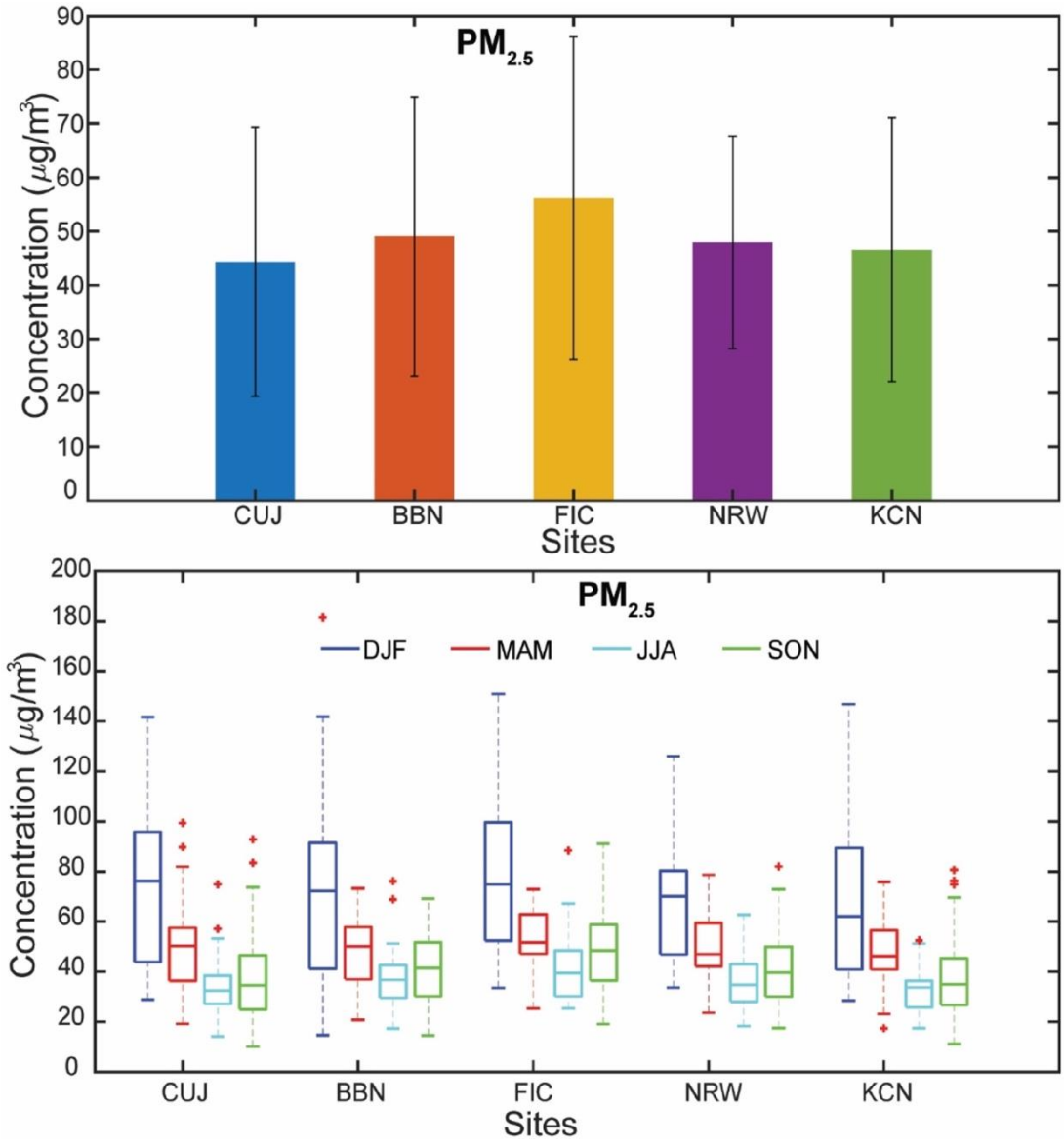


Fig. ES6. *Site wise annual average ambient concentration (μg/m^3) (top panel) and seasonal distribution (bottom panel) of $PM_{2.5}$.*

7. $PM_{2.5}$ associated Carbonaceous Aerosols in Jammu

Carbonaceous aerosols constitute a substantial fraction (20-50%) of $PM_{2.5}$ and the Total Carbon (TC) comprises of two main constituents: Organic Carbon (OC) and Elemental Carbon (EC). The seasonal distribution of OC, EC, and TC at five sampling sites is given in Fig. ES7. The annual mean concentrations of TC, OC, and EC in $PM_{2.5}$ samples collected from all five sampling sites were found to be 14.84±7.57 μg/m^3, 12.26±6.48 μg/m^3, and 2.39±1.44 μg/m^3 respectively. The OC fraction accounted for approximately 26% of the annual average $PM_{2.5}$ concentration, while EC contributed approximately 5%. Monthly mean values for OC concentration ranged from a maximum of 22.05±7.28 μg/m^3 in December to a minimum of 5.87±1.90 μg/m^3 in July. Similarly, for EC, the maximum and minimum monthly mean values were observed in November (3.31±1.46 μg/m^3) and July (1.34±0.96 μg/m^3), respectively. Statistical analysis using one-way ANOVA revealed significant seasonal variations ($p<0.05$) in the concentrations of TC, OC and EC at all sites. Besides this, both TC and EC concentrations exhibited significant spatial variation across all seasons and throughout the year ($p<0.05$). Whereas the spatial variation in OC concentration was significant ($p<0.05$) during the summer-monsoon (JJA) and autumn (SON) seasons and for the annual data, characterized by a high F-ratio and low p-value. During the winter (DJF) and spring (MAM) seasons, insignificant spatial variation ($p>0.05$) in OC concentration was observed.

The Bikram Chowk kerbside site (FIC), next to NH-44, had the highest amounts of $PM_{2.5}$, TC, OC and EC. The majority of CAs associated with $PM_{2.5}$ were traced back to emissions from vehicles, especially diesel trucks, with significant emissions coming from biomass burning as well. The OC/EC ratio is used as a metric for determining the origin of carbonaceous aerosols. The elevated OC/EC ratio showed the abundance of secondary organic carbon (SOC) production at the background site (CUJ). However, given the proximity to a prominent national highway, the observed lowest OC/EC ratio at the kerbside site (FIC), is likely due to primary emissions from vehicular exhausts. In the summer-monsoon season, high OC/EC ratios (>5) were related with decreased EC concentrations. In all, the results show that SOC is a significant contributor to TC at CUJ (57%), BBN (59%) and KCN (44%) and in Jammu as a whole (53%). From this, we might infer that a sizable fraction of OC is generated in the atmosphere by chemical reactions involving gaseous precursors.

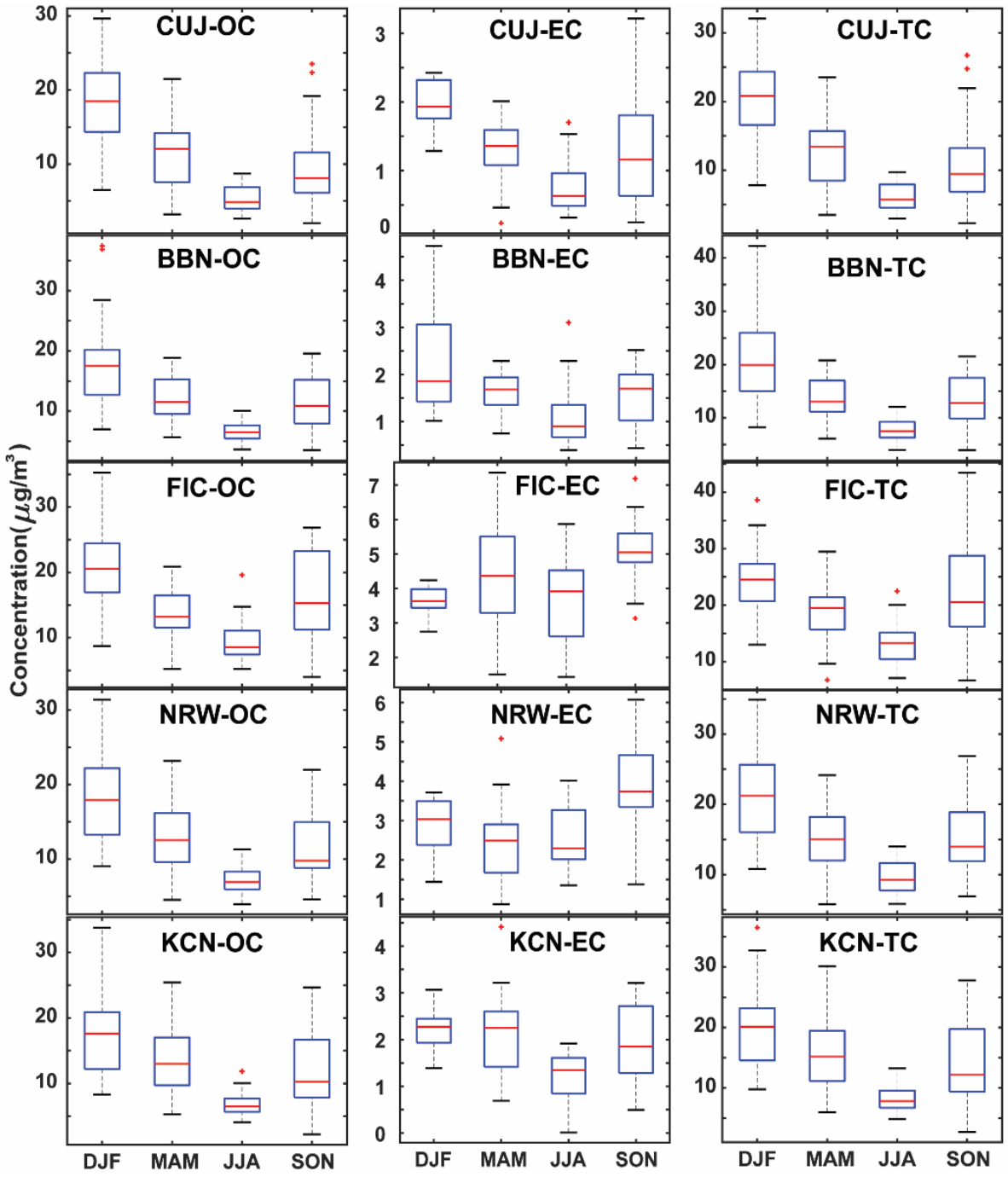


Fig. ES7. *Box and whisker plot showing the seasonal distribution of OC, EC, and TC at five sampling sites.*

CUJ (background site; r=0.63-0.88), BBN (industrial site; r=0.56 to 0.81), and KCN (residential site; r=0.55-0.91) all showed strong associations between OC and EC concentrations. Biomass burning, vehicular exhaust and coal combustion, may all be contributing factors to the high levels of OC and EC seen at these locations. On the other hand, weak correlations between OC and EC at FIC (r= 0.13 to 0.53) and NRW (r= 0.38 to 0.54) indicates a complex mix of diverse sources at these locations. The analysis of the

relationships of non-sea salt potassium (nss-K^+) with OC and EC at various sampling sites showed that biomass burning is a significant contributor to carbonaceous aerosols in Jammu. Moreover, the nss-K^+/OC and nss-K^+/EC ratios were also utilised to evaluate categories of biomass burning. At the CUJ, BBN, and KCN sites, biomass burning was found to be the year-round primary source of carbonaceous aerosols, but at the FIC and NRW sites, it was noted to be a significant source only during certain seasons in the year. The observed nss-K^+/OC ratio at CUJ (0.03 to 0.48), BBN (0.03 to 0.59), KCN (0.02 to 0.37), FIC (0.01 to 0.28), and NRW (0.02 to 0.37) are similar to those reported for the burning of tropical forest woods, charcoal, and agricultural waste in literature.

8. $PM_{2.5}$ associated Water Soluble Ionic Species (WSIS) in Jammu

As we delve into the intricate composition of $PM_{2.5}$, one facet that draws increasing attention is the presence of Water Soluble Ionic Species (WSIS). These WSIS ranging from sulphates and nitrates to ammonium, and chlorides etc, play a pivotal role in shaping the chemical and toxicological characteristics of $PM_{2.5}$. Unlike their insoluble counterparts, WSIS exhibit dynamic behaviour, undergoing dissolution and transformation in atmospheric water. Understanding the origin of WSIS in $PM_{2.5}$ is fundamental to deciphering the complexities of atmospheric pollution. Hence, it is necessary to understand the spatio-temporal dynamics in the concentration, source activity, and atmospheric processing of $PM_{2.5}$-associated WSIS over Jammu. Among the WSIS, SO_4^{2-} was the most dominant species present across all sites except for BBN site where the most abundant species was NO_3^-. The seasonal variations in WSIS concentration in ambient $PM_{2.5}$ are given in Fig. ES8. The concentration of SO_4^{2-} was consistent throughout the year, while the concentration of K^+ and NO_3^- were observed particularly during the autumn and winter months. On the other hand, the higher concentration of NH_4^+ was observed during summer months. The most prevalent anions present in the ambient $PM_{2.5}$ were SO_4^{2-} and NO_3^-, while the predominant cations were NH_4^+ and K^+. An interesting observation at BBN and NRW site was that in winter, NO_3^- surpassed SO_4^{2-} concentration. This dominant anion (NO_3^-) indicates the significance of diesel-driven vehicular emissions as source of WSIS in $PM_{2.5}$ samples at these sites. The most abundant species in terms of mass fraction and mass concentration remained same at all sites indicating that the mass fraction follows the same pattern as that of mass concentration. Higher mass fraction yet a reduced mass concentration of some species in ΣWSIS $PM_{2.5}$ indicates increased source activity or emission.

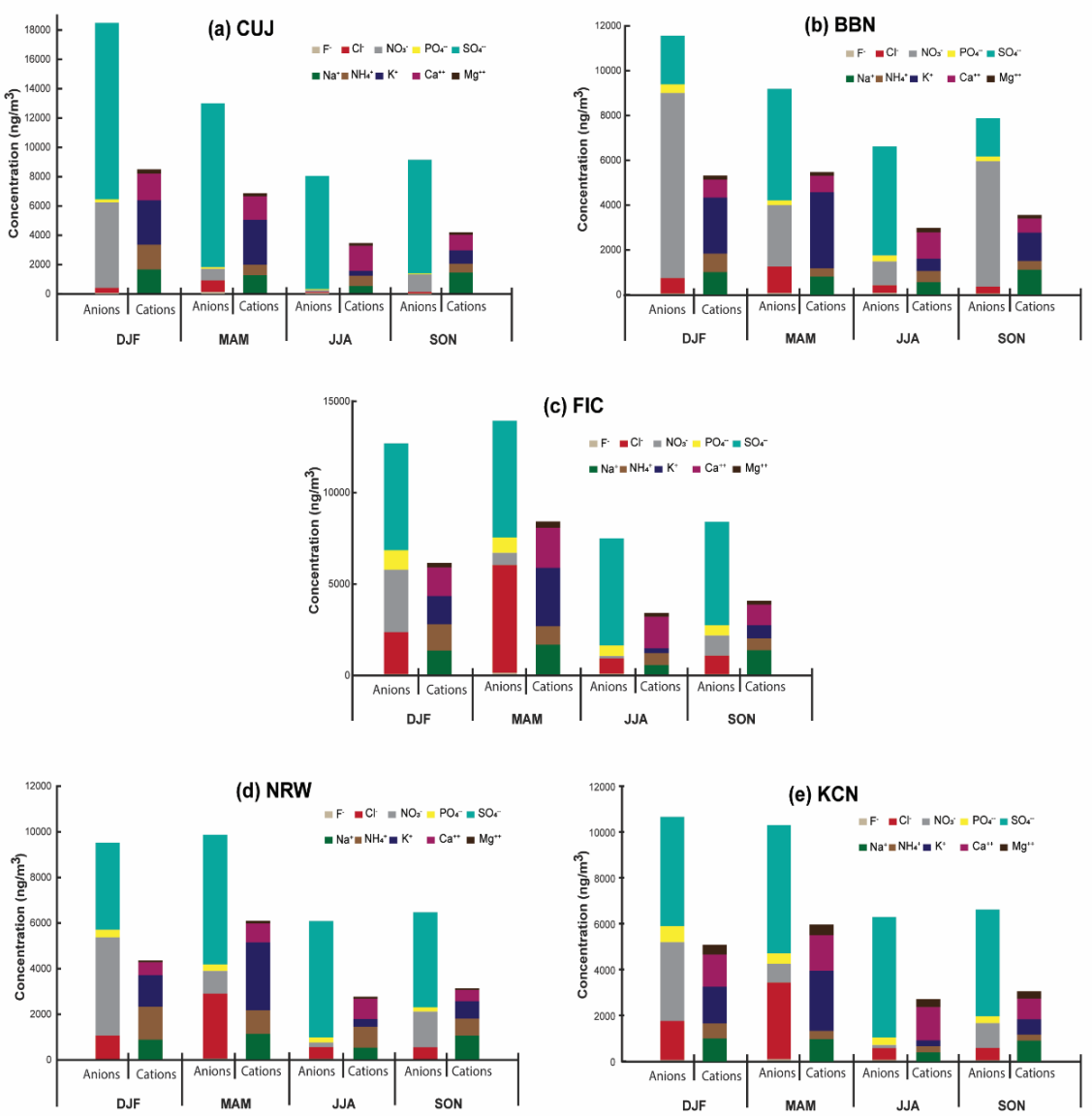


Fig. ES8. *Seasonal variations in WSIS concentration in ambient $PM_{2.5}$ at different sampling sites.*

In addition to this, assessment of the neutralization capacity of various cationic species that make up $PM_{2.5}$ over Jammu was also done. It was observed that (nss-K^++ NH_4^+) and (nss-Ca^{2+}+ nss-Mg^{2+}) were the primary neutralizing species linked to $PM_{2.5}$ in the Jammu region. The highest annual average value of 0.76 ± 0.21 and 0.56 ± 0.16 at BBN and NRW, respectively suggests that the major neutralizing species associated with $PM_{2.5}$ were NH_4^+ + nss-K^+, while at other three sites viz. CUJ, FIC, and KCN, the highest average values of 0.44 ± 0.13, 0.73 ± 0.21, and 0.78 ± 0.14, respectively, suggest that the nss-Ca^{2+} + nss-Mg^{2+} as the major neutralizing cationic species. On seasonal basis, the most active neutralizing agents during winter season at CUJ, BBN, NRW and FIC were NH_4^+ + nss-K^+; whereas at the KCN site the most dominant neutralizing agent during winter season was nss-Ca^{2+} + nss-Mg^{2+}. The

neutralization process was significantly influenced by the combination of terrestrial (crustal/mineral sources) cationic species nss-Ca^{2+} + nss-Mg^{2+} during spring season at CUJ and KCN; whereas at the other three sites the most dominant acid neutralizing species active during spring were found to be NH_4^+ + nss-K^+. During summer season, the major neutralizing agents were nss-Ca^{2+} + nss-Mg^{2+} at CUJ, BBN, FIC, and KCN expect for NRW site where NH_4^+ + nss-K^+ was more prominent species. During autumn season the most dominant neutralizing species at CUJ, FIC, and KCN were nss-Ca^{2+} + nss-Mg^{2+}; whereas, NH_4^+ + nss-K^+ was found to be the dominant agents at BBN and NRW. In the present study, annual average of NO_3^-/ SO_4^{2-} ratio was found greater than unity at BBN (1.5), suggested the predominance of mobile sources over stationary sources at this site; whereas at the other four sites the ratio (<1) of NO_3^-/ SO_4^{2-} indicated the predominance of stationary sources over mobile sources.

9. $PM_{2.5}$ associated Major and Trace Elements in Jammu

The major elements (MEs: Al, Fe, Ca, Mg, Na, K) and trace elements (TEs: Ba, Pb, Cr, Mn, Co, Ni, Cu, Zn, Cd) present in $PM_{2.5}$ were analysed using ICP-OES. The elevated levels of $PM_{2.5}$ and its associated elements observed in Jammu during winter months can be attributed to specific meteorological conditions, such as a lower height of the PBL and a calm wind regime. The seasonal variations in MEs (top panel) and TEs (bottom panel) concentration are given in Fig. ES9. The seasonal concentration of TEs was found to follow the similar pattern as that of $PM_{2.5}$ concentration. This investigation highlights that elevated PM concentrations may cause an increased accumulation of TEs in the atmosphere. During the winter (DJF), all sites (CUJ, BBN, FIC, NRW, and KCN) showed higher concentrations of TEs, while lower TE concentrations were observed in the spring season (MAM). Like TEs, concentration of MEs followed the same trend with maximum concentration in industrial site (BBN) followed by CUJ. In these two sites, the ME concentration was maximum in the spring season (MAM). In all the five sites, K and Al concentration were the highest during the autumn (SON) and the winter season (DJF).

The identification of these seasonal trends in elemental concentrations provides valuable insights into the sources and processes influencing the air quality in the region. Consistent vehicular emission emerged as a significant source, as evidenced by the high levels of lead, zinc, nickel, and barium. Biomass burning and transported dust were also identified as influential factors, contributing to the observed variations in elemental concentrations. The

presence of high concentrations of Al, Fe, and Ca may indicate weathering and erosion processes, while elevated levels of Cu, Zn, and Pb suggest industrial pollution. This multifactorial approach to study dynamics of different chemical species adds depth to our understanding of the complex interplay of natural and anthropogenic influences on aerosol concentration and air quality. These findings provide valuable insights for developing effective air pollution mitigation strategies in the area.

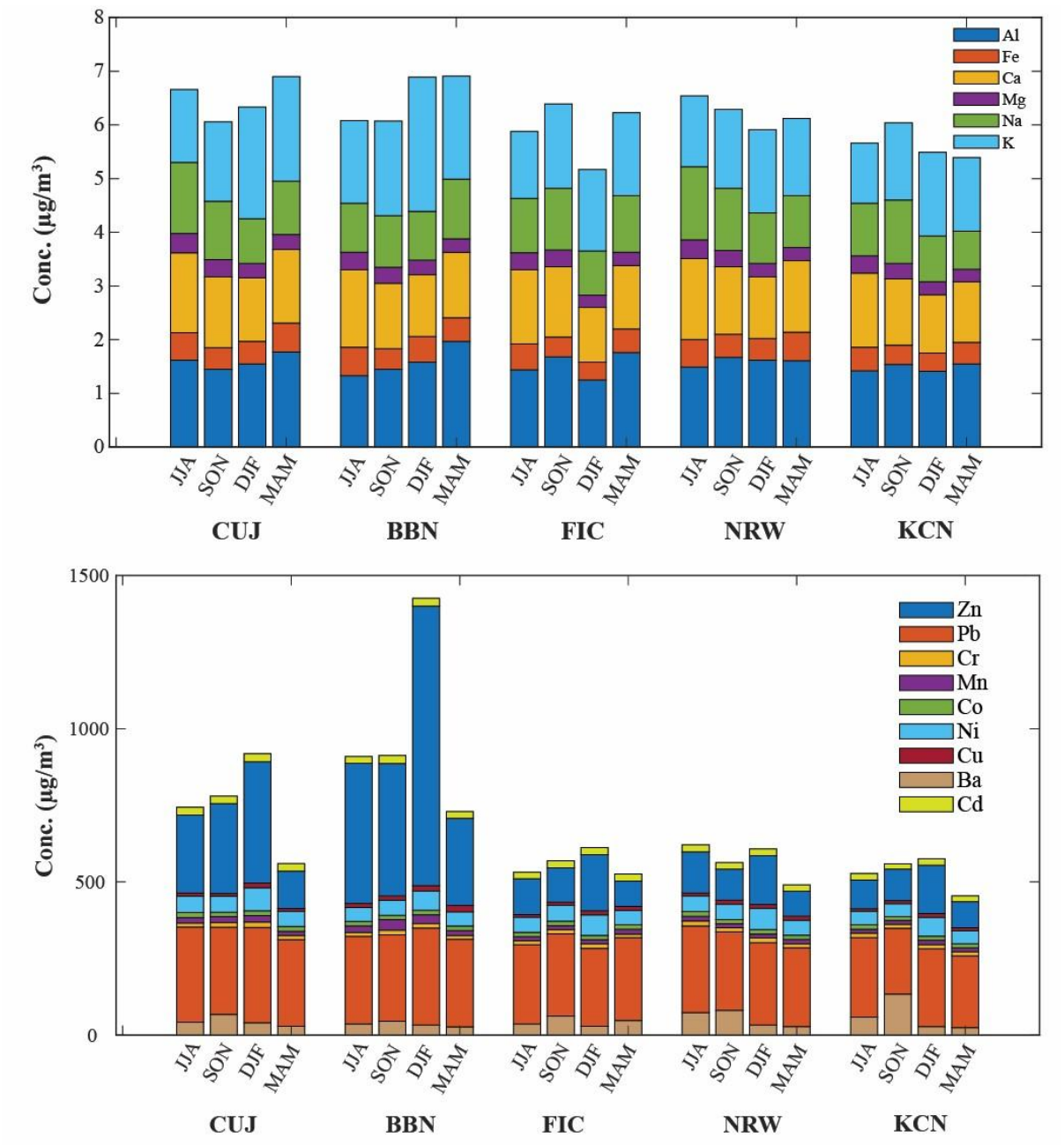


Fig. ES9. *Seasonal variations in MEs (top panel) and TEs (bottom panel) concentration in ambient $PM_{2.5}$ at different sampling sites.*

10. Source Apportionment of Aerosols using Positive Matrix Factorization (PMF) model

To elucidate the sources of $PM_{2.5,}$ the concentration and uncertainty datasets of $PM_{2.5}$ and all chemical species during the study period were analyzed using receptor modelling i.e., Positive Matrix Factorization (PMF). The PMF model serves as an effective method to deconvolute environmental dataset matrices. This is achieved by integrating species concentration profiles and factor contribution matrices, facilitating a more comprehensive understanding of existing pollution sources and their contribution to the overall pollution load. The concentration and uncertainty datasets of $PM_{2.5}$ and all chemical species [Organic (OC) and Elemental (EC) carbon (OC_{Peak1}, OC_{Peak2}, OC_{Peak3}, OC_{Peak4}, OC_{Peak5}, Pyrolytic Carbon, EC_{Peak1}, EC_{Peak2}, EC_{Peak3}, EC_{Peak4}, EC_{Peak5}, EC_{Peak6}), Water Soluble Ionic Species (Na^+, NH_4^+, K^+, Ca^{2+}, Mg^{2+}, F^-, Cl^-, NO_3^-, PO_4^{3-}, SO_4^{2-}), Major Elements (Mg, K, Na, Ca, Al, and Fe) and Trace Elements (Ba, Pb, Cr, Mn, Co, Ni, Cu, Zn, and Cd)] present in $PM_{2.5}$ samples were used as input to the PMF model. To find an optimum solution in PMF Model, meaningful and explainable number of factors are most crucial. In this study, for each site the number of factors/sources were determined based on the least Q_{robust} values along with F_{peak} rotations from the actual PMF solution. On examining the species contribution of each factor, different combinations of species were found to have major contribution for different sources/factors. A total of nine different PMF factors/source contributions were identified in this study. Fig. ES10 and Fig. ES11 shows the season-wise and site-specific sources of aerosols in Jammu respectively. Overall in Jammu, at annual scale, maximum contribution in the ambient $PM_{2.5}$ was observed from *Secondary Inorganic Aerosols* (22%) followed by *Heavy Commercial Vehicle/High-Capacity Engine Emissions* (16%), *Roadside Dust* (16%), *Biomass Burning* (15%), and *Re-suspended/Transported Dust* (14%). Comparatively lower contribution was observed from other sources like *Unidentified/ Tar Burning* (8%), *Light Motor Vehicle* (7%) and Unidentified Crustal (2%).

10.1 Source Apportionment of ($PM_{2.5}$) Aerosols at Seasonal Scale:

The seasonal source contributions of $PM_{2.5}$ in Jammu are as follows:

- During Summer Monsoon Season (June – July – August), *Roadside Dust* (47%), *Heavy Commercial Vehicle/High-Capacity Engine Emissions* (35%) and *Light Motor Vehicle* (9%) are the dominant sources of ambient $PM_{2.5}$ mass concentration over Jammu.

- During Autumn Season (September – October – November), *Biomass Burning* (27%), *Secondary Inorganic Aerosols* (23%), *Heavy Commercial Vehicle/High-Capacity Engine Emissions* (17%), *Light Motor Vehicle* (12%), and *Roadside Dust* (11%) are the dominant sources of ambient $PM_{2.5}$ mass concentration over Jammu.
- During Winter Season (December – January – February), *Secondary Inorganic Aerosols* (33%), *Unidentified/ Tar Burning* (21%), *Biomass Burning* (18%), *Heavy Commercial Vehicle/High-Capacity Engine Emissions* (17%) are the dominant sources of ambient $PM_{2.5}$ mass concentration over Jammu.
- During Spring Season (March – April – May), *Re-suspended/Transported Dust* (44%), *Biomass Burning* (17%), *Roadside Dust* (11%) and *Light Motor Vehicle* (11%) are the dominant sources of ambient $PM_{2.5}$ mass concentration over Jammu.

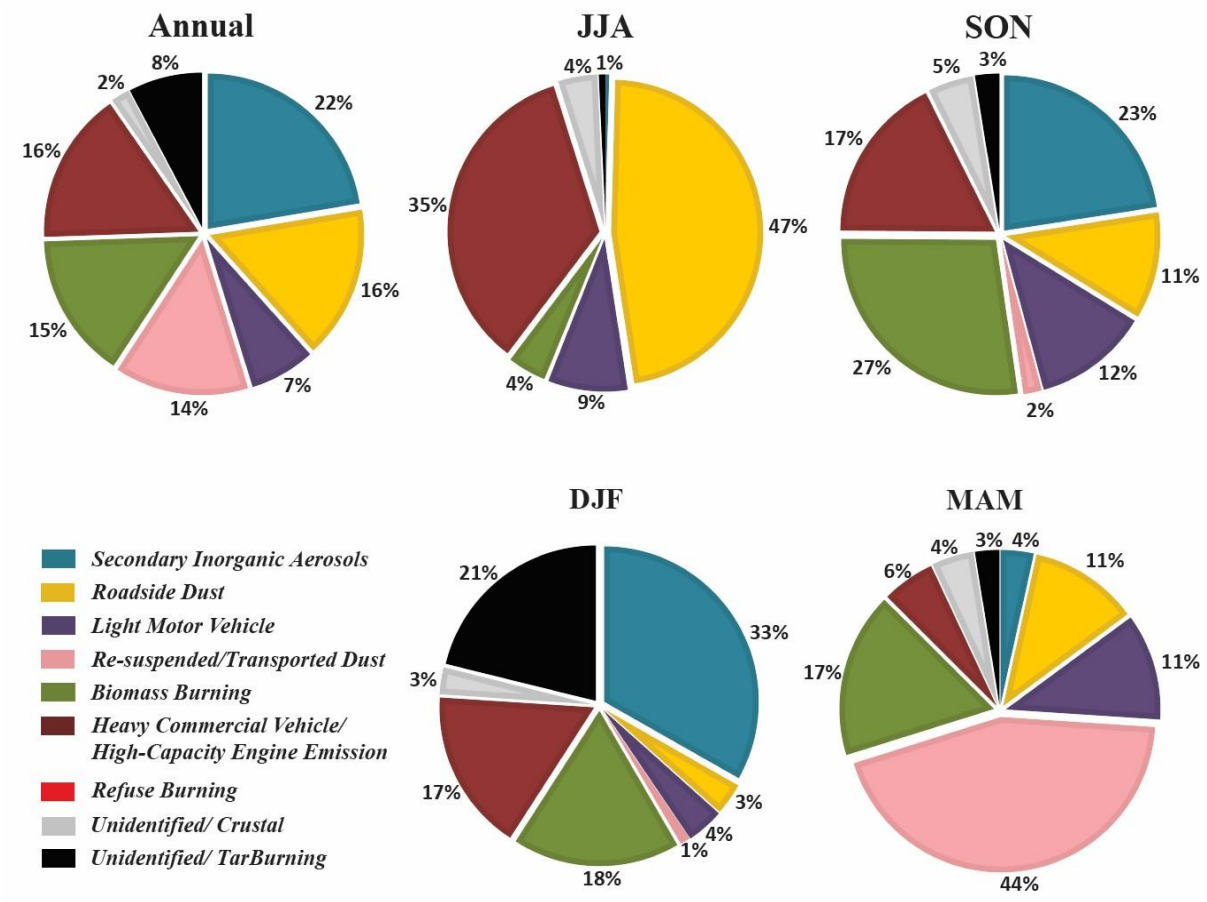


Fig. ES10. *Annual and seasonal percent Source/Factor contribution in ambient $PM_{2.5}$ at Jammu.*

10.2 Source Apportionment of ($PM_{2.5}$) Aerosols for respective sites in Jammu:

The site-specific source contributions of $PM_{2.5}$ in Jammu are as follows:

- The PMF analysis of Central University of Jammu (CUJ) site shows that the *Secondary Inorganic Aerosols* (29%) and *Re-suspended/Transported Dust* (27%) are the dominant sources of $PM_{2.5}$ here, followed by other sources like *Heavy Commercial Vehicle/High Capacity Engine Emissions* (17%), *Light Motor Vehicle* (12%), *Biomass Burning* (8%), and *Roadside Dust* (7%).
- The PMF analysis for Bari Brahmana (BBN) site reveals that the *Secondary Inorganic Aerosols* (40%) and *Re-suspended/Transported Dust* (31%) are the dominant sources of $PM_{2.5}$ here, followed by other sources like *Heavy Commercial Vehicle/High Capacity Engine Emissions* (8%), *Roadside Dust* (7%), *Light Motor Vehicle* (7%) and *Unidentified/ Tar Burning* (7%) sources.
- The PMF analysis for Bikram Chowk (FIC) site reveals that the *Re-suspended/Transported Dust* (25%) and *Secondary Inorganic Aerosols* (25%) sources contributed 50% of the $PM_{2.5}$ mass concentration. Whereas the rest half of the $PM_{2.5}$ mass concentration is contributed by the *Heavy Commercial Vehicle/High-Capacity Engine Emissions* (17%), *Biomass Burning* (13%), *Light Motor Vehicle* source (11%), and *Roadside Dust* (9%).
- The PMF analysis for Narwal (NRW) site reveals that the *Heavy Commercial Vehicle/High-Capacity Engine Emissions* (34%), *Roadside Dust* (18%), and *Refuse Burning* (17%) are the dominant sources of $PM_{2.5}$ here, followed by other sources like *Biomass Burning* (13%), *Light Motor Vehicle* (10%), and *Secondary Inorganic Aerosols* (8%).
- The PMF analysis for Kacchi Chawani (KCN) shows that the *Secondary Inorganic Aerosols* (32%) and *Re-suspended/Transported Dust* (29%) are the dominant sources of $PM_{2.5}$ here, followed by other sources like *Roadside Dust* (16%), *Biomass Burning* (14%), *Light Motor Vehicle* (7%), and *Unidentified/ Tar Burning* (2%).

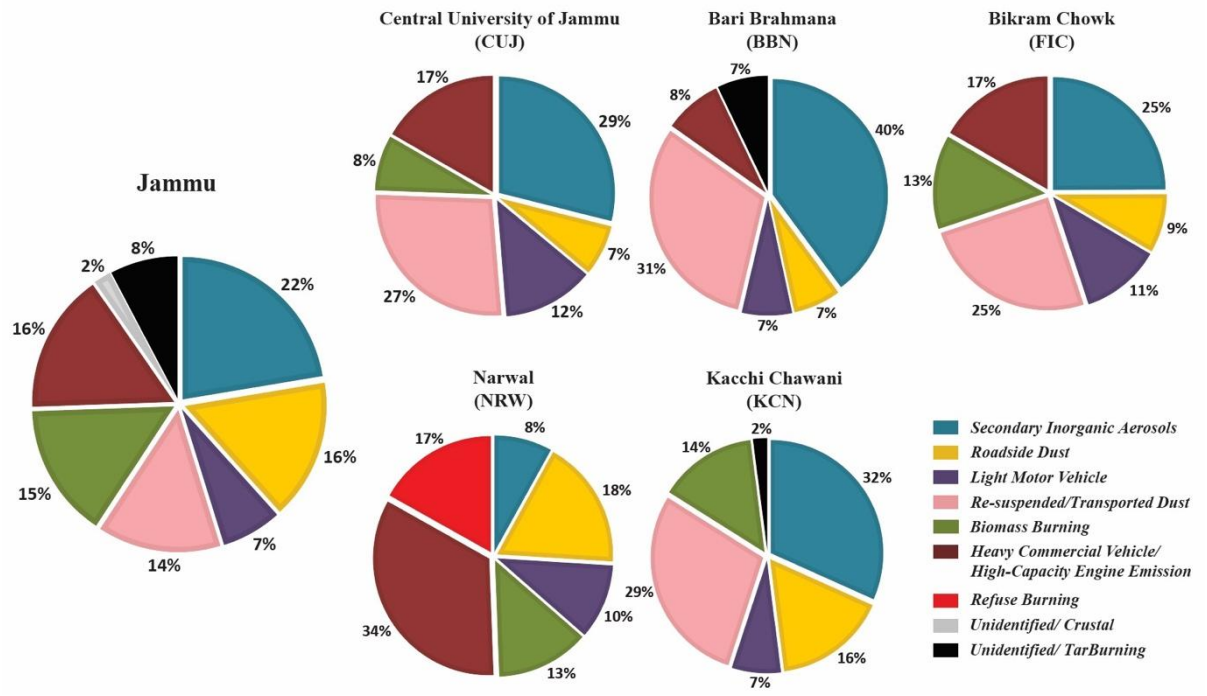


Fig. ES11. *Percent Source/Factor contribution in ambient $PM_{2.5}$ in Jammu and sampling sites.*

10.3 Concluding remarks

Overall, from the PMF assessment, it is evident that *Secondary Inorganic Aerosols*, *Heavy Commercial Vehicle/ High-Capacity Engine Emissions*, Biomass Burning and *Re-suspended/Transported Dust* are the major contributing sources of ambient $PM_{2.5}$ mass concentration in Jammu. *Secondary Inorganic Aerosols* contributes the most, around 40% of the aerosol mass on average for $PM_{2.5}$ mass concentration at BBN site, followed by 32%, 29%, and 25% at KCN, CUJ, and FIC, respectively. *Re-suspended/Transported Dust* on the other hand contributes equally at BBN (31%) and KCN (29%) site, followed by CUJ (27%) and FIC (25%). It is interesting to note that at NRW site, *Secondary Inorganic Aerosols* contributes the least (8%), while *Re-suspended/Transported Dust* has unidentifiable contribution to ambient $PM_{2.5}$ mass concentration at this site. Being the commercial site of Jammu (NRW), *Heavy Commercial Vehicle/ High-Capacity Engine Emissions* (34%) shows maximum contribution to $PM_{2.5}$ mass concentration at this site, whereas FIC (17%), CUJ (17%), and BBN (8%) show comparatively less contribution from *Heavy Commercial Vehicle/ High Capacity Engine Emissions* to $PM_{2.5}$. Interestingly, *Light Motor Vehicle* is the only source, which is a consistent contributor across all sites, contributing 12%, 11%, 10%, 7%, and 7% at CUJ, FIC, NRW, BBN, and KCN respectively. *Roadside Dust* is the another factor which is contributing to the ambient $PM_{2.5}$ mass concentration of all the sampling sites

of Jammu, maximum at NRW (18%), followed by KCN (16%), FIC (9%), CUJ (7%), and BBN (7%). While overall in Jammu, contribution of *Biomass Burning* is 15%, the site specific contribution ranges from 8% to 14% (CUJ-8%, FIC-13%, NRW-13%, and KCN-14%), while *Refuse Burning* shows its contribution only at the NRW (17%) site of Jammu. Interestingly, an unidentified source of episodic burning (*Unidentified/ Tar Burning*) overall contributes to 8% in Jammu and was also noted at KCN (2%) and BBN (7%) site only.

11. Recommendations

The source apportionment study of aerosols is important for understanding the proportional contribution of individual sources to aerosols, which further assists in understanding causes of air pollution, pollution outflow, and larger scale regional impacts. In this study, the fractional contributions of nine different sources to $PM_{2.5}$ in Jammu have been identified. These are:

i) Secondary Inorganic Aerosols

ii) Heavy Commercial Vehicle/ High-Capacity Engine Emissions

iii) Biomass Burning

iv) Re-suspended/Transported Dust

v) Light Motor Vehicle

vi) Roadside Dust

vii) Refuse Burning

viii) Unidentified/ Tar Burning and

ix) Unidentified/ crustal

In addition to the umbrella recommendations provided under National Clean Air Programme, coordinated action by all stakeholders and following source-specific recommendations may help in planning city-specific air quality management strategies for Jammu:

i. ***Secondary Inorganic Aerosols (SIA):*** The contribution from Secondary Inorganic Aerosols (SIA) is an indicator of gas to particle conversion of precursor gases like Nitrogen Oxides (NO_x), Sulfur dioxide (SO_2) and Ammonia (NH_3) leading to the formation of Ammonium Sulphate and Ammonium Nitrate aerosols. The control on

emission of these precursor gases may help in reducing SIA contribution and this can be achieved by separating the emissions of NO_x and SO_2 from NH_3 at spatial and temporal scale:

- Control on vehicular emissions, particularly the night-time movement of heavy vehicles.
- Usage of cleaner fuels (such as natural gas) in industrial processes and shift from coal or oil to cleaner alternatives.
- The anthropogenic hotspots of Ammonia emissions e.g. dairy farm houses, animal husbandry etc. (where Ammonia is mainly produced by breakdown and volatilization of urea) can be kept away from active sources of NO_x and SO_2 emissions.

ii. ***Vehicular Sources [Heavy Commercial Vehicle/ High-Capacity Engine Emissions and Light Motor Vehicle]:*** Vehicular emissions are the dominant contributors to many source factors identified here viz. directly to *Heavy Commercial Vehicle/ High-Capacity Engine Emissions and Light Motor Vehicle and indirectly to Secondary Inorganic Aerosols (SIA) and Roadside Dust.* Though the High-Capacity Engine emissions can also be contributed from industrial sector, special attention is required for control on diverse direct and indirect contributions/emissions from transport sector:

- Overloading of heavy commercial vehicles should be checked and their timely maintenance should be ensured.
- Cleaner fuel like Compressed Natural Gas (CNG) can be introduced for medium to light commercial vehicles.
- Adoption of electric vehicles for private/public transportation should be promoted as it will help in replacing the petrol and diesel engines. Investment in charging infrastructure and incentivizing bus operators for transition to electric fleets may help.
- Implementation of traffic management strategies viz. improving public transport and optimizing traffic flow may help in reducing congestion and traffic related emissions.

- Traffic light management with optimized stop time may help in reducing emissions from “stop and go movement” of vehicles.
- Overall, the strict enforcement of vehicular emission norms in the area should be ensured.

iii. ***Re-suspended/Transported Dust*****:** This source factor can only be controlled partially by controlling emissions within Jammu city and needs wider airshed based regional air quality management strategies. Following measures may help at city level:

- Transportation of construction material and demolition waste should be done in fully covered trucks without overloading to prevent fugitive emissions.
- Implementation of strict controls on construction sites is necessary and some measures like using barriers to contain dust and employing fogging systems to suppress airborne particles may help.

iv. ***Biomass & Refuse Burning:*** Biomass burning is one of the least studied contributors to $PM_{2.5}$ load and varies on spatio-temporal scale. Biomass burning for heating purpose is more prevalent in winter season and is common contributor in eateries/restaurants etc. for cooking purposes. On the other hand, refuse burning was only noted at Narwal site. Following broad measures may help in reducing contributions from these sources:

- Mandatory segregation of waste at source to ensure proper management of bio-degradable and non-biodegradable waste should be done effectively. The non-biodegradable waste should preferably be recycled. Waste that cannot be recycled, should be incinerated. Establishment of waste to energy plant can also be considered.
- Prohibition on burning of municipal waste, garden litter and waste wood should be enforced.
- To check biomass burning emissions from restaurants/eateries, wood and coal fired tandoors (clay-oven) should be replaced with gas/electric ovens.
- Promotion of the use of cleaner cooking technologies such as improved cookstoves etc. to reduce reliance on traditional biomass burning for cooking and heating should be encouraged.

v. ***Roadside Dust:*** The mixed contributions in roadside dust are from crustal signatures, direct and indirect vehicular emissions etc. and can be controlled in following ways:

- Cleaning of roads using vacuum sweepers may help in minimizing dust accumulation especially on high-traffic zones.
- Maintenance of roads (like paving of unpaved roads & regular pavement repairs) and expansion of green belts along heavy traffic roads may help in reducing road dust emissions.

Journey so far...

Memorandum of Understanding

Tripartite MoU Signed between MoEFCC, CUJammu and JKPCB on June 06, 2019 to work together to meet the objectives of the National Clean Air Programme (NCAP) in the Union Territory of Jammu & Kashmir.

MoU Signed between CUJammu and JKPCB on February 05, 2020 **to conduct** "Source apportionment of aerosols and carrying capacity in non-attainment cities of Jammu/Srinagar" and to establish the Himalayan Aerosol Research Instrumentation (HARI) facility in the CUJammu campus.

हिमालयन एरोसॉल अनुसंधान उपकरणीय सुविधा
Himalayan Aerosol Research Instrumentation Facility

अंतर्गत
under

राष्ट्रीय स्वच्छ वायु कार्यक्रम
National Clean Air Programme

संयुक्त पहल
Joint Initiative

जम्मू एवं कश्मीर प्रदूषण नियंत्रण बोर्ड एवं
जम्मू केंद्रीय विश्वविद्यालय
Jammu and Kashmir Pollution Control Board and
Central University of Jammu

Primary objectives of HARI facility

To augment the analytical infrastructure for aerosol research in the UT of J&K.

To conduct experiments for source apportionment of aerosols.

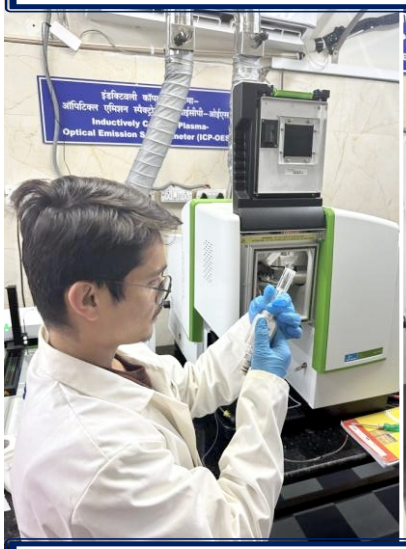
To impart knowledge and training to the budding researchers of the region by national and international collaborations.

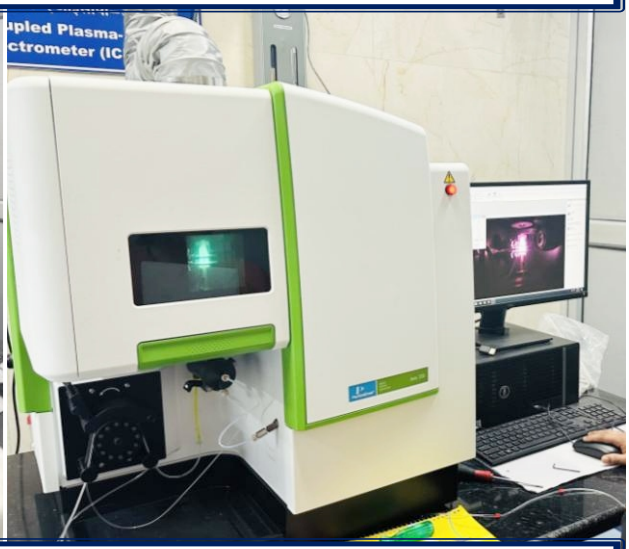
To help in monitoring, source identification and prioritization of source mitigation.

To provide regular inputs to the policymakers for implementation of the National Clean Air Programme.

Setting up of HARI Facility
(Installation, Calibration & Standardization Step)

Calibration of aerosol samplers





Calibration of ICP-OES

Setting up of gaseous supplies

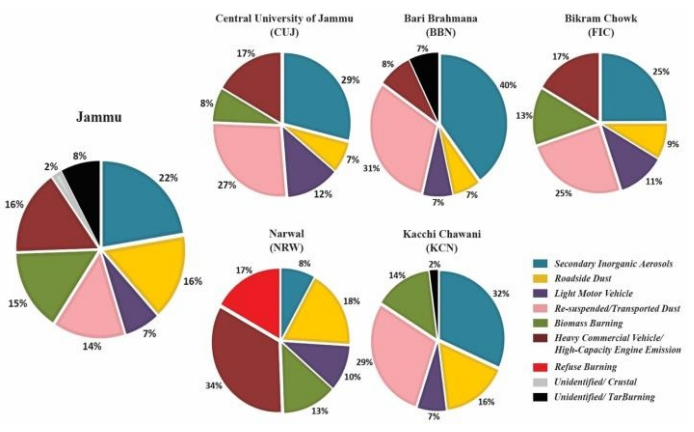
Steps of Source Apportionment Study

1. Aerosol Sampling

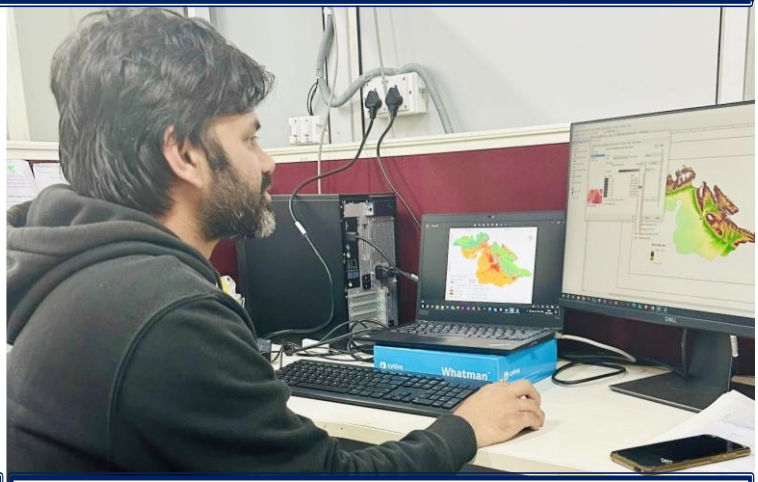
2. Carbon analysis

3. Ionic Species Analysis

4. Elemental Analysis



5. Source Apportionment using PMF



6. Report Compilation

1st Aerosol Winter School

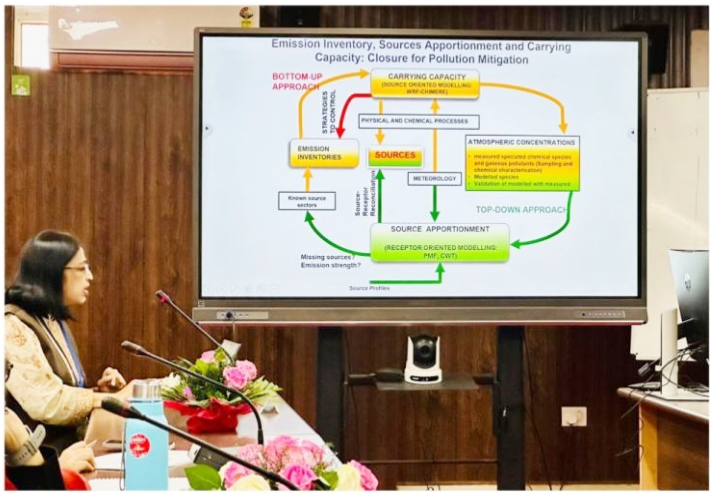
(20th -25th February, 2023)

"Hands on Training on Instrumentation and Analytical Techniques for Atmospheric Aerosol Measurements and Source Apportionment Studies" jointly organized by the Department of Environmental Sciences, Central University of Jammu, National Knowledge Network, NCAP and Indian National Young Academy of Science (INYAS).

2nd Aerosol Winter School

(26th Feb. – 1st Mar., 2024)

MANTHAN (Minds on Air quality humaN healTH & climAte Nexus) – 2024 organized by the Department of Environmental Sciences, Central University of Jammu in collaboration with Sindhu Central University, UT of Ladakh and Indian National Young Academy of Science (INYAS).



Capacity Building through Workshops/Training programmes

National Workshop on "Air Pollution and Health Impacts"
[1st June, 2022]

Training Programme on "Aerosol Sampling and Gravimetric Analysis"
[19th – 20th October, 2023]

Over the years, several students from all over India have been trained in HARI lab

जम्मू केंद्रीय विश्वविद्यालय

Central University of Jammu

Bagla (Rahya-Suchani), Distt. Samba - 181143
UT of J&K, India
www.cujammu.ac.in