Government of Nepal
Ministry of Forests and Environment
Department of Environment
Babarmahal, Kathmandu

Status of Air Quality in Nepal
Annual Report, 2024

June 2025

Authors:
Govinda Prasad Lamichhane, Environment Inspector, Department of Environment.
Nabina Maharjan, Environment Inspector, Department of Environment.
Prakash K.C., Environment Inspector, Department of Environment.

Editor:
Deepak Gyawali, Senior Divisional Chemist, Department of Environment.

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Deukhuri Dang Air Quality Monitoring Station
Photo Credit: Nabina Maharjan, Environment Inspector, Department of Environment.

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Phone: 01-5320837
Email: info@doenv.gov.np
Website: www.doenv.gov.np

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Foreword

It is my privilege to present the **Status of Air Quality in Nepal: Annual Report 2024**, a comprehensive analysis of air quality data collected from sixteen real-time monitoring stations across six provinces of Nepal between January 1 and December 31, 2024. This report reflects our unwavering commitment to understanding and improving the air we breathe, providing data-driven insights for effective air quality management.

The Department of Environment (DoEnv) consistently promotes a sustainable and healthy environment. This report marks a significant step forward in our efforts, and we aim to expand our analysis in future editions by incorporating data from all monitoring stations, further enhancing the monitoring of air quality at the national level.

The State of Global Air 2024 stated air pollution was the second-leading risk factor for public health in 2021. Additionally, the World Economic Forum's Global Risks Report 2025 ranks pollution as the sixth and tenth most pressing global risk in the short term (2 years) and long term (10 years), respectively. These findings underscore the persistent threat that air pollution poses to human health and ecosystems, reinforcing the urgent need for reliable data and evidence-based policymaking. This report serves as a vital resource for policymakers, stakeholders, and communities, empowering them to take informed actions toward effective air quality management and improved public well-being.

I extend my deepest gratitude to Rajendra Prasad Mishra (PhD.), Secretary of the Ministry of Forests and Environment, for his leadership and support. My sincere appreciation goes to the Air Quality Data Analysis Committee for their invaluable feedback throughout the report preparation journey, as well as to the ICIMOD team and experts from other institutions for their constructive insights. My special thanks to the DoEnv report preparation team for their dedication and tireless effort, along with all technical and non-technical staff who contributed to the development, editing, and design of the report.

Together, we can build a cleaner, healthier and more sustainable future. The Department of Environment welcomes your feedback to improve this report and our collective efforts toward a pollution-free environment.

Gyanraj Subedi
Director General
June, 2025

Office Address: Babarmahal, Kathmandu
Tel. No.: 01-4221797/4220837
Fax No.: 01-4221557
Email: info@doenv.gov.np
Website: www.pollution.gov.np

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Message

Air pollution remains one of the most pressing environmental and public health challenges in Nepal. Many areas, particularly urban centers, continue to experience air pollution levels that exceed the national ambient air quality standards. Seasonal haze, vehicular emissions, industrial activities, open burning, and transboundary pollution are persistent contributors to this problem. These issues directly impact the health and well-being of our citizens, especially vulnerable groups such as children, the elderly, and those with pre-existing health conditions.

To better understand the status of air quality, the Department of Environment has been publishing annual air quality reports. It is my privilege to present the Status of Air Quality in Nepal: Annual Report 2024, which provides a detailed analysis of air quality trends based on real-time data collected from 16 monitoring stations across six provinces. This report reflects our ongoing commitment to assessing and addressing the growing challenge of air pollution in Nepal.

The findings once again highlight the urgent need for coordinated action between different organizations and stakeholders. While significant challenges remain, we are encouraged by the expansion of our air quality monitoring network and the increasing awareness among policymakers and the public. However, progress must be reinforced with stronger enforcement mechanisms, effective local-level implementation, and multi-sectoral collaboration to achieve lasting improvements.

I would like to take this opportunity to express my sincere appreciation to the dedicated data analysts, technical experts, and partner institutions who contributed to the preparation of this report. Their expertise, hard work, and dedication were essential in producing accurate data and generating practical insights.

This report helps to serve as both a scientific benchmark and a guiding tool for policy development. I call upon all sectors of society including government, industry, academia, and the public to unite in our shared responsibility to improve air quality and safeguard public health.

Let us advance with strengthened commitment toward achieving improved air quality, enhanced public health outcomes, and long-term environmental sustainability in Nepal.

Shailesh Kumar Jha
Deputy Director General
June, 2025

Office Address: Babarmahal, Kathmandu
Tel. No.: 01-4221797/4220837
Fax No.: 01-4221557
Email: info@doenv.gov.np
Website: www.pollution.gov.np

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We would like to express our deepest gratitude to the individuals and experts whose invaluable support, guidance, and insights were instrumental in the preparation of this report.

We are profoundly grateful to Dr. Rajendra Prasad Mishra, Secretary of the Ministry of Forests and Environment; Mr. Gyanraj Subedi, Director General; Mr. Shailesh Kumar Jha, Deputy Director General; and all section heads of the Department of Environment for their generous guidance and leadership throughout this project.

We extend our sincere thanks to Dr. Kundan Lal Shrestha, Associate professor, Kathmandu University, Dr. Bhupesh Adhikary, Senior Air Quality Specialist; Dr. Ravi Sahu, Air Quality Specialist; Mr. Sagar Adhikari, Air Pollution Analyst; Mr. Dikra Prasad Bajgai, Air Pollution Associate and Dr. Arshini Saikia, Air Quality Modelling Analyst at ICIMOD, for their enlightening discussions, which greatly enhanced our approach. Additionally, special thanks to Mr. Suresh Pokhrel, Senior Research Associate at ICIMOD for his assistance with Ozone data analysis and coding. Their profound knowledge and insightful feedback have played a crucial role in refining the quality of our research.

We are equally thankful to the members of the Technical Committee: Dr. Ramesh Prasad Sapkota, Associate Professor, Central Department of Environmental Science, Tribhuvan University; Mr. Keshab Raj Joshi, Environment Inspector, Ministry of Forests and Environment; Mr. Sudarsan Guragain, Meteorologist, Department of Hydrology and Meteorology; and Dr. Khushboo Sharma, Air Pollution Analyst-Observation, ICIMOD, for their continuous guidance and expertise in preparing this report.

Our heartfelt appreciation goes to Mr. Sabit Desar Environment Inspector, Department of Environment for his valuable inputs on GIS analysis and mapping. We also greatly appreciate the support of Environment Inspectors Ms. Bina Ghimire, Ms. Arati Shrestha, Ms. Tika Regmi, Ms. Hasana Shrestha, Ms. Swasti Shrestha, Ms. Pritika Puspam along with all the staffs at Department of Environment, for their essential contributions in preparing this report.

Finally, we extend our thanks to all those who contributed, both directly and indirectly, with their time, expertise, and support. Your contributions have been invaluable, and we are deeply grateful for all your efforts.

EXECUTIVE SUMMARY

The "Status of Air Quality in Nepal: Annual Report 2024" presents a comprehensive analysis of key air pollutants monitored across the country during the period January 1 to December 31, 2024. The report focuses on particulate matter $PM_{2.5}$, PM_{10}, and Total Suspended Particulates (TSP) analyzed from sixteen air quality monitoring stations (AQMS), along with ozone (O_3) data from two stations. This assessment provides critical insights into spatial and temporal pollution trends, supporting evidence-based air quality management and policy planning. These sixteen stations represent six of the seven provinces of Nepal namely Koshi, Madhesh, Bagamati, Karnali, Lumbini and Sudurpashchim. The CSV-formatted data stored at central server located at the National Information Technology Centre (NITC), were downloaded from pollution.gov.np using Python, and the dataset was further analyzed using a combination of base R and other specialized R packages such as openair and ggplot2. Hourly averages were computed from the minute-level data, ensuring a data availability threshold of 80% for each hour. This criterion is such that at least 80% of the data within an hour is needed to be included to contribute to the hourly average calculation. Subsequently, daily averages were derived from these hourly averages, maintaining the same at least 80% data availability threshold. Similarly, the monthly averages were calculated from daily average data, but for only those months with daily data availability equal to or greater than 50%. The seasonal average is the mean of daily average data of that season. However, the seasonal average is calculated only for those seasons where monthly averages are available for at least 50% months in that season. For satellite-based analysis, tools such as Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT), Google Earth Engine (GEE), and Quantum Geographic Information System (QGIS) were employed to examine Aerosol Optical Depth (AOD), carbon monoxide (CO), and nitrogen dioxide (NO_2) levels.

The summary of analysis of data from 16 real time AQMS can be summarized in the table below:

SN	Province Name	Name of Station	Parameters	Compliance Status		Daily Average Mean (µg m^{-3})	Monthly Average (µg m^{-3})				Seasonal Average (µg m^{-3})				
				Total days of valid measurement	Total days exceeding NAAQS		Available months (Nos.)	Highest concentration		Lowest concentration		Available seasons (Nos.)	Highest concentration		Lowest concentration	
								Month	Value	Month	Value		Season	Value	Season	Value
1	Koshi	Dhankuta	$PM_{2.5}$	234	68	27.3	8	March	54.4	August	7	3	Pre-monsoon	43.1	Monsoon	10.3
			PM_{10}	234	0	37.8	8	April	81.2	August	8.2	3	Pre-monsoon	129.9	Monsoon	15.8
			TSP	233	45	65.1	8	April	198.3	August	9.5	3	Pre-monsoon	129.9	Monsoon	15.8
2		Ilam	$PM_{2.5}$	139	1	11.3	4	December	19	July	3.6	2	Post-monsoon	16.1	Monsoon	5.1
			PM_{10}	98	0	17.1	3	October	23.1	September	9.1	1	Post-monsoon			21
			TSP	139	0	19.2	4	October	29.7	July	8.8	2	Post-monsoon	27.9	Monsoon	12.4
3	Madhesh	Janakpur	$PM_{2.5}$	81	44	58.9	3	December	102.5	September	19.2	1	Post-monsoon			49.9
			PM_{10}	81	15	69	3	December	127	September	19.6	1	Post-monsoon			52.4
			TSP	81	24	78.7	3	December	151.2	September	19.8	1	Post-monsoon			53.5
4	Bagamati	Bhaisipati	$PM_{2.5}$	117	91	73.2	3	May	123.6	June	41.8	1	Winter			57.7
			PM_{10}	117	59	121	3	May	178.4	June	70.1	1	Winter			96.9
			TSP	113	96	222.8	3	May	288.8	June	157	1	Winter			172.1
5		Bhaktapur	$PM_{2.5}$	231	169	49.6	8	April	63.7	October	36.4	2	Pre-monsoon	54	Post-monsoon	43.4
			PM_{10}	231	6	69.4	8	April	97.7	October	51.5	2	Pre-monsoon	79.2	Post-monsoon	56.8
6		Bharatpur	$PM_{2.5}$	256	92	35.5	9	April	92.9	August	10.1	3	Pre-monsoon	59.4	Monsoon	14.6
			PM_{10}	256	25	73.5	8	May	121.3	July	17.8	2	Post-monsoon	60.4	Monsoon	27.6

SN	Province Name	Name of Station	Parameters	Compliance Status		Daily Average Mean (µg m^{-3})	Monthly Average (µg m^{-3})				Seasonal Average (µg m^{-3})				
				Total days of valid measurement	Total days exceeding NAAQS		Available months (Nos.)	Highest concentration		Lowest concentration		Available seasons (Nos.)	Highest concentration		Lowest concentration	
								Month	Value	Month	Value		Season	Value	Season	Value
			TSP	242	73	107.5	8	May	209	July	39.8	2	Post-monsoon	94.2	Monsoon	61.5
7		Hetauda	$PM_{2.5}$	171	15	15	5	April	41.3	October	5.1	2	Pre-monsoon	26.9	Post-monsoon	6.8
			PM_{10}	171	1	24.9	5	April	77.5	October	5.5	2	Pre-monsoon	51.1	Post-monsoon	7.2
			TSP	170	34	50.1	5	April	170.9	October	6.9	2	Pre-monsoon	110.7	Post-monsoon	9.1
8		Khumaltar	$PM_{2.5}$	351	194	43.5	12	April	78.6	August	9.8	4	Pre-monsoon	63	Monsoon	16.2
			PM_{10}	351	71	79.5	12	April	191	August	15	4	Pre-monsoon	135.8	Monsoon	27.6
			O_3 (ppb)*	328		29.2	11	April	52.3	July	15.3	4	Pre-monsoon	43.2	Winter	22.2
9		Pulchowk	O_3 (ppb)*	269		18.3	9	Mar-24	25.1	Dec-23	9.6	3	Pre-monsoon	23.1	Winter	13.6
10		Ratnapark	$PM_{2.5}$	268	179	59.2	9	January	85	June	14.5	3	Winter	85	Post-monsoon	45.1
			PM_{10}	269	119	99.5	9	April	161.2	June	15.2	3	Winter	122.4	Post-monsoon	76.8
			TSP	137	1	104.3	4	December	177.7	June	16	1	Post-monsoon			137.2
11		Shankhapark	$PM_{2.5}$	296	134	39.4	10	April	75.3	August	`12.7	4	Winter	56.8	Monsoon	19.7
			PM_{10}	296	65	85	10	April	249.9	August	20.5	4	Pre-monsoon	149.6	Monsoon	38.2
			TSP	295	119	210.8	10	April	674.8	November	43.6	4	Pre-monsoon	393	Post-monsoon	79.2
12		TU Kirtipur	$PM_{2.5}$	133	112	53.4	4	April	66.3	March	50.2	2	Pre-monsoon	55.8	Winter	55.1
			PM_{10}	133	26	89.6	4	April	137.7	March	77.1	2	Pre-monsoon	103.5	Winter	80.8
			TSP	133	27	168.8	4	April	297.8	March	132.2	2	Pre-monsoon	210.3	Winter	132.7

SN	Province Name	Name of Station	Parameters	Compliance Status		Daily Average Mean (µg m^{-3})	Monthly Average (µg m^{-3})					Seasonal Average (µg m^{-3})				
				Total days of valid measurement	Total days exceeding NAAQS		Available months (Nos.)	Highest concentration		Lowest concentration		Available seasons (Nos.)	Highest concentration		Lowest concentration	
								Month	Value	Month	Value		Season	Value	Season	Value
13	Lumbini	Deukhuri Dang	$PM_{2.5}$	125	42	33.1	4	December	70	August	10.5	2	Post-monsoon	46	Monsoon	12
			PM_{10}	125	0	45.6	4	December	89.9	August	15.3	2	Post-monsoon	66.8	Monsoon	17.7
			TSP	125	0	60.8	4	December	115.1	August	22.1	2	Post-monsoon	88.5	Monsoon	25
14	Karnali	Rara	$PM_{2.5}$	257	31	19.8	8	April	50.1	October	8.7	3	Pre-monsoon	33.1	Post-monsoon	8.7
			PM_{10}	257	4	26.4	8	April	65.4	October	9.6	3	Pre-monsoon	43.7	Post-monsoon	9.9
			TSP	257	0	42.3	8	April	108	October	11	3	Pre-monsoon	70.8	Post-monsoon	11.6
15	Sudurpashchim	Achham	$PM_{2.5}$	112	8	14.5	4	October	29.2	September	7	2	Post-monsoon	29.7	Monsoon	7.8
			PM_{10}	112	0	19.5	4	October	38.4	September	9.5	2	Post-monsoon	38.7	Monsoon	11.5
			TSP	112	0	29.6	4	October	54.4	August	14	2	Post-monsoon	59.4	Monsoon	17.3
16		Mahendranagar	$PM_{2.5}$	190	73	36.8	7	January	81.2	August	5.2	3	Winter	63.1	Monsoon	9.7
			PM_{10}	190	2	51	7	January	92.3	August	6.2	3	Winter	78	Monsoon	18.7
			TSP	190	0	86.4	7	January	112.1	August	9.4	3	Pre-monsoon	107.4	Monsoon	41.8

* In case of O_3 the values are in Parts per billion (ppb)

The HYSPLIT model of five days' backward trajectory analysis showed the wind pattern of Kathmandu Valley for January, February, March, April, November and December showing dominant mass arriving from south and western direction during all months. But during March and November the share of wind blowing from eastern direction was little bit higher compared to other months. The satellite imagery (Moderate Resolution Imaging Spectroradiometer (MODIS) true-color images) and fire-monitoring tool National Aeronautics and Space Administration (NASA) Fire Information for Resource Management System (FIRMS) (using MODIS and Visible Infrared Imaging Radiometer Suite (VIIRS) data) help track pollution from fire events. March and April are the months with high fire activities which directly influences quality of air. Furthermore, satellite data were also used for tracking pollutants such as Aerosol, NO_2 and CO. The annual mean tropospheric NO_2 level was high in some places where economic activities are relatively higher.

Satellite-derived AOD measurements reveal significant aerosol pollution in Nepal, with higher values indicating greater concentrations of $PM_{2.5}$. The Terai region-particularly eastern Terai-emerged as a pollution hotspot, likely due to a combination of local emissions and transboundary pollution. The model data shows annual $PM_{2.5}$ levels increased across almost all provinces in 2024 compared to 2023, with Madhesh Province having the highest annual $PM_{2.5}$ and Karnali Province the lowest.

Various regional as well as local sources influence air quality. Because of various sizes and characters of air pollutants, their life time in atmosphere vary along with their probable effects. The major sources of air pollution in Nepal include household emissions, industrial activities, vehicular emissions, construction activities, forest fires, and burning of agricultural residue. Air quality in Nepal is also adversely affected by transboundary pollution and emissions from natural sources. Maintaining clean air is one of the most pressing challenges today and can only be achieved through collaboration and cooperation at both local and regional levels.

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ACRONYMS AND ABBREVIATIONS

µm	:	Micrometer
µg m^{-3}	:	Microgram per cubic meter
AOD	:	Aerosol Optical Depth
AOT	:	Aerosol Optical Thickness
AQI	:	Air Quality Index
AQMS	:	Air Quality Monitoring Station
BC	:	Black Carbon
BCSMASS	:	Black Carbon Surface Mass Concentration
CO	:	Carbon-monoxide
CSV	:	Comma-separated Values
DHM	:	Department of Hydrology and Meteorology
DUSMASS25	:	Dust Surface Mass Concentration-$PM_{2.5}$
EDM	:	Environmental Dust Monitor
EPA	:	Environmental Protection Act
EPR	:	Environmental Protection Regulation
ESA	:	European Space Agency
FIRMS	:	Fire Information for Resource Management System
GDAS	:	Global Data Assimilation System
GEE	:	Google Earth Engine
GIBS	:	Global Imagery Browse Services
GMAO	:	Global Modeling and Assimilation Office
hPa	:	Hectopascal
HYSPLIT	:	Hybrid Single-Particle Lagrangian Integrated Trajectory
ICIMOD	:	International Centre for Integrated Mountain Development
kg	:	Kilogram
km	:	Kilometer
L/min	:	Liter per minute
m	:	Meter
MAIAC	:	Multi-Angle Implementation of Atmospheric Correction
MERRA-2	:	Modern-Era Retrospective analysis for Research and Applications Version 2
ML	:	Machine Learning
MODIS	:	Moderate Resolution Imaging Spectroradiometer
MoFE	:	Ministry of Forests and Environment
NAAQS	:	National Ambient Air Quality Standards
NASA	:	National Aeronautics and Space Administration
NITC	:	National Information Technology Centre
NO_2	:	Nitrogen dioxide

NOAA	:	National Oceanic and Atmospheric Administration
NO_x	:	Oxides of Nitrogen
NPC	:	National Planning Commission
O_3	:	Ozone
OC	:	Organic Carbon
OCSMASS	:	Organic Carbon Surface Mass Concentration
Pa	:	Pascal
PBL	:	Planetary Boundary Layer
PM	:	Particulate Matter
PM_1	:	Particulate Matter having aerodynamic diameter less than 1 micron
PM_{10}:	:	Particulate Matter having aerodynamic diameter less than 10 micron
$PM_{2.5}$	:	Particulate Matter having aerodynamic diameter less than 2.5 micron
PS	:	Surface Pressure
Q500	:	Specific humidity at 500 hPa
QGIS	:	Quantum Geographic Information System
QV10 m	:	Specific humidity
SD	:	Standard Deviation
SO_2	:	Sulphur dioxide
SO2SMASS	:	SO_2 Surface Mass Concentration
SO4SMASS	:	SO_4 Surface Mass Concentration
T10 m	:	Temperature at 10 m
T500	:	Temperature at 500 hPa
TOTEXTTAU	:	Total Aerosol Extinction AOT [550 nm]
TOUT	:	The Output Time Interval
TROPOMI	:	Tropospheric Monitoring Instrument
TSP	:	Total Suspended Particulates
TU	:	Tribhuvan University
UNEP	:	United Nations Environment Programme
VIIRS	:	Visible Infrared Imaging Radiometer Suite
VOCs	:	Volatile Organic Carbons
WHO	:	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The Constitution of Nepal ensures that every citizen has the fundamental right to live in a clean and healthy environment. The Government of Nepal (GoN) enacted the Environment Protection Act (EPA) in 2019 and the Environment Protection Regulation (EPR) in 2020, both emphasize environmentally balanced development. The National Environment Policy 2019 and the 16th Periodic Development Plan (2024/25) (NPC, 2024) also highlighted the need to reduce pollution across various sectors. Furthermore, the GoN has adopted the National Ambient Air Quality Standards (NAAQS) in 2012 to ensure cleaner air for all. The Department of Environment (DoEnv), under the Ministry of Forests and Environment (MoFE), is the primary government regulatory agency for environmental factors including air quality in Nepal.

Air pollution is a key global threat that transcends physical borders (UNEP, 2024). In 2021, it was responsible for 8.1 million deaths, with over one in eight deaths attributed to air pollution. It was the second leading risk factor for death among children under the age of five in 2021 (HEI, 2024). About 92% of the population residing in Asia and the Pacific regions are under serious health risk due to air pollution (UNEP, 2019). Epidemiological studies in Asia and the Pacific provide sufficient evidence that exposures to $PM_{2.5}$ and ground-level ozone (O_3) are the most damaging to health and contribute significantly to the attributable health burdens (UNEP, 2019). Residential solid biofuel has been considered as one of the dominant source of $PM_{2.5}$ pollution followed by anthropogenic fugitive, combustion and industrial dust in South Asian countries (Tamayo, 2023). O_3 is secondary air pollutant which is released in ambient air as a byproduct of chemical interactions between NO_x and Volatile Organic Carbons (VOCs) in presence of sunlight (Health Effects Institute, 2024).

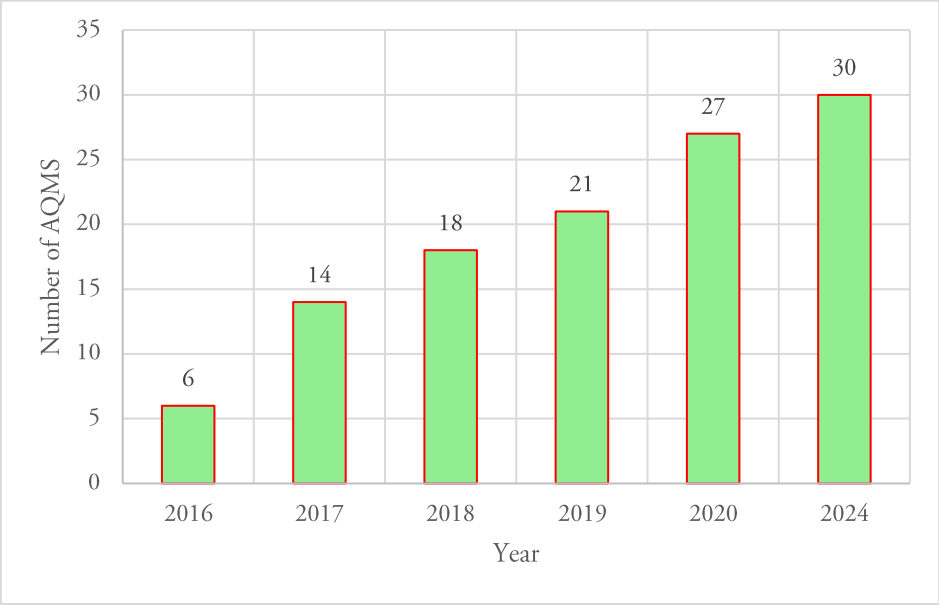


Figure 1: Establishment of Real Time AQMS with Years

GoN has formulated standards for all the criteria pollutants (Table 5). Criteria pollutants are group of air pollutants that are harmful to public health and environment (HEI, 2024) and are hence regulated by most of the regulatory agencies over the globe. As the regulatory body, the DoEnv started real time ambient air quality monitoring since 2016. By 2024, DoEnv has established thirty (Figure 1, and 2) AQMS throughout seven Provinces of Nepal (Figure 3). These AQMS helps to assess concentration of ambient air pollutants on the basis of available standards and guidelines.

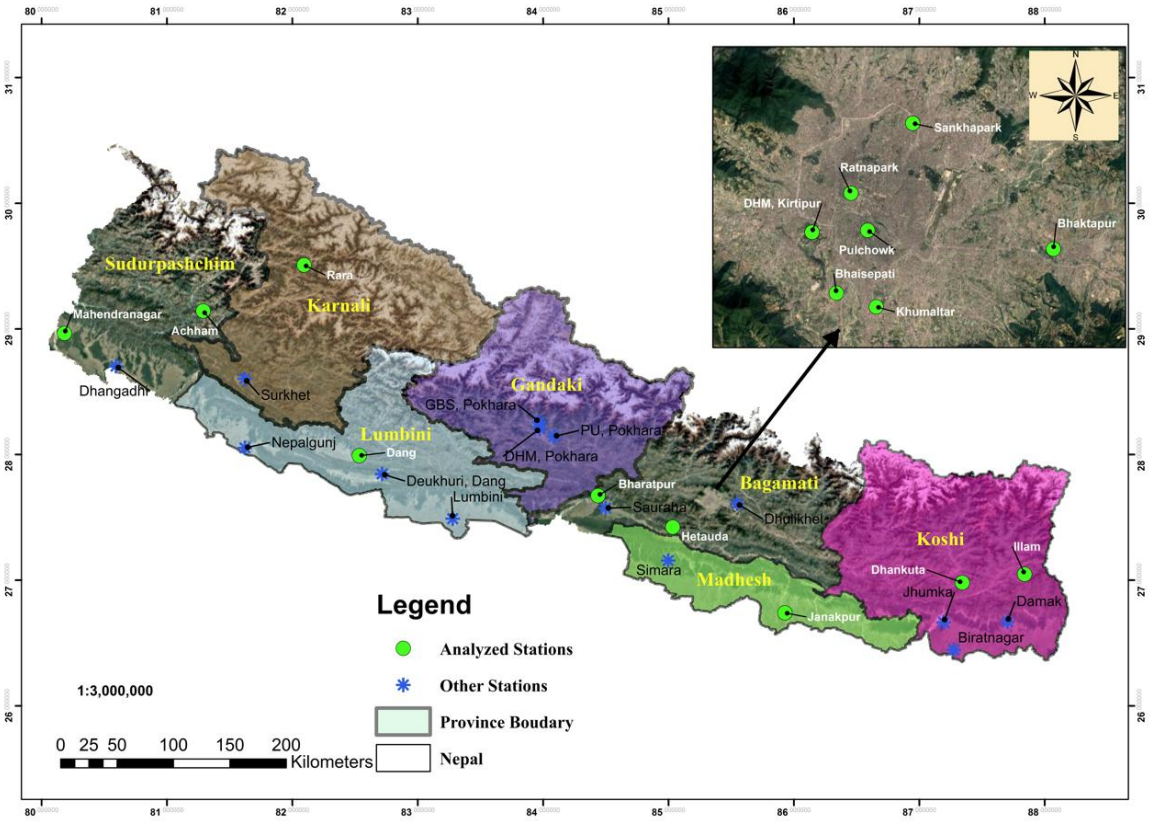


Figure 2: Distribution of AQMS in Nepal

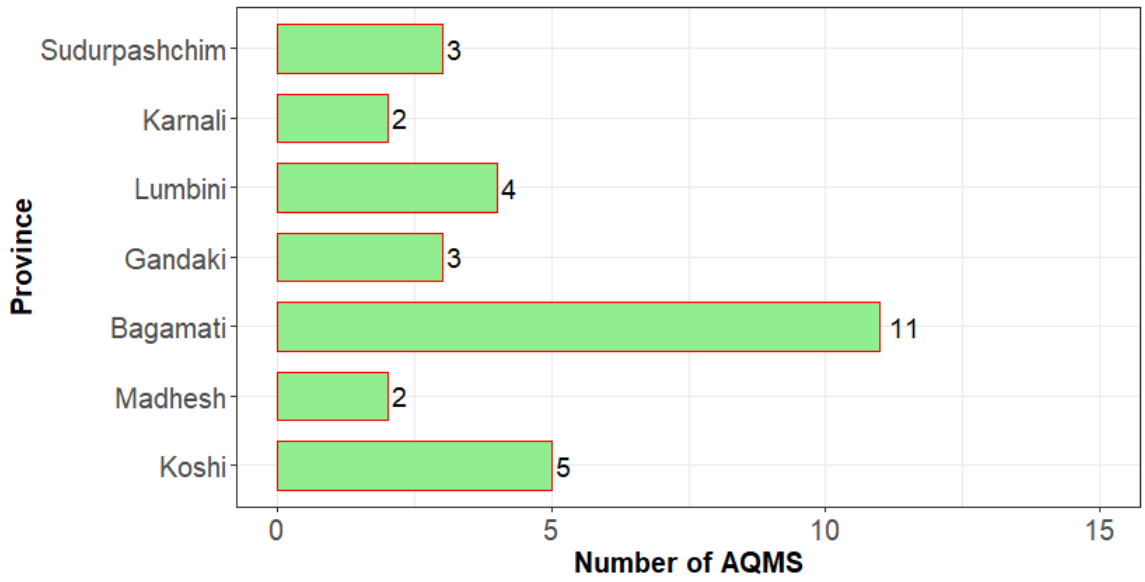


Figure 3: Provincial Distribution of AQMS

These thirty AQMS were installed to represent air quality of both urban as well as rural environments. All these stations measure PM_1, $PM_{2.5}$, PM_{10} and TSP. AQMS at Ratnapark, Dhulikhel, Khumaltar, and Lumbini measure CO, SO_2, NOx, and O_3, and AQMS at Sauraha and Pulchowk measure O_3 in addition to particulate matter.

This *Status of Air Quality in Nepal: Annual Report 2024* includes analysis of air quality data from sixteen Air Quality Monitoring Stations (AQMS) (Table 1). Data from the remaining stations were excluded due to limited data availability.

Table 1: List of AQMS Used for Data Analysis

SN	Name of AQMS	Location	Province Name	Coordinate
1	Bhaisepati	Bhaisepati residential area office, Lalitpur	Bagamati	85.3023° E, 27.6531° N
2	Bharatpur	District Administration Office, Chitwan	Bagamati	84.4384° E, 27.6725° N
3	Bhaktapur	Sainik Aawasiya Mahavidyalaya, Bhaktapur	Bagamati	85.4175° E, 27.6738° N
4	Hetauda	Hupra Chaur, Hetauda, Makawanpur	Bagamati	85.0344° E, 27.4227° N
5	Khumaltar	ICIMOD, Khumaltar, Lalitpur	Bagamati	85.3234° E, 27.6467° N
6	Kritipur	DHM Station, TU, Kirtipur, Kathmandu	Bagamati	85.2893° E, 27.6817° N
7	Pulchowk	Pulchowk Campus, Lalitpur	Bagamati	85.3188° E, 27.6826° N
8	Ratnapark	Shankhadhar Park, Kathmandu	Bagamati	85.3100° E, 27.7000° N
9	Shankapark	Shankapark, Kathmandu	Bagamati	85.3428° E, 27.7328° N
10	Rara	Rara National Park, Mugu	Karnali	82.0938° E, 29.5083° N
11	Dhankuta	Dhankuta Municipality Office, Dhankuta	Koshi	87.3439° E, 26.9807° N
12	Ilam	Kuhibhir, Ilam	Koshi	87.8408° E, 27.0478° N
13	Deukhari, Dang	Rapti Rural Municipality Office, Dang	Lumbini	82.7162° E, 27.8450° N
14	Janakpur	Madhesh Bhawan, Dhanusha	Madhesh	85.9285° E, 26.7398° N
15	Mahendranagar	Bhimdatta Municipality Office, Kanchanpur	Sudurpashchim	80.1829° E, 28.9651° N
16	Achham	Oli Gaun, Mangalsen, Achham	Sudurpashchim	81.2892° E, 29.1427° N

1.2 OBJECTIVES

The overall objective of this report is to present the air quality status of Nepal (2024), based on the data from the sixteen AQMS distributed throughout the country.

The specific objectives are:

- To determine the status of air quality based on $PM_{2.5}$, PM_{10}, TSP, and O_3.
- To analyze regional air quality across Nepal utilizing modeling techniques and satellite observations.

1.3 PARAMETERS ANALYZED FROM AIR QUALITY MONITORING STATIONS

The following parameters were analyzed in this assessment.

- $PM_{2.5}$: Includes particulate matter with an aerodynamic diameter less than or equal to 2.5 µm and is important in terms of health impacts.
- PM_{10}: Includes particulate matter with an aerodynamic diameter less than or equal to 10 µm.
- TSP: Includes all solid and liquid droplet particulate present in the air.
- O_3: Includes ground level ozone (tropospheric ozone) which can irritate eyes, nose and throat and can cause various other health impacts.

1.4 COMMITTEE FOR PROVIDING STRATEGIC DIRECTION AND OVERSIGHT

A committee (Annex 1) was formed including members from various organizations, to support the preparation of the report. This committee played a crucial role in making key decisions, providing strategic directions, and offering valuable guidance for data analysis. In addition to the committee's involvement, experts from various institutions were invited to contribute their expertise and offer feedback which further enhanced the quality and comprehensiveness of the report.

1.4.1 Data Averaging

Hourly data were calculated by averaging minute-level data, but only when at least 80% of the minute data were available for that hour. Similarly, daily data were derived from hourly data only if 80% or more of the hourly data were present for the day. Monthly averages were then calculated from daily data, provided that daily values were available for at least 50% of the days in that month. Seasonal averages were computed from daily data as well, but only when sufficient monthly data were available: at least two months of valid data were required for Winter, Pre-monsoon, and Monsoon seasons, while only one month of data was sufficient for the Post-monsoon season. The following months were considered for different seasons for seasonal data analysis:

- Winter season: December of the preceding year, January and February
- Pre-monsoon season: March, April and May
- Monsoon season: June, July, August and September
- Post-monsoon season: October and November

1.5 METHODS OF AIR QUALITY MONITORING AND DATA ANALYSIS

Particulate matter (PM)

The Environmental Dust Monitor (Grimm EDM 180+) is used for ambient dust measurement. It utilized laser light-scattering technology to count particles. Particles present in the sampled air are classified by size and number in the measuring chamber using scattered light measurement. During the process, a small measuring volume is exposed to a laser beam with downstream optics. For environmental measurements, the concentration of solids is so low that statistically there is only one particle in the sensing volume at a time. The scattered light emitted by each particle is captured by a second set of optics with a specific opening and scattering angle, deflected to a detector by a mirror, and the light intensity is measured. The particle size is proportional to the intensity of the reflected light beam. The count rate is determined from the number of particles and the volume flow rate. When the particle diameter and density are known, the particle mass is derived from the particle count based on the assumption that particles were spherical in shape.

A semiconductor laser served as the light source in the EDM 180+ spectrometer. To minimize the influence of refractive indices, the 90° scattered light is guided to a receiver diode by a mirror with an opening angle of approximately 120°. After amplification, the electrical signal from the diode is classified into 31 size channels according to signal strength. This allowed for the determination of the grain size distribution of the particles. The sample flow rate of the instrument is 1.2 L/min.

Ozone (O_3)

The Model 49i ozone analyzer is used for ozone measurement. It operates based on UV photometric detection, where ozone (O_3) absorbs ultraviolet (UV) light at 254 nm, following the Beer-Lambert Law.

$I=I_0.e^{-KLC}$

Where;

- I = Intensity of transmitted light
- I_0 = Intensity of incident light
- K = Absorption coefficient
- L = Path length (distance light travels through the medium)
- C = Concentration of the O_3

The analyzer measures the reduction in UV light intensity due to ozone absorption to determine the ozone concentration. A sample gas stream is split into two paths: One path passes through an ozone scrubber to become the reference gas (Io). The other path remains untreated as the sample gas (I). These gas streams are alternated between two optical cells (A and B) every 10 seconds using solenoid valves. UV light intensities are measured in both cells, with a short delay after switching to allow for gas flushing. The ozone concentration is calculated for each cell using the equation derived from the Beer-Lambert Law and averaged. Results are displayed on the front panel, and data are available via analog, serial, and Ethernet outputs.

1.5.1 Data Acquisition

This EDM instrument has the highest measurement resolution of six seconds, but measurement was taken in minute basis. The data was logged as one-minute averaged in CSV format into the data logger installed at each AQMS. This data logger system then transmits the data to the central server located at the NITC, Singha Durbar, Kathmandu which were displayed and downloaded from pollution.gov.np for further analysis.

Similarly, Ozone data was transmitted and stored via data loggers or networked systems for further analysis. Accurate data acquisition depends on regular instrument calibration, proper maintenance, and uninterrupted power supply to ensure high-quality, continuous monitoring of ground-level ozone.

1.5.2 Data Cleaning

Particulate Matter (PM)

For data analysis, downloaded minute data were first go through cleaning procedure. For this purpose, based on suggestion form GRIMM manufacturer, threshold value of 1500 µg m^{-3} was set for all three particulate parameters ($PM_{2.5}$, PM_{10} and TSP). All repeated data, along with negative and null data were removed for further analysis.

Ozone (O_3)

The ozone data cleaning process involves systematically reviewing and refining raw ozone concentration measurements to ensure accuracy and reliability. It begins with verifying time synchronization, removing duplicate or missing timestamps, and flagging data collected during instrument calibration, maintenance, or malfunction. Values outside the valid physical range (typically below 0 or above 300 ppb) were filtered out unless justified. Sudden spikes or anomalies are identified using rate-of-change and moving average methods. The process ensures at least 80% data completeness for daily averages, interpolates only short gaps with consistent trends, and marks longer gaps as missing. A final manual quality check was conducted using field logs and co-located data, resulting in a cleaned dataset with appropriate QA/QC flags and documentation for transparency and traceability.

1.5.3 Data Analysis Method and Plots/Graphs Used in the Report

Various tools were utilized for data analysis, with the results presented through a range of graphs and maps. Python programming (Python Software Foundation, 2023) was employed to automate the retrieval of large datasets from the central server. Data analysis was carried out using Base R (R CoreTeam, 2024) along with several R packages, including openair (Carslaw, 2019), ggplot2 (Wickham, 2016), and randomForest (Liaw and Wiener, 2002). For satellite data analysis, tools such as HYSPLIT (Stein et al., 2015), Google Earth Engine (GEE) (Gorelick et al., 2015), and QGIS (QGIS.org, 2024) were applied.

Histograms, monthly box plots, and hourly box plots were generated using hourly data. Bar charts were used to present the monthly and seasonal averages, as well as the daily compliance status of particulate matter concentrations at each station. The HYSPLIT model diagrams depicted the distribution of wind directions in relation to a selected pollutant.

Additionally, a calendar plot and a calendar pie chart were created to visualize the daily Air Quality Index (AQI), based exclusively on $PM_{2.5}$ data. The break points as shown in Table 2 were used for the calculation. The AQI group and their respective colour codes is as follows.

Table 2 : Air Quality Index (AQI) and AQI Break Points for $PM_{2.5}$

Air Quality Index (AQI) Values	Levels of Health Concern	Colors	$PM_{2.5}$ ($\mu g\ m^{-3}$) 24-hours average
0 to 50	Good	Green	0.0-20.0
51 to 100	Moderate	Yellow	20.0-40.0
101 to 150	Unhealthy for Sensitive Groups	Oranges	41.0-60.0
151 to 200	Unhealthy	Red	61.0-160.0
201 to 300	Very Unhealthy	Purple	161.0-260.0
301 to 400	Hazardous	Maroon	261.0-360.0
401 to 500	Very Hazardous	Maroon	>360.0

Source: MoFE

Each category corresponds to a different level of health concern. The seven levels of health concern can be described as:

- "Good" AQI is 0 to 50. Air quality is considered satisfactory, and air pollution poses little or no risk.
- "Moderate" AQI is 51 to 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people.
- "Unhealthy for Sensitive Groups" AQI is 101 to 150. Although general public is not likely to be affected at this AQI ranges, people with lung disease, older adults and children are at a greater risk from exposure to ozone, whereas persons with heart and lung disease, older adults and children are at greater risk from the presence of particles in the air.
- "Unhealthy" AQI is 151 to 200. Everyone may begin to experience some adverse health effects, and members of the sensitive groups may experience more serious effects.
- "Very Unhealthy" AQI is 201 to 300. This would trigger a health alert signifying that everyone may experience more serious health effects.
- "Hazardous" AQI is 301 to 400. This would trigger a health warnings of emergency conditions. The entire population is more likely to be affected.
- "Very Hazardous" AQI is 401 to 500. This would trigger health warnings of emergency conditions. The entire population is more likely to be affected.

Long Term Trend of $PM_{2.5}$ of Ratnapark Station:

Due to significant data gaps recorded in the Ratnapark air quality monitoring station, it was not feasible to analyse long term trend using ground-based data alone. To overcome this limitation, machine learning techniques were employed as an alternative approach (Sayeed et al., 2022). For this purpose, Modern-Era Retrospective Analysis for Research and Applications Version 2 (MERRA-2) dataset was used alongside ground based monitoring data. MERRA-2 is a NASA GMAO long-term global reanalysis that provides various meteorological and aerosol parameters since 1980.

Hourly-averaged meteorological and aerosol data were retrieved from MERRA-2. The $PM_{2.5}$ concentration was estimated using aerosol diagnostic products from MERRA-2, using the following equation:

$PM_{2.5} = Dust_{2.5} + BC + OC + 1.375 \times SO4$

Table 3 lists the MERRA-2 meteorological and aerosol parameters used as input for the machine learning (ML) model.

Table 3: Meteorological and Aerosol Parameters from MERRA-2 Used in the Model

S.N.	Name	Description	Units
Meteorology			
1	PS	Surface pressure	Pa
2	Q500	Specific humidity at 500 hPa	kg kg^{-1}
3	T500	Temperature at 500 hPa	K
4	T10 m	Temperature at 10 m	K
5	QV10 m	Specific humidity	kg kg^{-1}
6	WIND	Wind speed at 10 m	m s^{-1}
Aerosols			
1	DUSMASS25	Dust surface mass concentration-$PM_{2.5}$	µg m^{-3}
2	OCSMASS	Organic carbon surface mass concentration	µg m^{-3}
3	SO2SMASS	SO_2 surface mass concentration	µg m^{-3}
4	SO4SMASS	SO_4 surface mass concentration	µg m^{-3}
5	TOTEXTTAU	Total aerosol extinction AOT [550 nm]	Unit less
6	BCSMASS	Black carbon surface mass concentration	µg m^{-3}

Hourly ground level $PM_{2.5}$ concentration from the Ratnapark Station (2017–2024) were used for model training. Spatial collocation was done by selecting the MERRA-2 grid cell closest to the Ratnapark Station. Temporal collocation matched the same hourly timestamps from both MERRA-2 and the station data.

A Random Forest Regression Model was trained using ground level $PM_{2.5}$ values as the dependent variable and the corresponding MERRA-2 meteorological and aerosol parameters as independent variables. The dataset was split in a 70:30 ratios for model training and validation. The model yielded an R^2 value of 0.789. A scatterplot comparing observed and predicted $PM_{2.5}$ values were presented in the Annex 3. Using the trained model, annual average $PM_{2.5}$ concentrations were estimated based on the predicted values.

Estimating $PM_{2.5}$ over Nepal

Same approach used for Ratnapark Station was extended to calculate the annual average $PM_{2.5}$ across the entire country. In this case, hourly $PM_{2.5}$ data from several air quality monitoring stations across Nepal were used to train a general Random Forest Regression model. Table 4 lists the stations and corresponding years used for training.

Table 4: Lists of the Stations Used for Machine Learning

S. N.	Station	Year
1	Ratnapark	2023
2	Dhankuta	2023
3	Rara	2022 and 2023
5	Dhangadhi	2021
6	Biratnagar	2021

For this national model, the R^2 value was 0.854. The scatterplot between predicted and observed $PM_{2.5}$ concentrations for the validation data was presented in the Annex 3. Annual average $PM_{2.5}$ concentration was then calculated for all MERRA-2 grid cells covering Nepal using MERRA-2 data. These estimates were bias-corrected based on the model results to ensure consistency with the ground-based observations.

1.5.4 Satellite Data Analysis

The image of forest fire event was taken from NASA FIRMS (Fire information for resource management system) website. NASA FIRMS integrates satellite observations from the MODIS and VIIRS satellite instruments to detect active fires and thermal anomalies and deliver this information in near real-time to decision makers through email alerts, analysis ready data, online maps and web services. Similarly, true colour satellite imagery was also downloaded from FIRMS website. NASA Worldview Snapshots interface generates a true colour or derived data product satellite imagery subset at a spatial resolution of 250 meters. Subsets can be generated from the data record of daily corrected reflectance satellite imagery for listed satellite/sensor assets. Subsets are dynamically generated with the NASA Worldview Snapshots application using source imagery provided by the Global Imagery Browse Services (GIBS).

The Data from the ESA Copernicus TROPOMI instrument on board the Sentinel 5p satellite was used. The CO and NO_2 data of various time periods were downloaded from the Copernicus Sentinel-5P Mapping Portal. Then further analysis and visualization was done using QGIS.

Analysis of AOD

The MCD19A2 V6.1 data product was used for analysis of Aerosol Optical Depth (AOD). This is a MODIS Terra and Aqua Combined Multi-Angle Implementation of Atmospheric Correction (MAIAC) Land AOD gridded Level 2 product produced daily at 1 km resolution. Here AOD over land retrieved in the MODIS Green band (0.55 μm) was selected for the AOD analysis. Monthly average of AOD for all months of 2024 was calculated using the GEE. Then from monthly average

annual average was calculated in python and further analysis and visualization were done using QGIS.

Wind Pattern Analysis

To examine the wind patterns and air mass transport influencing Kathmandu, HYSPLIT model, developed by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory, was utilized. The model was driven using the Global Data Assimilation System (GDAS) 1-degree meteorological dataset.

Five-day (120-hour) backward trajectories were calculated for the months of January, February, March, April, November and December of 2024 for Kathmandu. For each month, trajectory from 6th of the day to the last day of the month was calculated. The trajectory calculations were performed at three-hour intervals, and the output time interval (TOUT) was set to 6 minutes, allowing for detailed resolution of air parcel paths.

The starting height for each trajectory was set at the mid-level of the planetary boundary layer (PBL) at the corresponding time, to better represent near-surface transport relevant to air quality. Frequency plots were then generated from the trajectories for each location and month, providing insights into the dominant transport pathways and potential source regions of air masses affecting the two cities.

1.5.5 National Ambient Air Quality Standards, 2012 (NAAQS)

The GoN has endorsed NAAQS in 2012. The NAAQS gives maximum concentration for major nine parameters including particulate matter, trace gases, heavy metal and others as shown in the Table 5.

Table 5: National Ambient Air Quality Standards, 2012

SN	Parameters	Units	Averaging time	Maximum concentration
1	$PM_{2.5}$	μg m^{-3}	24-hr	40
2	PM_{10}	μg m^{-3}	24-hr	120
3	TSP	μg m^{-3}	24-hr	230
4	Ozone	μg m^{-3}	8-hr	157
5	Sulphur Dioxide	μg m^{-3}	Annual	50
			24-hr	70
6	Nitrogen Dioxide	μg m^{-3}	Annual	40
			24-hr	80
7	Carbon monoxide	μg m^{-3}	8-hr	10,000
8	Lead	μg m^{-3}	Annual	0.5
9	Benzene	μg m^{-3}	Annual	5

CHAPTER 2: RESULTS

2.1 KOSHI PROVINCE

2.1.1 Dhankuta Air Quality Monitoring Station

The Dhankuta AQMS, established in 2019, is located next to the Dhankuta Municipality Office in Dhankuta District, Koshi Province. Positioned in an urban setting, the main contributors to air pollution at this site are likely vehicle emissions and pollutants carried from nearby areas, including smoke from forest fires during the fire season.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 27.3 ± 20.0 µg m^{-3} (Table 6). Out of the total 234 days of available daily average data, 68 days exceeded NAAQS (Figure A4-13). Most of those exceedances occurred during February, March, and April, which can also be visualized in the calendar plot (Figure A4-25).

Table 6: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Dhankuta Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.2	9.4	21.2	27.1 ± 21.6	41.0	164.9
Daily	2.5	9.1	21.6	27.3 ± 20.0	42.3	93.3

Monthly data analysis for eight months (March, April, May, June, August, September, October and November) revealed that March had the highest average $PM_{2.5}$ concentration (54.4 µg m^{-3}), while August recorded the lowest (7.0 µg m^{-3}) (Figure A4-19). Among the three seasons with available seasonal averages (Pre-monsoon, Monsoon and Post-Monsoon), the Pre-monsoon season exhibited the highest average $PM_{2.5}$ concentration (43.1 µg m^{-3}), while the Monsoon season had the lowest seasonal average (10.3 µg m^{-3}) (Figure A4-22).

PM_{10}

The mean of daily average PM_{10} concentration was 37.8 ± 31.2 µg m^{-3} (Table 7). Out of the total 234 days of available daily average data, none of the days exceeded the NAAQS (Figure A4-14).

Table 7: Summary of PM_{10} (µg m^{-3}) Concentration for Dhankuta Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.3	11.2	26.4	37.2 ± 32.3	55.7	194.5
Daily	2.6	10.5	26.9	37.8 ± 31.2	57.1	118.2

Monthly data analysis for eight months (March, April, May, June, August, September, October and November) revealed that April had the highest average PM_{10} concentration (81.2 µg m^{-3}), while August recorded the lowest (8.2 µg m^{-3}) (Figure A4-20). Among the three seasons with available seasonal averages (Pre-monsoon, Monsoon and Post-Monsoon), the Pre-monsoon season exhibited the highest average PM_{10} concentration (65.1 µg m^{-3}), while the Monsoon season had the lowest seasonal average (12.8 µg m^{-3}) (Figure A4-23).

TSP

The mean of daily average TSP concentration was 65.1 ± 74.9µg m^{-3} (Table 8). Out of the total 233 days of available daily average data, 45 days exceeded the NAAQS (Figure A4-15). Those exceedances occurred during February, March, April and May.

Table 8: Summary of TSP (µg m^{-3}) Concentration for Dhankuta Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.4	12.9	32.4	64.1 ± 82.3	75.8	741.9
Daily	2.8	12.6	34.0	65.1 ± 74.9	90.5	345.5

Monthly data analysis for eight months (March, April, May, June, August, September, October and November) revealed that April had the highest average TSP concentration (198.3 µg m^{-3}), while August recorded the lowest (9.5 µg m^{-3}) (Figure A4-21). Among the three seasons with available seasonal averages (Pre-monsoon, Monsoon and Post-Monsoon), the Pre-monsoon season exhibited the highest average TSP concentration (129.9 µg m^{-3}), while the Monsoon season had the lowest seasonal average (15.8 µg m^{-3}) (Figure A4-24).

2.1.2 Ilam Air Quality Monitoring Station

The Ilam AQMS was established in 2024 and is located at Kuhibhir in Ilam Municipality, Ilam District, Koshi Province. Kuhibhir is one of the famous local tourist destination and represents the highest-altitude landscape within Ilam Municipality. The station is situated near the boundary of Ilam and Panchthar districts. As the station is situated in a rural area, the primary sources of air pollution include pollutants transported from surrounding areas particularly emissions from forest fire during fire seasons.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 11.3 ± 9.5 µg m^{-3} (Table 9).

Table 9: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Ilam Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	0.1	2.4	7.9	11.2 ± 11.6	16.2	96.9
Daily	0.5	4.2	8.2	11.3 ± 9.5	15.7	40.4

Monthly data analysis for four months (July, September, October and December) revealed that December had the highest average $PM_{2.5}$ concentration (19.0 µg m^{-3}), while July recorded the lowest (3.6 µg m^{-3}) (Figure A4-45). Among the two seasons with available seasonal averages, the Post-monsoon season exhibited the highest average $PM_{2.5}$ concentration (16.1 µg m^{-3}), while the Monsoon season had the lowest seasonal average (5.1 µg m^{-3}) (Figure A4-48).

PM_{10}

The mean of daily average PM_{10} concentration was 17.1 ± 11.4 µg m^{-3} (Table 10). Out of the total 98 days of available daily average data, none of the days exceeded the NAAQS (Figure A4-40).

Table 10: Summary of PM_{10} (µg m^{-3}) Concentration for Ilam Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	0.2	5.7	12.1	16.0 ± 15.2	22.2	145.0
Daily	0.4	9.2	13.9	17.1 ± 11.4	23.1	51.5

Monthly data analysis for three months (September, October and December) revealed that October had the highest average PM_{10} concentration (23.1 µg m^{-3}), while September recorded the lowest (9.1 µg m^{-3}) (Figure A4-46). Among the seasonal averages, only the Post-monsoon season was analyzed, with an average PM_{10} concentration of 21.0 µg m^{-3} (Figure A4-49).

TSP

The mean of daily average TSP concentration was 19.2 ± 15.9 µg m^{-3} (Table 11). Out of the total 139 days of available daily average data, all days meet the NAAQS (Figure A4-41).

Table 11: Summary of TSP (µg m^{-3}) Concentration for Ilam Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	0.2	3.2	12.3	19.3 ± 38.0	25.1	1262.2
Daily	0.4	8.6	14.9	19.2 ± 15.9	25.9	73.9

Monthly data analysis revealed that out of four months (July, September, October and December) with available monthly mean October had the highest average TSP concentrations (29.7 µg m^{-3}), while July recorded the lowest (8.8 µg m^{-3}) (Figure A4-47). Among the two seasons with available seasonal averages, the Post-monsoon season exhibited the highest average TSP concentration (27.9 µg m^{-3}), while the Monsoon season had the lowest seasonal average (12.4 µg m^{-3}) (Figure A4-50).

2.2 MADHESH PROVINCE

2.2.1 Janakpur Air Quality Monitoring Station

The air quality monitoring station located within the premises of Madhesh Bhawan, the provincial government office complex in Janakpur, Madhesh Province, was established in 2020. It is located in Dhanusha district of Madhesh Province and represents the air quality of urban area. The local air quality may be influenced by industrial emission, regional and local fires as well as transboundary air pollution.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 58.9 ± 41.8 µg m^{-3} (Table 12). Out of the total 81 days of available daily average data, 44 days exceeded the NAAQS (Figure A4-65). Most of those exceedances occurred during December which can also be visualized in the calendar plot (Figure A4-77).

Table 12: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Janakpur Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.2	16.8	38.8	57.5 ± 53.2	83.3	258.2
Daily	3.1	21.8	56.9	58.9 ± 41.8	90.5	149.3

Monthly data analysis for only three months (September, October and December) revealed that December had the highest average $PM_{2.5}$ concentrations (102.5 µg m^{-3}), while September recorded the lowest (19.2 µg m^{-3}) (Figure A4-71). Among the seasonal averages, only the Post-monsoon season was analyzed, with an average $PM_{2.5}$ concentration of 49.9 µg m^{-3} (Figure A4-74).

PM_{10}

The mean of daily average PM_{10} concentration was 69.0 ± 53.3 µg m^{-3} (Table 13). Out of the total 81 days of available daily average data, 15 days in December exceeded the NAAQS (Figure A4-66).

Table 13: Summary of PM_{10} (µg m^{-3}) Concentration for Janakpur Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.2	18.0	43.7	67.4 ± 63.4	100.6	304.2
Daily	3.2	22.2	58.4	69.0 ± 53.3	108.0	178.3

Monthly data analysis for only three months (September, October and December) revealed that December had the highest average PM_{10} concentration (127.0 µg m^{-3}), while September recorded the lowest (19.6 µg m^{-3}) (Figure A4-72). Among the seasonal averages, only the Post-monsoon season was analyzed, with an average PM_{10} concentration of 52.4 µg m^{-3} (Figure A4-75).

TSP

The mean of daily average TSP concentration was 78.7 ± 64.9 µg m^{-3} (Table 14). Out of the total 81 days of available daily average data, 24 days in December exceeded the NAAQS (Figure A4-67).

Table 14: Summary of TSP (µg m^{-3}) Concentration for Janakpur Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.2	18.2	46.7	76.5 ± 72.1	124.0	341.9
Daily	3.2	22.3	28.4	78.7 ± 64.9	130.8	222.8

Monthly data analysis for only three months (September, October and December) revealed that December had the highest average TSP concentration (151.2 µg m^{-3}), while September recorded the lowest (19.8 µg m^{-3}) (Figure A4-73). Among the seasonal averages, only the Post-monsoon season was analyzed, with an average TSP concentration of 53.5 µg m^{-3} (Figure A4-76).

2.3 BAGAMATI PROVINCE

2.3.1 Bhaisepati Air Quality Monitoring Station

Bhaisepati AQMS was established in 2017 at Bhaisepati of Lalitpur Metropolitan city, Bagamati Province. This station is located in the compound of Bhaisepati residential area office at Lalitpur. This station represents the urban residential area. Emission from vehicles may be considered as major sources of pollution in the area.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 73.2 ± 40.9 µg m^{-3} (Table 15). Out of the total 117 days of available daily average data, 91 days exceeded the NAAQS (Figure A4-91). Most of those exceedances occurred during January to May, which can also be visualized in the calendar plot (Figure A4-103).

Table 15: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Bhaisepati Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	3.7	37.2	59.7	70.3 ± 47.0	91.4	244.5
Daily	8.4	42.9	67.1	73.2 ± 40.9	100.5	171.4

Monthly data analysis for three months (February, May and June) revealed that May had the highest average $PM_{2.5}$ concentration (123.6 µg m^{-3}), while June recorded the lowest (41.8 µg m^{-3}) (Figure A4-97). Among the seasonal averages, only the Winter season was analyzed, with an average $PM_{2.5}$ concentration of 57.7 µg m^{-3} (Figure A4-100).

PM_{10}

The mean of daily average PM_{10} concentration was 121.0 ± 64.7 µg m^{-3} (Table 16). Out of the total 117 days of available daily average data, 59 days exceeded the NAAQS (Figure A4-92). Most of those exceedances occurred during February and May.

Table 16: Summary of PM_{10} (µg m^{-3}) Concentration for Bhaisepati Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	5.2	64.5	107.2	122.4 ± 81.9	166.2	666.6
Daily	10.9	76.4	121.7	121.0 ± 64.7	156.8	300.6

Monthly data analysis for three months (February, May and June) revealed that May had the highest average PM_{10} concentration (178.4 µg m^{-3}), while June recorded the lowest (70.1 µg m^{-3}) (Figure A4-98). Among the seasonal averages, only the Winter season was analyzed, with an average PM_{10} concentration of 96.9 µg m^{-3} (Figure A4-101).

TSP

The mean of daily average TSP concentration was 222.8 ± 114.9 µg m^{-3} (Table 17). Out of the total 113 days of available daily average data, 96 days exceeded the NAAQS (Figure A4-93). Most of those exceedances occurred during January to June.

Table 17: Summary of TSP (µg m^{-3}) Concentration for Bhaisepati Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	6.1	85.1	187.3	231.2 ± 182.0	332.6	944.3
Daily	13.5	152.5	223.3	222.8 ± 114.9	271.4	541.8

Monthly data analysis for three months (February, May and June) revealed that May had the highest average TSP concentration (288.8 µg m^{-3}), while June recorded the lowest (157.0 µg m^{-3}) (Figure A4-99). Among the seasonal averages, only the Winter season was analyzed, with an average TSP concentration of 172.1 µg m^{-3} (Figure A4-102).

2.3.2 Bhaktapur Air Quality Monitoring Station

Bhaktapur AQMS was established in 2016 at Sainik Awasiya Mahavidyalaya, Bhaktapur Municipality, Bagamati Province. This station represents the urban area. Emission from nearby industries specially form brick industries, vehicles may be major sources of pollution in the area.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 49.6 ± 14.9 µg m^{-3} (Table 18). Out of the total 231 days of available daily average data, 169 days exceeded the NAAQS (Figure A4-113). Most of those exceedances occurred during February to March and November to December, which can also be visualized in the calendar plot (Figure A4-121).

Table 18 : Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Bhaktapur Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	2.5	25.3	42.6	45.9 ± 26.4	62.5	243.8
Daily	15.3	39.0	49.3	49.6 ± 14.9	58.5	90.4

Monthly data analysis for eight months (February, March, April, May, June, October, November and December) revealed that April had the highest average $PM_{2.5}$ concentration (63.7 µg m^{-3}), while October recorded the lowest (36.4 µg m^{-3}) (Figure A4-117). Among the two seasons with available seasonal averages, the Pre-monsoon season exhibited the highest average $PM_{2.5}$ concentrations (54.0µg m^{-3}), while the Post-monsoon season had the lowest seasonal average (43.4 µg m^{-3}) (Figure A4-119).

PM_{10}

The mean of daily average PM_{10} concentration was 69.4 ± 25.1 µg m^{-3} (Table 19). Out of the total 231 days of available daily average data, 6 days exceeded the NAAQS (Figure A4-114). All of those exceedances occurred during April.

Table 19: Summary of PM_{10} (µg m^{-3}) Concentration for Bhaktapur Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	3.3	36.5	57.9	64.3 ± 39.4	83.9	378.1
Daily	21.3	52.1	64.7	69.4 ± 25.1	82.0	202.7

Monthly data analysis for eight months (February, March, April, May, June, October, November and December) revealed that April had the highest average PM_{10} concentration (97.7 µg m^{-3}), while October recorded the lowest (51.5 µg m^{-3}) (Figure A4-118). Among the two seasons with available seasonal averages, the Pre-monsoon season exhibited the highest average PM_{10} concentration (79.2 µg m^{-3}), while the Post-monsoon season had the lowest seasonal average (56.8 µg m^{-3}) (Figure A4-120).

2.3.3 Bharatpur Air Quality Monitoring Station

Bharatpur AQMS was established in 2017 in the premises of District Administration Office, Bharatpur, Chitwan, Bagamati Province. This station represents the urban area. Emission from vehicles may be considered as major sources of pollution in the area.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 35.5 ± 27.6 µg m^{-3} (Table 20). Out of the total 256 days of available daily average data, 92 days exceeded the NAAQS (Figure A4-135). The majority of those exceedances occurred during April, November and December which can also be visualized in the calendar plot (Figure A4-147).

Table 20: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Bharatpur Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.5	11.7	25.6	35.3 ± 32.2	46.5	269.3
Daily	4.5	11.8	26.7	35.5 ± 27.6	49.9	123.6

Monthly data analysis for nine months (April to December) revealed that April had the highest average $PM_{2.5}$ concentrations (92.9 µg m^{-3}), while July and August recorded the lowest (10.1µg m^{-3}) (Figure A4-141). Among the three seasons with available seasonal averages (Pre-monsoon, Monsoon and Post-Monsoon), the Pre-monsoon season exhibited the highest average $PM_{2.5}$ concentrations (59.4 µg m^{-3}), while the Monsoon season had the lowest seasonal average (14.6 µg m^{-3}) (Figure A4-144).

PM_{10}

The mean of daily average PM_{10} concentration was 73.5 ± 79.9 µg m^{-3} (Table 21). Out of the total 256 days of available daily average data, 25 days exceeded the NAAQS (Figure A4-136). The majority of those exceedances occurred during April.

Table 21: Summary of PM_{10} (µg m^{-3}) Concentration for Bharatpur Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	2.6	20.6	46.7	73.3 ± 86.9	82.9	710.9
Daily	7.8	22.1	53.3	73.5 ± 79.9	82.5	367.2

Monthly data analysis for eight months (May to December) revealed that May had the highest average PM_{10} concentration (121.3 µg m^{-3}), while July recorded the lowest (17.8 µg m^{-3}) (Figure A4-142). Among the two seasons with available seasonal averages, the Post-monsoon season exhibited the highest average PM_{10} concentration (60.4 µg m^{-3}), while the Monsoon season had the lowest seasonal average (27.6 µg m^{-3}) (Figure A4-145.

TSP

The mean of daily average TSP concentration was 107.5 ± 94.1 µg m^{-3} (Table 22). Out of the total 242 days of available daily average data, 73 days exceeded the NAAQS (Figure A4-137). Those exceedances occurred during April, May, June, November and December.

Table 22: Summary of TSP (µg m^{-3}) Concentration for Bharatpur Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	2.9	34.8	74.6	118.9 ± 128.8	144.7	882.3
Daily	10.8	48.7	90.9	107.5 ± 94.1	128.4	564.6

Monthly data analysis for eight months (May to December) revealed that May had the highest average TSP concentration (209.0 µg m^{-3}), while July recorded the lowest (39.8 µg m^{-3}) (Figure A4-143). Among the two seasons with available seasonal averages, the Post-monsoon season exhibited the highest average TSP concentration (94.2 µg m^{-3}), while the Monsoon season had the lowest seasonal average (61.5 µg m^{-3}) (Figure A4-146).

2.3.4 Hetauda Air Quality Monitoring Station

Hetauda AQMS was established in 2020 at Hetauda submetropolitan city in Makawanpur district, Bagamati Province. This station is located adjacent to the office of ward number 4, on the football ground at Hupra chaur by the side of the road. This station represents the urban area.

Emission from vehicles and industries may be main sources of pollution in the area surrounding the station. Dust form the nearby football ground may also contribute to the particulate matter measured at this site.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 15.0 ± 15.2 µg m^{-3} (Table 23). Out of the total 171 days of available daily average data, 15 days in April exceeded the NAAQS (Figure A4-161), which can also be visualized in the calendar plot (Figure A4-173).

Table 23: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Hetauda Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.1	3.5	7.0	13.9 ± 17.4	15.9	156.2
Daily	1.4	4.7	8.0	15.0 ± 15.2	23.5	80.1

Monthly data analysis for five months (April, May, June, October and November) revealed that April had the highest average $PM_{2.5}$ concentrations (41.3 µg m^{-3}), while October recorded the lowest (5.1 µg m^{-3}) (Figure A4-167). Among the two seasons with available seasonal averages, the Pre-monsoon season exhibited the highest average $PM_{2.5}$ concentrations (26.9 µg m^{-3}), while the Post-monsoon season had the lowest seasonal average (6.8µg m^{-3}) (Figure A4-170).

PM_{10}

The mean of daily average PM_{10} concentration was 24.9 ± 30.7 µg m^{-3} (Table 24).

Table 24: Summary of PM_{10} (µg m^{-3}) Concentration for Hetauda Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.1	3.9	8.1	22.8 ± 37.1	24.6	385.5
Daily	1.5	5.4	9.9	24.9 ± 30.7	32.0	120.6

Monthly data analysis for five months (April, May, June, October and November) revealed that April had the highest average PM_{10} concentration (77.5 µg m^{-3}), while October recorded the lowest (5.5 µg m^{-3}) (Figure A4-168). Among the two seasons with available seasonal averages, the Pre-monsoon season exhibited the highest average PM_{10} concentration (51.1 µg m^{-3}), while the Post-monsoon season had the lowest seasonal average (7.2 µg m^{-3}) (Figure A4-171).

TSP

The mean of daily average TSP concentration was 50.1 ± 66.0 µg m^{-3} (Table 25). Out of the total 170 days of available daily average data, 34 days exceeded the NAAQS (Figure A4-163). The majority of those exceedances occurred during April.

Table 25: Summary of TSP (µg m^{-3}) Concentration for Hetauda Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.1	4.3	10.0	44.5 ± 78.7	44.5	633.4
Daily	1.5	6.9	14.1	50.1 ± 66.0	56.9	248.3

Monthly data analysis for five months (April, May, June, October and November) revealed that April had the highest average TSP concentration (170.9 µg m^{-3}), while October recorded the lowest (6.9 µg m^{-3}) (Figure A4-169). Among the two seasons with available seasonal averages, the Pre-monsoon season exhibited the highest average TSP concentration (110.7 µg m^{-3}), while the Post-monsoon season had the lowest seasonal average (9.1 µg m^{-3}) (Figure A4-172).

2.3.5 Khumaltar Air Quality Monitoring Station

Khumaltar AQMS was established in 2022 at Lalitpur Municipality in Lalitpur district, Bagamati Province. It is located on the rooftop of ICIMOD's building and it represents the urban area. Emissions from vehicles, residential emission and road dust suspension may be main source of pollution in this area. Occasional construction activities around the area also contribute to the particulate matter measured by this station.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 43.5 ± 26.8 µg m^{-3} (Table 26). Out of the total 351 days of available daily average data, 194 days exceeded the NAAQS (Figure A4-187). The majority of those exceedances occurred during January to April and November to December which can also be visualized in the calendar plot (Figure A4-198).

Table 26: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Khumaltar Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.0	15.8	38.3	43.7 ± 31.5	64.5	210.7
Daily	4.6	15.6	44.6	43.5 ± 26.8	65.5	110.7

Monthly data analysis for all twelve months revealed that April had the highest average $PM_{2.5}$ concentrations (78.6 µg m^{-3}), while August recorded the lowest (9.8 µg m^{-3}) (Figure A4-192). In terms of seasonal averages, the Pre-monsoon season exhibited the highest average $PM_{2.5}$ concentrations (63.0 µg m^{-3}), whereas the Monsoon season had the lowest seasonal average (16.2 µg m^{-3}) (Figure A4-195).

PM_{10}

The mean of daily average PM_{10} concentration was 79.5 ± 57.4 µg m^{-3} (Table 27). Out of the total 351 days of available daily average data, 71 days exceeded the NAAQS (Figure A4-188). The majority of those exceedances occurred during April.

Table 27: Summary of PM_{10} (µg m^{-3}) Concentration for Khumaltar Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.4	25.5	67.9	80.1 ± 66.6	111.2	481.5
Daily	6.6	24.3	75.5	79.5 ± 57.4	113.3	280.4

Monthly data analysis for all twelve months revealed that April had the highest average PM_{10} concentration (191.0 µg m^{-3}), while August recorded the lowest (15.0 µg m^{-3}) (Figure A4-193). In terms of seasonal averages, the Pre-monsoon season exhibited the highest average PM_{10} concentration (135.8 µg m^{-3}), whereas the Monsoon season had the lowest seasonal average (27.6 µg m^{-3}) (Figure A4-196).

Ozone (O_3)

For this station daily average data for O_3 are available for 328 days in 2025. The mean of daily average O_3 concentration was 29.2±12.2 ppb (Table 28). Similarly, eight hour running average ranges from 1.8 ppb to 98.1 ppb while daily maximum of eight our running average ranges from 6.5 ppb to 98.1 ppb.

Table 28: Summary of O_3 (ppb) Concentration for Khumaltar Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	0.1	14.1	24.6	29.2±19.7	41.1	114.9
Daily	5.1	20.6	25.8	29.2±12.2	37.5	62.7
Eight hour running	1.8	16.7	25.8	29.2±17.0	39.3	98.1
Daily maximum of eight hour running	6.5	31.7	43.1	44.5±18.5	54.1	98.1

Monthly data analysis revealed that among the 11 months with available monthly mean (all months except February), April had the highest average O_3 concentrations (52.3 ppb), while July recorded the lowest (15.3 ppb) (Figure A4-194). In terms of seasonal averages, Pre-monsoon season exhibited the highest average O_3 concentrations (43.2 ppb), while the Winter season had the lowest seasonal average (22.2 ppb) (Figure A4-197). The NAAQS for O_3 is 157 µg/m³ based on an 8-hour average. However, since our dataset reports O_3 concentrations in parts per billion (ppb), a direct comparison with the NAAQS requires unit conversion. At normal temperature and pressure (25°C and 1 atm), 157 µg/m³ of O_3 is approximately equivalent to 80 ppb. Therefore, 80 ppb has been used as the threshold for comparison. Out of 328 days with valid data, the daily maximum 8-hour average O_3 concentration exceeded 80 ppb on 20 days.

2.3.6 Pulchowk Air Quality Monitoring Station

Pulchowk AQMS was established in 2016 at roof top of Pulchowk Engineering college building, Pulchowk, Lalitpur. This station represents the urban area and most of the pollution measured by this station might be road dust and other local pollution.

Ozone (O_3)

For this station, only O_3 data were analyzed. The data from September 2023 to May 2024 were found compatible for the analysis. The daily average data for O_3 were available for 269 days in this period.

The mean of daily average O_3 concentration was 18.3 ± 7.0 ppb (Table 29). Similarly, eight hour running average ranges from 0.8 ppb to 60.5 ppb while daily maximum of eight our running average ranges from 3.3 ppb to 60.5 ppb.

Table 29: Summary of O_3 (ppb) Concentration for Pulchowk Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	0.3	7.0	14.6	18.3 ±14.0	27.1	70.0
Daily	2.0	13.8	18.5	18.3 ± 7.0	22.5	36.0
Eight hour running	0.8	9.2	16.3	18.3 ±11.4	25.8	60.5
Daily maximum of eight hour running	3.3	24.8	32.3	31.9±10.9	38.2	60.5

Monthly data analysis for nine months (September 2023 to May 2024) revealed March 2024 had the highest average O_3 concentrations (25.1 ppb), while December 2023 recorded the lowest monthly average (9.6 ppb) (Figure A4-207). Among the three seasons with available seasonal averages (Post-Monsoon of 2023, Winter and Pre-Monsoon of 2024), the Pre-monsoon season exhibited the highest average O_3 concentrations (23.1 ppb), while the Winter season had the lowest seasonal average (13.6 ppb) (Figure A4-208).

2.3.7 Ratnapark Air Quality Monitoring Station

Ratnapark AQMS was established in 2016 at Shankhadhar Park near Rani Pokhari. This station is situated at the center of Kathmandu and represents the urban area. Emission from vehicles may be major source of pollution in the area. Particle re-suspension and solid waste burning are other contributing sources of air pollution in the winter season. Regional haze is a common problem in this location. In the pre-monsoon season pollution from forest fires in different parts of the country becomes one of the major sources of pollution.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 59.2 ± 30.4 µg m^{-3} (Table 30). Out of the total 268 days of available daily average data, 179 days exceeded the NAAQS (Figure A4-221). The majority of those exceedances occurred during January to April and November to December which can also be visualized in the calendar plot (Figure A4-233).

Table 30: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Ratnapark Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	2.0	26.9	54.8	59.0 ± 36.9	86.1	277.2
Daily	3.4	30.9	66.2	59.2 ± 30.4	83.9	115.8

Monthly data analysis for nine months (January, February, March, April, May, June, October, November and December) revealed that January had the highest average $PM_{2.5}$ concentrations (85.0 µg m^{-3}), while June recorded the lowest (14.5 µg m^{-3}) (Figure A4-227). Among the three seasons with available seasonal averages (Winter, Pre-monsoon and Post-monsoon), the Winter season exhibited the highest average $PM_{2.5}$ concentration (85.0 µg m^{-3}), while the Post-monsoon season had the lowest seasonal average (45.1 µg m^{-3}) (Figure A4-230).

PM_{10}

The mean of daily average PM_{10} concentration was 99.5 ± 53.9 µg m^{-3} (Table 31). Out of the total 269 days of available daily average data, 119 days exceeded the NAAQS (Figure A4-222). The majority of those exceedances occurred during January to April and December.

Table 31: Summary of PM_{10} (µg m^{-3}) Concentration for Ratnapark Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	2.0	50.5	97.2	99.1 ± 62.4	139.7	398.7
Daily	3.4	54.7	112.2	99.5 ± 53.9	142.3	208.1

Monthly data analysis of nine months (January, February, March, April, May, June, October, November and December) revealed that April had the highest average PM_{10} concentrations (161.2 µg m^{-3}), while June recorded the lowest (15.2 µg m^{-3}) (Figure A4-228). Among the three seasons with available seasonal averages (Winter, Pre-monsoon and Post-monsoon), the Winter season exhibited the highest average PM_{10} concentration (122.4 µg m^{-3}), while the Post-monsoon season had the lowest seasonal average (76.8 µg m^{-3}) (Figure A4-231).

TSP

The mean of daily average TSP concentration was 104.3 ± 69.9 µg m^{-3} (Table 32). A total of 137 days of daily average data were available.

Table 32: Summary of TSP (µg m^{-3}) Concentration for Ratnapark Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	2.0	20.5	91.6	104.2 ± 87.4	162.4	462.0
Daily	3.5	19.4	120.2	104.3 ± 69.9	163.8	233.9

Monthly data analysis of four months (June, October, November and December) revealed that December had the highest average TSP concentrations (177.7 µg m^{-3}), while June recorded the lowest (16.0 µg m^{-3}) (Figure A4-229). Among the seasonal averages, only the Post-monsoon season was analyzed, with an average TSP concentration of 137.2 µg m^{-3} (Figure A4-232).

2.3.8 Shankhapark Air Quality Monitoring Station

Shankhapark AQMS was established in the year 2017 at Shankhapark near Ring road in Kathmandu. It represents the urban area. Emissions from vehicles and re-suspended dust from roads along with solid waste burning may be main source of pollution in the area. In Pre-monsoon season, pollution from forest fires in different parts of the country becomes one of the major sources of pollution.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 39.4 ± 22.4 µg m^{-3} (Table 33). Out of the total 296 days of available daily average data, 134 days exceeded the NAAQS (Figure A4-247). Most of

those exceedances occurred during January to April which can also be visualized in the calendar plot (Figure A4-259).

Table 33: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Shankhapark Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.7	18.1	34.7	39.4 ± 25.6	55.3	191.4
Daily	8.1	18.8	36.3	39.4 ± 22.4	56.6	104.8

Monthly data analysis of ten months (all months except September and December) revealed that April had the highest average $PM_{2.5}$ concentrations (75.3 µg m^{-3}), while August recorded the lowest (12.7 µg m^{-3}) (Figure A4-253). Winter season exhibited the highest average $PM_{2.5}$ concentrations (56.8 µg m^{-3}), while the Monsoon season had the lowest seasonal average (19.7 µg m^{-3}) (Figure A4-256).

PM_{10}

The mean of daily average PM_{10} concentration was 85.0 ± 69.9 µg m^{-3} (Table 34). Out of the total 296 days of available daily average data, 65 days exceeded the NAAQS (Figure A4-248). Those exceedances occurred during January to June.

Table 34: Summary of PM_{10} (µg m^{-3}) Concentration for Shankhapark Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.8	27.2	63.3	84.8 ± 78.3	114.5	587.9
Daily	10.0	27.1	67.6	85.0 ± 69.9	115.9	358.7

Monthly data analysis of ten months (all months except September and December) revealed that April had the highest average PM_{10} concentrations (249.9 µg m^{-3}), while August recorded the lowest (20.5 µg m^{-3}) (Figure A4-254). Pre-monsoon season exhibited the highest average PM_{10} concentrations (149.6 µg m^{-3}), while the Monsoon season had the lowest seasonal average (38.2 µg m^{-3}) (Figure A4-257).

TSP

The mean of daily average TSP concentration was 210.8 ± 190.1 µg m^{-3} (Table 35). Out of the total 295 days of available daily average data, 119 days exceeded the NAAQS (Figure A4-249). The majority of those exceedances occurred during January to June.

Table 35: Summary of TSP (µg m^{-3}) Concentration for Shankhapark Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.8	38.3	110.0	212.2 ± 247	300.5	1497.8
Daily	10.1	59.2	152.2	210.8 ± 190.1	302.3	901.3

Monthly data analysis of ten months (all months except September and December) with available monthly mean revealed that April had the highest average TSP concentrations (674.8 µg m^{-3}), while November recorded the lowest (43.6 µg m^{-3}) (Figure A4-255). Pre-monsoon season exhibited

the highest average TSP concentrations (393.0 µg m^{-3}), while the Post-monsoon season had the lowest seasonal average (79.2 µg m^{-3}) (Figure A4-258).

2.3.9 TU Kirtipur Air Quality Monitoring Station

TU Kirtipur AQMS was established in the year 2016. It lies inside the premises of Tribhuvan university near the Department of Hydrology and Metrology (DHM) weather station in Kirtipur, Kathmandu. Being situated within the university premises, there is relatively low traffic in the immediate vicinity of the station. However, the ring road is nearby, within a distance of less than 1 kilometer. The station is positioned on the eastern side of Kirtipur municipality, with Kathmandu Metropolitan City lying to the east, signifying its urban setting. Emissions from the vehicles may be main source of pollution in the area. Besides emission from industries and solid waste burning may be other sources of pollution. Sometimes pollution from other parts of the country enters the city. In Pre-monsoon season pollution from forest fire in different parts of the country become one of the major source of pollution.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 53.4 ± 17.4 µg m^{-3} (Table 36). Out of the total 133 days of available daily average data, 112 days exceeded the NAAQS (Figure A4-273). Those exceedances occurred during January to May which can also be visualized in the calendar plot (Figure A4-285).

Table 36: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for TU Kirtipur Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.2	34.5	52.4	52.5 ± 24.6	69.3	152.1
Daily	4.4	44.0	54.7	53.4 ± 17.4	66.2	98.3

Monthly data analysis of four months (January to April) revealed that April had the highest average $PM_{2.5}$ concentrations (66.3 µg m^{-3}), while March recorded the lowest (50.2 µg m^{-3}) (Figure A4-279). Among the two seasons with available seasonal averages, the Pre-monsoon season exhibited the highest average $PM_{2.5}$ concentration (55.8 µg m^{-3}), while the Winter season had the lowest seasonal average (55.1 µg m^{-3}) (Figure A4-282).

PM_{10}

The mean of daily average PM_{10} concentration was 89.6 ± 37.3 µg m^{-3} (Table 37). Out of the total 133 days of available daily average data, 26 days exceeded the NAAQS (Figure A4-274). Those exceedances occurred during February to May.

Table 37: Summary of PM_{10} (µg m^{-3}) Concentration for TU Kirtipur Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.2	57.6	81.2	88.4 ± 48.0	113.0	287.5
Daily	6.5	68.9	84.4	89.6 ± 37.3	105.3	175.8

Monthly data analysis of four months (January to April) revealed that April had the highest average PM_{10} concentrations (137.7 µg m^{-3}), while March recorded the lowest (77.1 µg m^{-3}) (Figure A4-280). Among the two seasons with available seasonal averages, the Pre-monsoon season exhibited the highest average PM_{10} concentration (103.6 µg m^{-3}), while the Winter season had the lowest seasonal average (80.8 µg m^{-3}) (Figure A4-283).

TSP

The mean of daily average TSP concentration was 168.8 ± 96.2 µg m^{-3} (Table 38). Out of the total 133 days of available daily average data, 27 days exceeded the NAAQS (Figure A4-275). Those exceedances occurred during February to May.

Table 38: Summary of TSP (µg m^{-3}) Concentration for TU Kirtipur Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.2	72.7	135.2	167.8 ± 125.1	236.3	1093.6
Daily	13.7	114.8	145.7	168.8 ± 96.2	185.4	616.1

Monthly data analysis of four months (January to April) revealed that April had the highest average TSP concentrations (297.8 µg m^{-3}), while March recorded the lowest (132.2 µg m^{-3}) (Figure A4-281). Among the two seasons with available seasonal averages, the Pre-monsoon season exhibited the highest average TSP concentration (210.3 µg m^{-3}), while the Winter season had the lowest seasonal average (132.7 µg m^{-3}) (Figure A4-284).

2.4 LUMBINI PROVINCE

2.4.1 Deukhuri Dang Air Quality Monitoring Station

Deukhuri AQMS was established in 2024 at Masuriya, Deukhari Dang of Rapti Rural Municipality, Lumbini Province. This station is located inside the compound of Rapti Rural Municipality office at Dang. It represents air quality of semi urban area. The local air quality may be influenced by emission from vehicles, residential buildings, forest fires. The air quality may be also influenced by transboundary air pollution. The station was installed at June 2024.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 33.1 ± 26.7 µg m^{-3} (Table 39). Out of total 125 days of available daily average data, 42 days exceeded the NAAQS (Figure A4-299). Those exceedances occurred during October to December which can also be visualized in the calendar plot (Figure A4-311).

Table 39: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Deukhuri Dang Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.1	9.1	19.7	32.9 ± 34.5	45.1	476.5
Daily	3.5	10.6	20.4	33.1 ± 26.7	57.6	94.4

Monthly data analysis of four months (July, August, October and December) revealed that December had the highest average $PM_{2.5}$ concentrations (70.0 µg m^{-3}), while August recorded the lowest (10.5 µg m^{-3}) (Figure A4-305). Among the two seasons with available seasonal averages, the Post-monsoon season exhibited the highest average $PM_{2.5}$ concentration (46.0 µg m^{-3}), while the Monsoon season had the lowest seasonal average (12.0µg m^{-3}) (Figure A4-308).

PM_{10}

The mean of daily average PM_{10} concentration was 45.6 ± 34.8 µg m^{-3} (Table 40). Out of total 125 days of available daily average data, none of the days exceeded the NAAQS (Figure A4-300).

Table 40: Summary of PM_{10} (µg m^{-3}) Concentration for Deukhuri Dang Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.4	13.8	30.4	45.6 ± 43.9	66.8	642.8
Daily	4.6	15.5	31.7	45.6 ± 34.8	78.4	115.7

Monthly data analysis of four months (July, August, October and December) revealed that December had the highest average PM_{10} concentration (89.9 µg m^{-3}), while August recorded the lowest (15.3 µg m^{-3}) (Figure A4-306). Among the two seasons with available seasonal averages, the Post-monsoon season exhibited the highest average PM_{10} concentration (66.8 µg m^{-3}), while the Monsoon season had the lowest seasonal average (17.7 µg m^{-3}) (Figure A4-309).

TSP

The mean of daily average TSP concentration was 60.8 ± 43.6 µg m^{-3} (Table 41). Out of the total 125 days of available daily average data, none of the days exceeded the NAAQS (Figure A4-301).

Table 41: Summary of TSP (µg m^{-3}) Concentration for Deukhuri Dang Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.8	19.9	38.6	60.2 ± 56.1	84.8	651.1
Daily	5.8	23.6	45.9	60.8 ± 43.6	104.9	148.9

Monthly data analysis of four months (July, August, October and December) revealed that December had the highest average TSP concentration (115.1 µg m^{-3}), while August recorded the lowest (22.1 µg m^{-3}) (Figure A4-307). Among the two seasons with available seasonal averages, the Post-monsoon season exhibited the highest average TSP concentration (88.5 µg m^{-3}), while the Monsoon season had the lowest seasonal average (25.0 µg m^{-3}) (Figure A4-310).

2.5 KARNALI PROVINCE

2.5.1 Rara Air Quality Monitoring Station

Inside the premises of Rara National Park, the Rara AQMS was established in the year 2020. It lies in Mugu district of Karnali Province. This station represents air quality of high mountain (also stated as background AQMS). The local air quality might be influenced by regional haze, regional fire and local emission activities.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 19.8 ± 21.2 µg m^{-3} (Table 42). Out of the total 257 days of available daily average data, 31 days exceeded the NAAQS (Figure A4-325). Those exceedances occurred during April to June which can also be visualized in the calendar plot (Figure A4-337).

Table 42: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Rara Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.3	6.1	11.6	19.1 ± 22.5	22.7	197.2
Daily	2.3	7.2	12.9	19.8 ± 21.2	23.1	154.7

Monthly data analysis of eight months (January, February, March, April, May, June, October and November) revealed that April had the highest average $PM_{2.5}$ concentrations (50.1 µg m^{-3}), while October recorded the lowest (8.7 µg m^{-3}) (Figure A4-331). Among the three seasons with available seasonal averages (Winter, Pre-monsoon and Post- monsoon), the Pre-monsoon season exhibited the highest average $PM_{2.5}$ concentration (33.1 µg m^{-3}), while the Post-monsoon season had the lowest seasonal average (8.7 µg m^{-3}) (Figure A4-334).

PM_{10}

The mean of daily average PM_{10} concentration was 26.4 ± 27.8 µg m^{-3} (Table 43). Out of the total 257 days of available daily average data, 4 days in December exceeded the NAAQS (Figure A4-326).

Table 43: Summary of PM_{10} (µg m^{-3}) Concentration for Rara Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.4	7.5	14.7	25.5 ± 29.6	31.1	232.1
Daily	2.6	9.0	17.1	26.4 ± 27.8	32.0	180.5

Monthly data analysis of eight months (January, February, March, April, May, June, October and November) revealed that April had the highest average PM_{10} concentrations (65.4 µg m^{-3}), while October recorded the lowest (9.6 µg m^{-3}) (Figure A4-332). Among the three seasons with available seasonal averages (Winter, Pre-monsoon and Post- monsoon), the Pre-monsoon season exhibited the highest average PM_{10} concentration (43.7 µg m^{-3}), while the Post-monsoon season had the lowest seasonal average (9.9µg m^{-3}) (Figure A4-335).

TSP

The mean of daily average TSP concentration was 42.3 ± 45.8 µg m^{-3} (Table 44). Out of the total 257 days of available daily average data, all days meet the NAAQS (Figure A4-327).

Table 44: Summary of TSP (µg m^{-3}) Concentration for Rara Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.4	8.8	19.7	40.9 ± 53.1	48.8	652.1
Daily	2.6	11.1	27.0	42.3 ± 45.8	51.4	228.9

Monthly data analysis of eight months January, February, March, April, May, June, October and November) revealed that April had the highest average TSP concentrations (108.0 µg m^{-3}), while October recorded the lowest (11.0 µg m^{-3}) (Figure A4-333). Among the three seasons with available seasonal averages (Winter, Pre-monsoon and Post- monsoon), the Pre-monsoon season exhibited the highest average TSP concentration (70.8 µg m^{-3}), while the Post-monsoon season had the lowest seasonal average (11.6 µg m^{-3}) (Figure A4-336).

2.6 SUDURPASHCHIM PROVINCE

2.6.1 Achham Air Quality Monitoring Station

Achham AQMS was established in the year 2024. It lies at Oli Gaun of Mangalsen municipality in Achham district of Sudurpashchim Province. This station represents air quality of mountain (also stated as background AQMS). As the station is situated in a rural area, the primary sources of air pollution include pollutants transported from surrounding areas particularly emissions from forest fire during forest fire seasons.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 14.5 ± 11.9 µg m^{-3} (Table 45). Out of the total 112 days of available daily average data, 8 days in October and November exceeded the NAAQS (Figure A4-351). Those exceedances occurred during October and November which can also be visualized in the calendar plot (Figure A4-363).

Table 45: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Achham Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	0.5	5.9	10.8	14.8 ± 12.6	19.5	72.9
Daily	2.5	6.8	9.3	14.5 ± 11.9	19.9	56.6

Monthly data analysis of four months (July to October) revealed that October had the highest average $PM_{2.5}$ concentration (29.2 µg m^{-3}), while September recorded the lowest (7.0 µg m^{-3}) (Figure A4-357). Among the two seasons with available seasonal averages, the Post-monsoon season exhibited the highest average $PM_{2.5}$ concentration (29.7 µg m^{-3}), while the Monsoon season had the lowest seasonal average (7.8 µg m^{-3}) (Figure A4-360).

PM_{10}

The mean of daily average PM_{10} concentration was 19.5 ± 15.3 µg m^{-3} (Table 46). Out of the total 112 days of available daily average data, and none of the days exceeded the NAAQS (Figure A4-352).

Table 46: Summary of PM_{10} (µg m^{-3}) Concentration for Achham Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.4	8.5	14.7	19.9 ± 16.3	25.8	95.9
Daily	3.3	9.8	12.7	19.5 ± 15.3	26.4	74.5

Monthly data analysis of four months (July to October) revealed that October had the highest average PM_{10} concentration (38.4 µg m^{-3}), while September recorded the lowest (9.5 µg m^{-3}) (Figure A4-358). Among the two seasons with available seasonal averages, the Post-monsoon season exhibited the highest average PM_{10} concentration (38.7 µg m^{-3}), while the Monsoon season had the lowest seasonal average (11.5 µg m^{-3}) (Figure A4-361).

TSP

The mean of daily average TSP concentration was 29.6 ± 23.1 µg m^{-3} (Table 47). Out of the total 112 days of available daily average data and none of the days exceeded the NAAQS (Figure A4-353).

Table 47: Summary of TSP (µg m^{-3}) Concentration for Achham Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.2	11.4	20.9	30.7 ± 33.5	36.7	442.0
Daily	4.4	14.2	20.3	29.6 ± 23.1	35.2	103.0

Monthly data analysis of four months (July to October) revealed that October had the highest average TSP concentration (54.4 µg m^{-3}), while August recorded the lowest (14.0 µg m^{-3}) (Figure A4-359). Among the two seasons with available seasonal averages, the Post-monsoon season exhibited the highest average TSP concentration (59.4 µg m^{-3}), while the Monsoon season had the lowest seasonal average (17.3 µg m^{-3}) (Figure A4-362).

2.6.2 Mahendranagar Air Quality Monitoring Station

Mahendranagar AQMS was established in the year 2018 in the premises of municipality administration office of Bhimdatta municipality, Sudurpashchim Province. It represents the urban area. The main sources of pollution in this region may be residential emission, vehicles and industries. Agriculture residue burning and transboundary air pollution may also affect air quality in this station.

$PM_{2.5}$

The mean of daily average $PM_{2.5}$ concentration was 36.8 ± 27.6 µg m^{-3} (Table 48). Out of the total 190 days of available daily average data, 73 days exceeded the NAAQS (Figure A4-377). Those exceedances occurred during January to May which can also be visualized in the calendar plot (Figure A4-389).

Table 48: Summary of $PM_{2.5}$ (µg m^{-3}) Concentration for Mahendranagar Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.4	9.4	24.1	34.7 ± 32.1	51.5	182.0
Daily	2.7	12.9	32.1	36.8 ± 27.6	52.0	104.7

Monthly data analysis of seven months (January, February, March, May, June, July and August) revealed that January had the highest average $PM_{2.5}$ concentrations (81.2 µg m^{-3}), while August recorded the lowest (5.2 µg m^{-3}) (Figure A4-383). Among the three seasons with available seasonal averages (Winter, Pre-monsoon and Monsoon), the Winter season exhibited the highest average $PM_{2.5}$ concentration (63.1 µg m^{-3}), while the Monsoon season had the lowest seasonal average (9.7 µg m^{-3}) (Figure A4-386).

PM_{10}

The mean of daily average PM_{10} concentration was 51.0 ± 31.9 µg m^{-3} (Table 49). The total of 190 days' daily average data was available for this station.

Table 49: Summary of PM_{10} (µg m^{-3}) Concentration for Mahendranagar Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.4	13.4	44.1	48.7 ± 39.3	69.4	342.1
Daily	3.0	22.2	53.3	51.0 ± 31.9	70.2	127.7

Monthly data analysis of seven months (January, February, March, May, June, July and August) revealed that January had the highest average PM_{10} concentrations (92.3 µg m^{-3}), while August recorded the lowest (6.2 µg m^{-3}) (Figure A4-384). Among the three seasons with available seasonal averages (Winter, Pre-monsoon and Monsoon), the Winter season exhibited the highest average PM_{10} concentration (78.0 µg m^{-3}), while the Monsoon season had the lowest seasonal average (18.7 µg m^{-3}) (Figure A4-387).

TSP

The mean of daily average TSP concentration was 86.4±51.7 µg m^{-3} (Table 50). Out of the total 190 days of available daily average data and none of the days exceeded the NAAQS (Figure A4-379).

Table 50: Summary of TSP (µg m^{-3}) Concentration for Mahendranagar Station

Averaging Period	Minimum	1st quartile	Median	Mean ± SD	3rd quartile	Maximum
Hourly	1.4	21.9	67.6	83.3 ± 80.6	119.5	1112.1
Daily	3.7	41.7	93.7	86.4±51.7	118.1	212.7

Monthly data analysis of seven months (January, February, March, May, June, July and August) revealed that January had the highest average TSP concentrations (112.1 µg m^{-3}), while August recorded the lowest (9.4 µg m^{-3}) (Figure A4-385). Among the three seasons with available seasonal averages (Winter, Pre-monsoon and Monsoon), the Pre-monsoon exhibited the highest average TSP concentration (107.4 µg m^{-3}), while the Monsoon season had the lowest seasonal average (41.8 µg m^{-3}) (Figure A4-388).

2.7 DIURNAL PATTERN OF POLLUTION

$PM_{2.5}$ and PM_{10} exhibit a bimodal diurnal pattern, with peaks typically observed during the morning and evening hours in most of the monitoring stations. This is a common pattern influenced by high vehicular traffic during these times, coupled with meteorological conditions. During the daytime, rising temperatures and increased wind speeds enhance the dispersion of pollutants, leading to lower concentrations. In contrast, cooler morning temperatures and atmospheric stability contribute to pollutant accumulation, resulting in elevated levels.

However, stations like Ilam (Figure A4-33 and A4-34) and Rara (Figure A4-318 and A4-319) displayed a different diurnal pattern. These are considered background stations with minimal local pollution sources. The pollution levels here are mainly influenced by regional transport of pollutants (e.g., long-range transport from other regions or countries), natural sources (e.g., dust), local meteorological conditions etc. As a result, their diurnal variation differs from that observed at more urbanized or traffic-influenced sites.

The diurnal pattern of TSP also deviated from that of $PM_{2.5}$ and PM_{10}. At many stations, TSP levels peak during the daytime, likely due to increased wind speeds that re-suspended larger particles from the ground.

The diurnal variation of ozone is quite different from that of particulate matter. Ozone is a secondary pollutant, formed through photochemical reactions involving precursors such as nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. Ozone (O_3), data from Pulchowk and Khumaltar stations show a similar diurnal trend. Ozone concentrations begin to rise sharply after 7 AM, peak around 11 AM at Khumaltar and 12 PM at Pulchowak, and then gradually decline throughout the afternoon. This pattern is influenced by both increased traffic emissions and sunlight, which drives the photochemical formation of ozone.

2.8 TREND OF ANNUAL AVERAGE OF $PM_{2.5}$ AT KATHMANDU

Data from the Ratnapark Station was used to train the MERRA-2 dataset within the Random Forest model, as described in the methodology. The predicted hourly concentrations from the Random Forest model were then used to calculate the annual average. Trend analysis was conducted for Kathmandu, as it has long-term air quality data available. Additionally, Kathmandu is the capital and the largest city of Nepal, making it a key location for such analysis. In contrast, other parts of the country lack long-term air quality data, making trend analysis in those areas challenging. The graph illustrates the annual average $PM_{2.5}$ concentration of eight years from 2017 to 2024, which showed significant fluctuations over the years. The $PM_{2.5}$ concentration seems to decrease from 2018 till 2020. The lowest concentration during 2020 was likely due to reduced human activity during the global COVID pandemic. The levels then increased again to 45.5 µg m^{-3} in 2023 and reached 49.0 µg m^{-3} in 2024, the highest in the period.

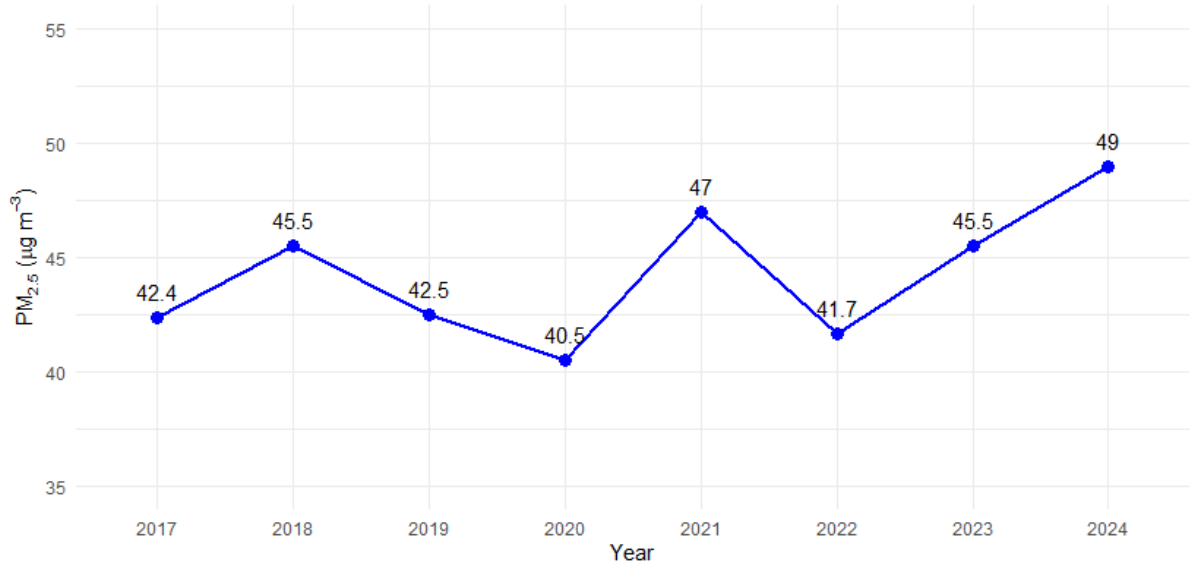


Figure 4: Annual Average of $PM_{2.5}$ at Ratnapark Station Over Years

2.9 REGIONAL LEVEL AIR POLLUTION OVER NEPAL

2.9.1 Meteotrological Factors Affecting Air pollution

Meteorological factors such as temperature, precipitation, wind direction, and wind speed significantly influence air quality. During winter, higher temperatures promote the dispersion of pollutants, thereby reducing local pollution levels. In contrast, high temperatures combined with low precipitation in the pre-monsoon season can increase the risk of forest fires, which in turn degrade air quality. Precipitation plays a vital role in cleansing the atmosphere by removing airborne pollutants, making it especially important during the winter and pre-monsoon seasons. Additionally, wind direction and wind speed are crucial for air quality, as they govern the long-range transport of pollutants from one region to another.

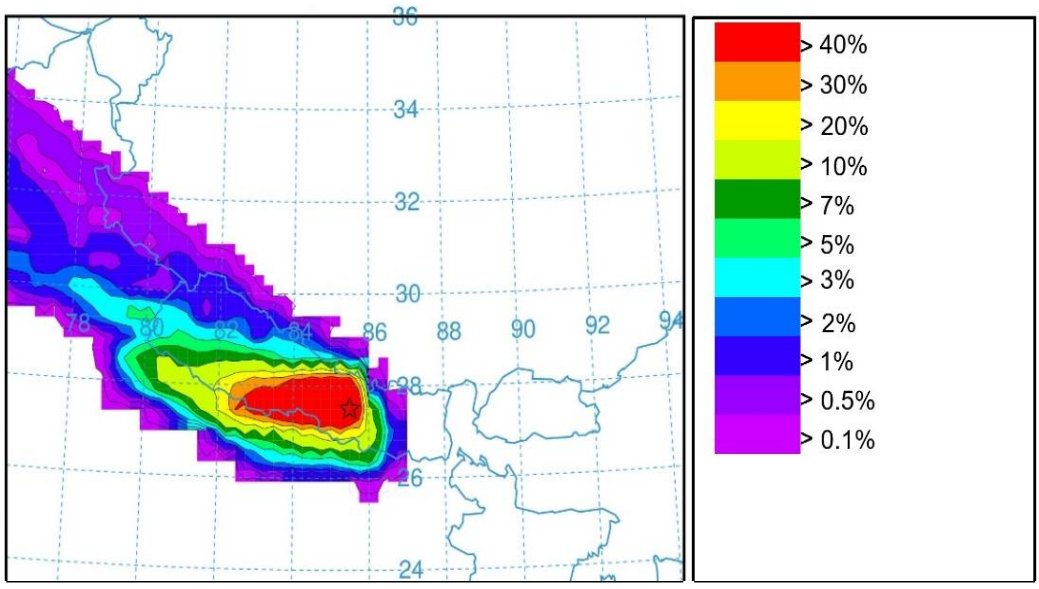
During the winter season of 2024 (December 2023 – February 2024), Nepal received only 19.8% of the normal precipitation, leading to extreme drought conditions across most of the country (DHM, 2024a). Maximum temperatures were below normal over the southern plains, while other regions experienced near-normal to above-normal values. Minimum temperatures were below normal in the northern and western regions. In the pre-monsoon season (March – May 2024), precipitation was 80.9% of the normal, indicating below-normal rainfall and resulting in moderate to severe drought in several areas (DHM, 2024b). Both maximum and minimum temperatures were above normal across most of the country. The monsoon season (June – September 2024) saw 122.0% of the normal precipitation, with most areas experiencing above-normal maximum and minimum temperatures (DHM, 2024c). Post-monsoon precipitation was 80.4% of the normal, with above-normal maximum temperatures prevailing across much of the country, though parts of Karnali, Madhesh, Bagamati, and Koshi Provinces recorded near to below-normal values. Minimum temperatures were below normal in the north and above normal in the south (DHM, 2024d).

These climatic conditions, particularly the prolonged dry spells other than the monsoon season, contributed to the deterioration of air quality. Reduced precipitation limited the natural cleansing of the atmosphere. Additionally, increased dryness may have intensified dust levels and wildfire activities.

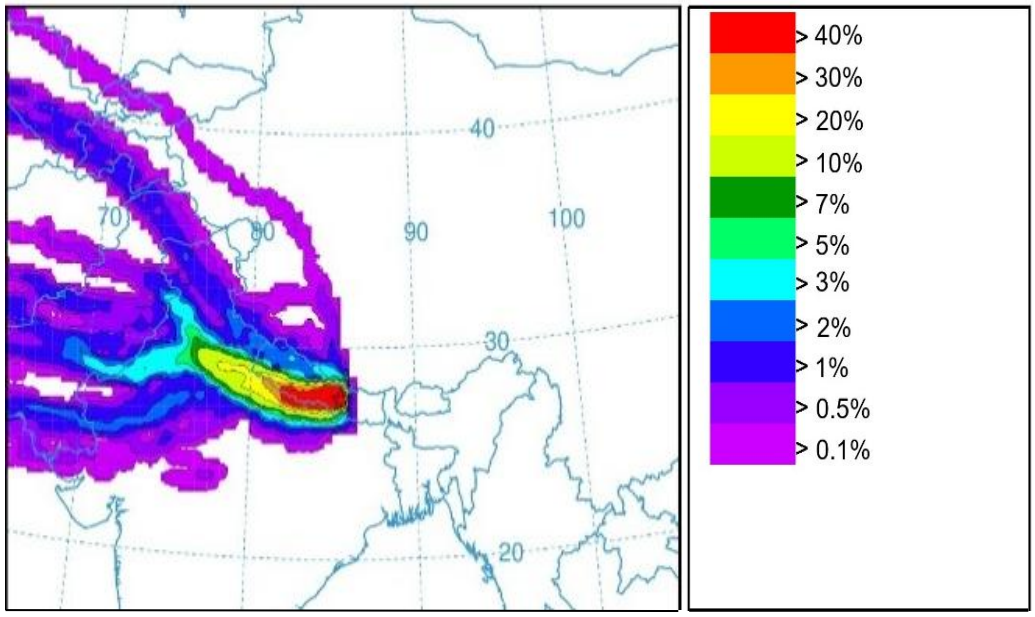
2.9.2 Wind Pattern and PM Pollution

Wind plays a key role in transporting pollution from one area to another, often across regional and national boundaries. Backward trajectory analysis is a crucial method for understanding how these wind patterns influence air pollution in a given region. By tracing the path of air masses backward in time, this technique helps identify the geographic origin and transport routes of pollutants. This makes it particularly valuable for assessing transboundary pollution. When combined with ground-based measurements and satellite observations, backward trajectory analysis provides a more comprehensive understanding of pollution dynamics, especially those shaped by seasonal wind patterns.

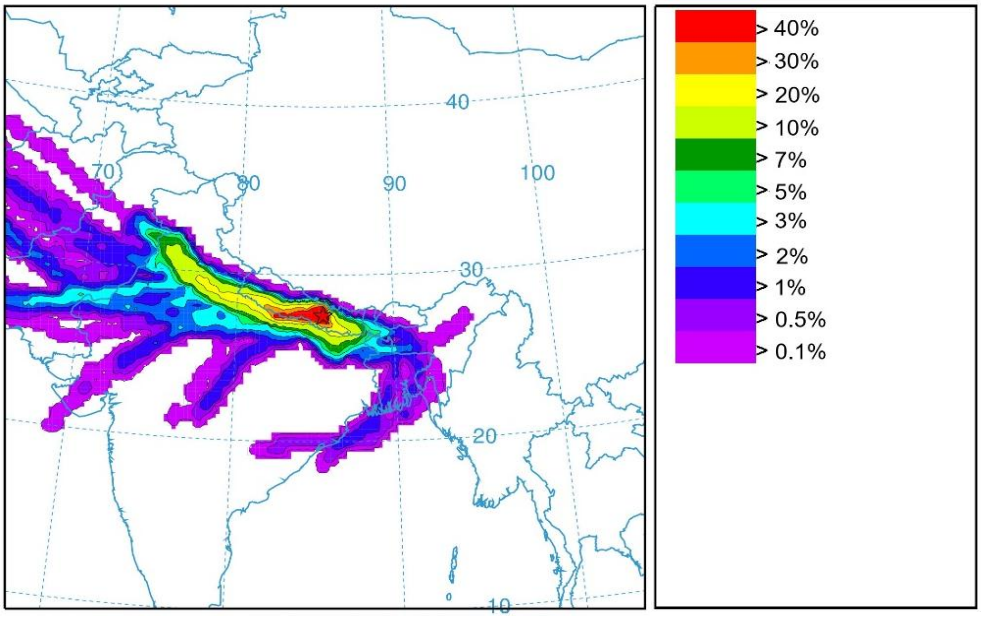
A frequency analysis of backward trajectories in the Kathmandu Valley was conducted for January, February, March, April, November, and December 2024, as these months represent periods of high particulate matter (PM) pollution. GDAS 1-degree meteorological data was used, and five days' backward trajectory (120 hour) at the middle height of the PBL was simulated (Figure 5).



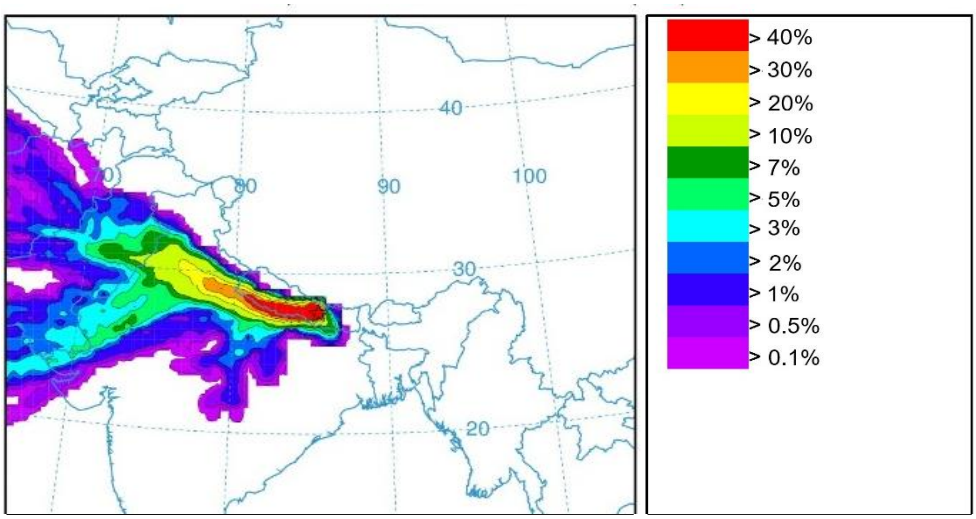
A. January



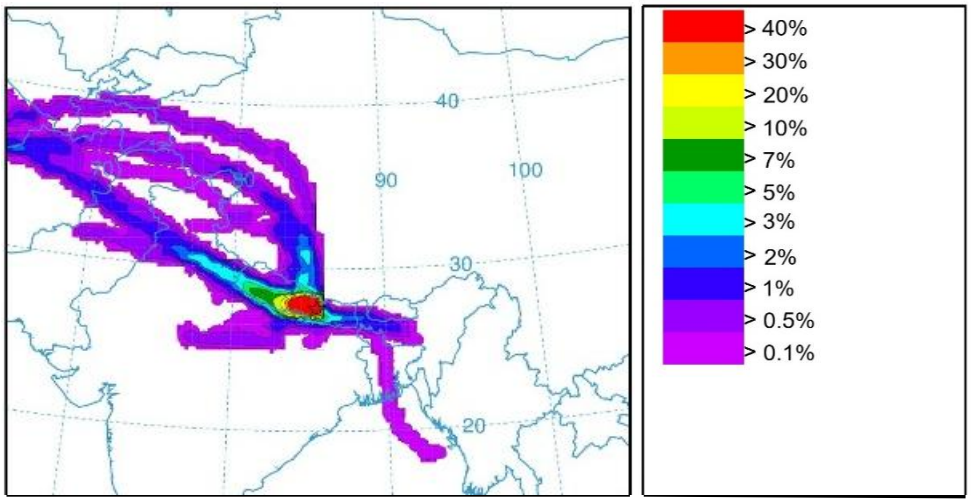
B. February



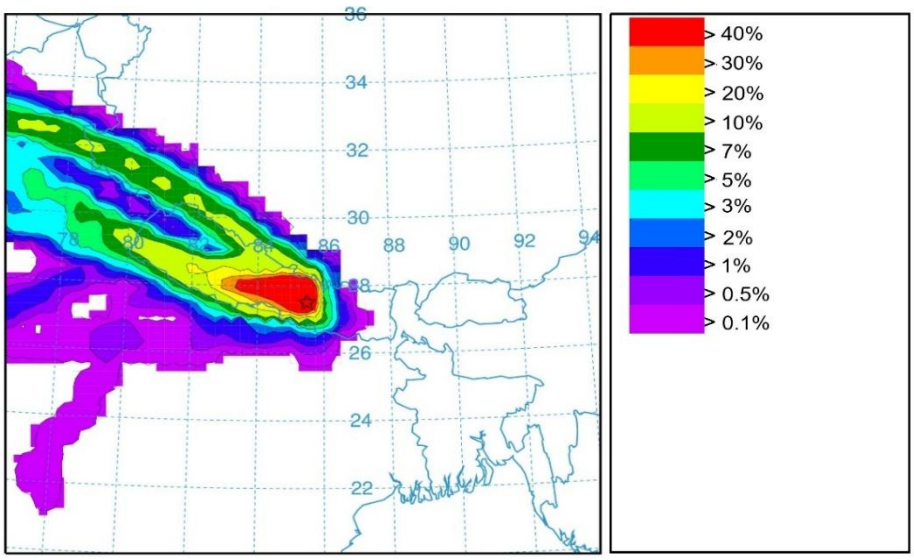
C. March



D. April



E. November



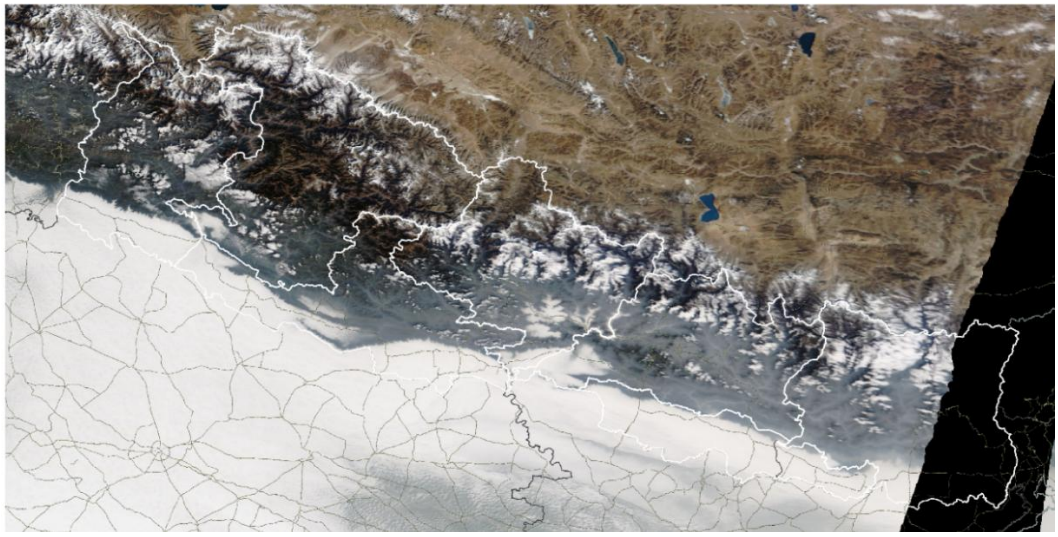
E. December

Figure 5: Backward Trajectory Frequency for Kathmandu in Different Months

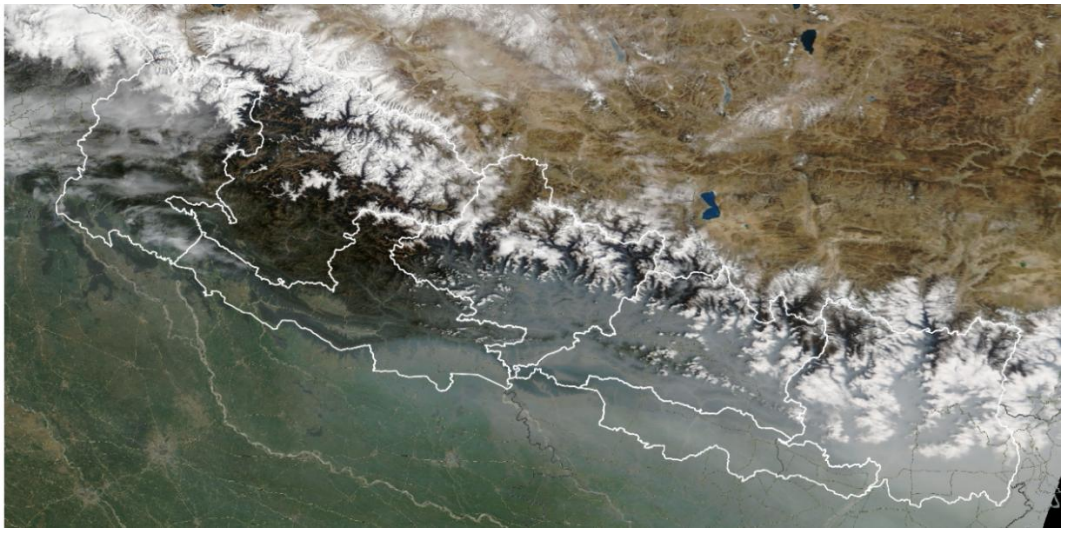
The red colour on the map indicates the dominant source of air masses entering Kathmandu Valley (for 40% of the total time in last five days.) In all six months- January to April, November and December predominant direction for the air masses arriving in the Kathmandu Valley is from the western regions. However, in April, the share of air mass was more from the southern direction where as in March and November they were more likely to come from eastern side as compared to other two months. Additionally, Figure 5 illustrates the trajectory of air mass from the Punjab region, encompassing parts of India and Pakistan, towards the Kathmandu Valley. This region is known for large-scale biomass burning, particularly during November and December, which may contribute to increase in regional air pollution levels.

2.9.3 Satellite Observations and Model Based Data

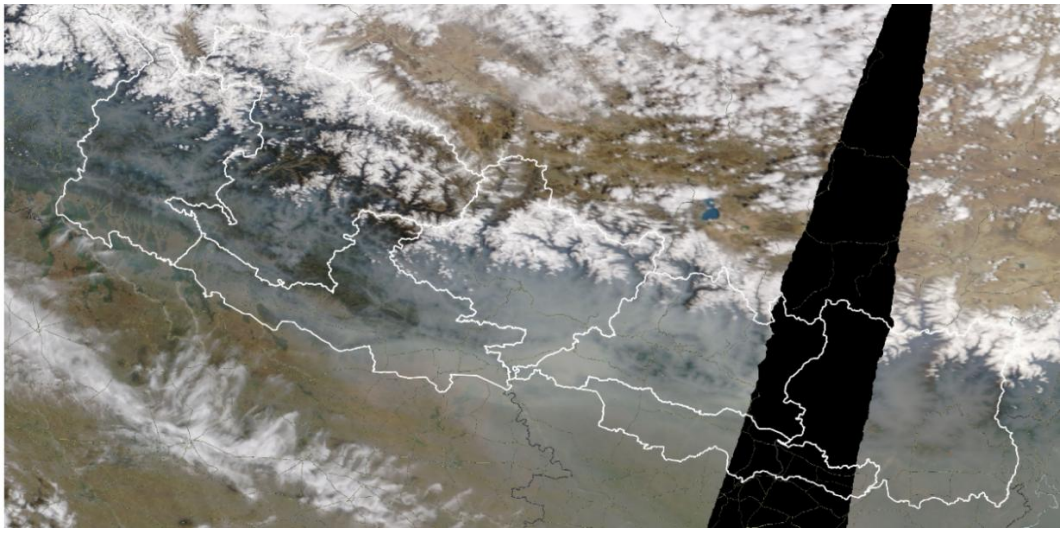
Satellite images and satellite-based products show spatial extent and regional level of pollution. The gray color in the following true color imagery from MODIS satellite shows the smog while white color shows cloud, snow and fog. These satellite images show the extent of high PM pollution at regional level in different months of the year (Figure 6).



a. True color Terra MODIS January 20, 2024



b. True color Terra MODIS March 01, 2024



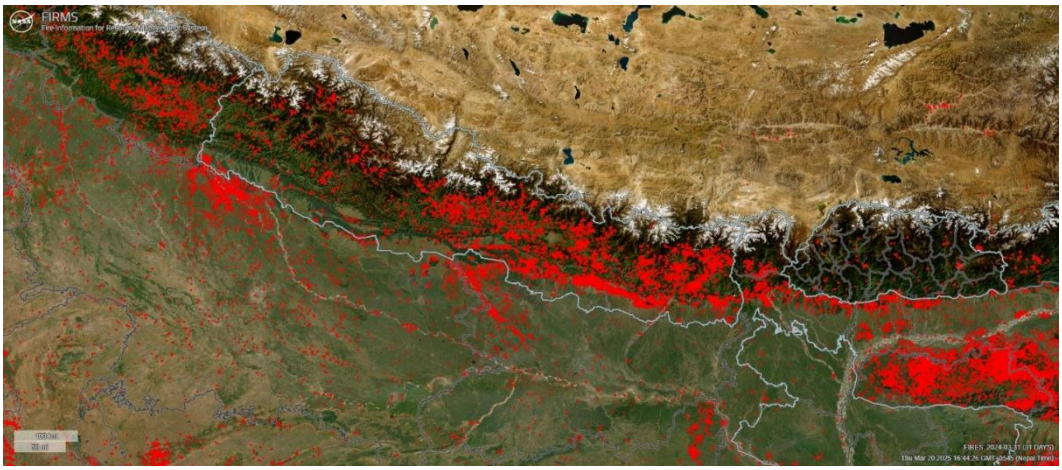
c. True color Terra MODIS April 09, 2024

Source: NASA EOSDIS (https://wvs.earthdata.nasa.gov)

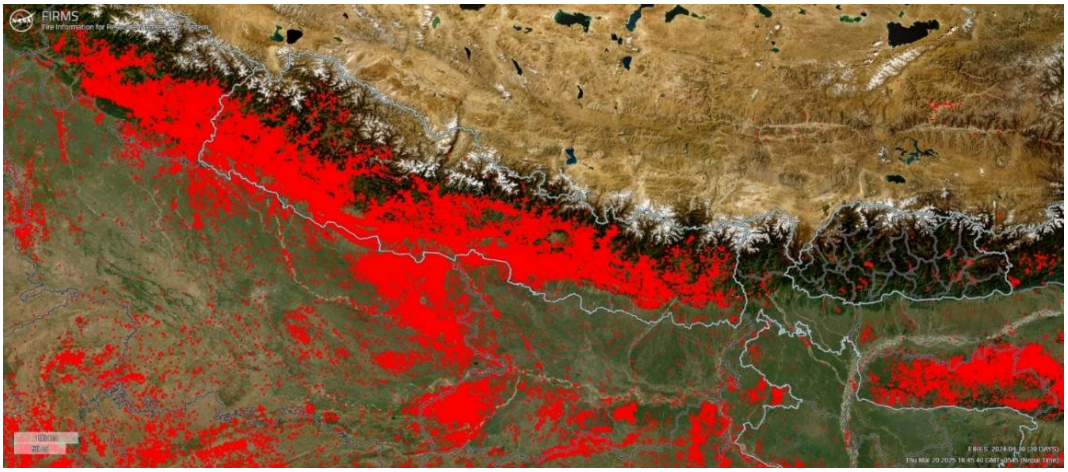
Figure 6: True Color Images on Different Dates

These satellite images from different months illustrate unbound nature of air pollution which knows no physical boundaries. In particular, during the winter season, the entire Indo-Gangetic Plain was often blanketed in thick smog. On several occasions, severe smog had affected the entire country. During many days in March and April, smoke from forest fires had spread across large parts of the country, demonstrating unrestrained nature of air. Additionally, in winter, presence of fog, particularly in the Terai region, can worsen particulate matter pollution by trapping pollutants near the surface.

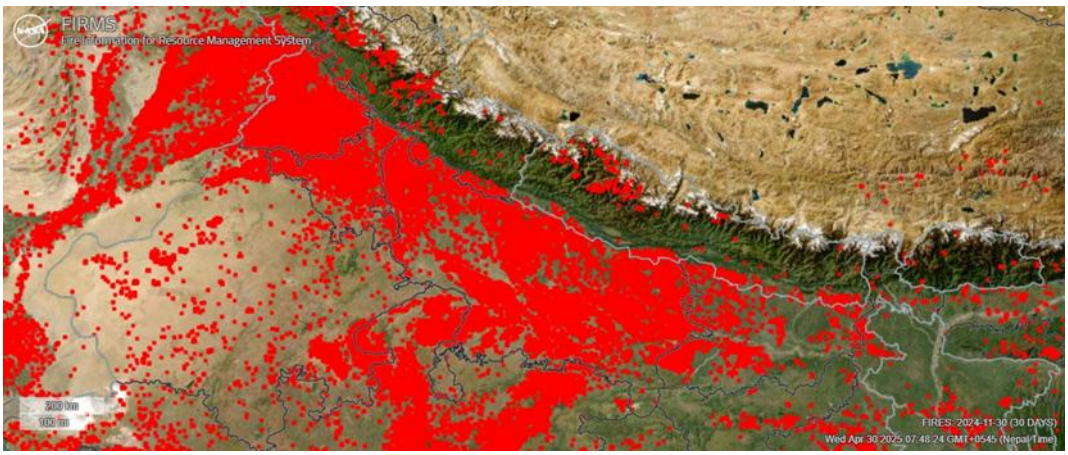
The high number of fire events during March and April can be linked to high levels of air pollution. NASA FIRMS uses satellite observations from the MODIS and VIIRS instruments to detect active fires and thermal anomalies and deliver this information in near real-time. The following images from FIRMS show the fire events throughout the country during March and April (Figure 7). Both forest fires and burning agricultural residue contribute significantly to air pollution emissions the high number of fire events in the neighbouring country may also affect the air quality of Nepal.



a. March, 2024



b. April, 2024



c. November, 2024

Source: NASA/FIRMS

Figure 7: Fire Events Detected by Satellite in Different Months

NO_2 and CO concentration over Nepal

Satellite imagery plays a crucial role in identifying sources of air pollutants. Different satellite products are used to detect pollutants such as NO_2, SO_2, CO and $PM_{2.5}$ along with their potential sources, including industrial and vehicular emissions, forest fires, and biomass burning etc. Satellite data helps pinpoint air pollution hotspots and assess conditions of transboundary air pollution.

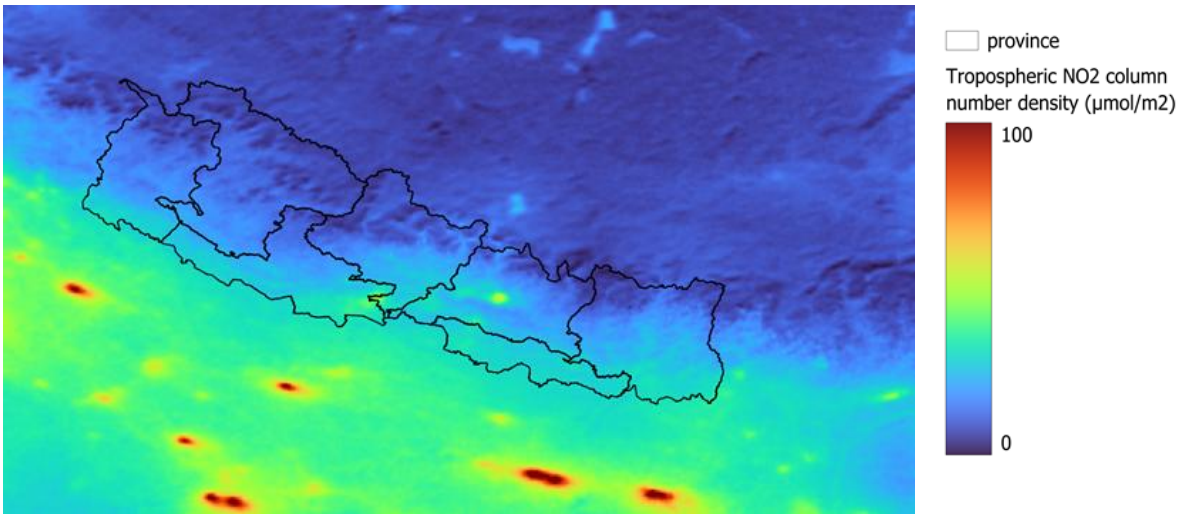


Figure 8: Annual NO_2 Concentration in 2024

Transportation and production sectors are important sources of NO_2, CO and SO_2 (UNEP, 2024) along with biomass burning. Nitrogen oxides (NO_x) are primarily generated through human activities involving the combustion of fossil fuels. Major sources include road traffic and various industrial operations. Biomass burning and wildfires also substantially contribute to NO_2 levels in the atmosphere. NO_2 poses direct health risks and also contributes indirectly by promoting the formation of ground-level ozone and fine particulate matter. The annual mean tropospheric NO_2 concentrations were particularly elevated in areas characterized by substantial economic and industrial activity (Figure 8), such as Kathmandu Valley, Nepal's capital, likely due to heavy traffic,

and the Lumbini area, possibly due to industrial activities. Although fire events were detected across the country, NO_2 levels were not consistently high. This may be because of the variation in intensity of satellite-detected fire events.

CO is a harmful gaseous air pollutant, which adversely affects placental and fetal development (Health Effects Institute, 2024). It disrupts the blood's ability to carry oxygen. In the atmosphere, CO levels vary by location, and the gas typically persists for about one month. The primary source of CO is the incomplete combustion or oxidation of carbon-based fuels. This occurs in various activities such as motor vehicle transportation, industrial processes, fuel burning and household fuel use. Additional sources include forest fires and the burning of agriculture residue burning. In Nepal, annual CO concentrations are higher in the hilly and Terai regions compared to those in the Himalayan regions, likely due to the increased combustion of carbonaceous fuels at lower elevations.

The movement of CO tends to follow river channel paths, as its dispersion is influenced by atmospheric transport. This pattern may be affected by temperature inversions in river valleys, which trap pollutants and direct airflow along the terrain.

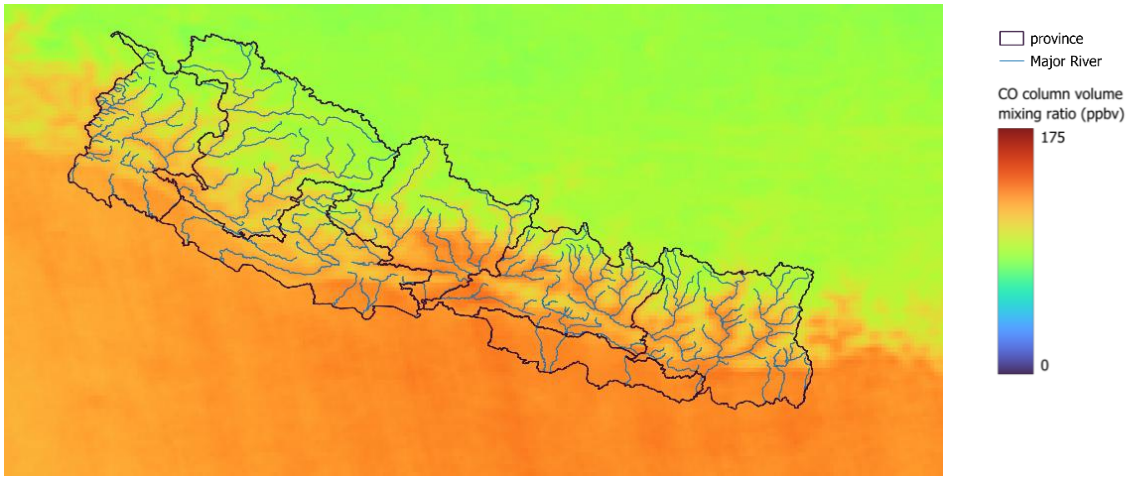


Figure 9: Annual CO Concentration in 2024

Spatial variability of AOD

Aerosols are fine particulate matter, including urban haze, smoke particles, desert dust, and sea salt, that remain suspended in the atmosphere. The aerosol Optical Depth (AOD) is a measures of these concentration of aerosols distributed throughout a vertical column of air, from the Earth's surface to the top of the atmosphere (https://aeronet.gsfc.nasa.gov/new_web/Documents/Aerosol_Optical_Depth.pdf). AOD measurement is based on the amount of light scattered and absorbed by the aerosols from the Earth's surface to space (World Bank, 2022). AOD less than 0.1 is considered "clean" with clear blue sky and maximum visibility whereas as visibility decreases with increase in AOD value. The AOD with greater than 3.0 indicates presence of dense aerosols that covers the Sun (https://www.earthdata.nasa.gov/news/worldview-image-archive/high-aerosol-optical-depth-over-india). Higher the AOD higher the air pollution with particulate matter specially PM2.5 (https://aaqr.org/articles/aaqr-22-09-oa-0311). Figure 10 shows the average

annual AOD over Nepal and neighboring regions. The scale was set from 0 to 1 for easier comparison.

In 2024, elevated levels of AOD were observed in the Terai region of the country, with particularly high concentrations in the eastern Terai (Figure 10). The emergence of the Terai region as the pollution hotspot might be attributed to combine effect of both local and transboundary air pollution.

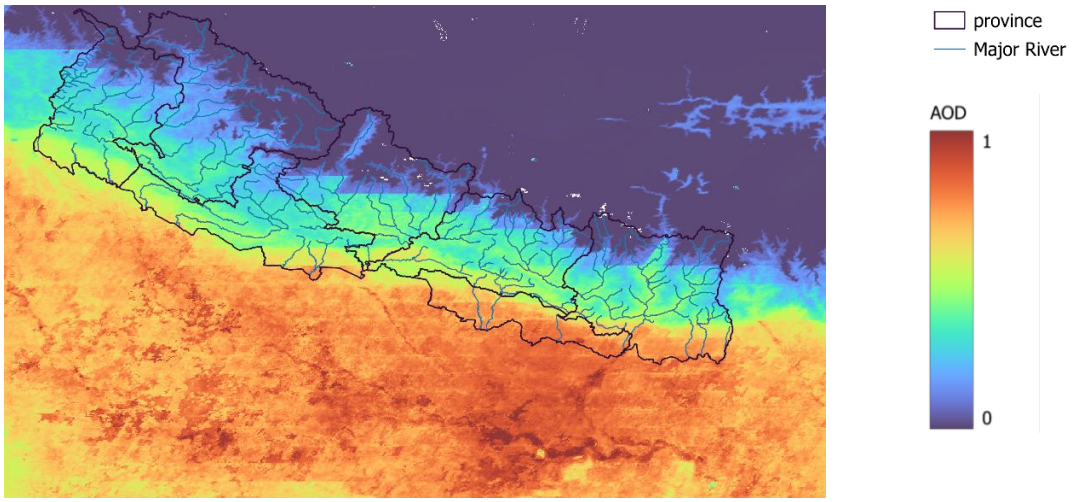
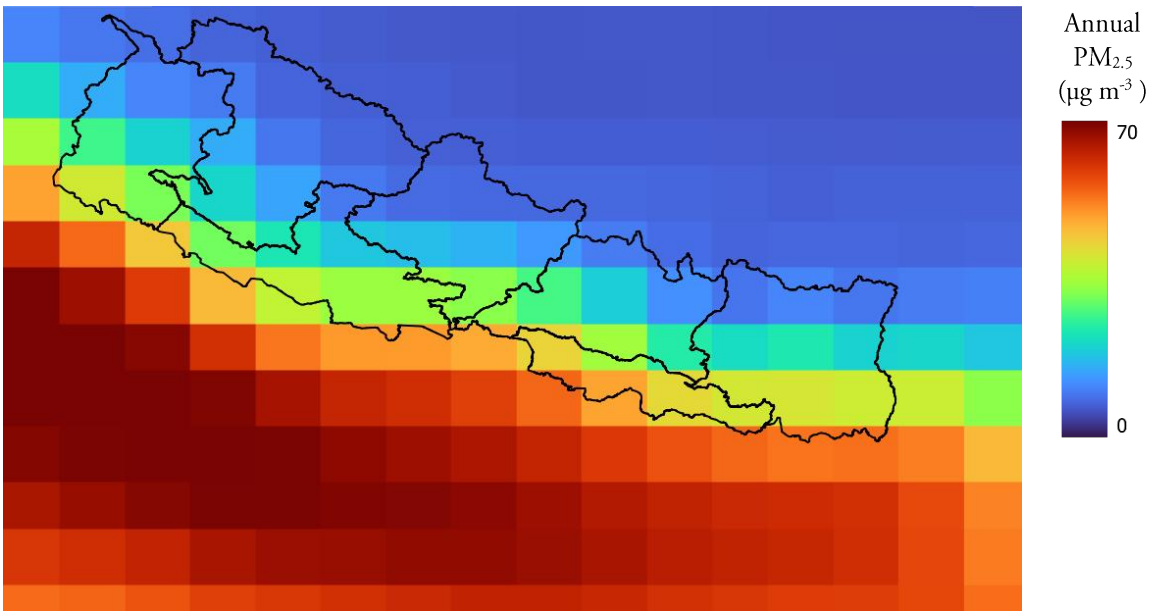


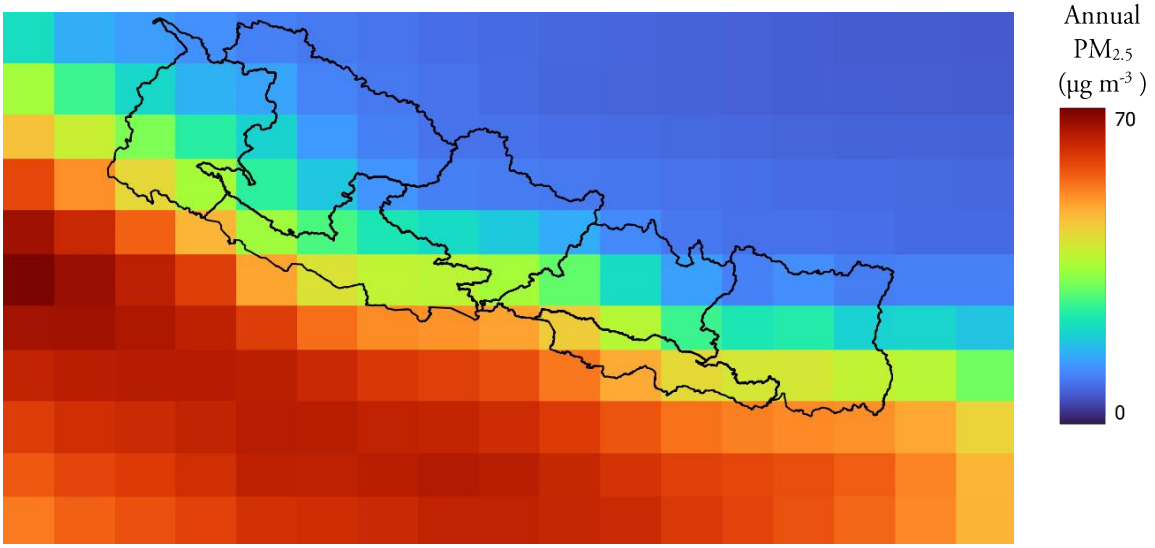
Figure 10: Annual AOD Analysis for 2024

Spatial variability of $PM_{2.5}$

To assess $PM_{2.5}$ levels across Nepal, MERRA-2 data was used as described in the methodology. A random forest model was applied to bias-correct the $PM_{2.5}$ estimates from MERRA-2 using ground-based data from various stations and time periods. Figure 11 presents the annual average $PM_{2.5}$ concentrations for 2023 and 2024 across different provinces of Nepal. Due to the coarse resolution of MERRA-2 (i.e., larger grid sizes), the data cannot capture pollution levels at a local or city scale. However, it effectively illustrates large-scale variability in air pollution. The data shows that $PM_{2.5}$ concentrations were generally higher in the southern part of the country, particularly in the Terai region. Based on this dataset, the average $PM_{2.5}$ concentrations at the provincial level were calculated and are presented in Table 51. Overall, $PM_{2.5}$ concentrations increased in 2024 compared to 2023 across all provinces. Madhesh Province recorded the highest annual average $PM_{2.5}$ in both years, while Karnali Province consistently had the lowest. Southern part of the country had higher $PM_{2.5}$ concentrations than the Northern regions. This might be because of local as well as transboundary sources of air pollution.



A. 2023



B. 2024

Figure 11: Annual Average $PM_{2.5}$ for 2023 and 2024

Table 51 : Annual Average of $PM_{2.5}$ for 2023 and 2024

S. N.	Province Name	Annual average $PM_{2.5}$ ($\mu g\ m^{-3}$) concentration	
		2023	2024
1	Karnali	12.7	16
2	Gandaki	15.7	18
3	Bagamati	21.6	25
4	Sudurpashchim	22.9	26
5	Koshi	25.9	27
6	Lumbini	29.5	33
7	Madhesh	43.1	43.4

CHAPTER 3: CONCLUSION

The report analyzes air quality data from sixteen air quality monitoring stations across Nepal, revealing significant variations in pollution levels between provinces. In Koshi Province, Dhankuta experienced higher pollution, particularly in the pre-monsoon months (March-April), with 68 days (about 2 months and 1 week) out of 234 measured days exceeding $PM_{2.5}$ standards, while Ilam had much cleaner air. Janakpur station in Madhesh Province recorded severe pollution, especially in December, with 44 days (about 1 and a half months) out of 81measured days exceeding national $PM_{2.5}$ limits. Bagamati Province, including Kathmandu Valley, had the worst air quality, with stations showing severely high $PM_{2.5}$ and TSP levels, particularly during winter and pre-monsoon seasons. In contrast, Karnali Province's Rara station had the cleanest air, though $PM_{2.5}$ still exceeded NAAQS for 31 days (about 1 month) out of 257 measured days.

Ozone levels at Khumaltar Station in 2024 showed notable seasonal and monthly variation, with the highest concentrations during the pre-monsoon and lowest in winter season. The 8-hour running average exceeded 80 ppb concentration on 20 days, indicating occasional episodes of elevated ozone pollution. Variations in pollution levels across stations also depend on their location, as some of the stations are located in rural areas and some in highly populated areas.

Seasonal trends indicated that the Winter and Pre-monsoon seasons were the most polluted periods. During these seasons, limited rainfall reduces the removal of pollutants from the atmosphere. In the Winter season, low temperatures promote temperature inversion, while prevailing wind patterns favor the transboundary transport of pollutants, both factors contributing to elevated air pollution levels. During Pre-Monsoon period, forest fires are one of the major contributors to air pollution. Similarly, HYSPLIT trajectory analysis shows that air masses originating from the Punjab region encompassing parts of India and Pakistan and is known for large-scale biomass burning, particularly during November and December, often travel toward the Kathmandu Valley. This suggests that such transboundary pollution may contribute to elevated regional air pollution levels. Satellite data indicated that Madhesh Province (eastern Terai) had the highest aerosol pollution, likely due to both local and transboundary sources. Additionally, model data showed an increase in $PM_{2.5}$ concentrations in 2024 compared to 2023, with the southern region of all provinces experiencing more $PM_{2.5}$ concentrations than the northern regions.

The major sources of air pollution in Nepal include residential emission, industrial activities, vehicular emissions, construction activities, forest fires, and burning of agricultural residue, with notable contributions from transboundary pollution and emissions from natural sources. The findings highlight poor air quality and regional disparities in exposure, which urge for the urgent need for local, regional as well as international collaboration to address air pollution. Formulation of stringent air quality policies, better monitoring, and regional cooperation strategy will definitely support to combat the challenging air pollution crisis of the country.

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ANNEX 1: COMPOSITION OF TECHNICAL COMMITTEE, 2024

SN	Name	Organization	Designation
1	Mr. Deepak Gyawali, Senior Divisional Chemist	Department of Environment	Coordinator
2	Dr. Ramesh Prasad Sapkota, Associate Professor	Tribhuvan University, Central Department of Environment Science	Member
3	Mr. Keshab Raj Joshi, Environment Inspector	Ministry of Forests and Environment	Member
4	Mr. Sudarsan Guragain, Meteorologist	Department of Hydrology and Meteorology	Member
5	Dr. Khushboo Sharma, Air Pollution Analyst- Observation	ICIMOD	Member
6	Mr. Govinda Prasad Lamichhane, Environment Inspector	Department of Environment	Member
7	Mr. Sameer Panthi, Account Officer	Department of Environment	Member
8	Ms. Nabina Maharjan, Environment Inspector	Department of Environment	Member Secretary

ANNEX 2: LIST OF EXPERTS CONTRIBUTED AND REVIEWED IN THE REPORT

Following are list of experts beside the members of the data analysis committee, who reviewed the report and gave valuable feedbacks.

SN	Name of Expert	Organization
1	Dr. Kundan Lal Shrestha, Associate Professor	Kathmandu University
2	Dr. Bhupesh Adhikary, Senior Air Quality Specialist	ICIMOD
2	Dr. Ravi Sahu, Air Quality Specialist	
3	Mr. Sagar Adhikari, Air Pollution Analyst-Mitigation	
4	Mr. Suresh Pokheral, Senior Air Pollution Associate (Observation)	
5	Dr. Arshini Saikia, Air quality Modelling Analyst	
6	Mr. Dikra Bajgai, Air Pollution Associate	
6	Mr. Jagdish Dotel, Air Pollution Specialist	Eco and Green Leaves Research Consultancy
7	Mr. Sabit Deshar, Environment Inspector	DoEnv
8	Ms. Bina Ghimire, Environment Inspector	
9	Ms. Arati Shrestha, Environment Inspector	
10	Ms. Tika Regmi, Environment Inspector	
11	Ms. Hasana Shrestha, Environment Inspector	
12	Ms. Swasti Shrestha, Environment Inspector	
13	Ms. Pritika Puspam, Environment Inspector	

ANNEX 3: SCATTERPLOT BETWEEN OBSERVED $PM_{2.5}$ AND PREDICTED $PM_{2.5}$ FROM RANDOM FOREST MODEL

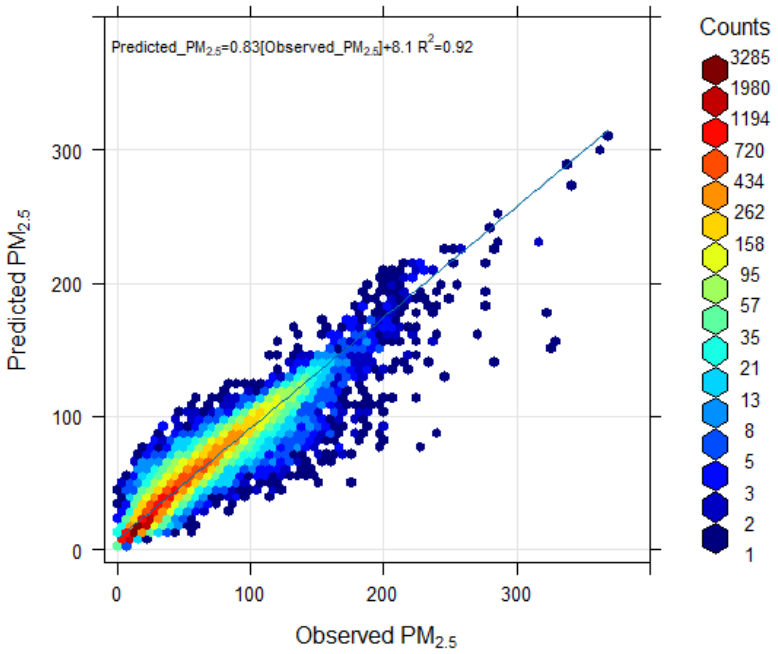

Figure A3-1: Scatterplot between Observed $PM_{2.5}$ and Predicted $PM_{2.5}$ for Ratnapark Station

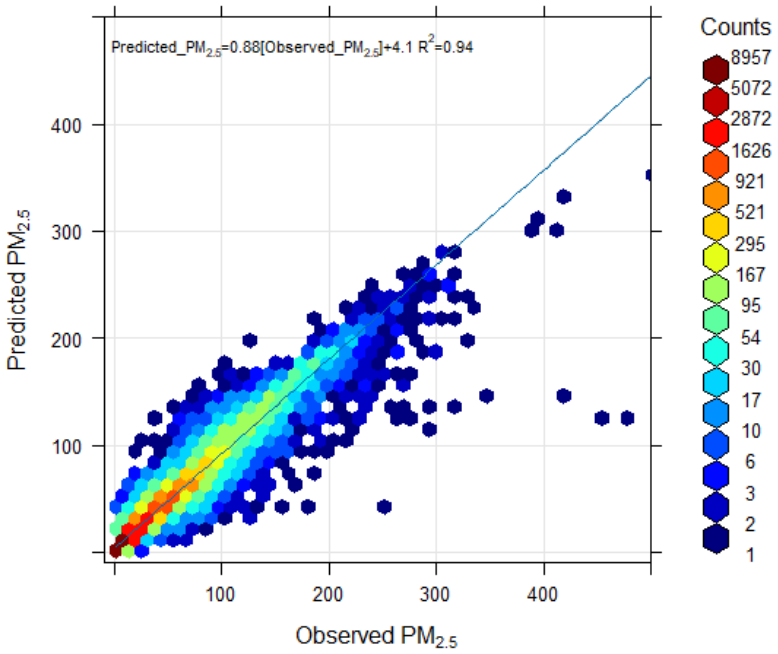

Figure A3-2: Scatterplot between Observed $PM_{2.5}$ and Predicted $PM_{2.5}$ over Nepal

ANNEX 4: FIGURES OF DIFFERENT STATIONS

DHANKUTA AIR QUALITY MONITORING STATION

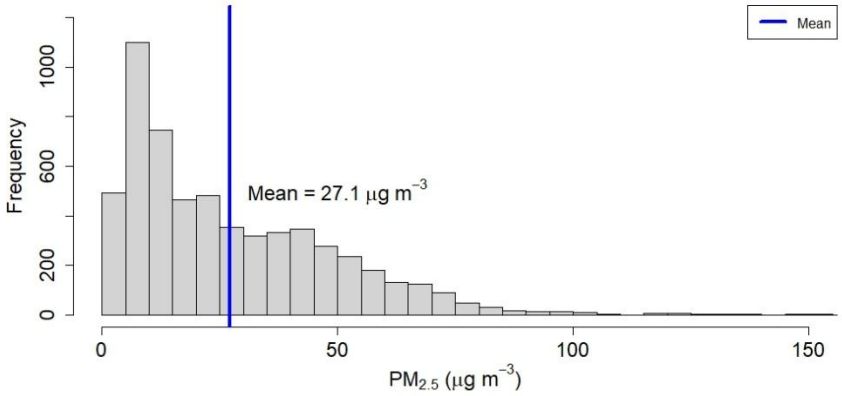

Figure A4-1: Histogram of $PM_{2.5}$ for Dhankuta Station

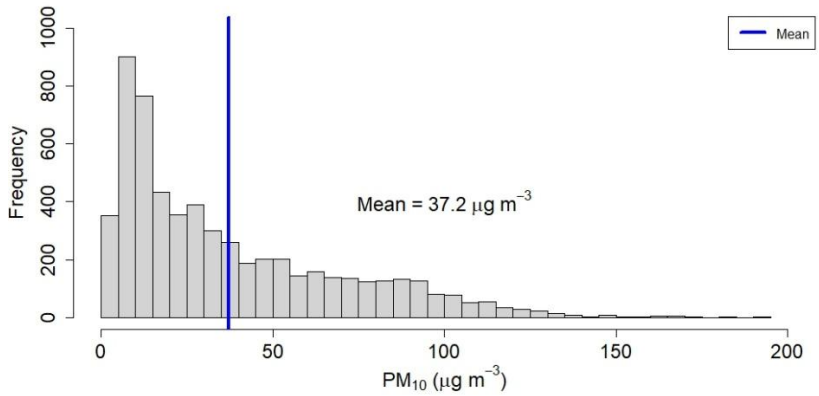

Figure A4-2: Histogram of PM_{10} for Dhankuta Station

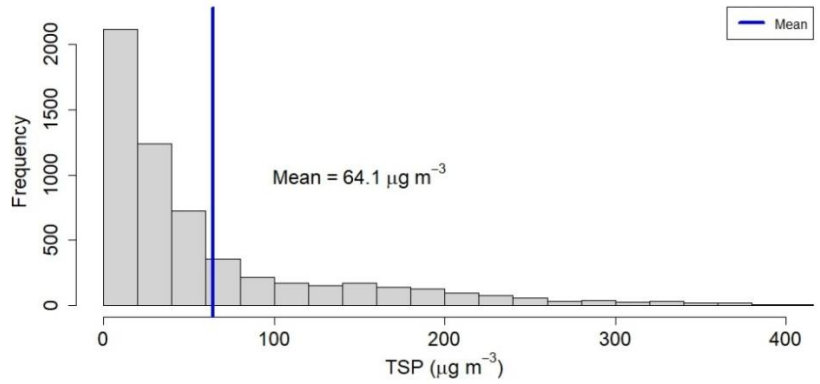

Figure A4-3: Histogram of TSP for Dhankuta Station

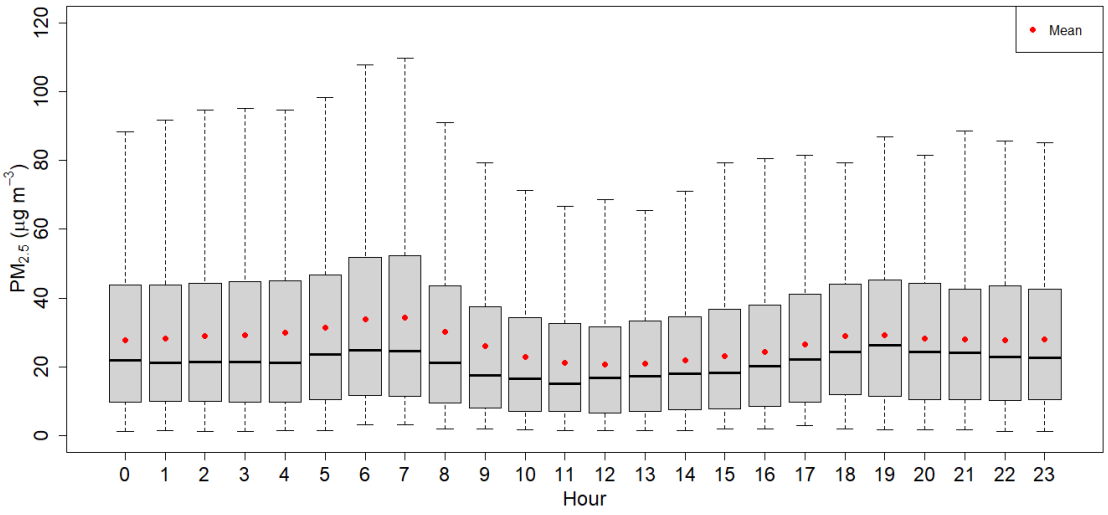

Figure A4-4: Diurnal Variation of $PM_{2.5}$ for Dhankuta Station

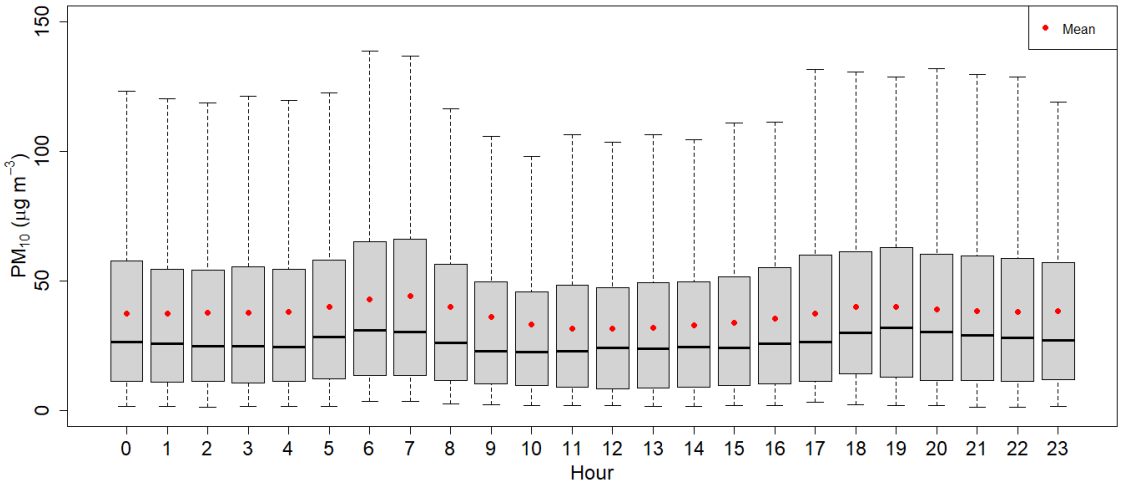

Figure A4-5: Diurnal Variation of PM_{10} for Dhankuta Station

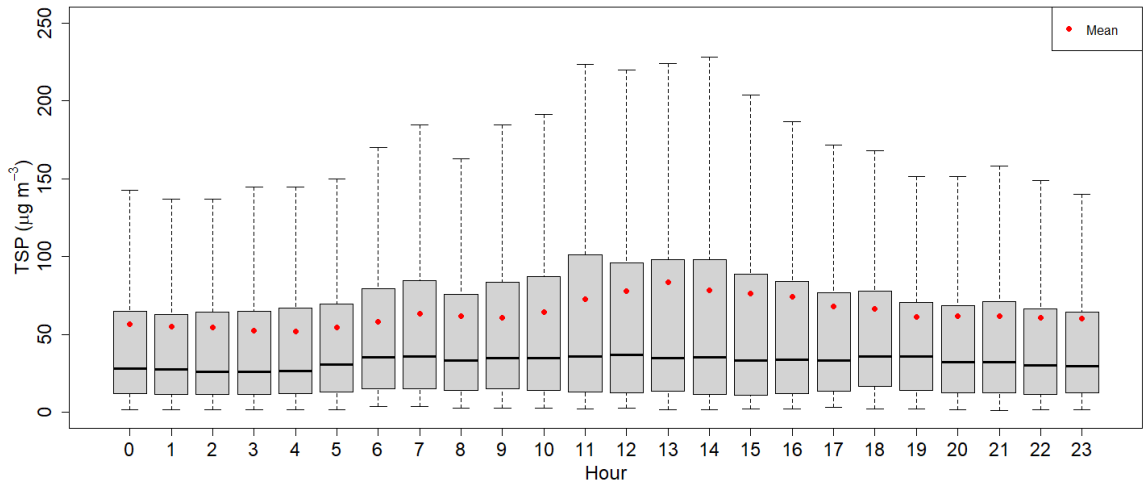

Figure A4-6: Diurnal Variation of TSP for Dhankuta Station

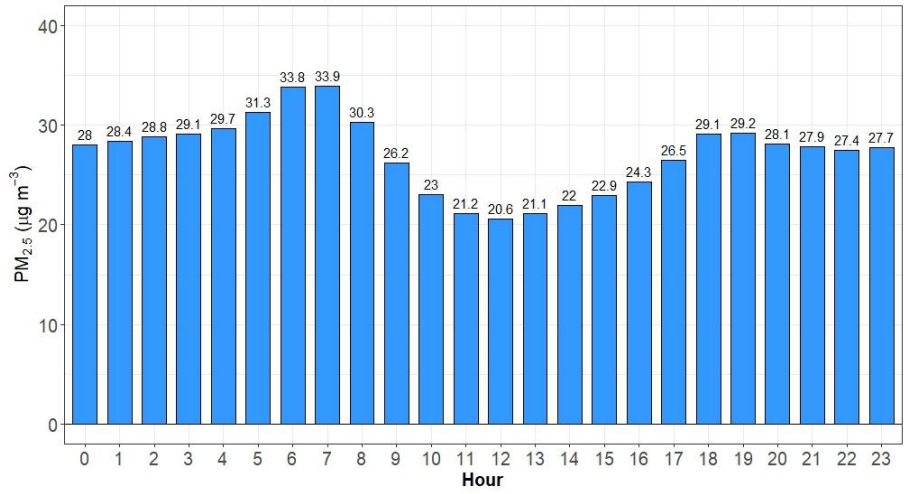

Figure A4-7: Hourly Average of $PM_{2.5}$ for Dhankuta Station

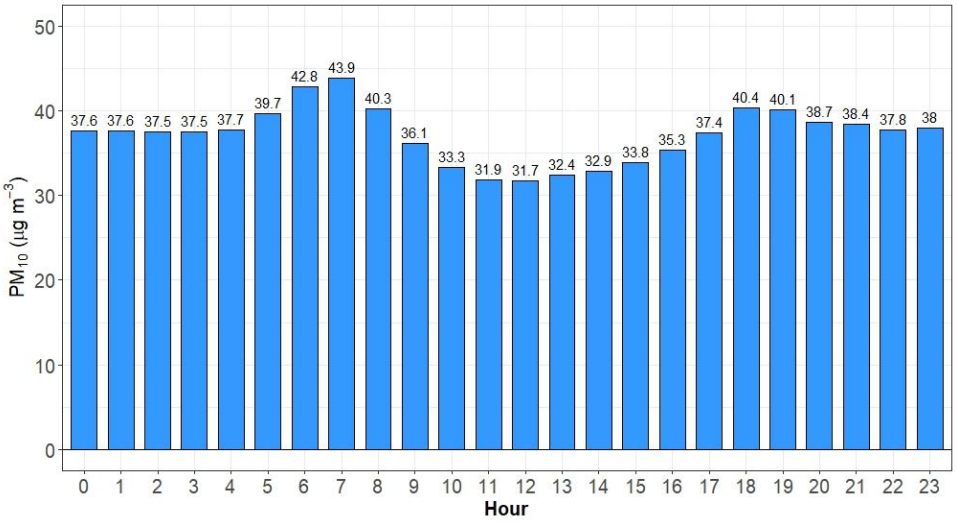

Figure A4-8: Hourly Average of PM_{10} for Dhankuta Station

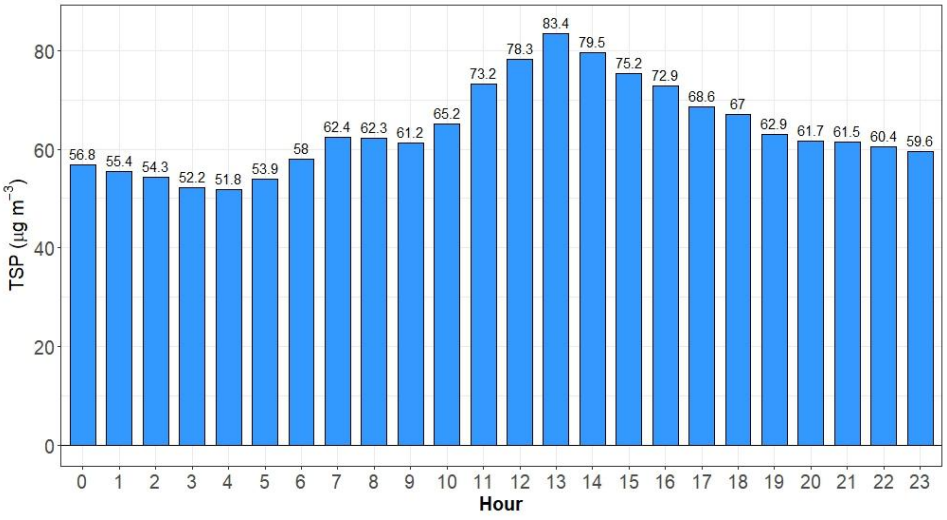

Figure A4-9: Hourly Average of TSP for Dhankuta Station

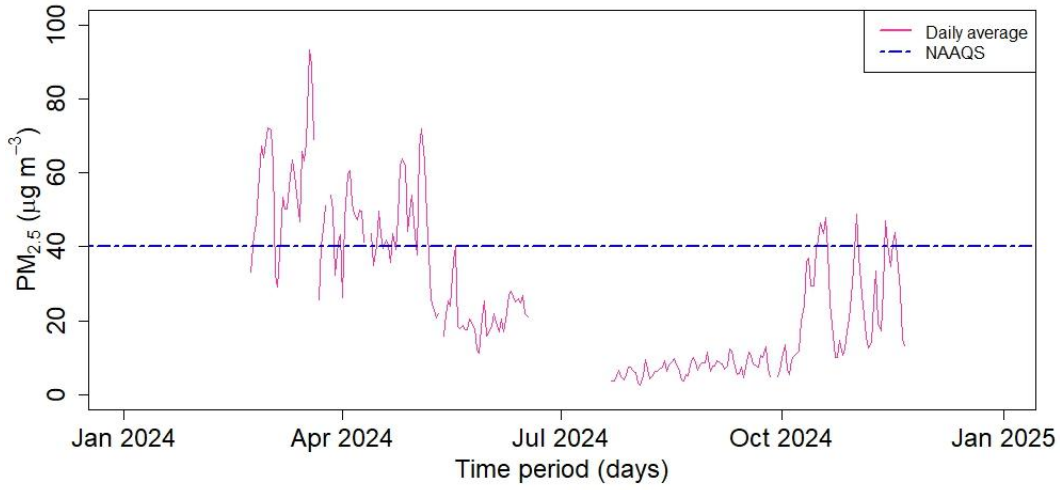

Figure A4-10: Daily Average of $PM_{2.5}$ for Dhankuta Station

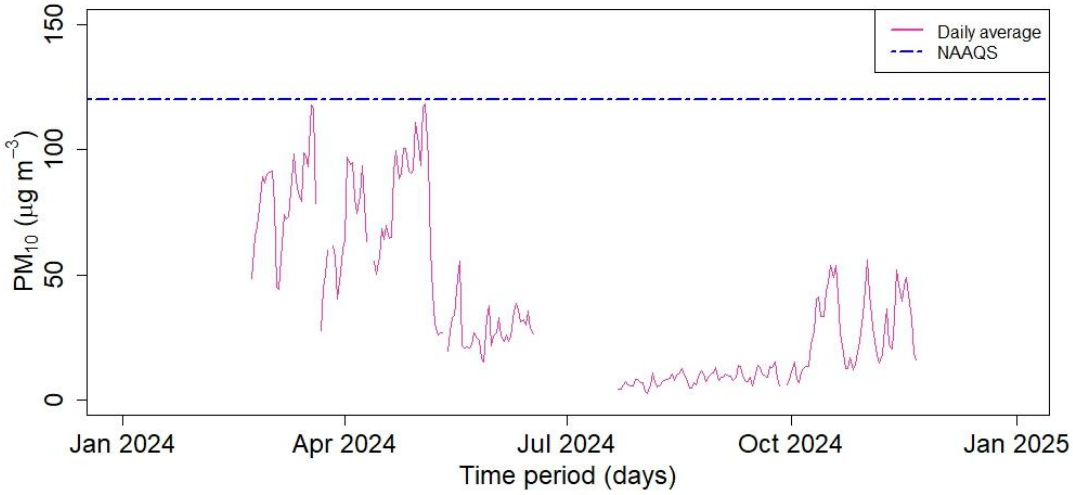

Figure A4-11: Daily Average of PM_{10} for Dhankuta Station

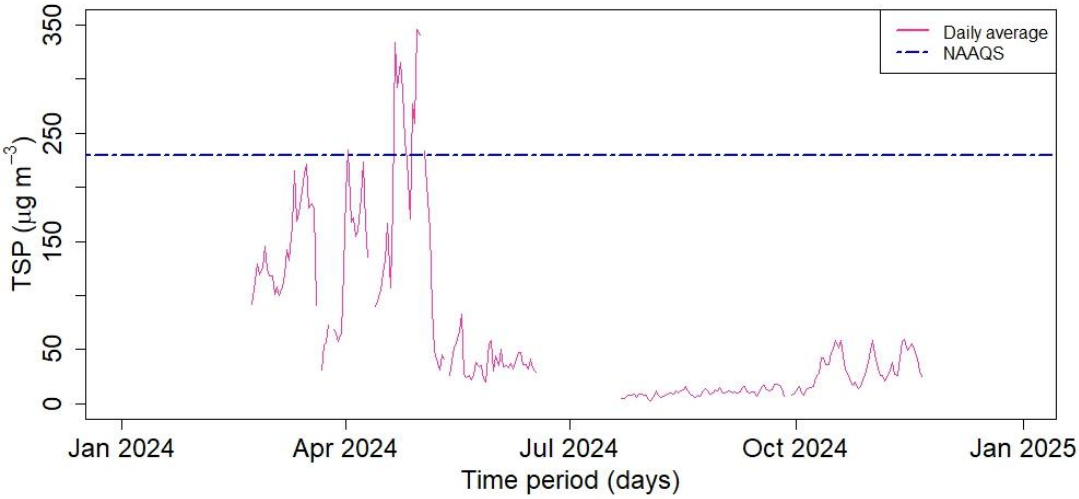

Figure A4-12: Daily Average of TSP for Dhankuta Station

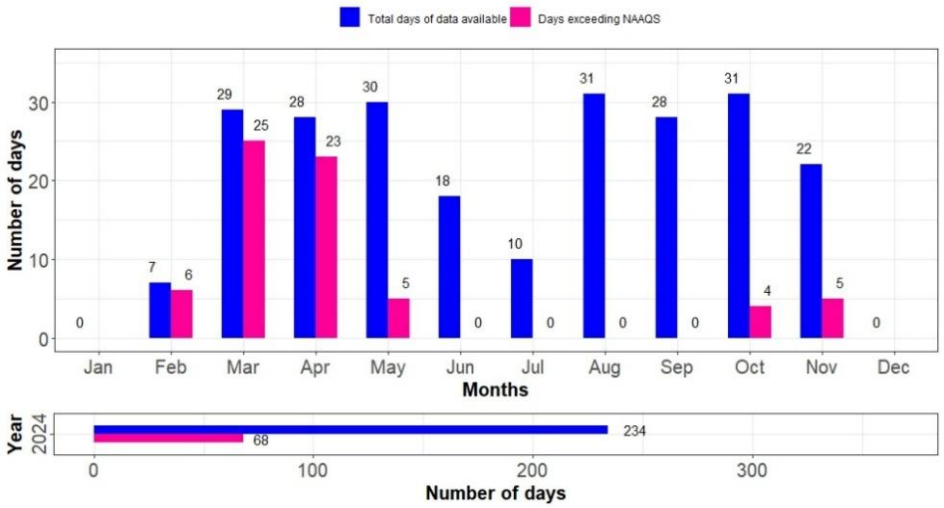

Figure A4-13: Compliance Status of $PM_{2.5}$ for Dhankuta Station

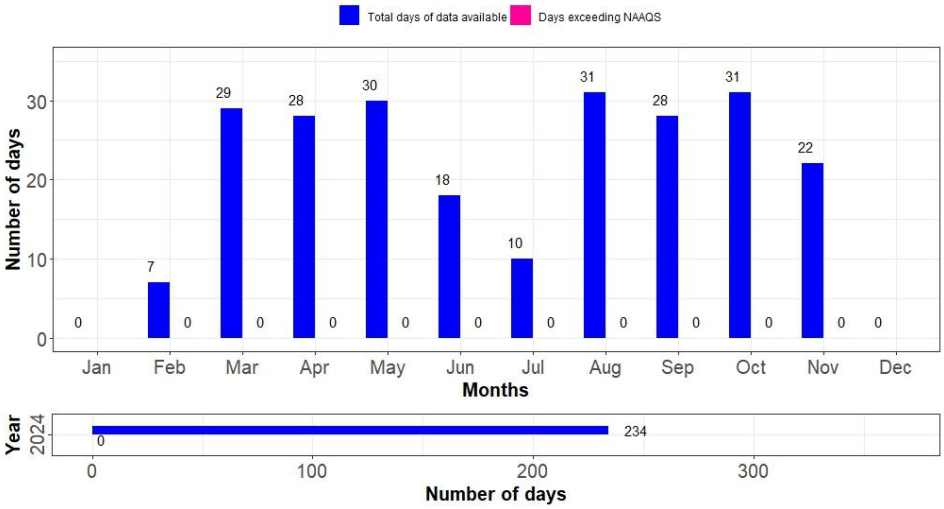

Figure A4-14: Compliance Status of PM_{10} for Dhankuta Station

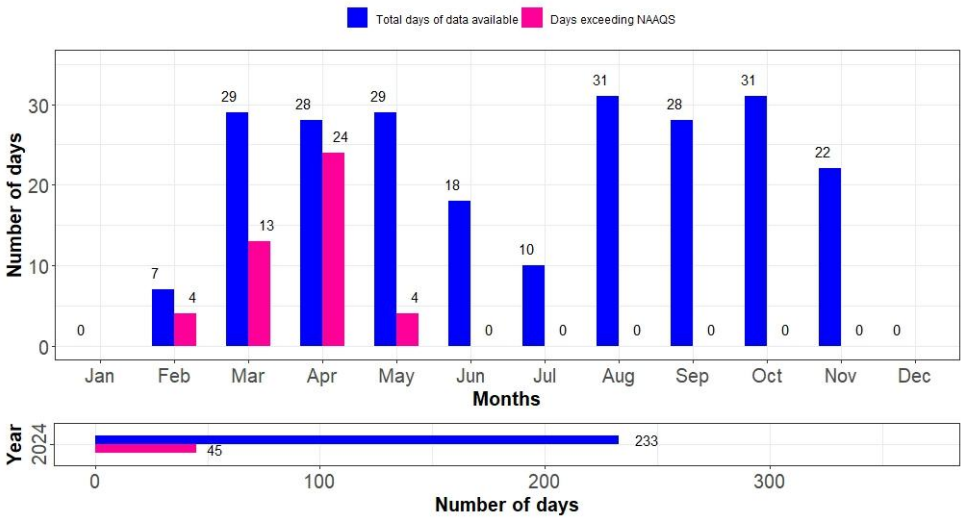

Figure A4-15: Compliance Status of TSP for Dhankuta Station

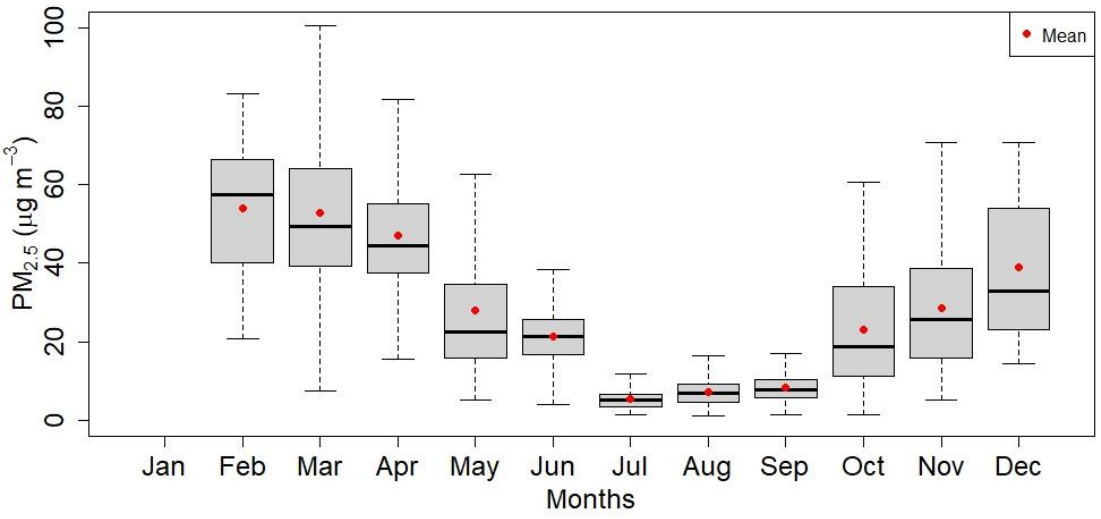

Figure A4-16: Monthly Variation of $PM_{2.5}$ for Dhankuta Station

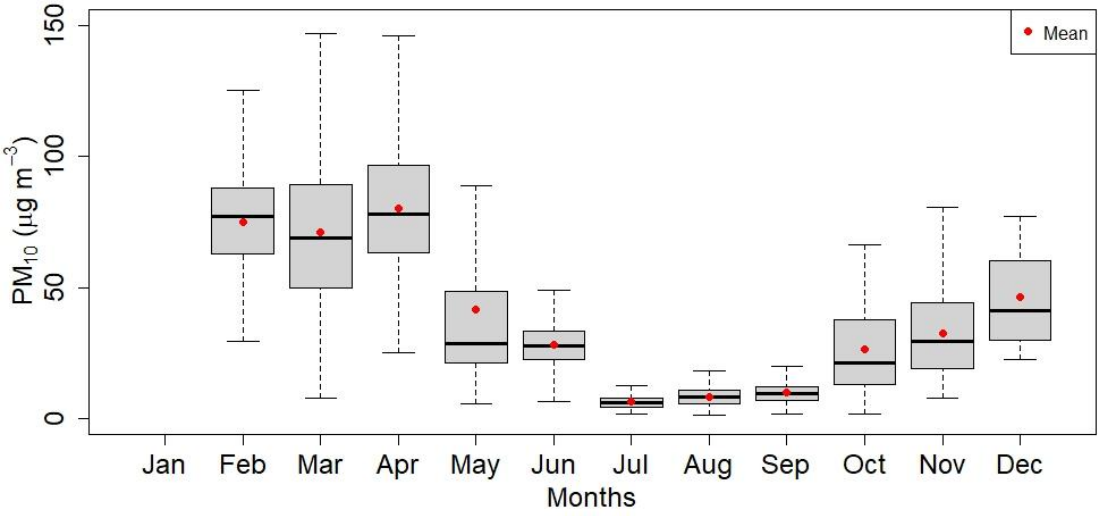

Figure A4-17: Monthly Variation of PM_{10} for Dhankuta Station

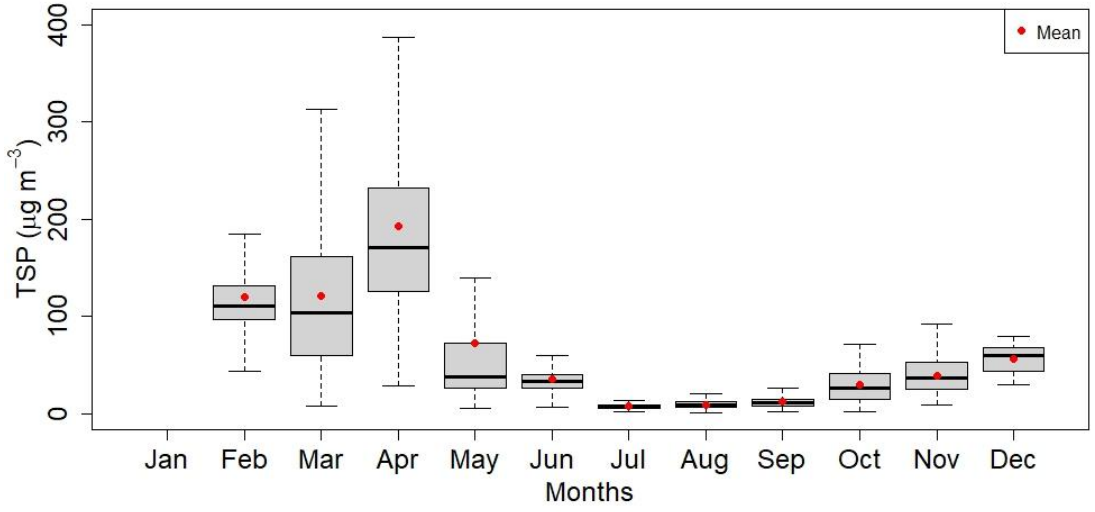

Figure A4-18: Monthly Variation of TSP for Dhankuta Station

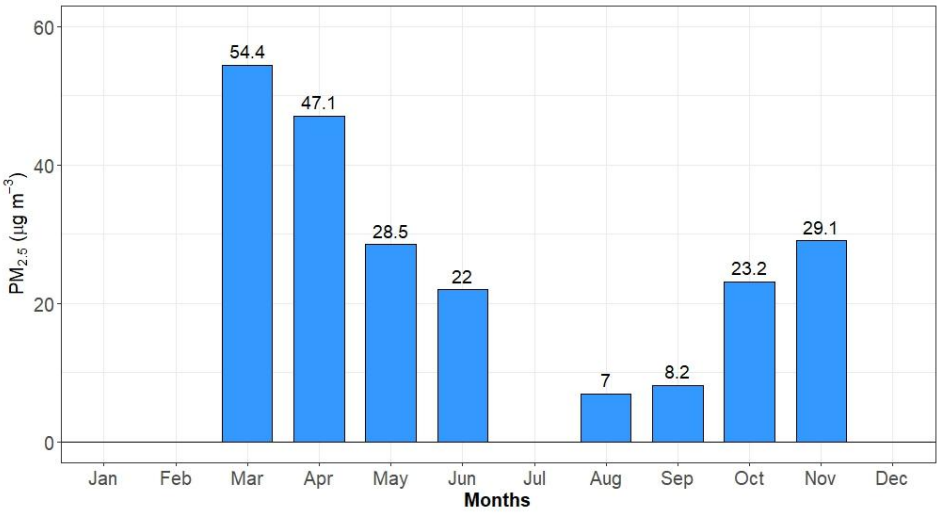

Figure A4-19: Monthly Average of $PM_{2.5}$ for Dhankuta Station

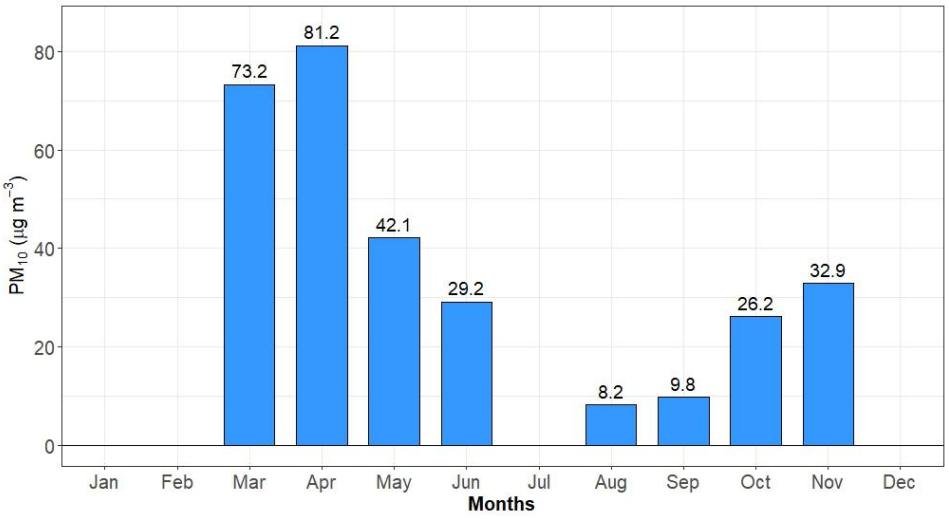

Figure A4-20: Monthly Average of PM_{10} for Dhankuta Station

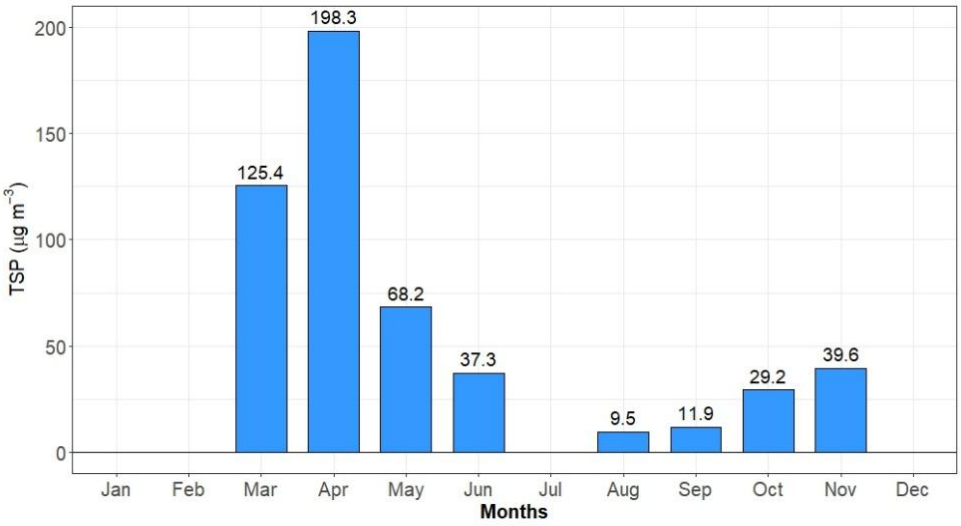

Figure A4-21: Monthly Average of TSP for Dhankuta Station

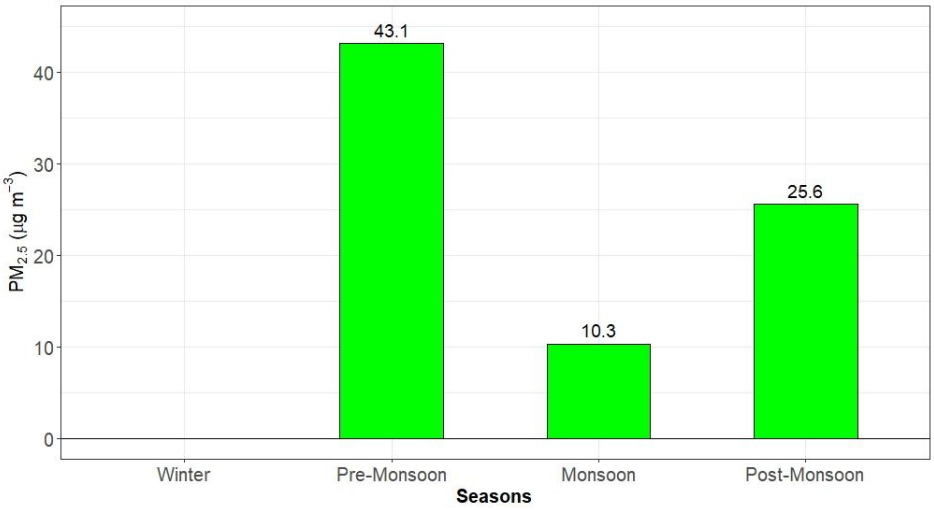

Figure A4-22: Seasonal Average of $PM_{2.5}$ for Dhankuta Station

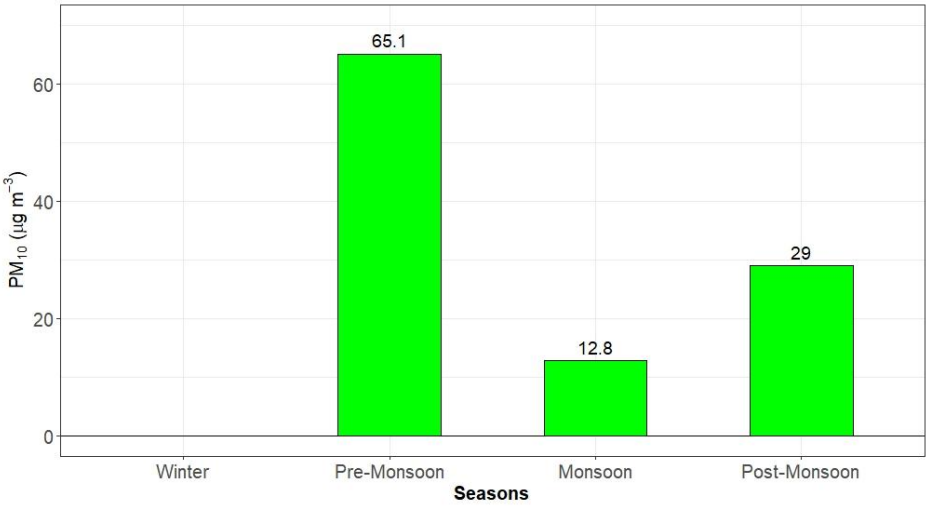

Figure A4-23: Seasonal Average of PM_{10} for Dhankuta Station

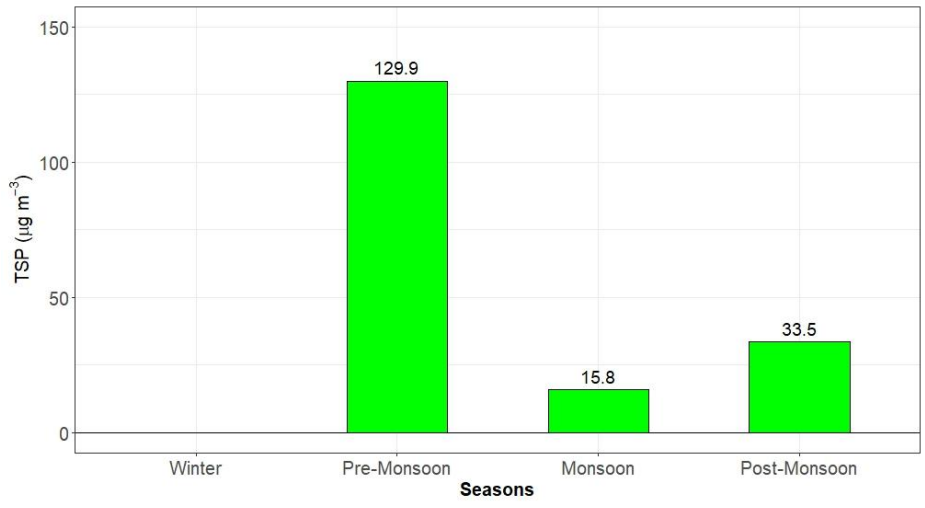

Figure A4-24: Seasonal Average of TSP for Dhankuta Station

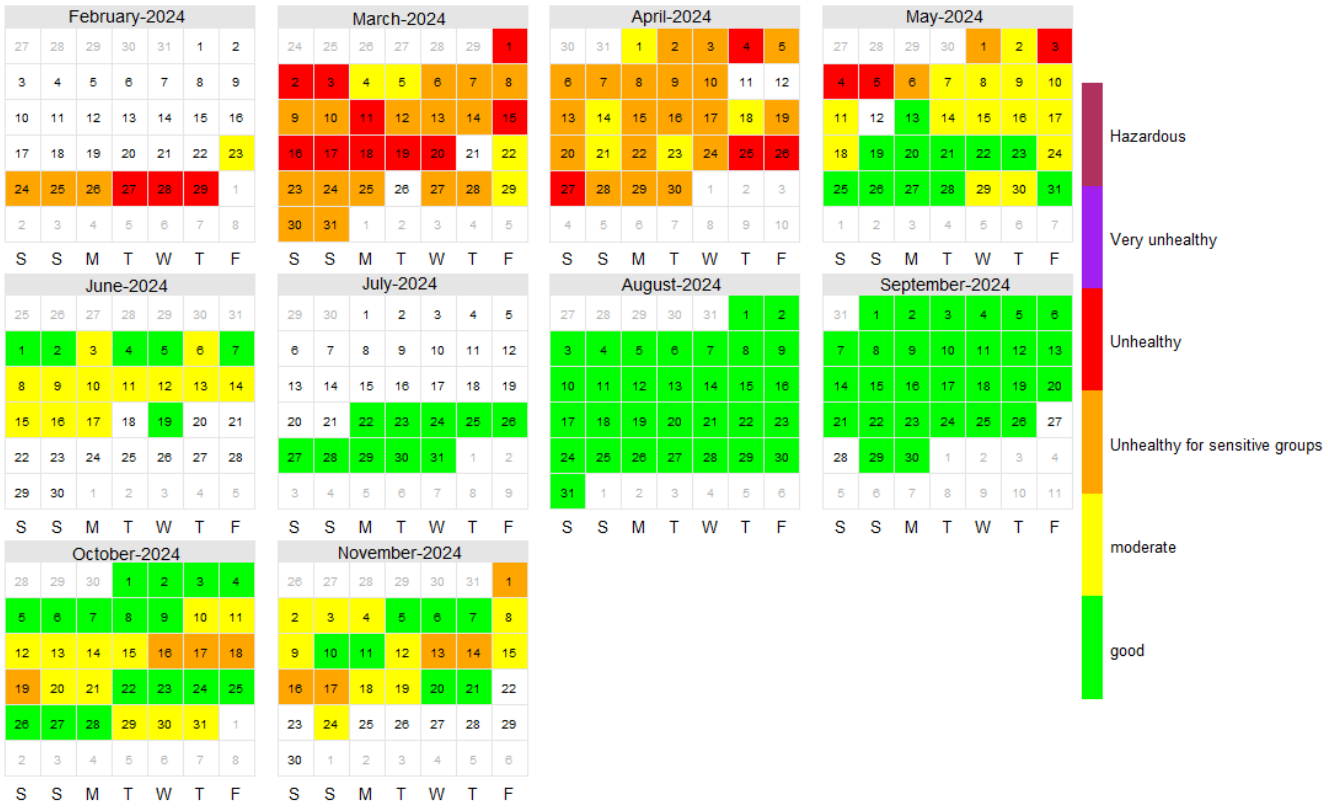

Figure A4-25: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Dhankuta Station

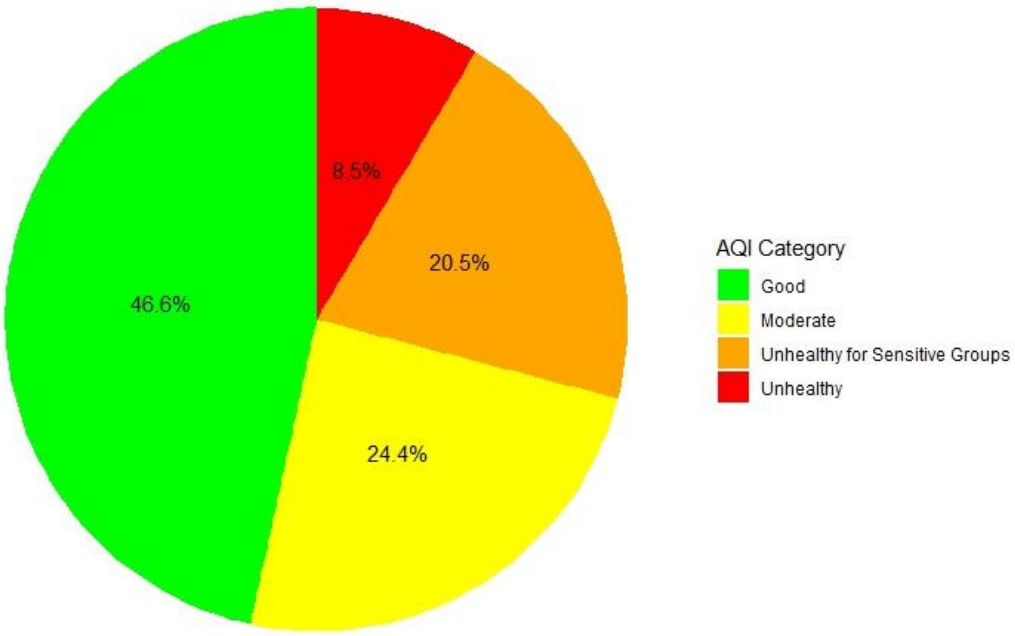

Figure A4-26: AQI Category Distribution for Dhankuta Station

ILAM AIR QUALITY MONITORING STATION

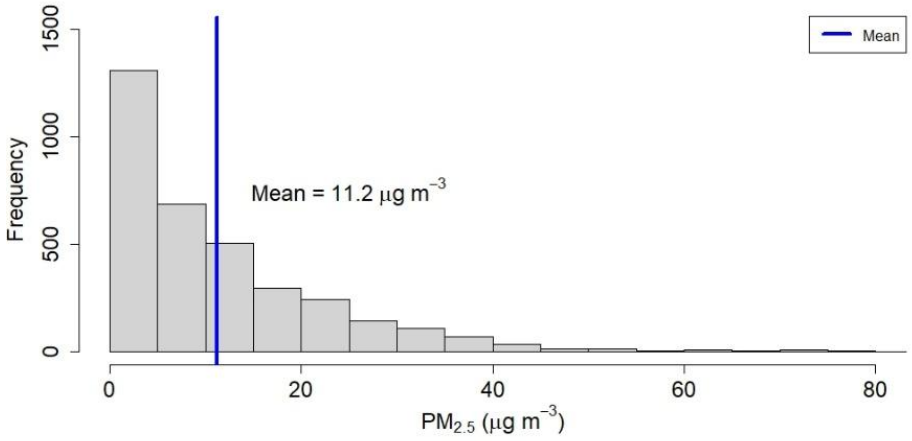

Figure A4-27: Histogram of $PM_{2.5}$ for Ilam Station

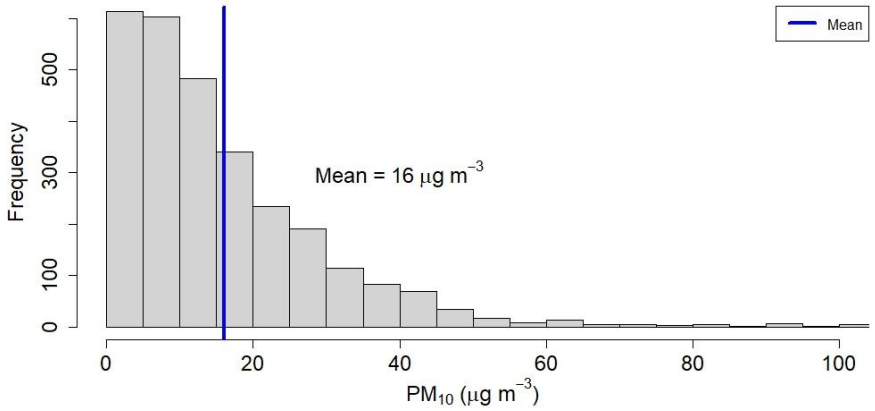

Figure A4-28: Histogram of PM_{10} for Ilam Station

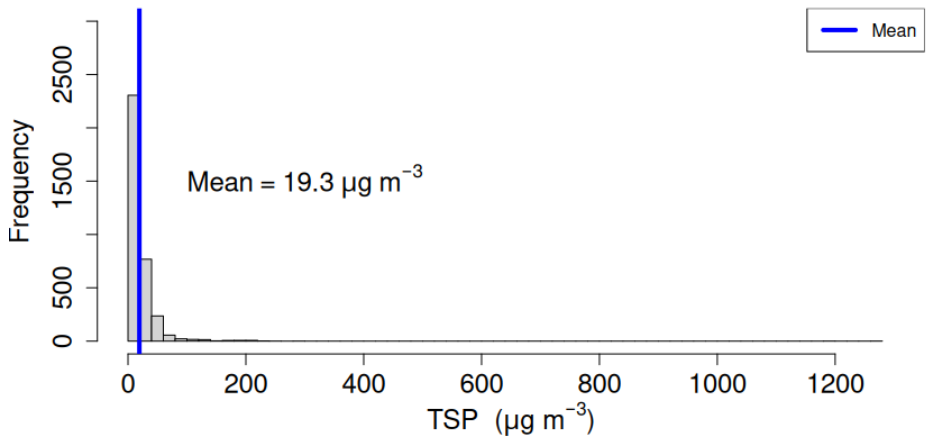

Figure A4-29: Histogram of TSP for Ilam Station

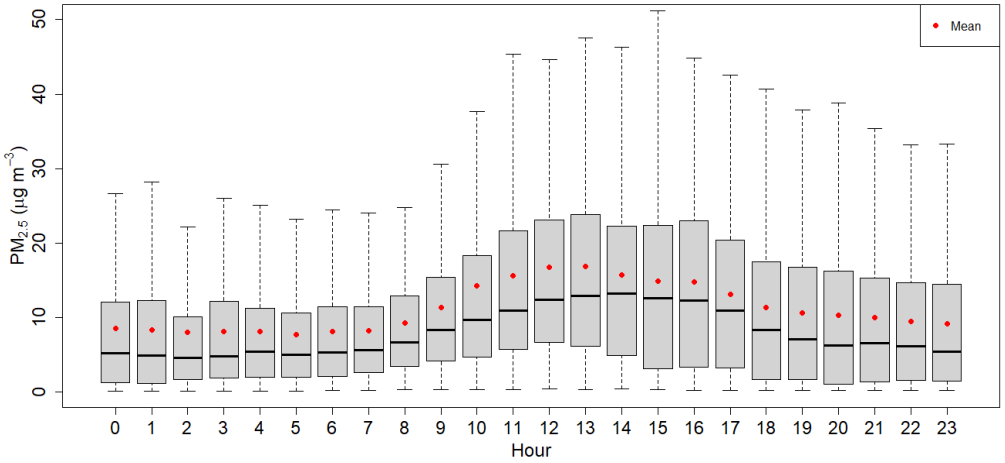

Figure A4-30: Diurnal Variation of $PM_{2.5}$ for Ilam Station

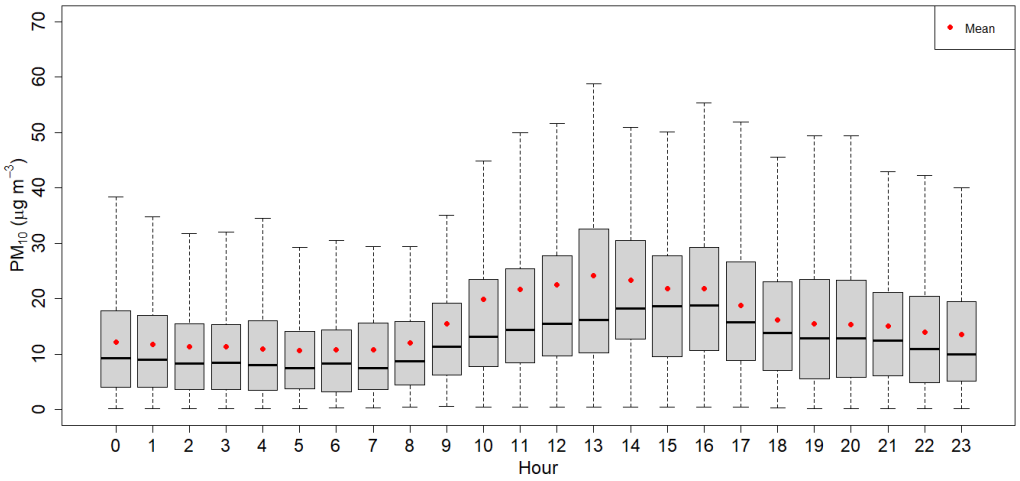

Figure A4-31: Diurnal Variation of PM_{10} for Ilam Station

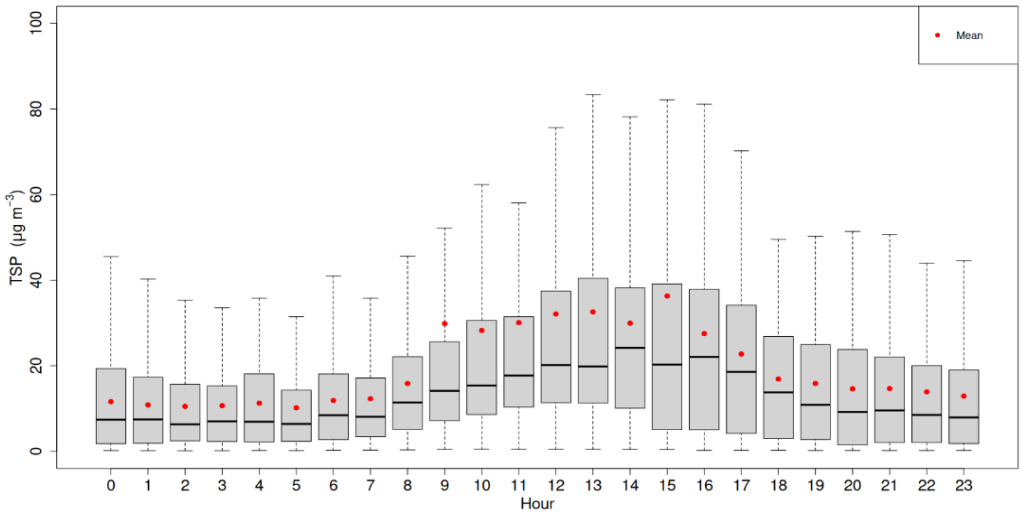

Figure A4-32: Diurnal Variation of TSP for Ilam Station

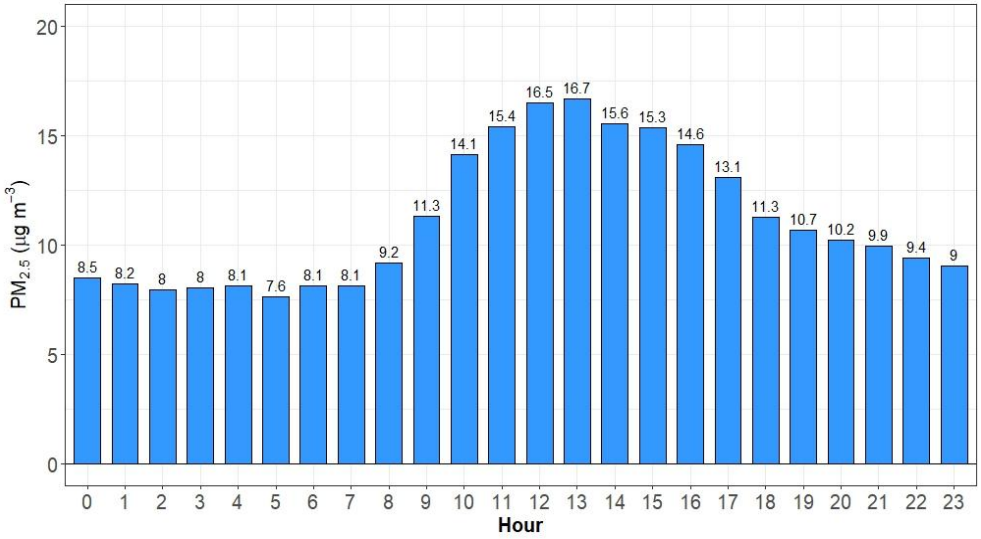

Figure A4-33: Hourly Average of $PM_{2.5}$ for Ilam Station

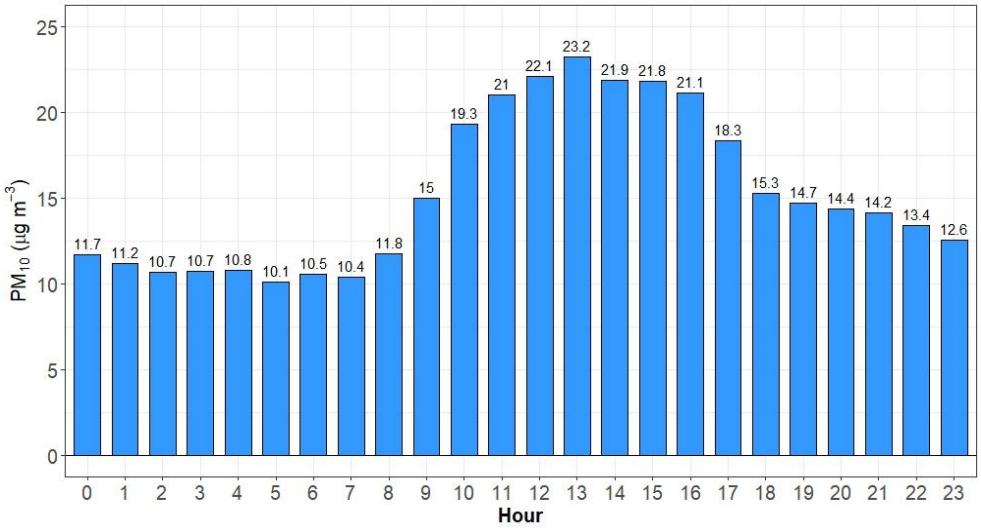

Figure A4-34: Hourly Average of PM_{10} for Ilam Station

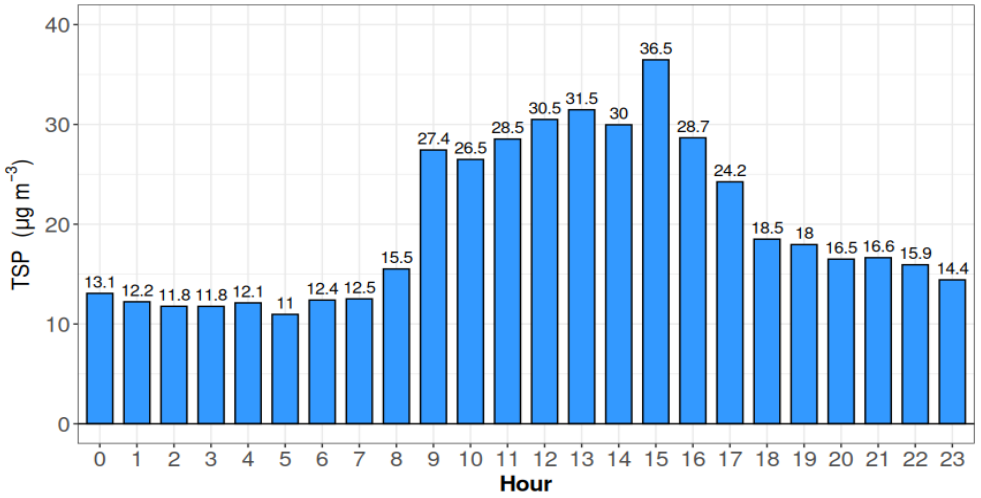

Figure A4-35: Hourly Average of TSP for Ilam Station

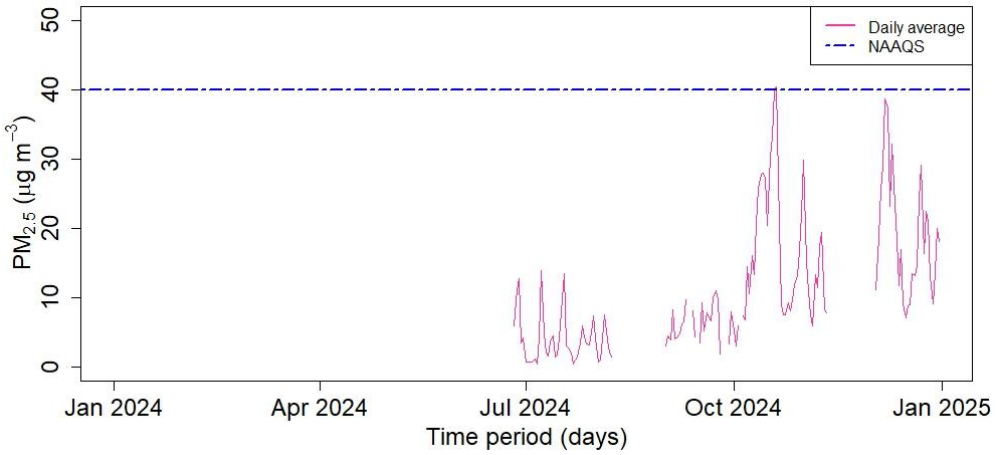

Figure A4-36: Daily Average of $PM_{2.5}$ for Ilam Station

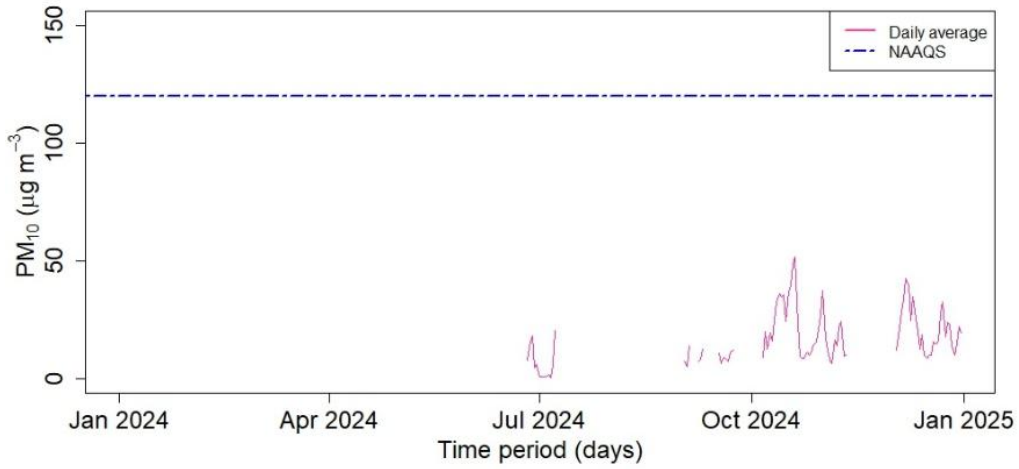

Figure A4-37: Daily Average of PM_{10} for Ilam Station

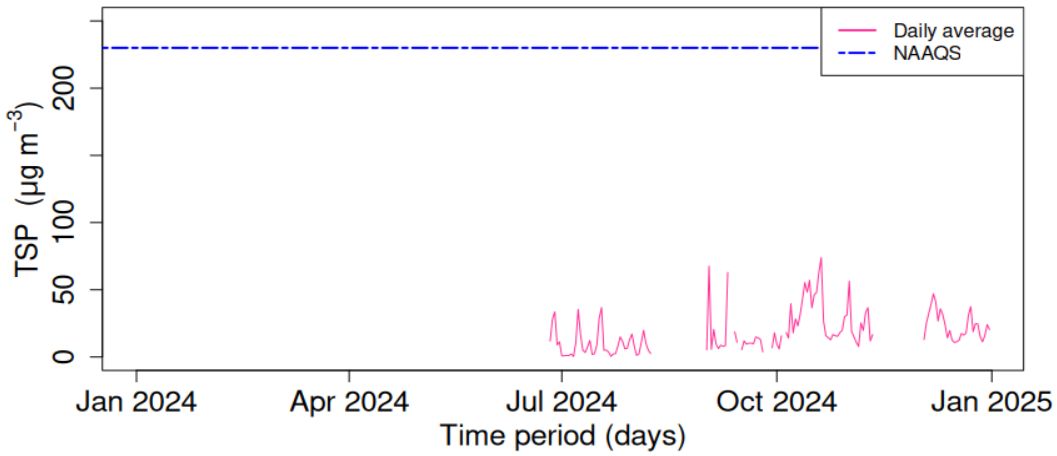

Figure A4-38: Daily Average of TSP for Ilam Station

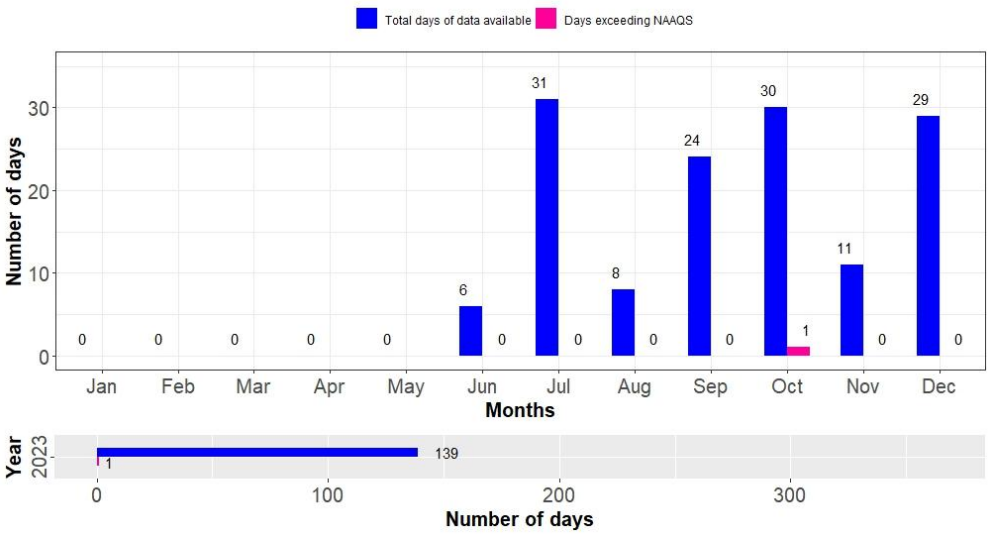

Figure A4-39: Compliance Status of $PM_{2.5}$ for Ilam Station

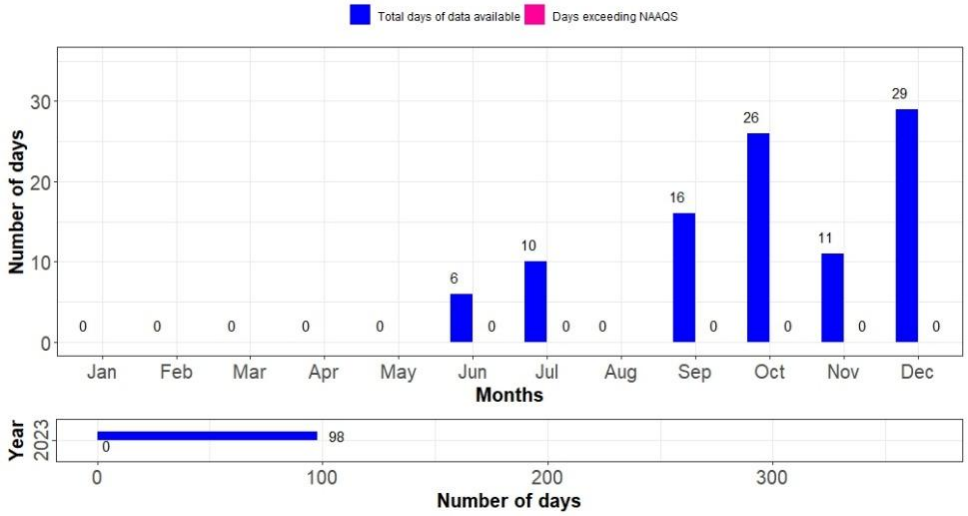

Figure A4-40: Compliance Status of PM_{10} for Ilam Station

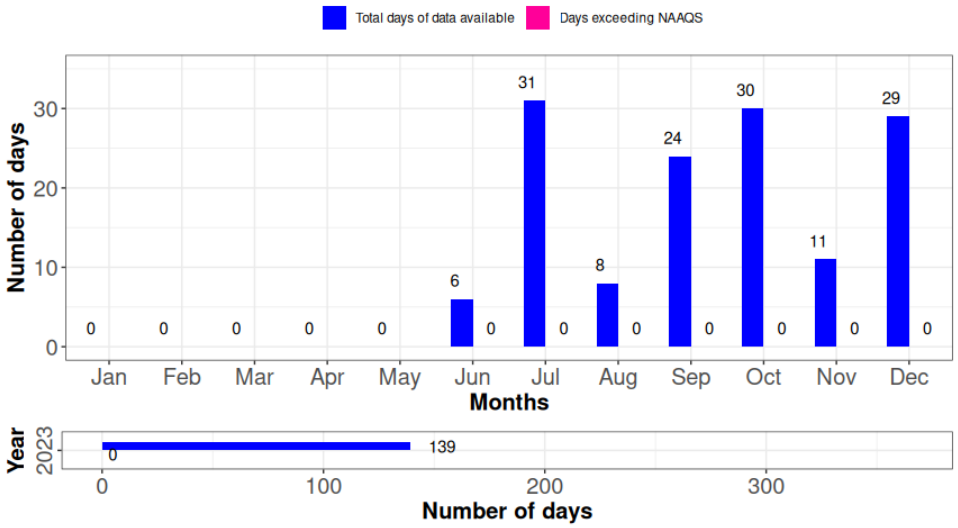

Figure A4-41: Compliance Status of TSP for Ilam Station

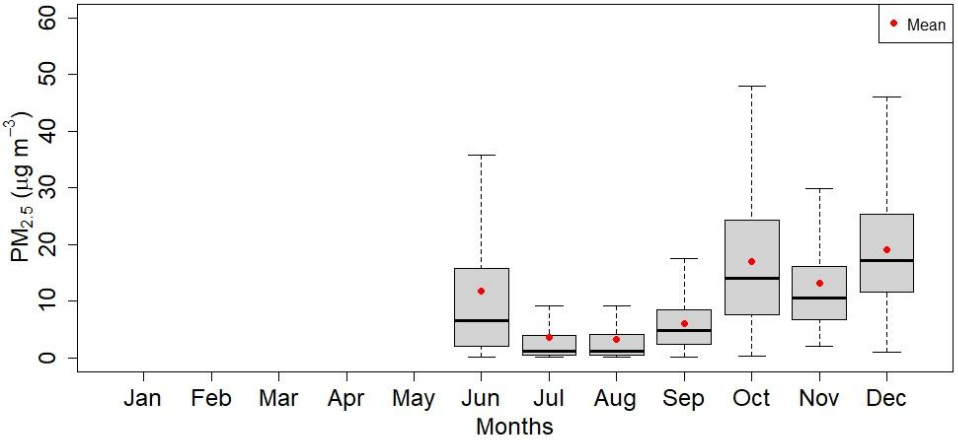

Figure A4-42: Monthly Variation of $PM_{2.5}$ for Ilam Station

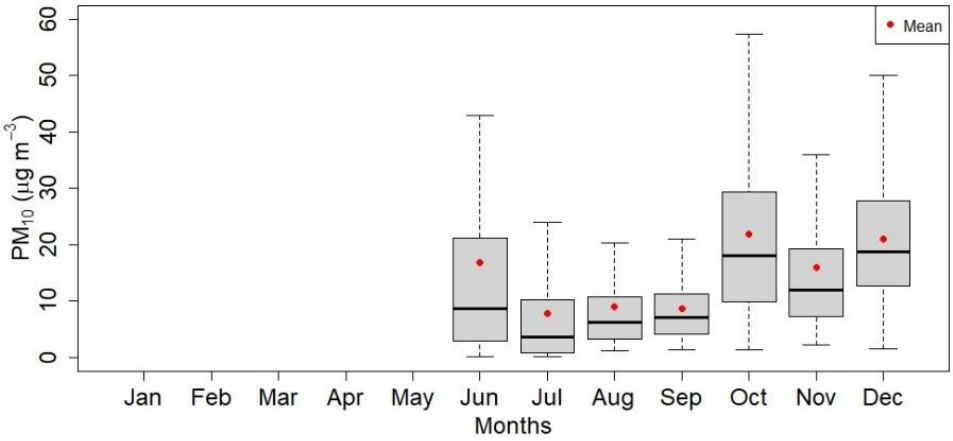

Figure A4-43: Monthly Variation of PM_{10} for Ilam Station

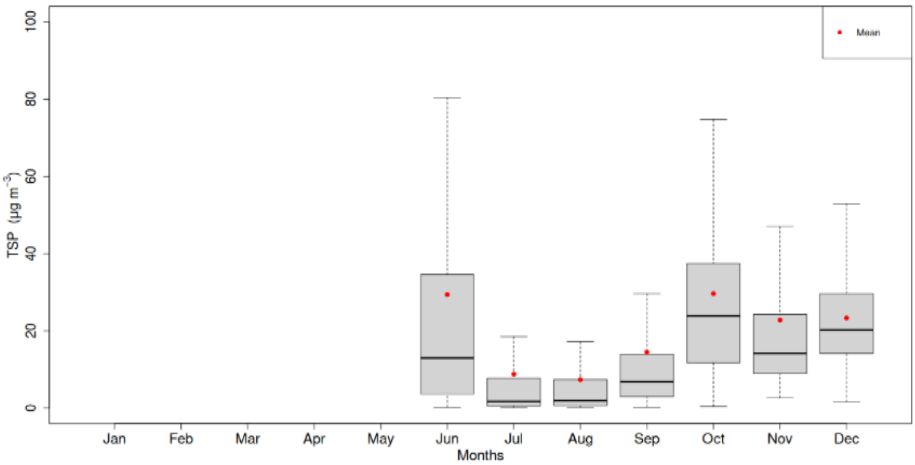

Figure A4-44: Monthly Variation of TSP for Ilam Station

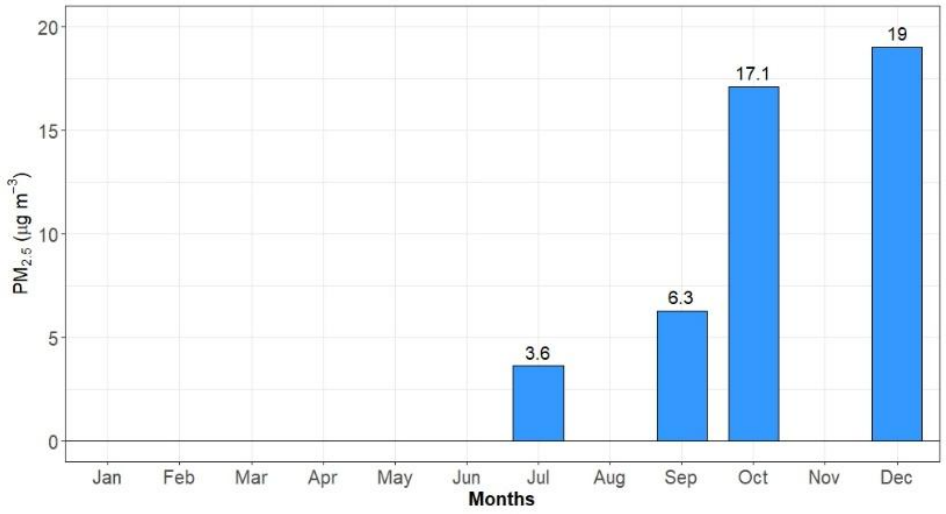

Figure A4-45: Monthly Average of $PM_{2.5}$ for Ilam Station

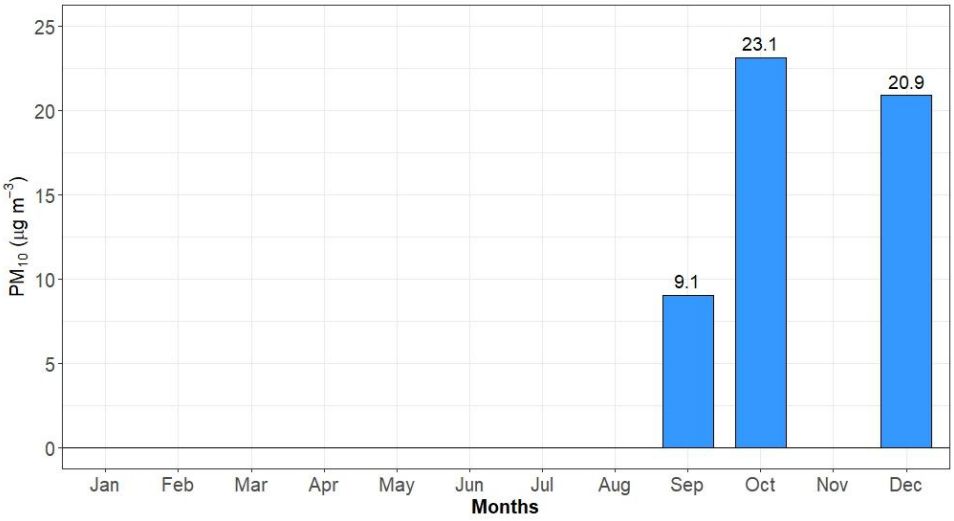

Figure A4-46: Monthly Average of PM_{10} for Ilam Station

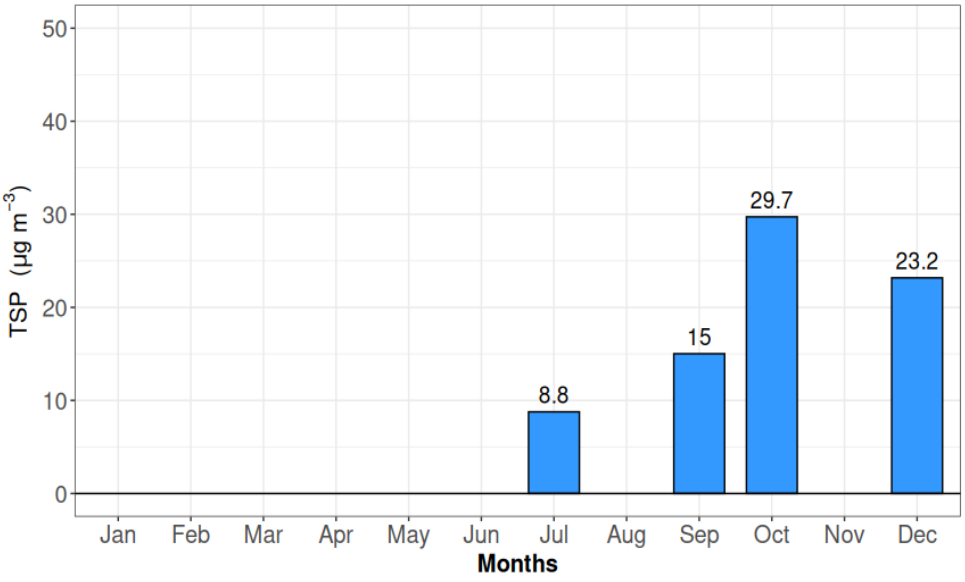

Figure A4-47: Monthly Average of TSP for Ilam Station

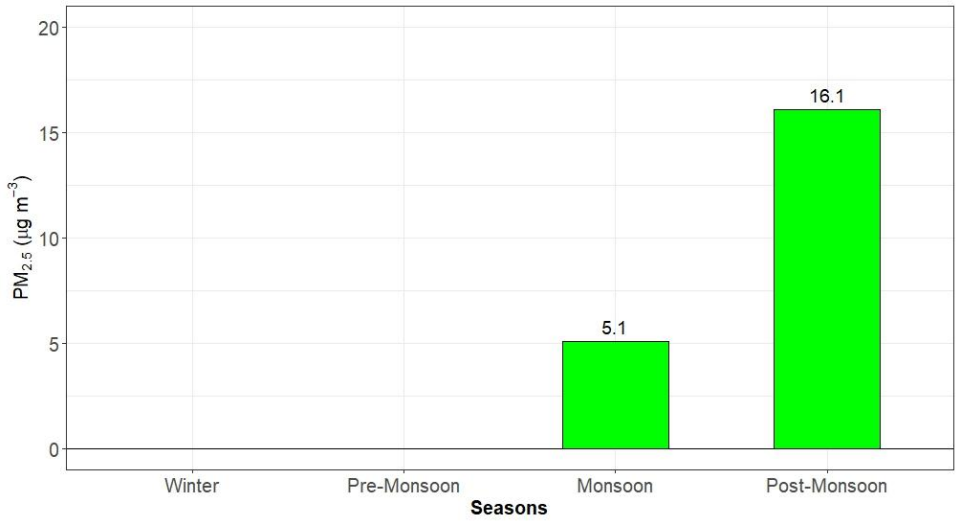

Figure A4-48: Seasonal Average of $PM_{2.5}$ for Ilam Station

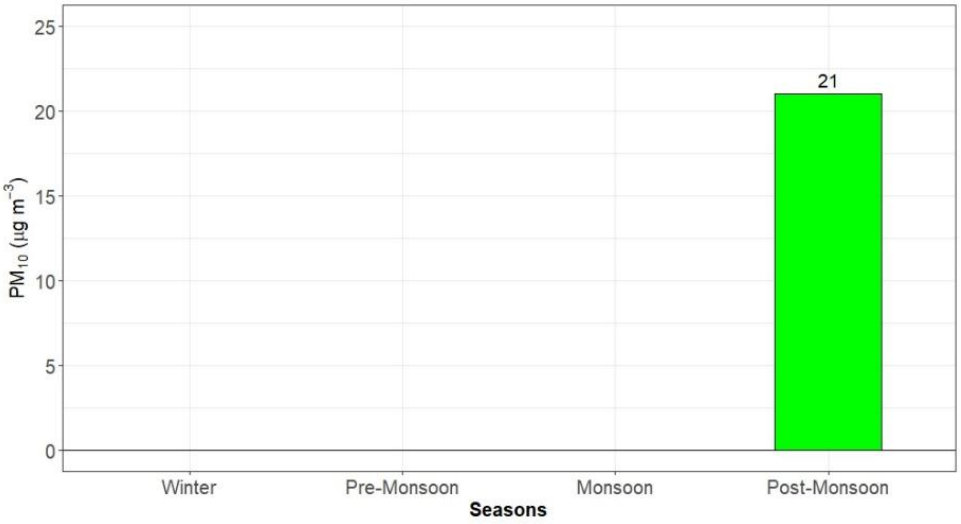

Figure A4-49: Seasonal Average of PM_{10} for Ilam Station

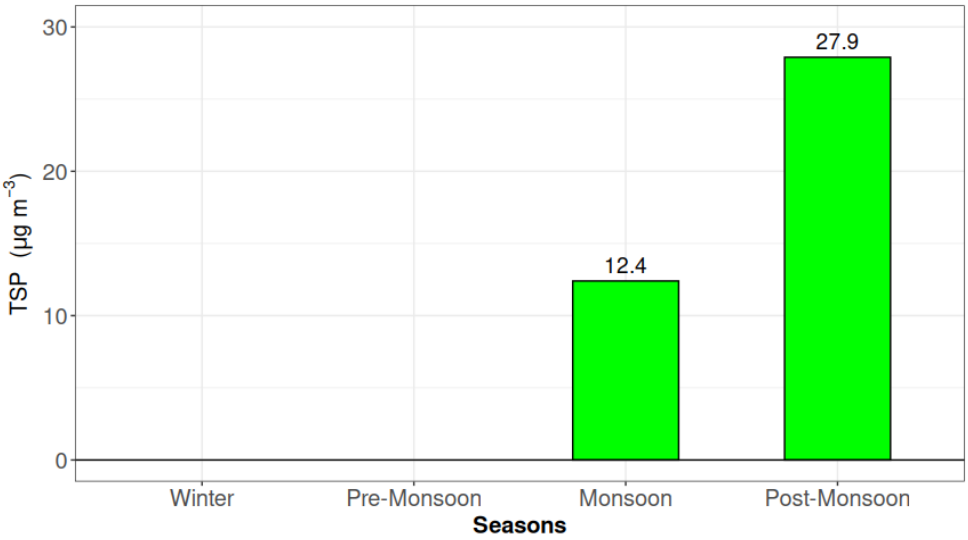

Figure A4-50: Seasonal Average of TSP for Ilam Station

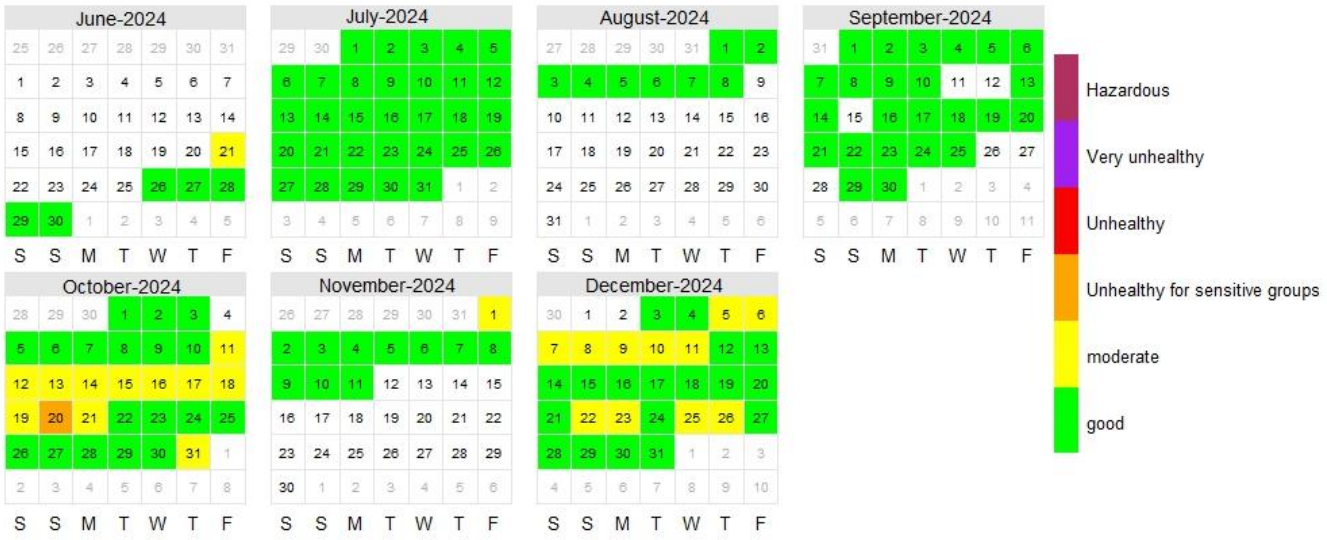

Figure A4-51: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Ilam Station

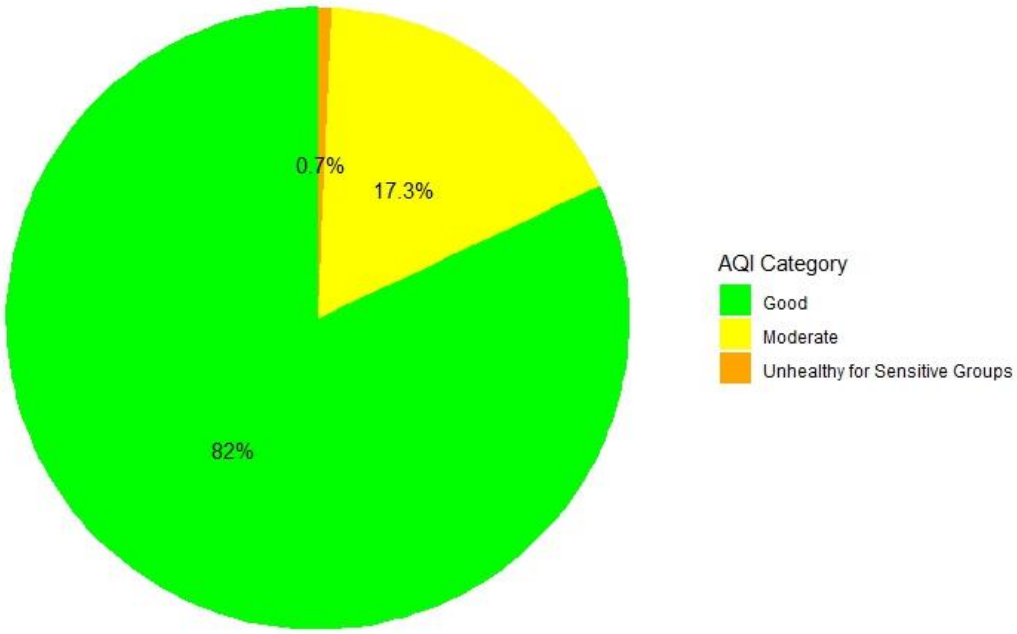

Figure A4-52: AQI Category Distribution for Ilam Station

JANAKPUR AIR QUALITY MONITORING STATION

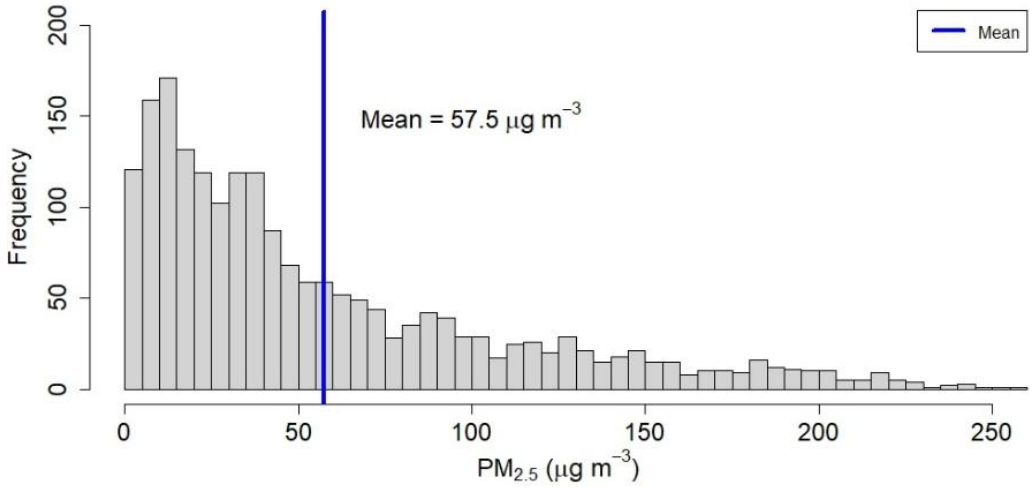

Figure A4-53: Histogram of $PM_{2.5}$ for Janakpur Station

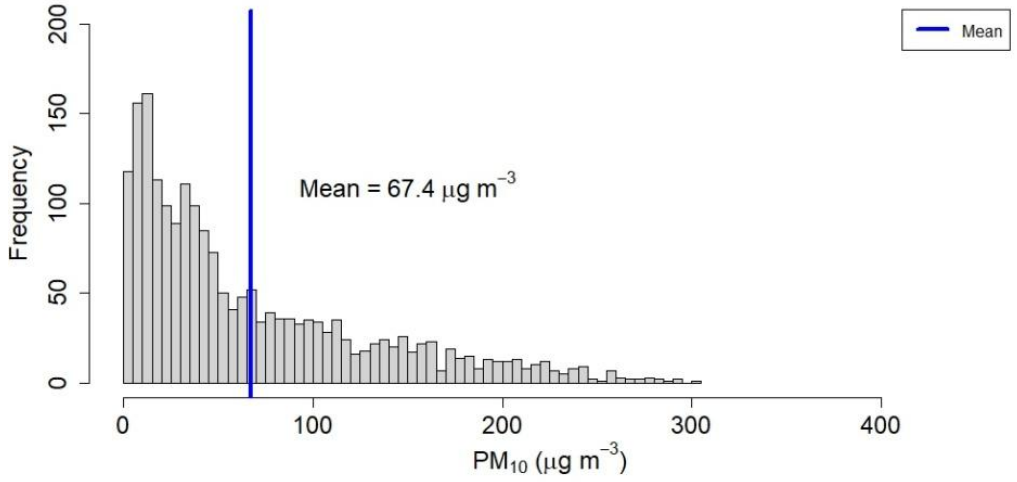

Figure A4-54: Histogram of PM_{10} for Janakpur Station

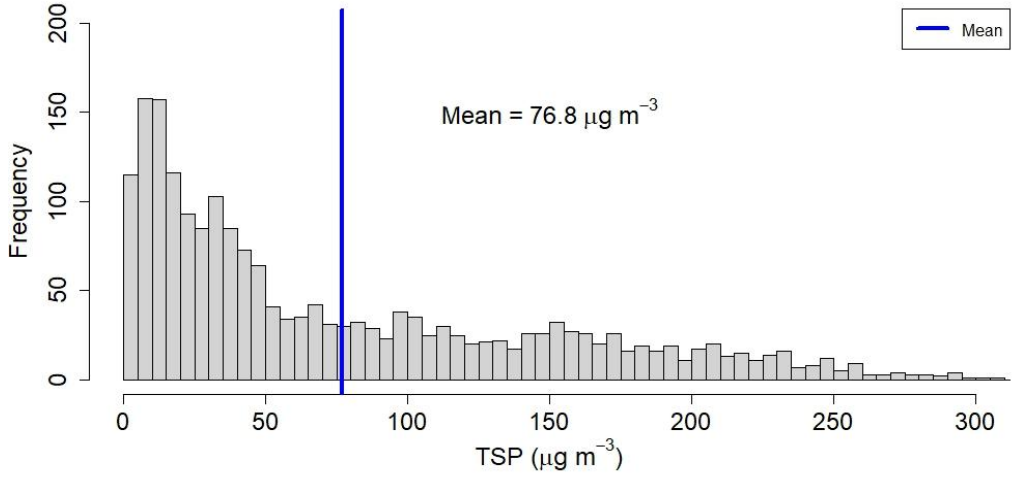

Figure A4-55: Histogram of TSP for Janakpur Station

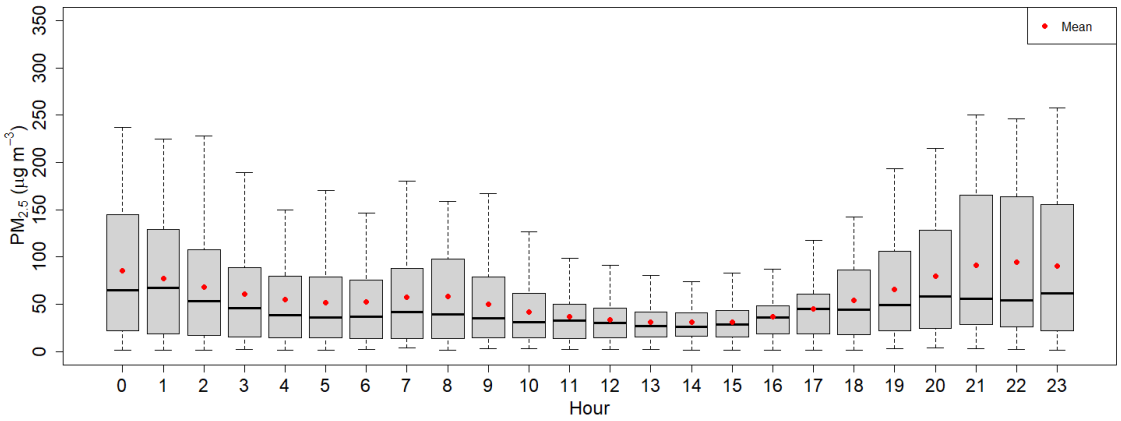

Figure A4-56: Diurnal Variation of $PM_{2.5}$ for Janakpur Station

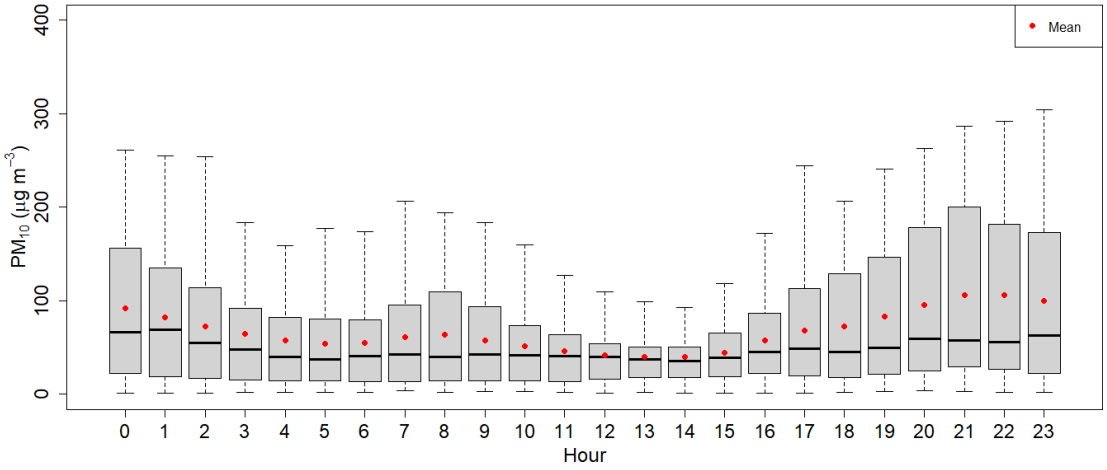

Figure A4-57: Diurnal Variation of PM_{10} for Janakpur Station

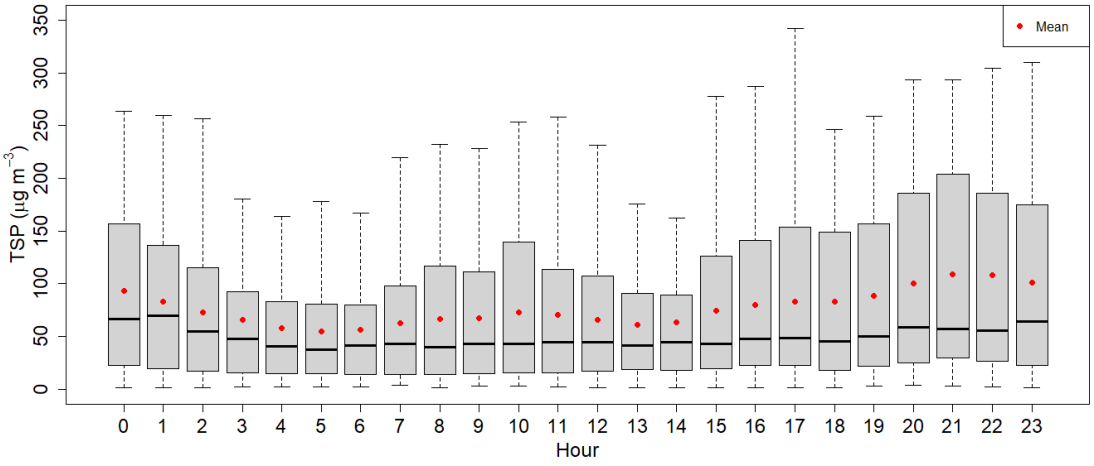

Figure A4-58: Diurnal Variation of TSP for Janakpur Station

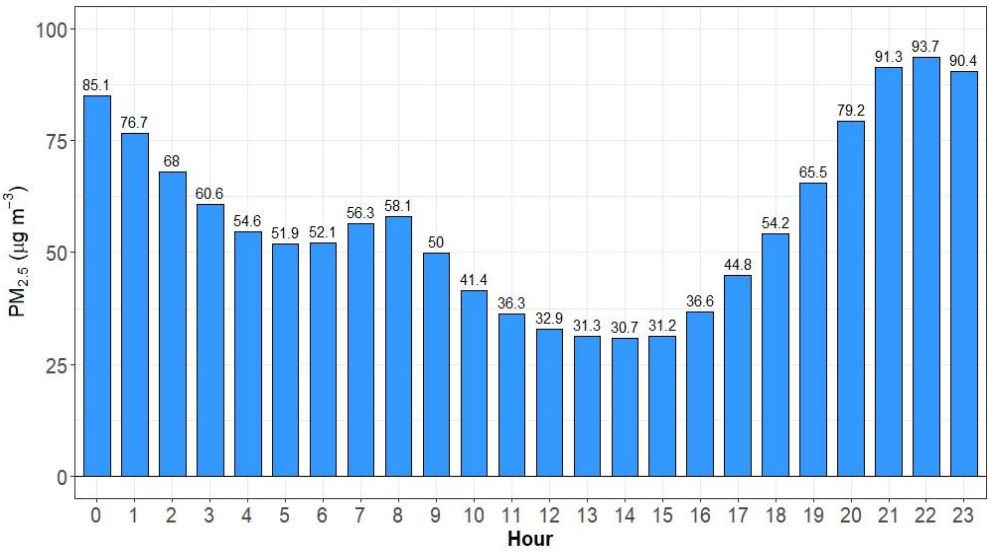

Figure A4-59: Hourly Average of $PM_{2.5}$ for Janakpur Station

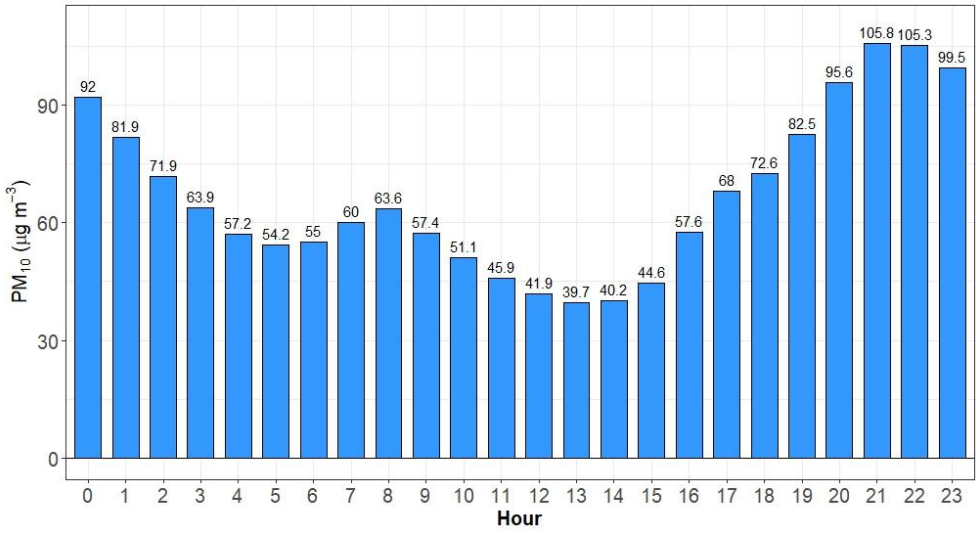

Figure A4-60: Hourly Average of PM_{10} for Janakpur Station

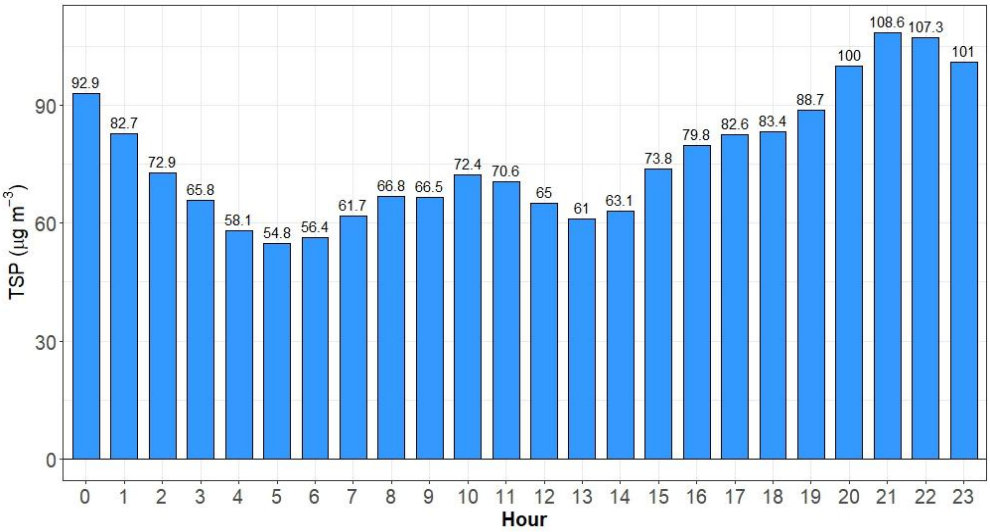

Figure A4-61: Hourly Average of TSP for Janakpur Station

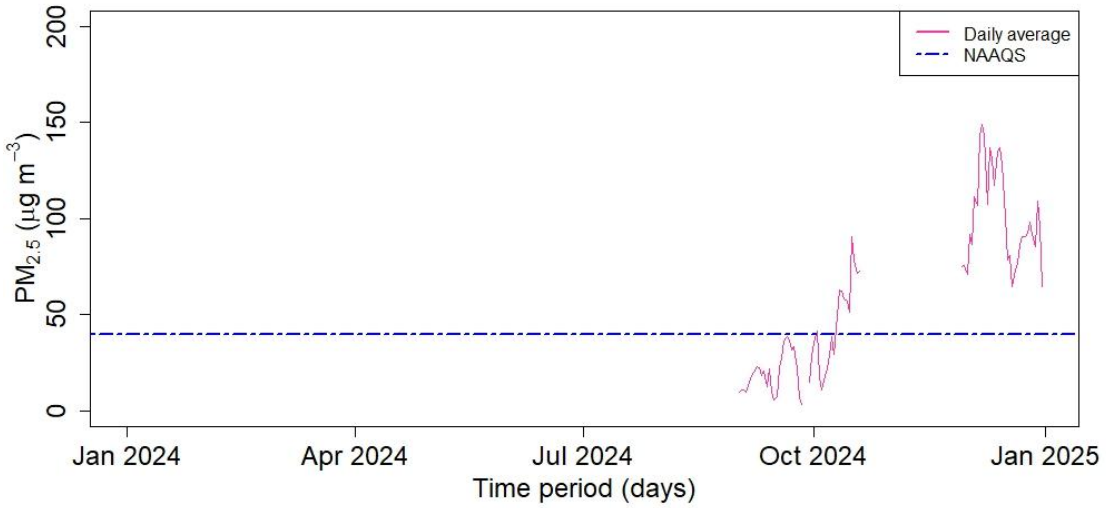

Figure A4-62: Daily Average of $PM_{2.5}$ for Janakpur Station

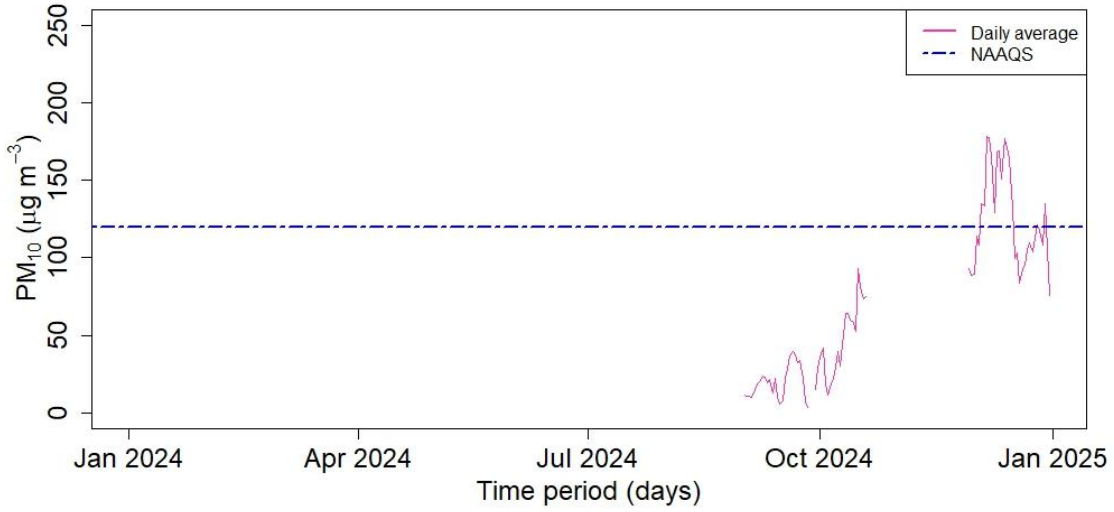

Figure A4-63: Daily Average of PM_{10} for Janakpur Station

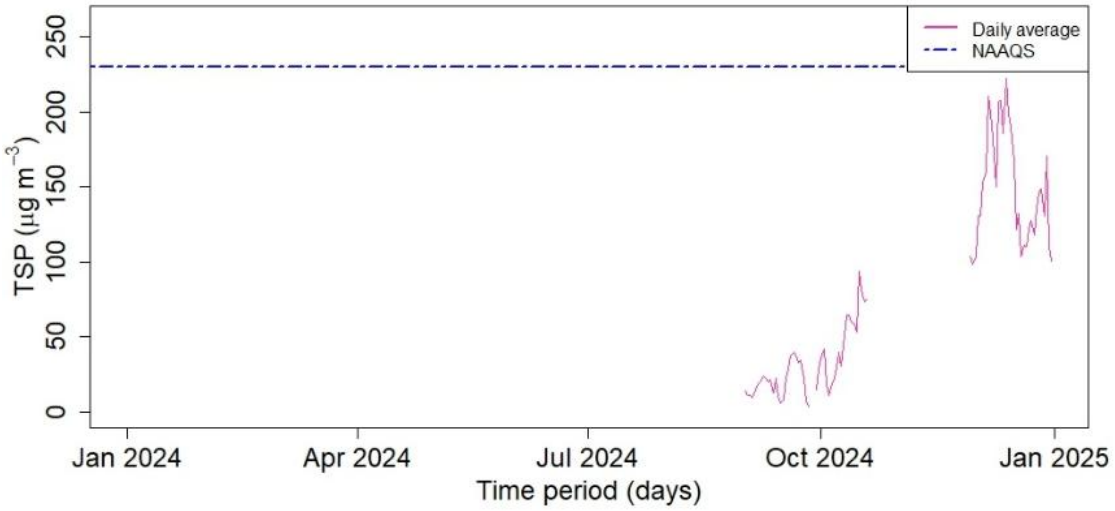

Figure A4-64: Daily Average of TSP for Janakpur Station

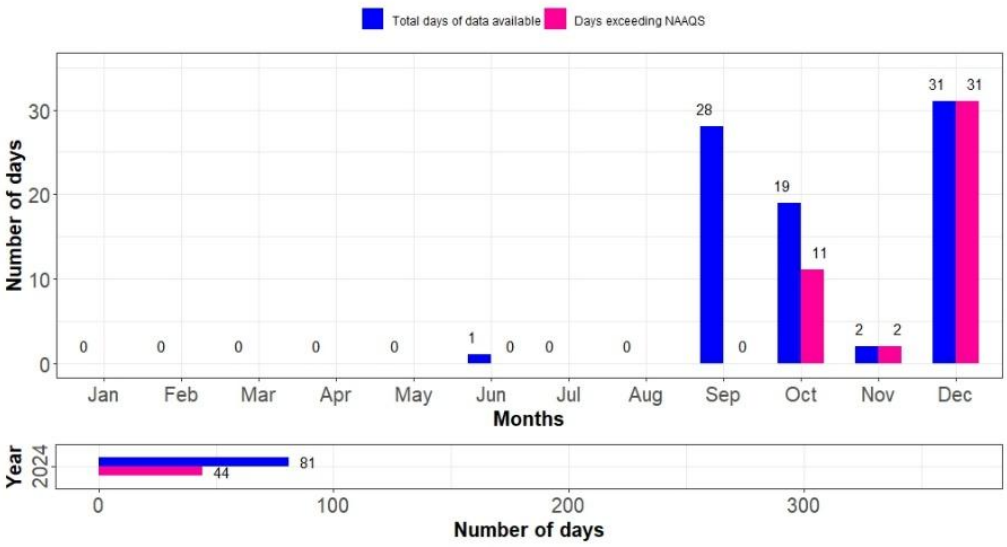

Figure A4-65: Compliance Status of $PM_{2.5}$ for Janakpur Station

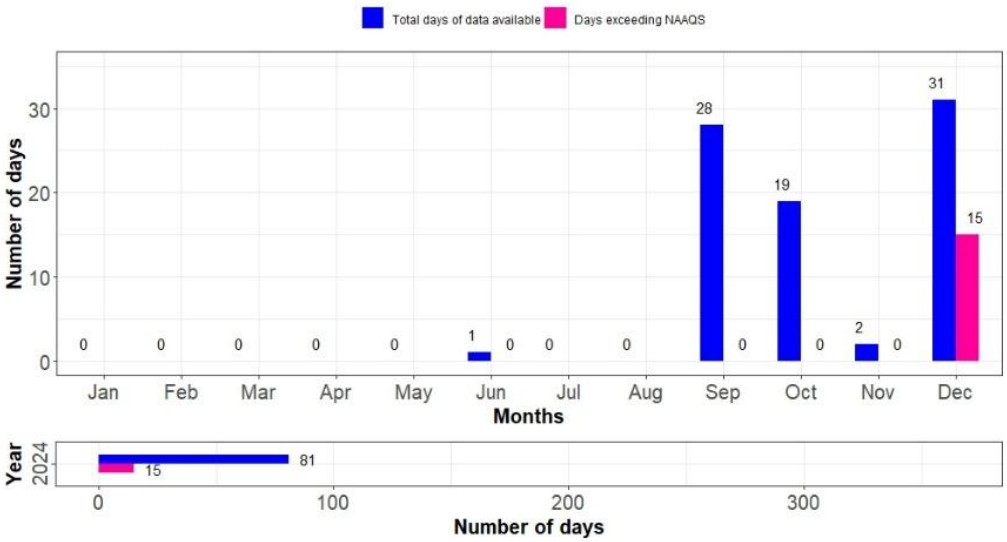

Figure A4-66: Compliance Status of PM_{10} for Janakpur Station

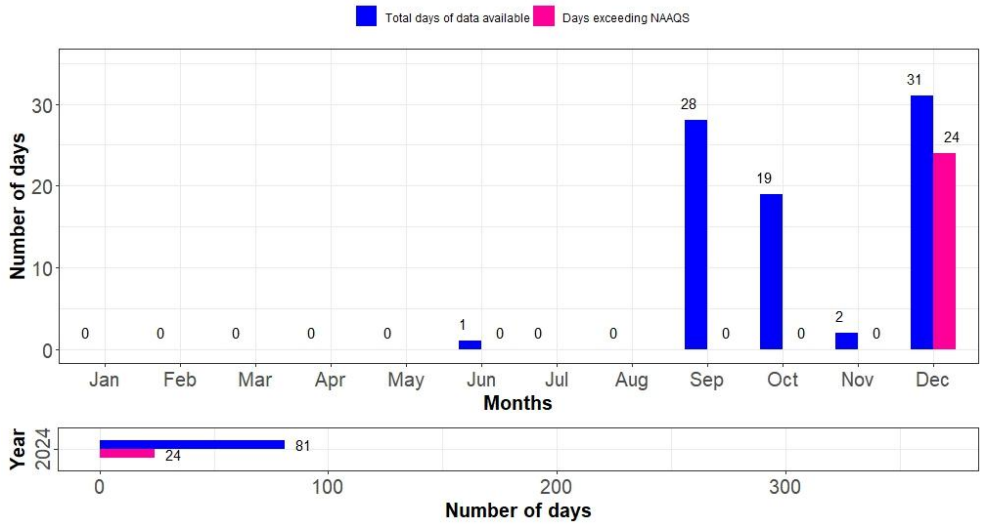

Figure A4-67: Compliance Status of TSP for Janakpur Station

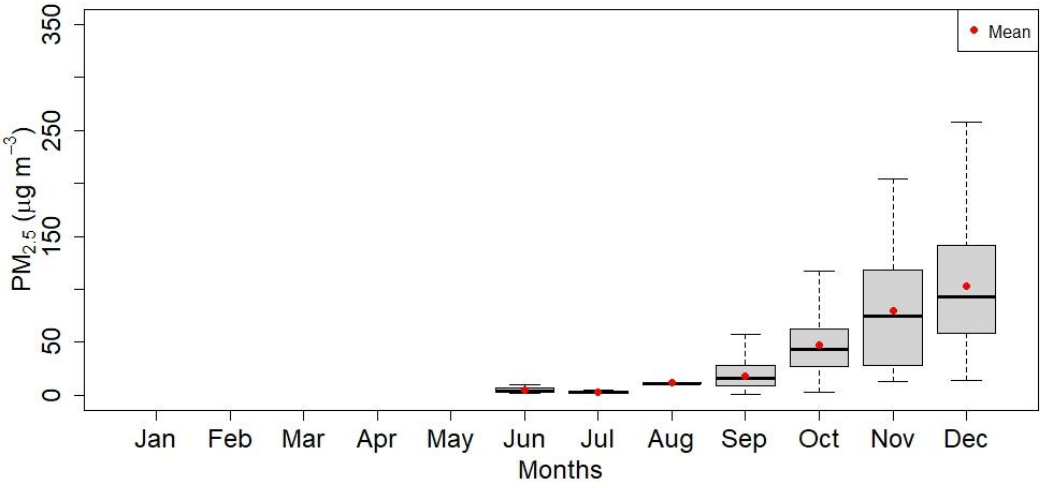

Figure A4-68: Monthly Variation of $PM_{2.5}$ for Janakpur Station

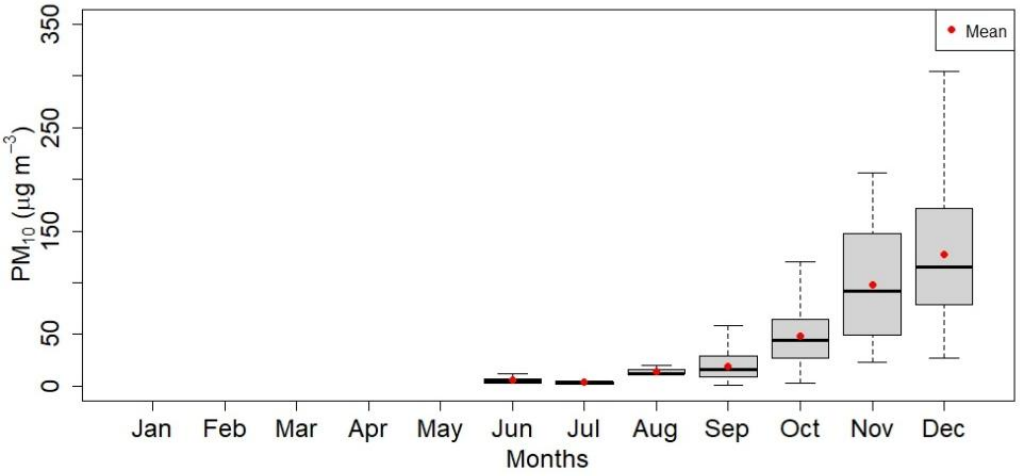

Figure A4-69: Monthly Variation of PM_{10} for Janakpur Station

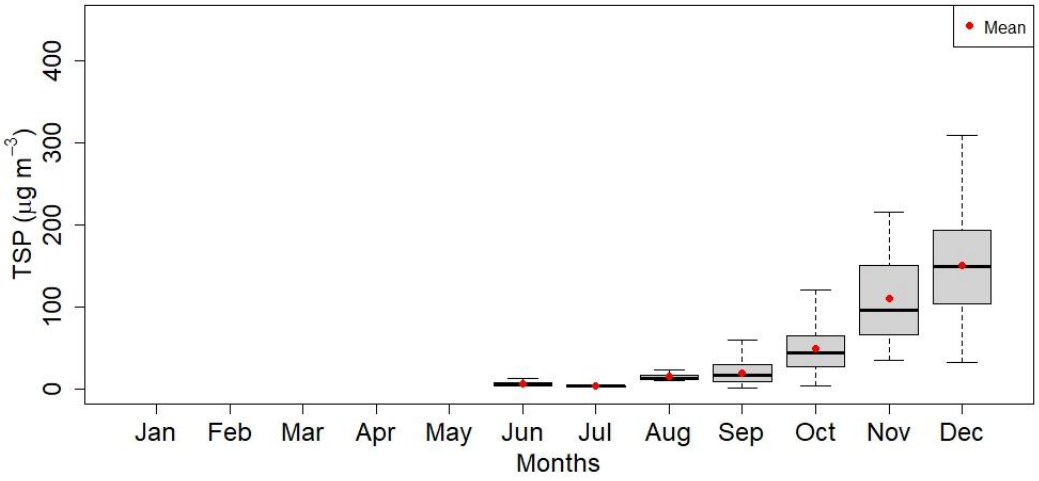

Figure A4-70: Monthly Variation of TSP for Janakpur Station

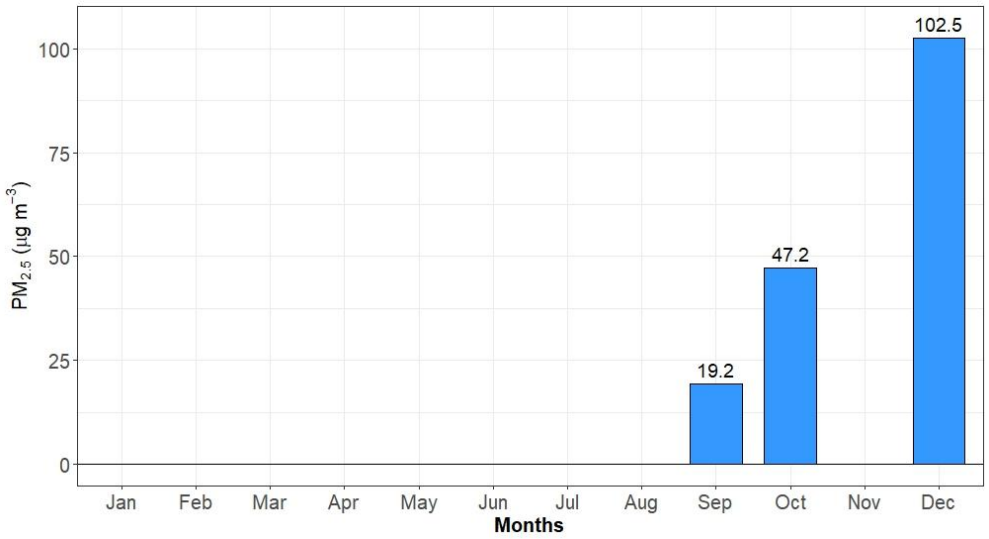

Figure A4-71: Monthly Average of $PM_{2.5}$ for Janakpur Station

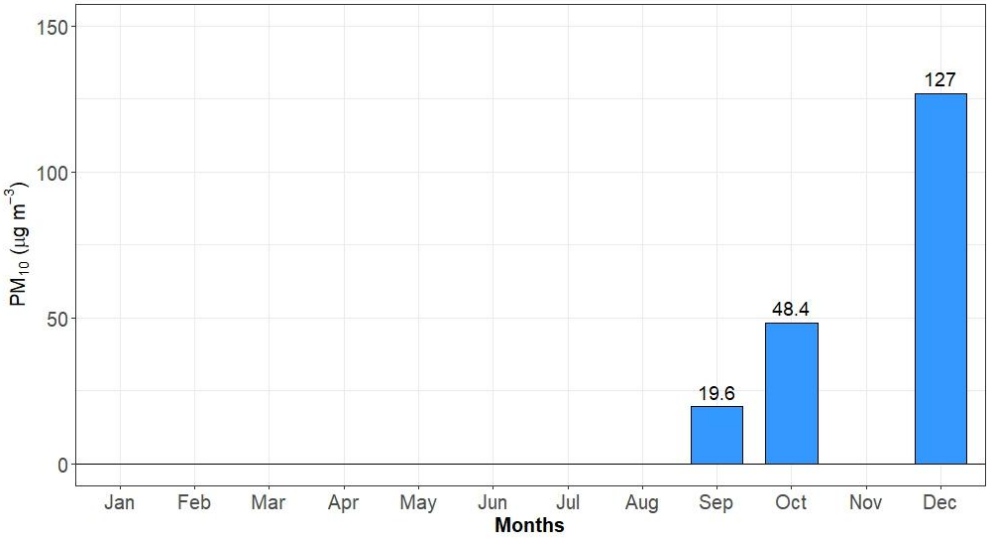

Figure A4-72: Monthly Average of PM_{10} for Janakpur Station

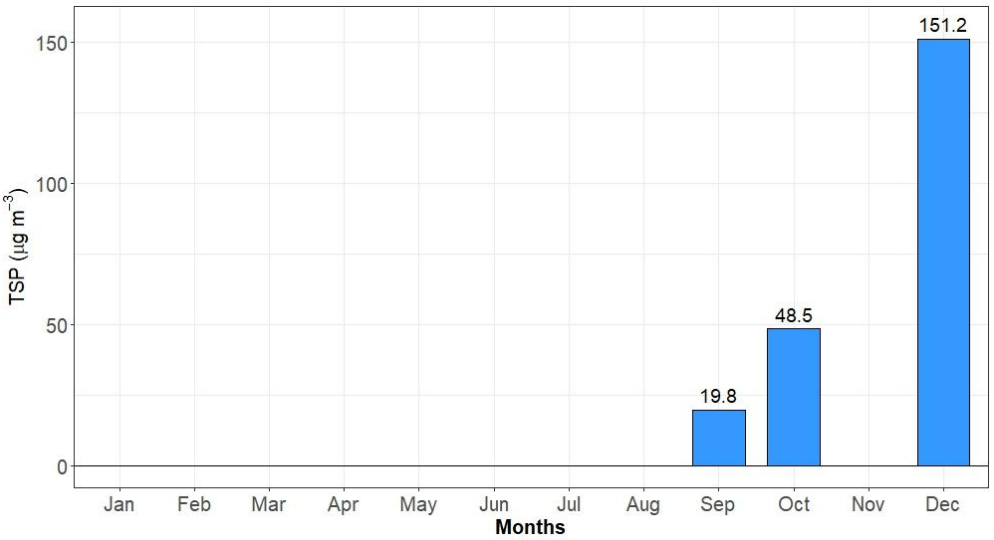

Figure A4-73: Monthly Average of TSP for Janakpur Station

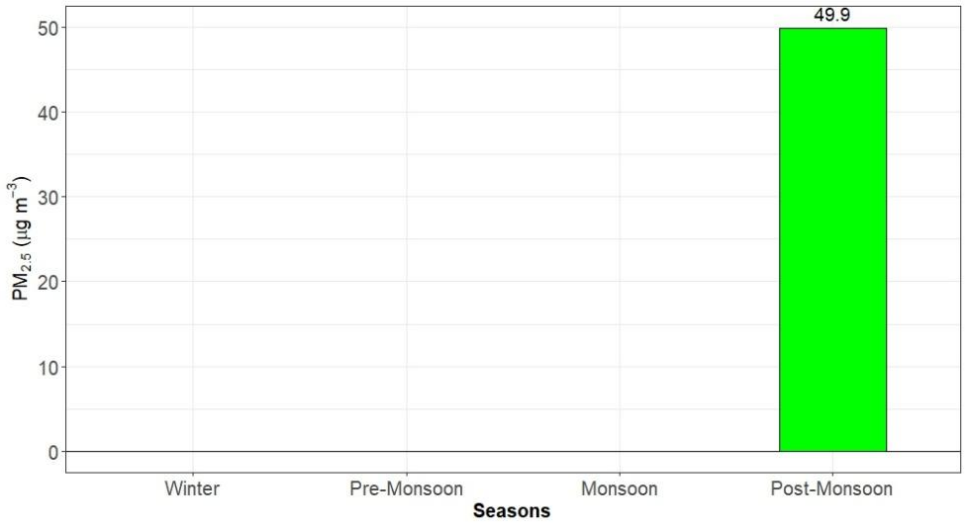

Figure A4-74: Seasonal Average of $PM_{2.5}$ for Janakpur Station

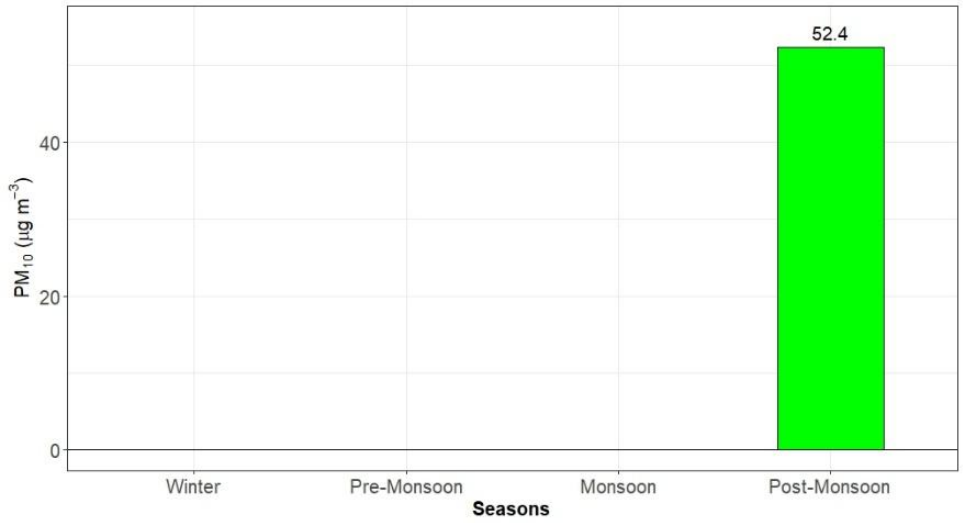

Figure A4-75: Seasonal Average of PM_{10} for Janakpur Station

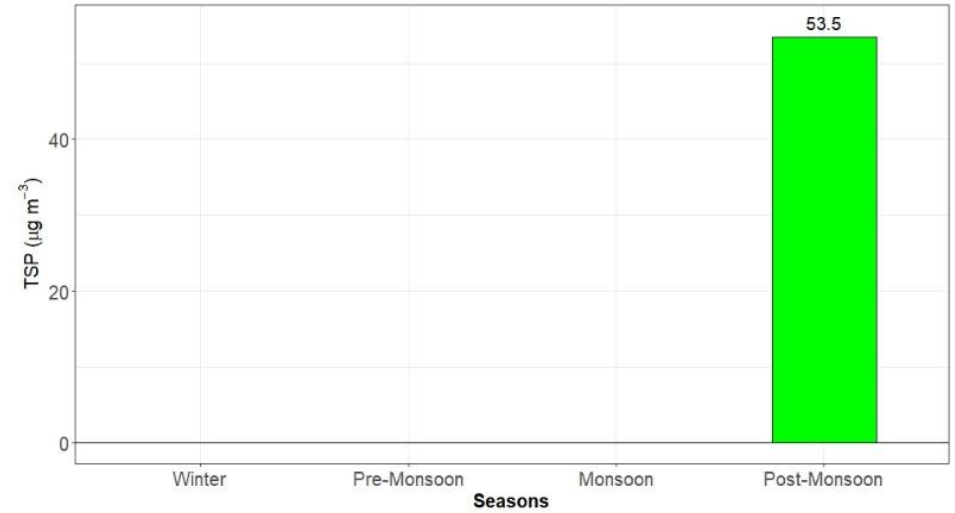

Figure A4-76: Seasonal Average of TSP for Janakpur Station

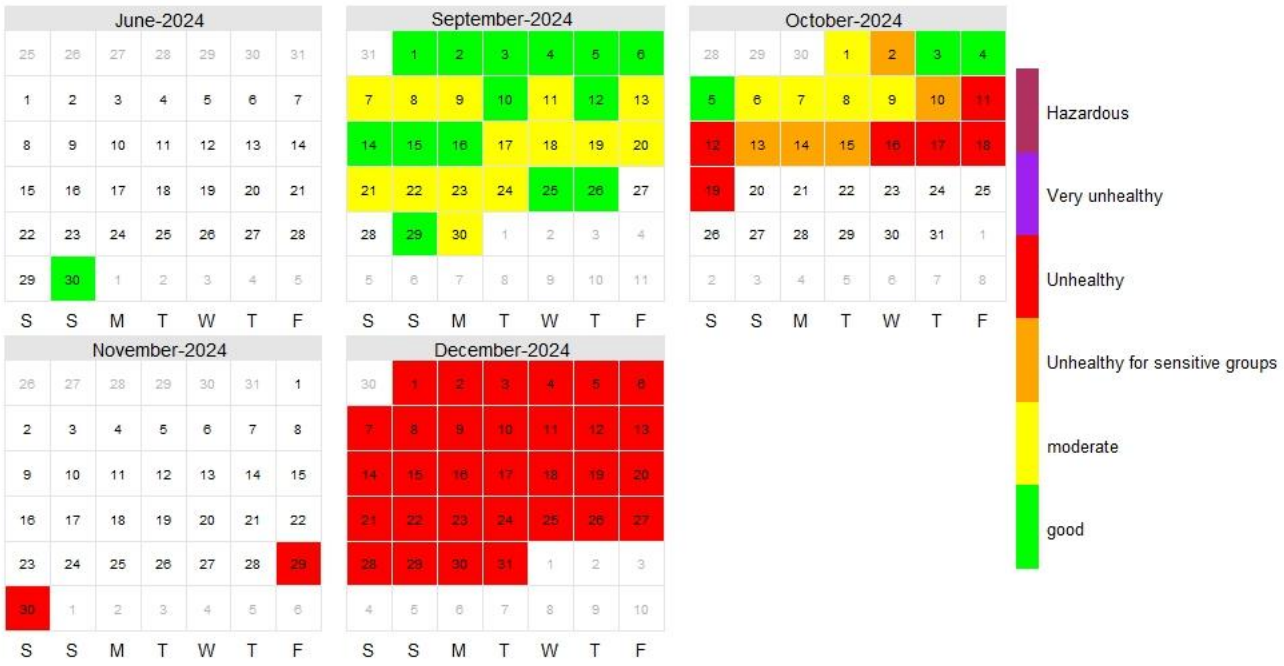

Figure A4-77: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Janakpur Station

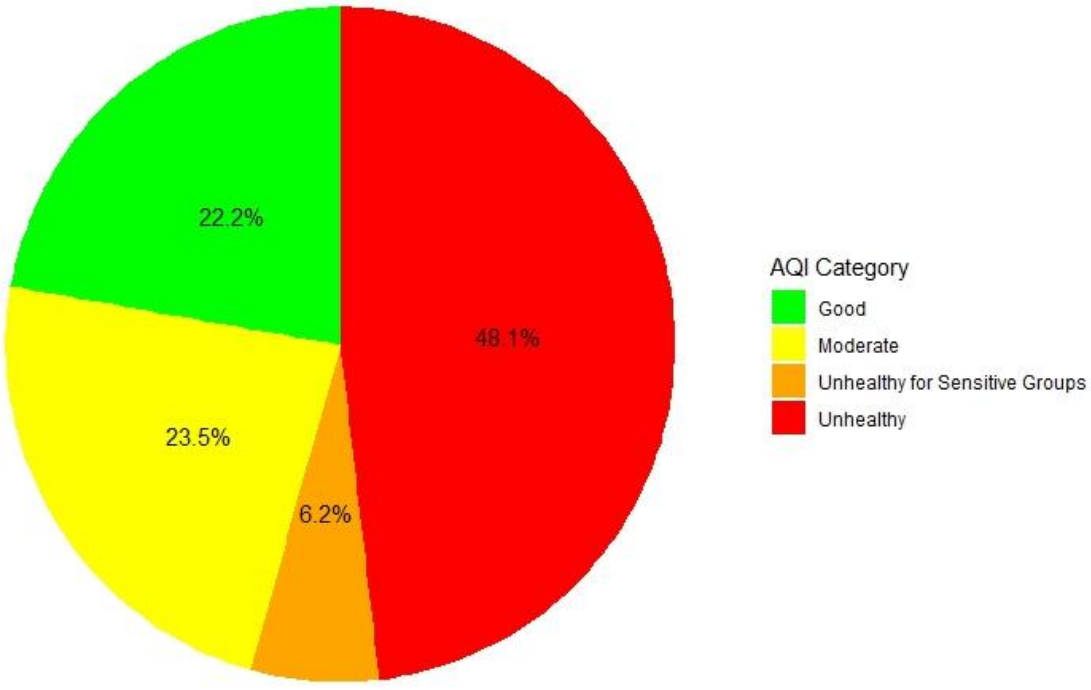

Figure A4-78: AQI Category Distribution for Janakpur Station

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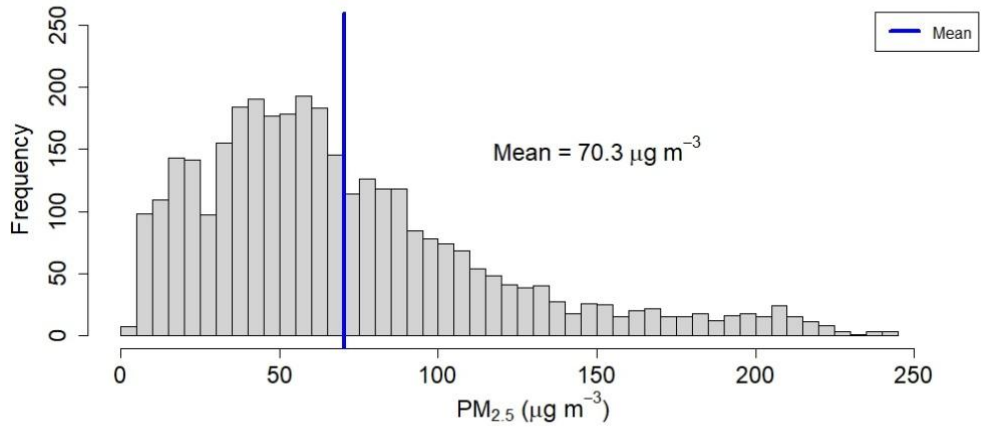

Figure A4-79: Histogram of $PM_{2.5}$ for Bhaisepati Station

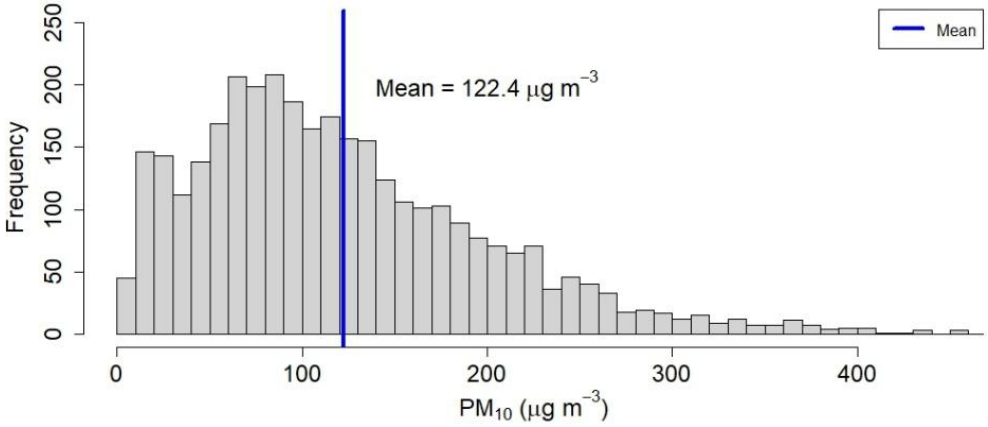

Figure A4-80: Histogram of PM_{10} for Bhaisepati Station

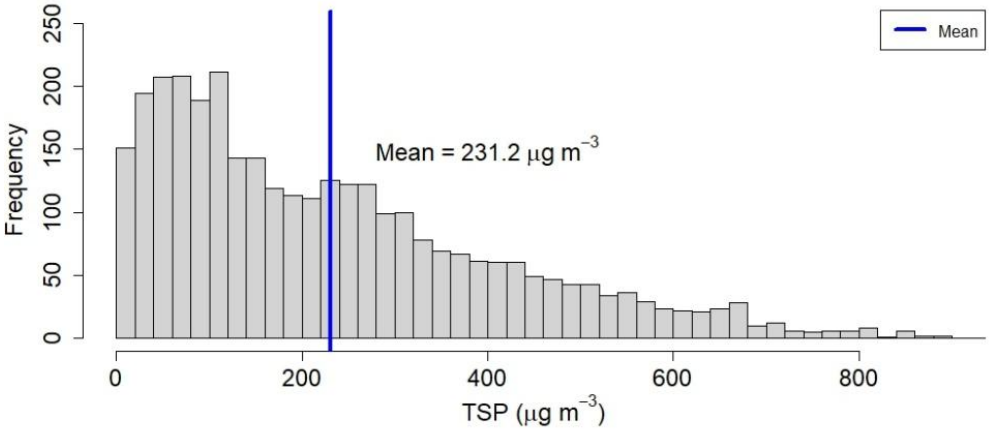

Figure A4-81: Histogram of TSP for Bhaisepati Station

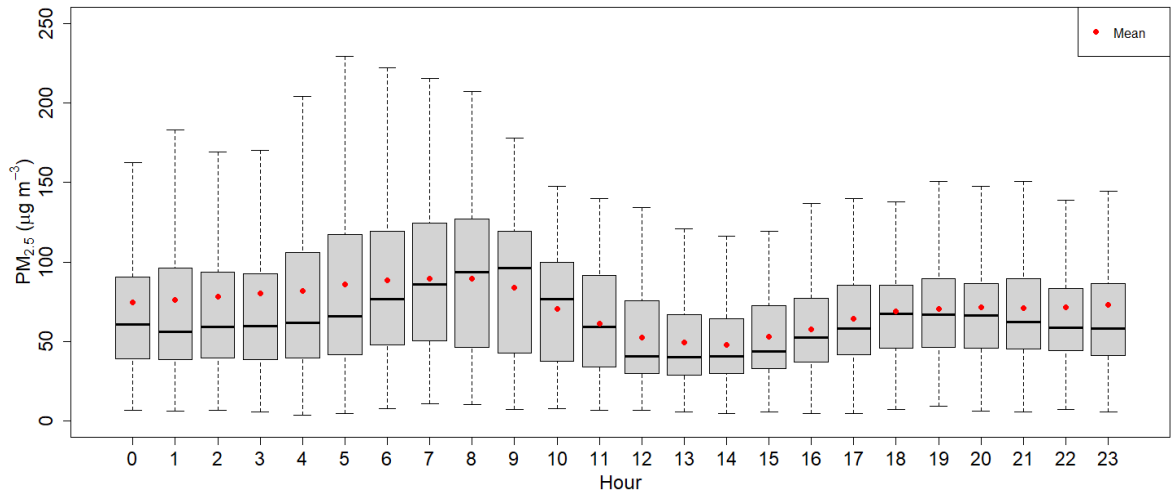

Figure A4-82: Diurnal Variation of $PM_{2.5}$ for Bhaisepati Station

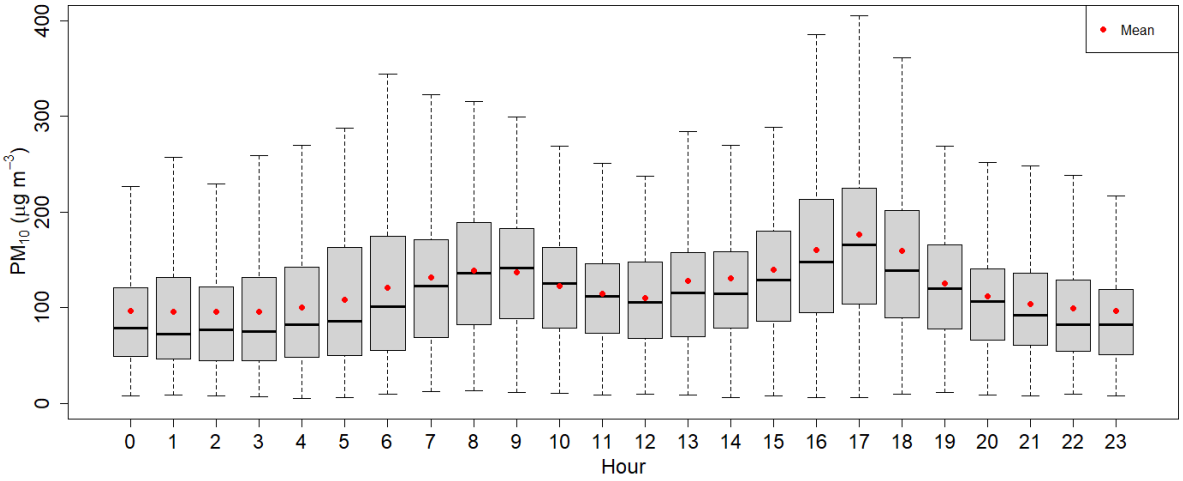

Figure A4-83: Diurnal Variation of PM_{10} for Bhaisepati Station

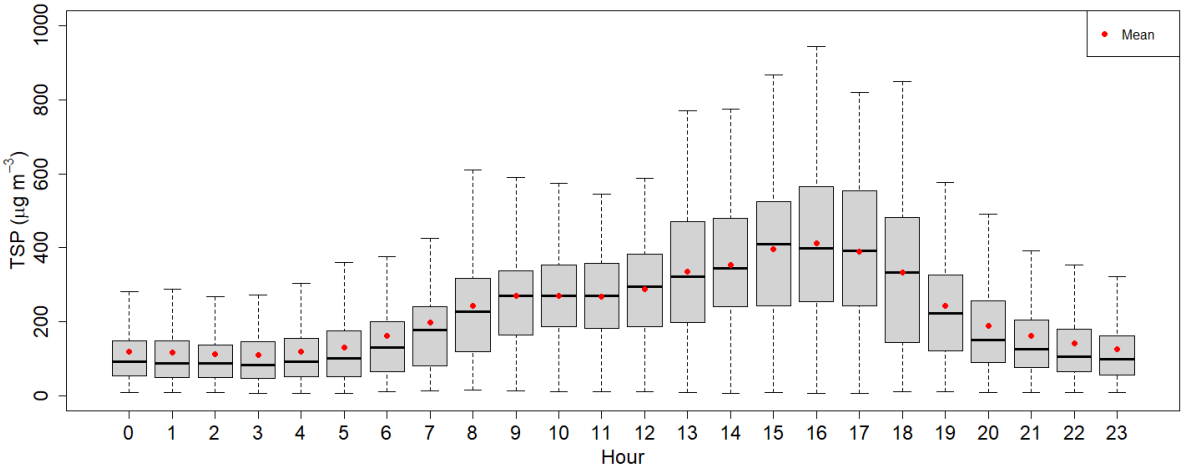

Figure A4-84: Diurnal Variation of TSP for Bhaisepati Station

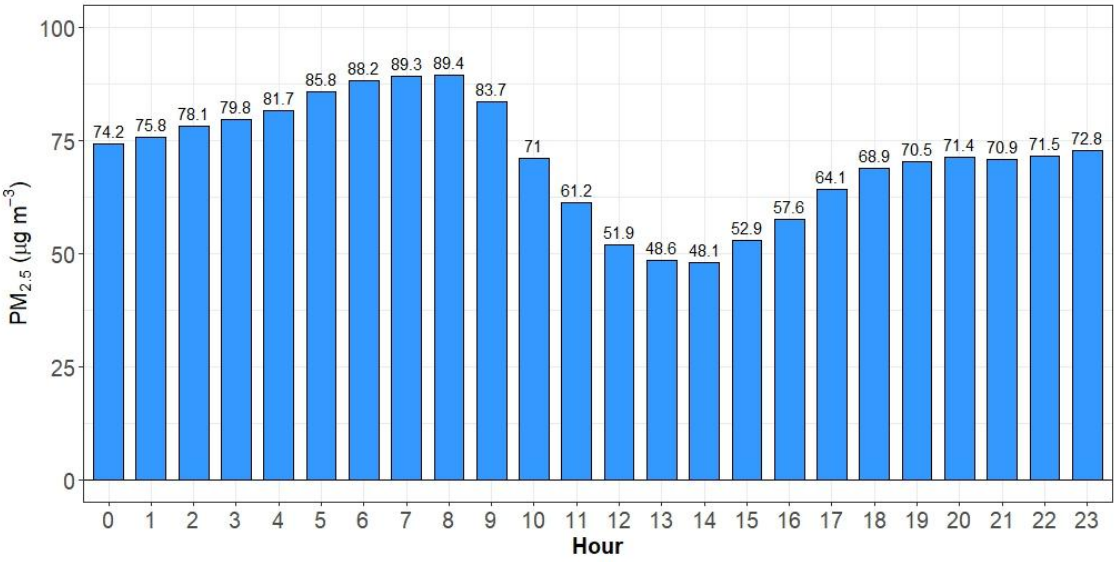

Figure A4-85: Hourly Average of $PM_{2.5}$ for Bhaisepati Station

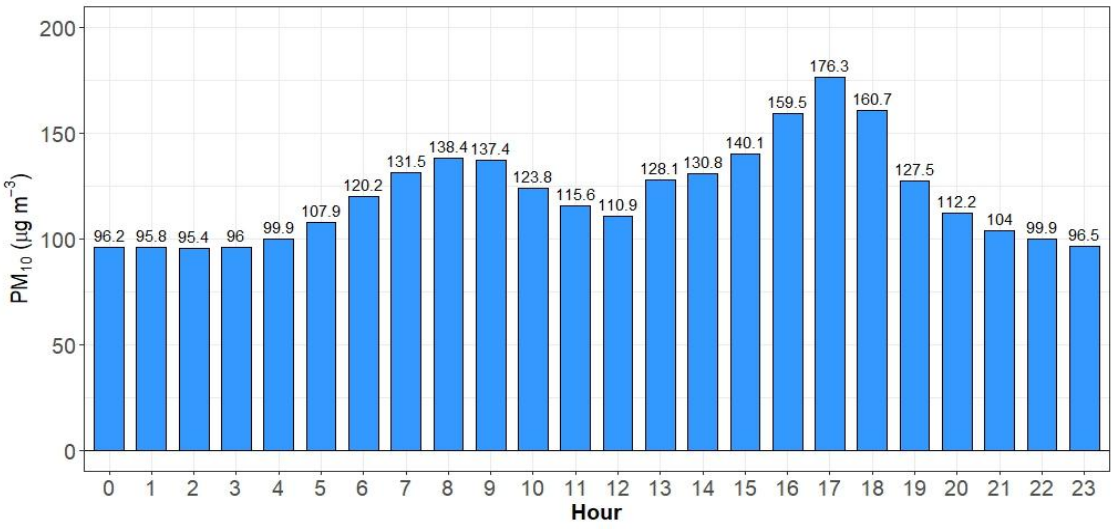

Figure A4-86: Hourly Average of PM_{10} for Bhaisepati Station

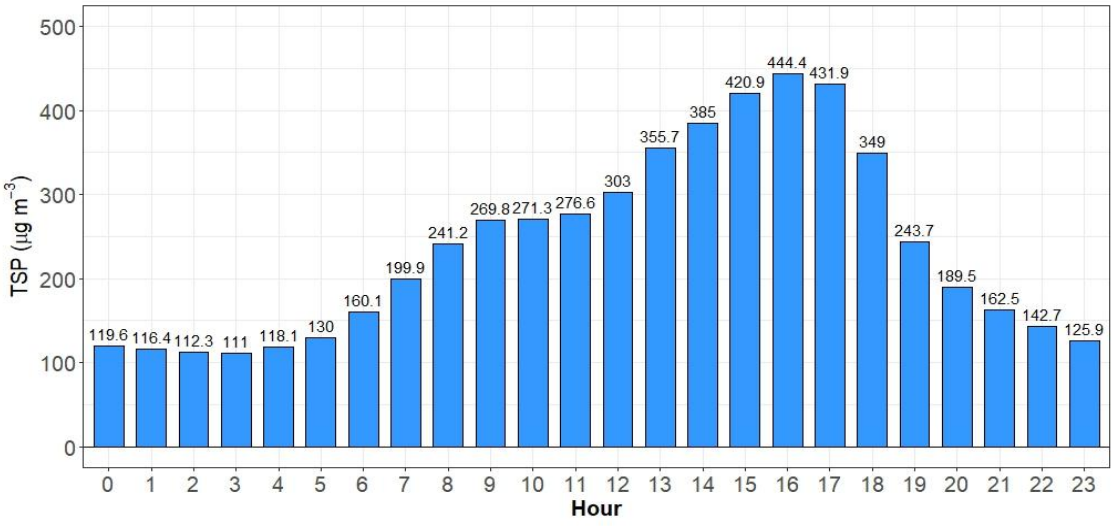

Figure A4-87: Hourly Average of TSP for Bhaisepati Station

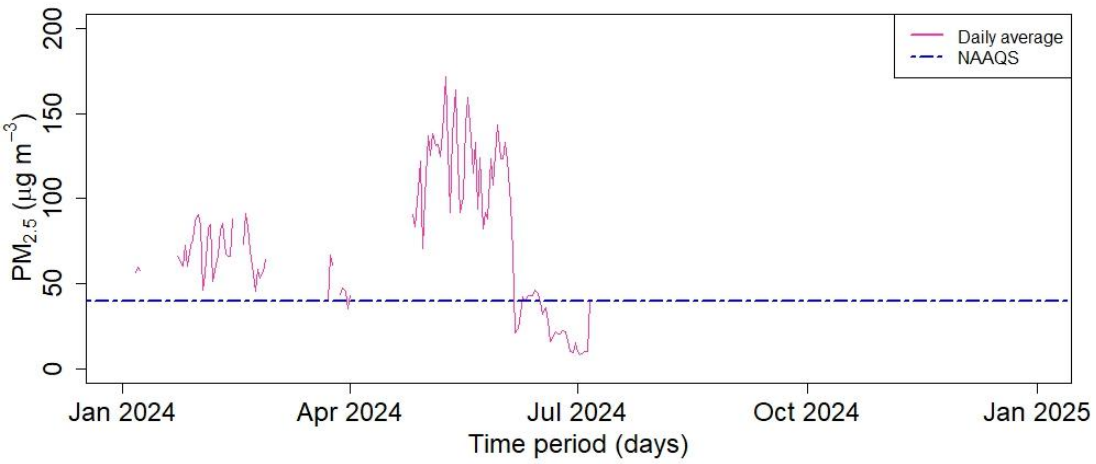

Figure A4-88: Daily Average of $PM_{2.5}$ for Bhaisepati Station

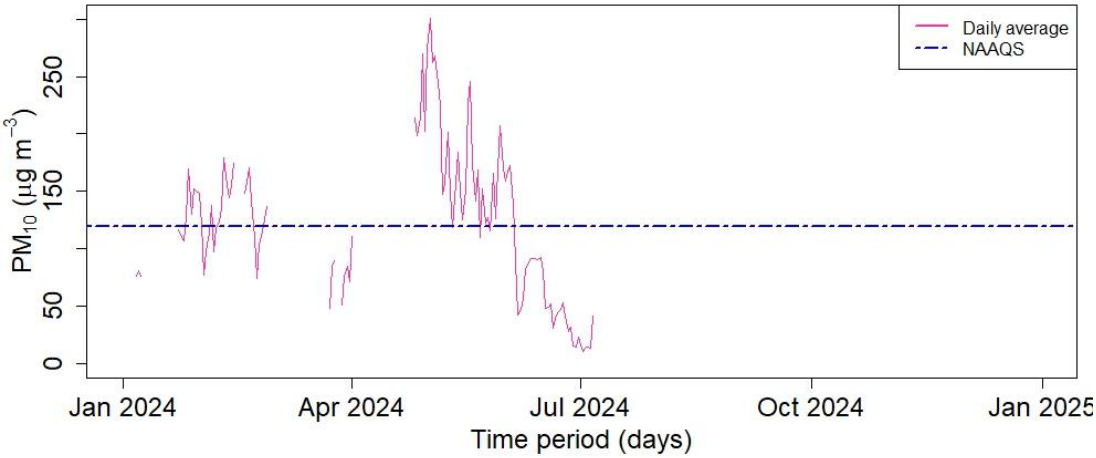

Figure A4-89: Daily Average of PM_{10} for Bhaisepati Station

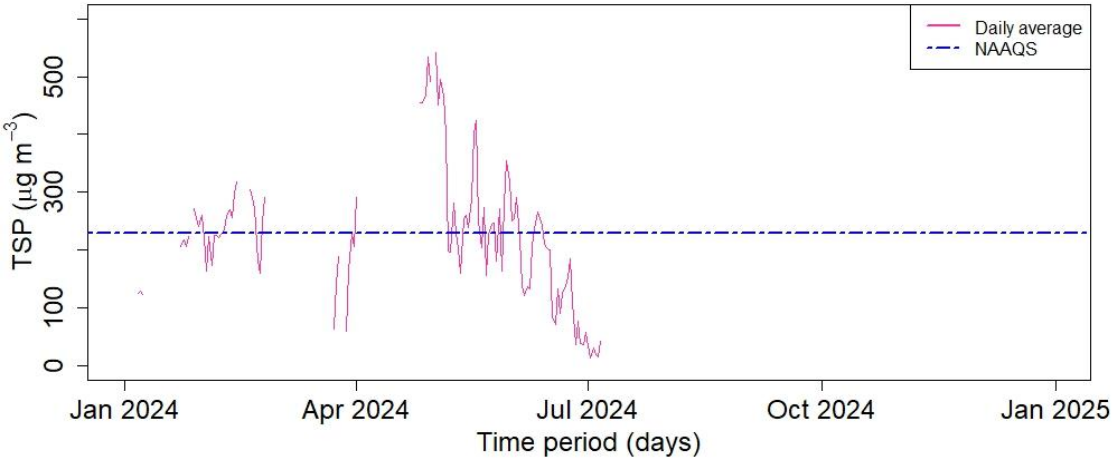

Figure A4-90: Daily Average of TSP for Bhaisepati Station

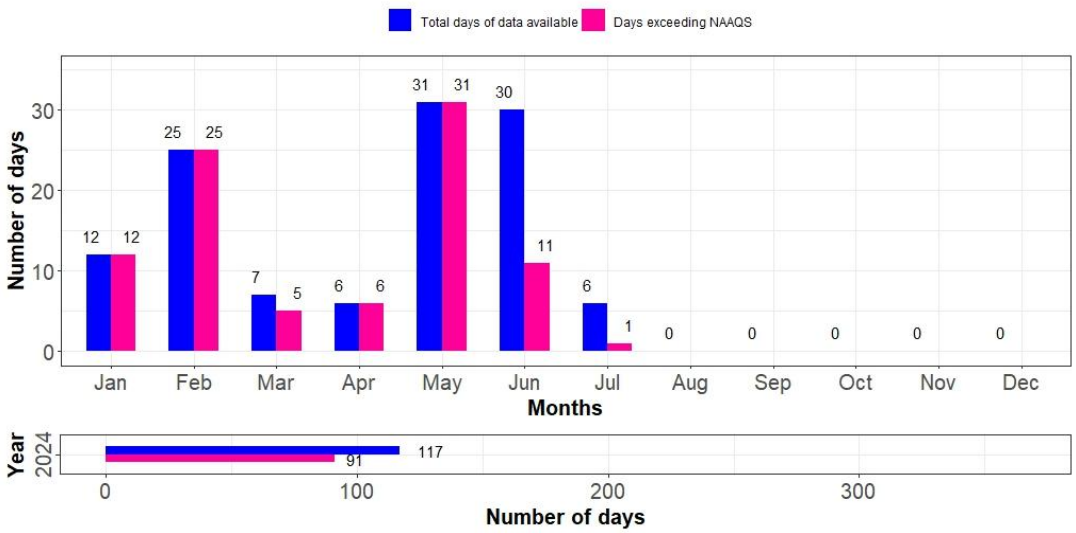

Figure A4-91: Compliance Status of $PM_{2.5}$ for Bhaisepati Station

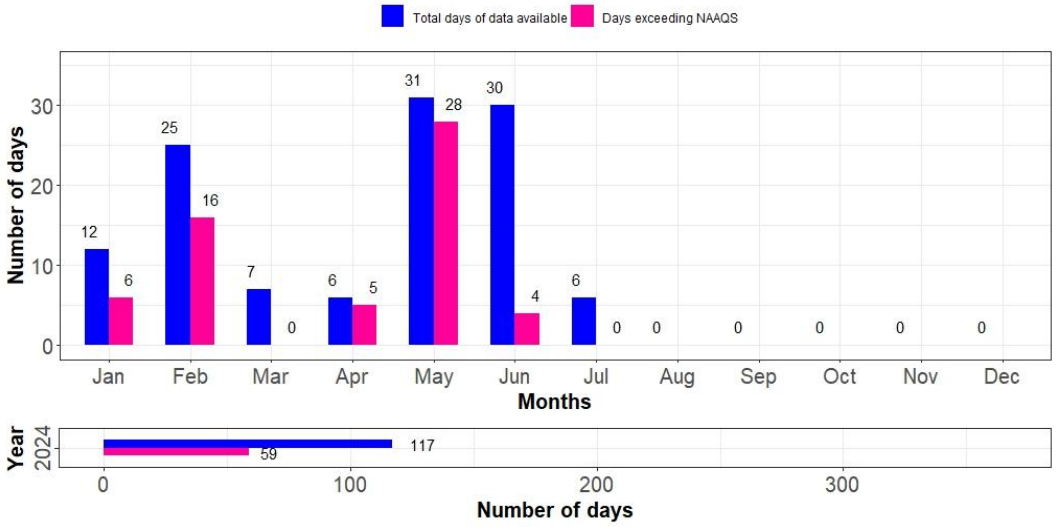

Figure A4-92: Compliance Status of PM_{10} for Bhaisepati Station

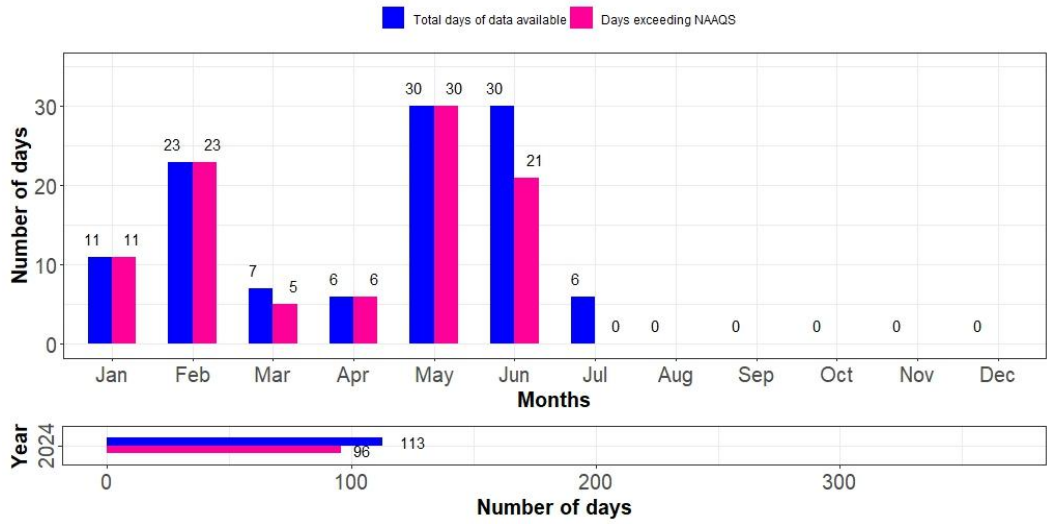

Figure A4-93: Compliance Status of TSP for Bhaisepati Station

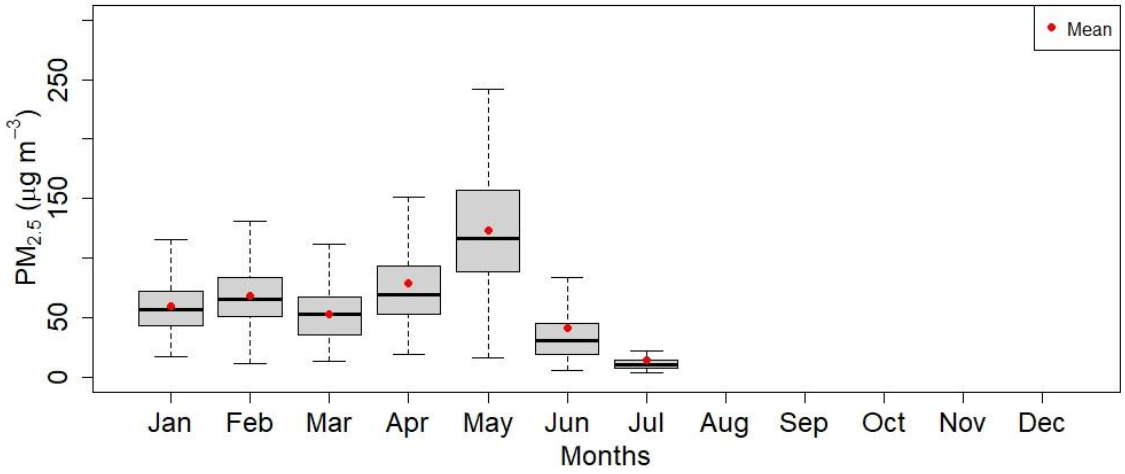

Figure A4-94: Monthly Variation of $PM_{2.5}$ for Bhaisepati Station

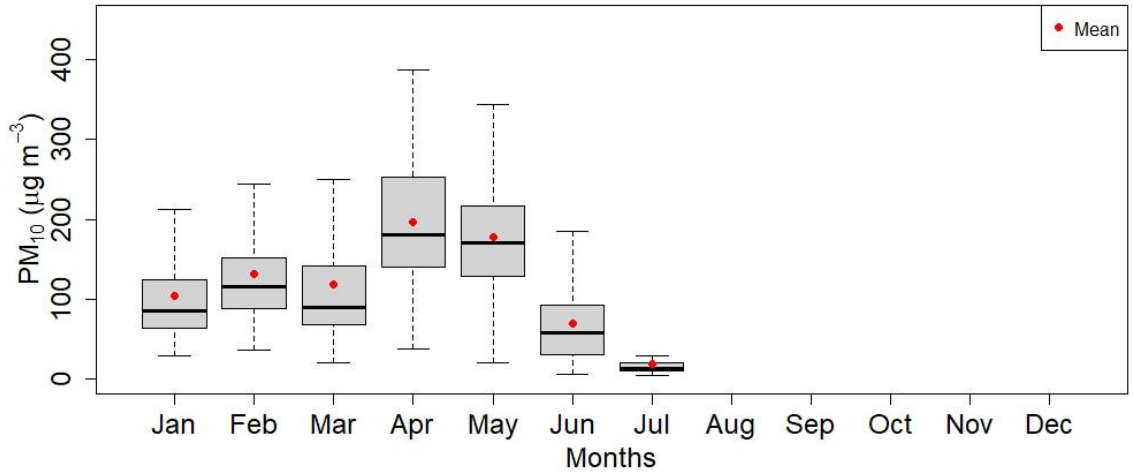

Figure A4-95: Monthly Variation of PM_{10} for Bhaisepati Station

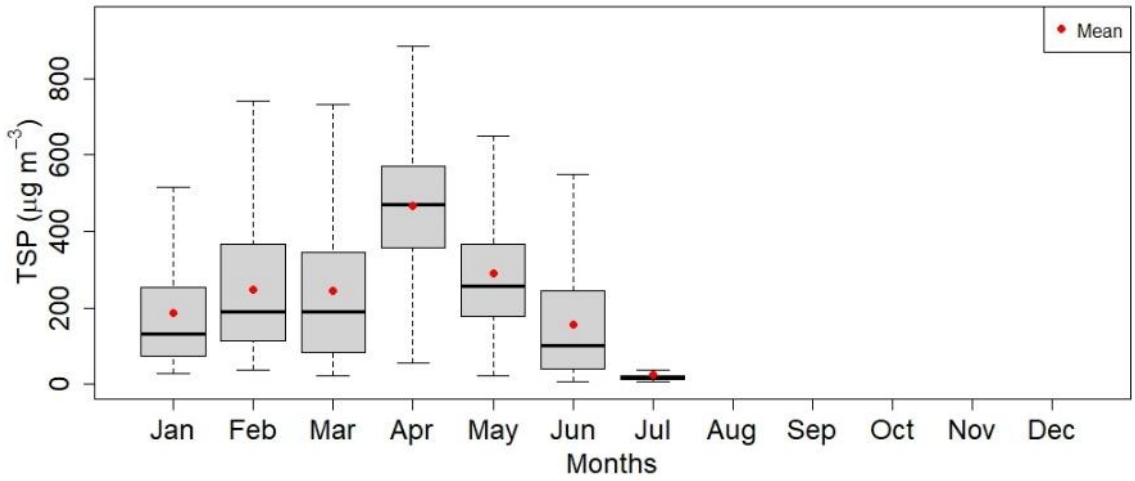

Figure A4-96: Monthly Variation of TSP for Bhaisepati Station

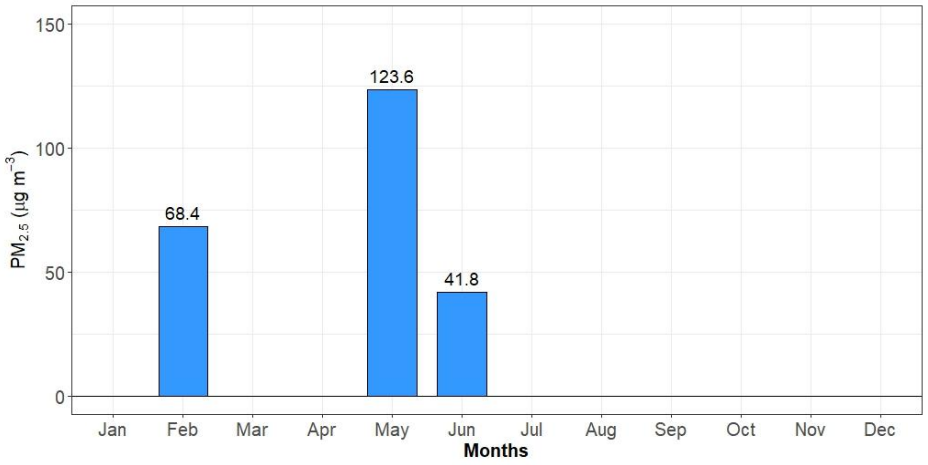

Figure A4-97: Monthly Average of $PM_{2.5}$ for Bhaisepati Station

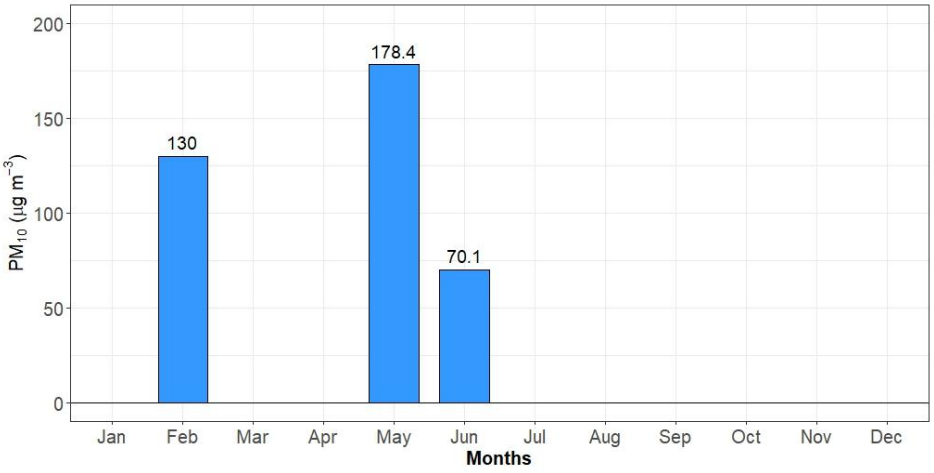

Figure A4-98: Monthly Average of PM_{10} for Bhaisepati Station

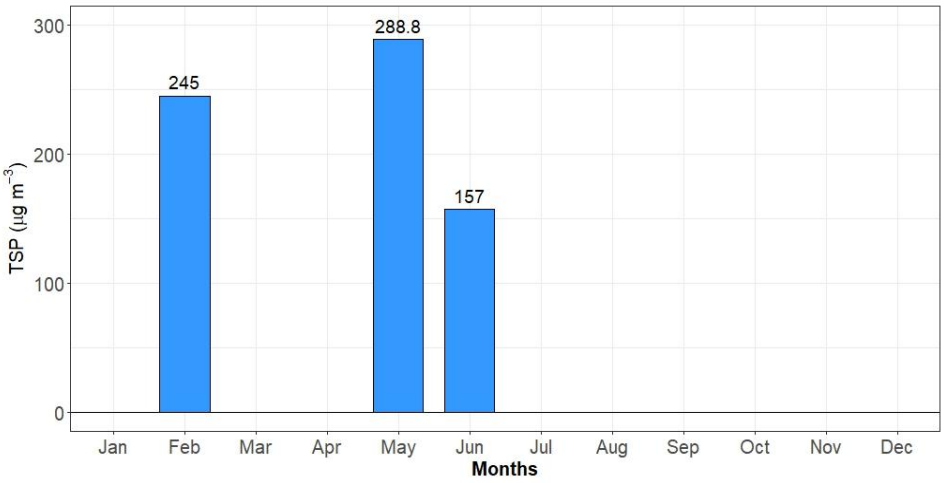

Figure A4-99: Monthly Average of TSP for Bhaisepati Station

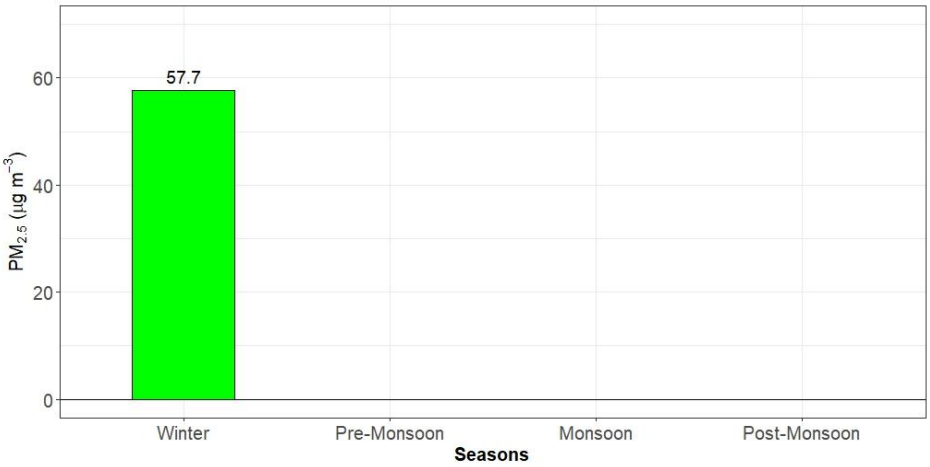

Figure A4-100: Seasonal Average of $PM_{2.5}$ for Bhaisepati Station

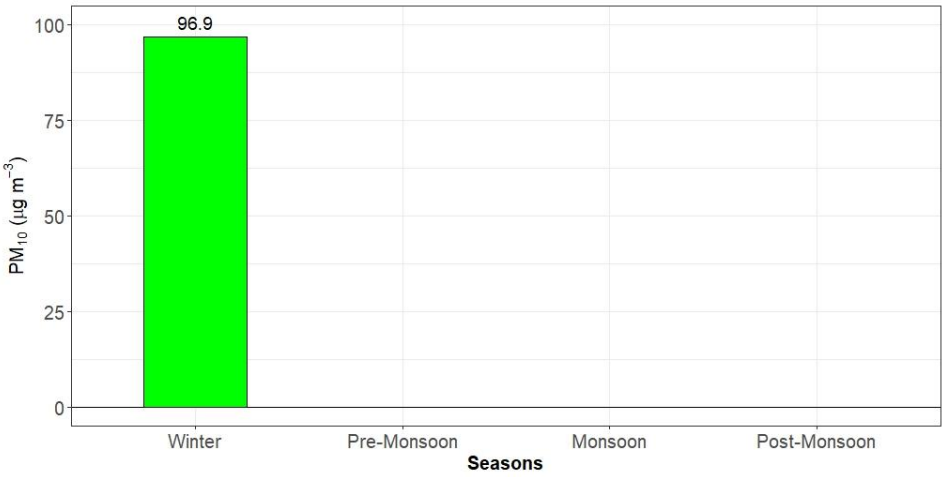

Figure A4-101: Seasonal Average of PM_{10} for Bhaisepati Station

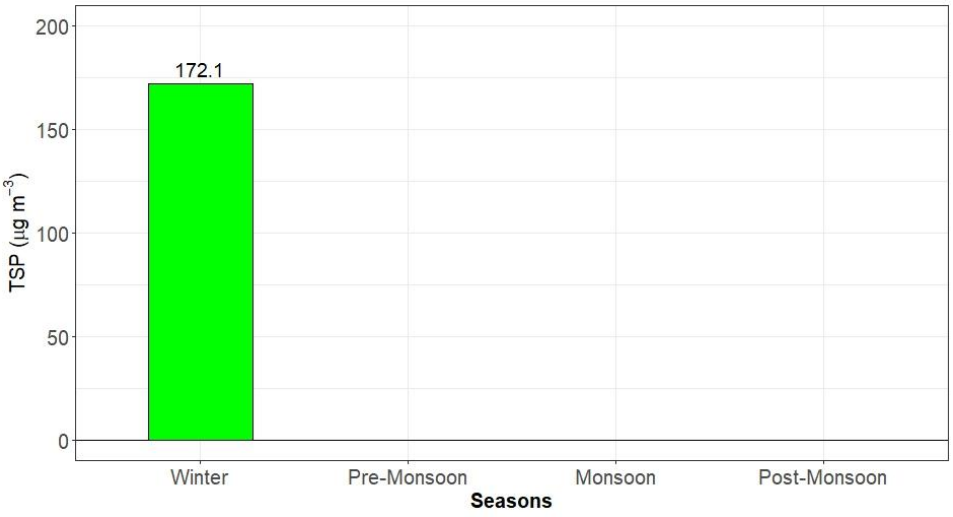

Figure A4-102: Seasonal Average of TSP for Bhaisepati Station

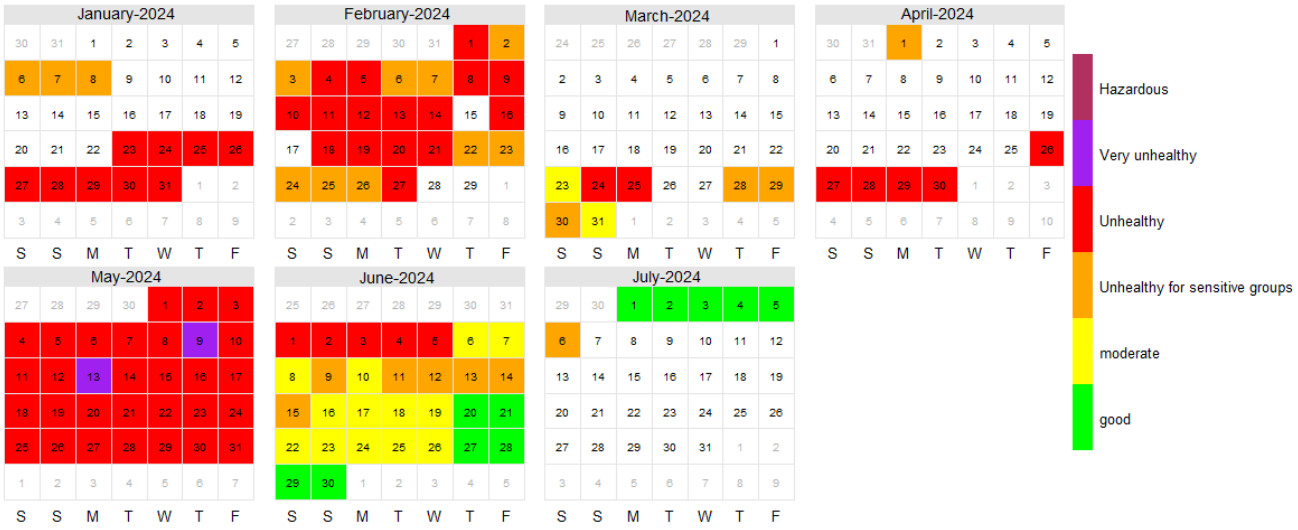

Figure A4-103: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Bhaisepati Station

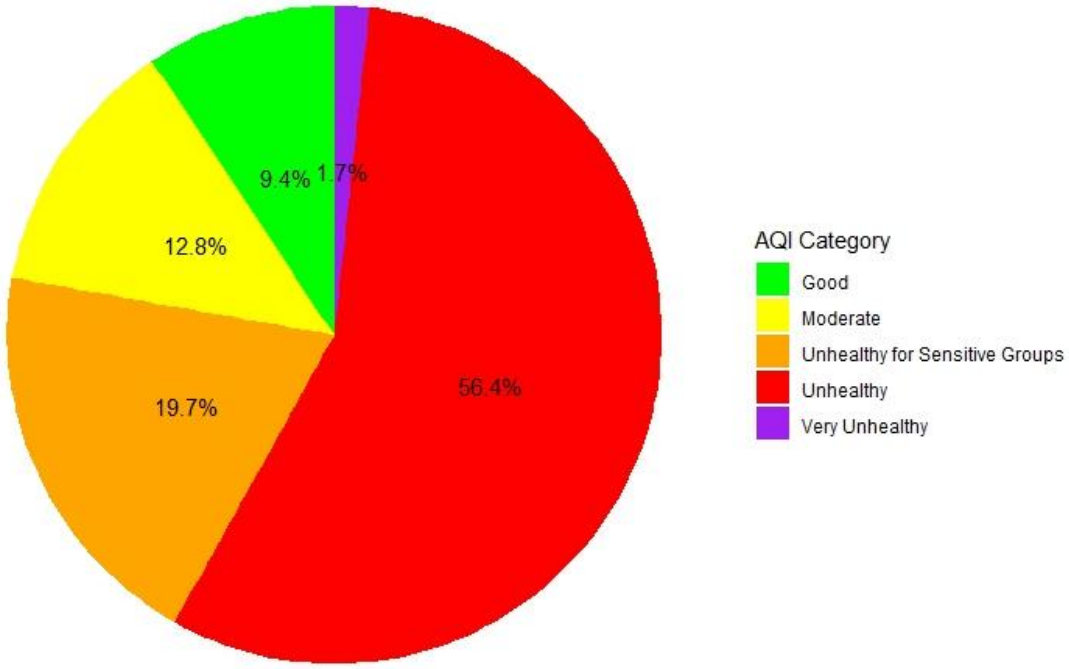

Figure A4-104: AQI Category Distribution for Bhaisepati Station

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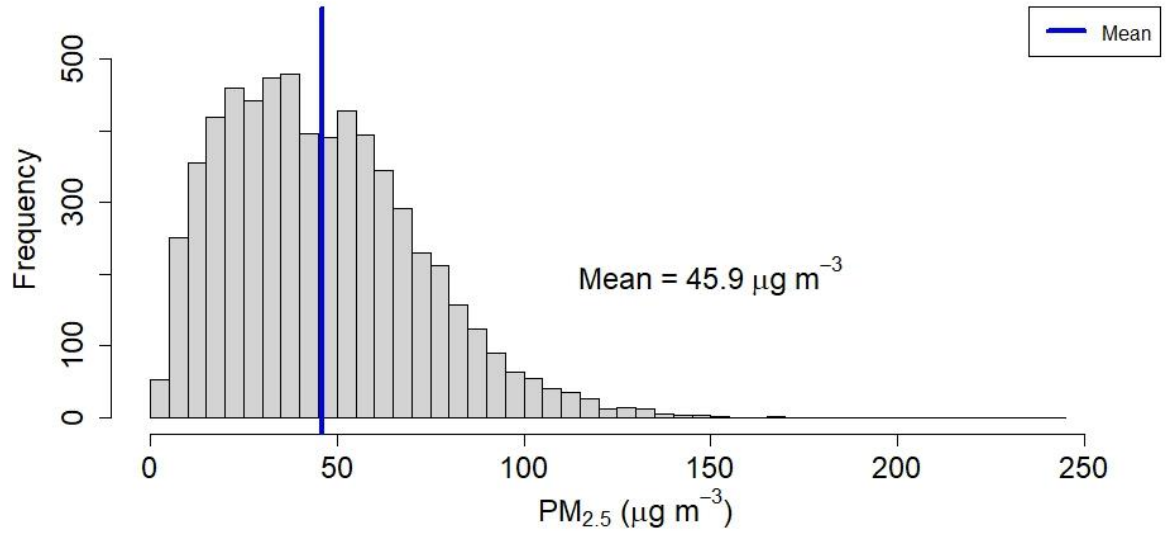

Figure A4-105: Histogram of $PM_{2.5}$ for Bhaktapur Station

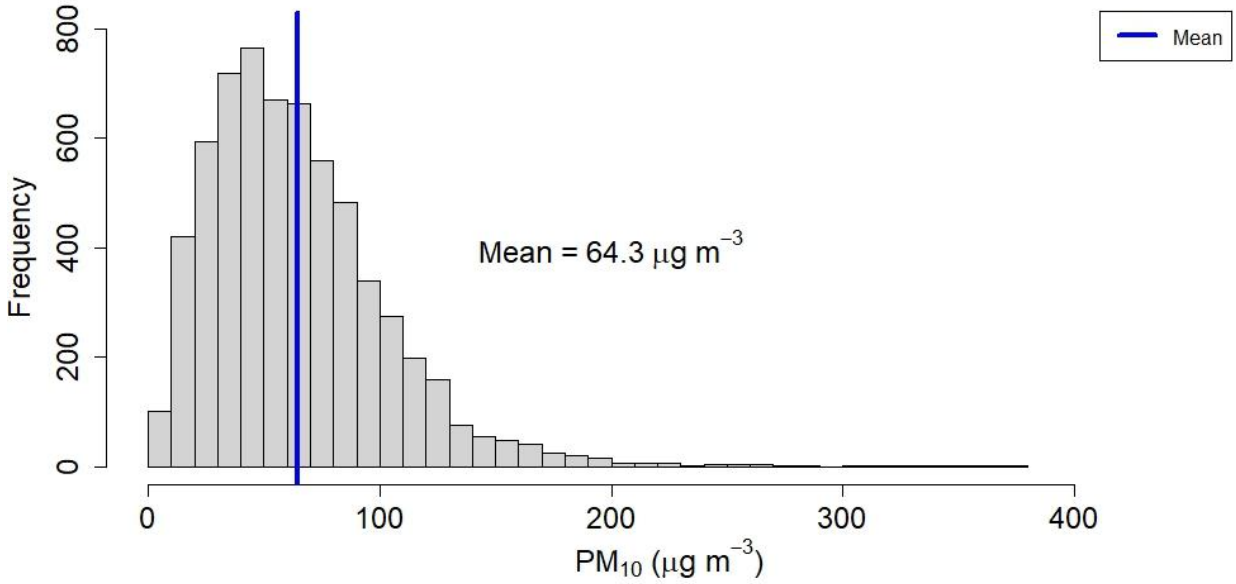

Figure A4-106: Histogram of PM_{10} for Bhaktapur Station

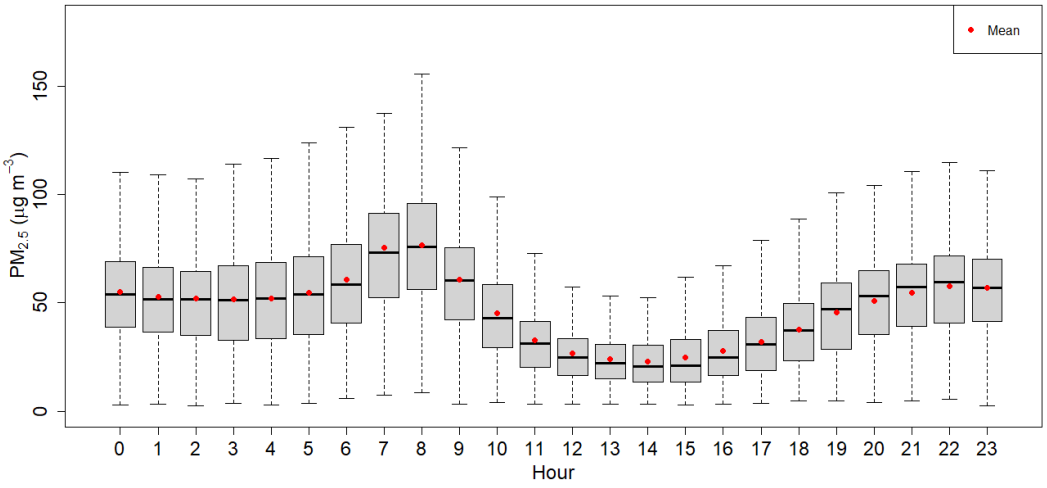

Figure A4-107: Diurnal Variation of $PM_{2.5}$ for Bhaktapur Station

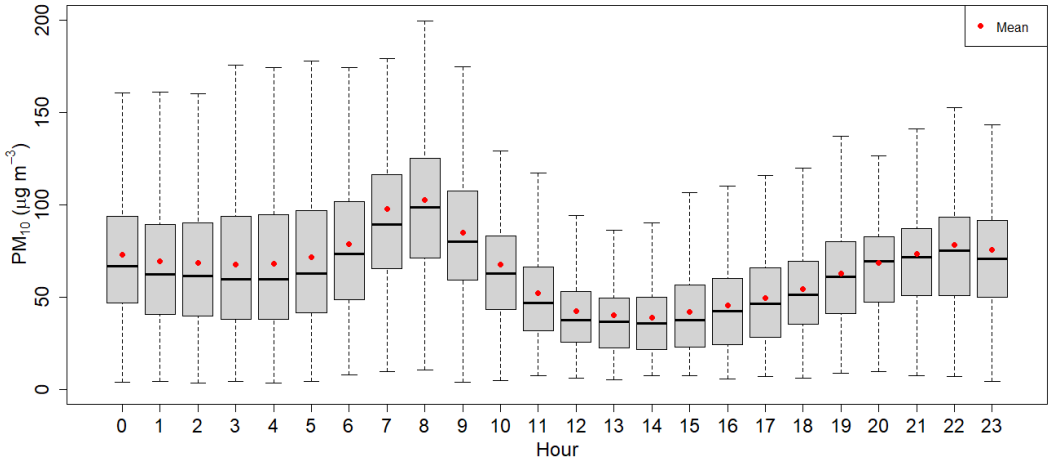

Figure A4-108: Diurnal Variation of PM_{10} for Bhaktapur Station

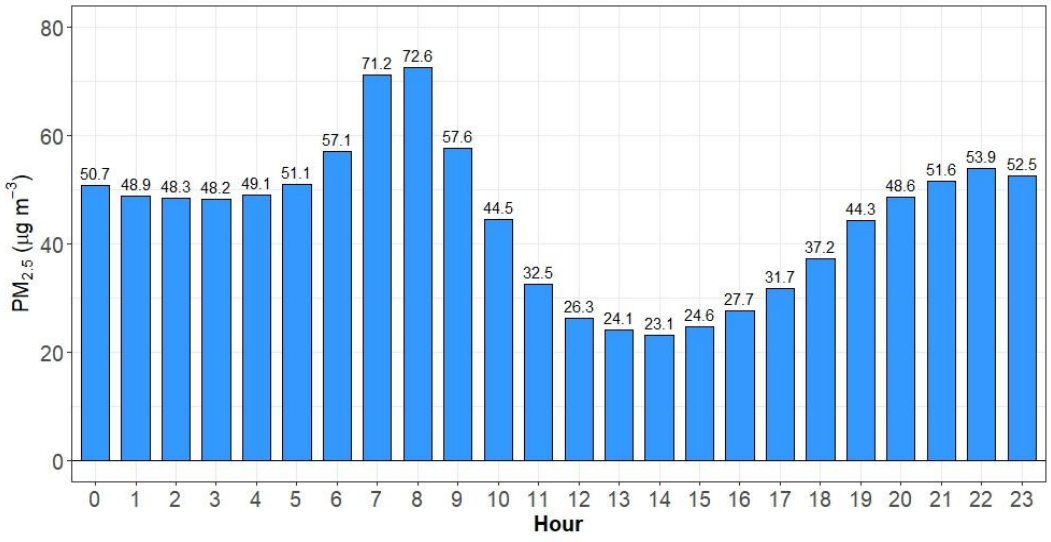

Figure A4-109: Hourly Average of $PM_{2.5}$ for Bhaktapur Station

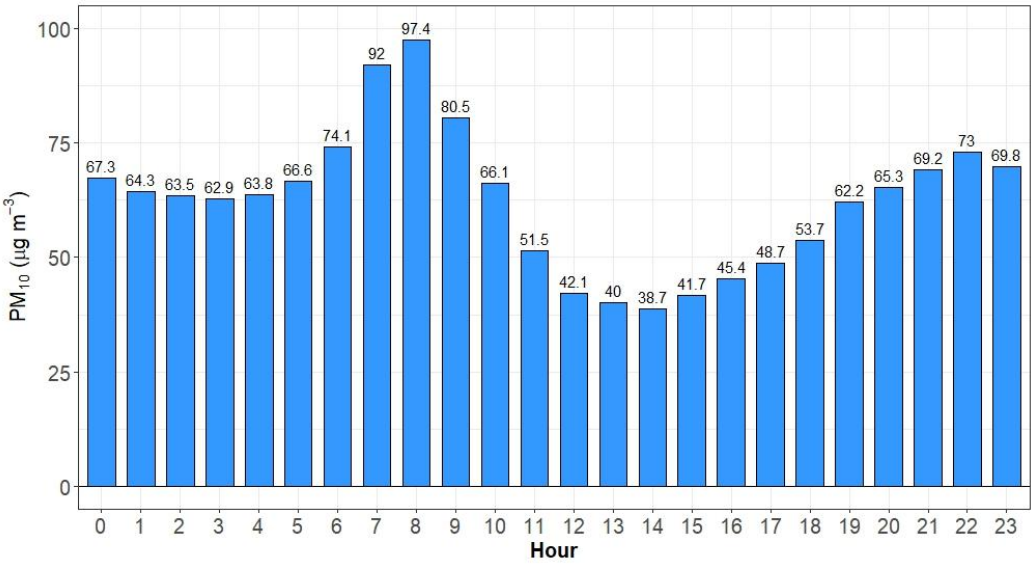

Figure A4-110: Hourly Average of PM_{10} for Bhaktapur Station

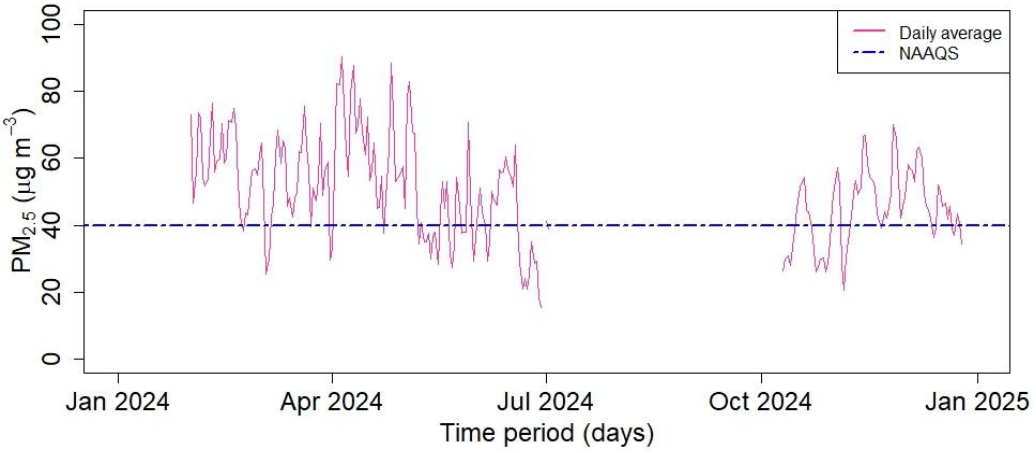

Figure A4-111: Daily Average of $PM_{2.5}$ for Bhaktapur Station

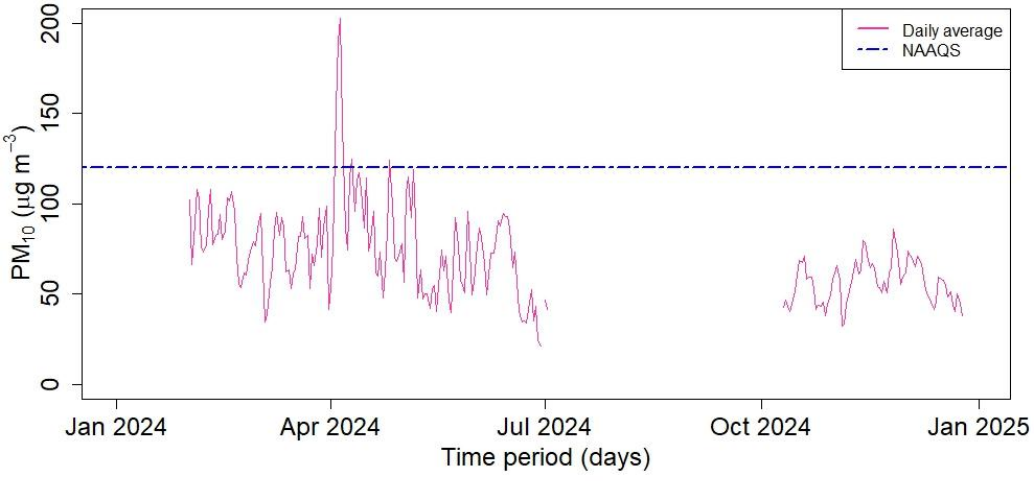

Figure A4-112: Daily Average of PM_{10} for Bhaktapur Station

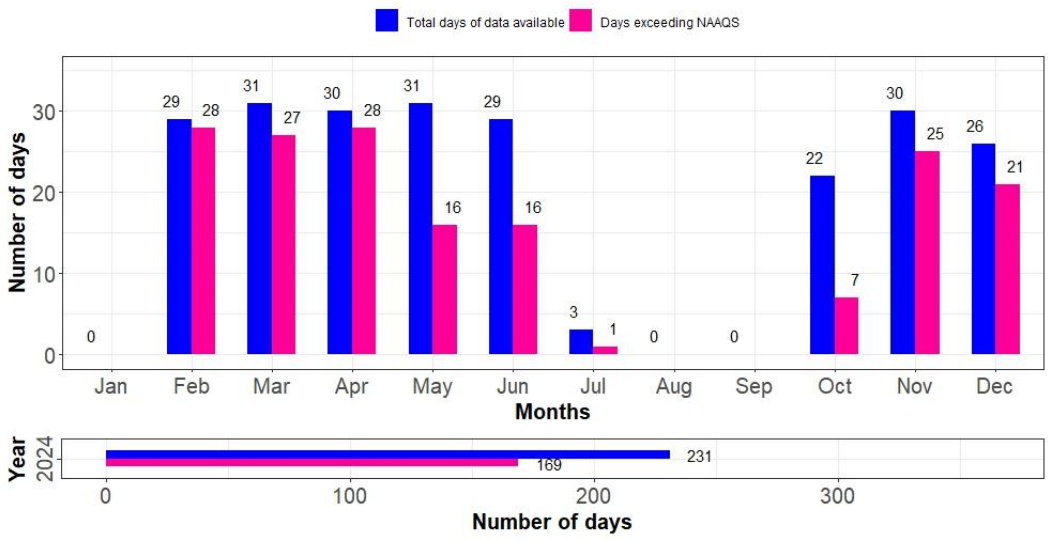

Figure A4-113: Compliance Status of $PM_{2.5}$ for Bhaktapur Station

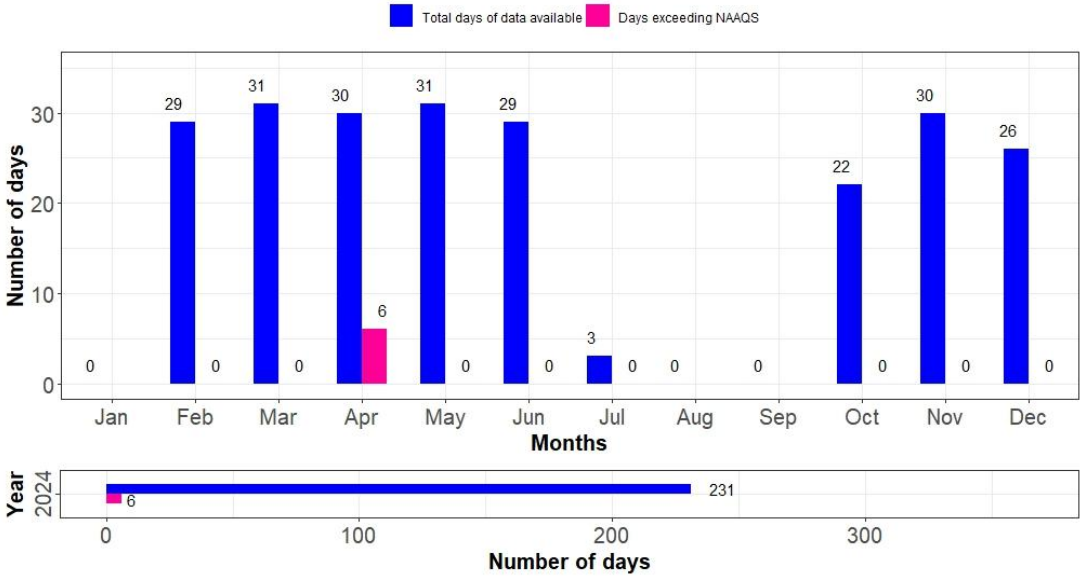

Figure A4-114: Compliance Status of PM_{10} for Bhaktapur Station

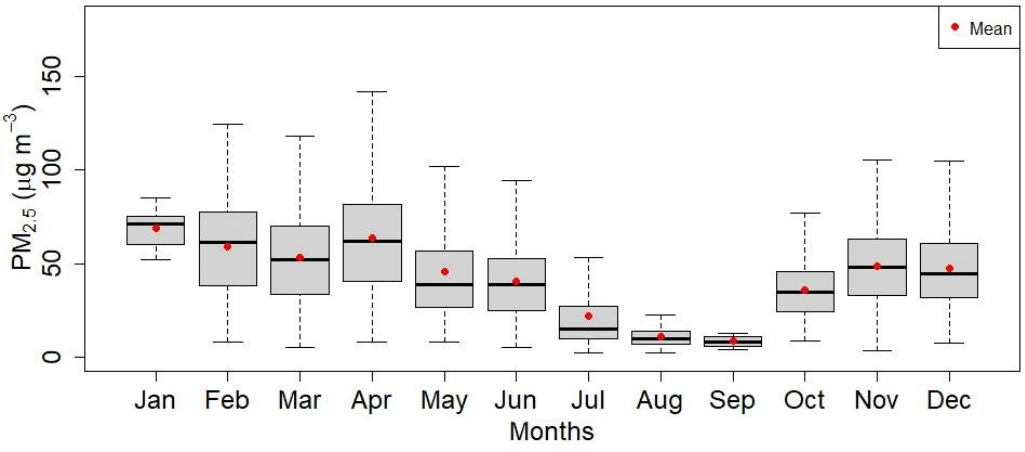

Figure A4-115: Monthly Variation of $PM_{2.5}$ for Bhaktapur Station

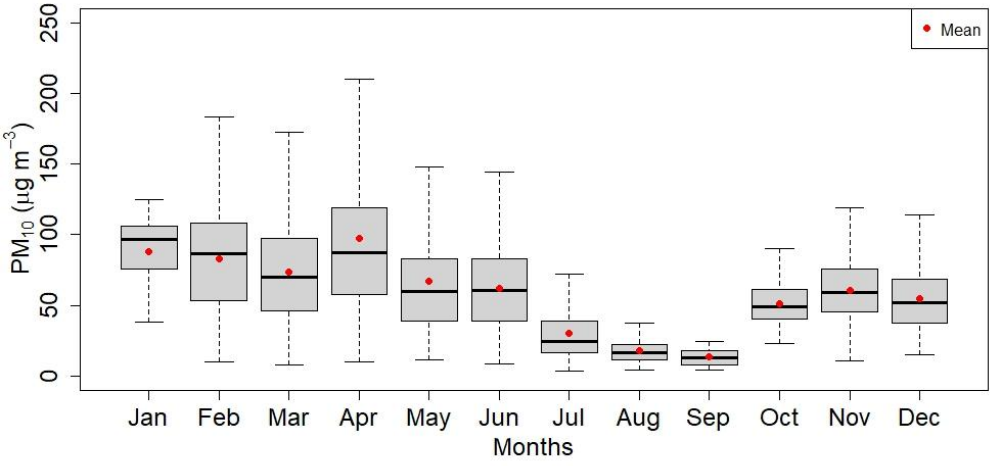

Figure A4-116: Monthly Variation of PM_{10} for Bhaktapur Station

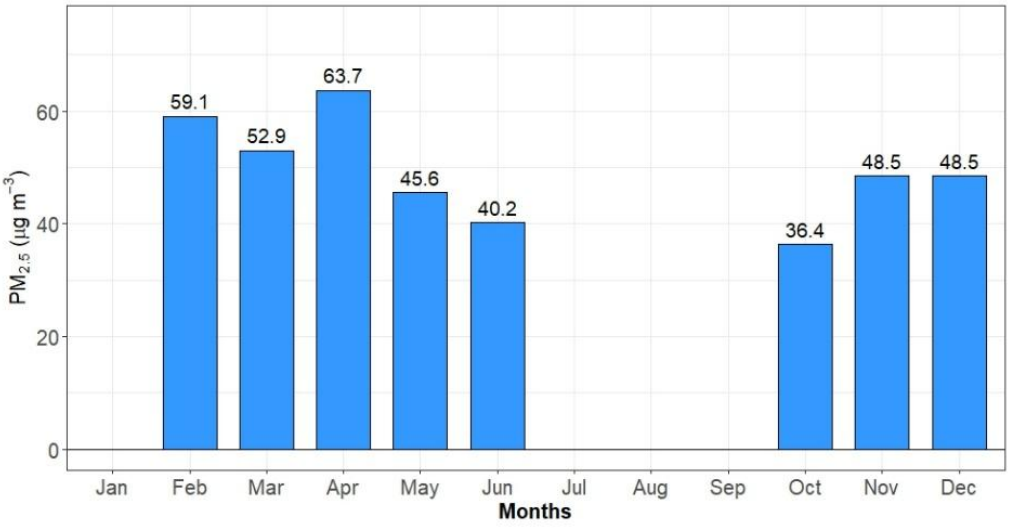

Figure A4-117: Monthly Average of $PM_{2.5}$ for Bhaktapur Station

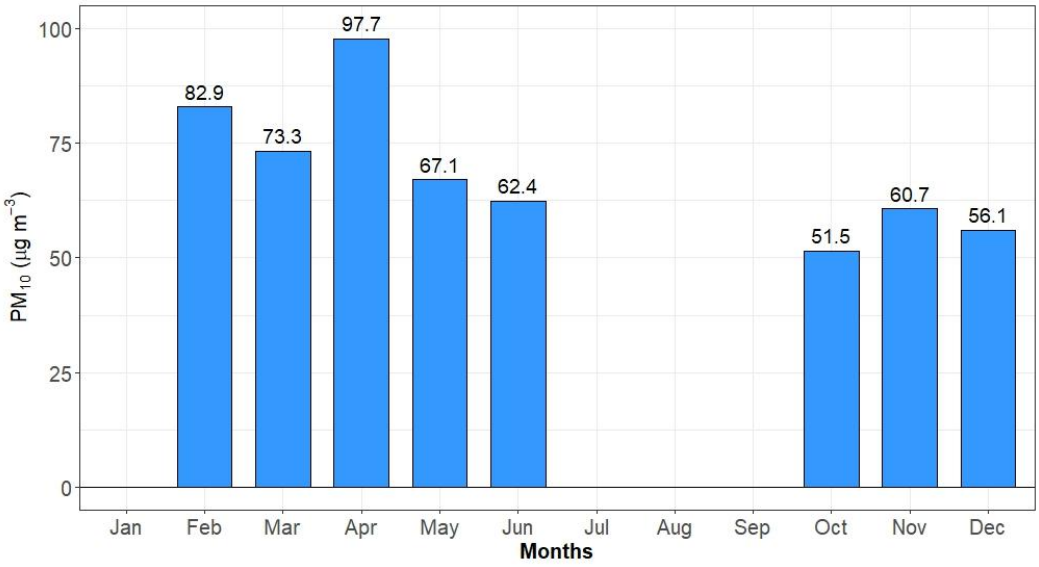

Figure A4-118: Monthly Average of PM_{10} for Bhaktapur Station

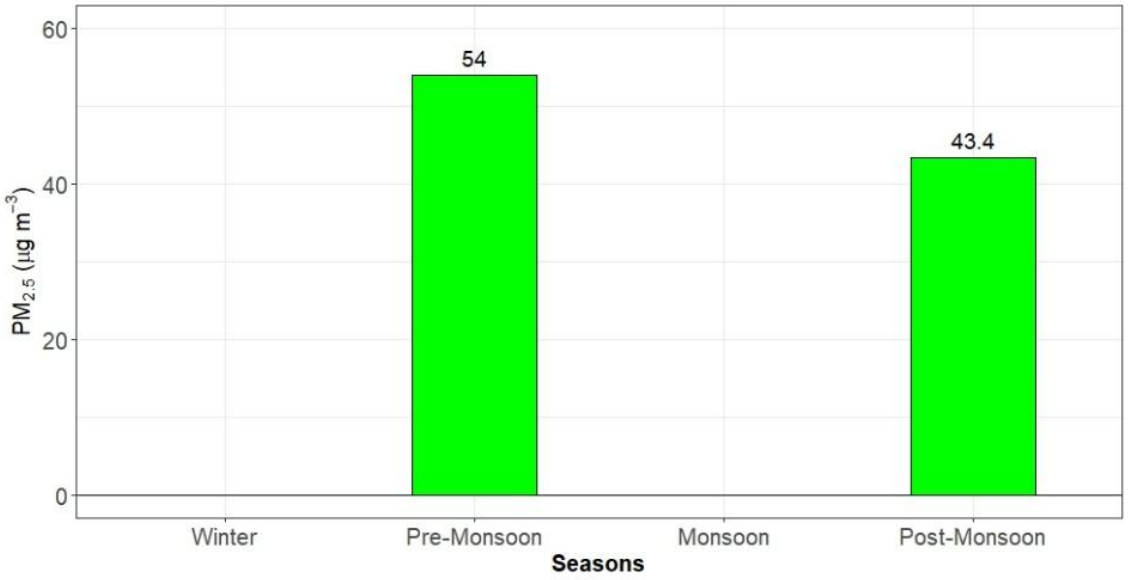

Figure A4-119: Seasonal Average of $PM_{2.5}$ for Bhaktapur Station

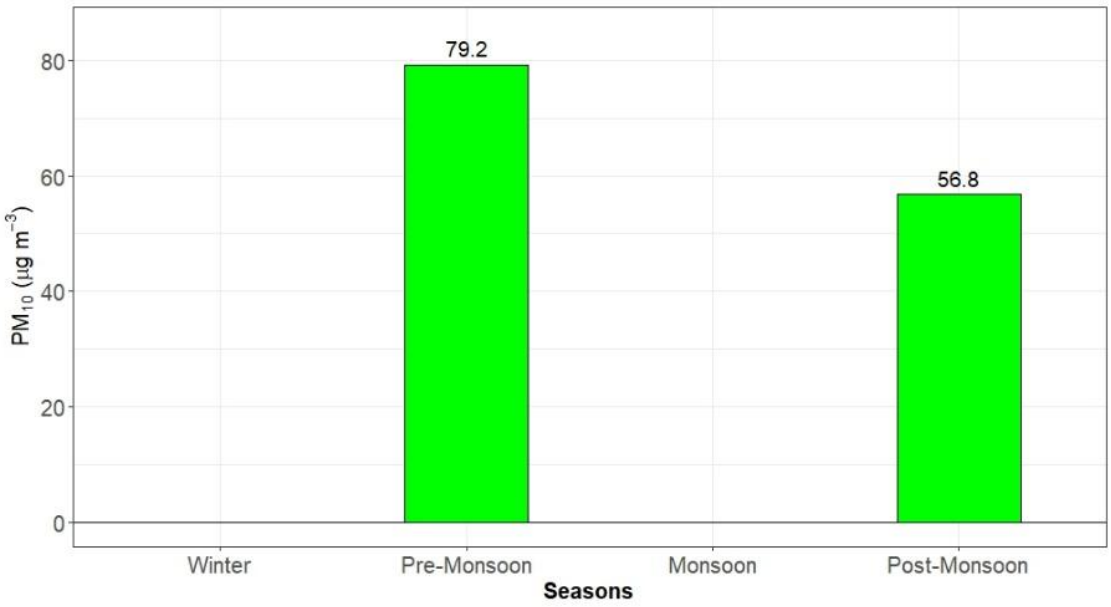

Figure A4-120: Seasonal Average of PM_{10} for Bhaktapur Station

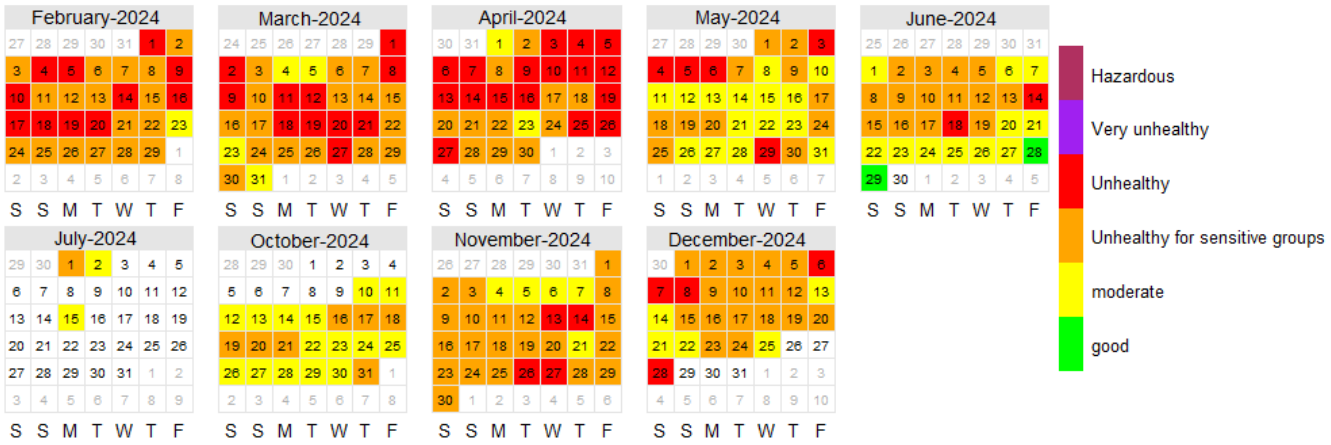

Figure A4-121: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Bhaktapur Station

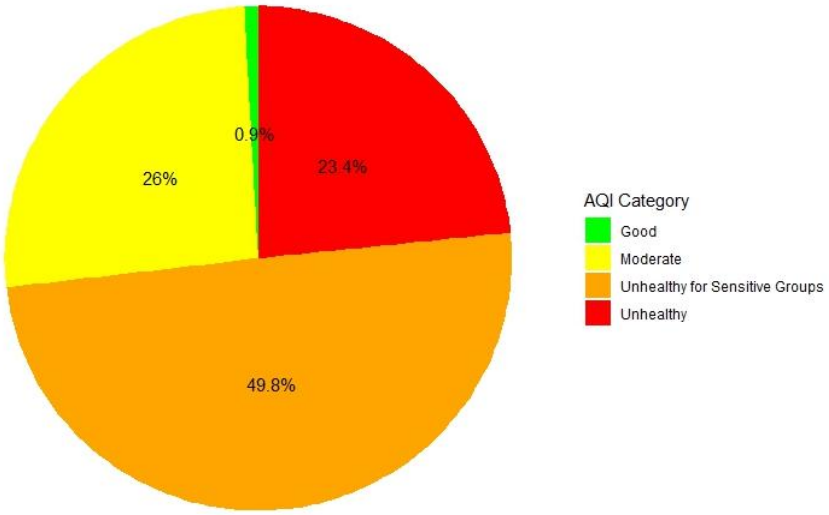

Figure A4-122: AQI Category Distribution for Bhaktapur Station

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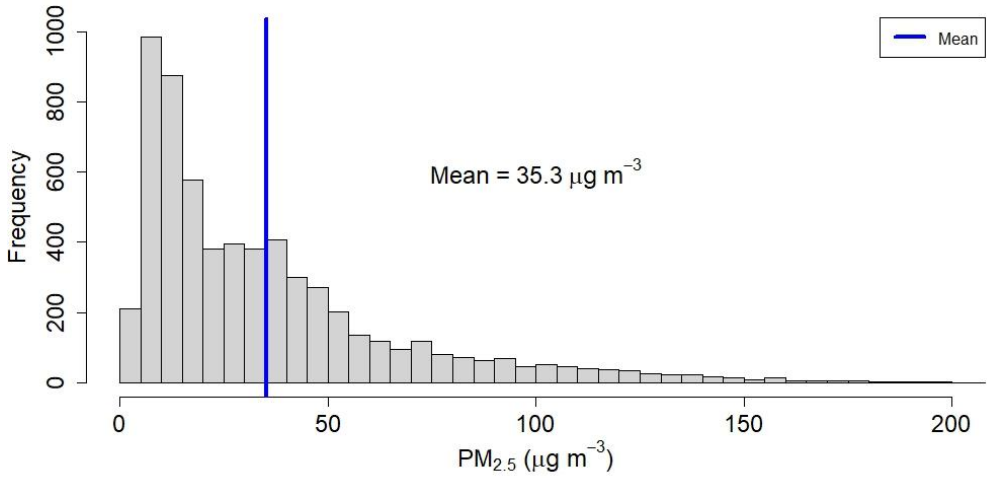

Figure A4-123: Histogram of $PM_{2.5}$ for Bharatpur Station

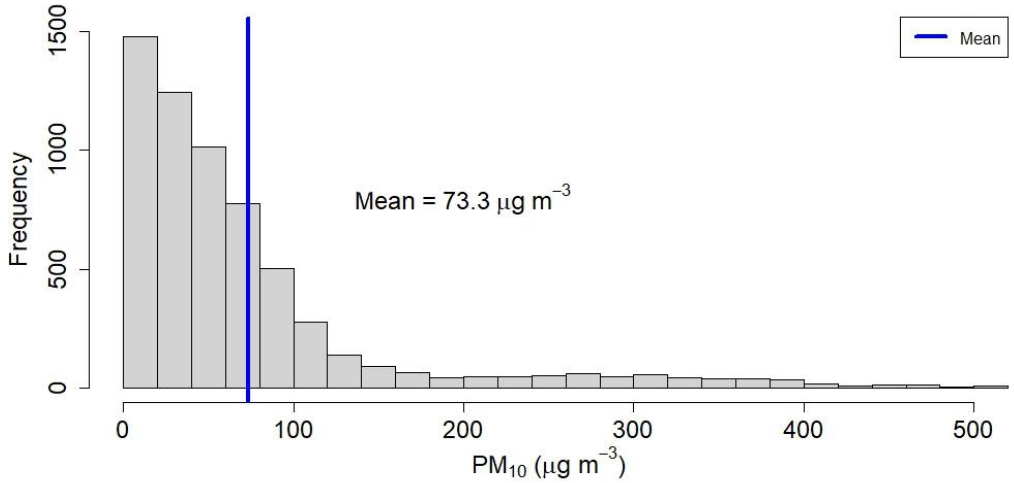

Figure A4-124: Histogram of PM_{10} for Bharatpur Station

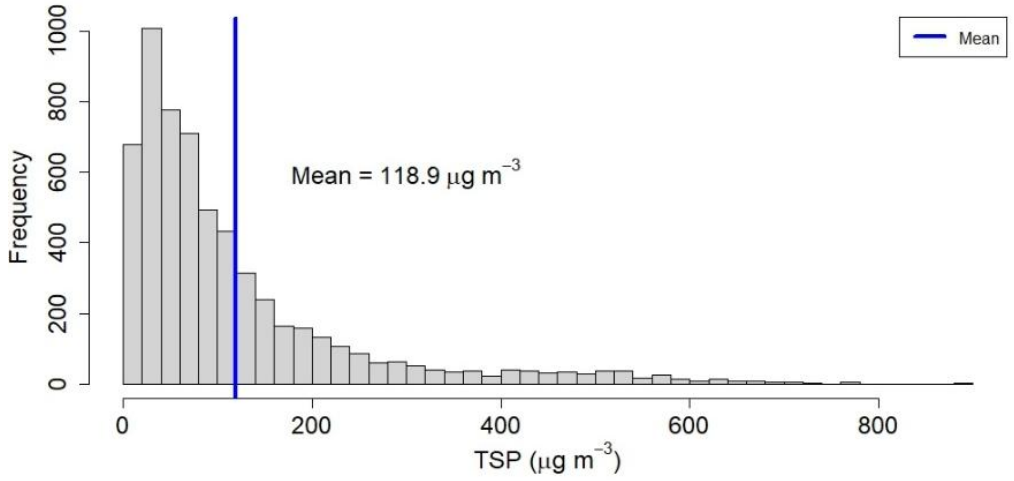

Figure A4-125: Histogram of TSP for Bharatpur Station

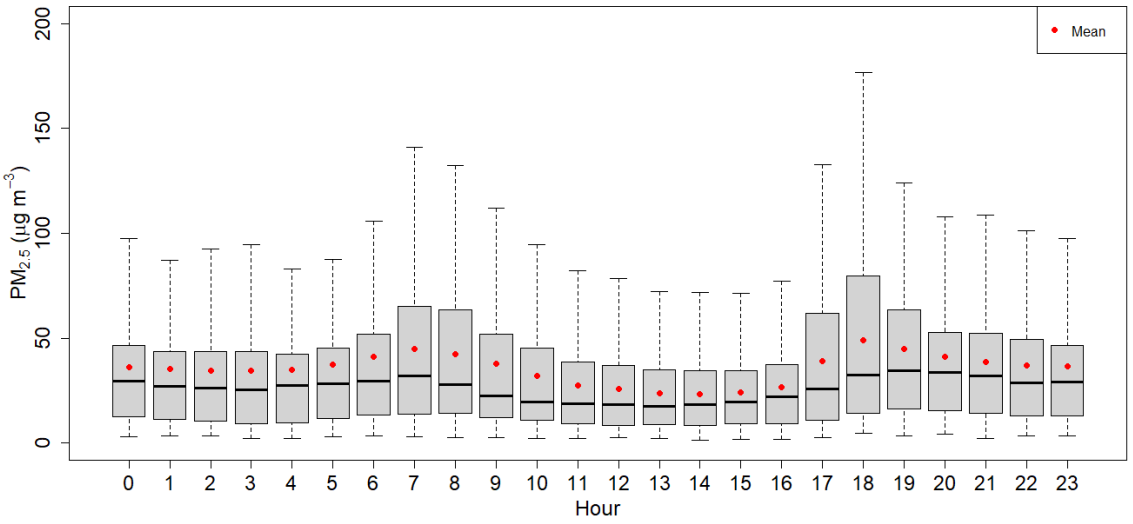

Figure A4-126: Diurnal Variation of $PM_{2.5}$ for Bharatpur Station

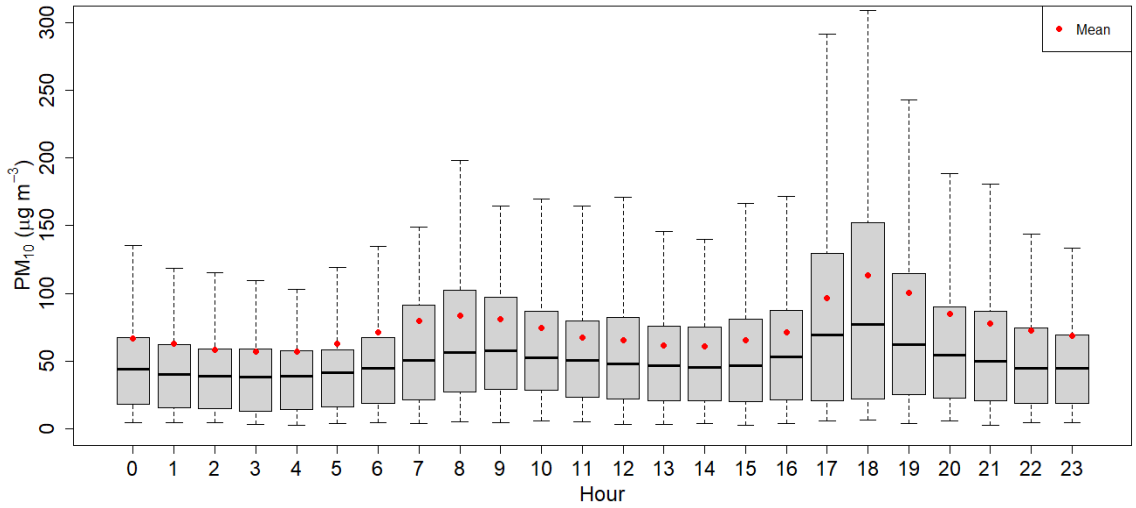

Figure A4-127: Diurnal Variation of PM_{10} for Bharatpur Station

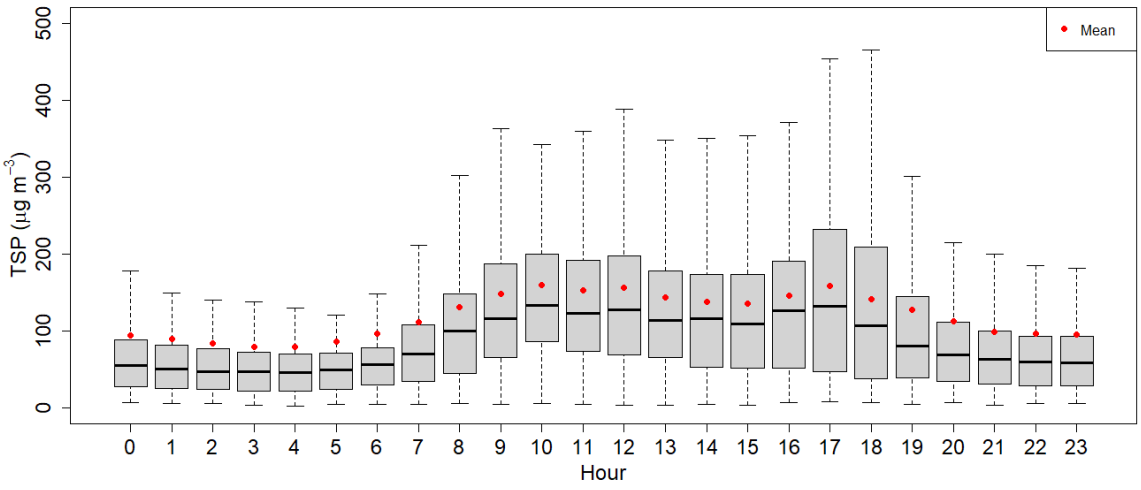

Figure A4-128: Diurnal Variation of TSP for Bharatpur Station

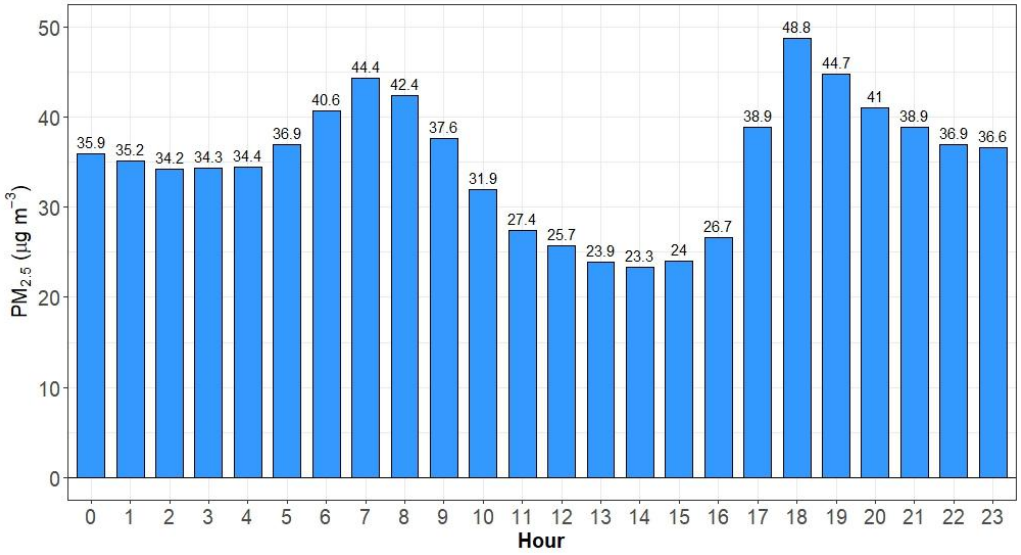

Figure A4-129: Hourly Average of $PM_{2.5}$ for Bharatpur Station

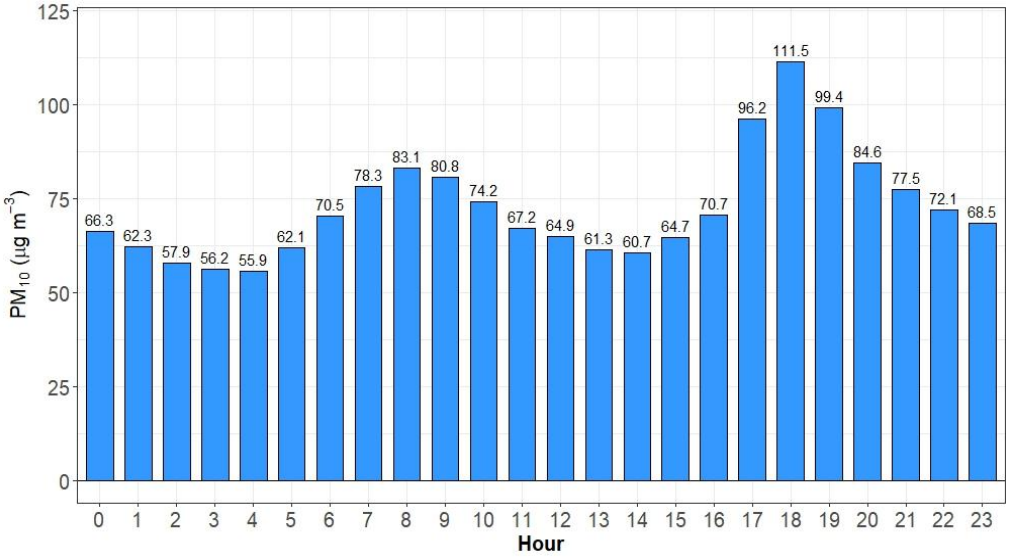

Figure A4-130: Hourly Average of PM_{10} for Bharatpur Station

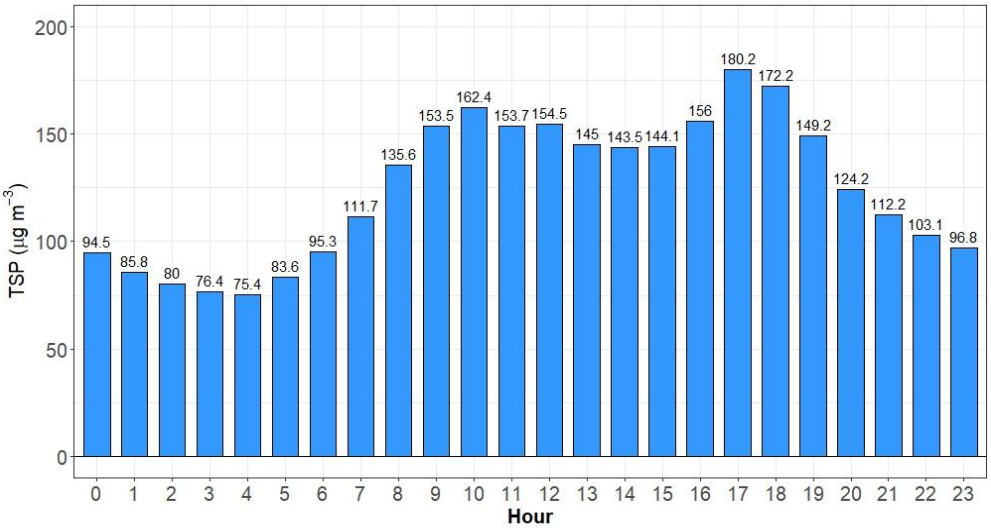

Figure A4-131: Hourly Average of TSP for Bharatpur Station

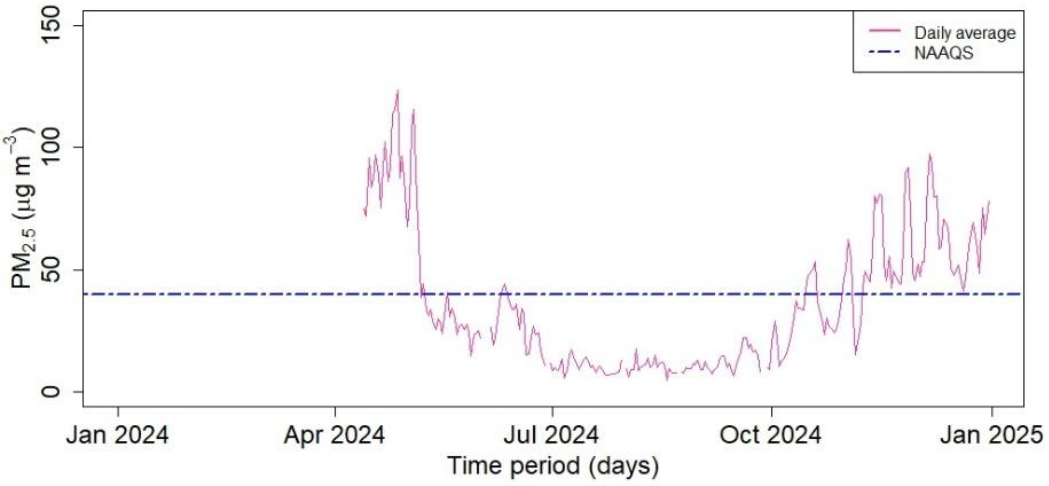

Figure A4-132: Daily Average of $PM_{2.5}$ for Bharatpur Station

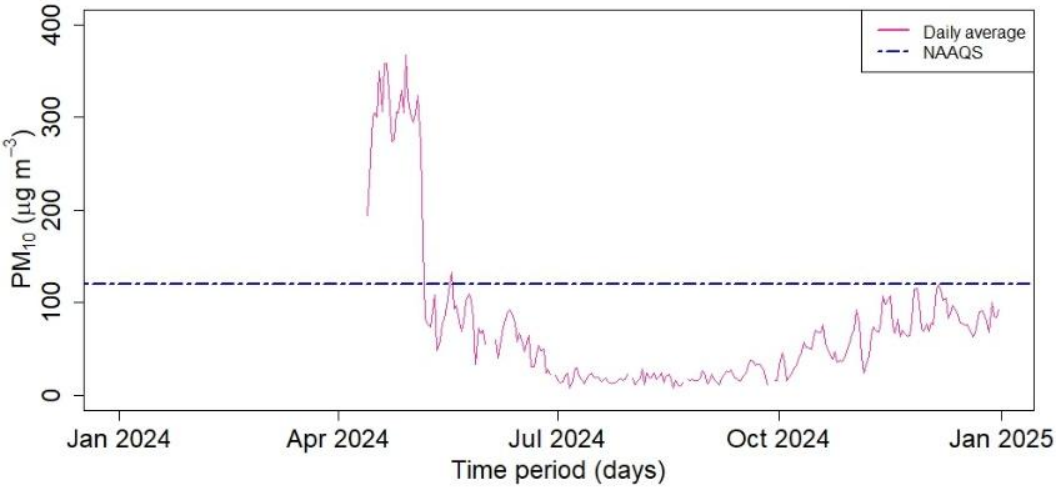

Figure A4-133: Daily Average of PM_{10} for Bharatpur Station

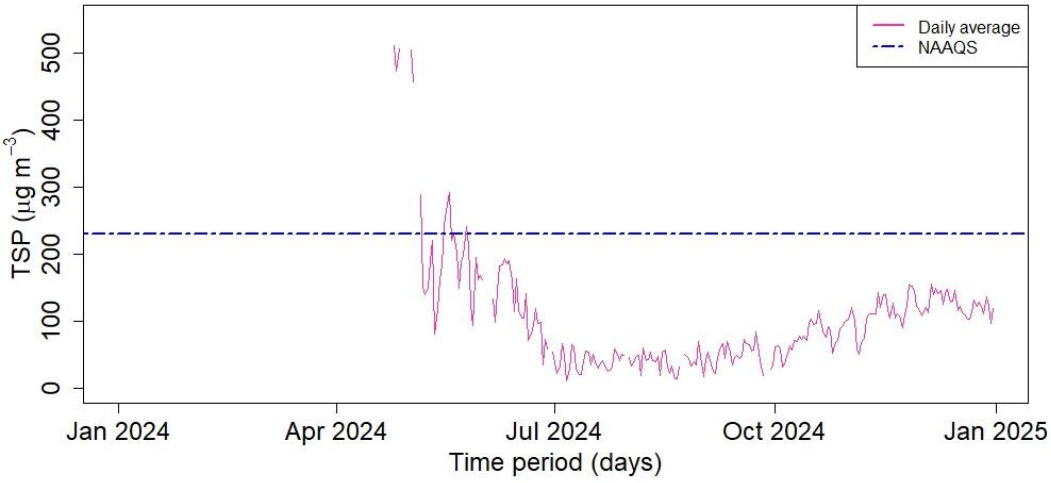

Figure A4-134: Daily Average of TSP for Bharatpur Station

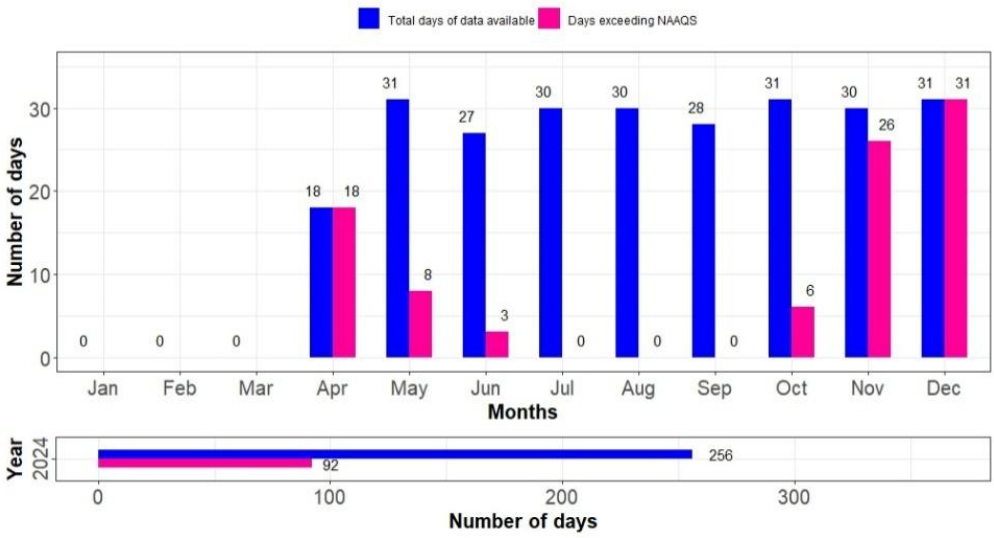

Figure A4-135: Compliance Status of $PM_{2.5}$ for Bharatpur Station

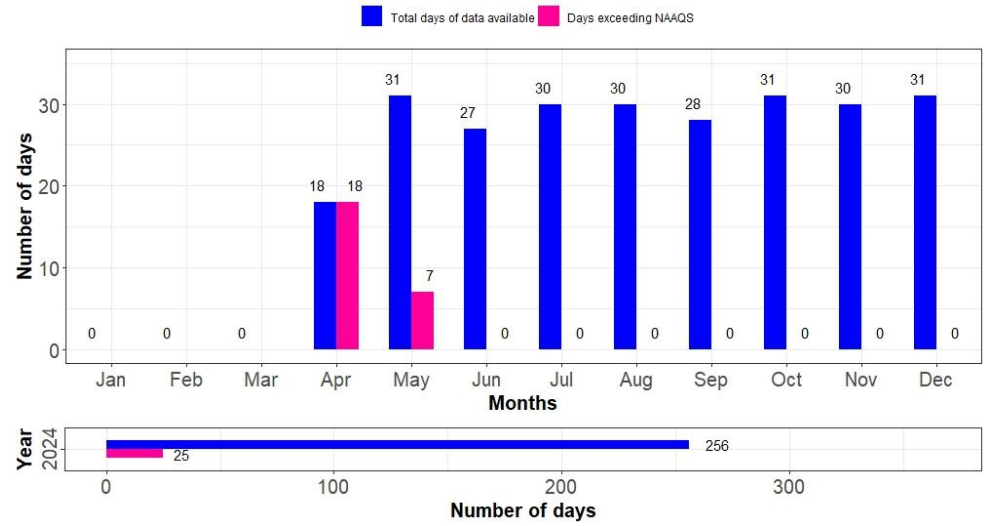

Figure A4-136: Compliance Status of PM_{10} for Bharatpur Station

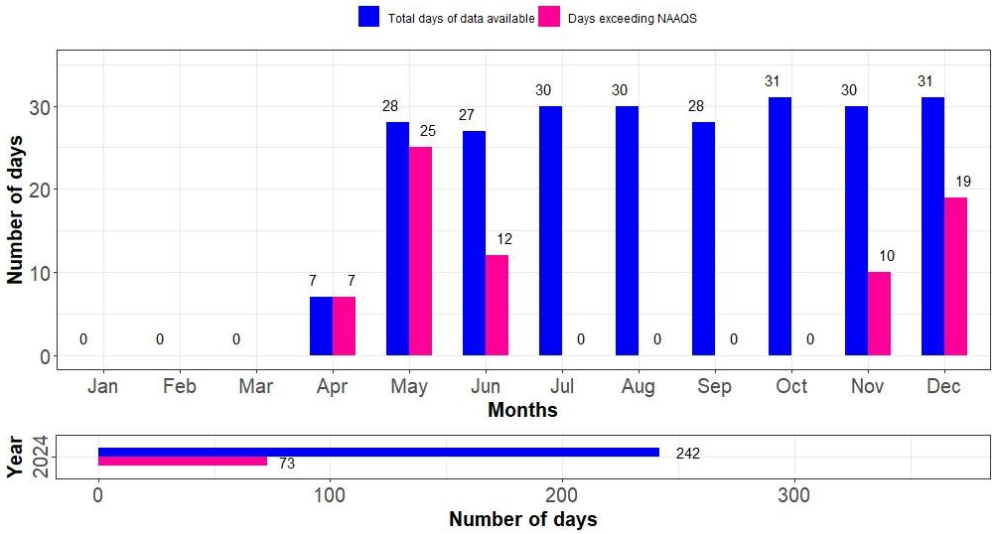

Figure A4-137: Compliance Status of TSP for Bharatpur Station

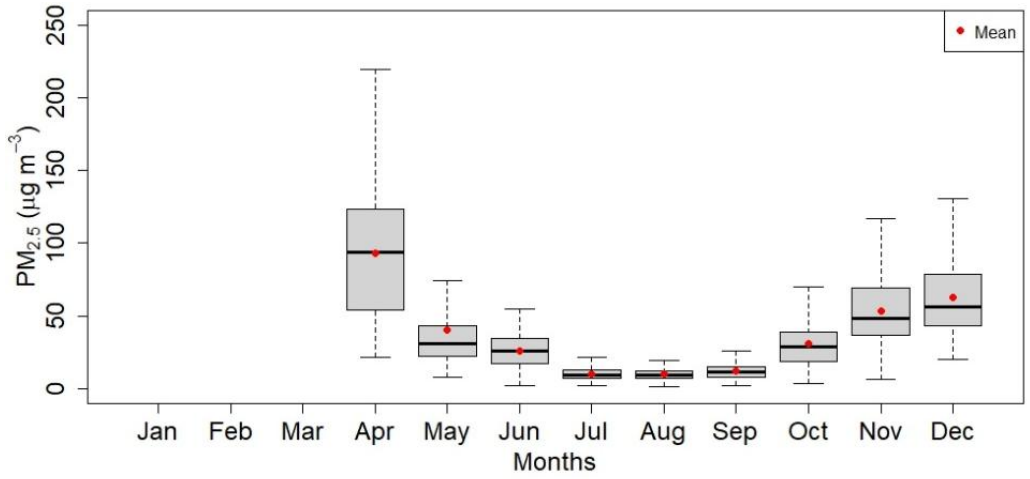

Figure A4-138: Monthly Variation of $PM_{2.5}$ for Bharatpur Station

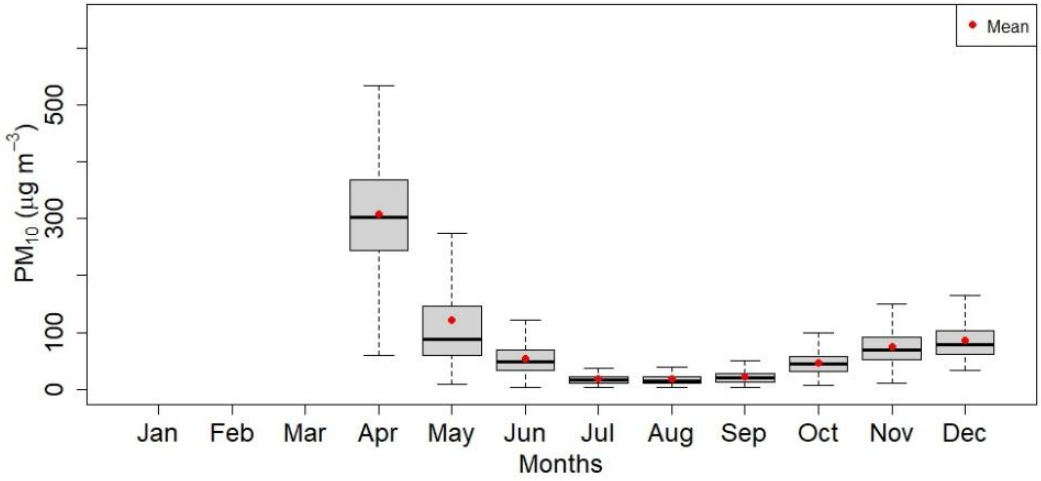

Figure A4-139: Monthly Variation of PM_{10} for Bharatpur Station

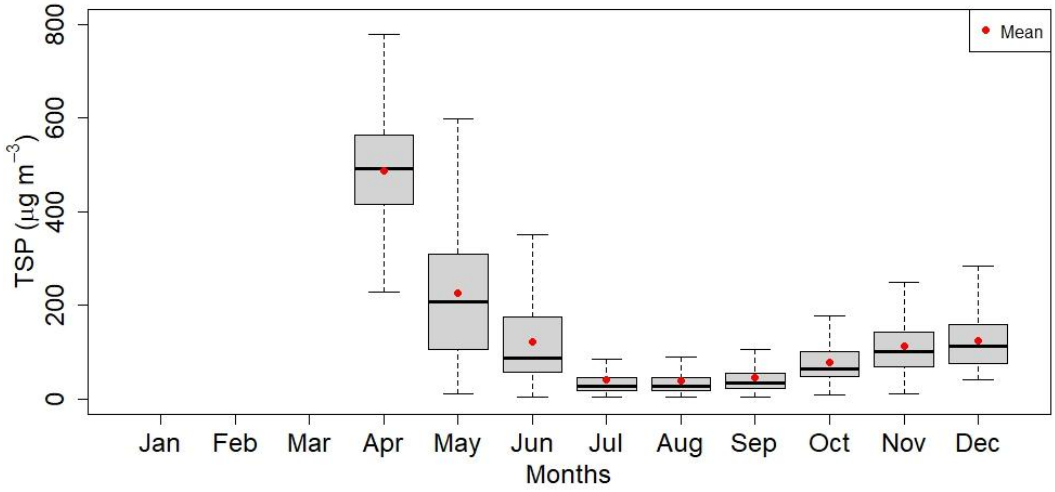

Figure A4-140: Monthly Variation of TSP for Bharatpur Station

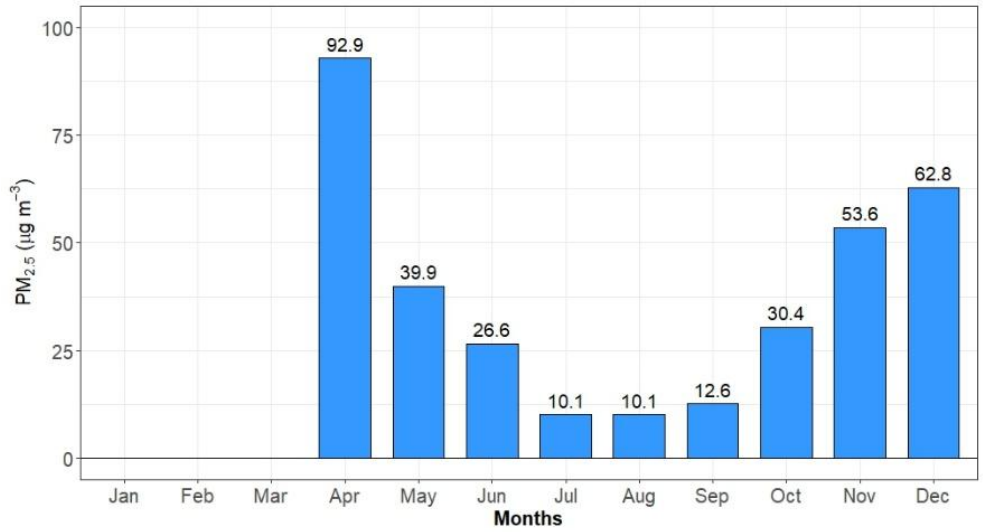

Figure A4-141: Monthly Average of $PM_{2.5}$ for Bharatpur Station

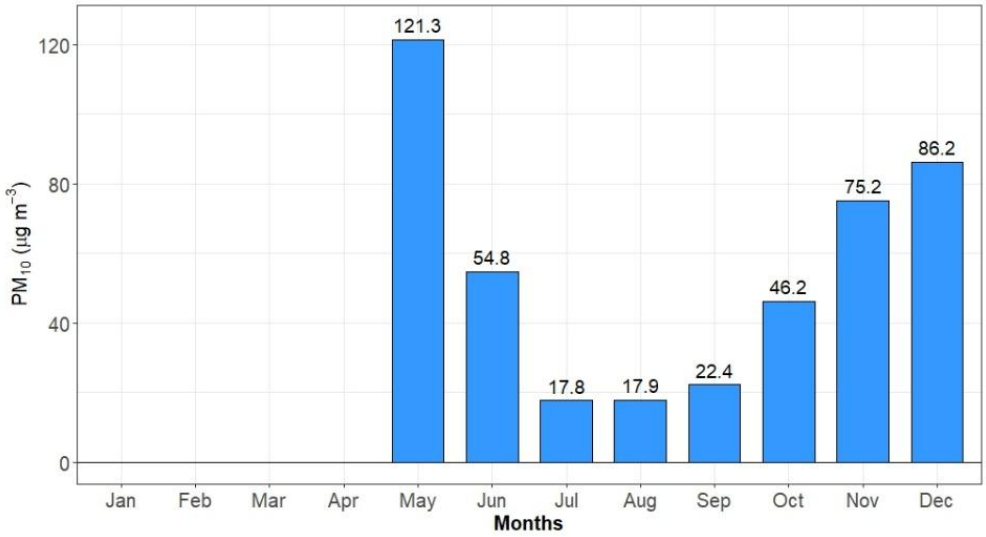

Figure A4-142: Monthly Average of PM_{10} for Bharatpur Station

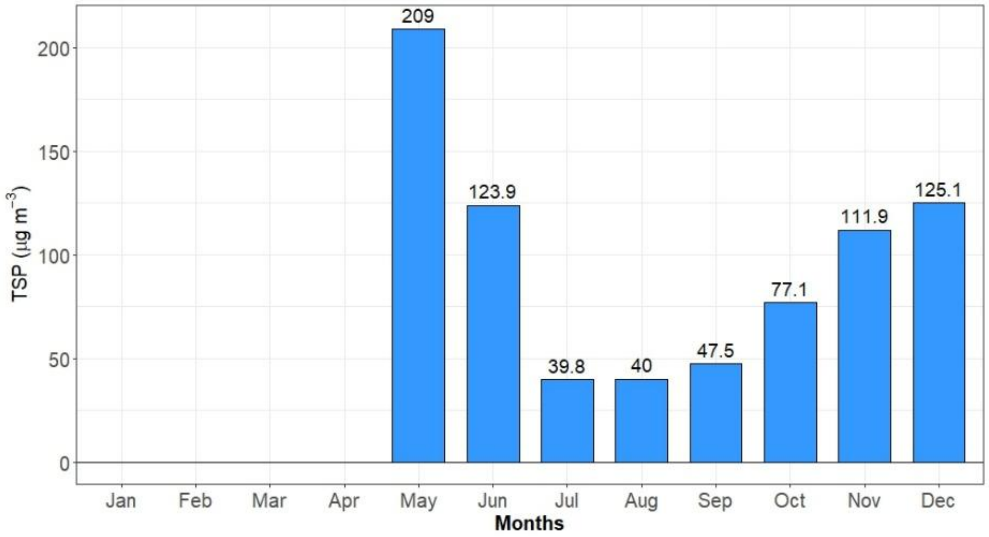

Figure A4-143: Monthly Average of TSP for Bharatpur Station

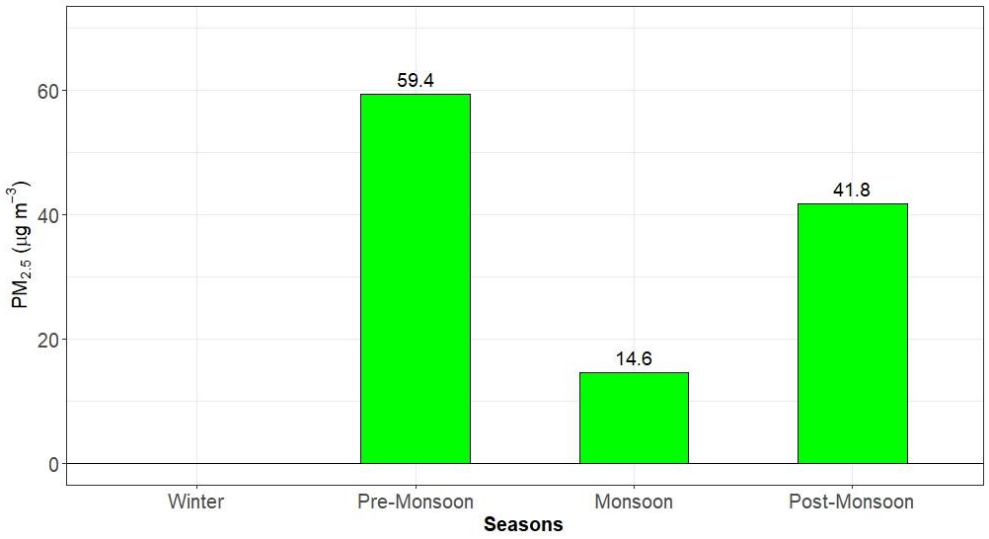

Figure A4-144: Seasonal Average of $PM_{2.5}$ for Bharatpur Station

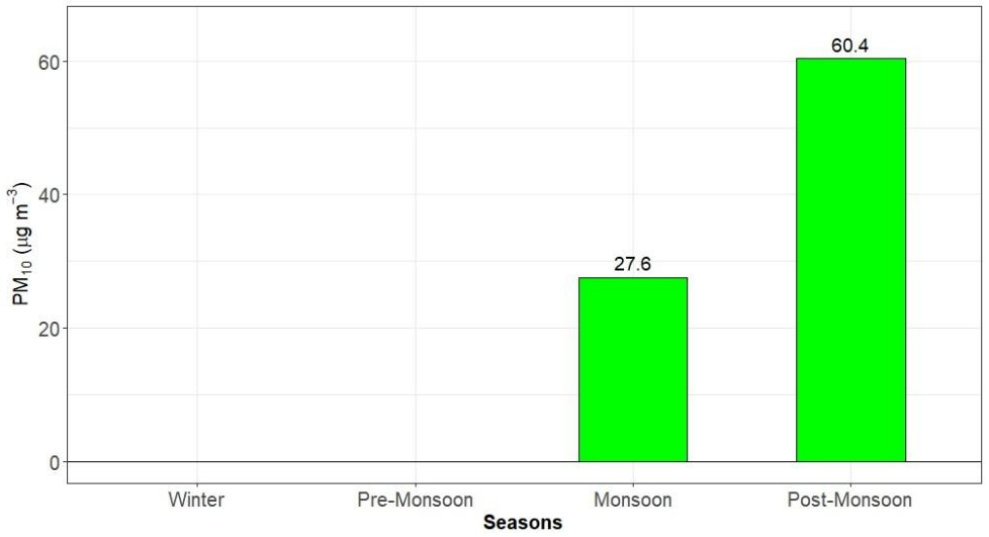

Figure A4-145: Seasonal Average of PM_{10} for Bharatpur Station

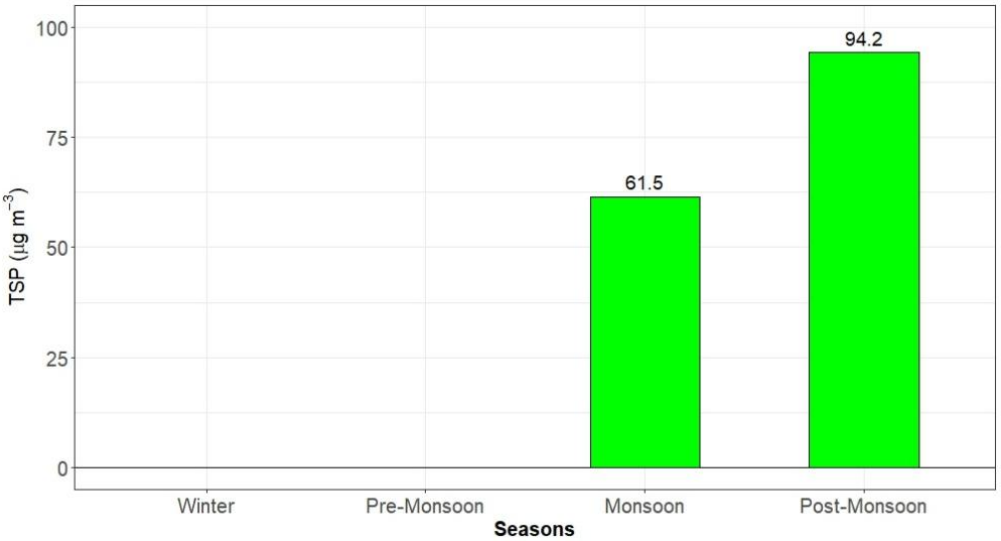

Figure A4-146: Seasonal Average of TSP for Bharatpur Station

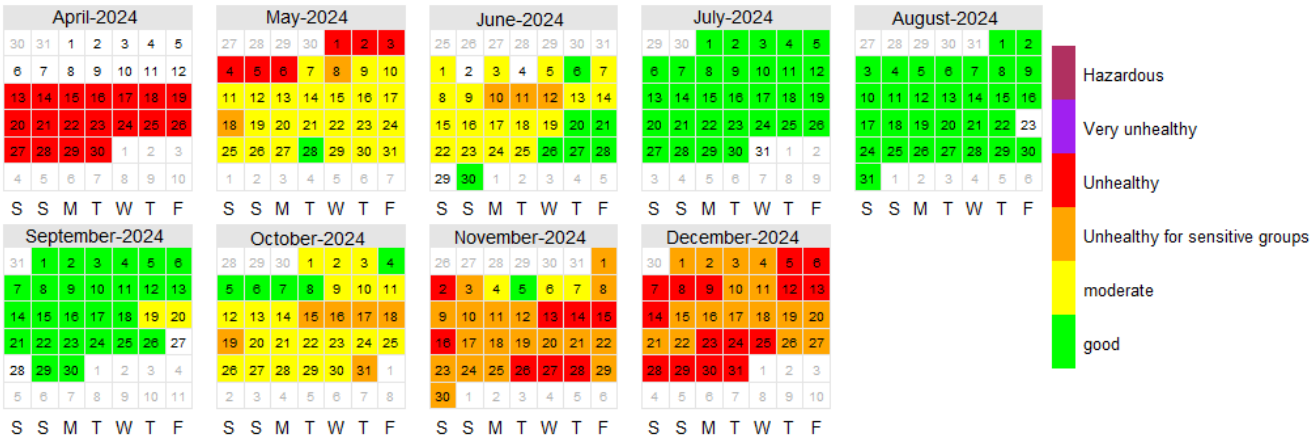

Figure A4-147: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Bharatpur Station

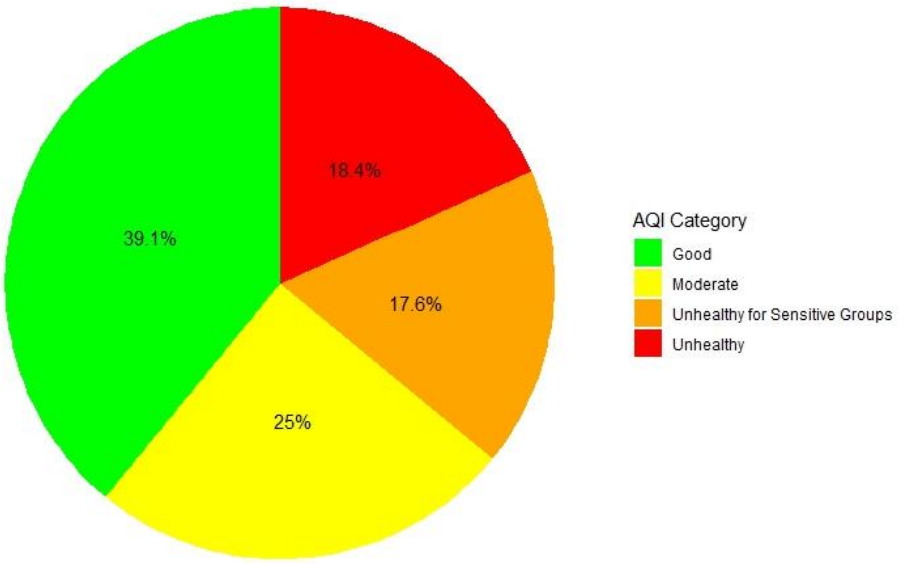

Figure A4-148: AQI Category Distribution for Bharatpur Station

HETAUDA AIR QUALITY MONITORING STATION

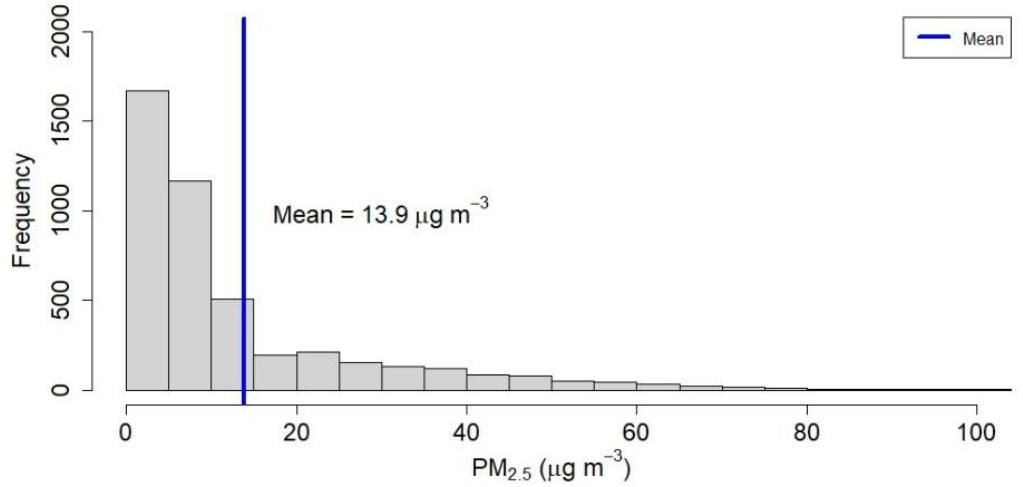

Figure A4-149: Histogram of $PM_{2.5}$ for Hetauda Station

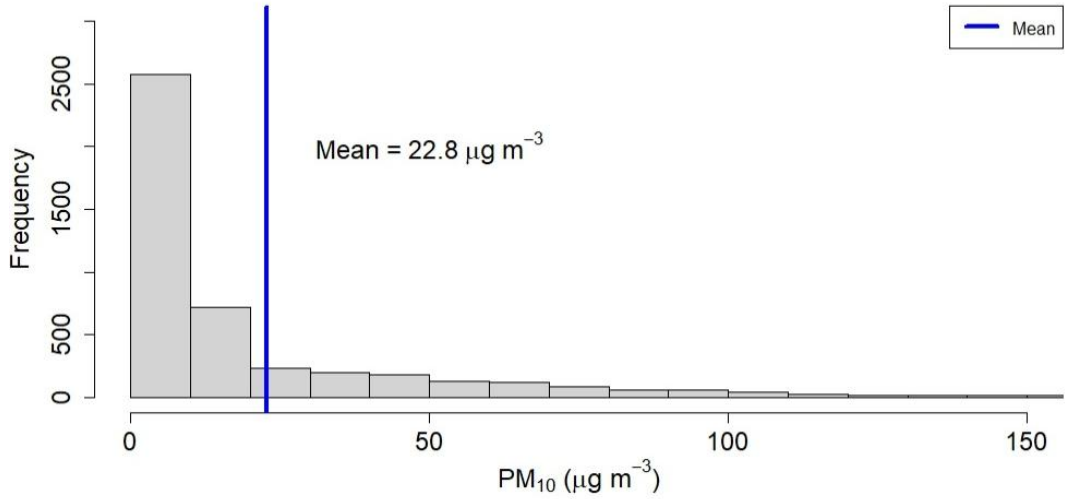

Figure A4-150: Histogram of PM_{10} for Hetauda Station

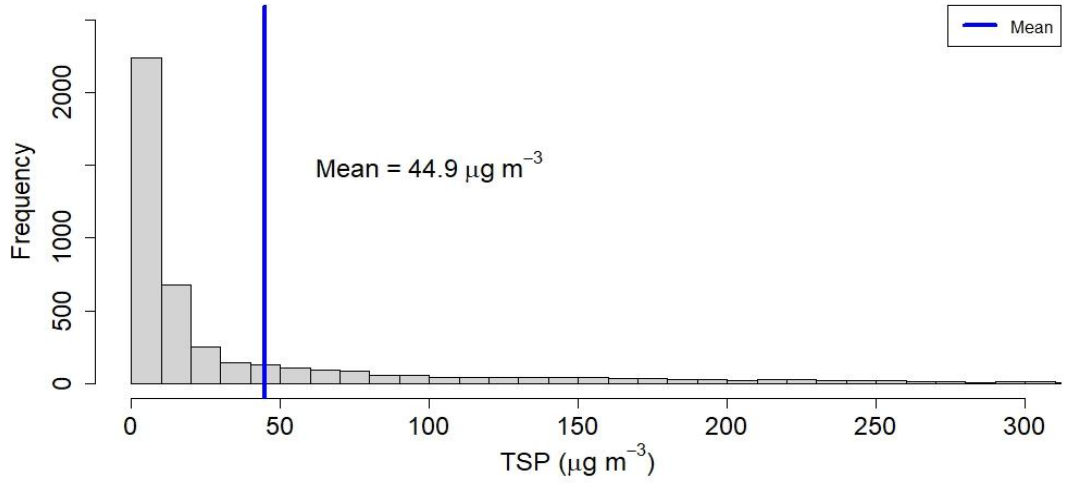

Figure A4-151: Histogram of TSP for Hetauda Station

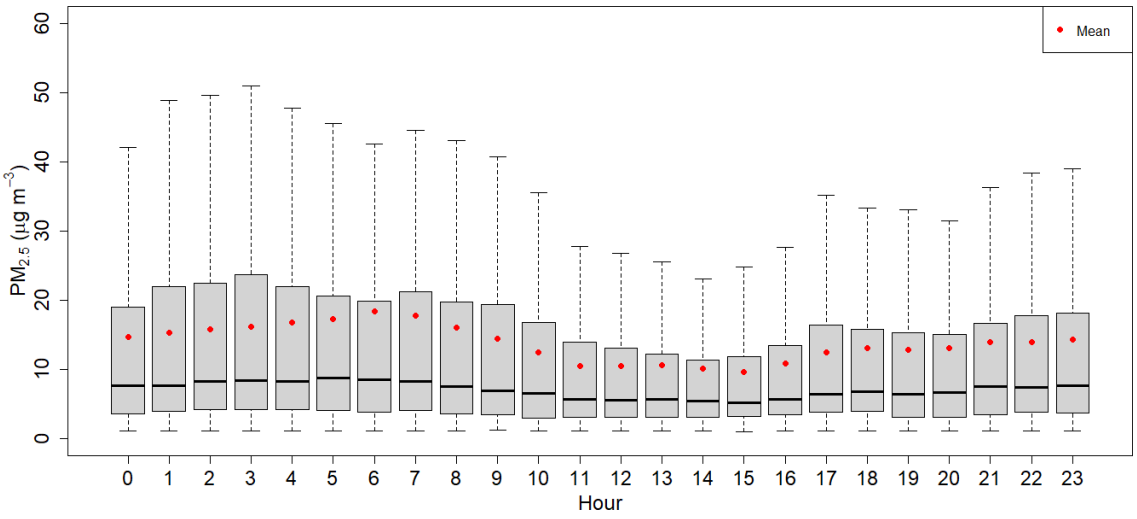

Figure A4-152: Diurnal Variation of $PM_{2.5}$ for Hetauda Station

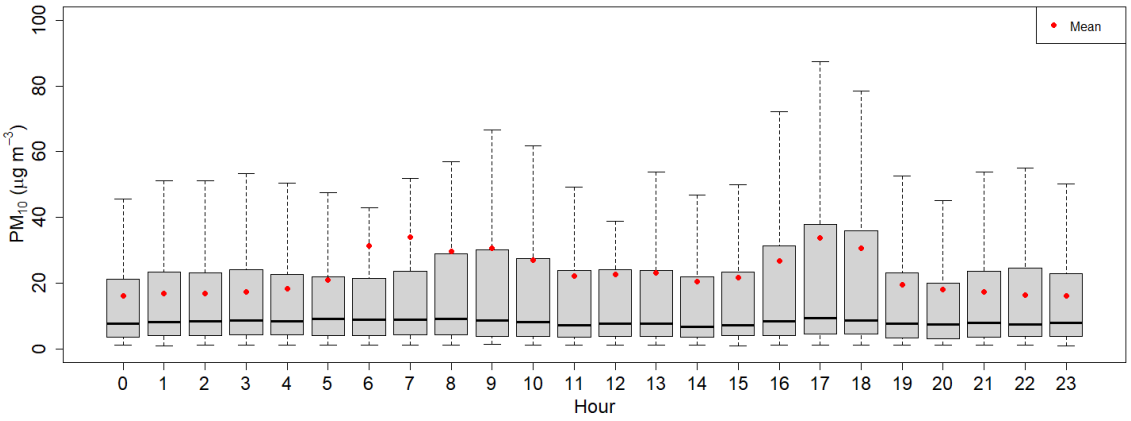

Figure A4-153: Diurnal Variation of PM_{10} for Hetauda Station

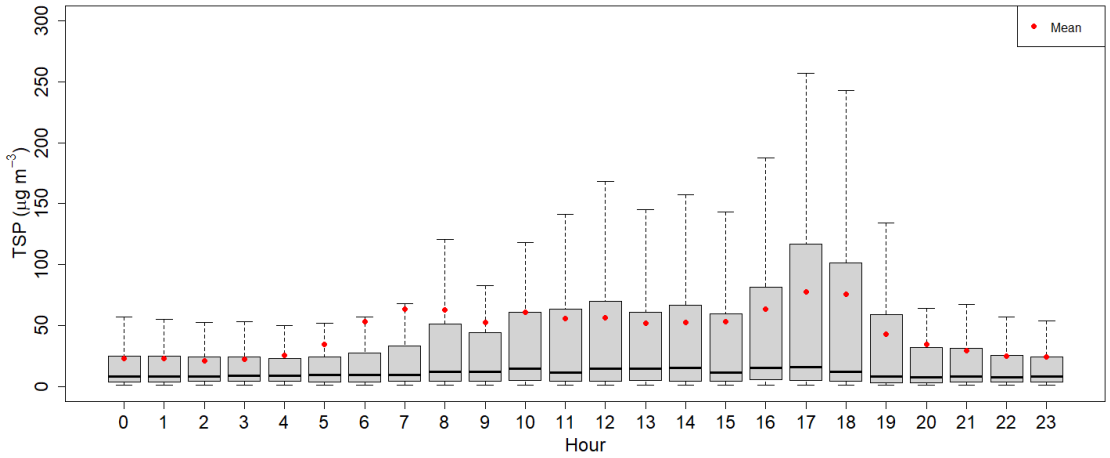

Figure A4-154: Diurnal Variation of TSP for Hetauda Station

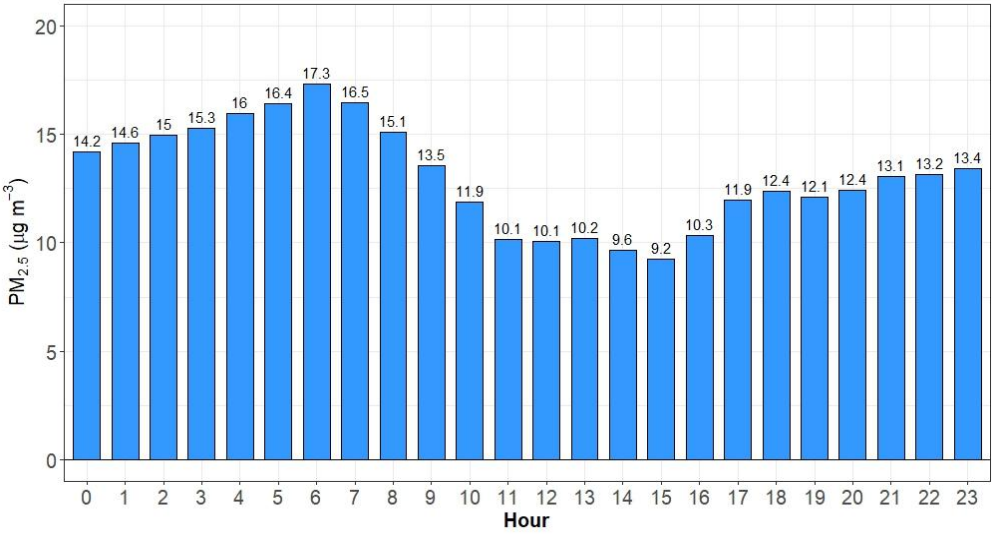

Figure A4-155: Hourly Average of $PM_{2.5}$ for Hetauda Station

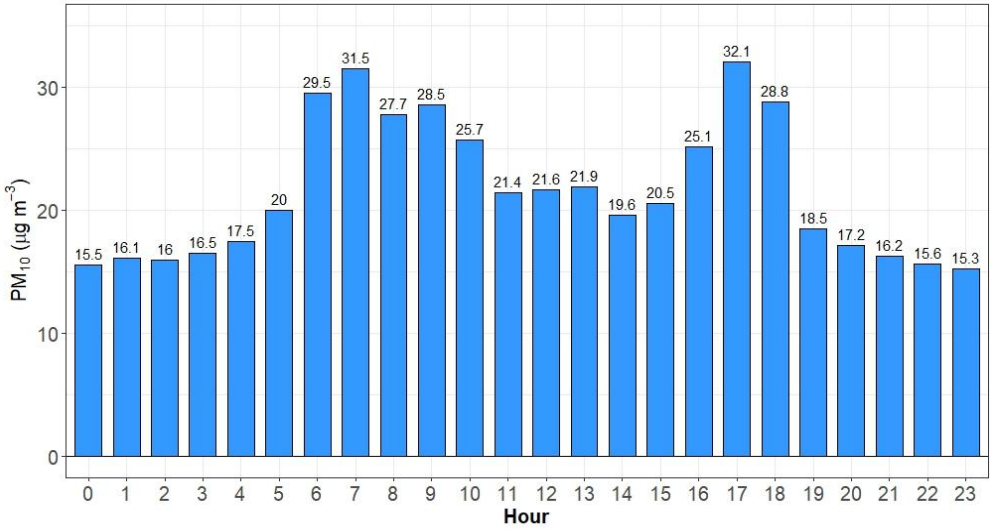

Figure A4-156: Hourly Average of PM_{10} for Hetauda Station

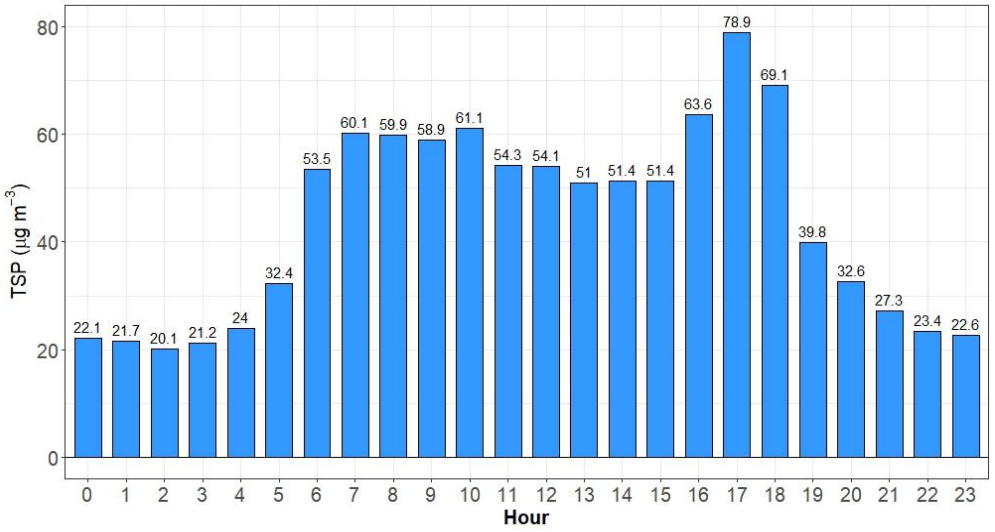

Figure A4-157: Hourly Average of TSP for Hetauda Station

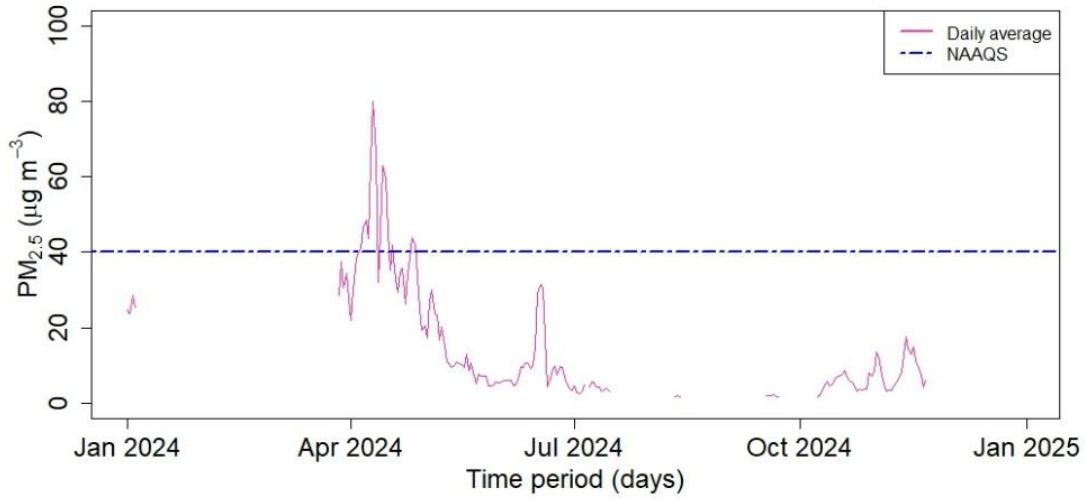

Figure A4-158: Daily Average of $PM_{2.5}$ for Hetauda Station

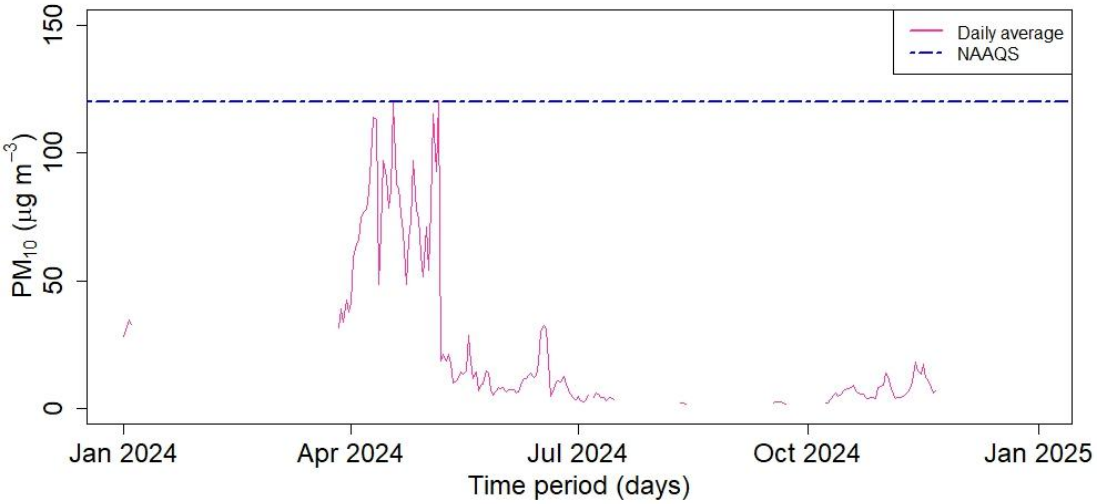

Figure A4-159: Daily Average of PM_{10} for Hetauda Station

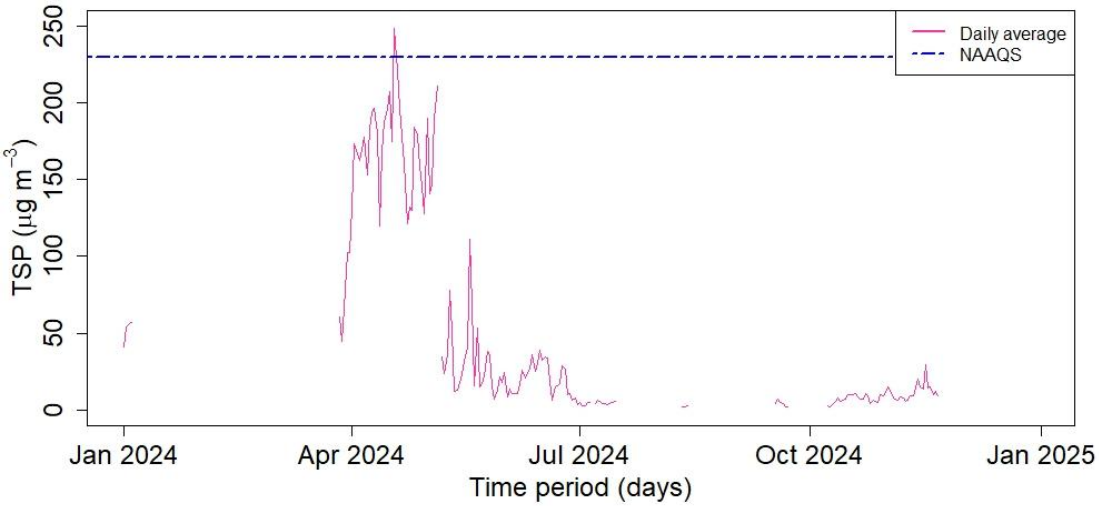

Figure A4-160: Daily Average of TSP for Hetauda Station

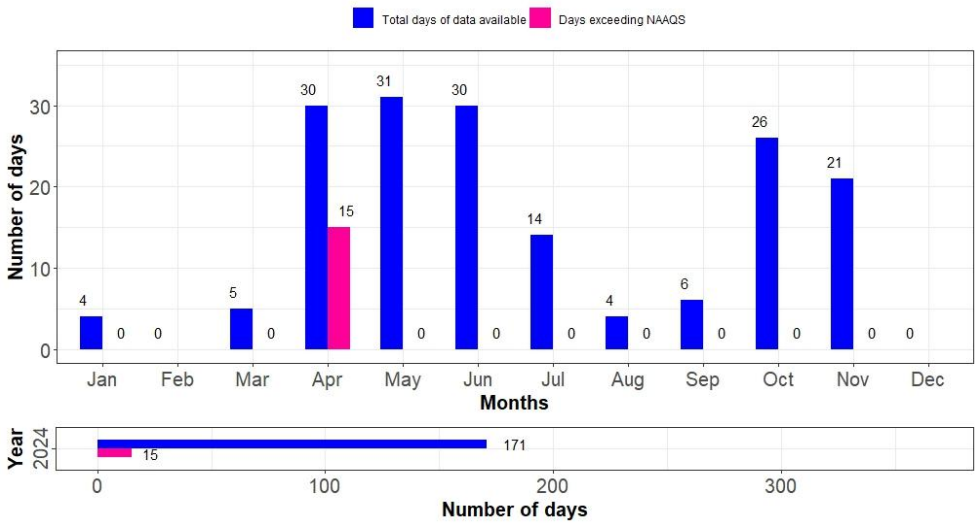

Figure A4-161: Compliance Status of $PM_{2.5}$ for Hetauda Station

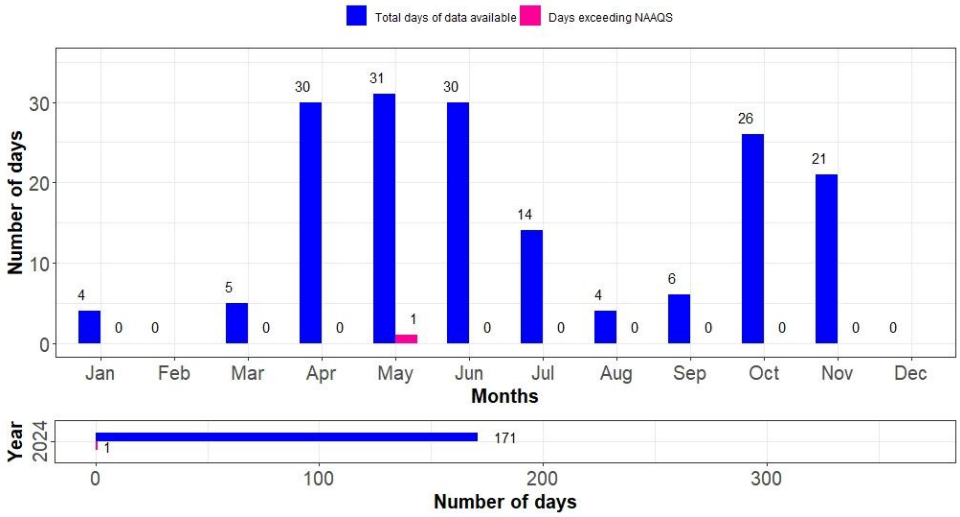

Figure A4-162: Compliance Status of PM_{10} for Hetauda Station

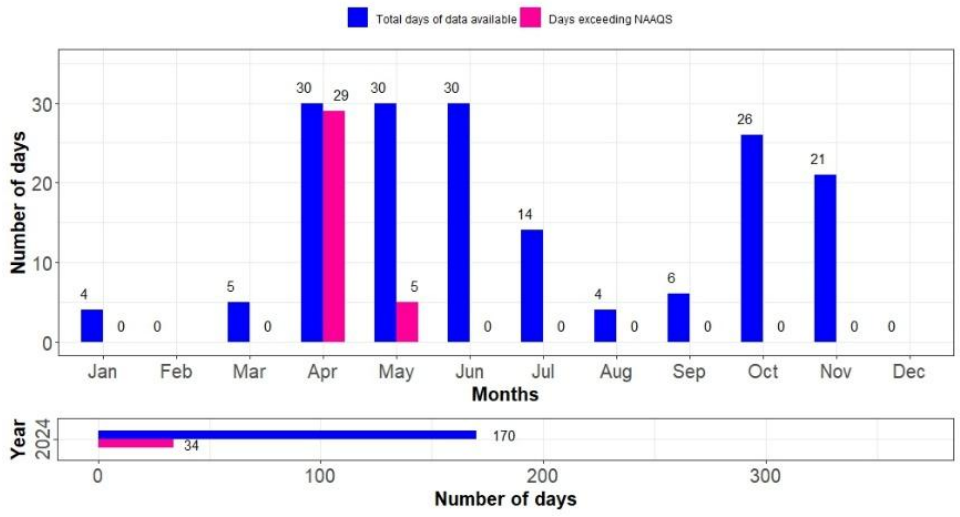

Figure A4-163: Compliance Status of TSP for Hetauda Station

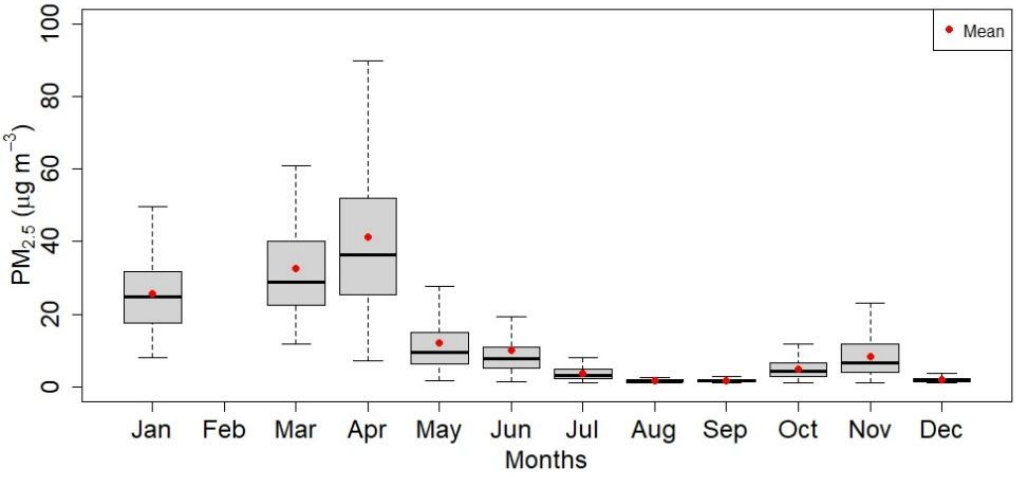

Figure A4-164: Monthly Variation of $PM_{2.5}$ for Hetauda Station

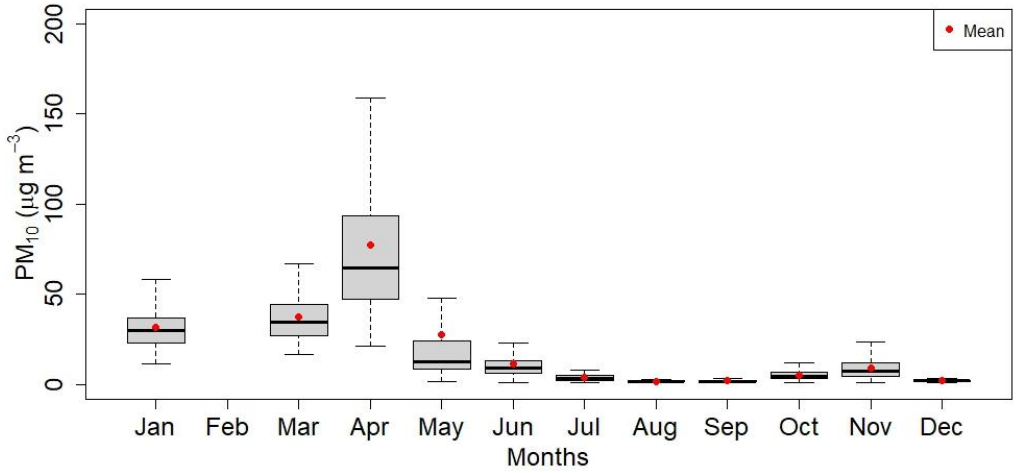

Figure A4-165: Monthly Variation of PM_{10} for Hetauda Station

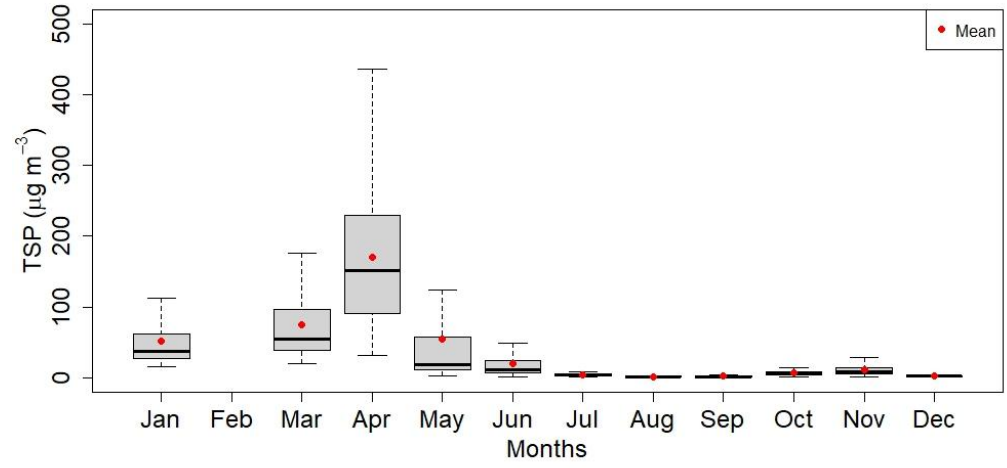

Figure A4-166: Monthly Variation of TSP for Hetauda Station

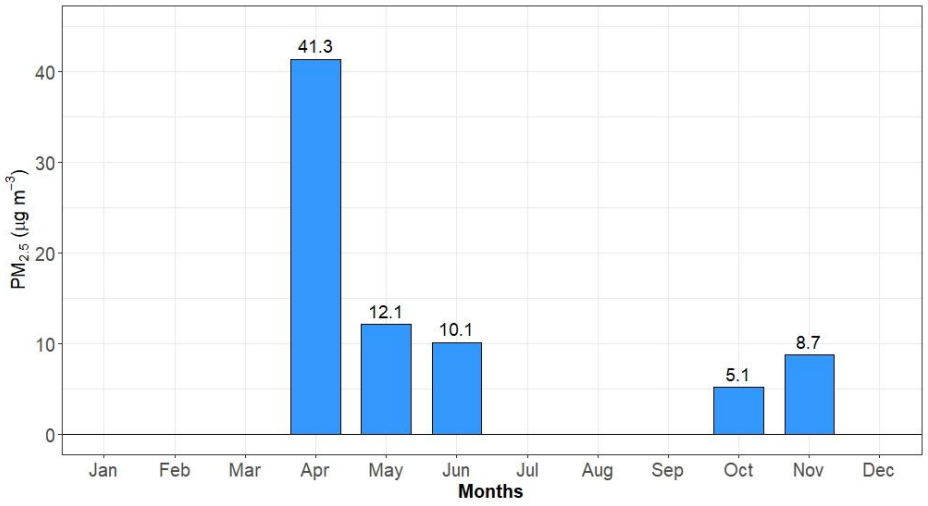

Figure A4-167: Monthly Average of $PM_{2.5}$ for Hetauda Station

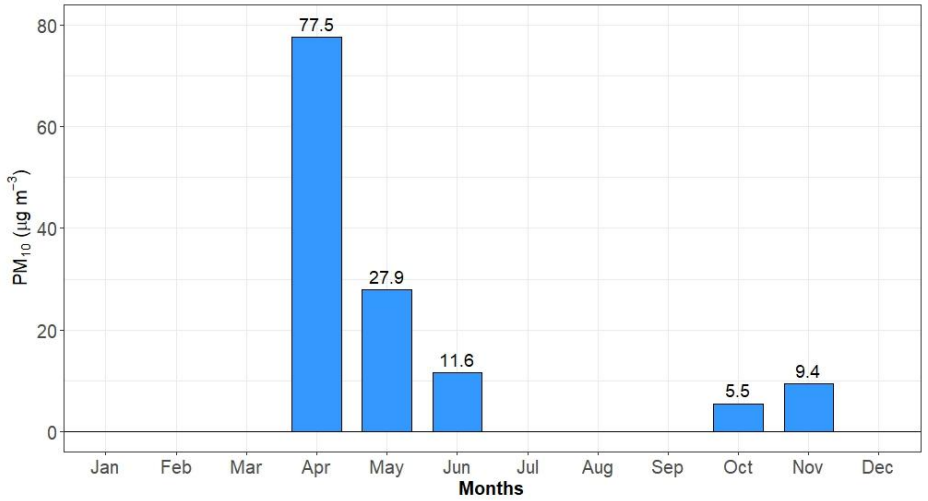

Figure A4-168: Monthly Average of PM_{10} for Hetauda Station

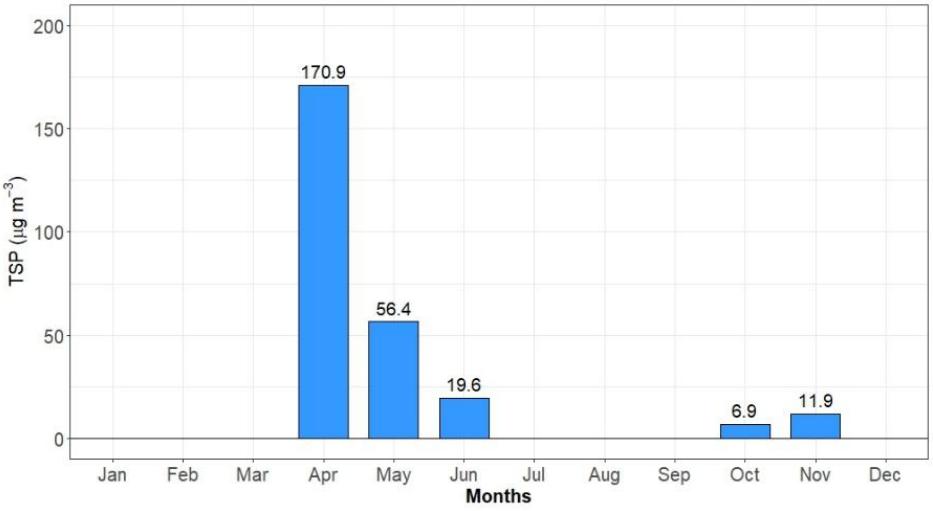

Figure A4-169: Monthly Average of TSP for Hetauda Station

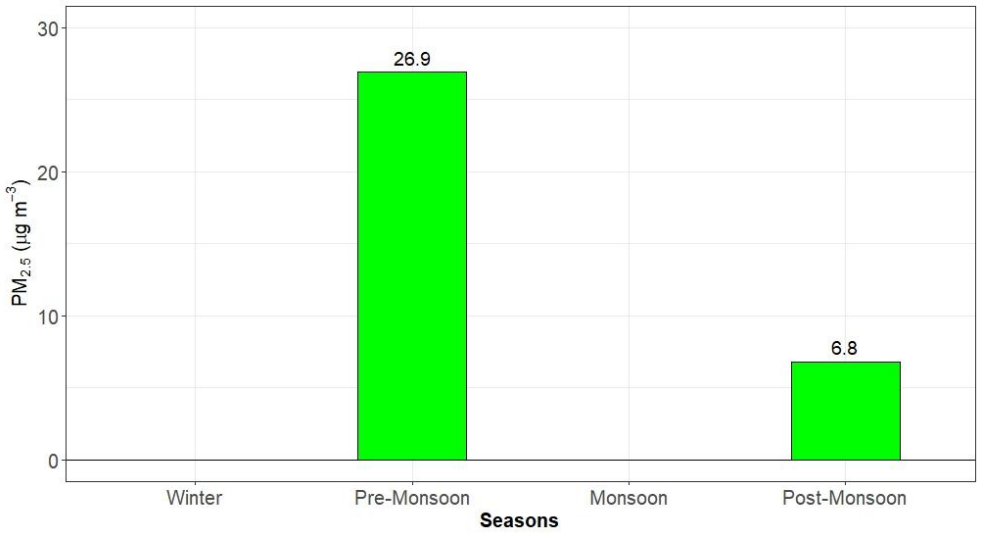

Figure A4-170: Seasonal Average of $PM_{2.5}$ for Hetauda Station

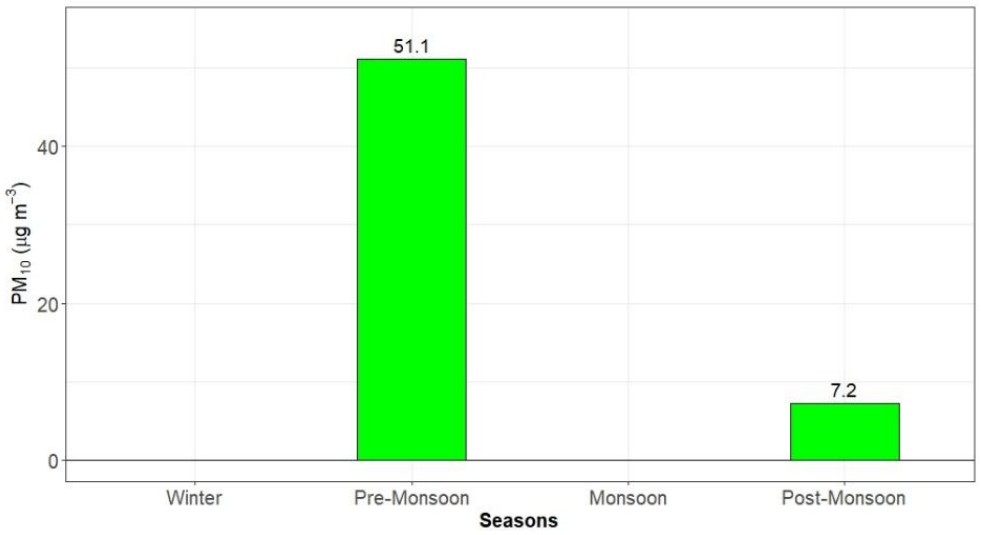

Figure A4-171: Seasonal Average of PM_{10} for Hetauda Station

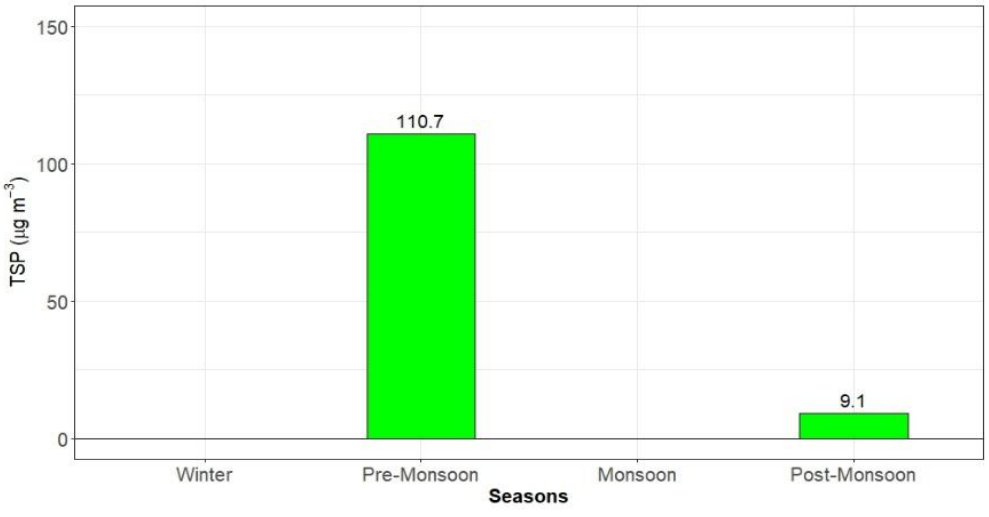

Figure A4-172: Seasonal Average of TSP for Hetauda Station

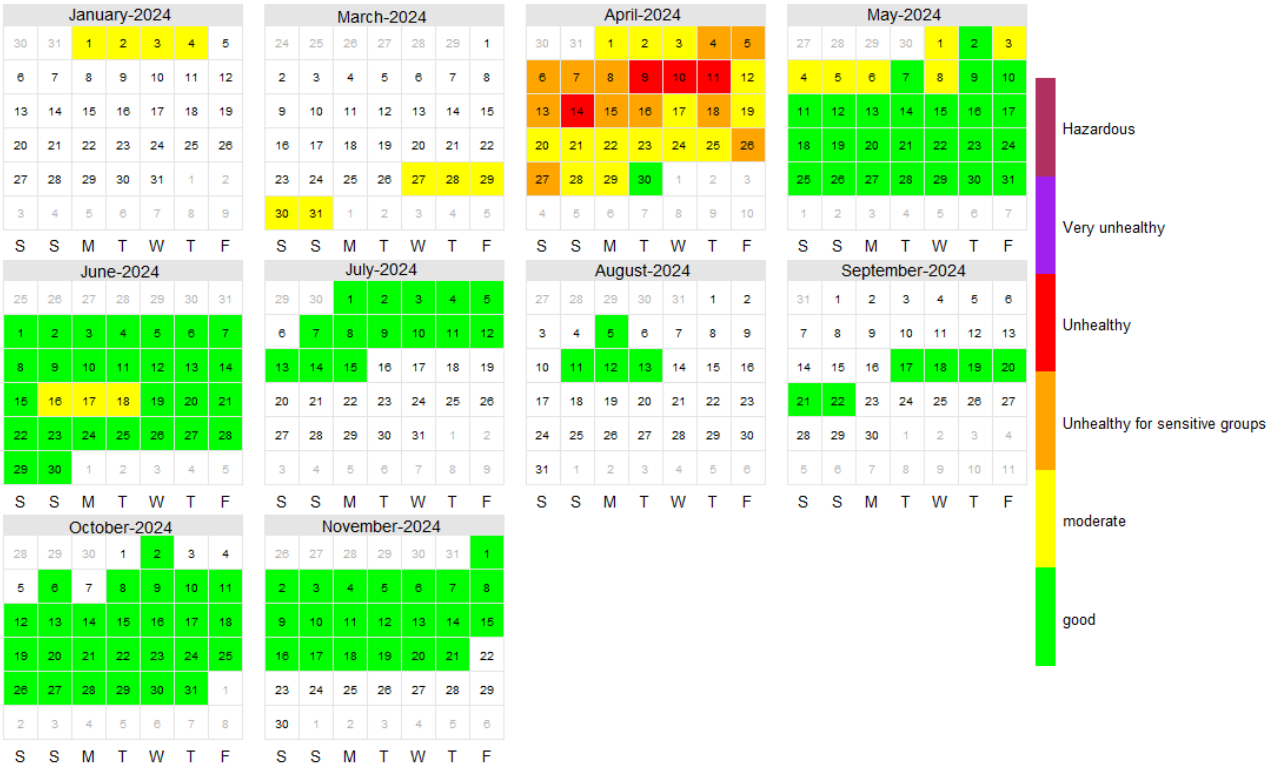

Figure A4-173: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Hetauda Station

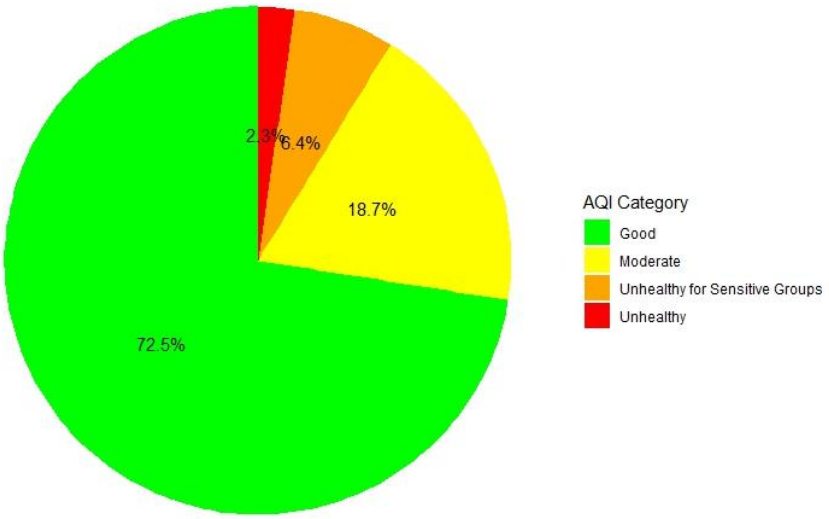

Figure A4-174: AQI Category Distribution for Hetauda Station

KHUMALTAR AIR QUALITY MONITORING STATION

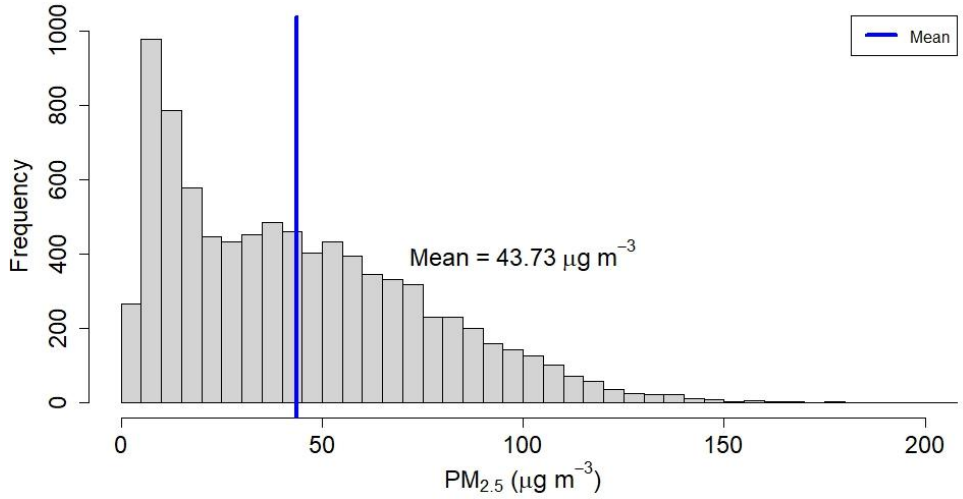

Figure A4-175: Histogram of $PM_{2.5}$ for Khumaltar Station

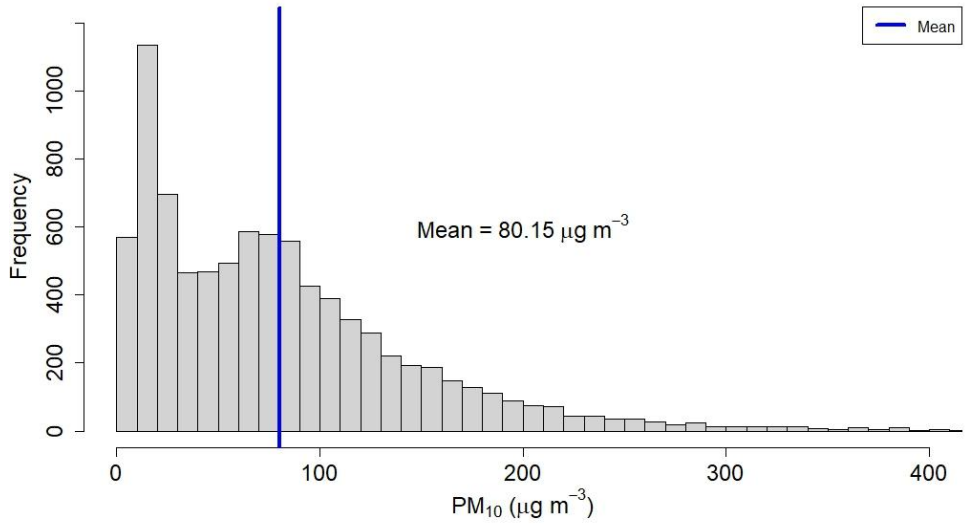

Figure A4-176: Histogram of PM_{10} for Khumaltar Station

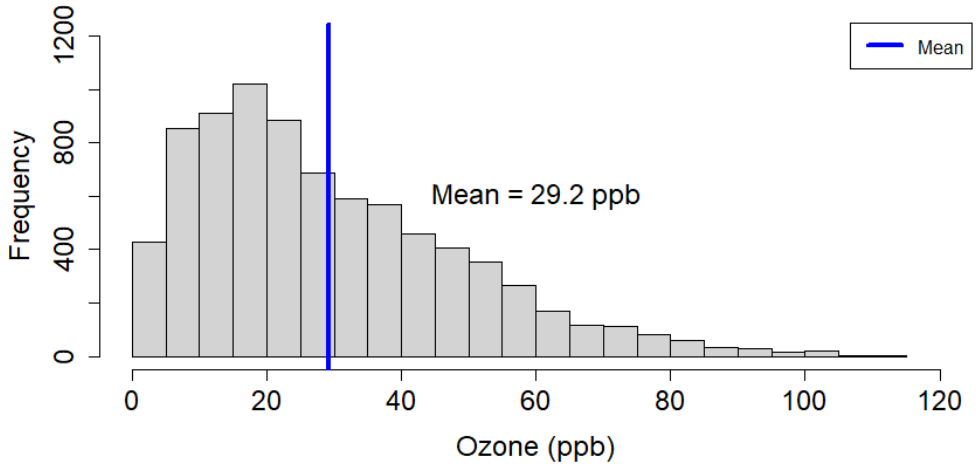

Figure A4-177: Histogram of Ozone for Khumaltar Station

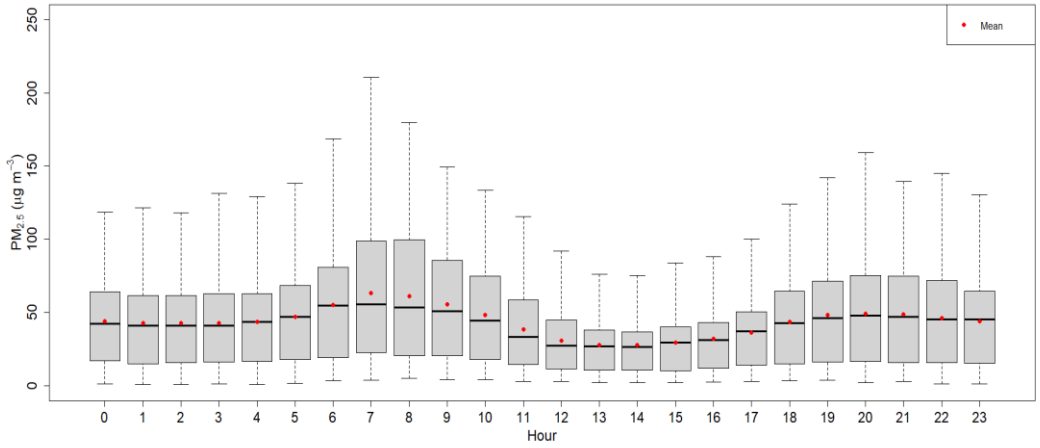

Figure A4-178: Diurnal Variation of $PM_{2.5}$ for Khumaltar Station

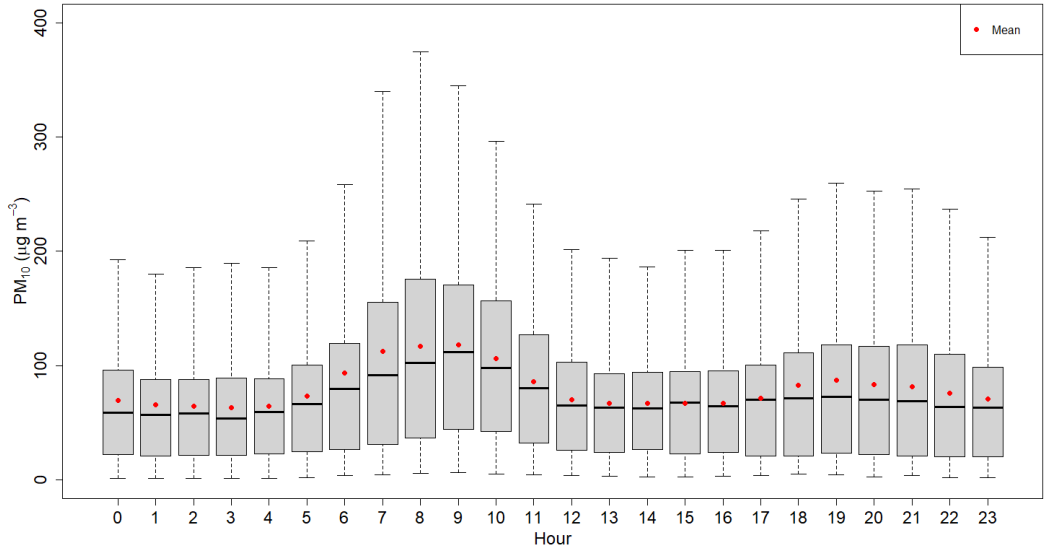

Figure A4-179: Diurnal Variation of PM_{10} for Khumaltar Station

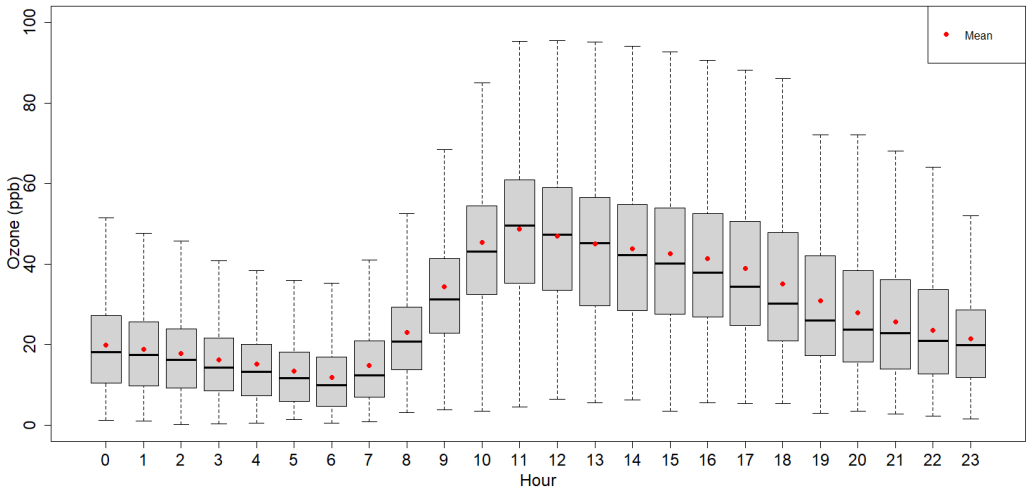

Figure A4-180: Diurnal Variation of Ozone for Khumaltar Station

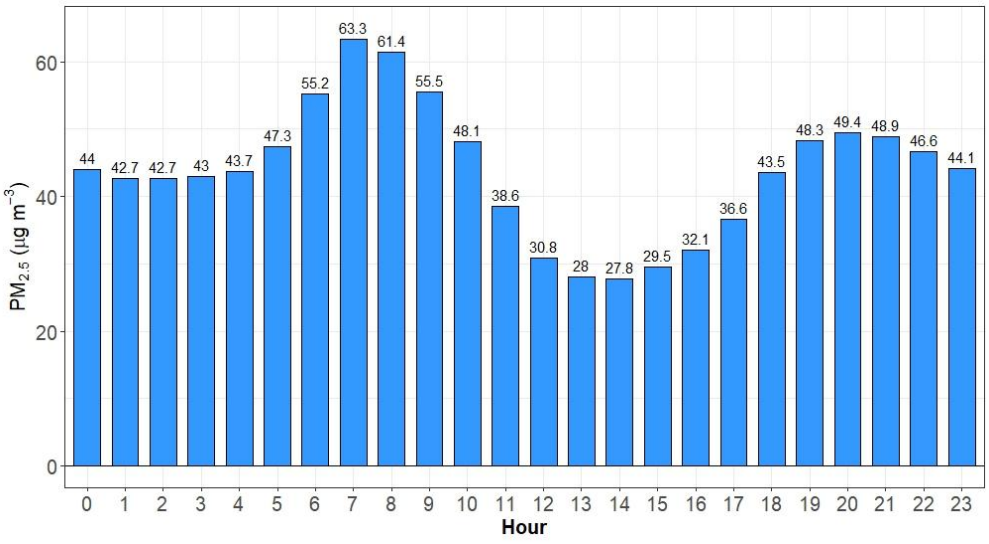

Figure A4-181: Hourly Average of $PM_{2.5}$ for Khumaltar Station

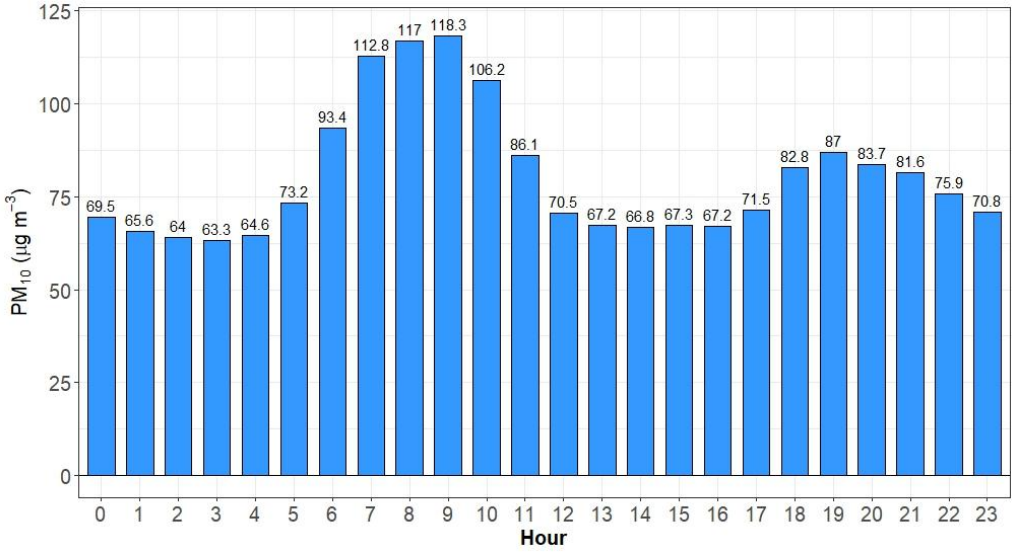

Figure A4-182: Hourly Average of PM_{10} for Khumaltar Station

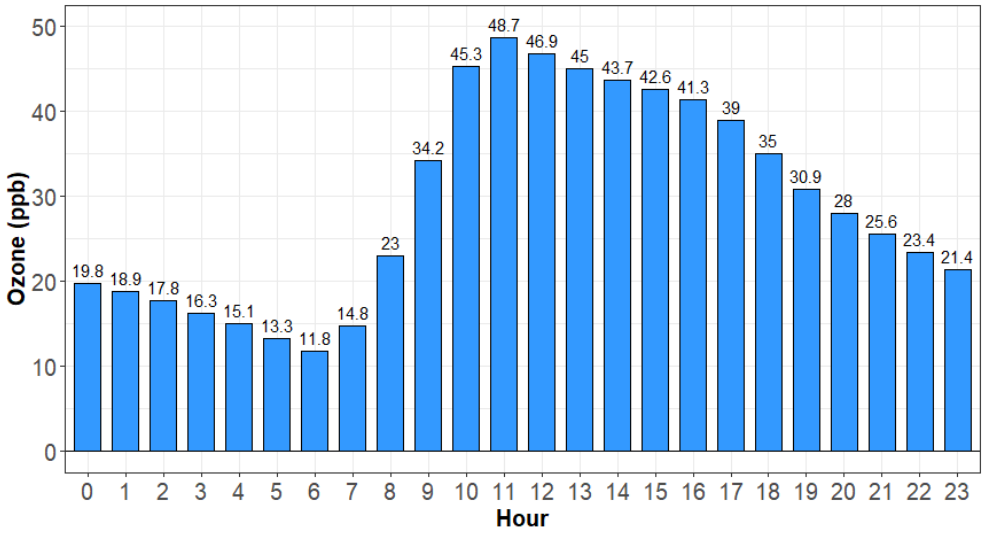

Figure A4-183: Hourly Average of PM_{10} for Khumaltar Station

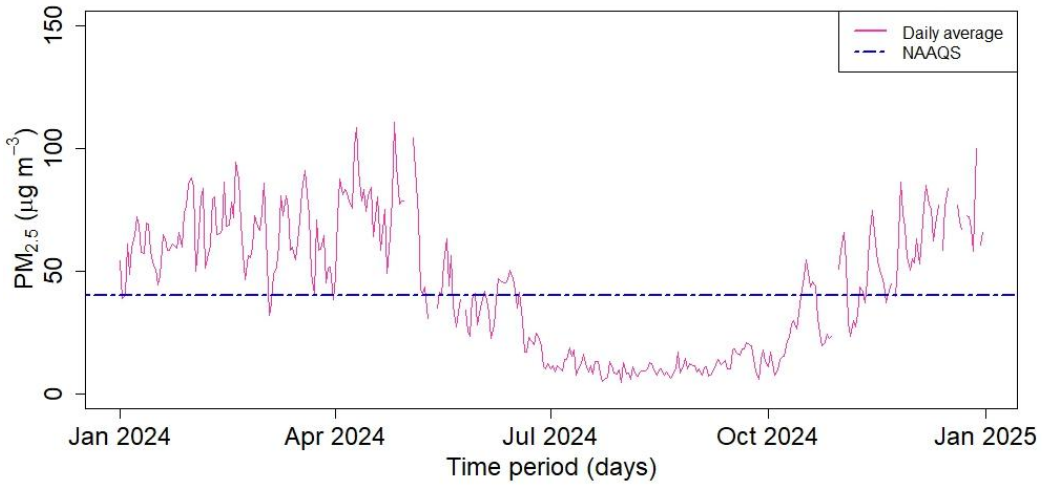

Figure A4-184: Daily Average of $PM_{2.5}$ for Khumaltar Station

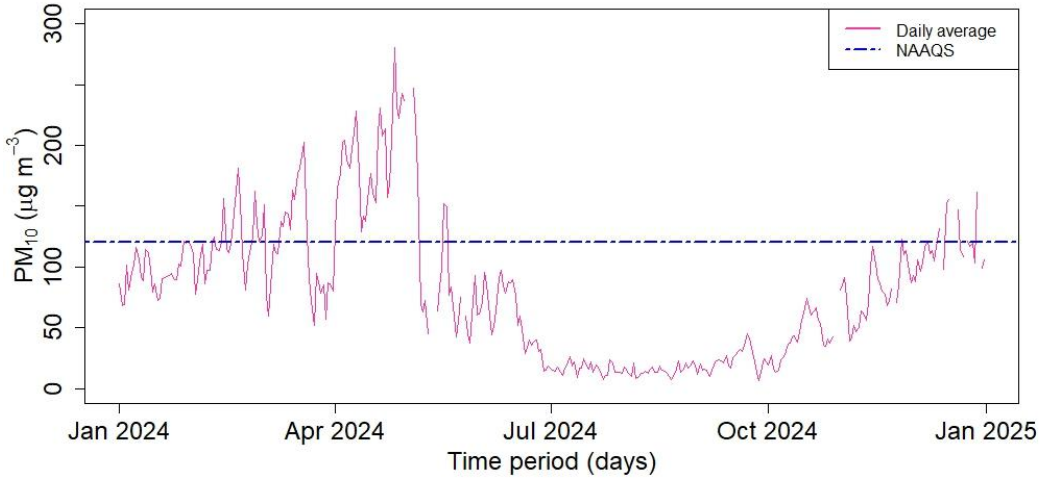

Figure A4-185: Daily Average of PM_{10} for Khumaltar Station

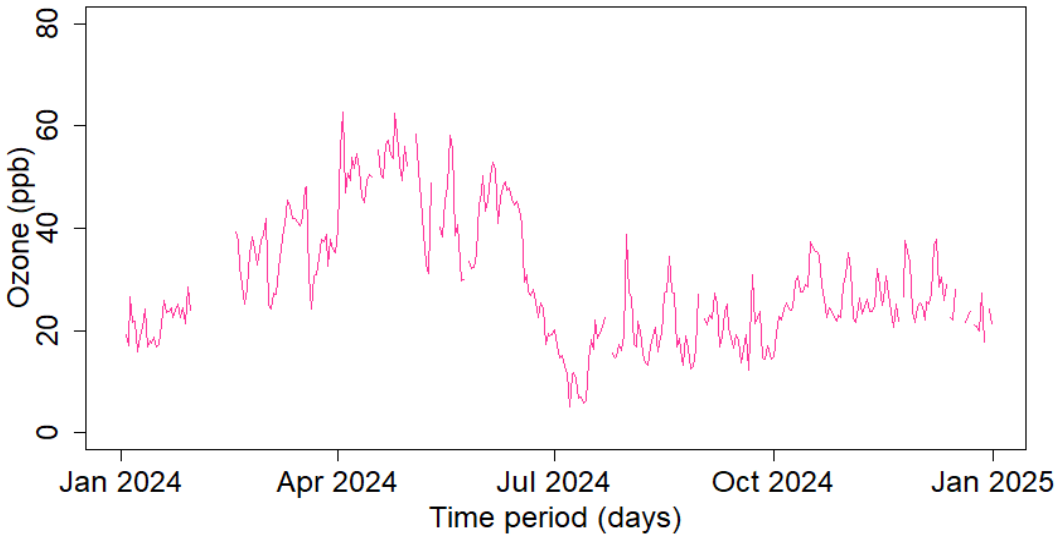

Figure A4-186: Daily Average of Ozone for Khumaltar Station

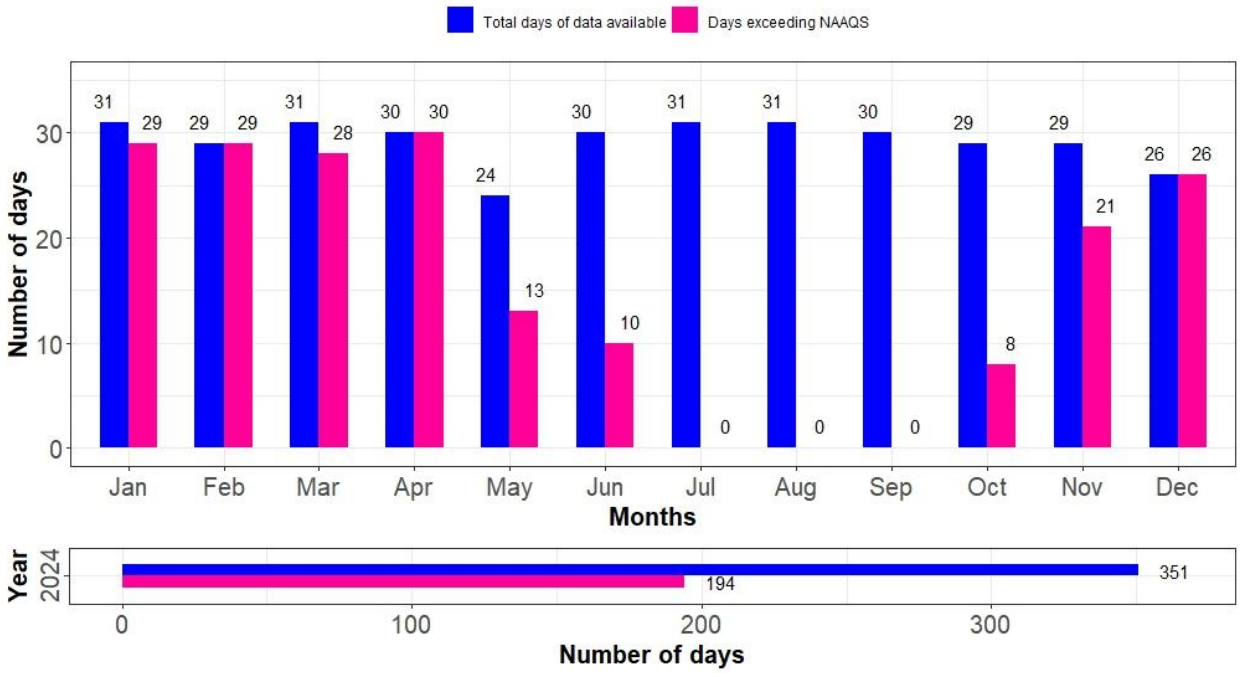

Figure A4-187: Compliance Status of $PM_{2.5}$ for Khumaltar Station

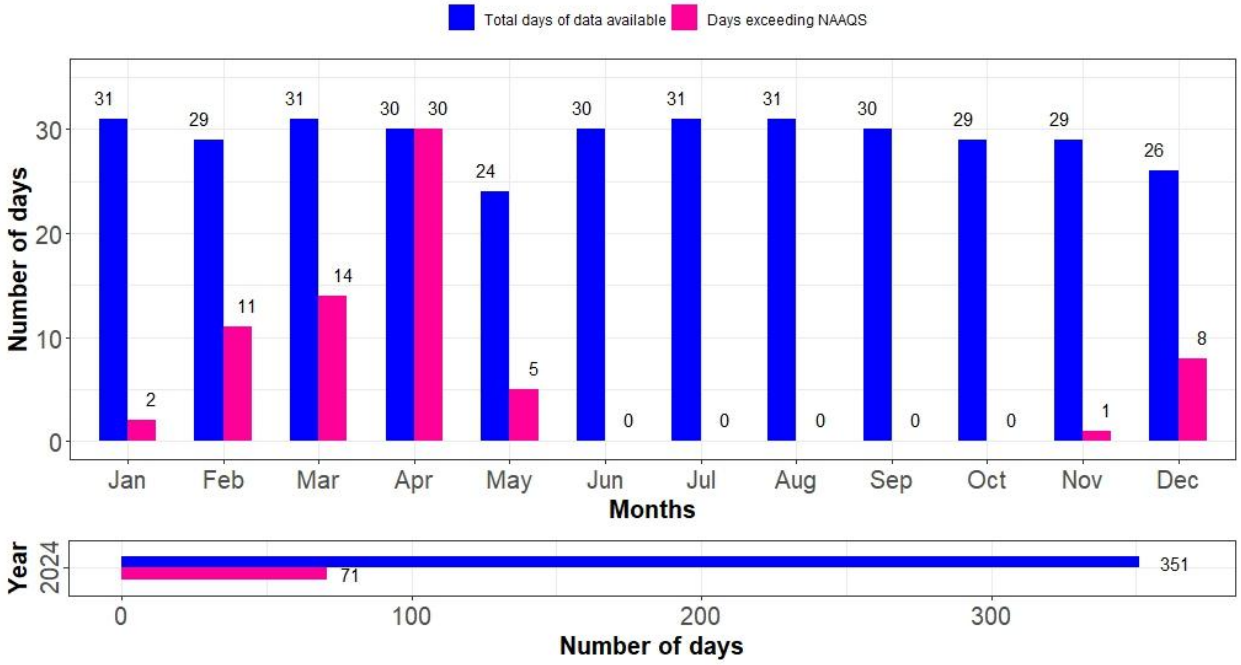

Figure A4-188: Compliance Status of PM_{10} for Khumaltar Station

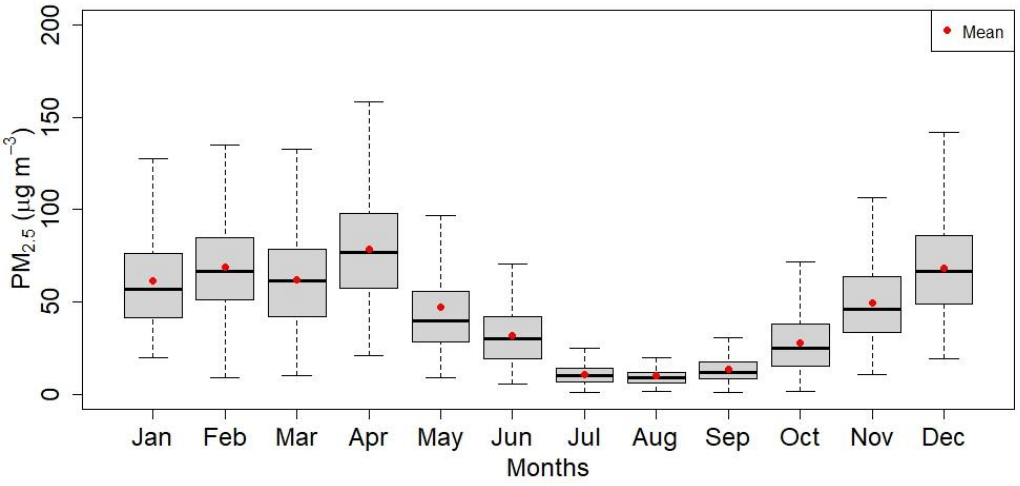

Figure A4-189: Monthly Variation of $PM_{2.5}$ for Khumaltar Station

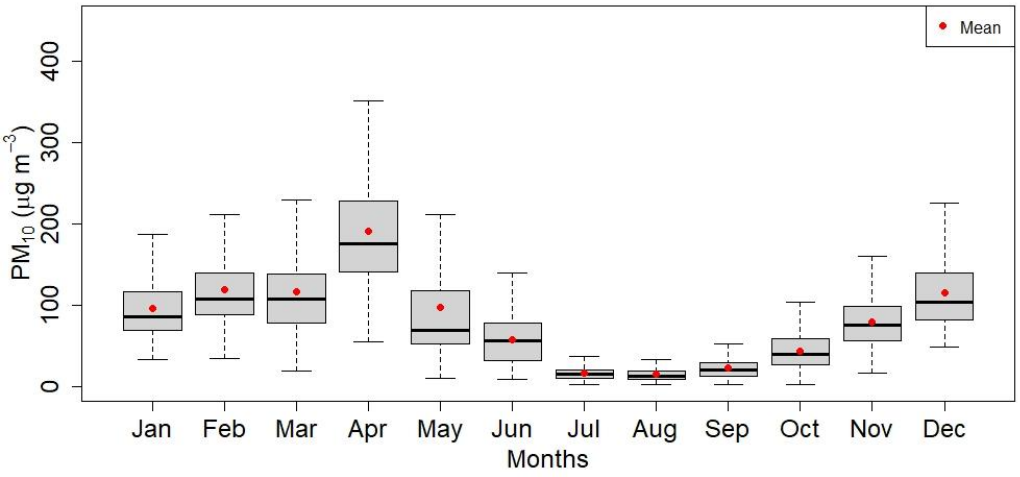

Figure A4-190: Monthly Variation of PM_{10} for Khumaltar Station

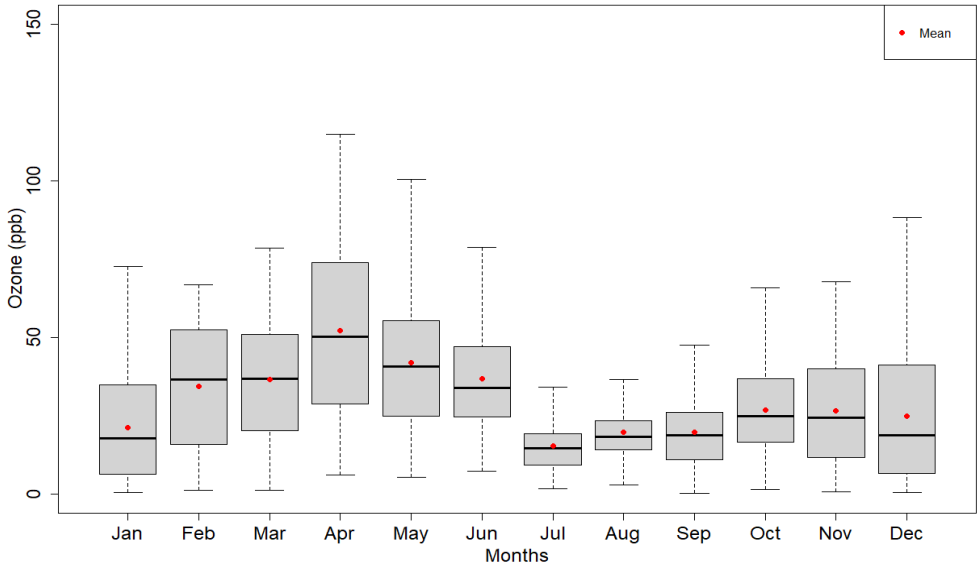

Figure A4-191: Monthly Variation of Ozone for Khumaltar Station

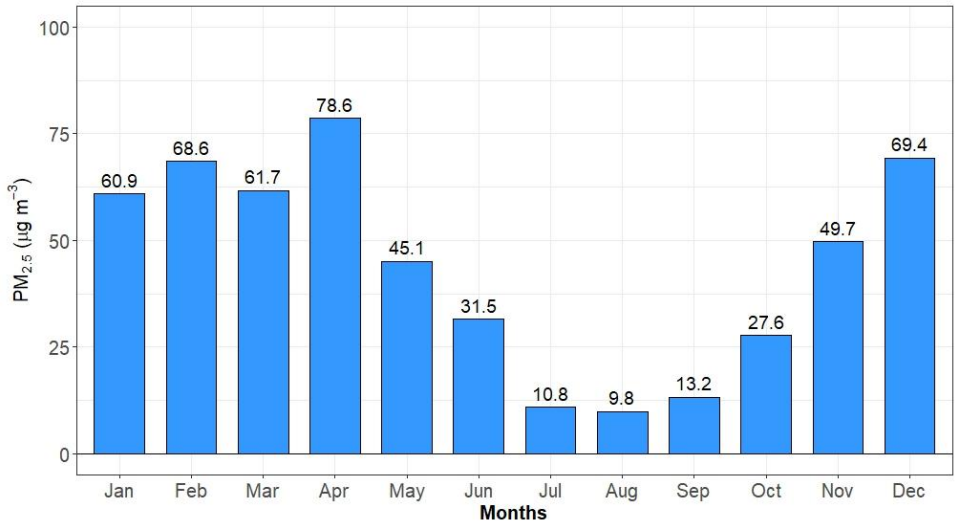

Figure A4-192: Monthly Average of $PM_{2.5}$ for Khumaltar Station

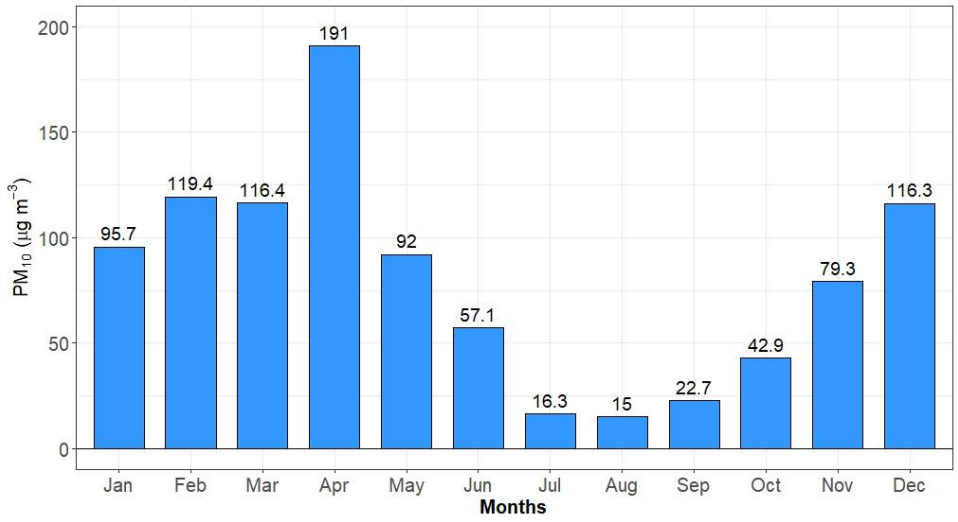

Figure A4-193: Monthly Average of PM_{10} for Khumaltar Station

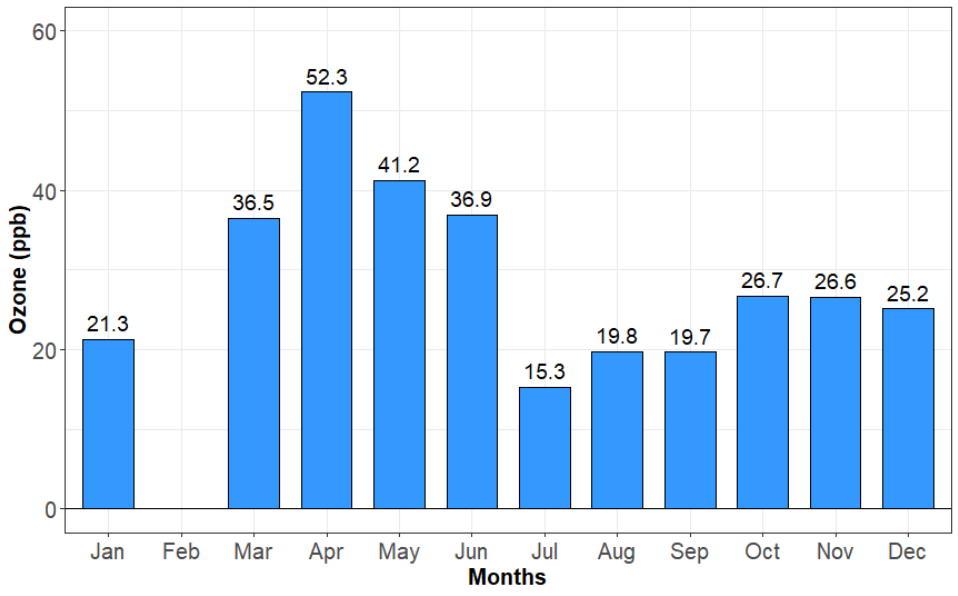

Figure A4-194: Monthly Average of Ozone for Khumaltar Station

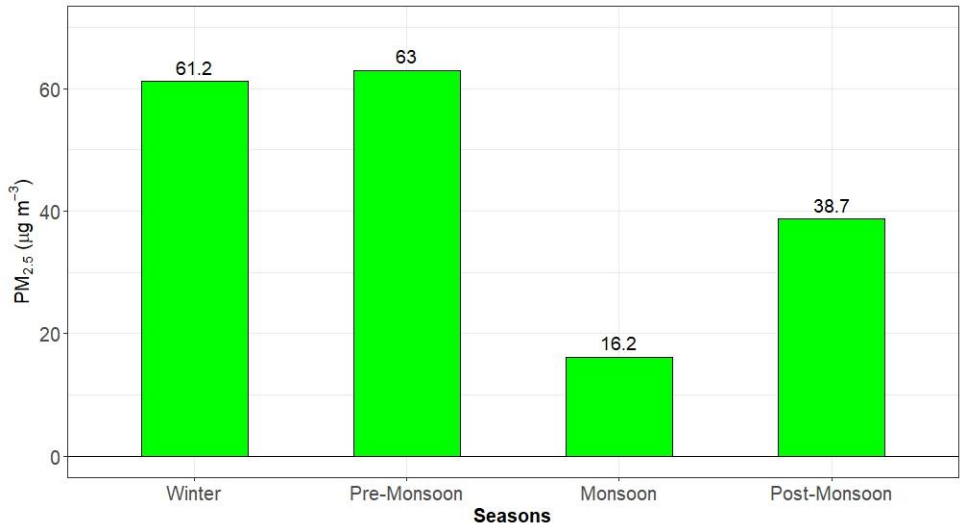

Figure A4-195: Seasonal Average of $PM_{2.5}$ for Khumaltar Station

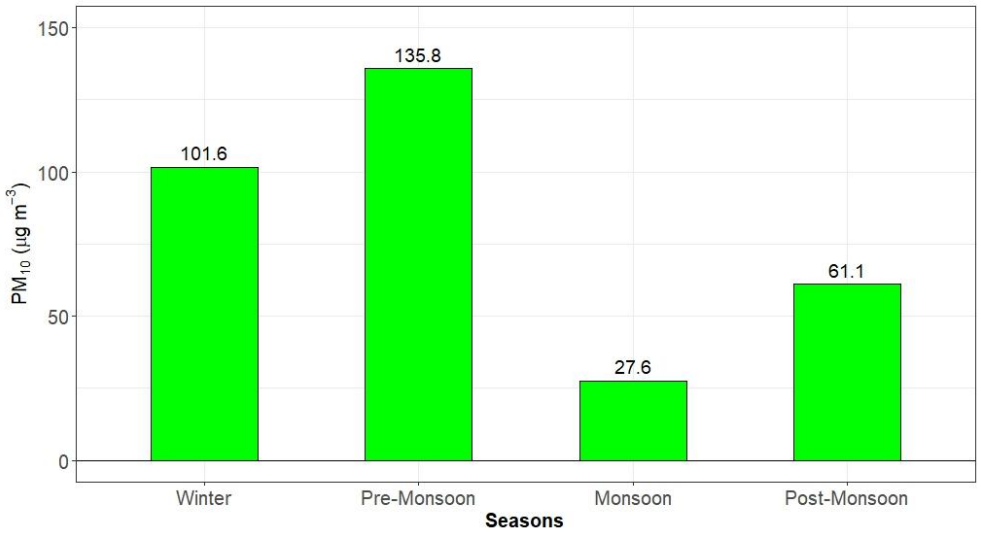

Figure A4-196: Seasonal Average of PM_{10} for Khumaltar Station

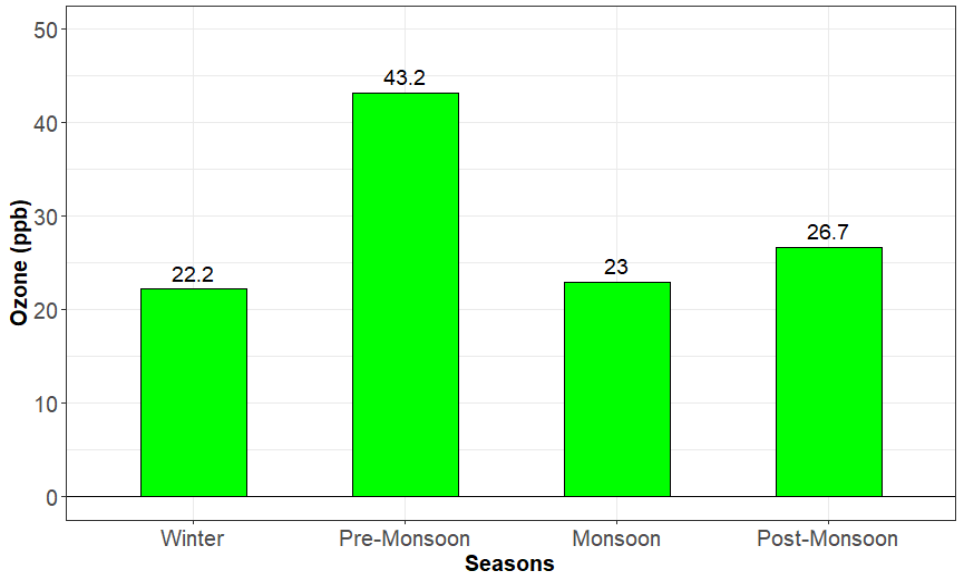

Figure A4-197: Seasonal Average of Ozone for Khumaltar Station

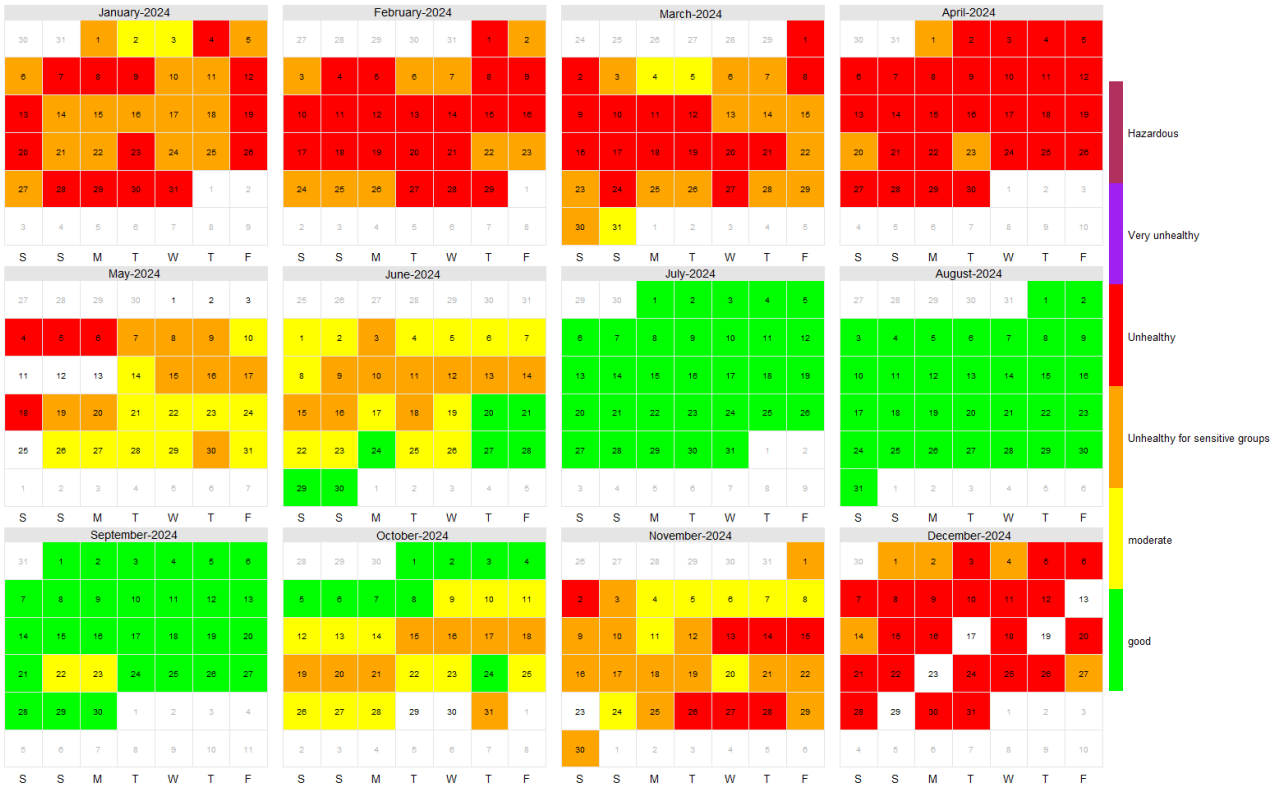

Figure A4-198: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Khumaltar Station

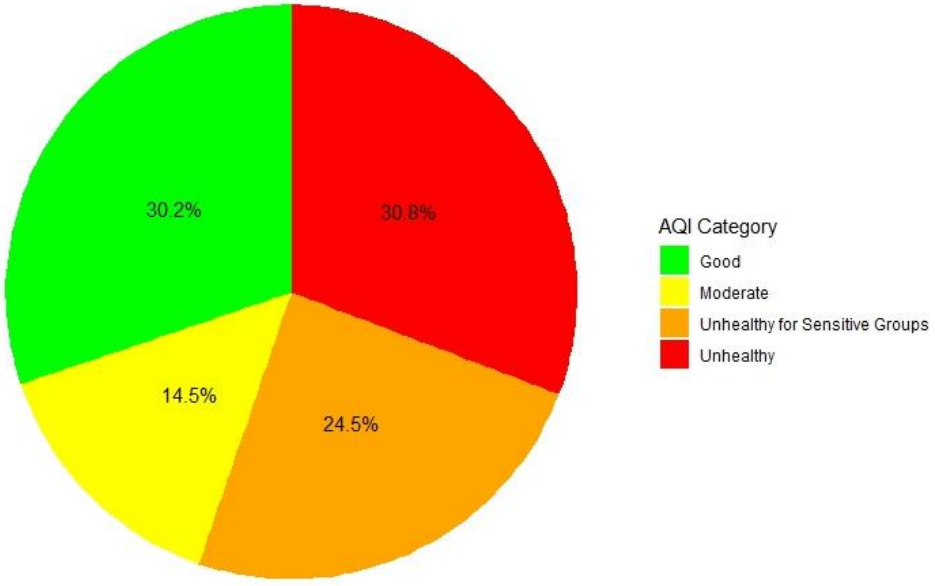

Figure A4-199: AQI Category Distribution for Khumaltar Station

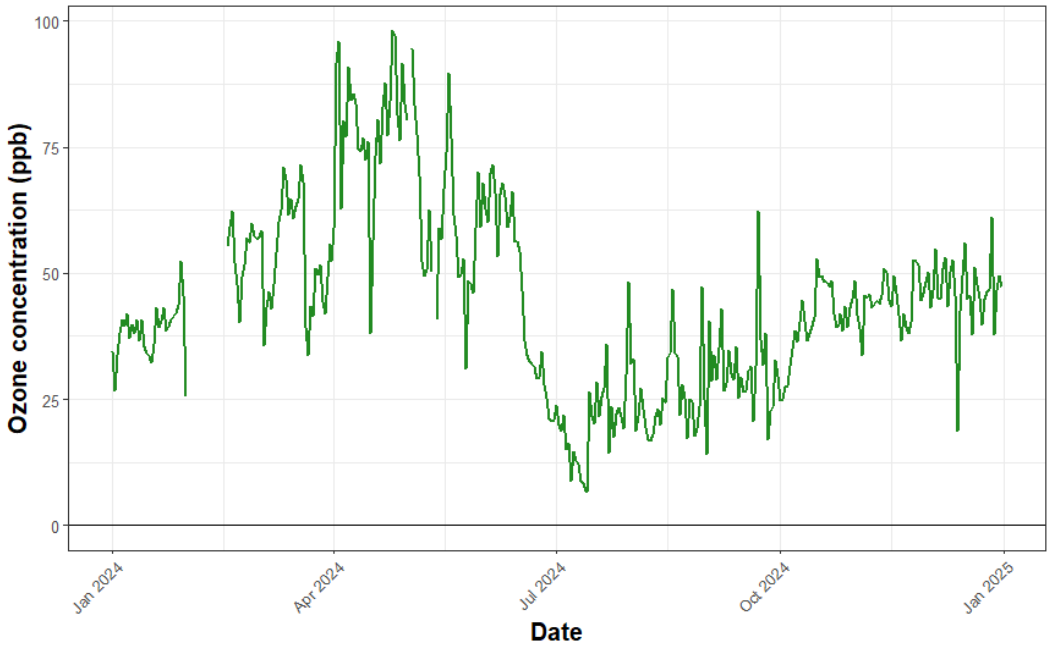

Figure A4-200: Maximum of Eight Hour Running Average of a Day

PULCHOWAK AIR QUALITY MONITORING STATION

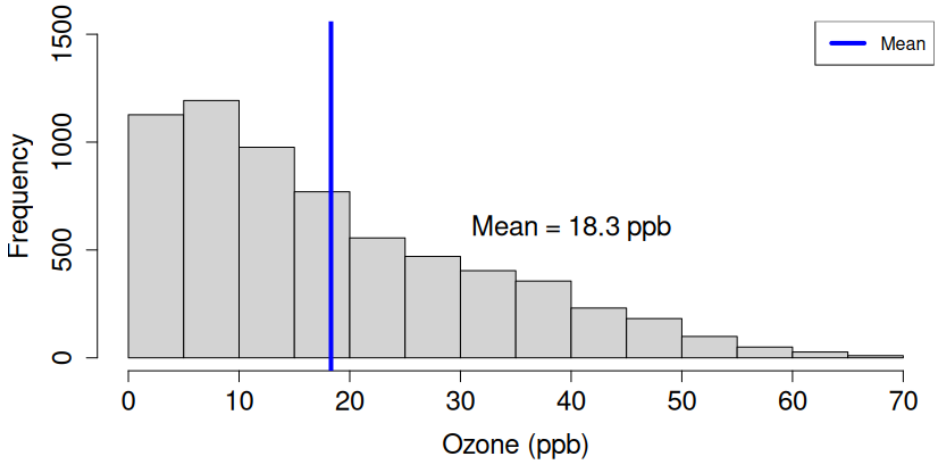

Figure A4-201: Histogram of O_3 for Pulchowk Station

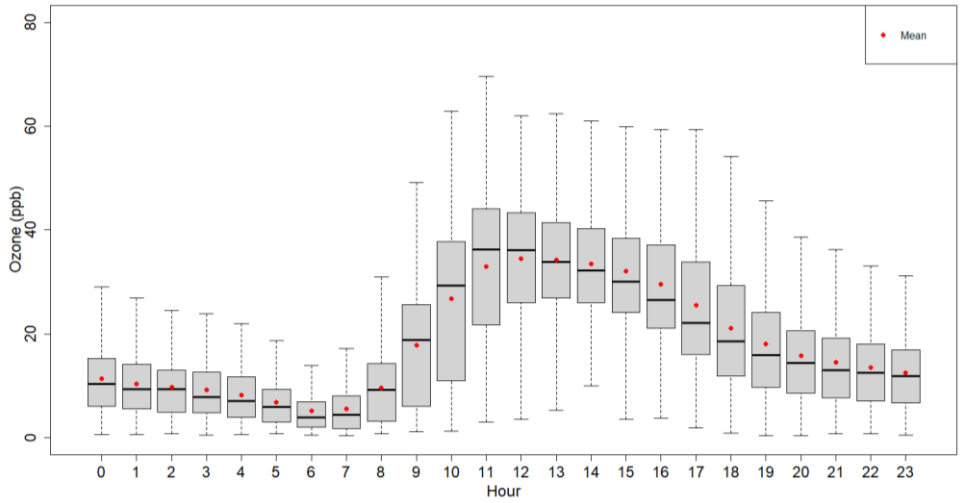

Figure A4-202: Diurnal Variation of O_3 for Pulchowk Station

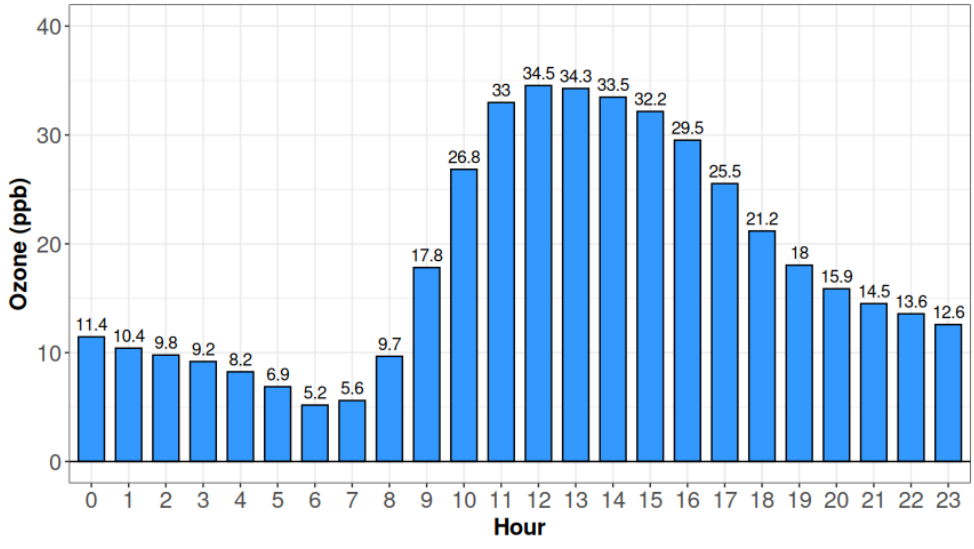

Figure A4-203: Hourly Average of O_3 for Pulchowk Station

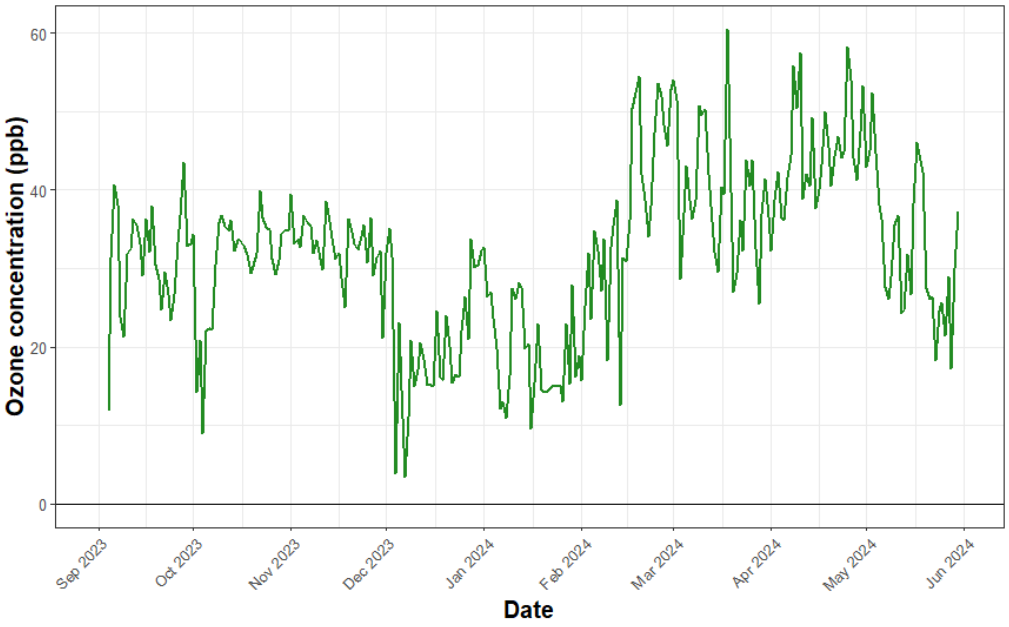

Figure A4-204: Hourly Average of O_3 for Pulchowk Station

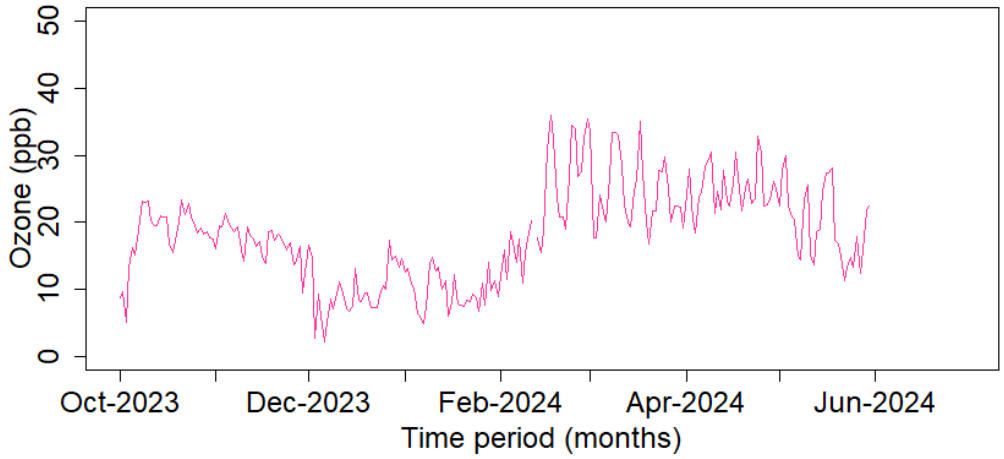

Figure A4-205: Daily Average of O_3 for Pulchowk Station

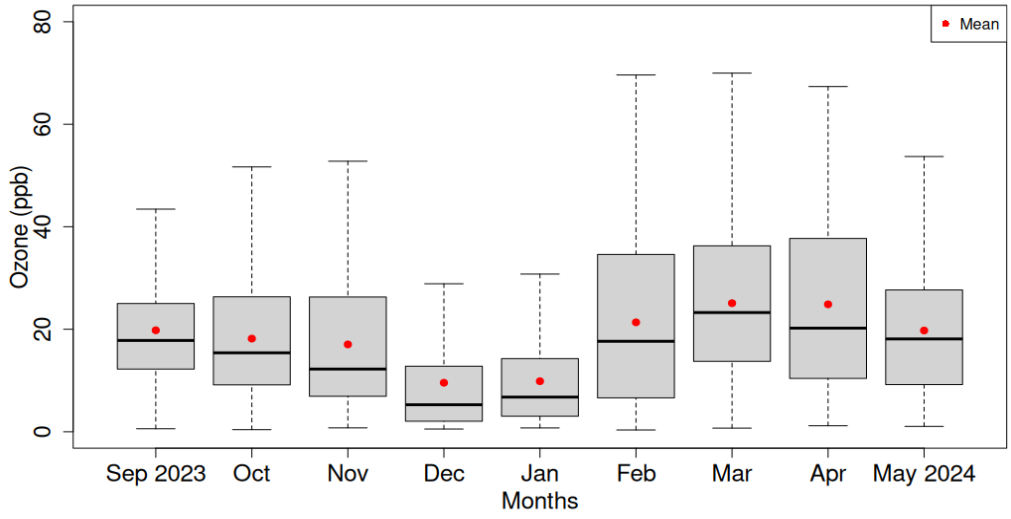

Figure A4-206: Monthly Variation of O_3 for Pulchowak Station

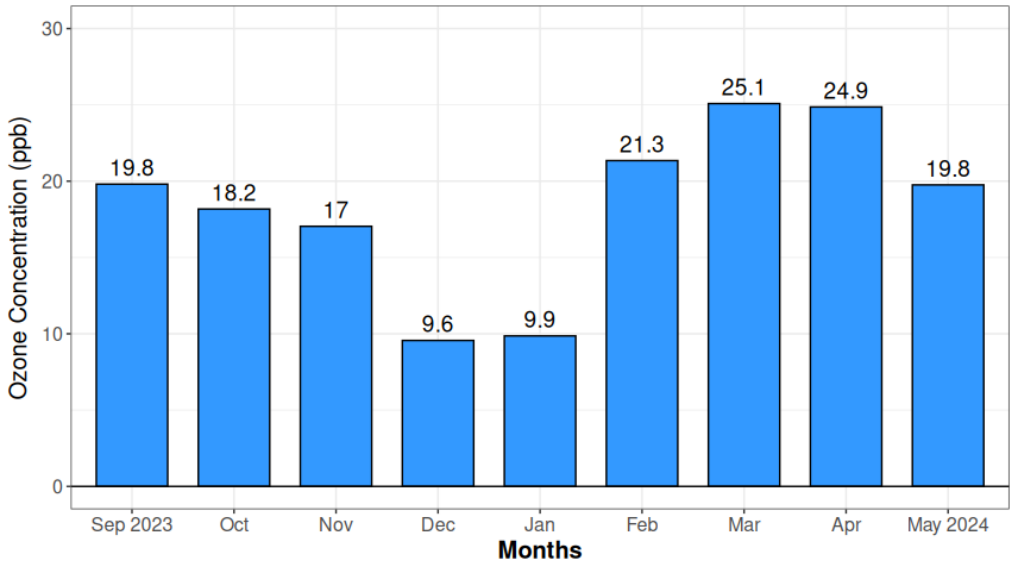

Figure A4-207: Monthly Average of O_3 for Pulchowk Station

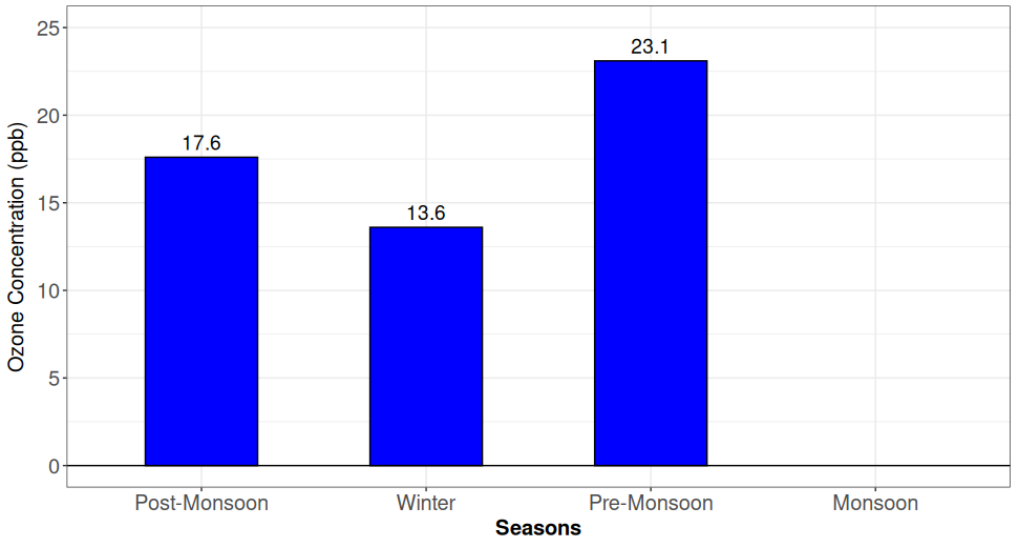

Figure A4-208: Seasonal Average of O_3 for Pulchowk Station

RATNAPARK AIR QUALITY MONITORING STATION

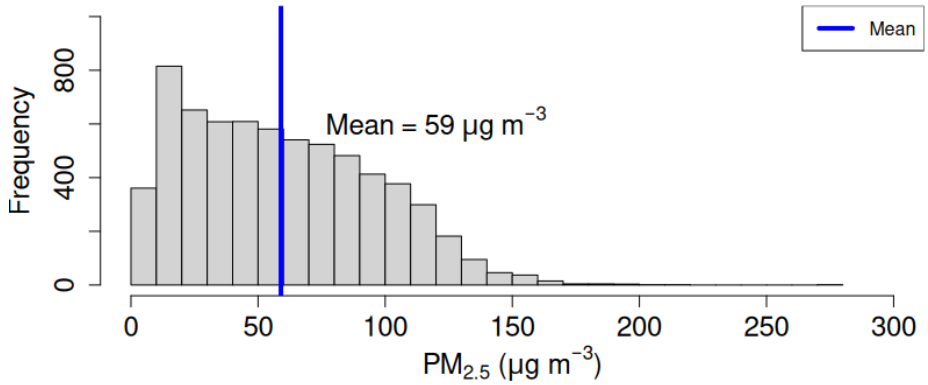

Figure A4-209: Histogram of $PM_{2.5}$ for Ratnapark Station

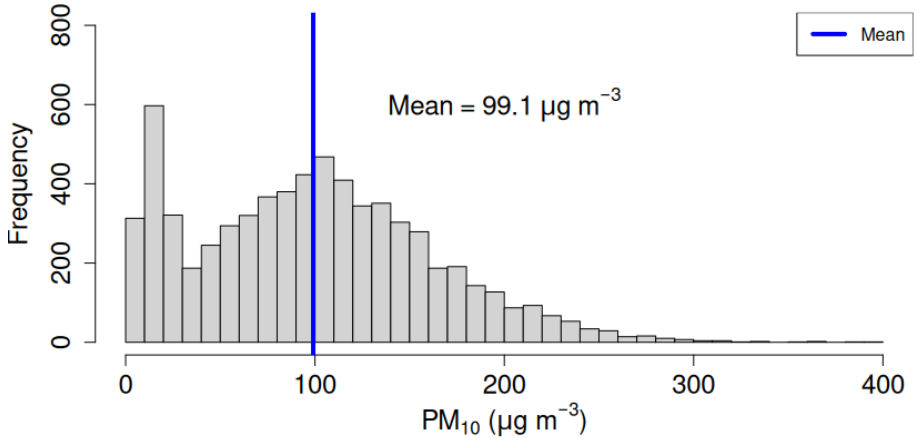

Figure A4-210: Histogram of PM_{10} for Ratnapark Station

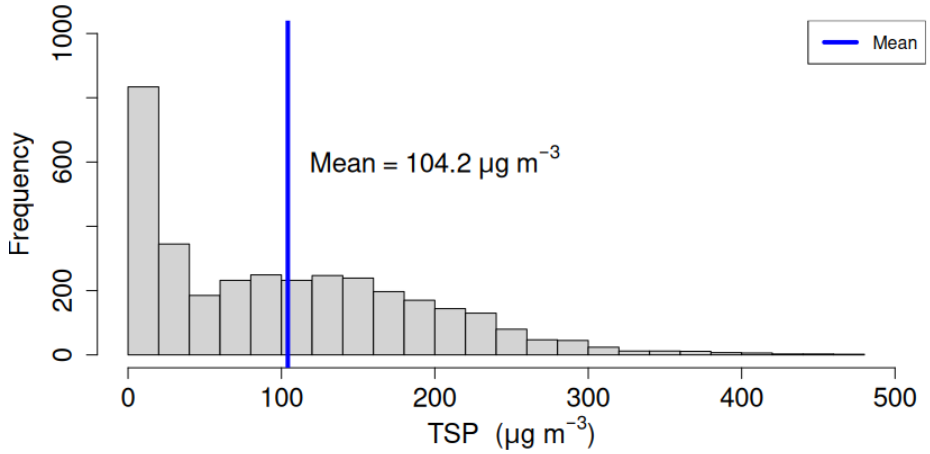

Figure A4-211: Histogram of TSP for Ratnapark Station

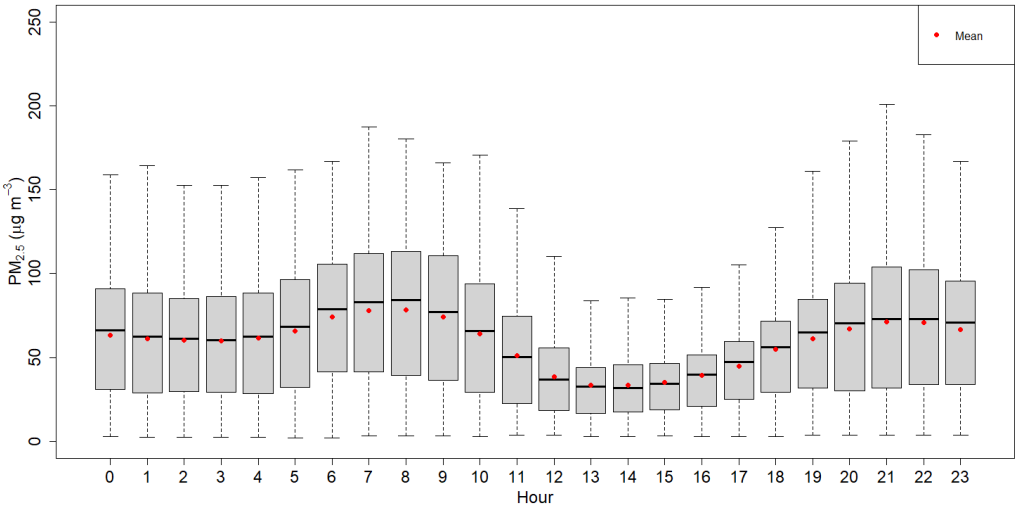

Figure A4-212: Diurnal Variation of $PM_{2.5}$ for Ratnapark Station

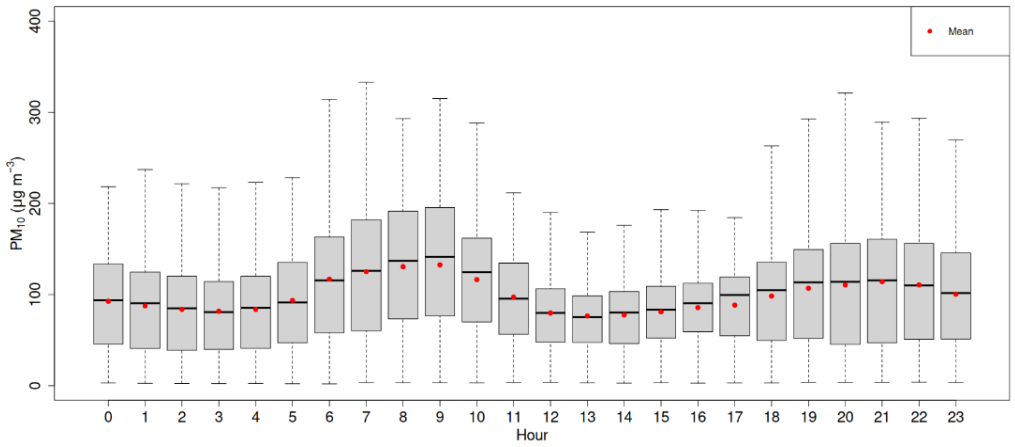

Figure A4-213: Diurnal Variation of PM_{10} for Ratnapark Station

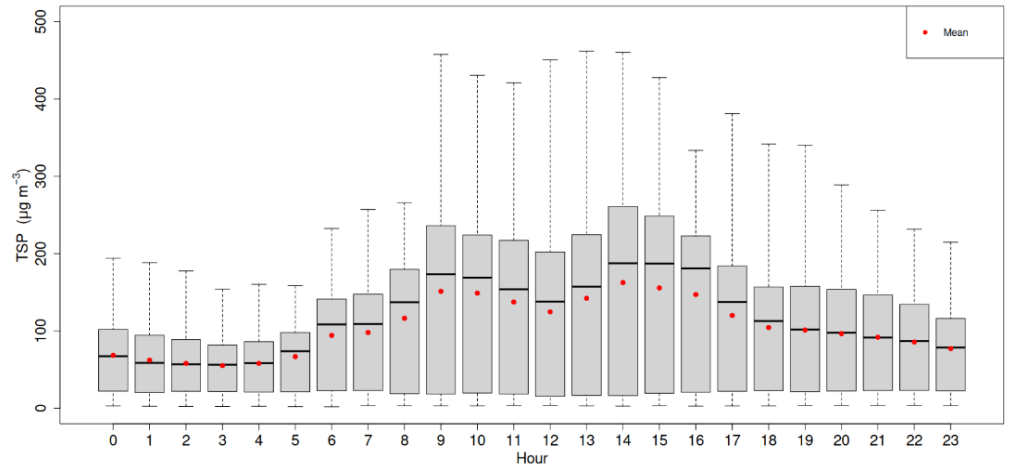

Figure A4-214: Diurnal Variation of TSP for Ratnapark Station

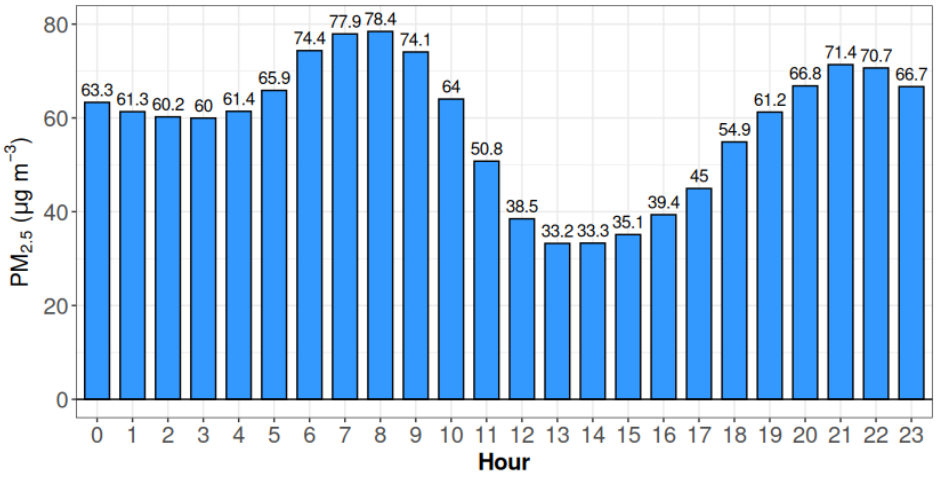

Figure A4-215: Hourly Average of $PM_{2.5}$ for Ratnapark Station

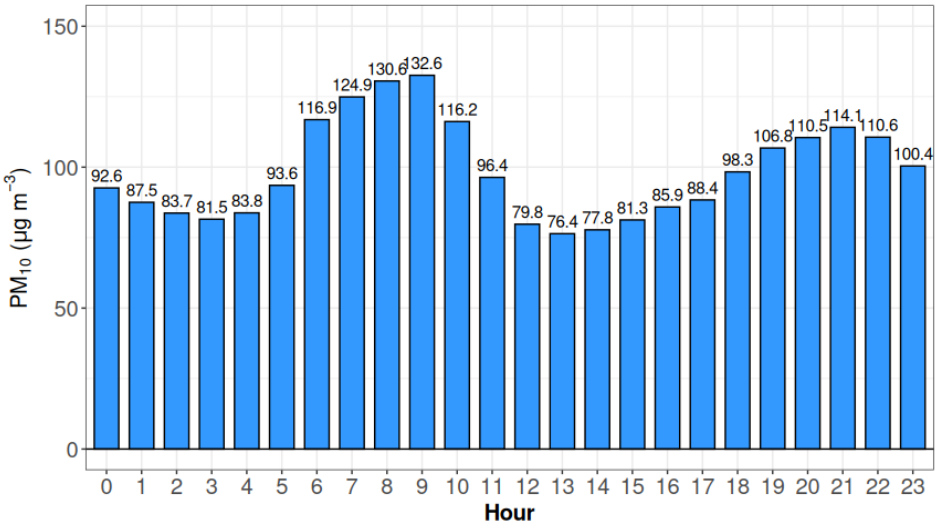

Figure A4-216: Hourly Average of PM_{10} for Ratnapark Station

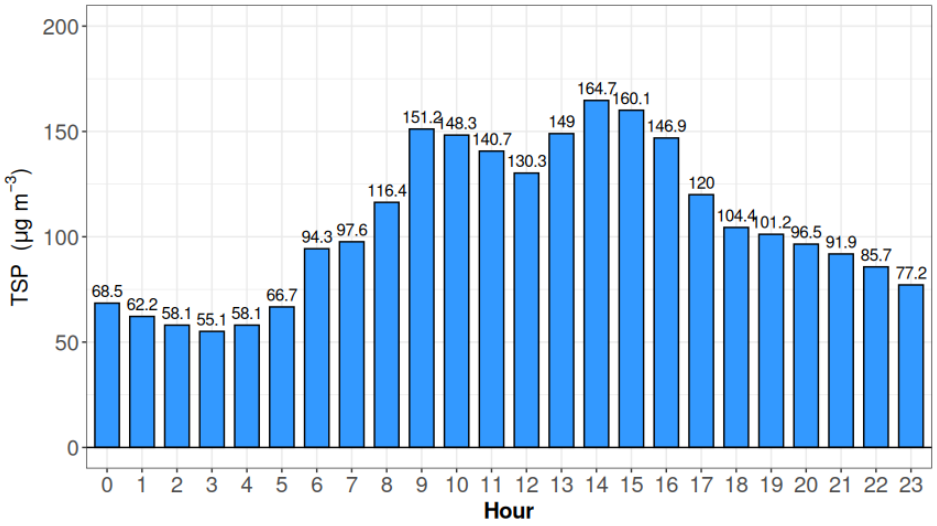

Figure A4-217: Hourly Average of TSP for Ratnapark Station

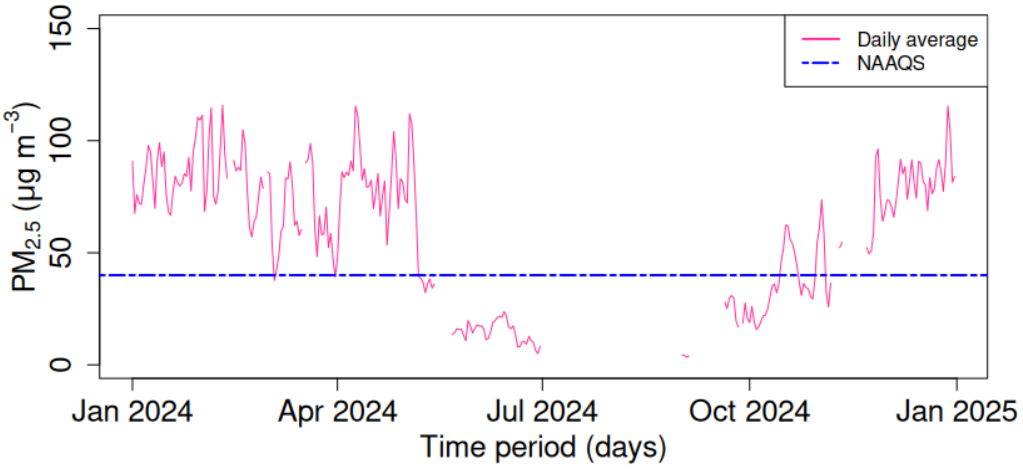

Figure A4-218: Daily Average of $PM_{2.5}$ for Ratnapark Station

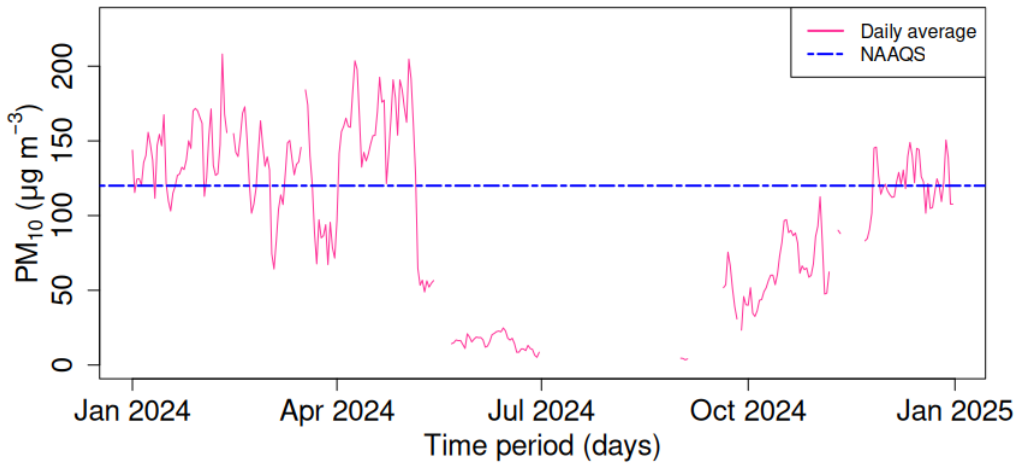

Figure A4-219: Daily Average of PM_{10} for Ratnapark Station

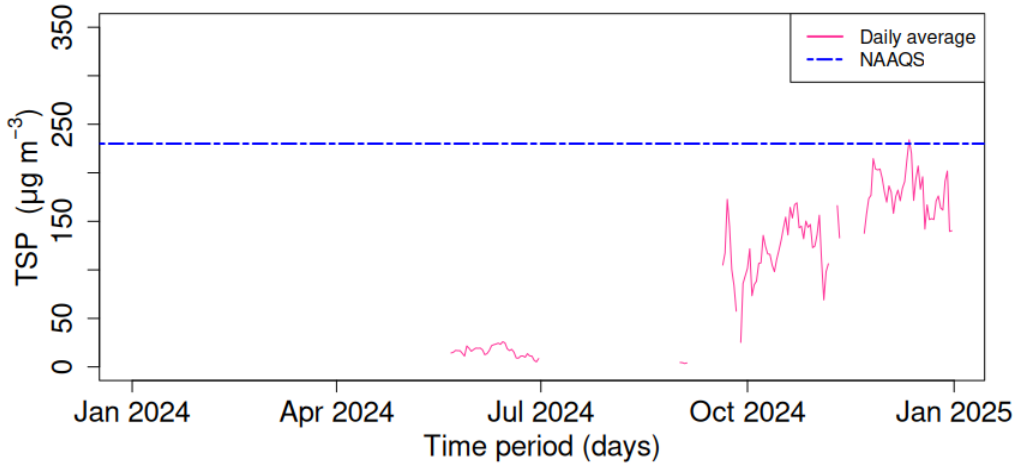

Figure A4-220: Daily Average of TSP for Ratnapark Station

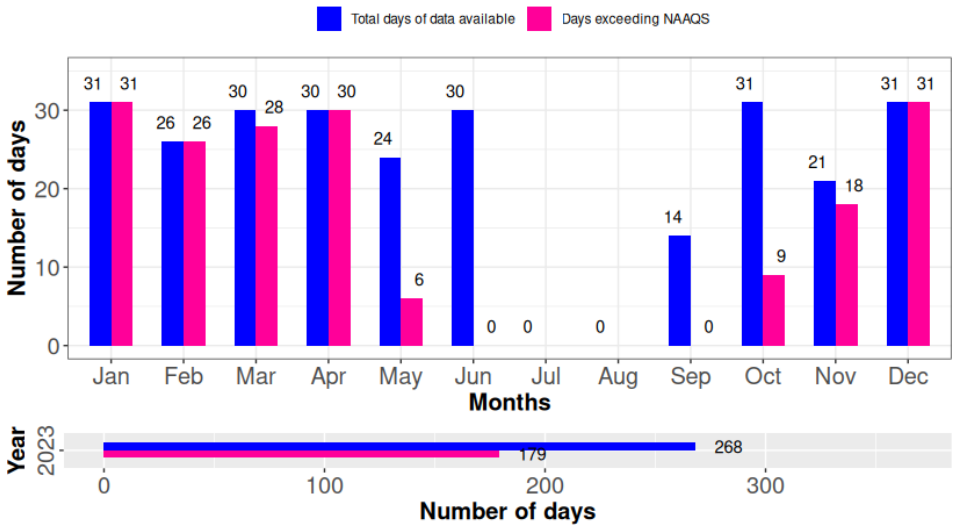

Figure A4-221: Compliance Status of $PM_{2.5}$ for Ratnapark Station

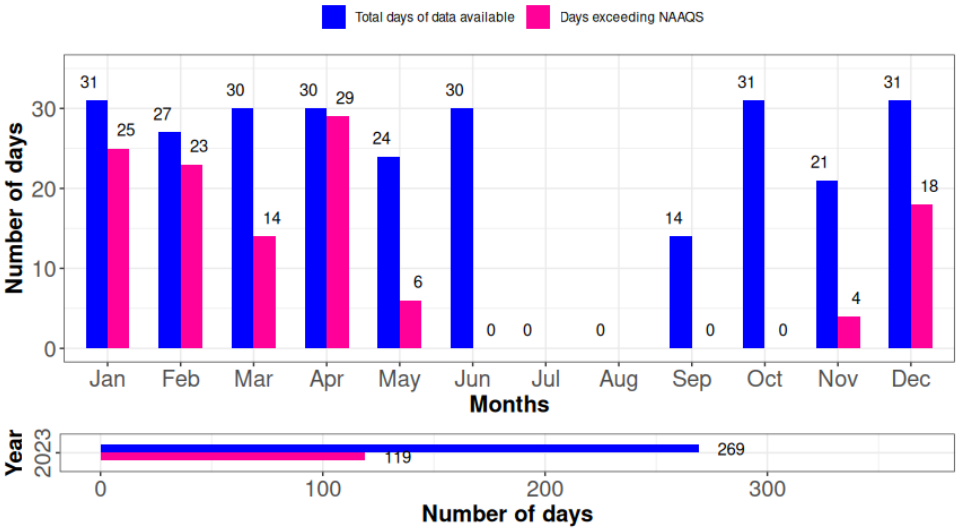

Figure A4-222: Compliance Status of PM_{10} for Ratnapark Station

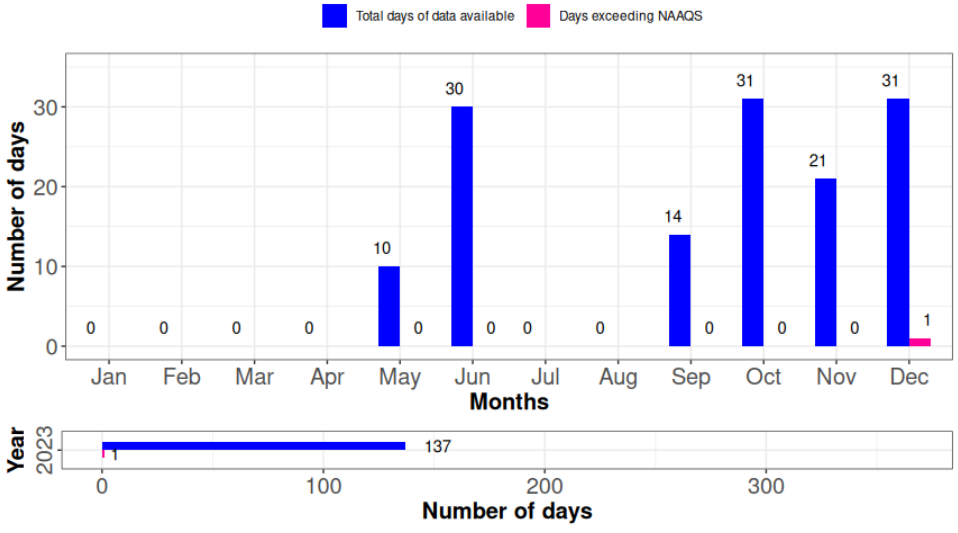

Figure A4-223: Compliance Status of TSP for Ratnapark Station

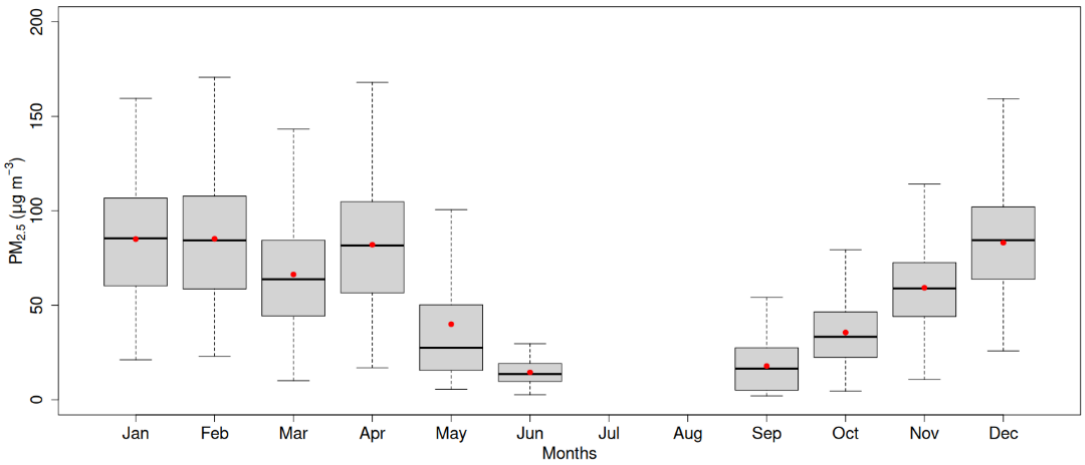

Figure A4-224: Monthly Variation of $PM_{2.5}$ for Ratnapark Station

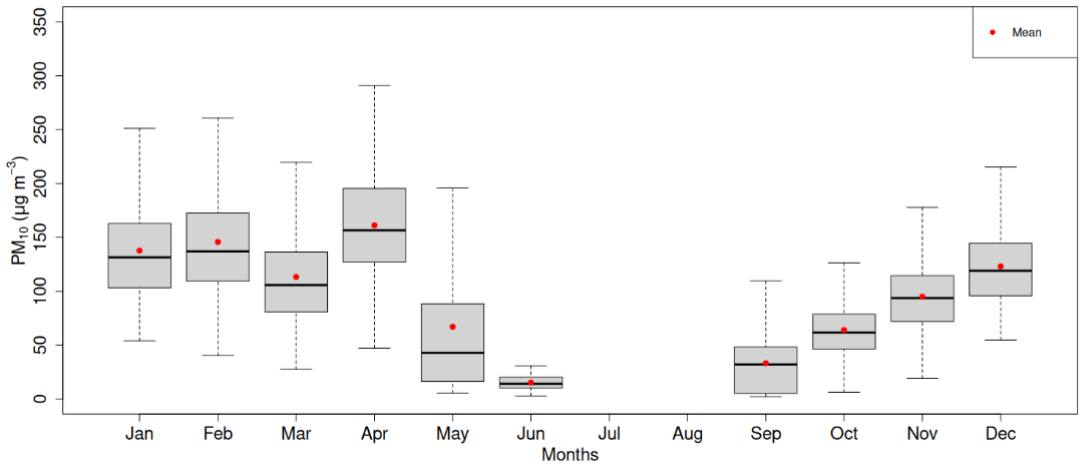

Figure A4-225: Monthly Variation of PM_{10} for Ratnapark Station

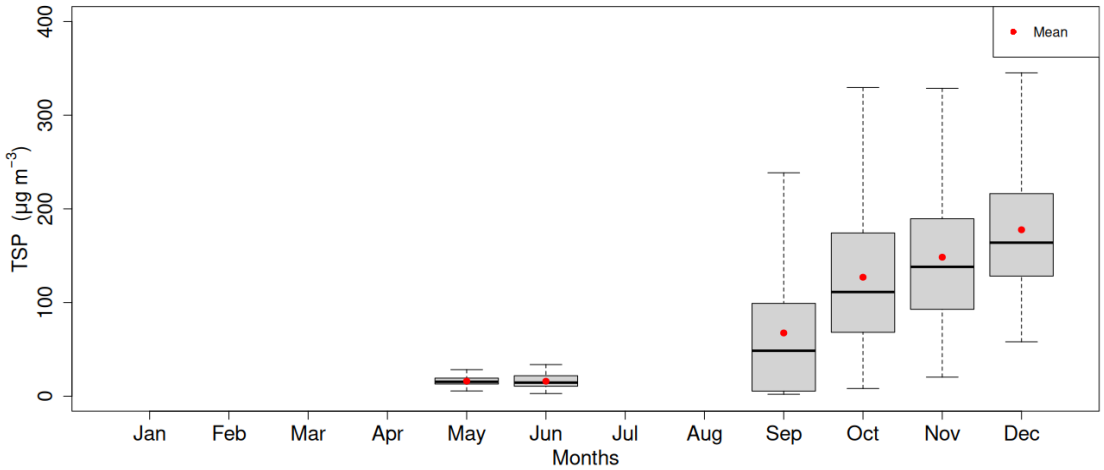

Figure A4-226: Monthly Variation of TSP for Ratnapark Station

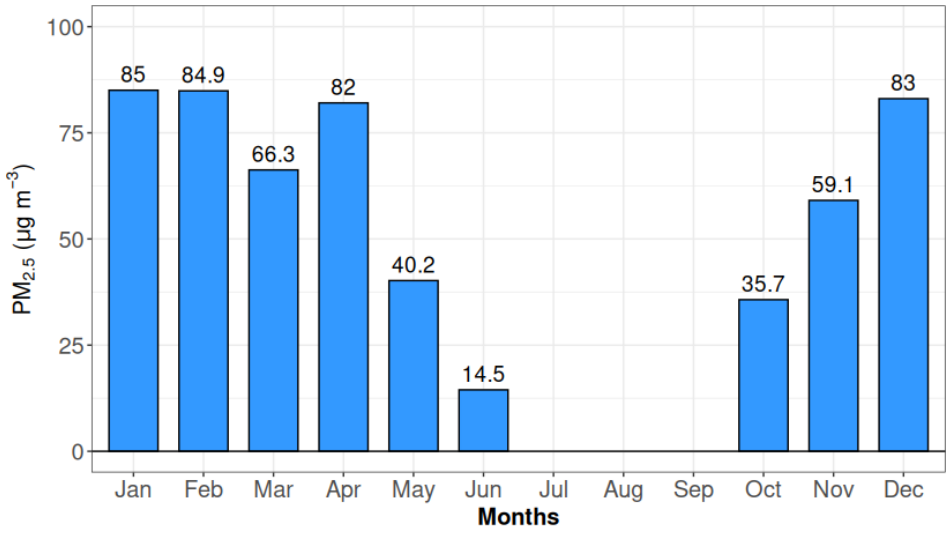

Figure A4-227: Monthly Average of $PM_{2.5}$ for Ratnapark Station

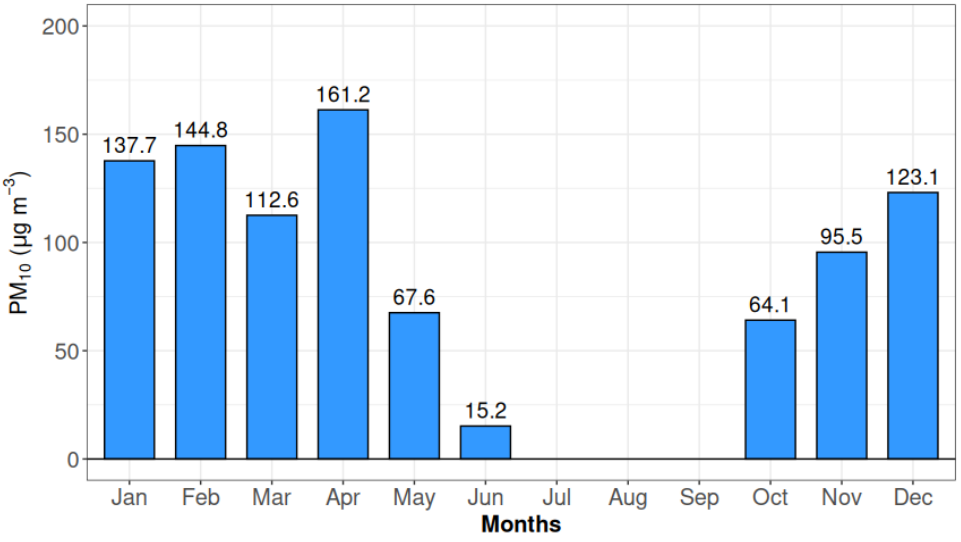

Figure A4-228: Monthly Average of PM_{10} for Ratnapark Station

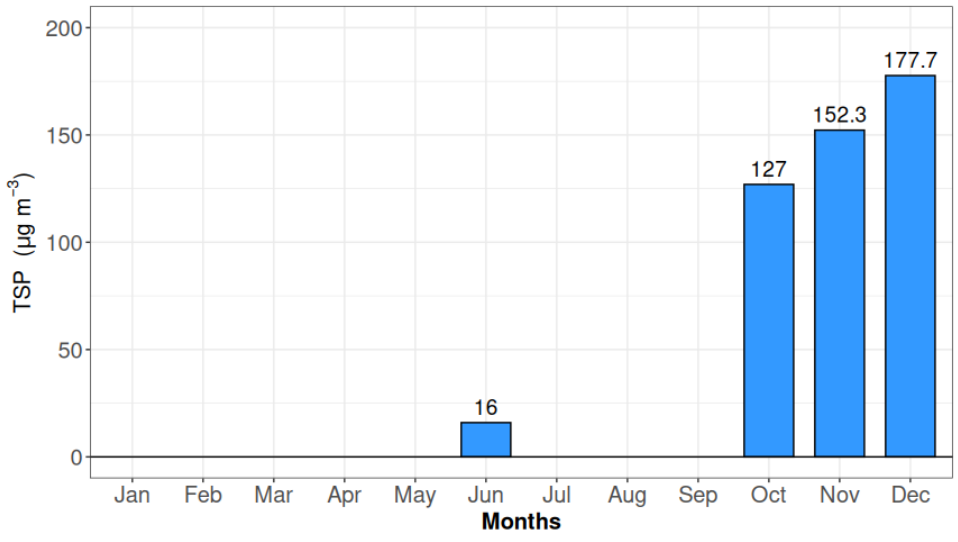

Figure A4-229: Monthly Average of TSP for Ratnapark Station

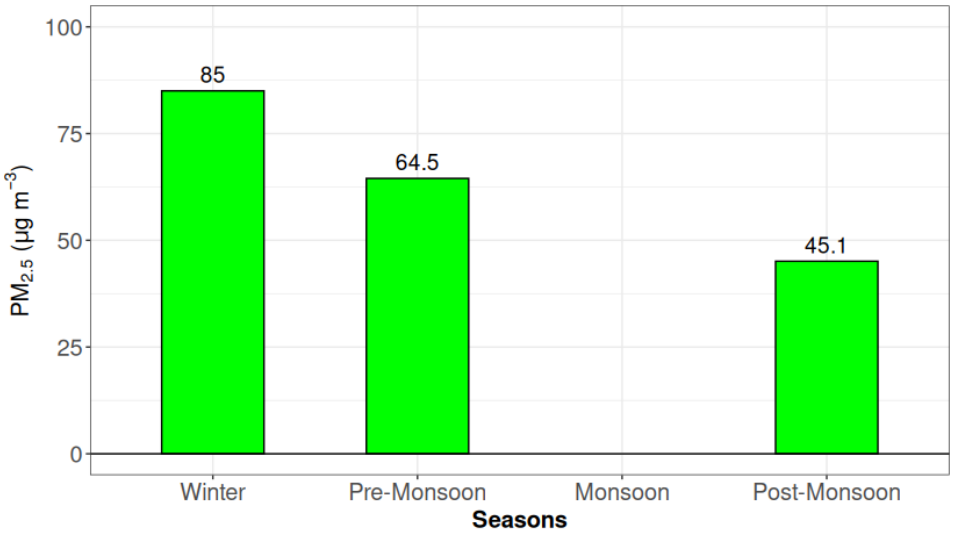

Figure A4-230: Seasonal Average of $PM_{2.5}$ for Ratnapark Station

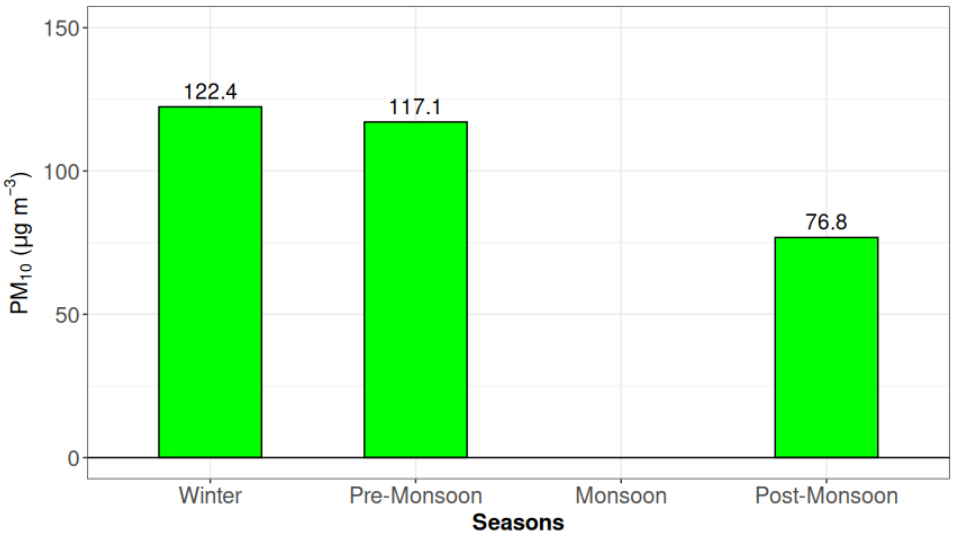

Figure A4-231: Seasonal Average of PM_{10} for Ratnapark Station

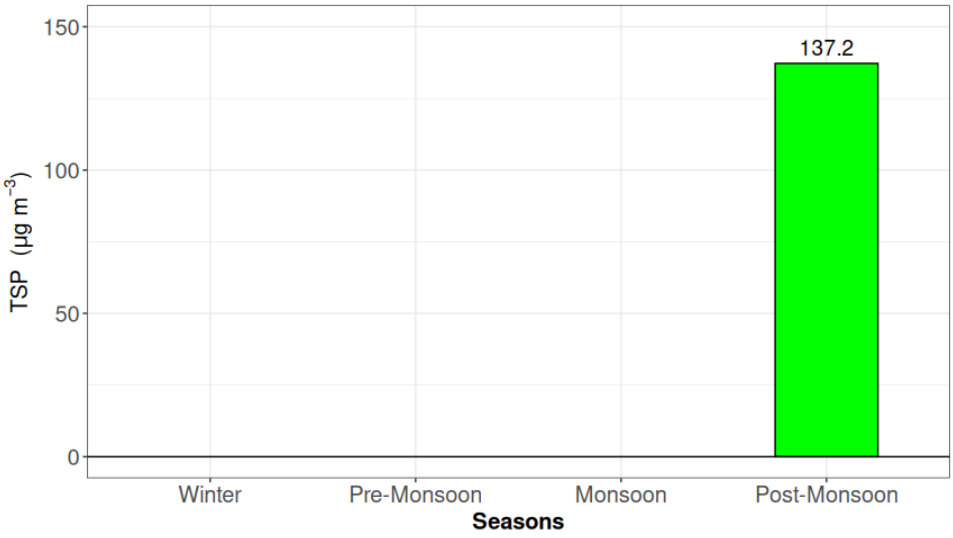

Figure A4-232: Seasonal Average of TSP for Ratnapark Station

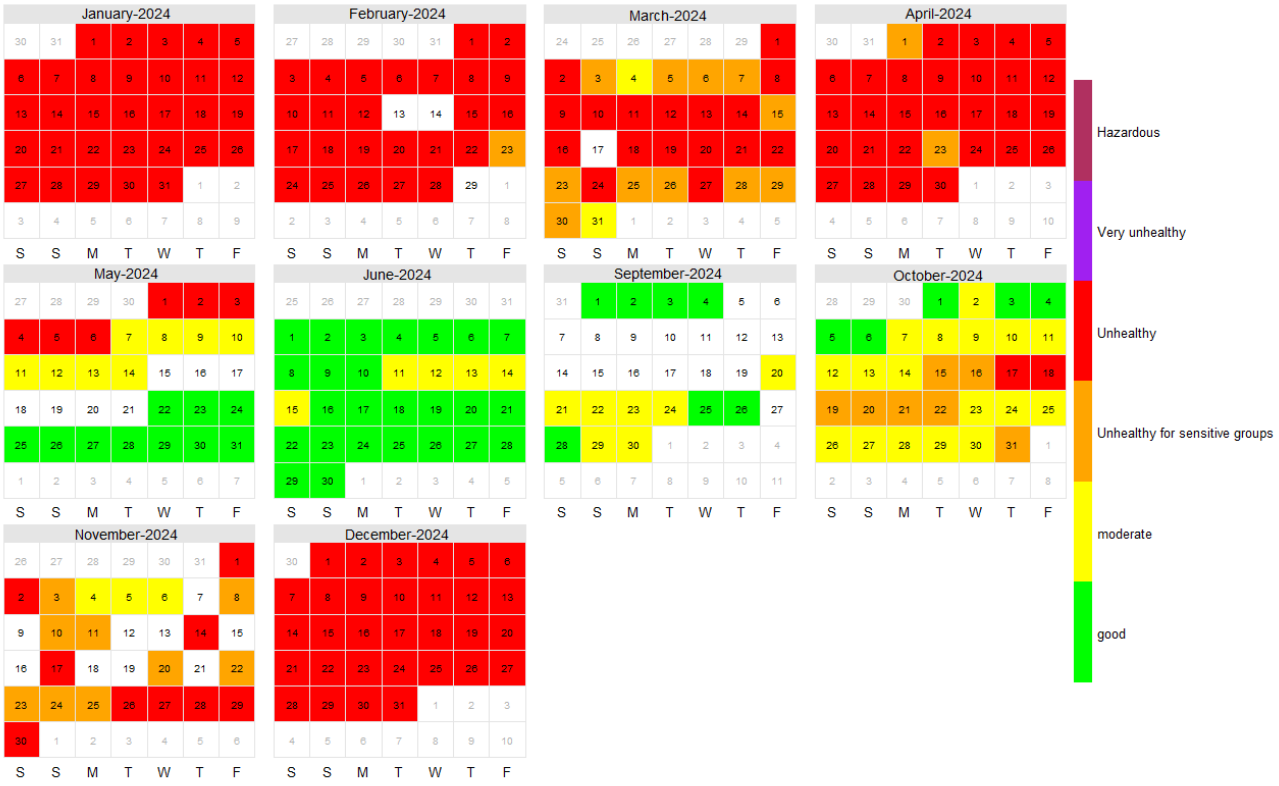

Figure A4-233: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Ratnapark Station

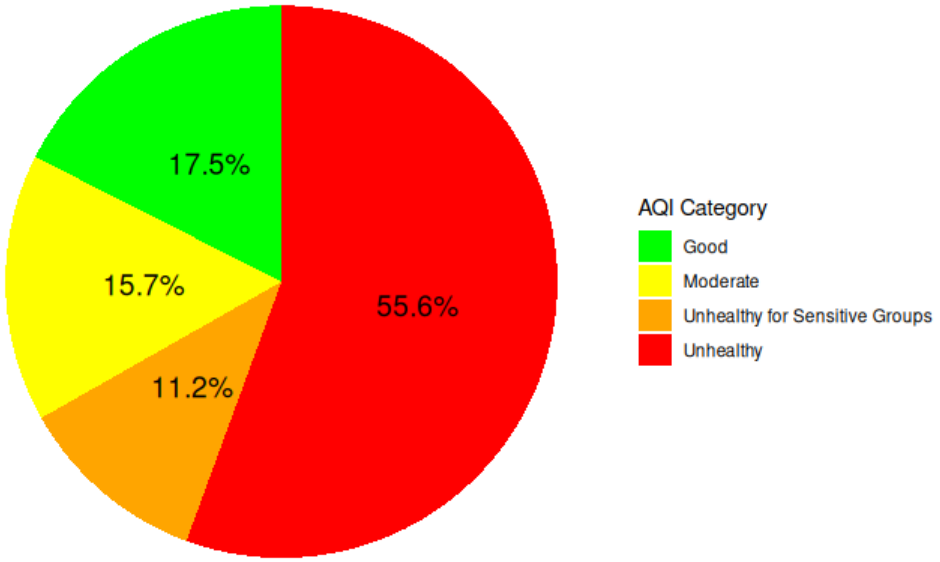

Figure A4-234: AQI Category Distribution for Ratnapark Station

SHANKHAPARK AIR QUALITY MONITORING STATION

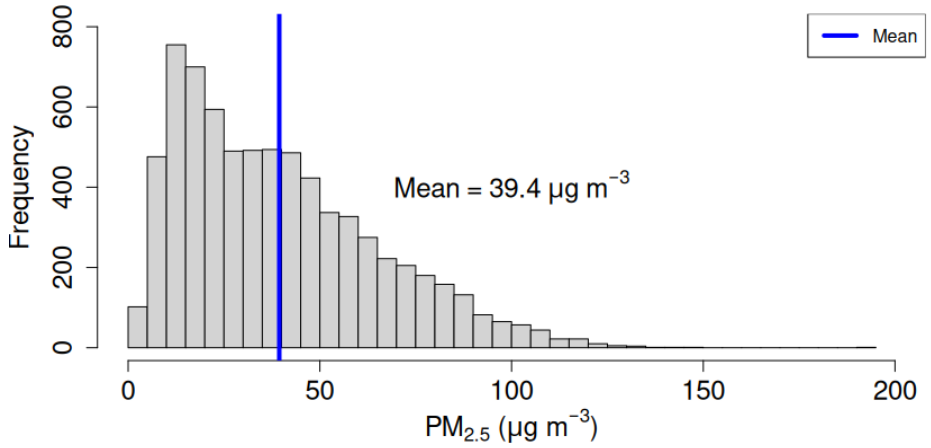

Figure A4-235: Histogram of $PM_{2.5}$ for Shankhapark Station

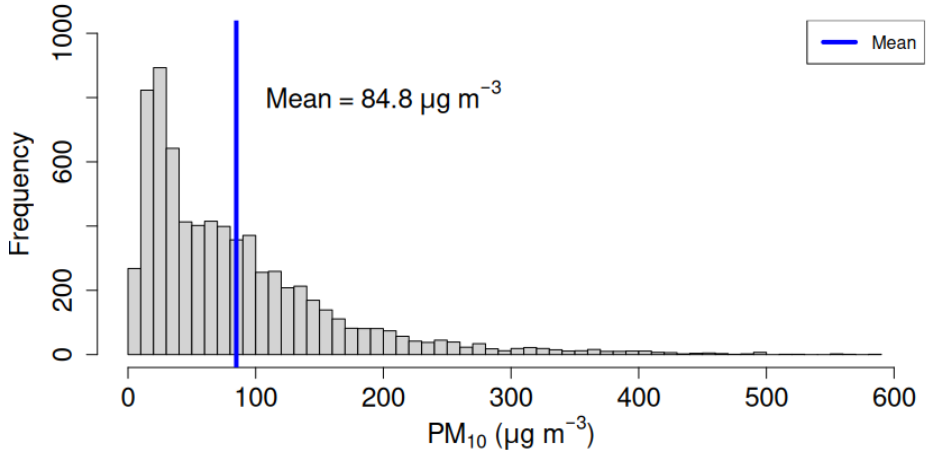

Figure A4-236: Histogram of PM_{10} for Shankhapark Station

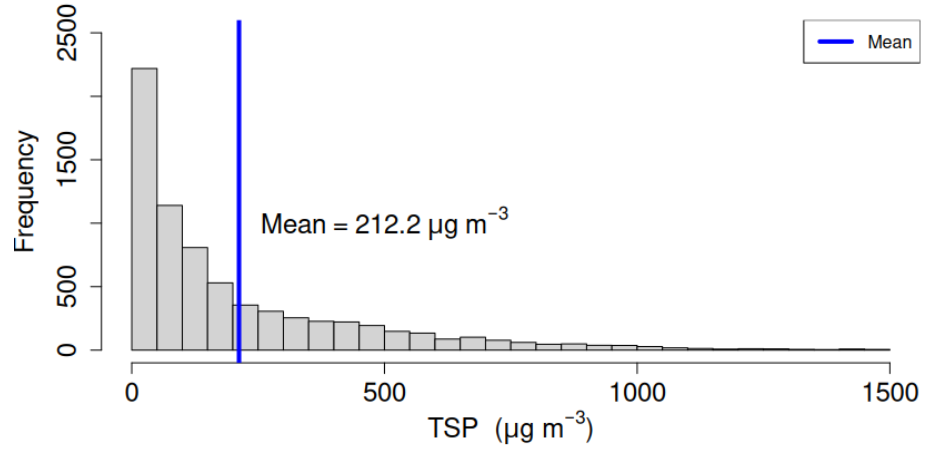

Figure A4-237: Histogram of TSP for Shankhapark Station

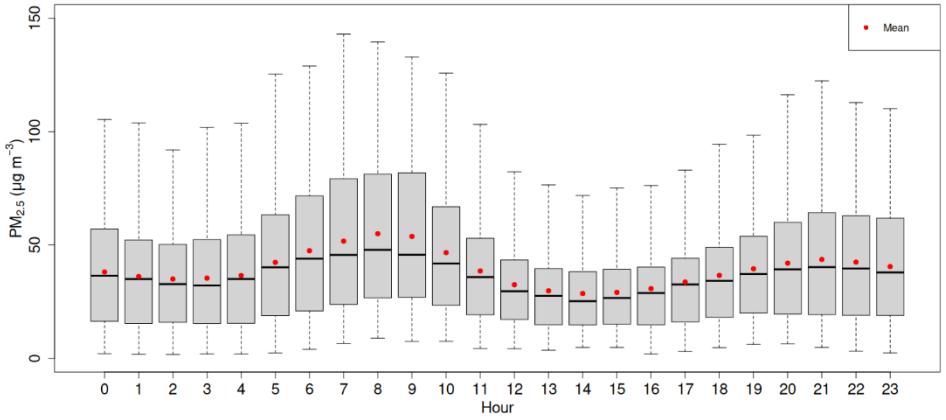

Figure A4-238: Diurnal Variation of $PM_{2.5}$ for Shankhapark Station

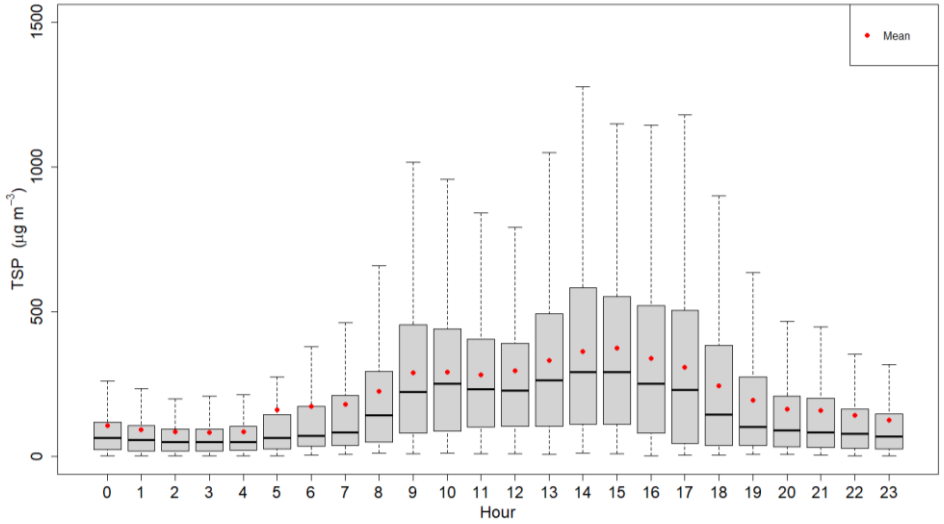

Figure A4-239: Diurnal Variation of PM_{10} for Shankhapark Station

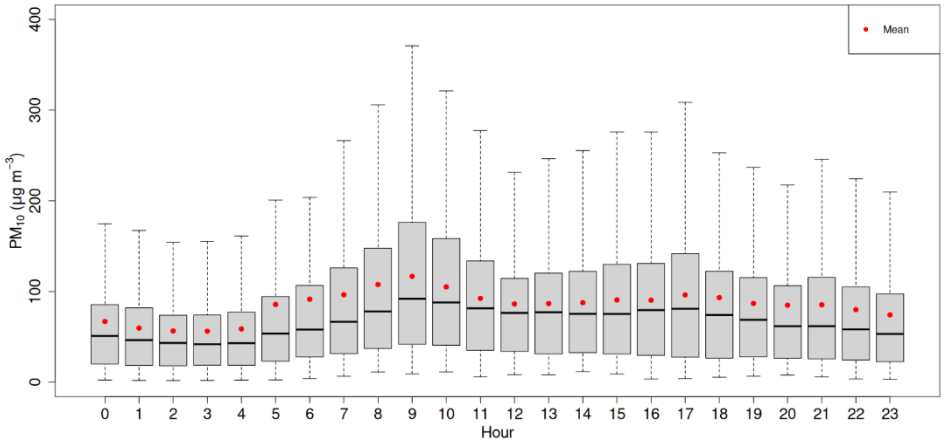

Figure A4-240: Diurnal Variation of TSP for Shankhapark Station

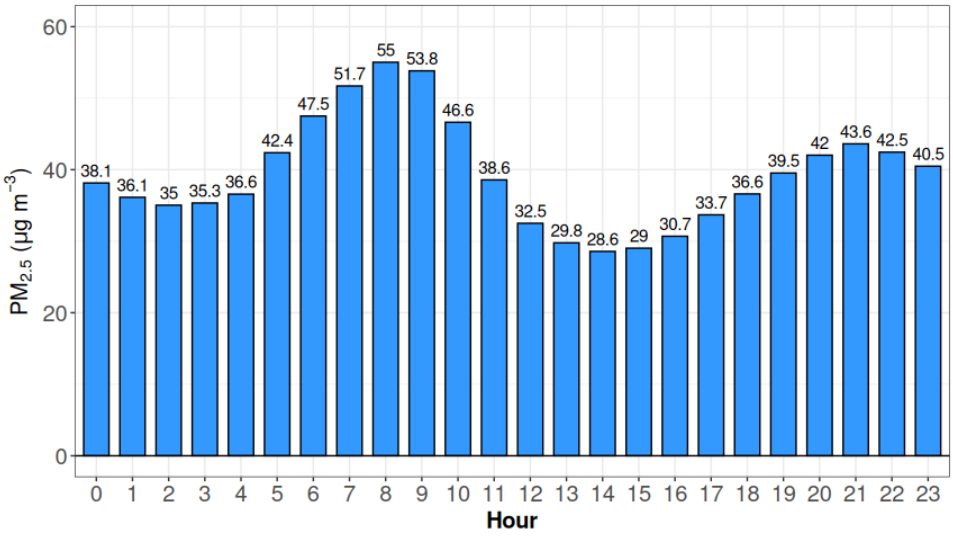

Figure A4-241: Hourly Average of $PM_{2.5}$ for Shankhapark Station

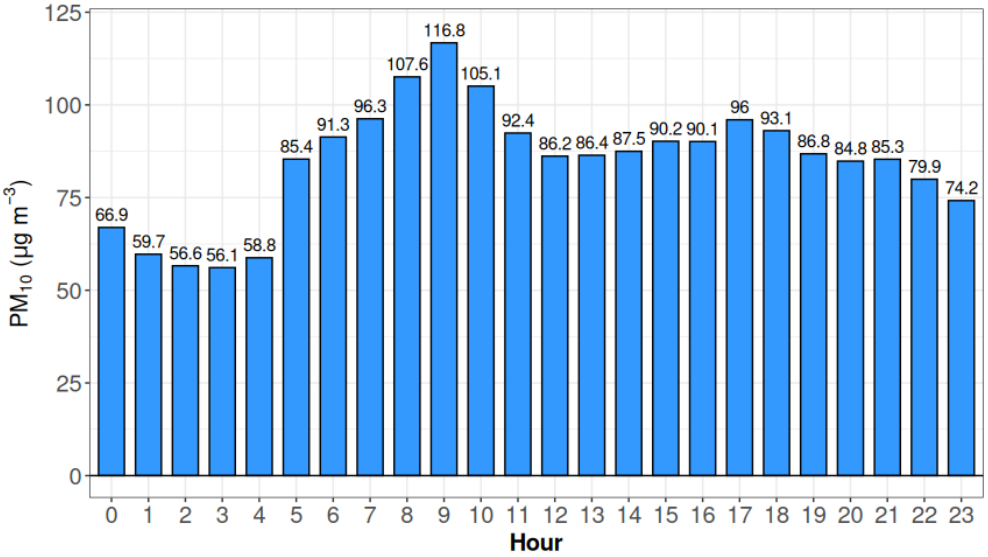

Figure A4-242: Hourly Average of PM_{10} for Shankhapark Station

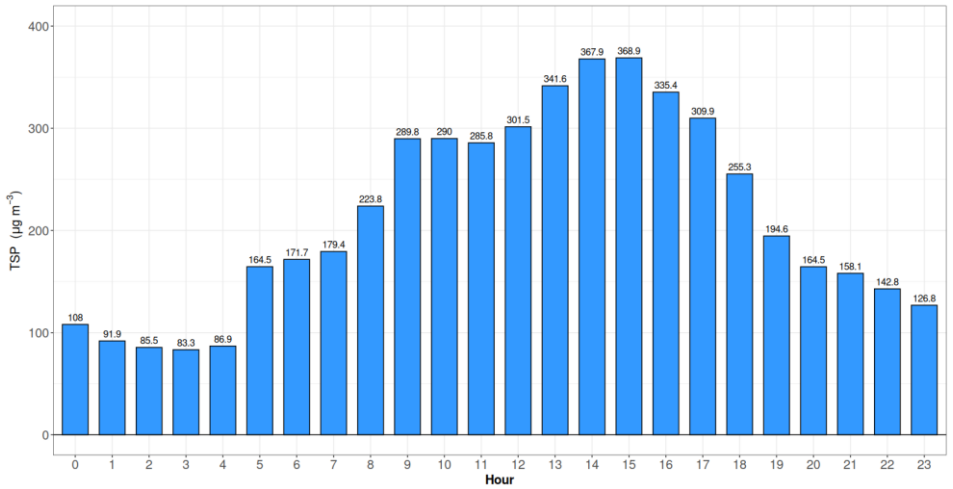

Figure A4-243: Hourly Average of TSP for Shankhapark Station

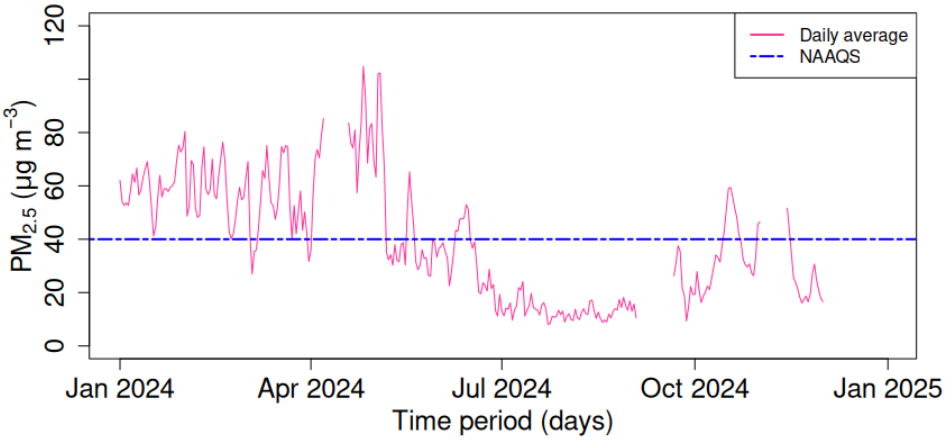

Figure A4-244: Daily Average of $PM_{2.5}$ for Shankhapark Station

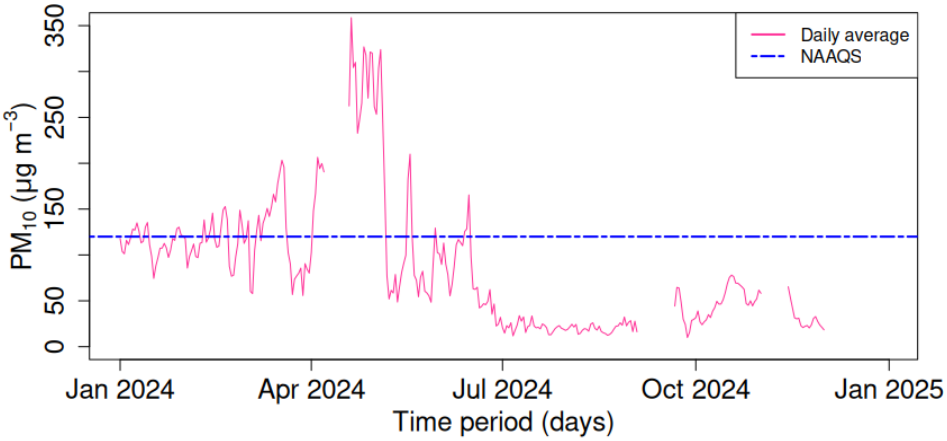

Figure A4-245: Daily Average of PM_{10} for Shankhapark Station

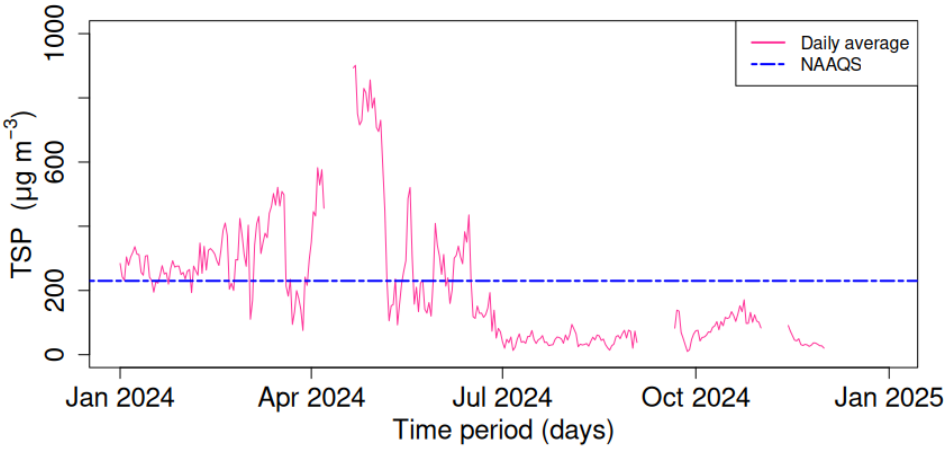

Figure A4-246: Daily Average of TSP for Shankhapark Station

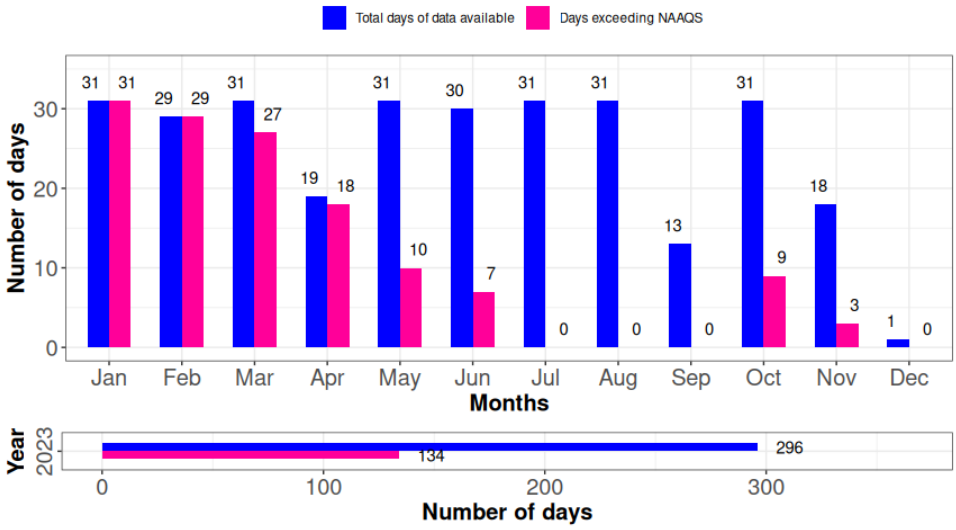

Figure A4-247: Compliance Status of $PM_{2.5}$ for Shankhapark Station

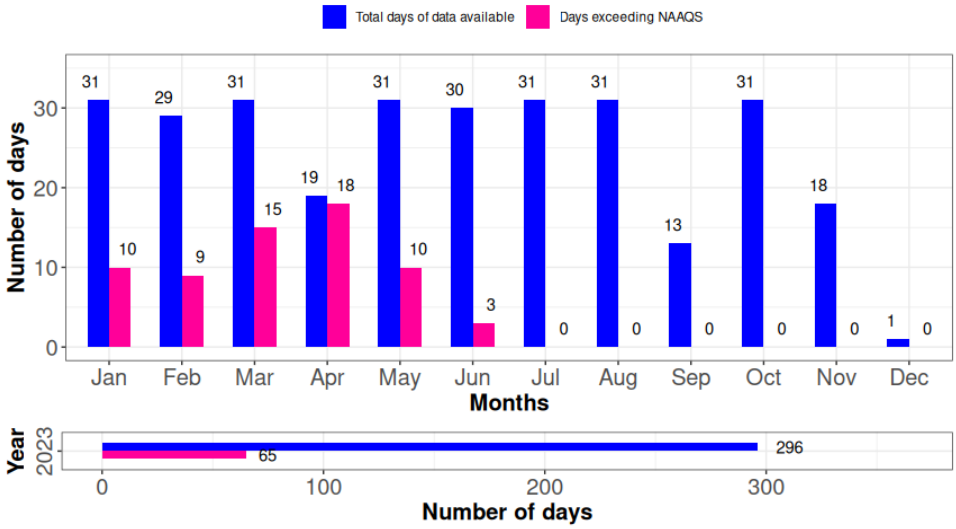

Figure A4-248: Compliance Status of PM_{10} for Shankhapark Station

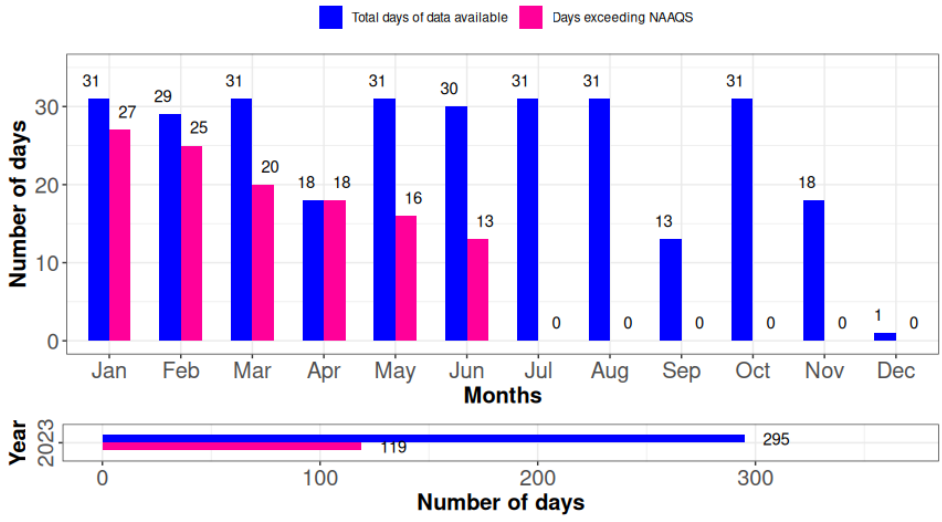

Figure A4-249: Compliance Status of TSP for Shankhapark Station

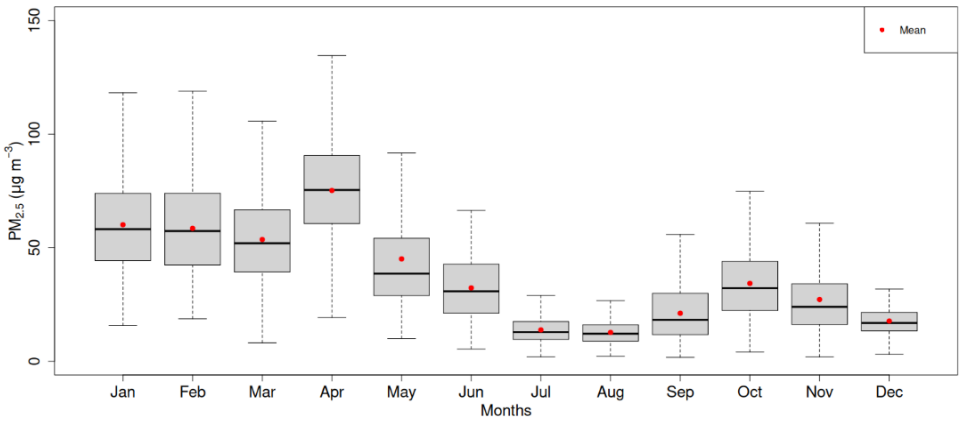

Figure A4-250: Monthly Variation of $PM_{2.5}$ for Shankhapark Station

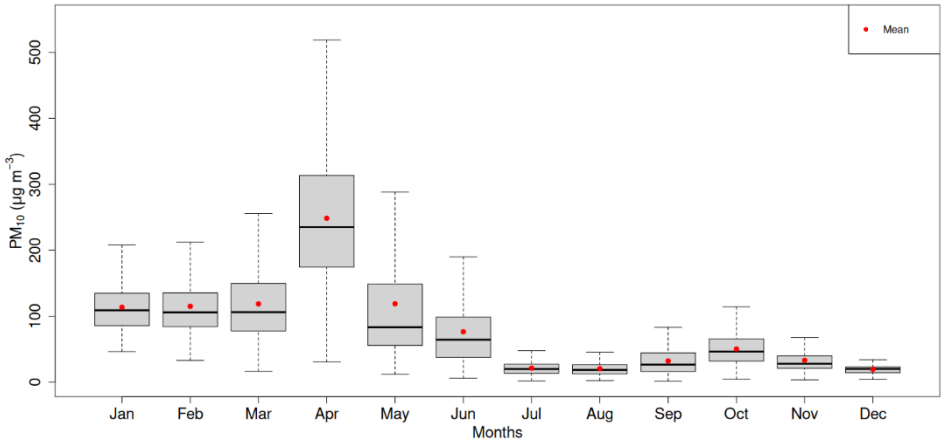

Figure A4-251: Monthly Variation of PM_{10} for Shankhapark Station

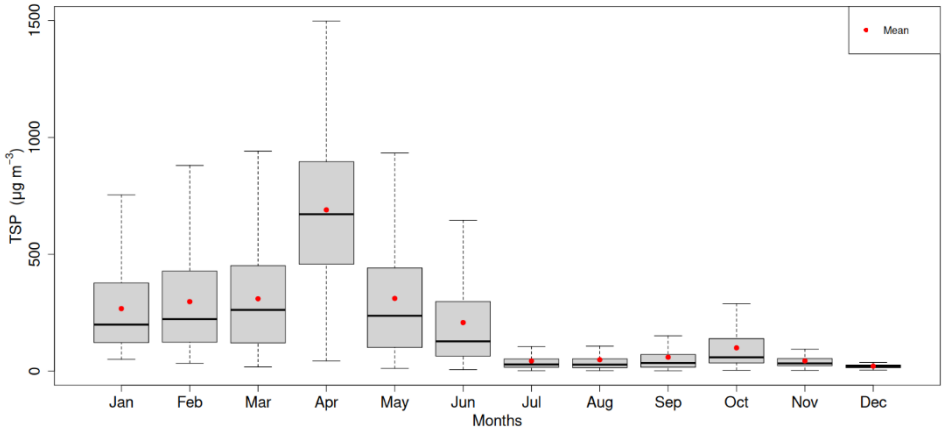

Figure A4-252: Monthly Variation of TSP for Shankhapark Station

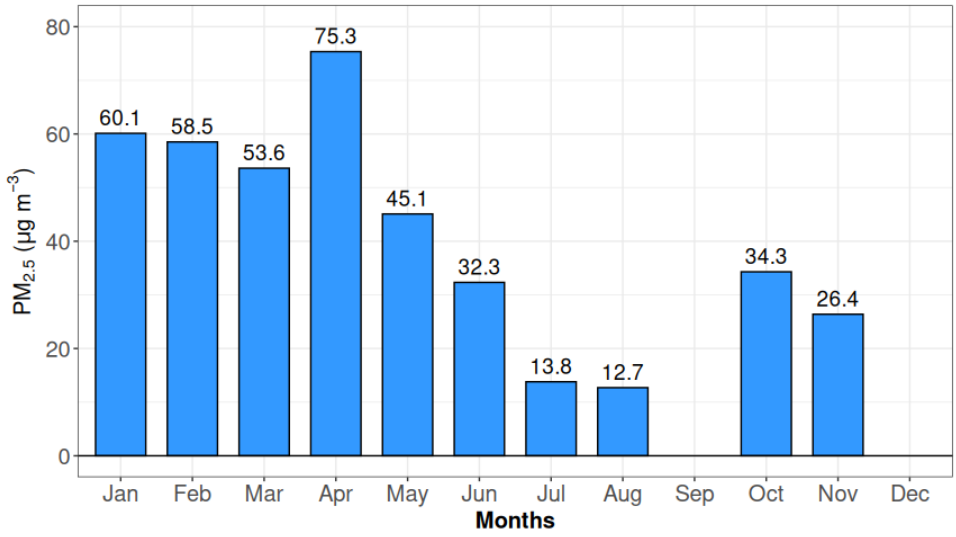

Figure A4-253: Monthly Average of $PM_{2.5}$ for Shankhapark Station

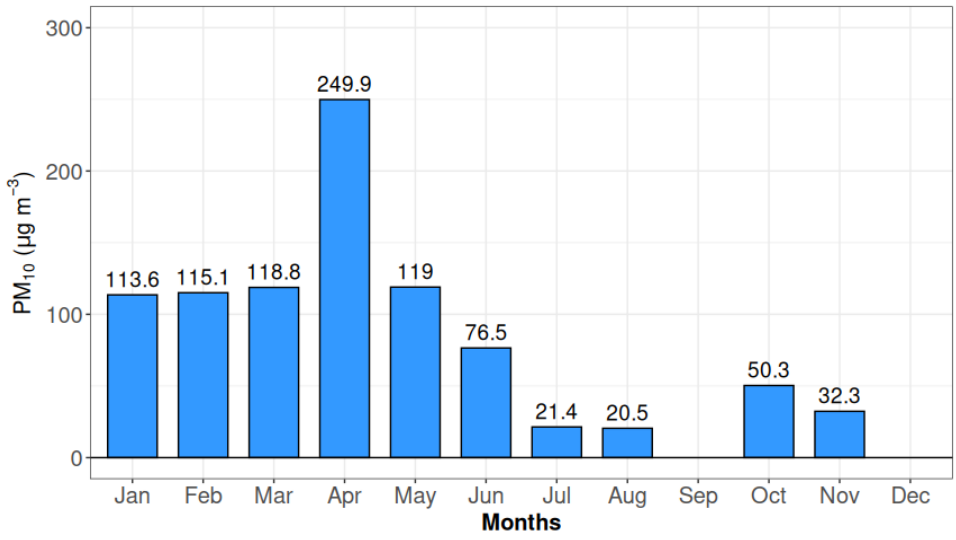

Figure A4-254: Monthly Average of PM_{10} for Shankhapark Station

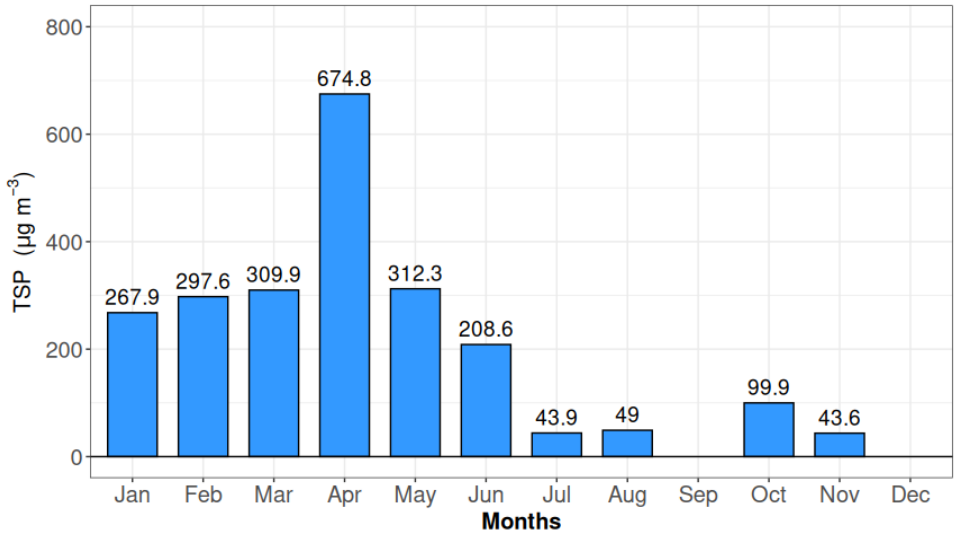

Figure A4-255: Monthly Average of TSP for Shankhapark Station

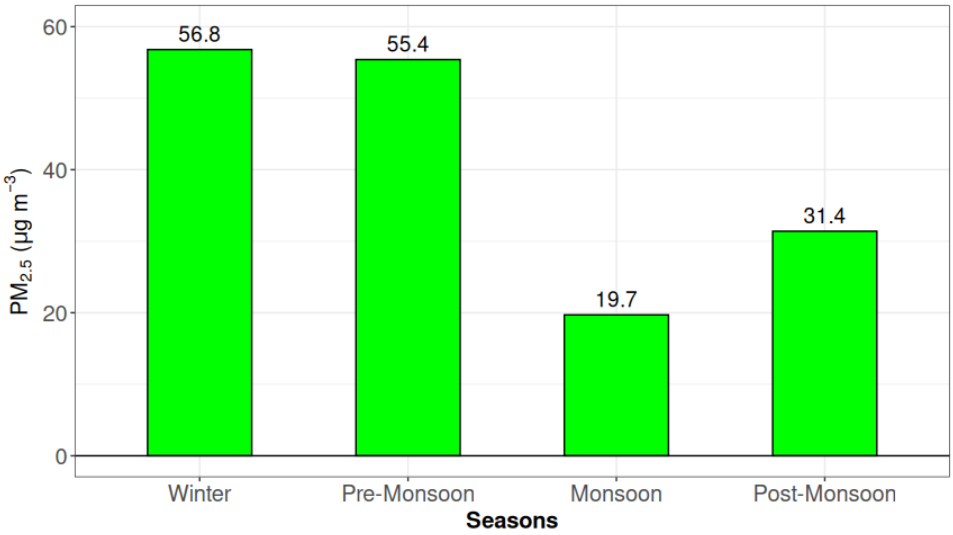

Figure A4-256: Seasonal Average of $PM_{2.5}$ for Shankhapark Station

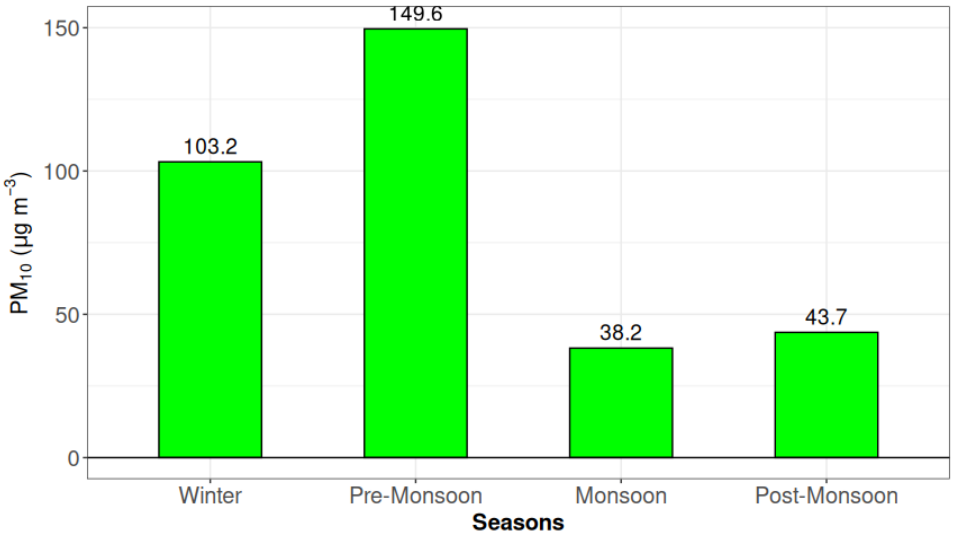

Figure A4-257: Seasonal Average of PM_{10} for Shankhapark Station

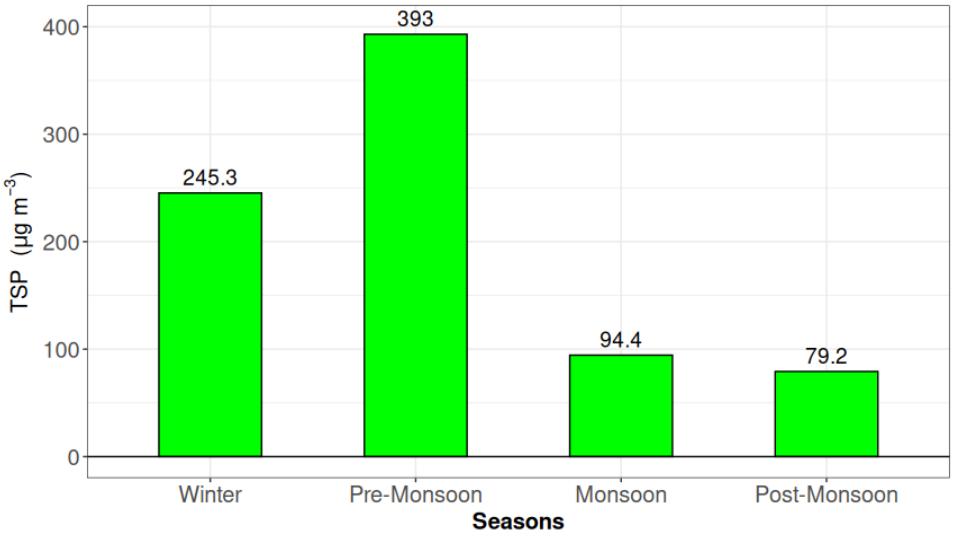

Figure A4-258: Seasonal Average of TSP for Shankhapark Station

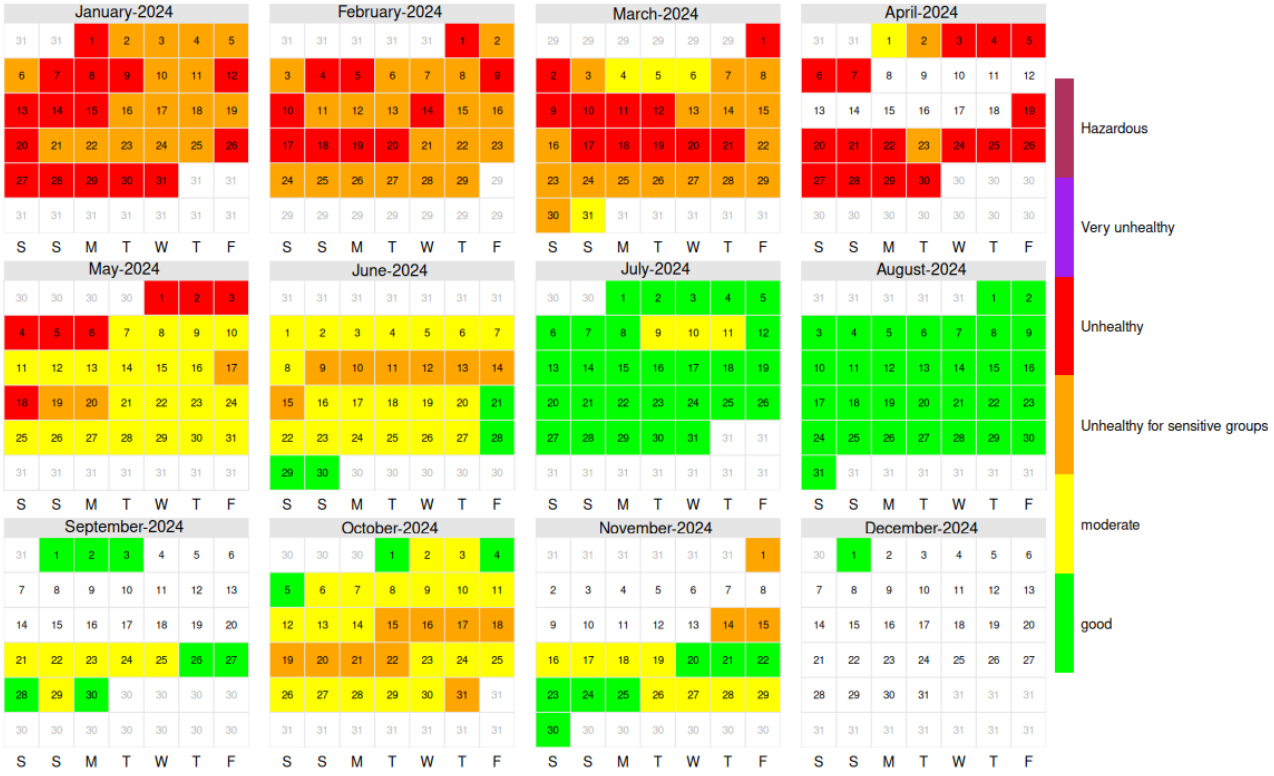

Figure A4-259: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Shankhapark Station

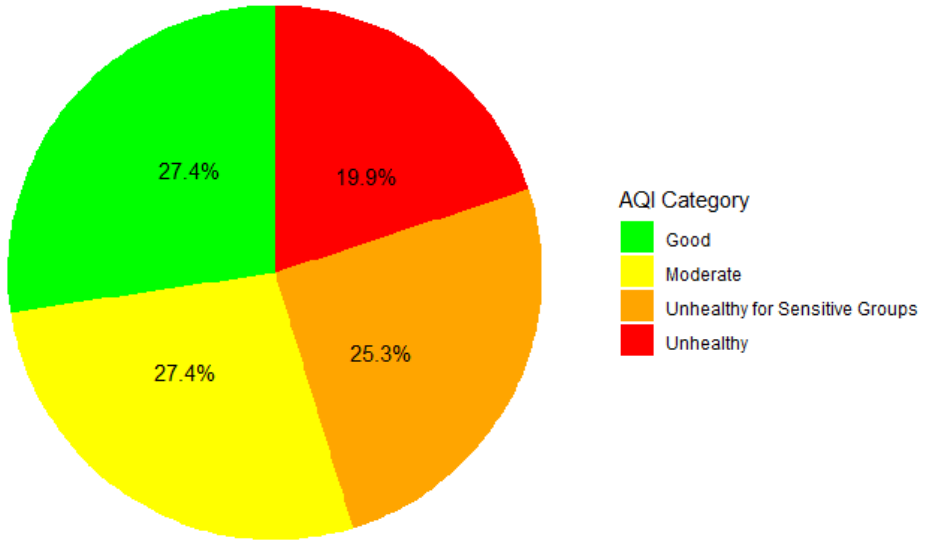

Figure A4-260: AQI Category Distribution for Shankhapark Station

TU KIRTIPUR AIR QUALITY MONITORING STATION

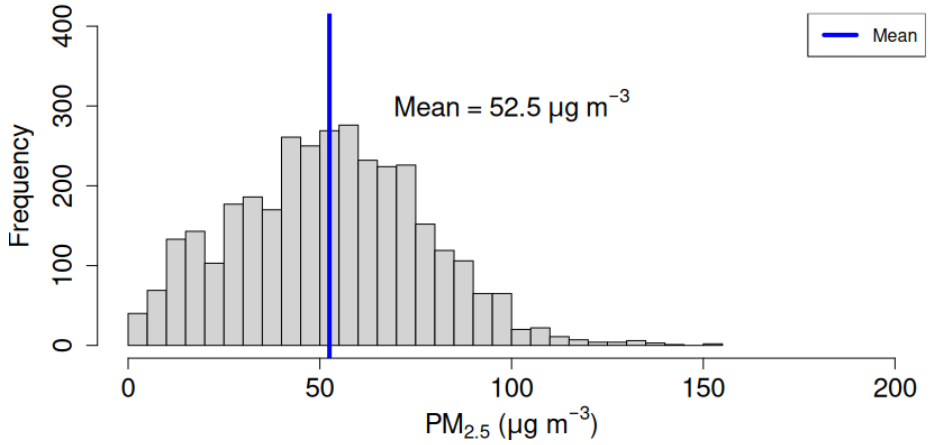

Figure A4-261: Histogram of $PM_{2.5}$ for TU Kirtipur Station

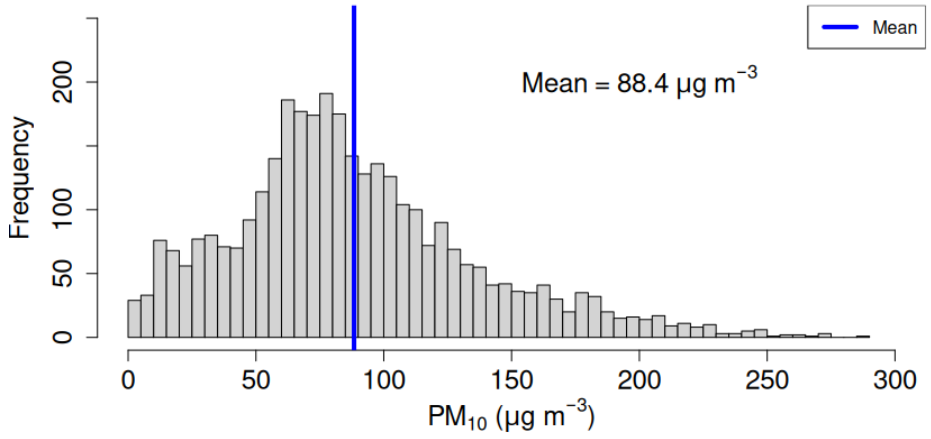

Figure A4-262: Histogram of PM_{10} for TU Kirtipur Station

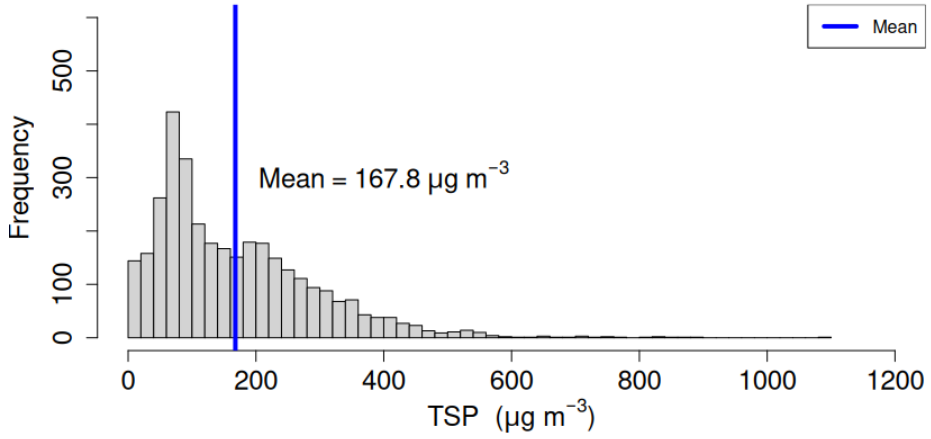

Figure A4-263: Histogram of TSP for TU Kirtipur Station

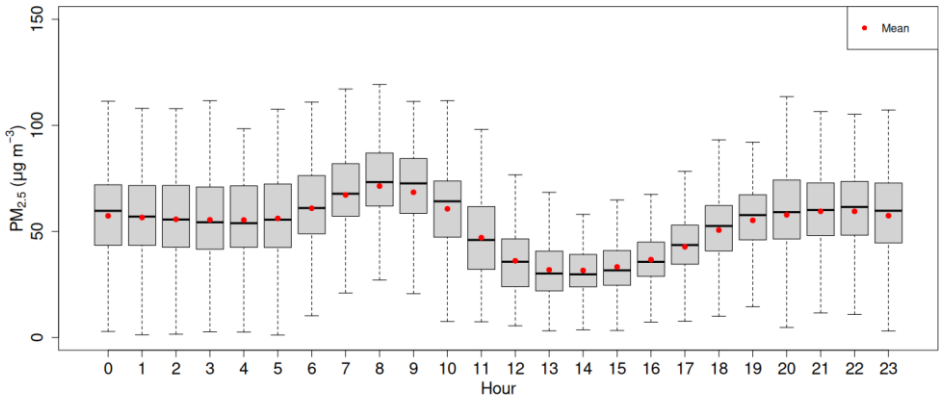

Figure A4-264: Diurnal Variation of $PM_{2.5}$ for TU Kirtipur Station

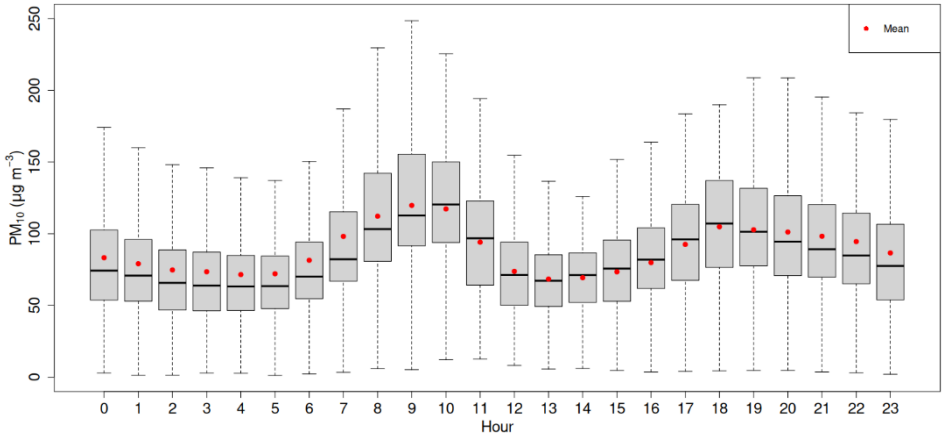

Figure A4-265: Diurnal Variation of PM_{10} for TU Kirtipur Station

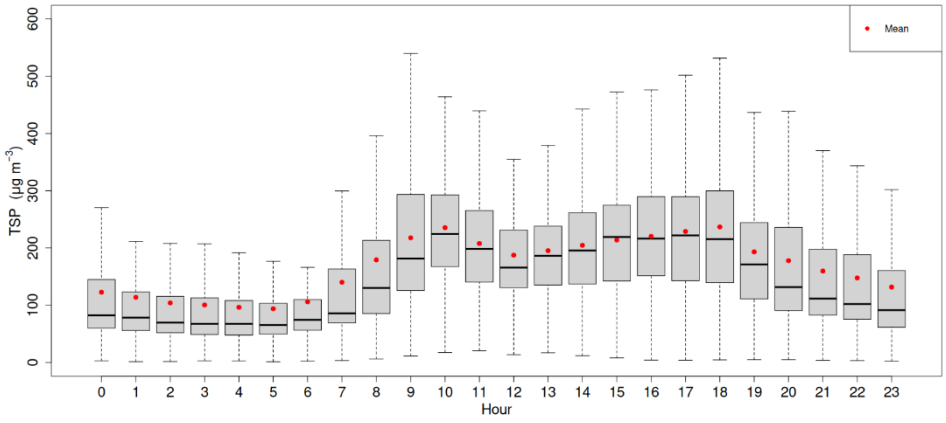

Figure A4-266: Diurnal Variation of TSP for TU Kirtipur Station

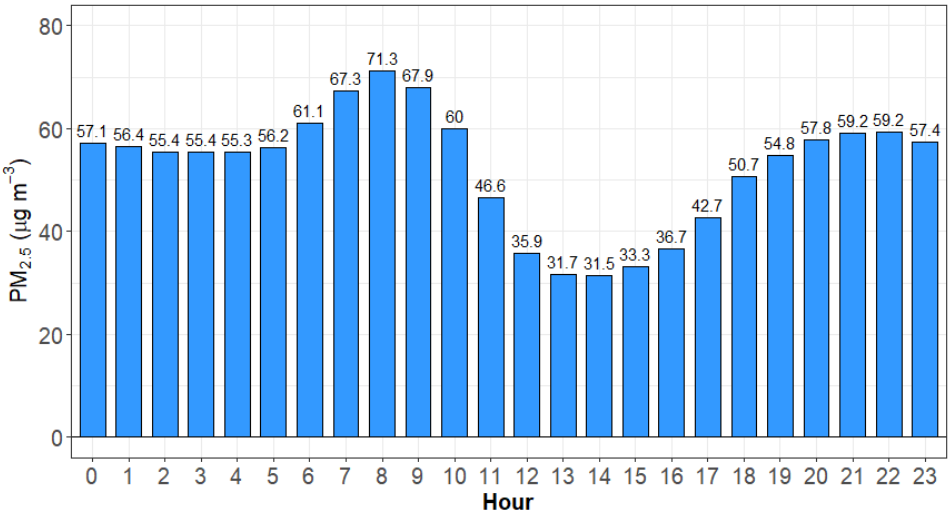

Figure A4-267: Hourly Average of $PM_{2.5}$ for TU Kirtipur Station

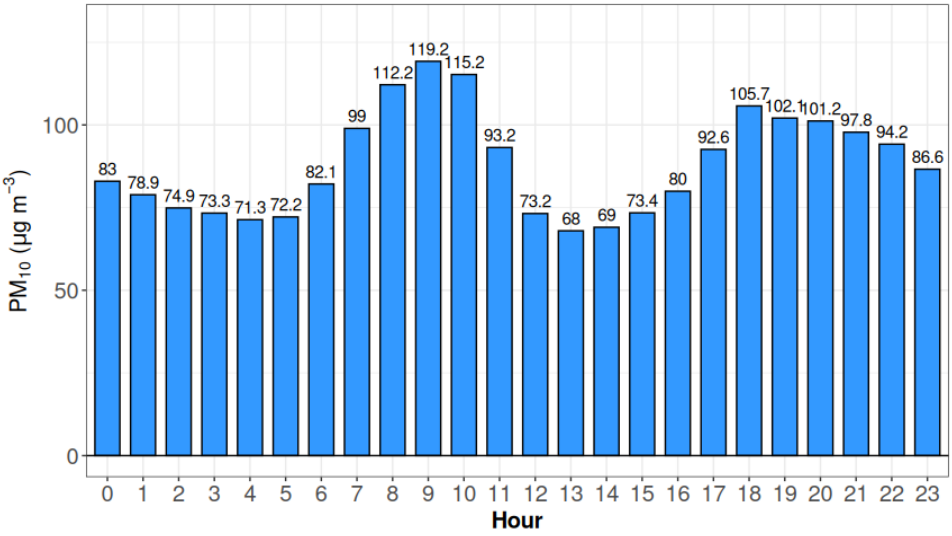

Figure A4-268: Hourly Average of PM_{10} for TU Kirtipur Station

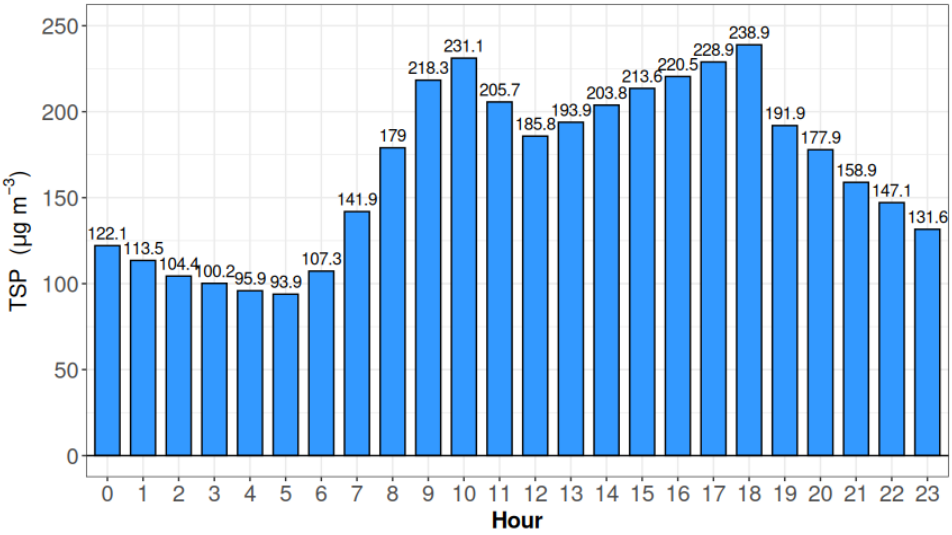

Figure A4-269: Hourly Average of TSP for TU Kirtipur Station

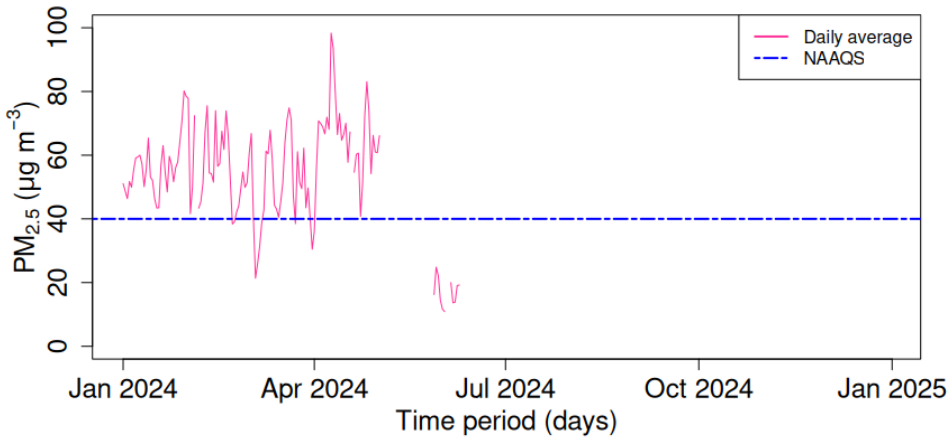

Figure A4-270: Daily Average of $PM_{2.5}$ for TU Kirtipur Station

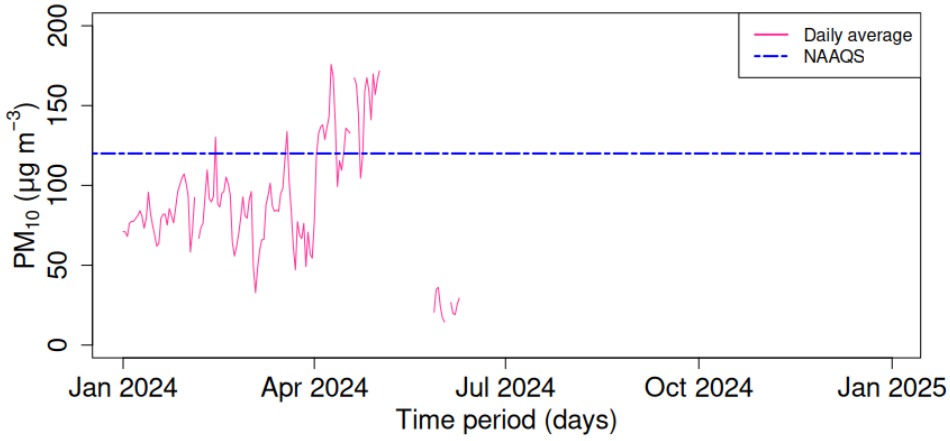

Figure A4-271: Daily Average of PM_{10} for TU Kirtipur Station

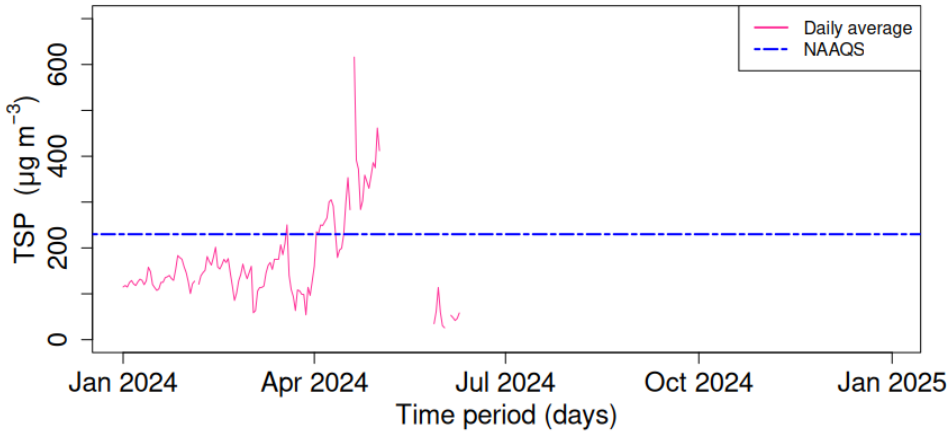

Figure A4-272: Daily Average of TSP for TU Kirtipur Station

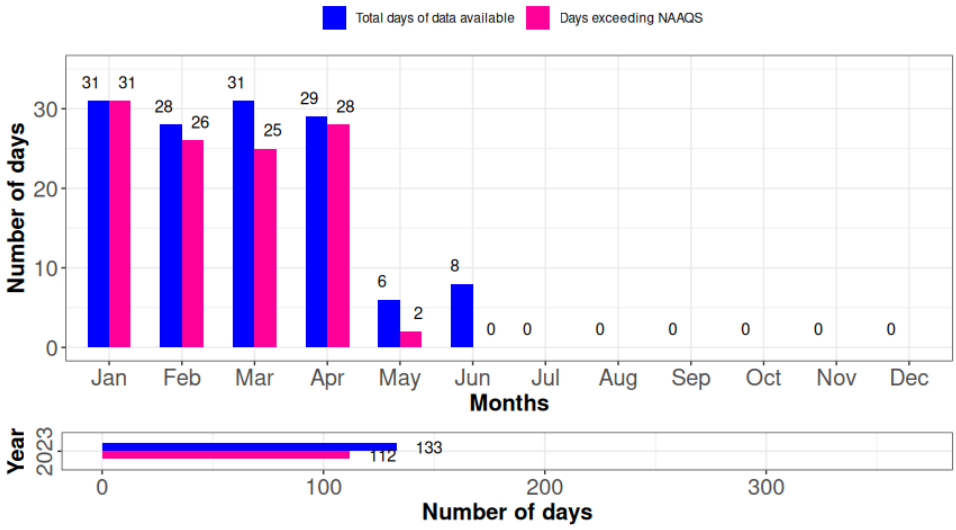

Figure A4-273: Compliance Status of $PM_{2.5}$ for TU Kirtipur Station

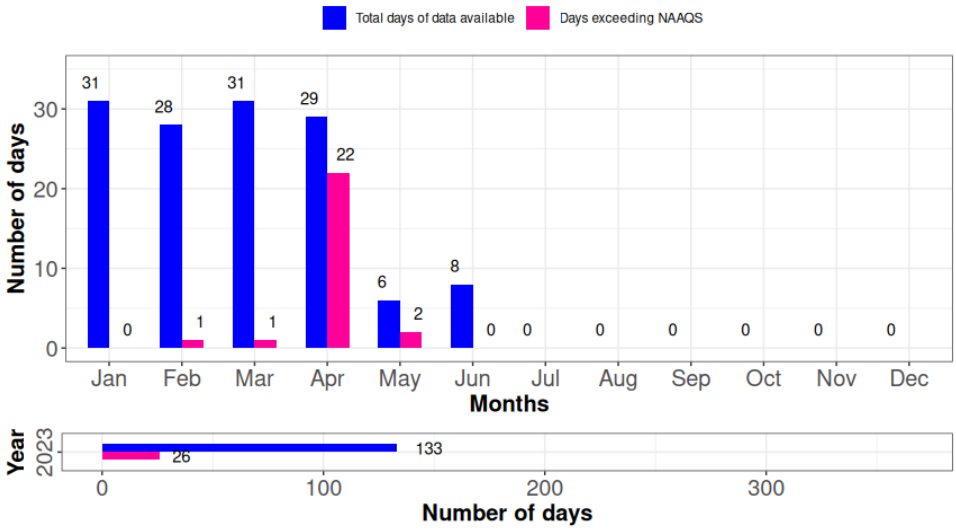

Figure A4-274: Compliance Status of PM_{10} for TU Kirtipur Station

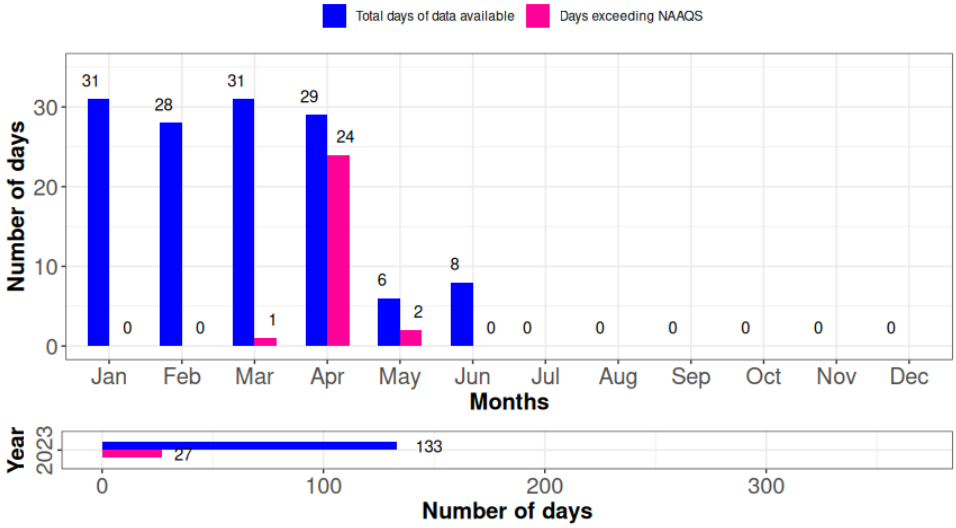

Figure A4-275: Compliance Status of TSP for TU Kirtipur Station

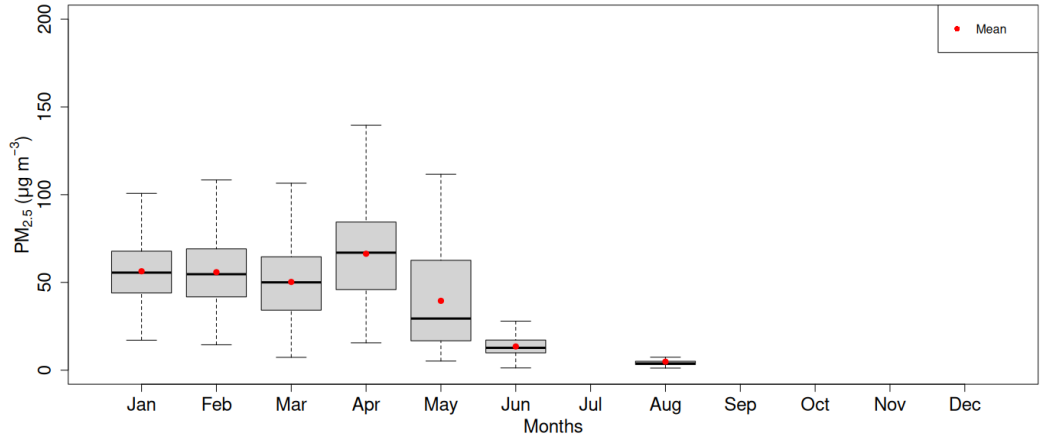

Figure A4-276: Monthly Variation of $PM_{2.5}$ for TU Kirtipur Station

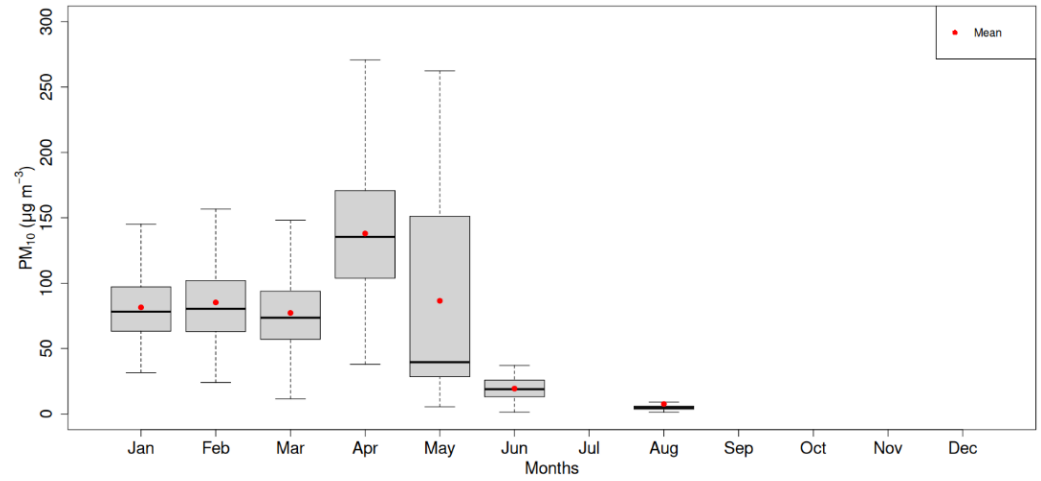

Figure A4-277: Monthly Variation of PM_{10} for TU Kirtipur Station

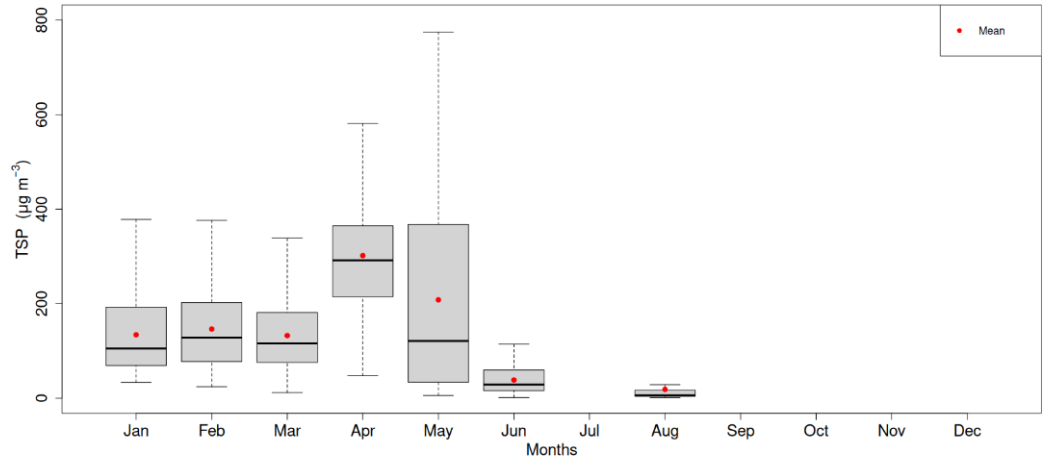

Figure A4-278: Monthly Variation of TSP for TU Kirtipur Station

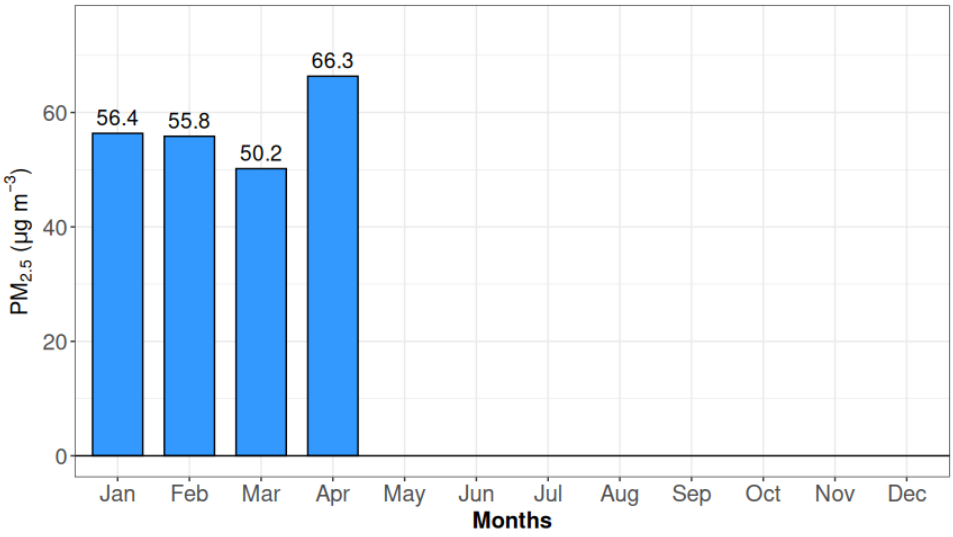

Figure A4-279: Monthly Average of $PM_{2.5}$ for TU Kirtipur Station

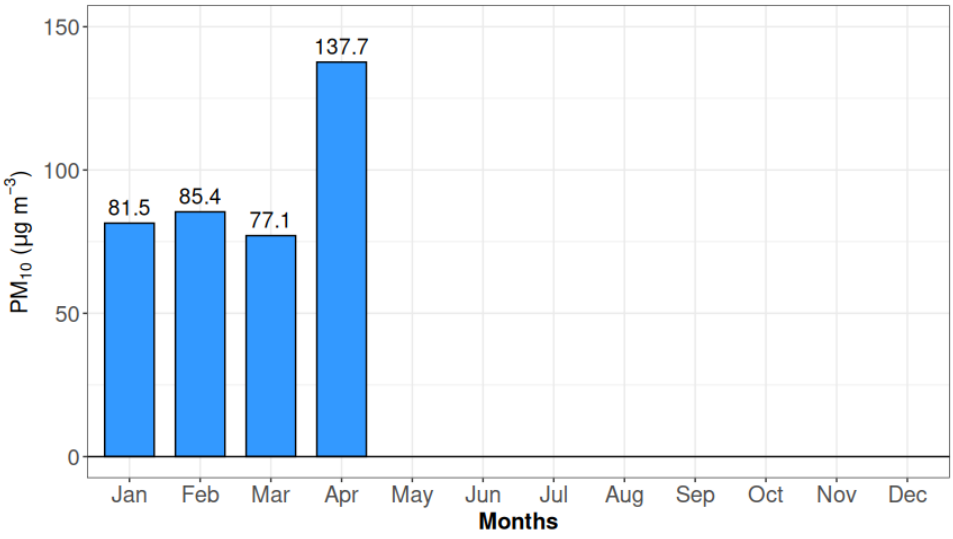

Figure A4-280: Monthly Average of PM_{10} for TU Kirtipur Station

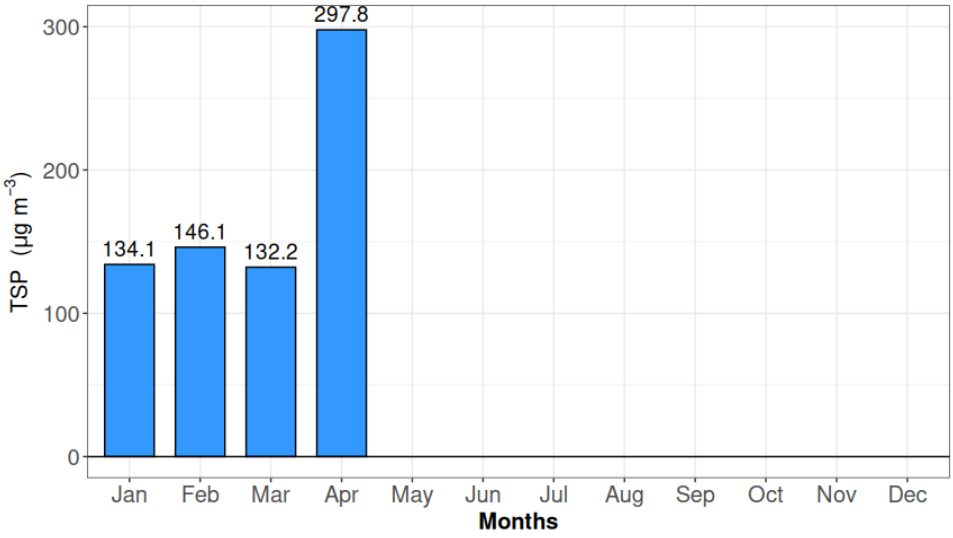

Figure A4-281: Monthly Average of TSP for TU Kirtipur Station

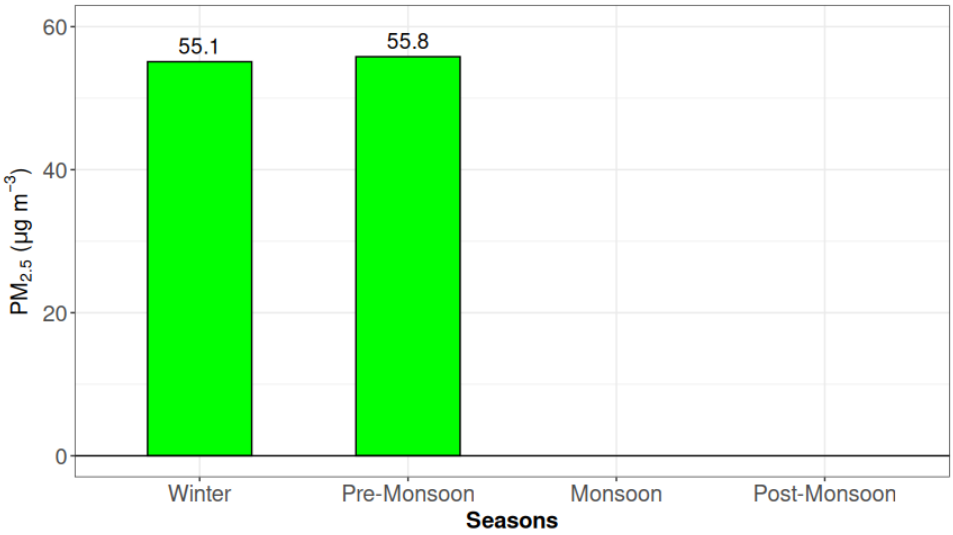

Figure A4-282: Seasonal Average of $PM_{2.5}$ for TU Kirtipur Station

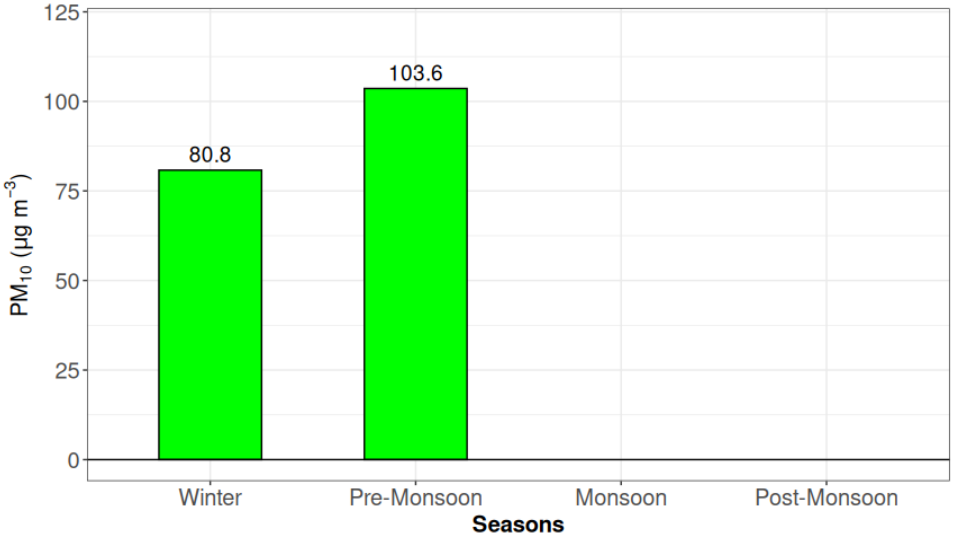

Figure A4-283: Seasonal Average of PM_{10} for TU Kirtipur Station

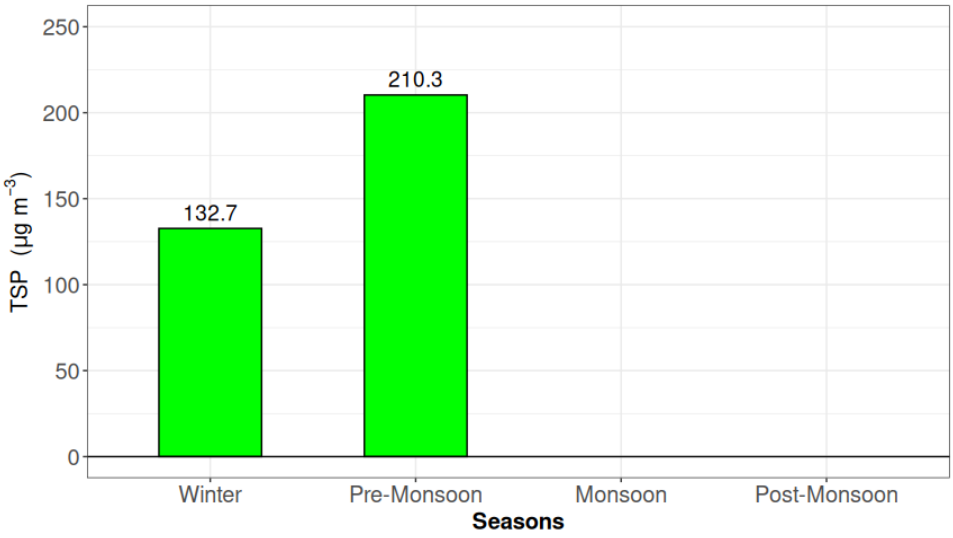

Figure A4-284: Seasonal Average of TSP for TU Kirtipur Station

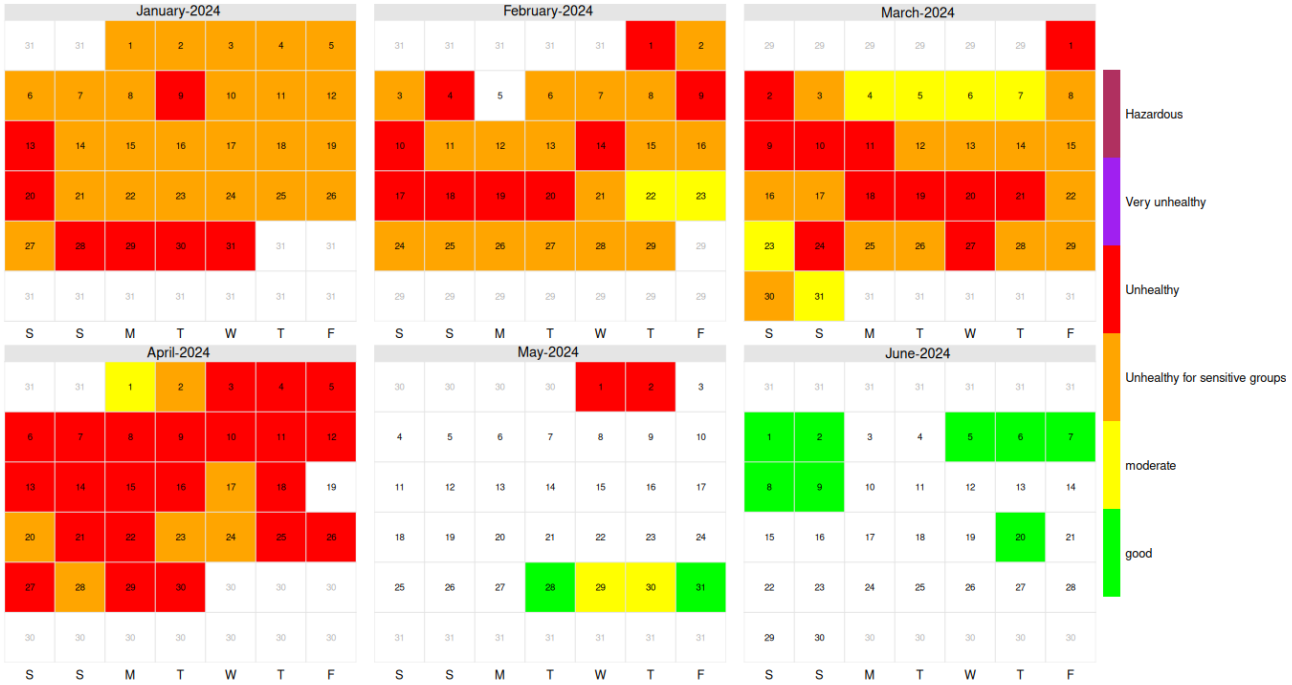

Figure A4-285: Calendar Plot of AQI Category Based on $PM_{2.5}$ for TU Kirtipur Station

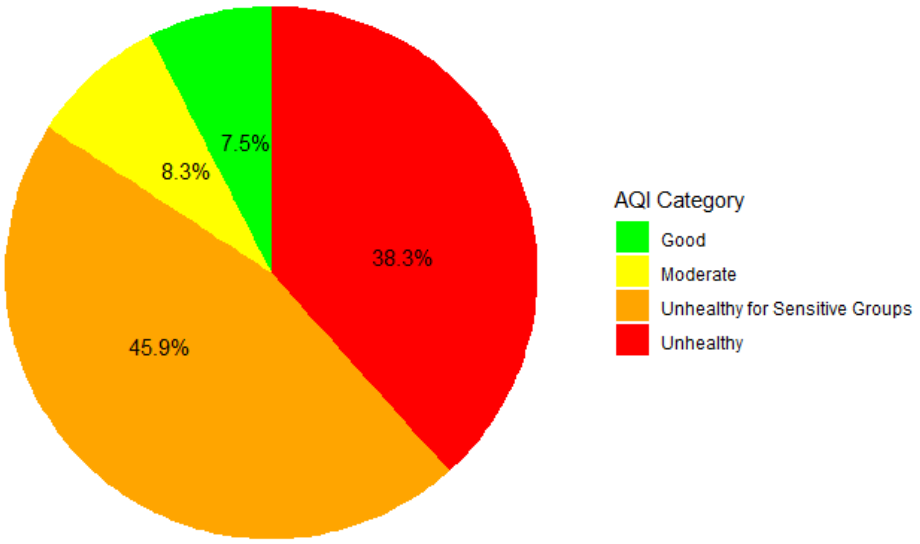

Figure A4-286: AQI Category Distribution for TU Kirtipur Station

DEUKHURI DANG AIR QUALITY MONITORING STATION

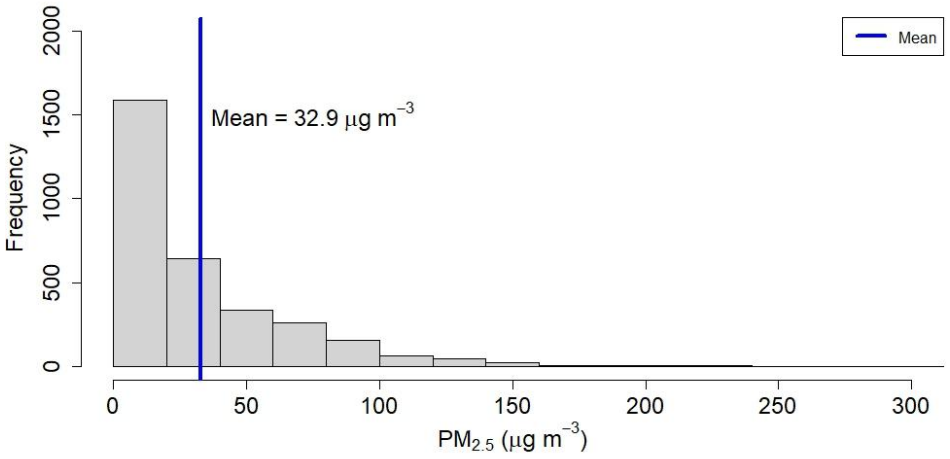

Figure A4-287: Histogram of $PM_{2.5}$ for Deukhuri Dang Station

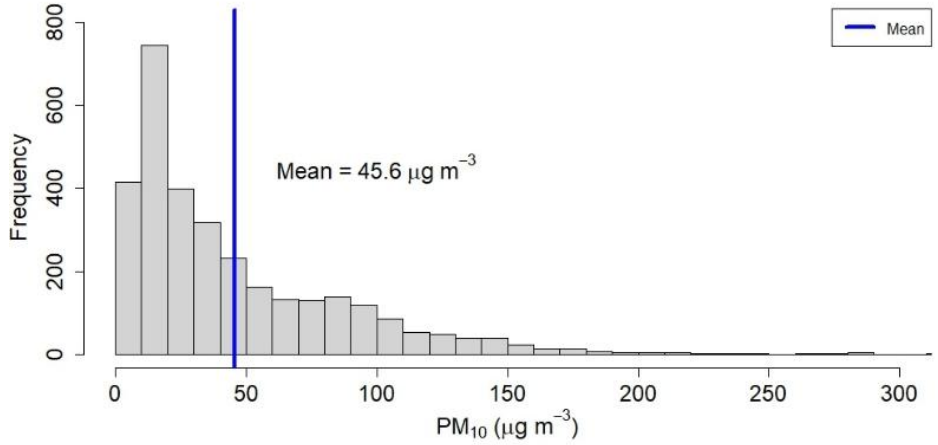

Figure A4-288: Histogram of PM_{10} for Deukhuri Dang Station

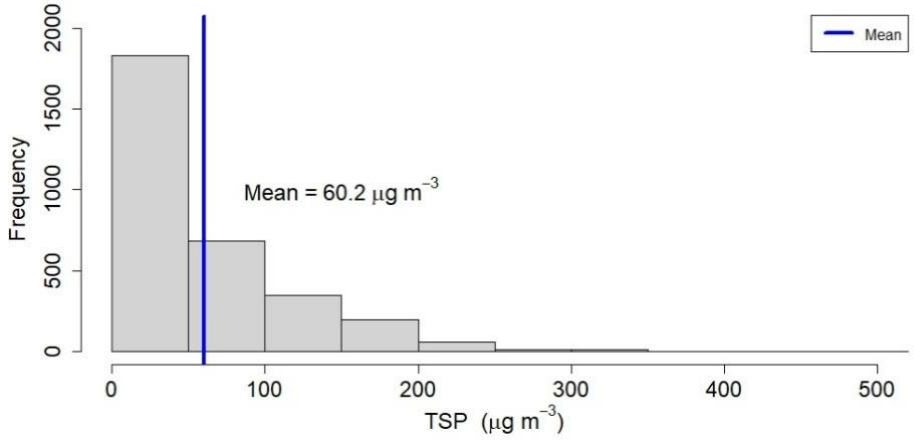

Figure A4-289: Histogram of TSP for Deukhuri Dang Station

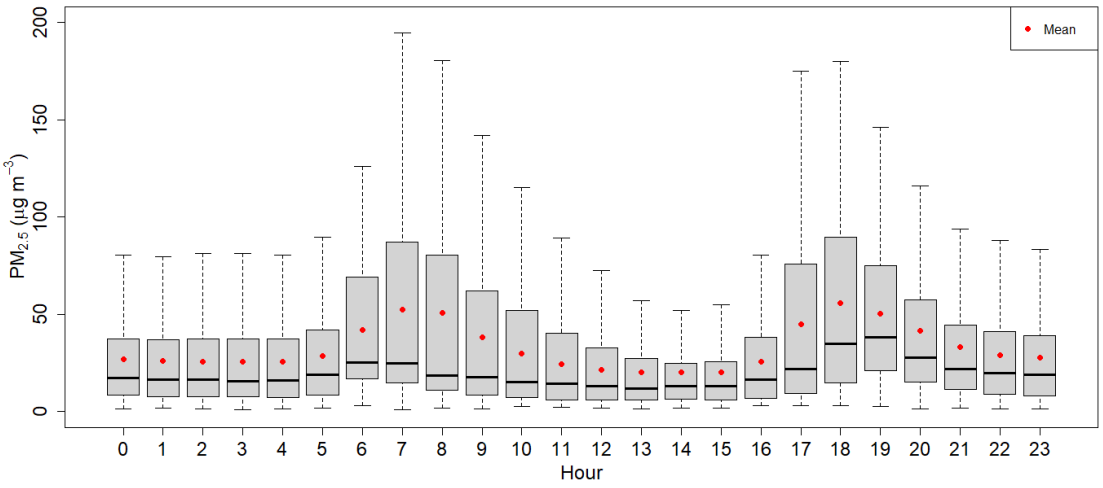

Figure A4-290: Diurnal Variation of $PM_{2.5}$ for Deukhuri Dangi Station

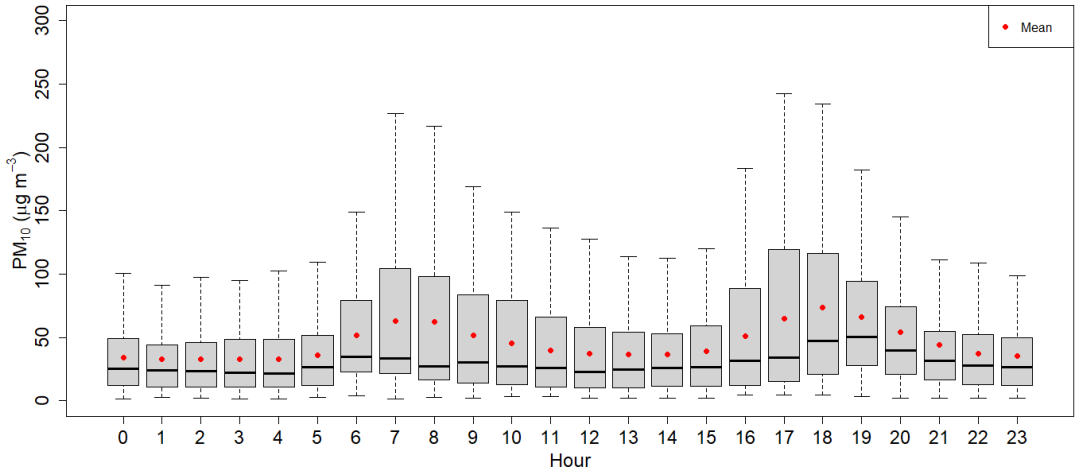

Figure A4-291: Diurnal Variation of PM_{10} for Deukhuri Dangi Station

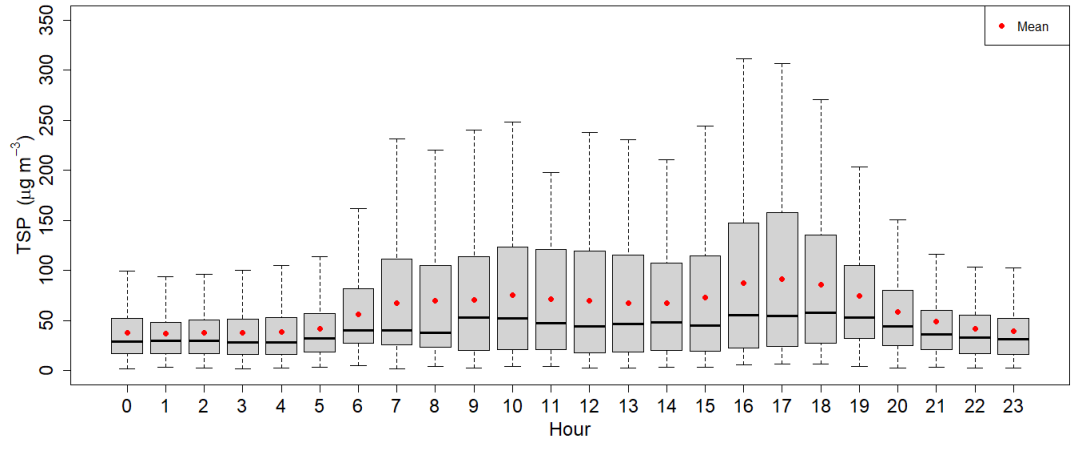

Figure A4-292: Diurnal Variation of TSP for Deukhuri Dangi Station

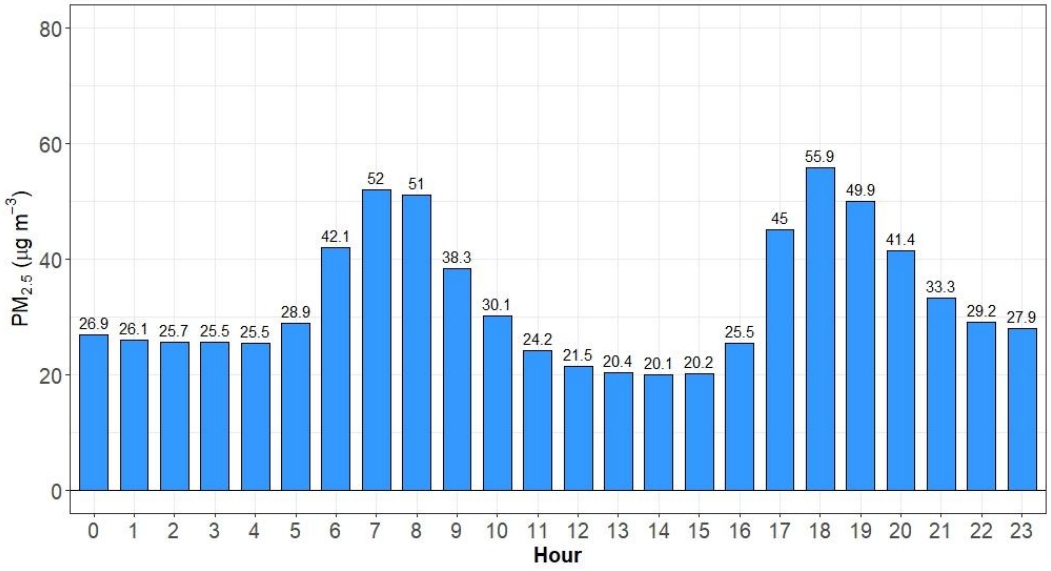

Figure A4-293: Hourly Average of $PM_{2.5}$ for Deukhuri Dang Station

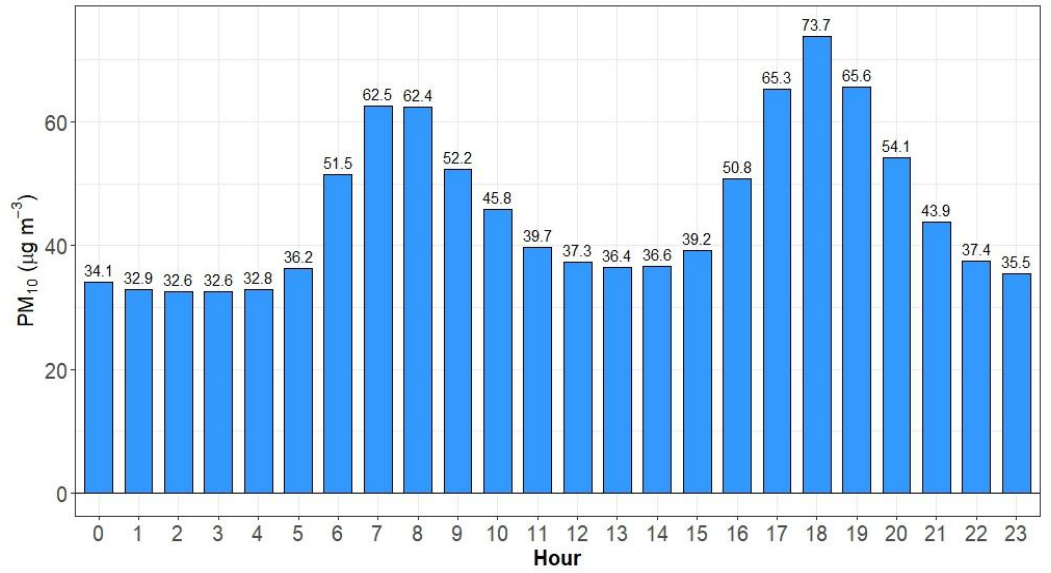

Figure A4-294: Hourly Average of $PM_{2.5}$ for Deukhuri Dang Station

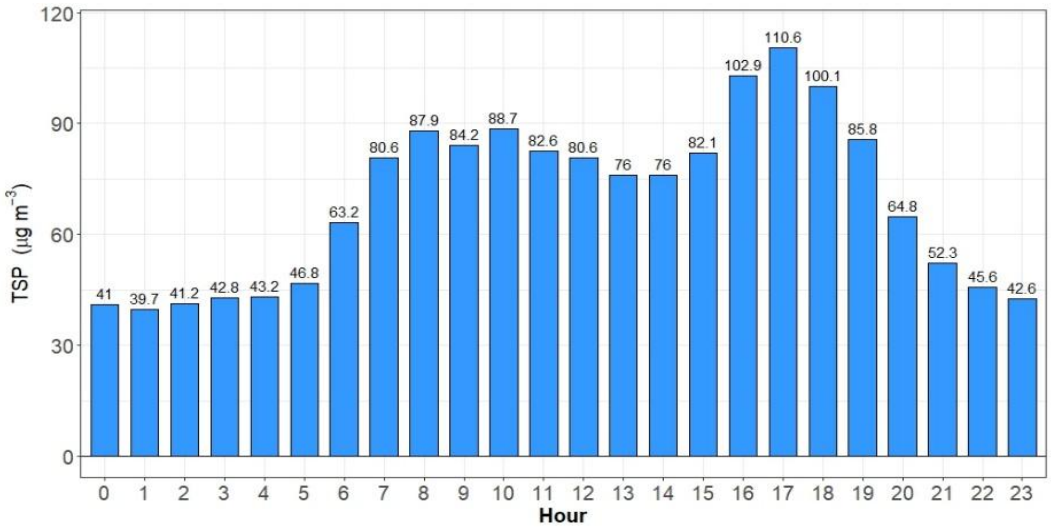

Figure A4-295: Hourly Average of TSP for Deukhuri Dang Station

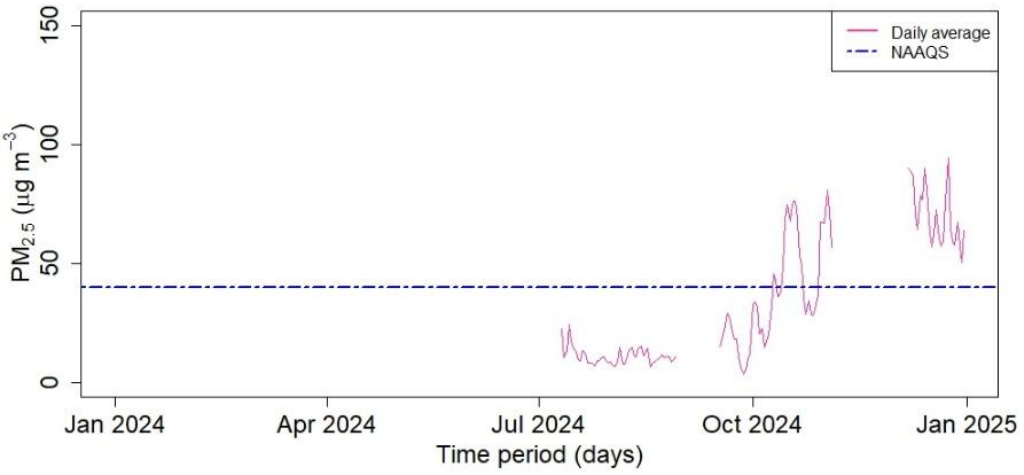

Figure A4-296: Daily Average of $PM_{2.5}$ for Deukhuri Dang Station

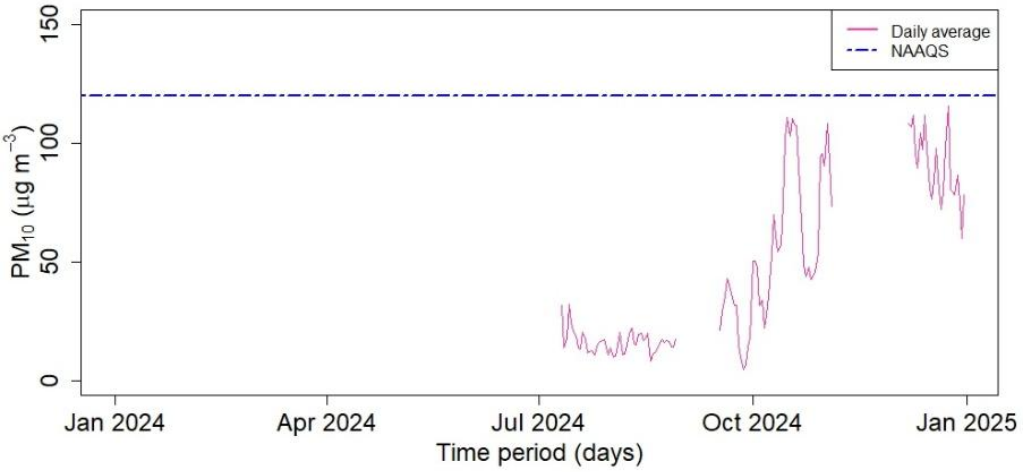

Figure A4-297: Daily Average of PM_{10} for Deukhuri Dang Station

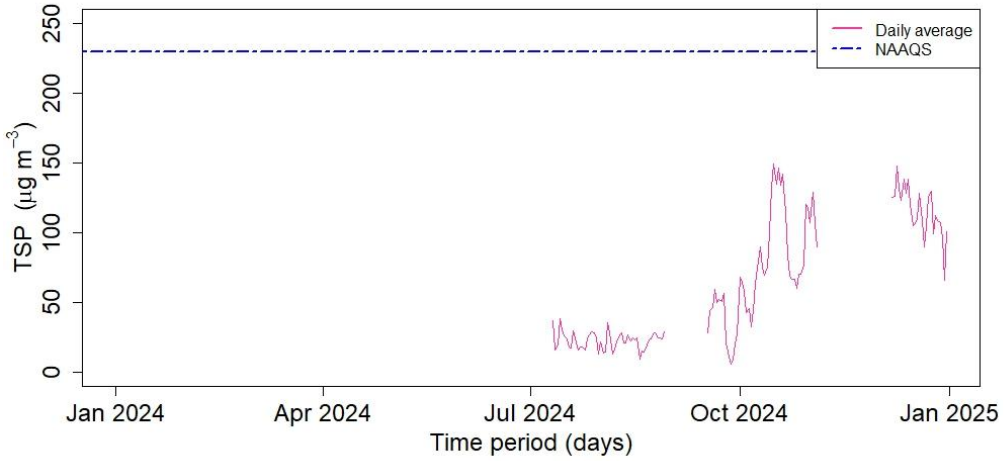

Figure A4-298: Daily Average of TSP for Deukhuri Dang Station

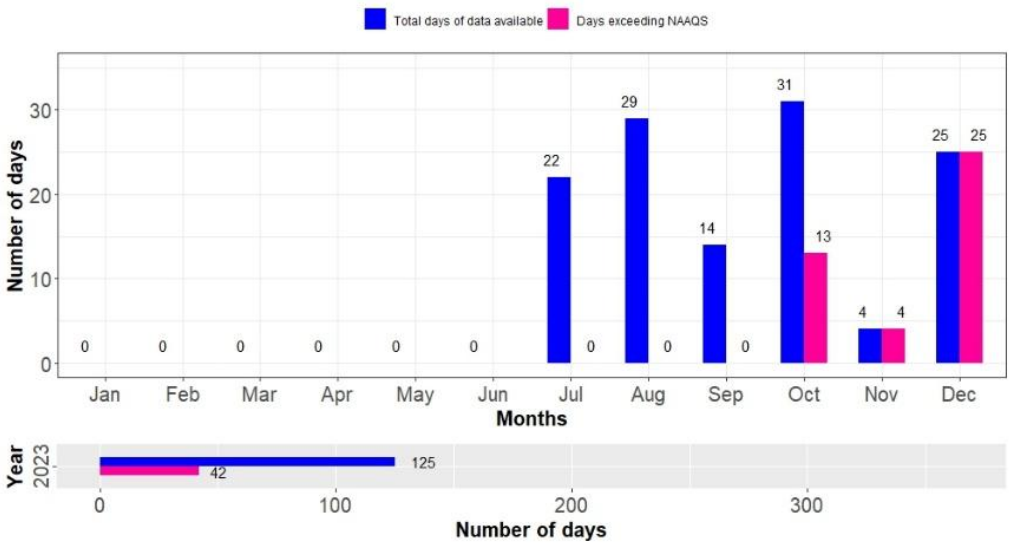

Figure A4-299: Compliance Status of $PM_{2.5}$ for Deukhuri Dang Station

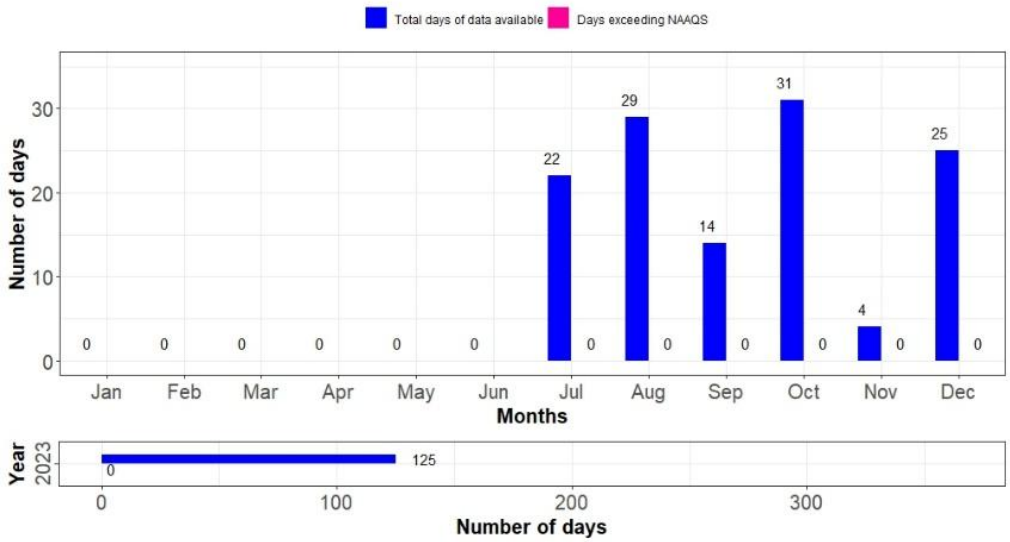

Figure A4-300: Compliance Status of PM_{10} for Deukhuri Dang Station

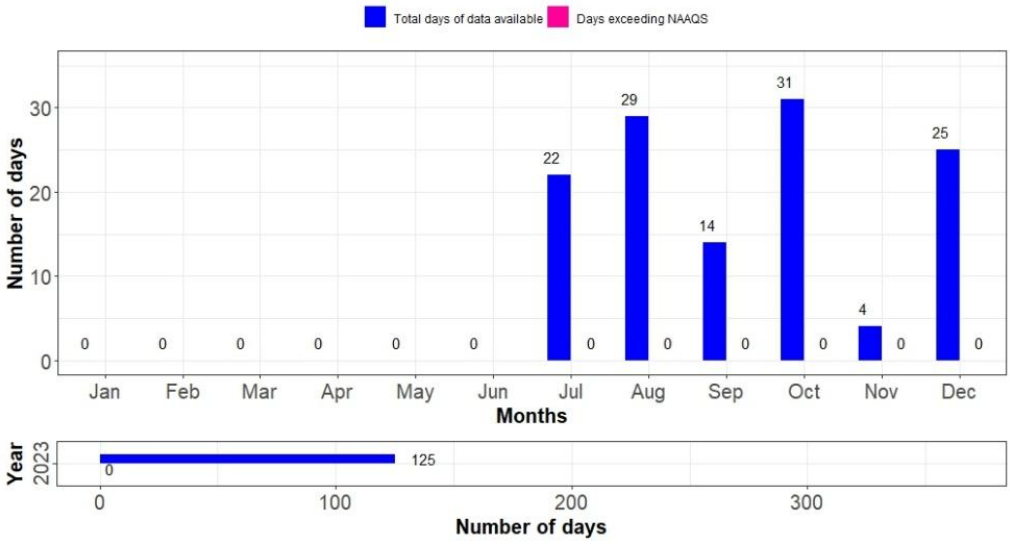

Figure A4-301: Compliance Status of TSP for Deukhuri Dang Station

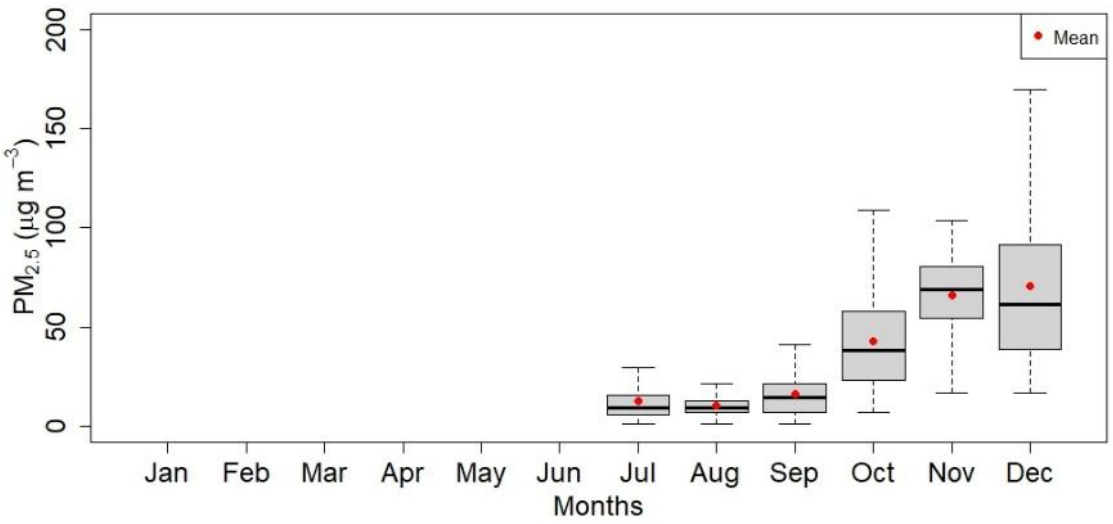

Figure A4-302: Monthly Variation of $PM_{2.5}$ for Deukhuri Dang Station

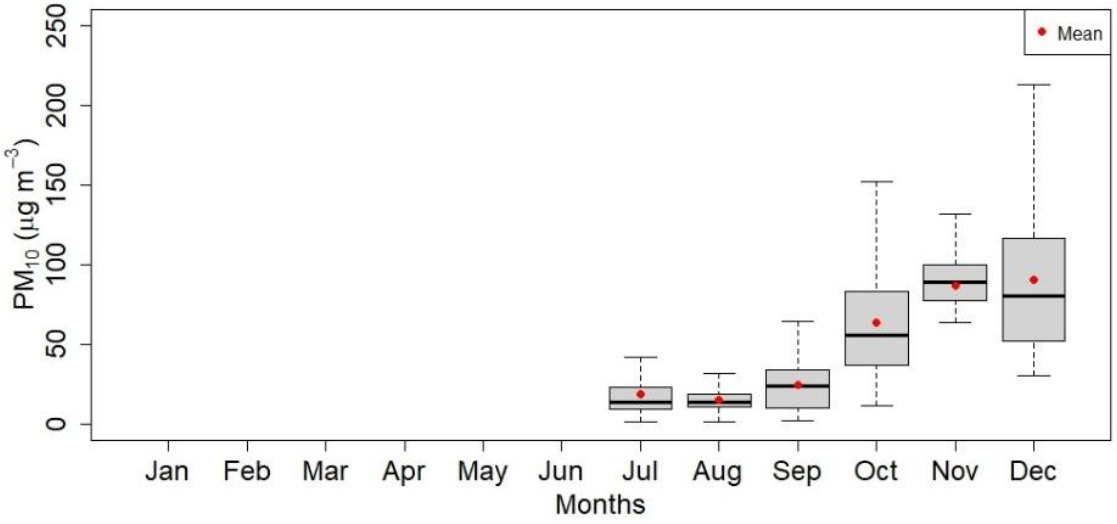

Figure A4-303: Monthly Variation of PM_{10} for Deukhuri Dang Station

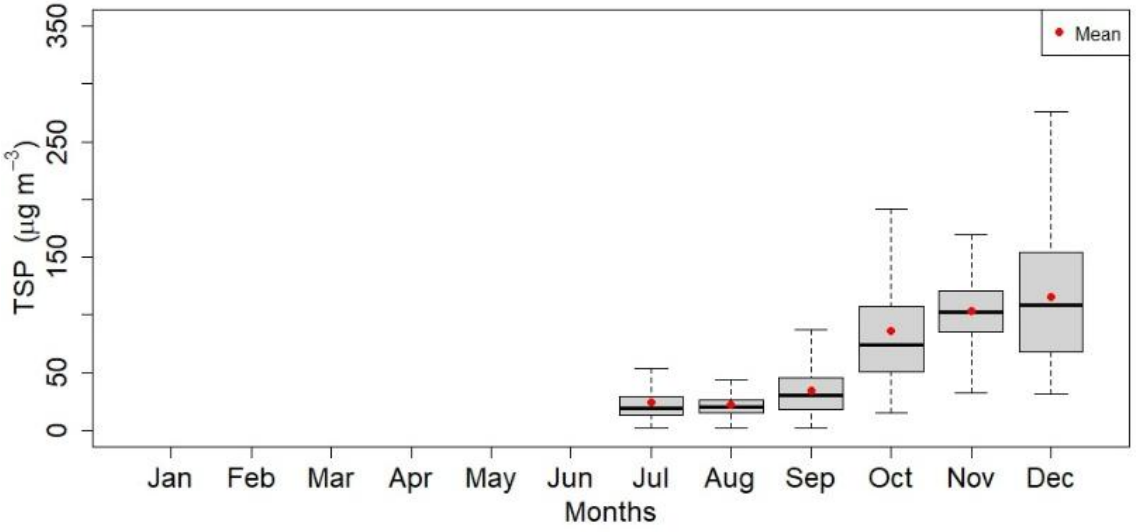

Figure A4-304: Monthly Variation of TSP for Deukhuri Dang Station

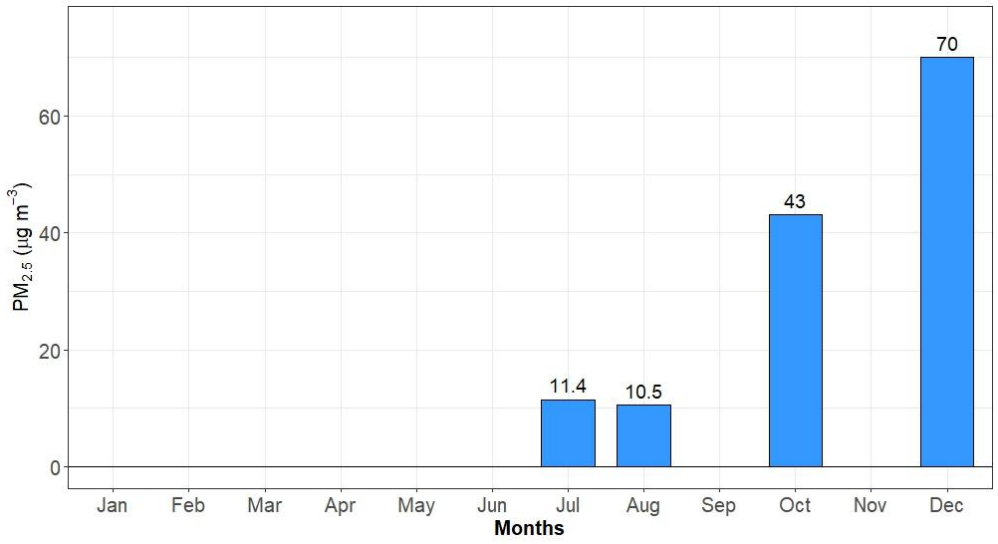

Figure A4-305: Monthly Average of $PM_{2.5}$ for Deukhuri Dang Station

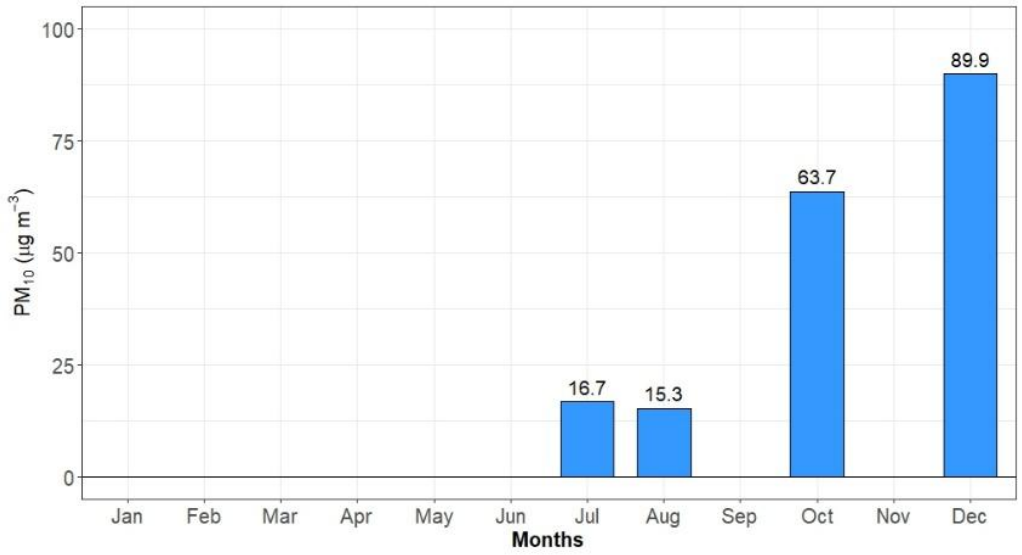

Figure A4-306: Monthly Average of PM_{10} for Deukhuri Dang Station

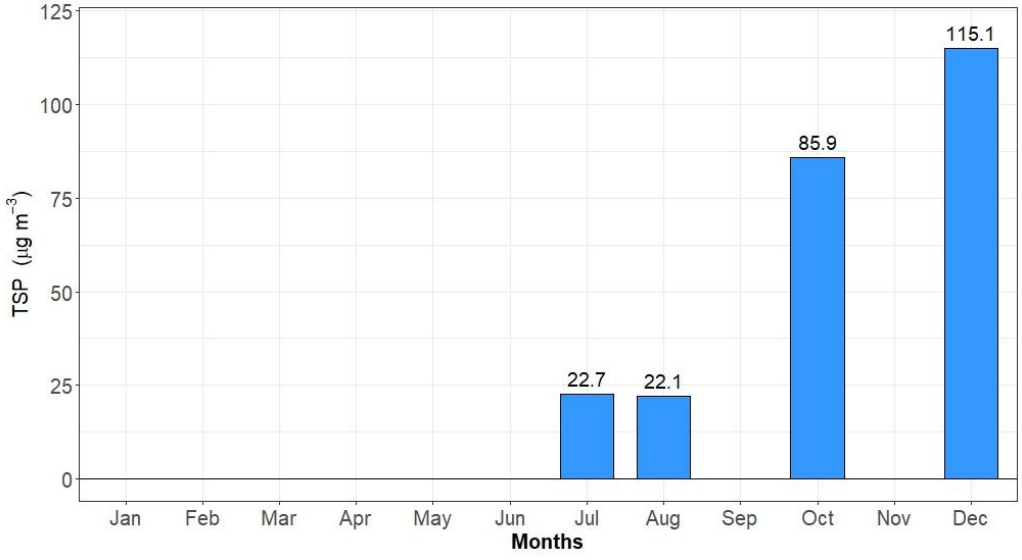

Figure A4-307: Monthly Average of TSP for Deukhuri Dang Station

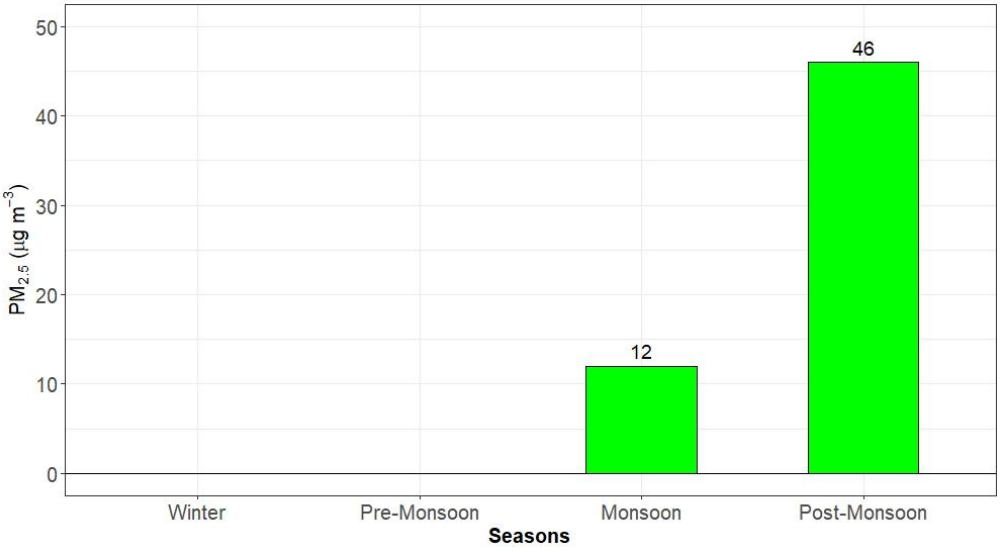

Figure A4-308: Seasonal Average of $PM_{2.5}$ for Deukhuri Dang Station

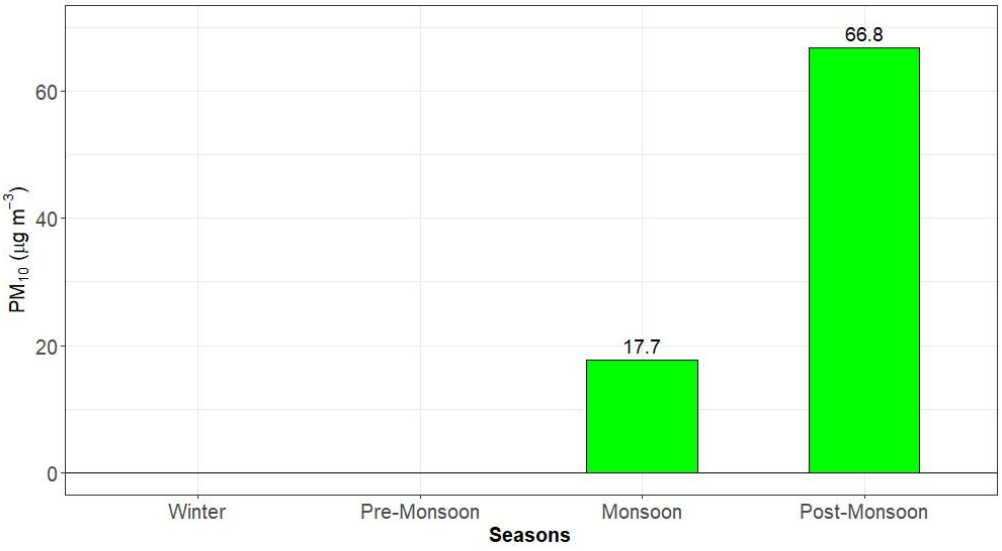

Figure A4-309: Seasonal Average of PM_{10} for Deukhuri Dang Station

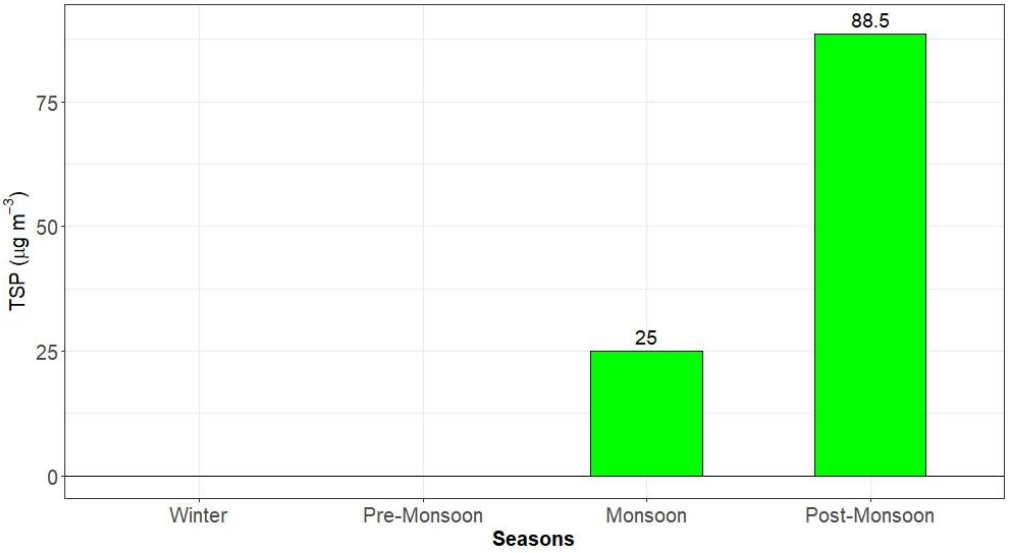

Figure A4-310: Seasonal Average of TSP for Deukhuri Dang Station

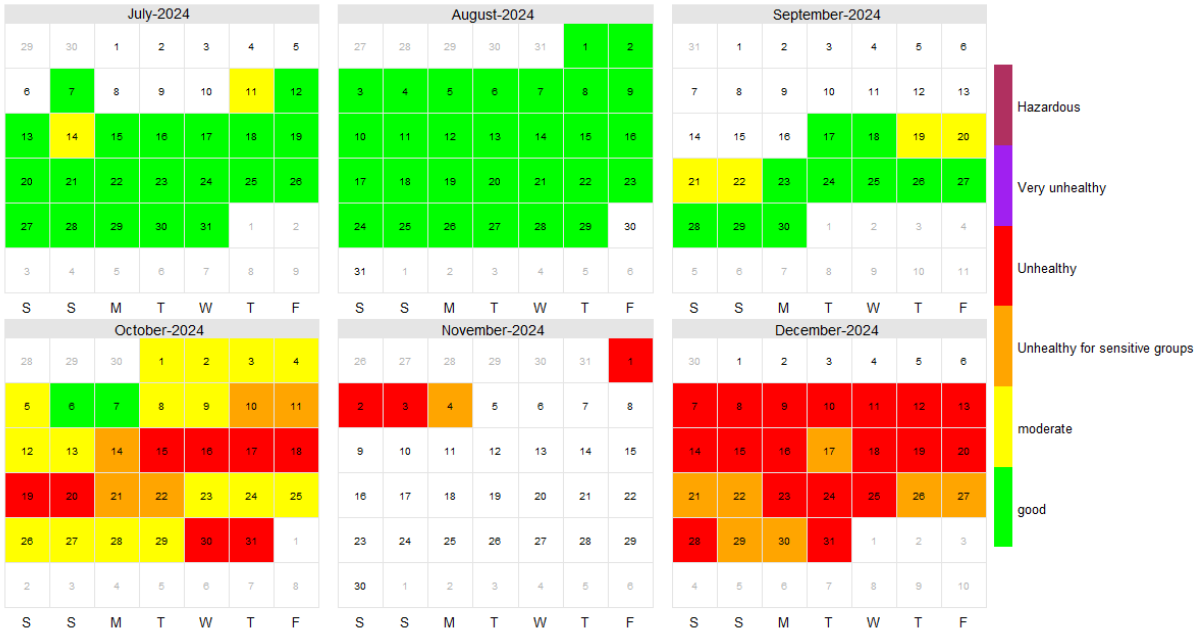

Figure A4-311: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Deukhuri Dang Station

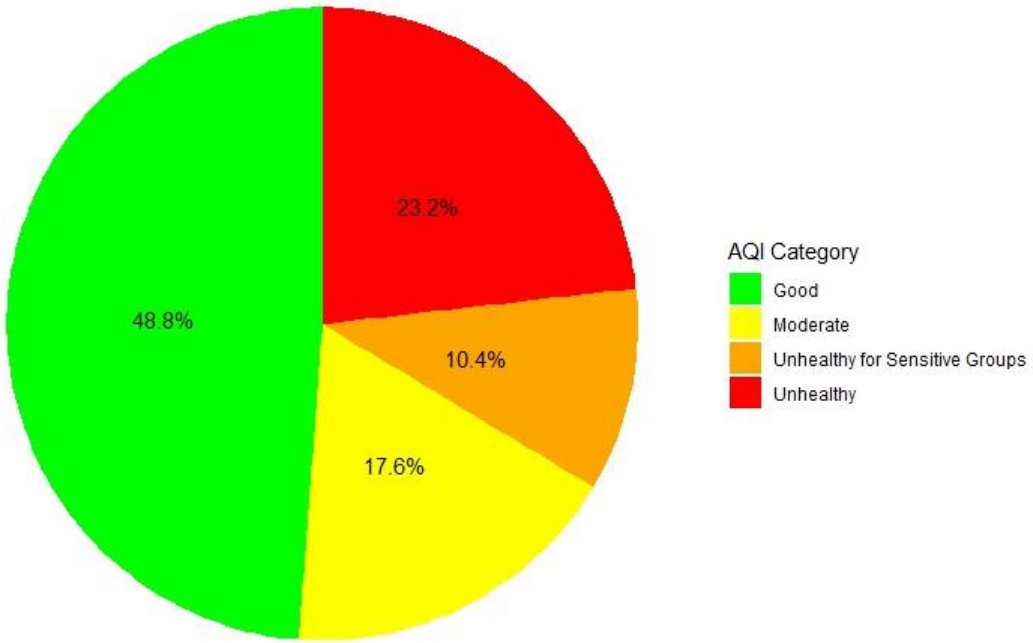

Figure A4-312: AQI Category Distribution for Deukhuri Dang Station

RARA AIR QUALITY MONITORING STATION

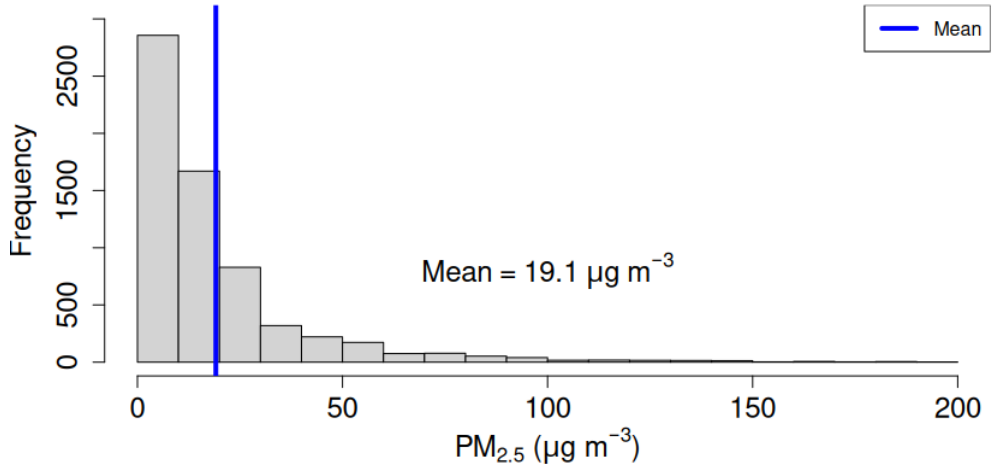

Figure A4-313: Histogram of $PM_{2.5}$ for Rara Station

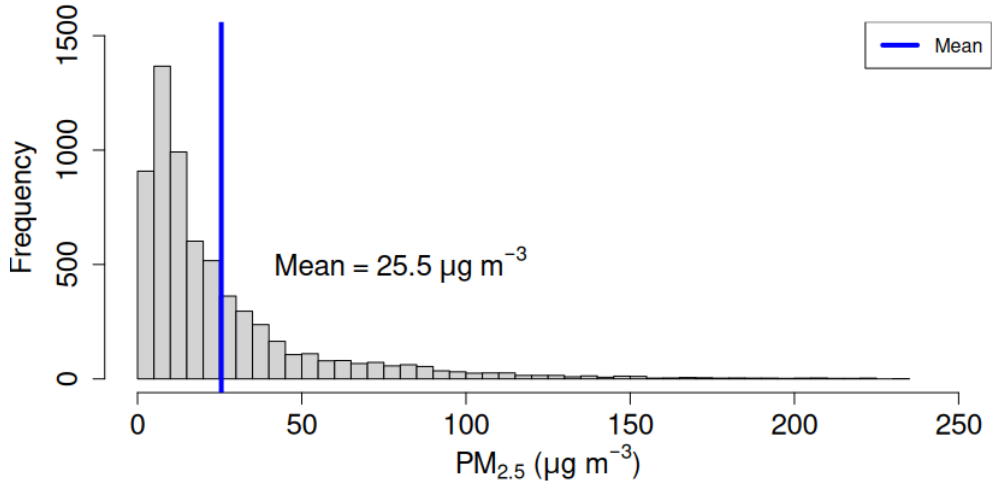

Figure A4-314: Histogram of PM_{10} for Rara Station

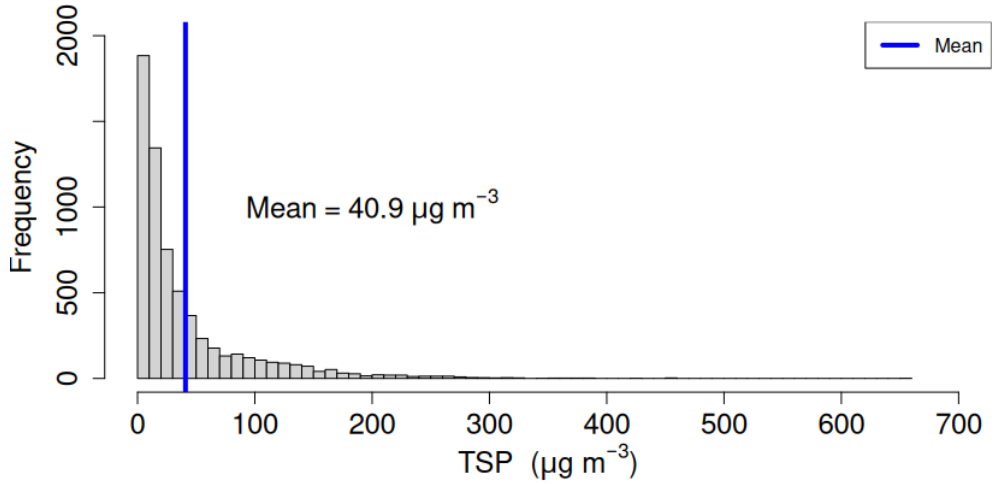

Figure A4-315: Histogram of TSP for Rara Station

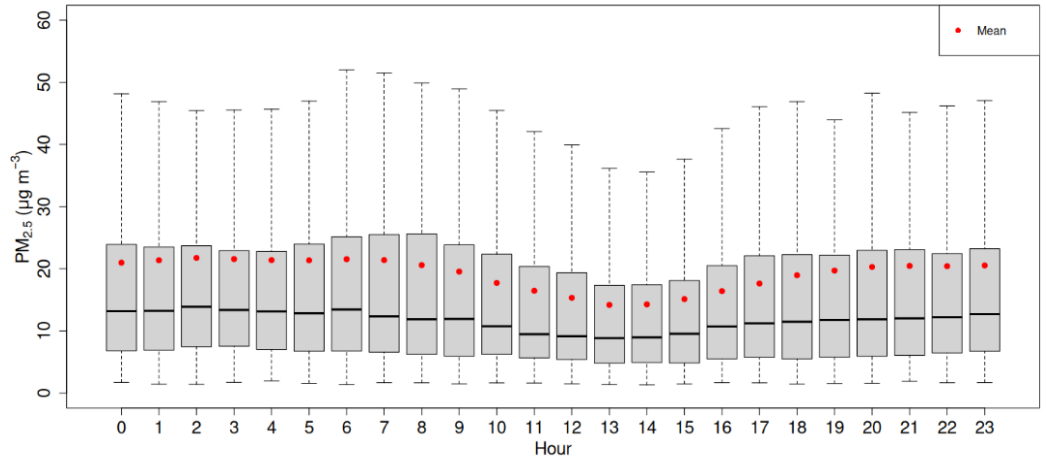

Figure A4-316: Diurnal Variation of $PM_{2.5}$ for Rara Station

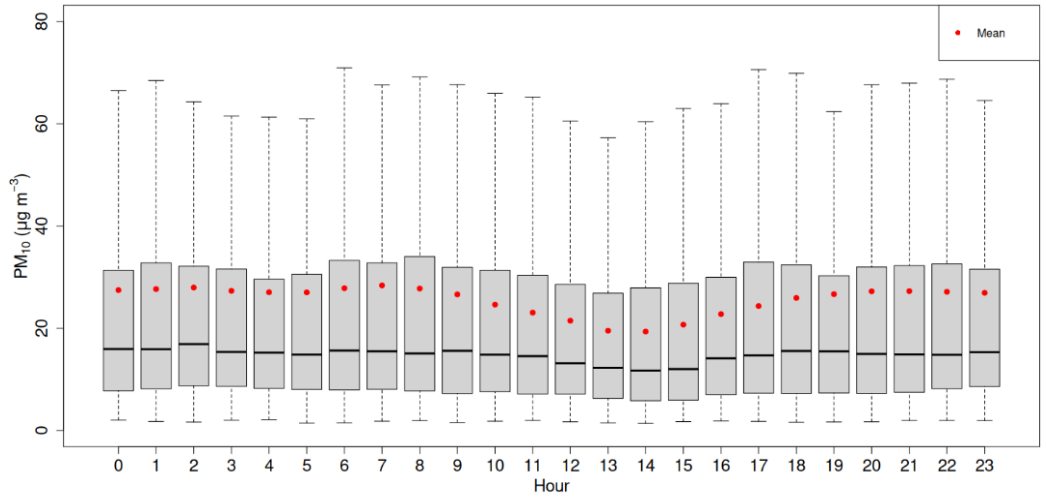

Figure A4-317: Diurnal Variation of PM_{10} for Rara Station

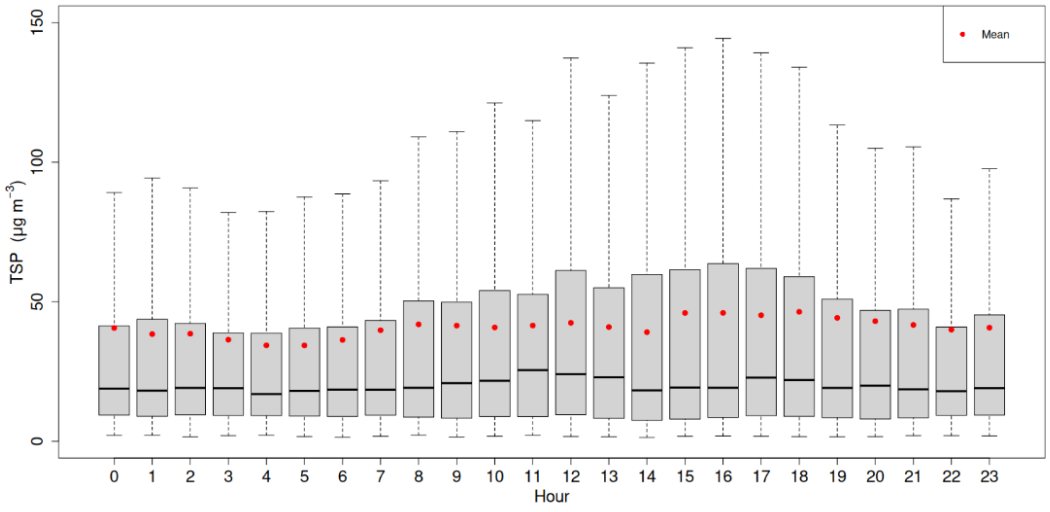

Figure A4-318: Diurnal Variation of TSP for Rara Station

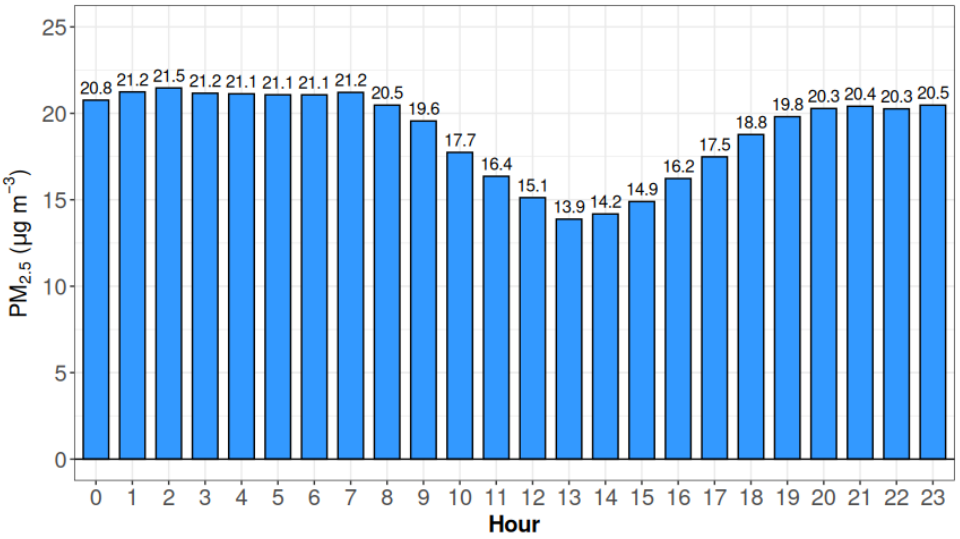

Figure A4-319: Hourly Average of $PM_{2.5}$ for Rara Station

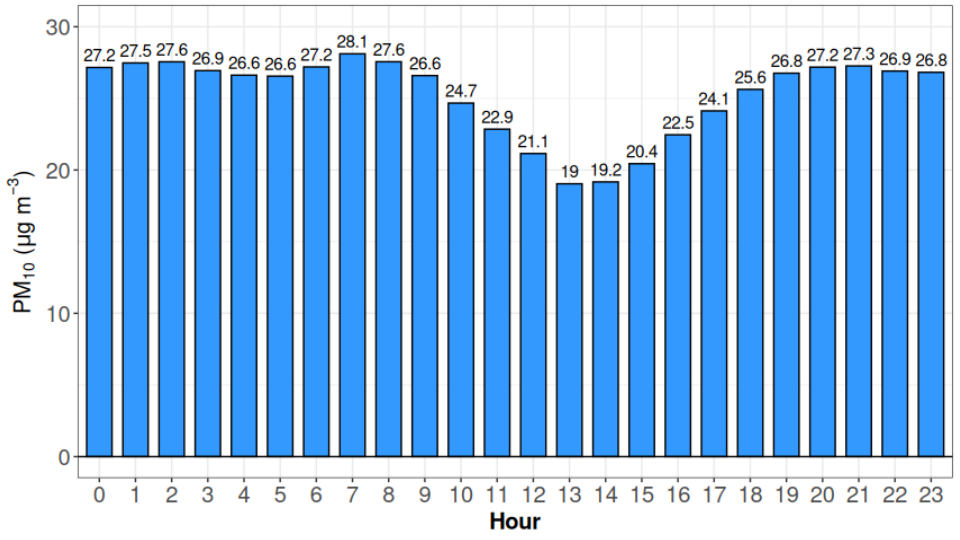

Figure A4-320: Hourly Average of PM_{10} for Rara Station

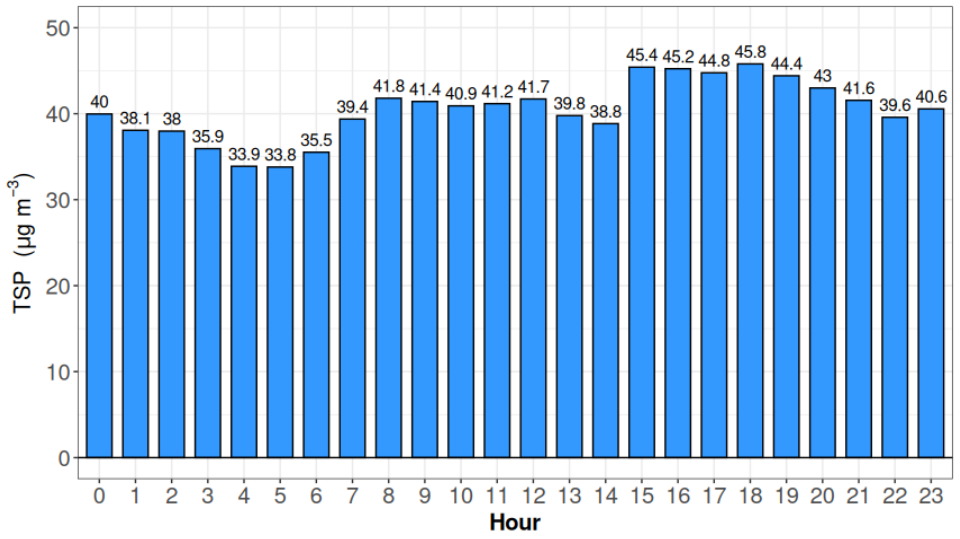

Figure A4-321: Hourly Average of TSP for Rara Station

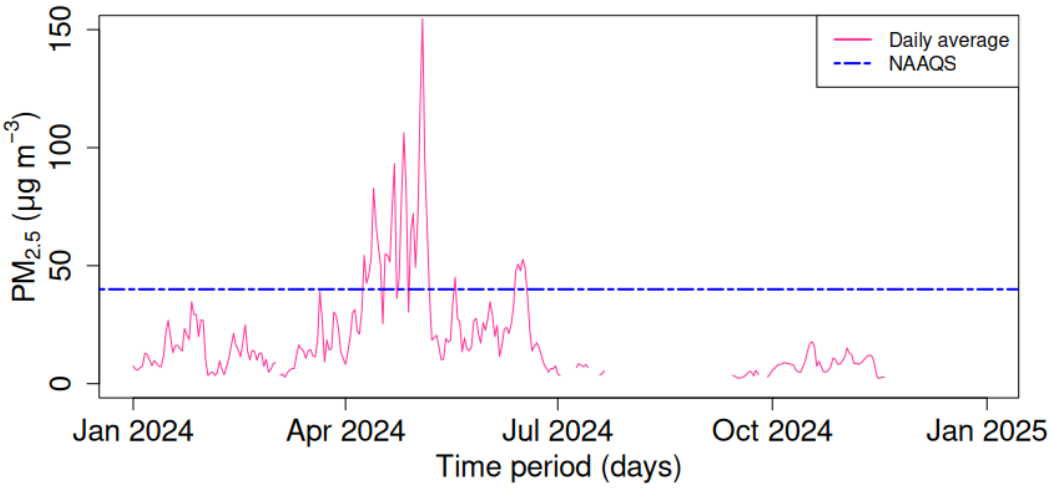

Figure A4-322: Daily Average of $PM_{2.5}$ for Rara Station

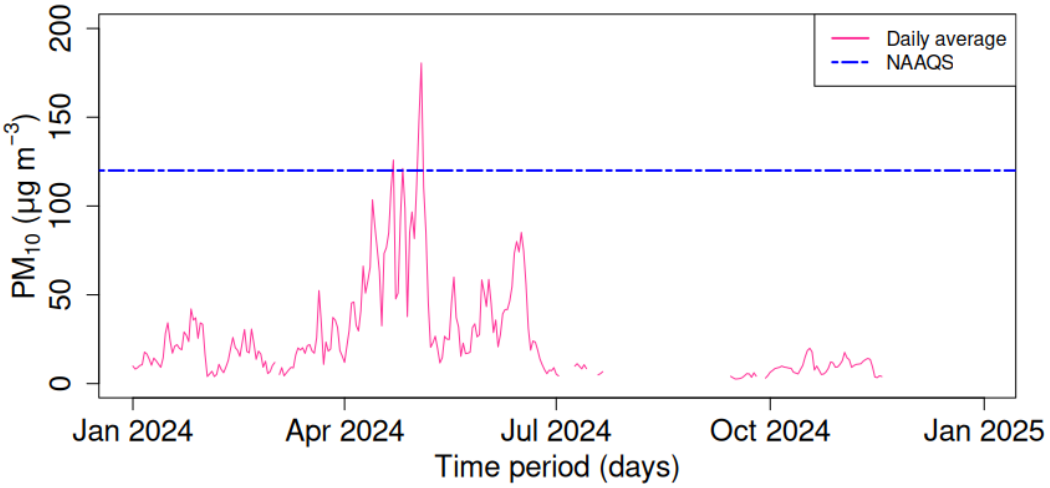

Figure A4-323: Daily Average of PM_{10} for Rara Station

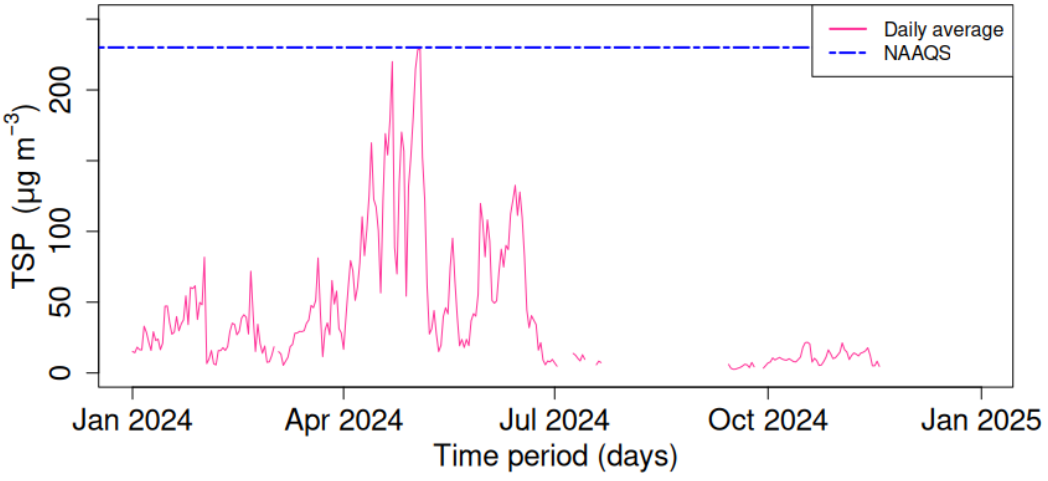

Figure A4-324: Daily Average of TSP for Rara Station

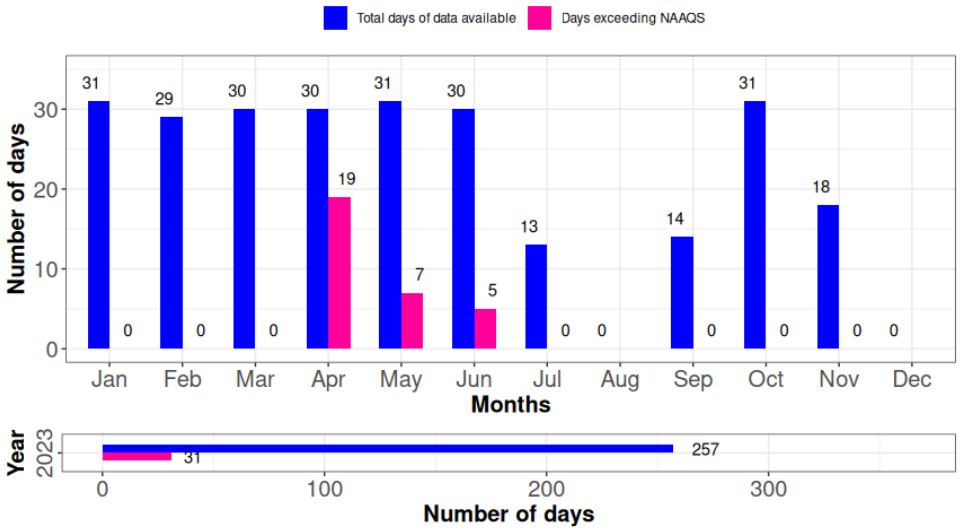

Figure A4-325: Compliance Status of $PM_{2.5}$ for Rara Station

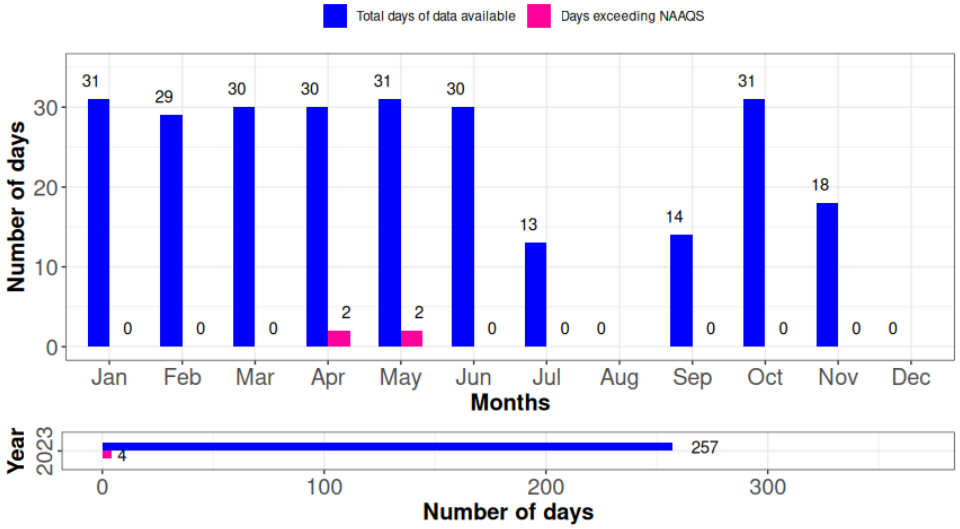

Figure A4-326: Compliance Status of PM_{10} for Rara Station

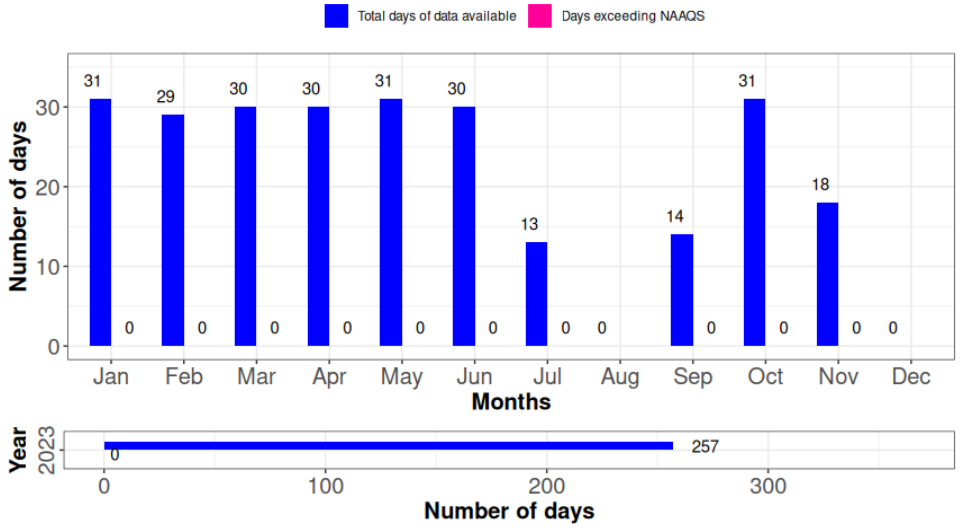

Figure A4-327: Compliance Status of TSP for Rara Station

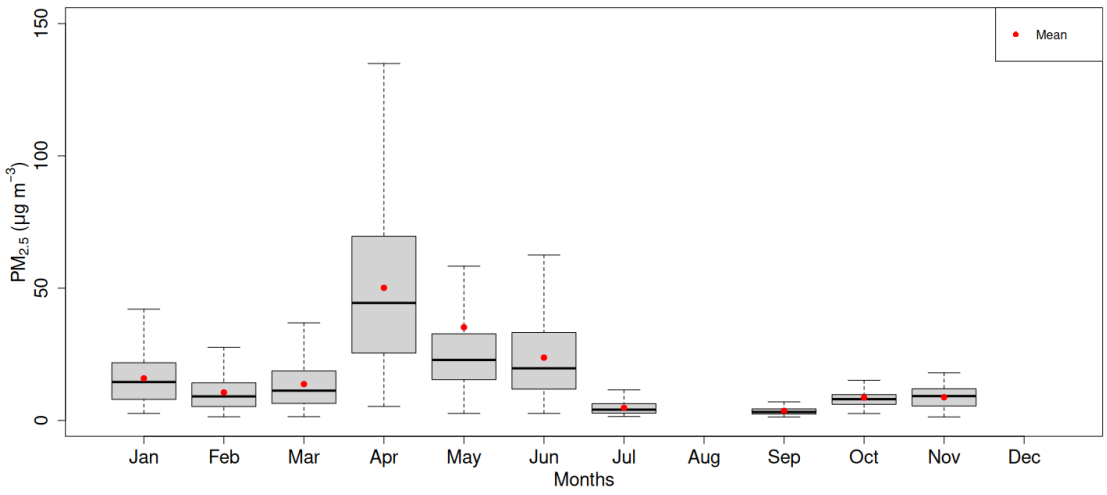

Figure A4-328: Monthly Variation of $PM_{2.5}$ for Rara Station

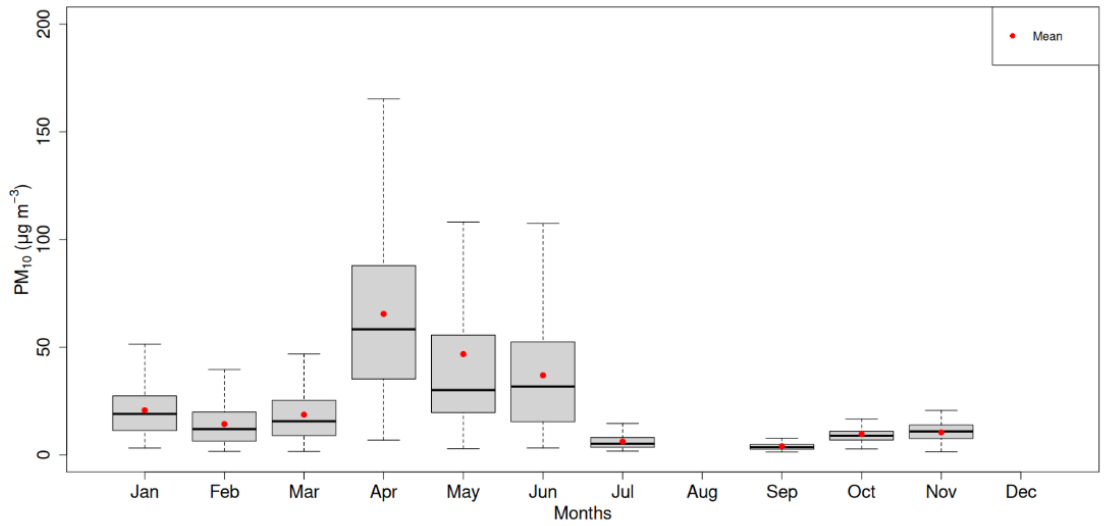

Figure A4-329: Monthly Variation of PM_{10} for Rara Station

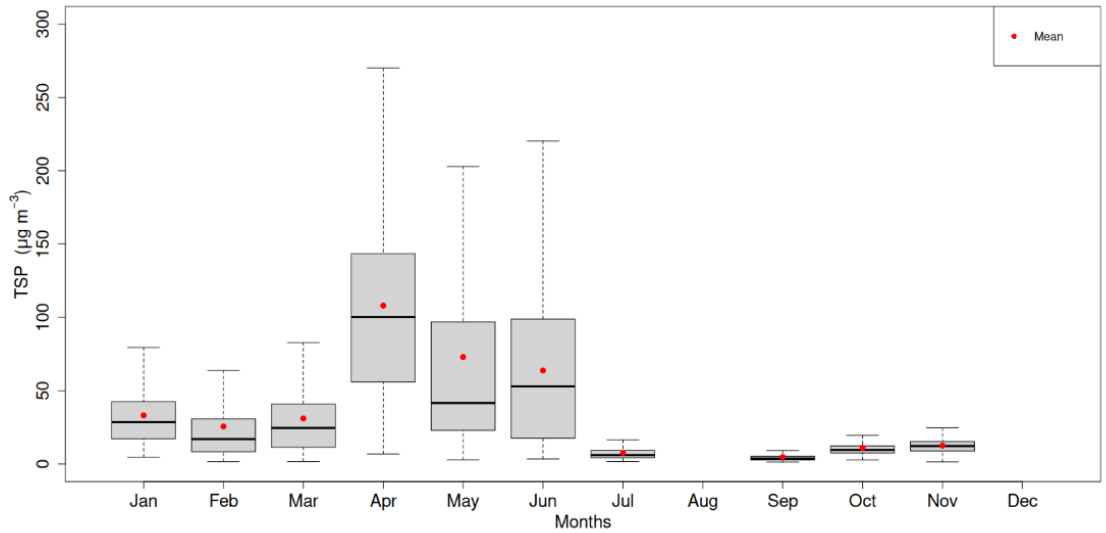

Figure A4-330: Monthly Variation of TSP for Rara Station

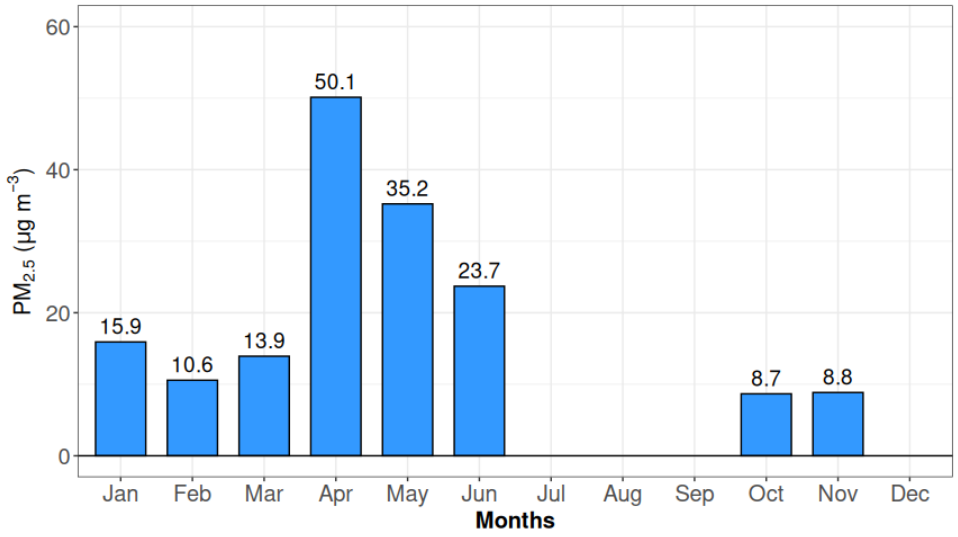

Figure A4-331: Monthly Average of $PM_{2.5}$ for Rara Station

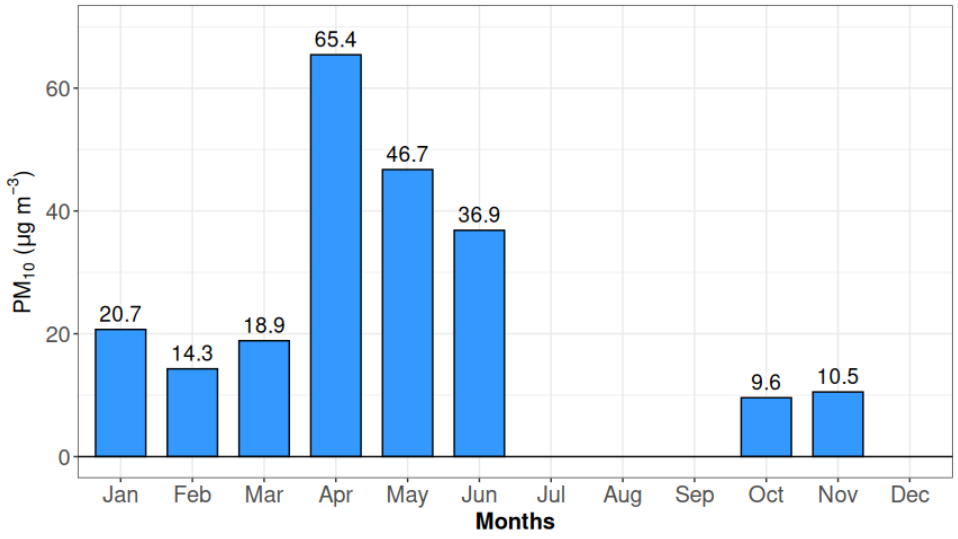

Figure A4-332: Monthly Average of PM_{10} for Rara Station

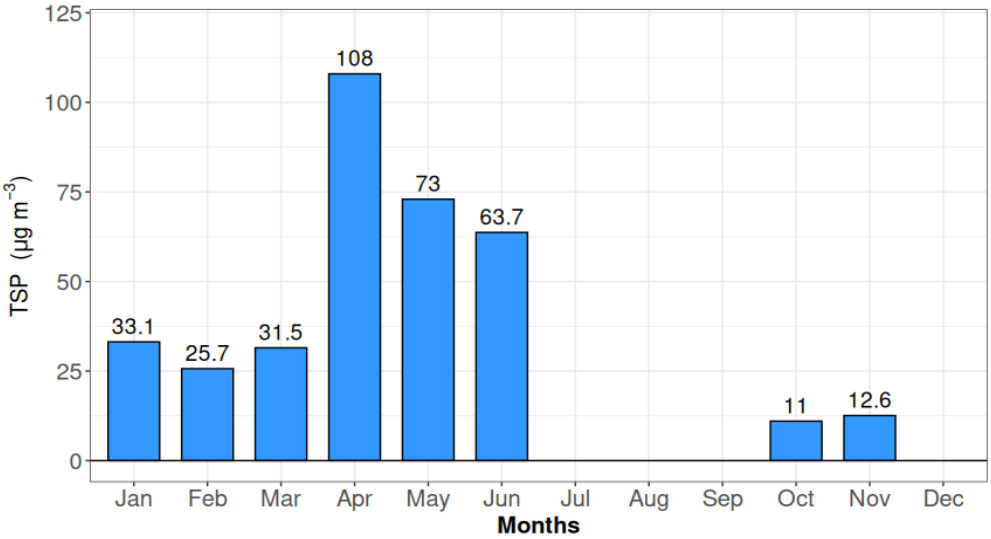

Figure A4-333: Monthly Average of TSP for Rara Station

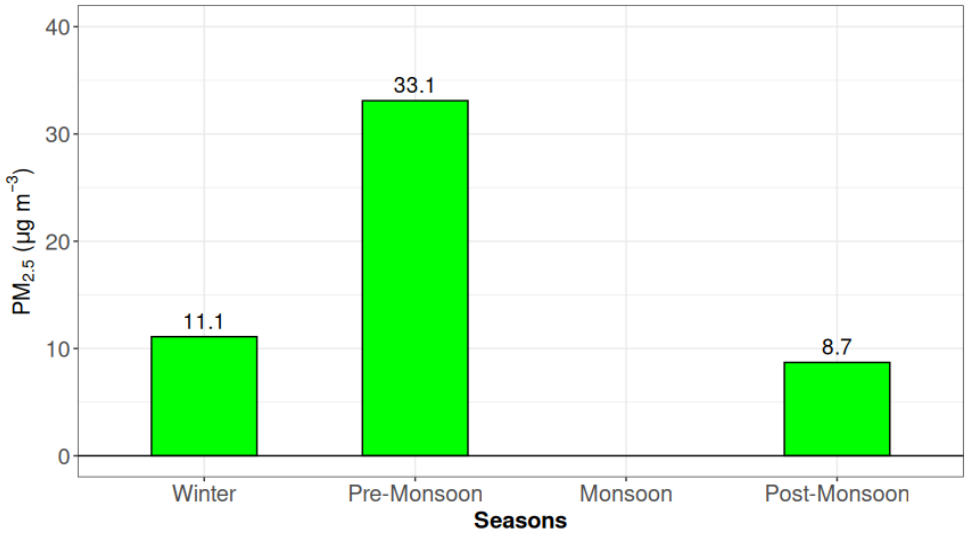

Figure A4-334: Seasonal Average of $PM_{2.5}$ for Rara Station

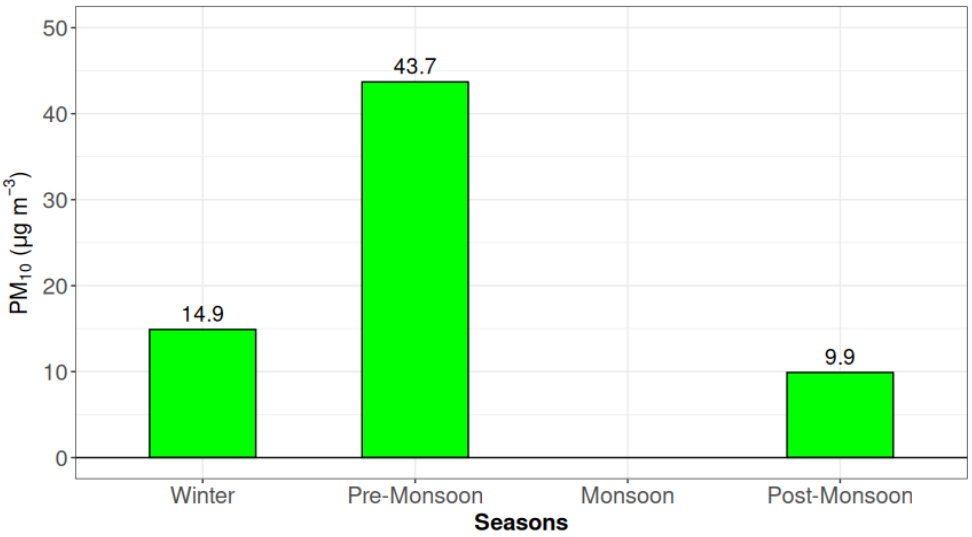

Figure A4-335: Seasonal Average of PM_{10} for Rara Station

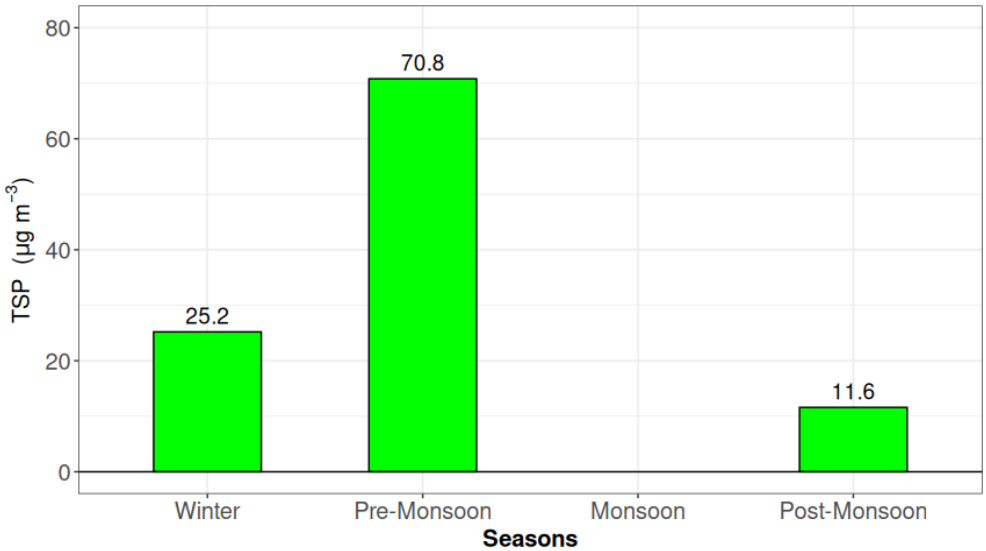

Figure A4-336: Seasonal Average of TSP for Rara Station

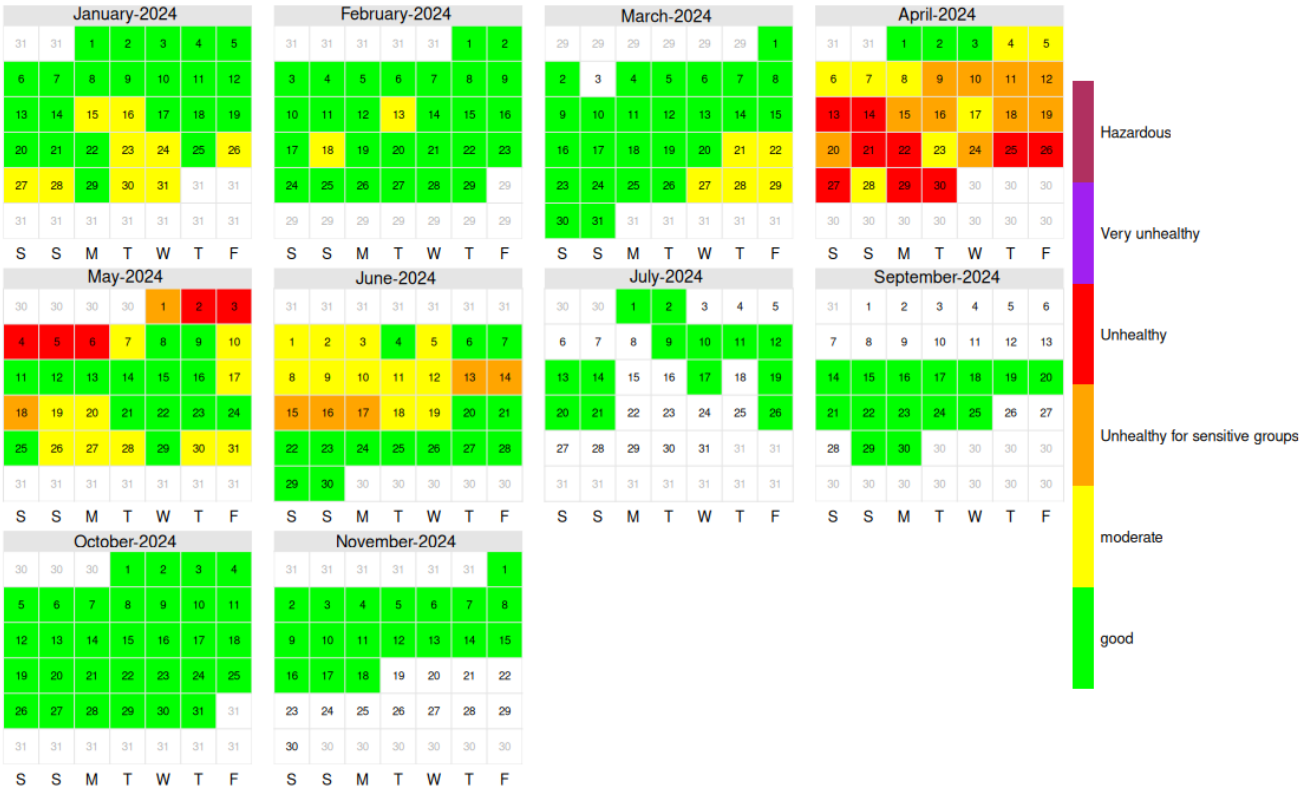

Figure A4-337: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Rara Station

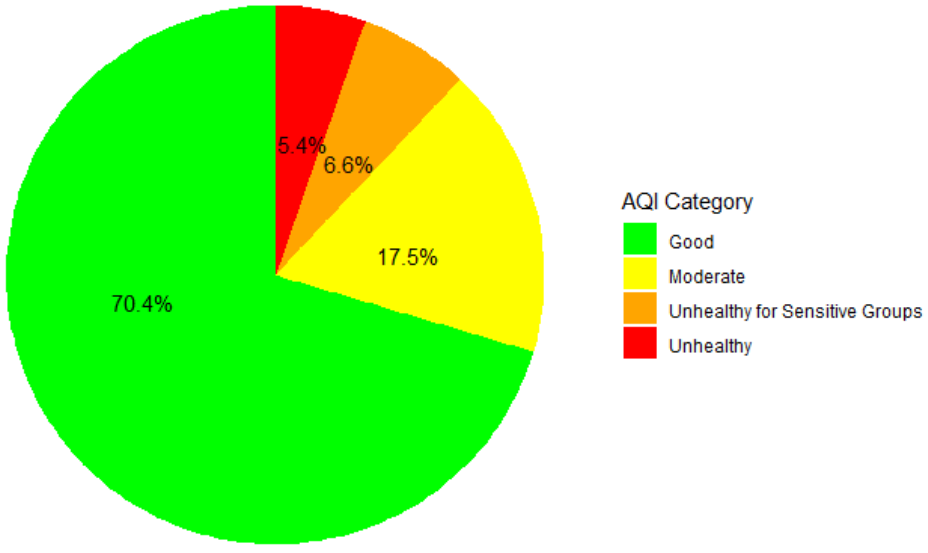

Figure A4-338: AQI Category Distribution for Rara Station

ACHHAM AIR QUALITY MONITORING STATION

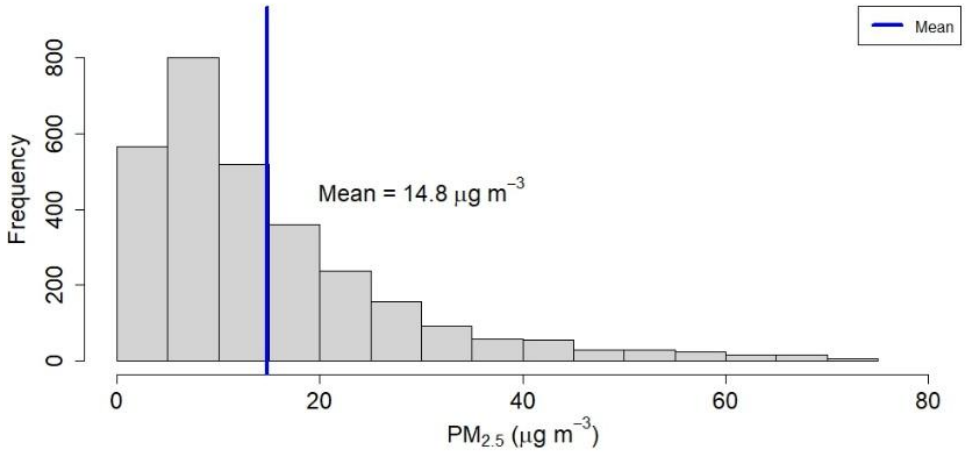

Figure A4-339: Histogram of $PM_{2.5}$ for Achham Station

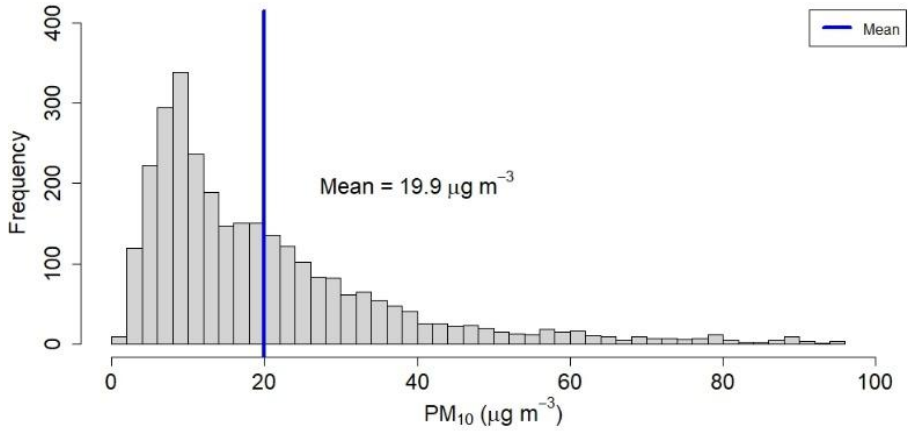

Figure A4-340: Histogram of PM_{10} for Achham Station

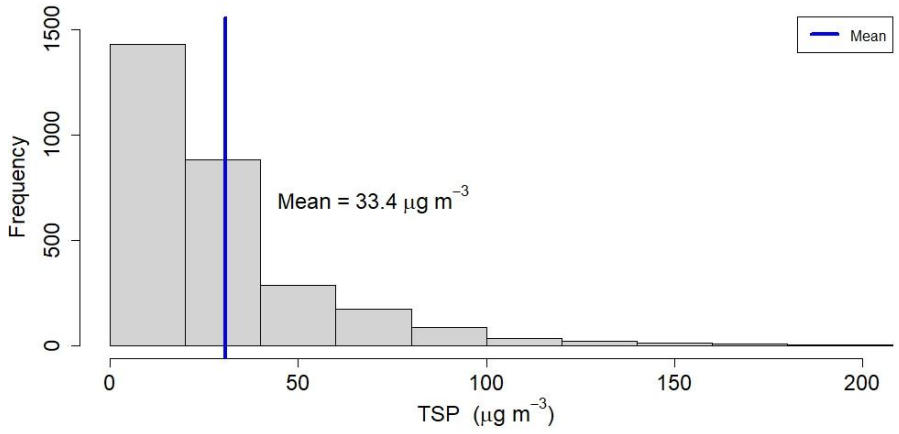

Figure A4-341: Histogram of TSP for Achham Station

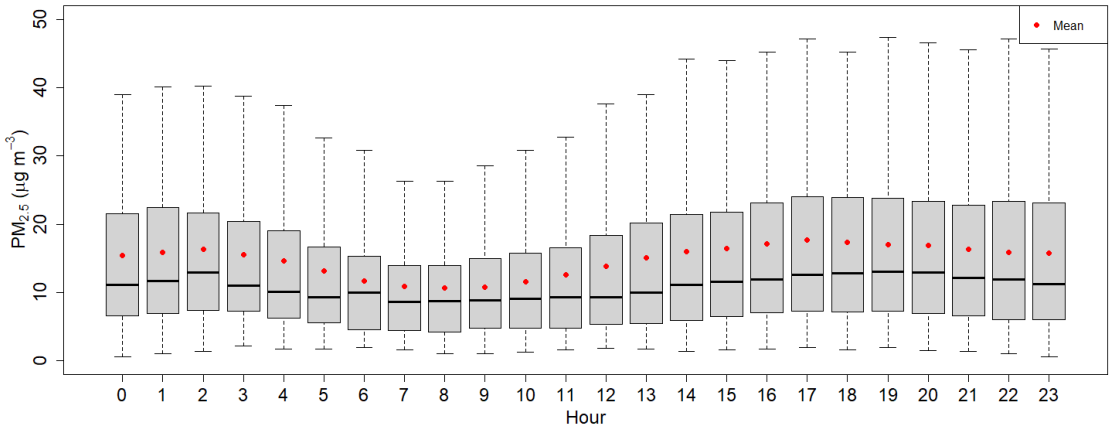

Figure A4-342: Diurnal Variation of $PM_{2.5}$ for Achham Station

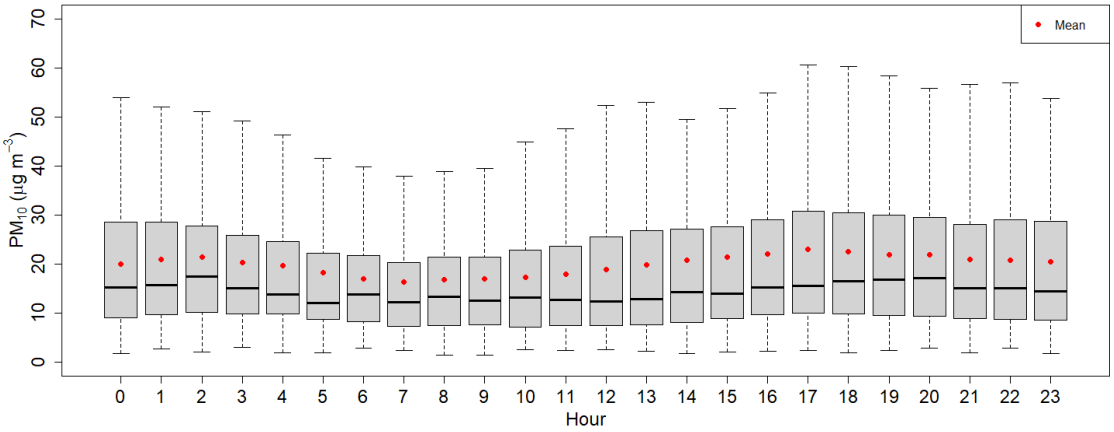

Figure A4-343: Diurnal Variation of PM_{10} for Achham Station

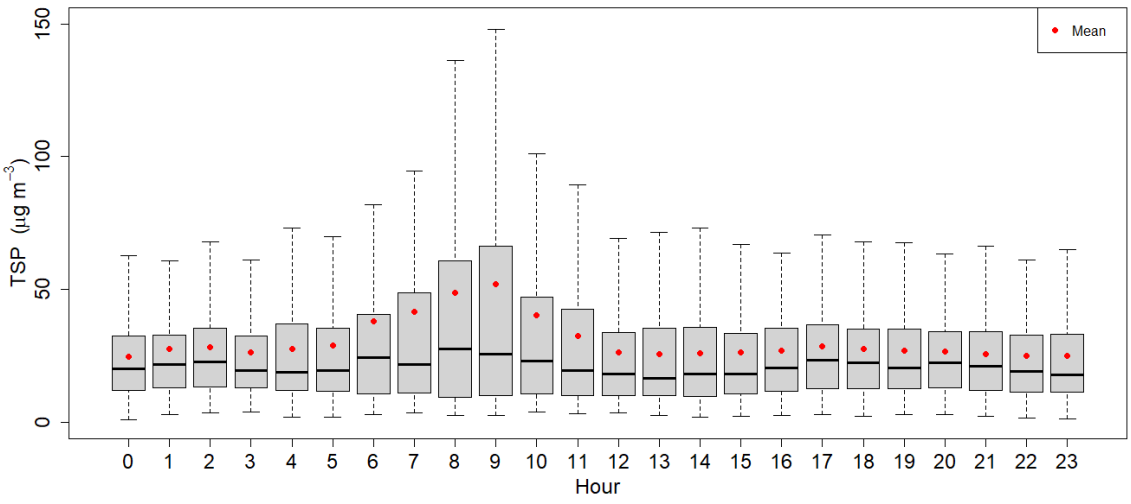

Figure A4-344: Diurnal Variation of TSP for Achham Station

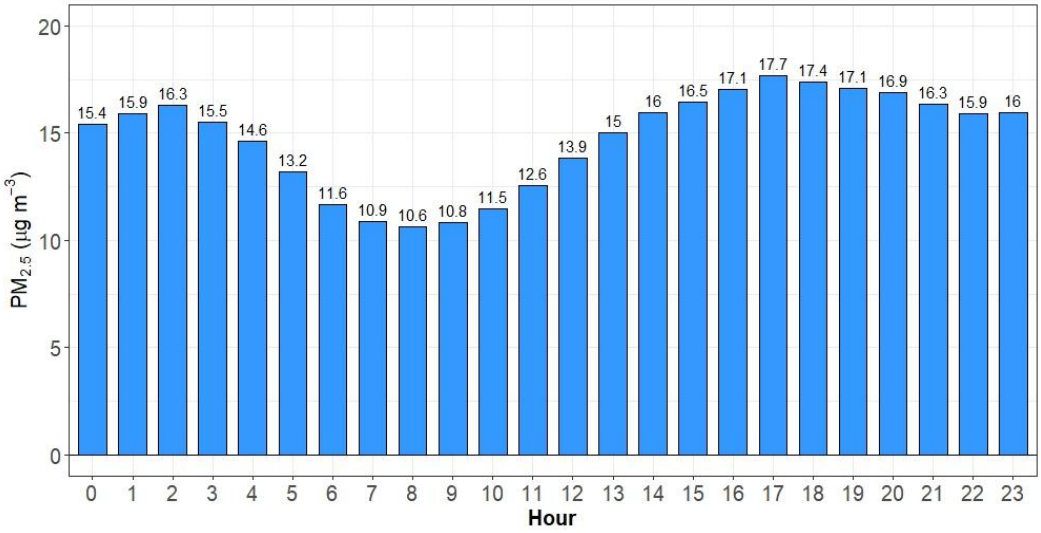

Figure A4-345: Hourly Average of $PM_{2.5}$ for Achham Station

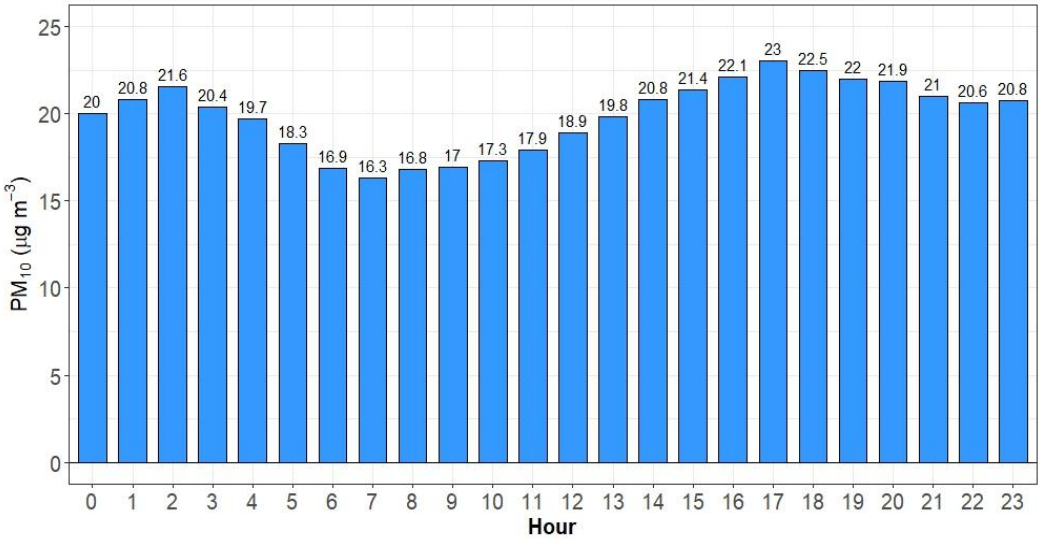

Figure A4-346: Hourly Average of PM_{10} for Achham Station

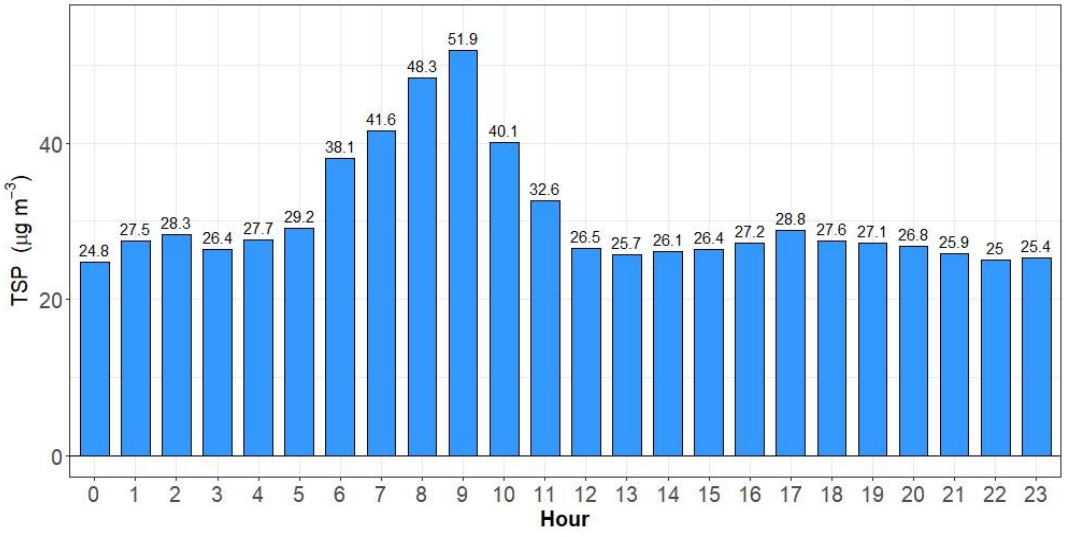

Figure A4-347: Hourly Average of TSP for Achham Station

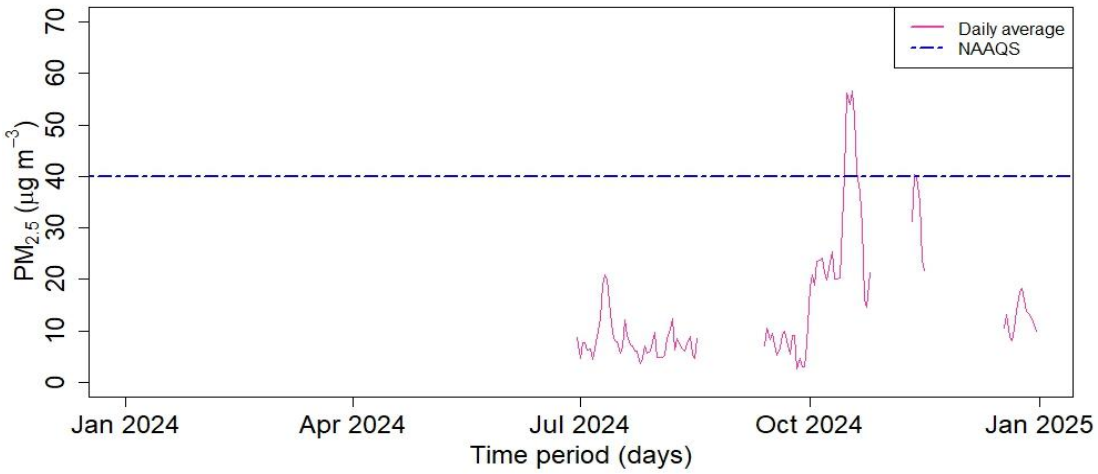

Figure A4-348: Daily Average of $PM_{2.5}$ for Achham Station

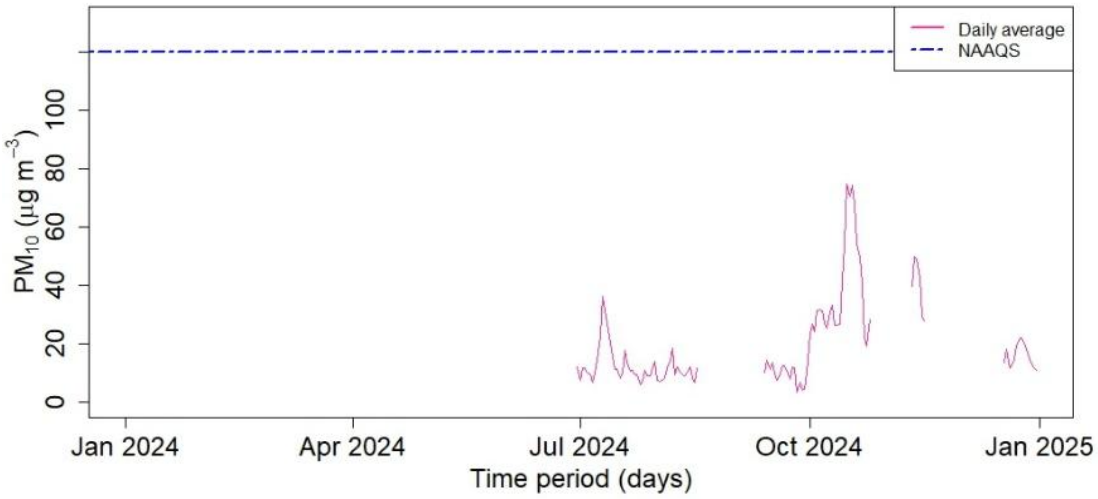

Figure A4-349: Daily Average of PM_{10} for Achham Station

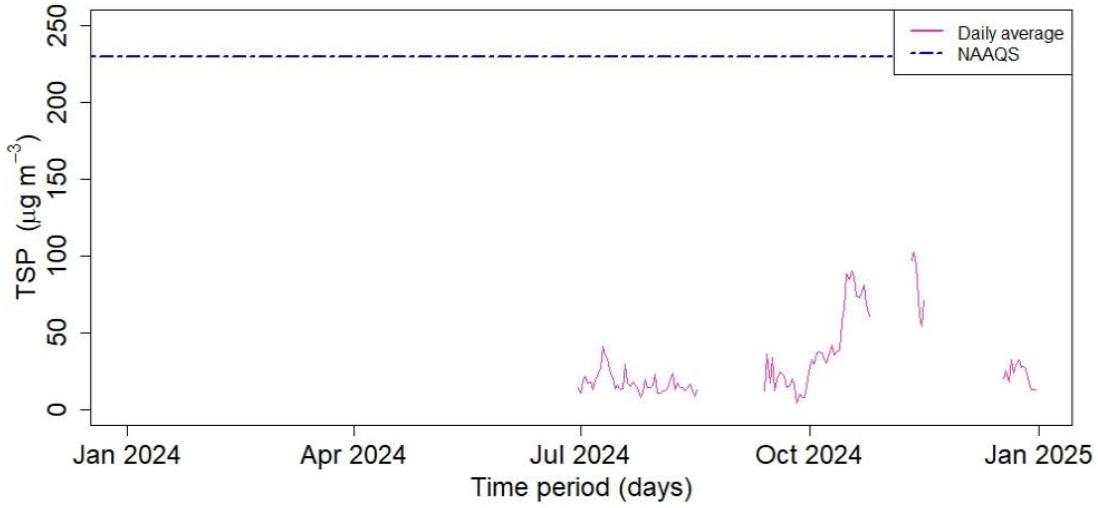

Figure A4-350: Daily Average of TSP for Achham Station

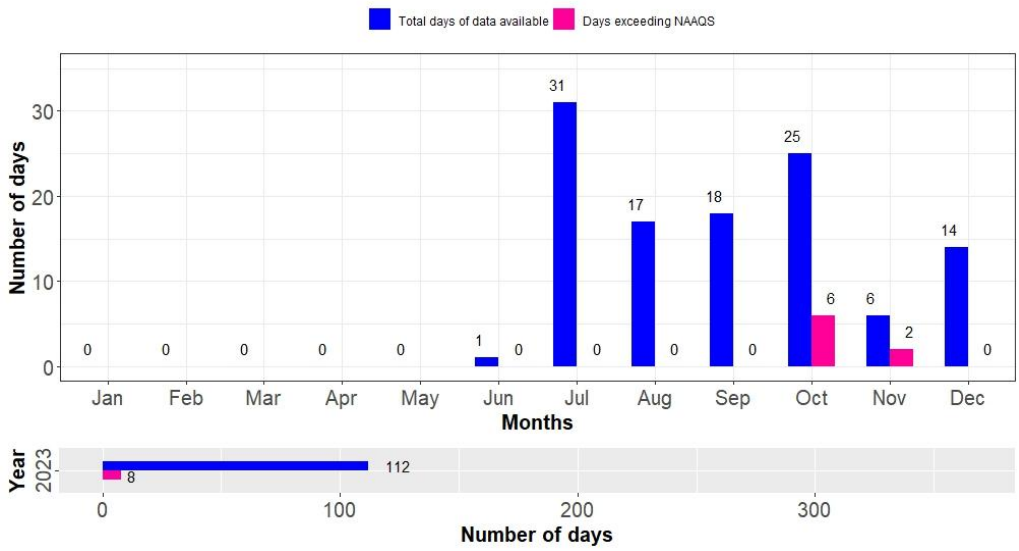

Figure A4-351: Compliance Status of $PM_{2.5}$ for Achham Station

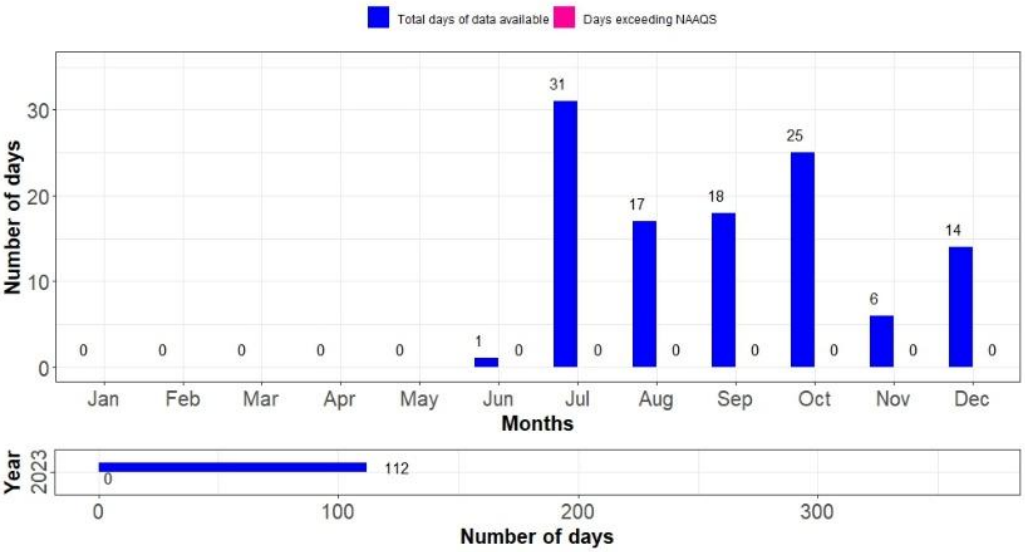

Figure A4-352: Compliance Status of PM_{10} for Achham Station

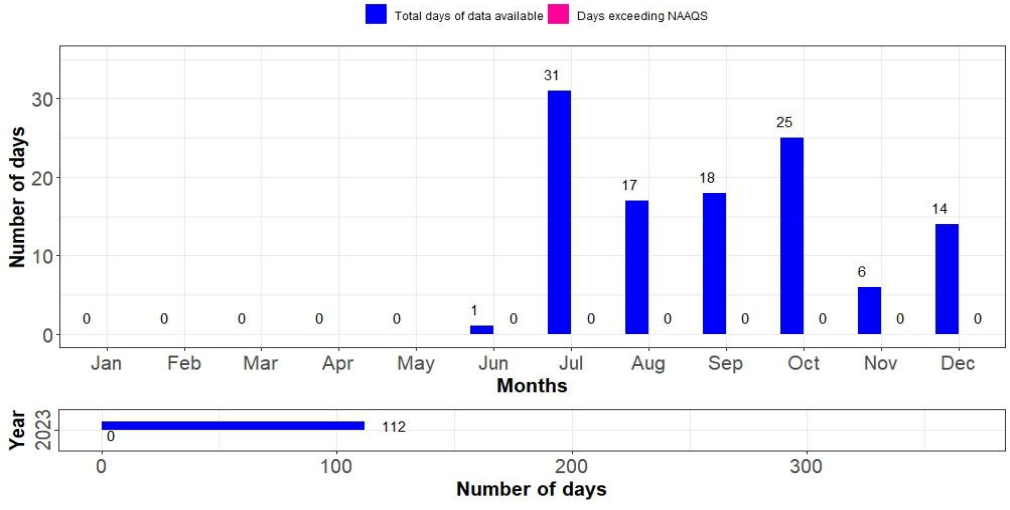

Figure A4-353: Compliance Status of TSP for Achham Station

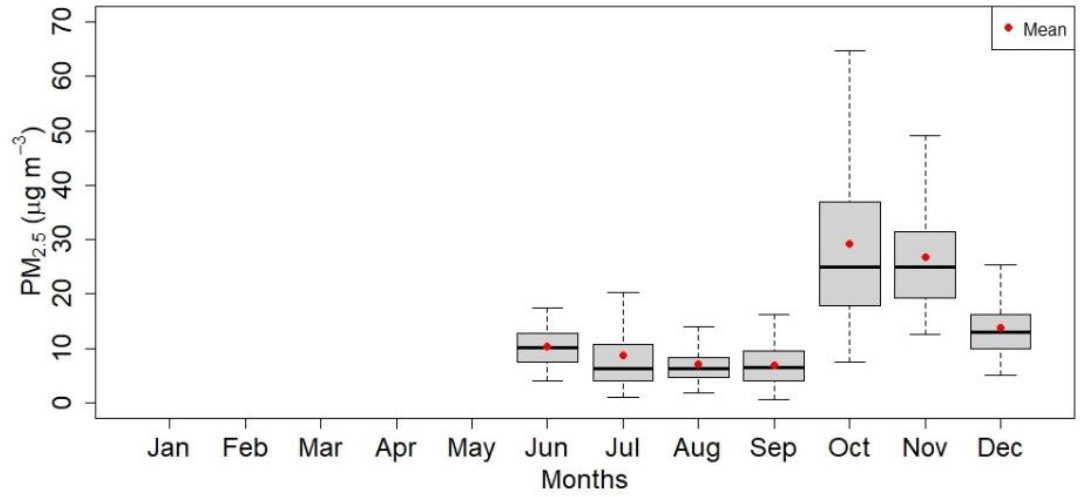

Figure A4-354: Monthly Variation of $PM_{2.5}$ for Achham Station

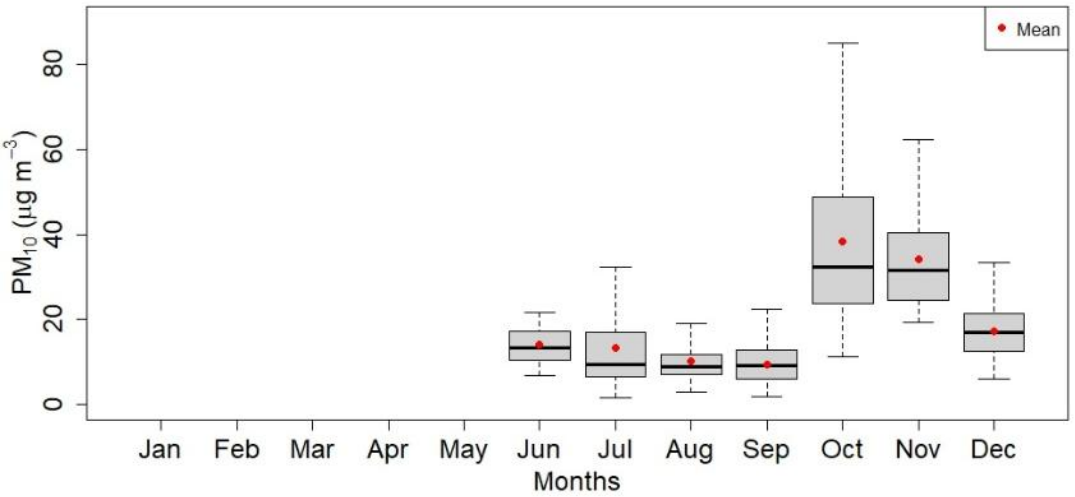

Figure A4-355: Monthly Variation of PM_{10} for Achham Station

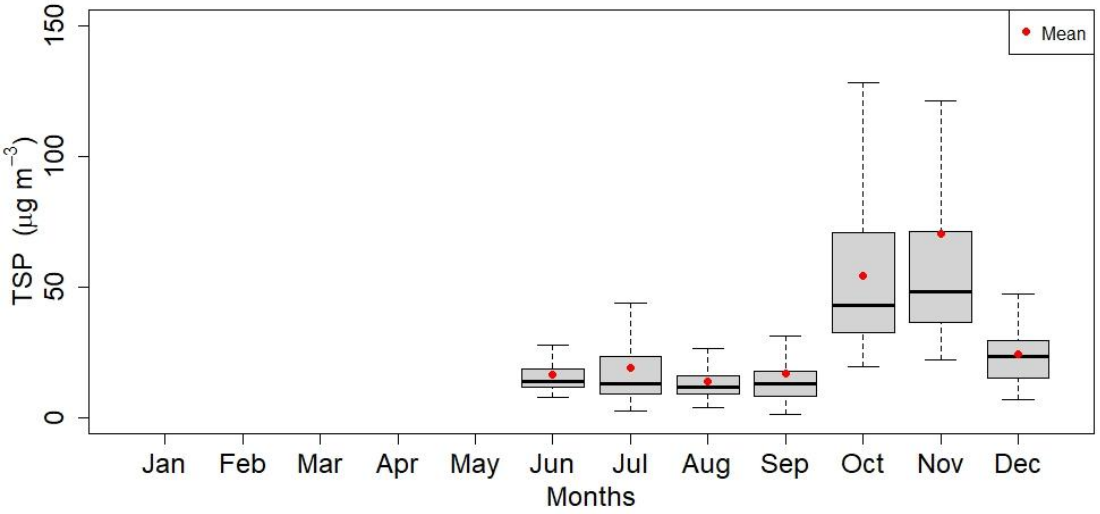

Figure A4-356: Monthly Variation of TSP for Achham Station

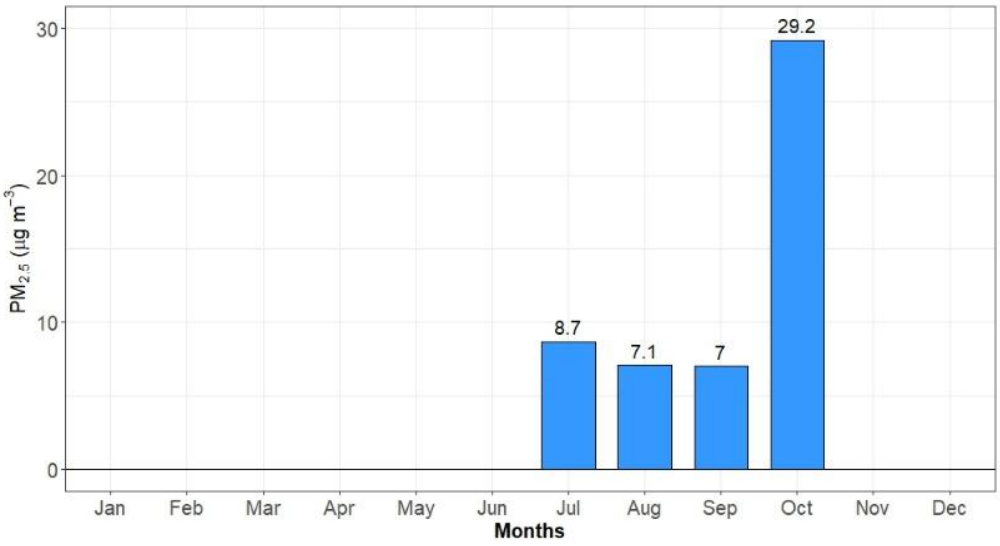

Figure A4-357: Monthly Average of $PM_{2.5}$ for Achham Station

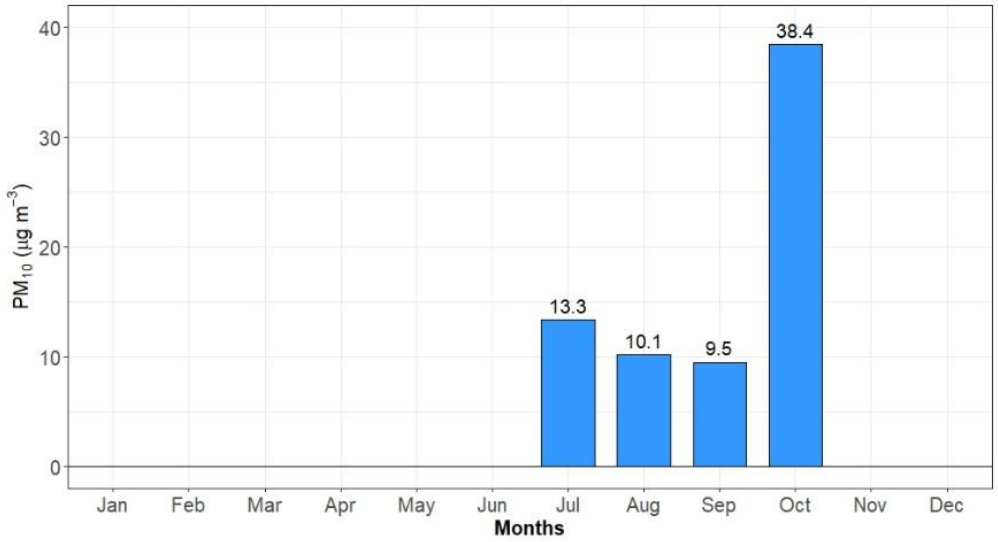

Figure A4-358: Monthly Average of PM_{10} for Achham Station

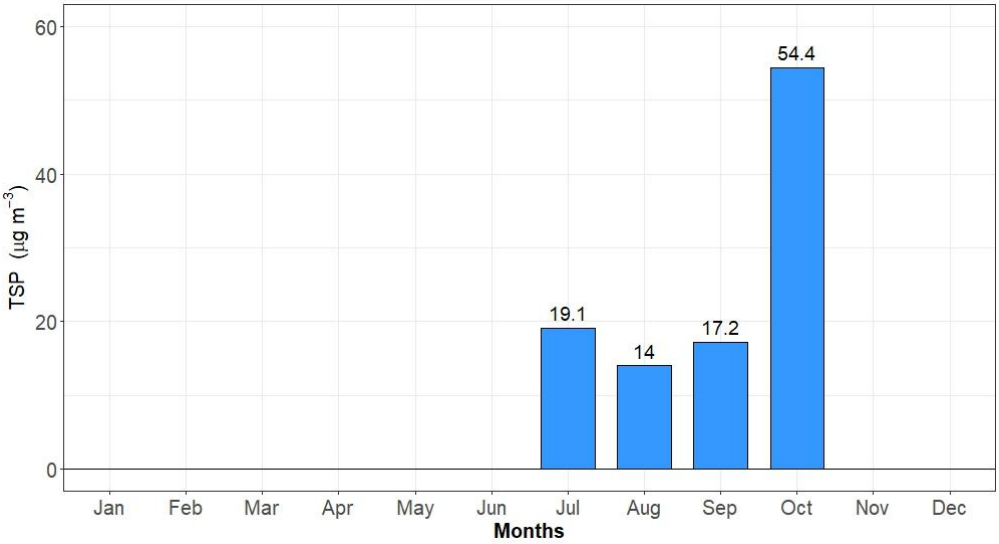

Figure A4-359: Monthly Average of TSP for Achham Station

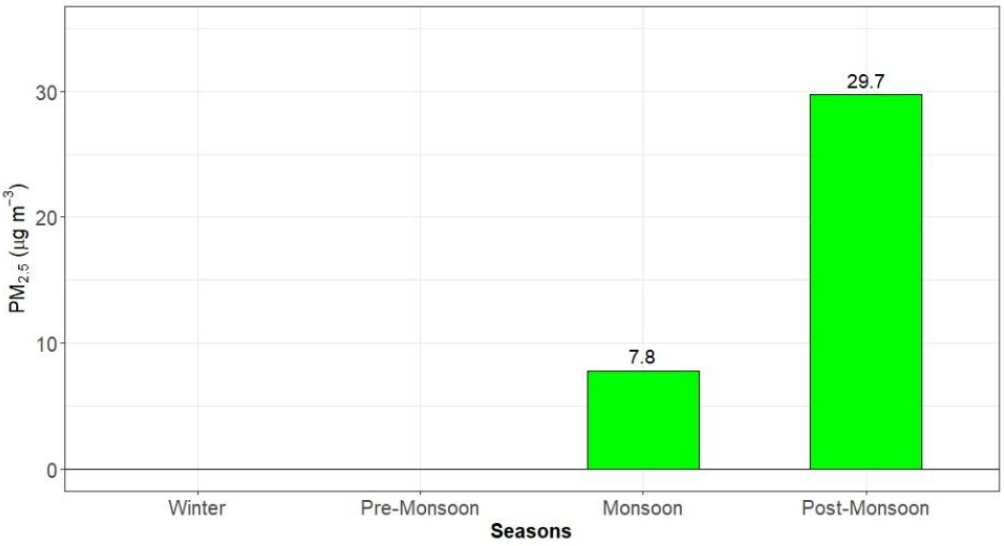

Figure A4-360: Seasonal Average of $PM_{2.5}$ for Achham Station

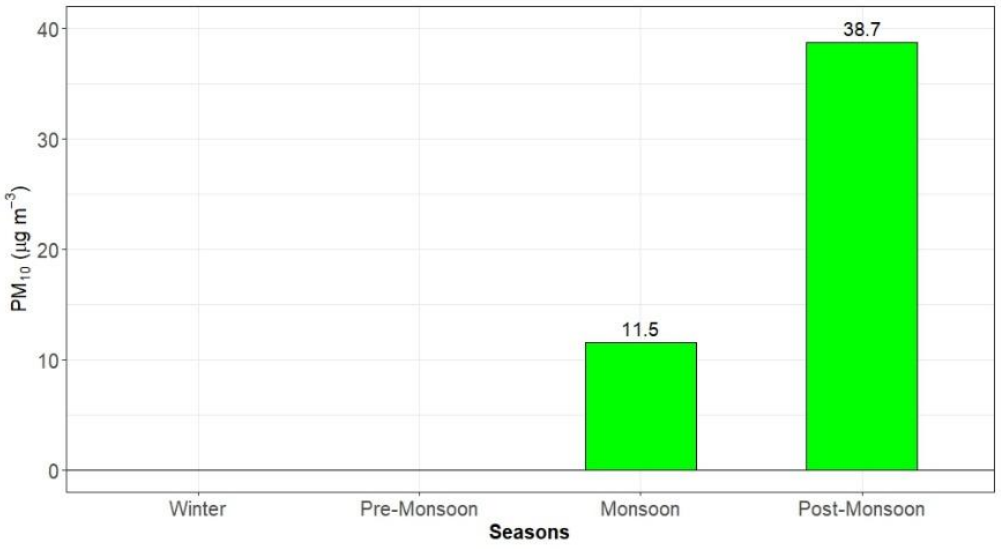

Figure A4-361: Seasonal Average of PM_{10} for Achham Station

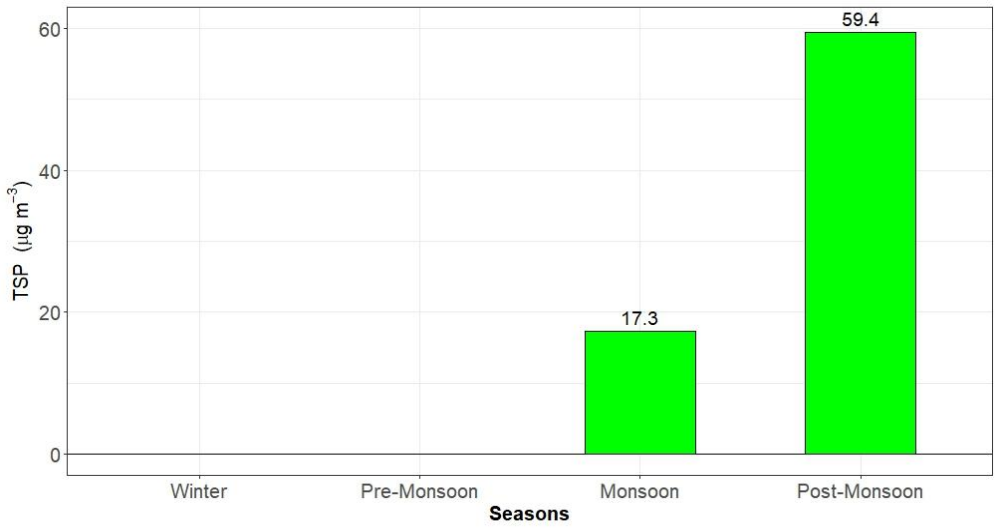

Figure A4-362: Seasonal Average of TSP for Achham Station

Figure A4-363: Calendar Plot of AQI Category Based on AQI based on $PM_{2.5}$ for Achham Station

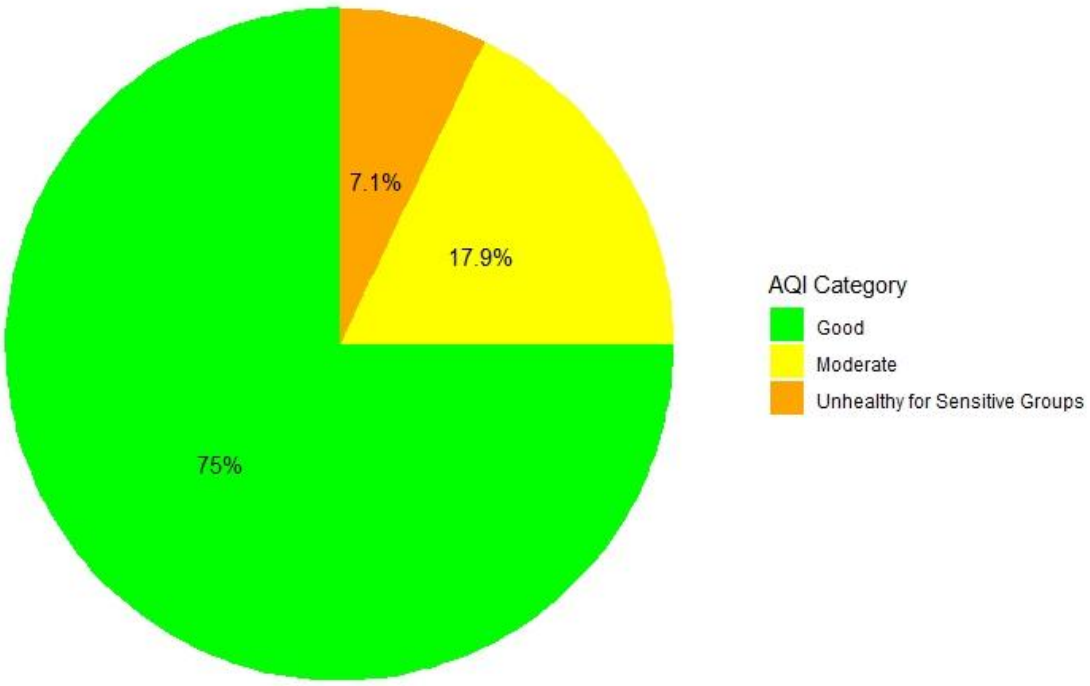

Figure A4-364: AQI Category Distribution for Achham Station

MAHENDRANAGAR AIR QUALITY MONITORING STATION

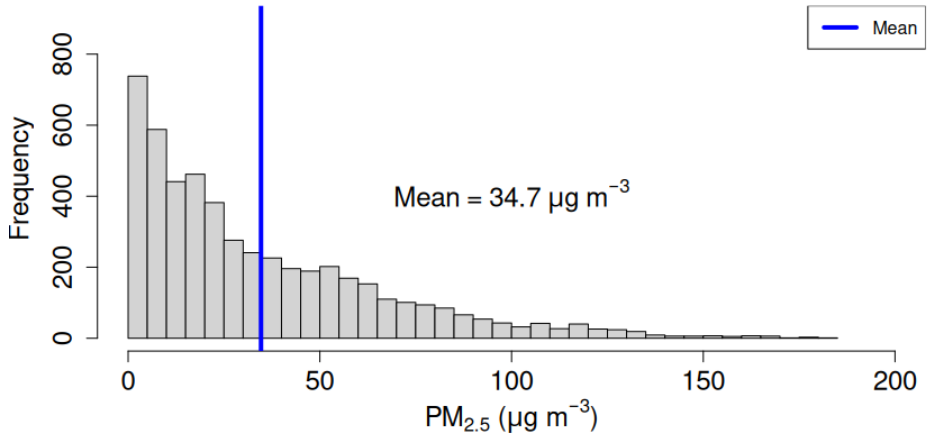

Figure A4-365: Histogram of $PM_{2.5}$ for Mahendranagar Station

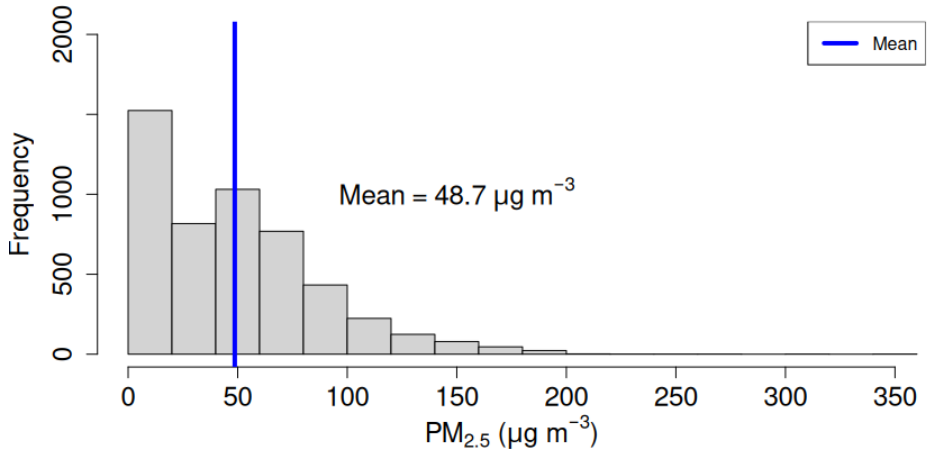

Figure A4-366: Histogram of PM_{10} for Mahendranagar Station

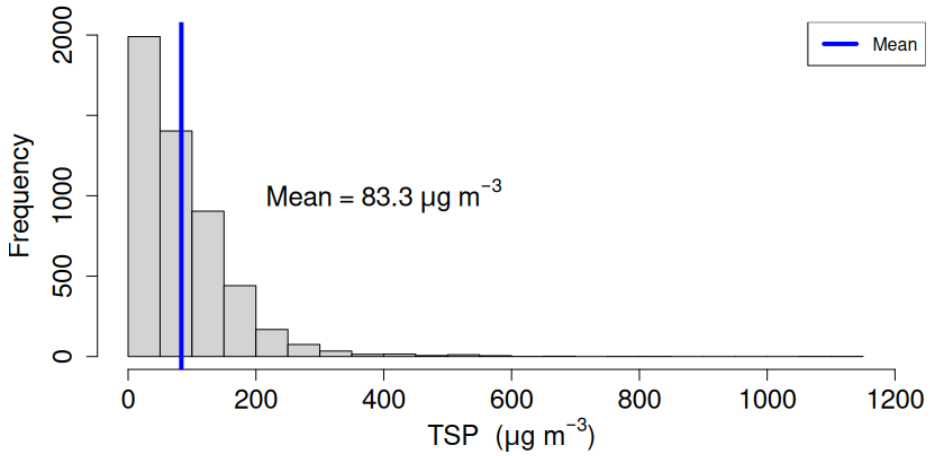

Figure A4-367: Histogram of TSP for Mahendranagar Station

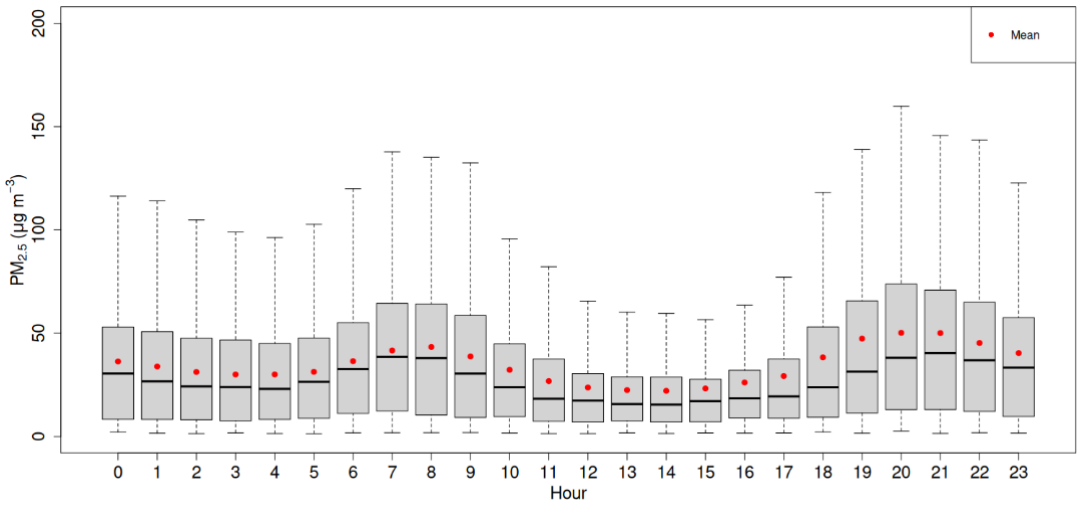

Figure A4-368: Diurnal Variation of $PM_{2.5}$ for Mahendranagar Station

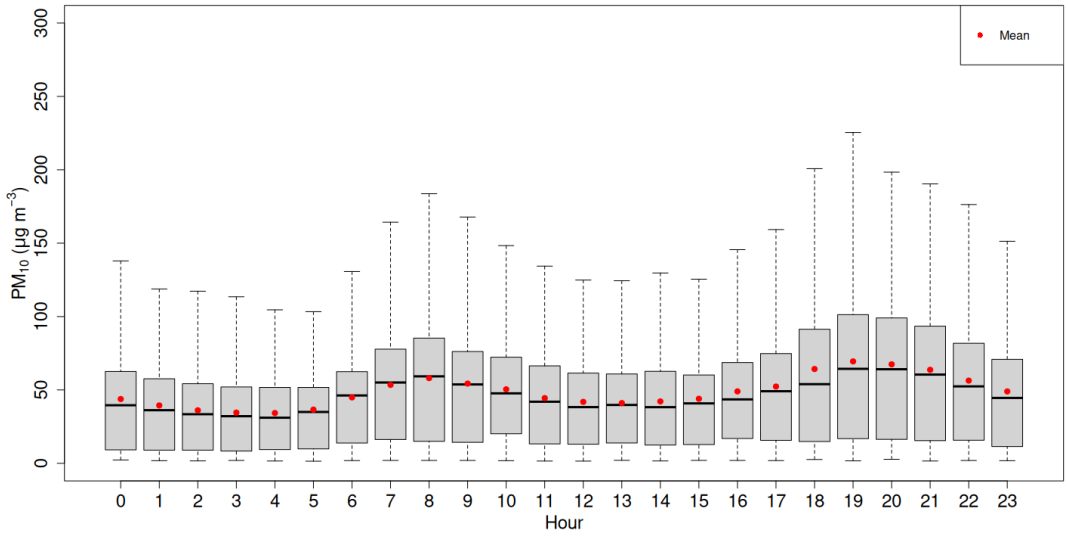

Figure A4-369: Diurnal Variation of PM_{10} for Mahendranagar Station

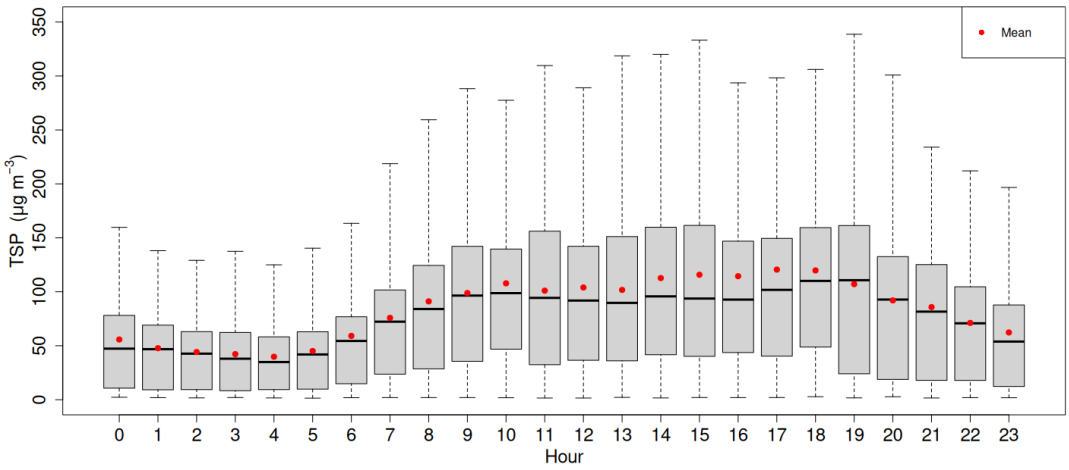

Figure A4-370: Diurnal Variation of TSP for Mahendranagar Station

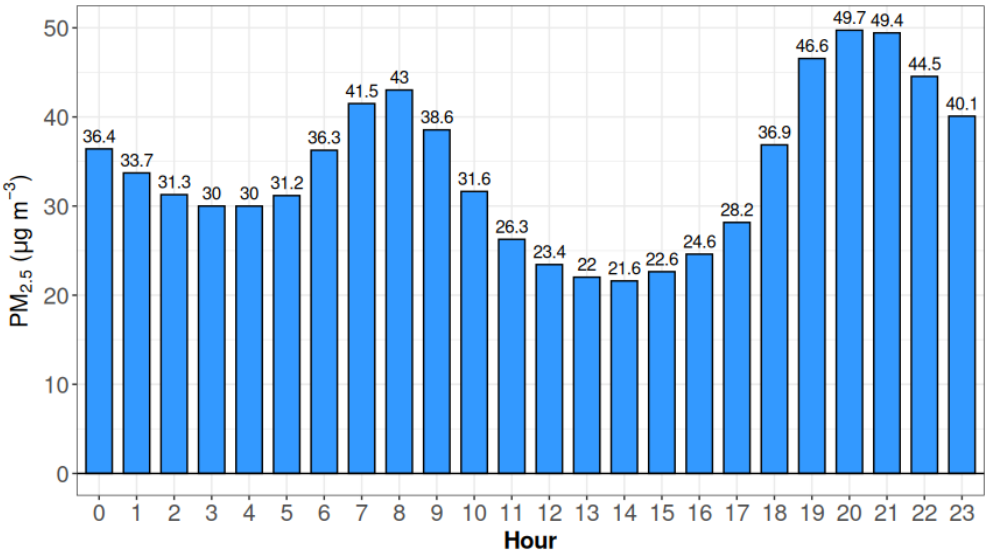

Figure A4-371: Hourly Average of $PM_{2.5}$ for Mahendranagar Station

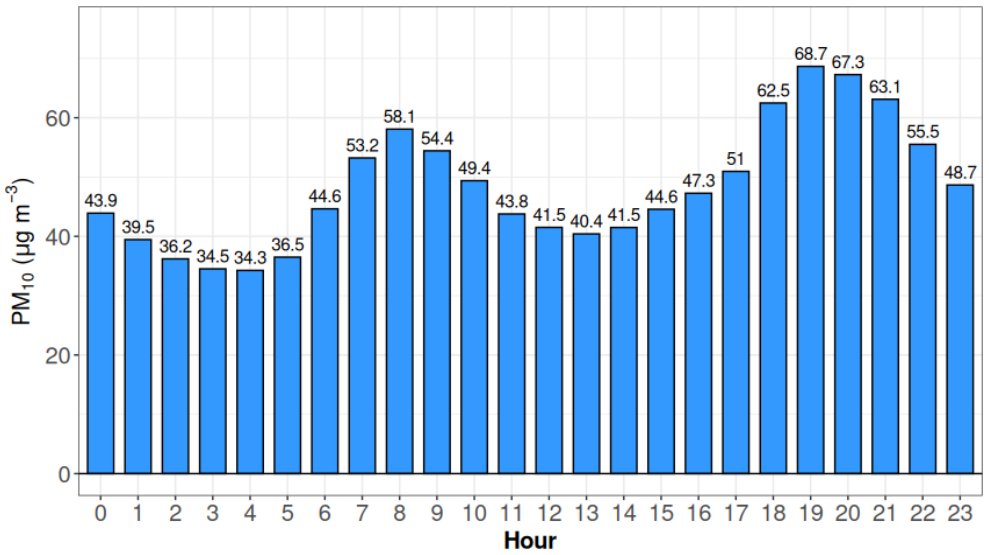

Figure A4-372: Hourly Average of PM_{10} for Mahendranagar Station

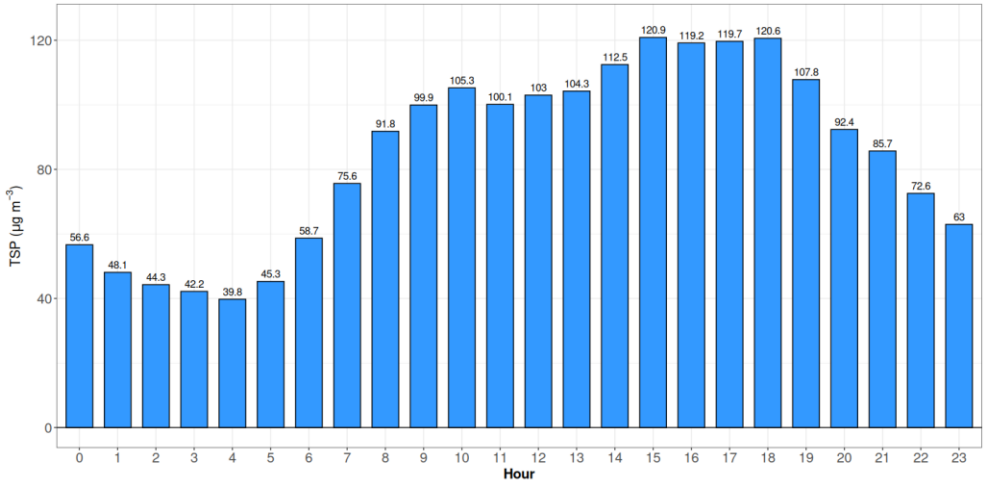

Figure A4-373: Hourly Average of TSP for Mahendranagar Station

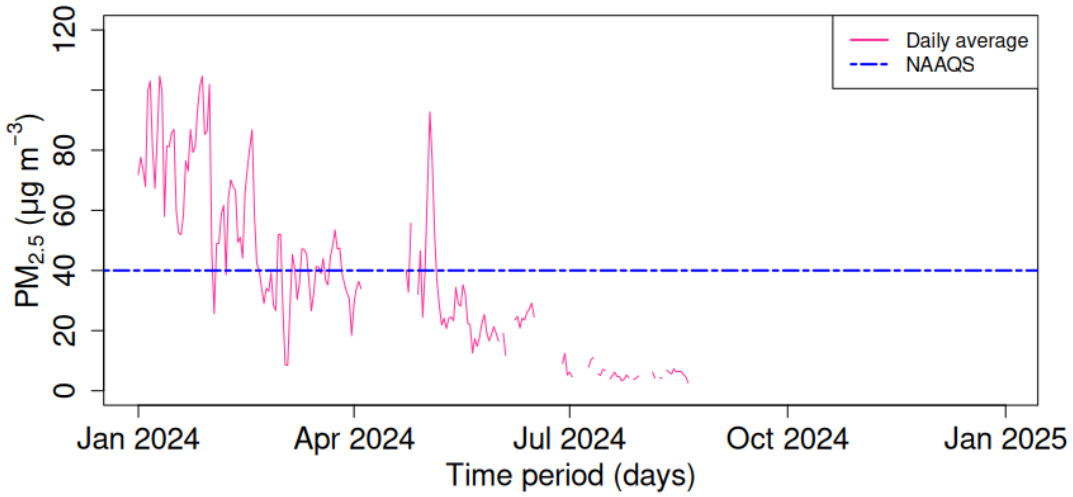

Figure A4-374: Daily Average of $PM_{2.5}$ for Mahendranagar Station

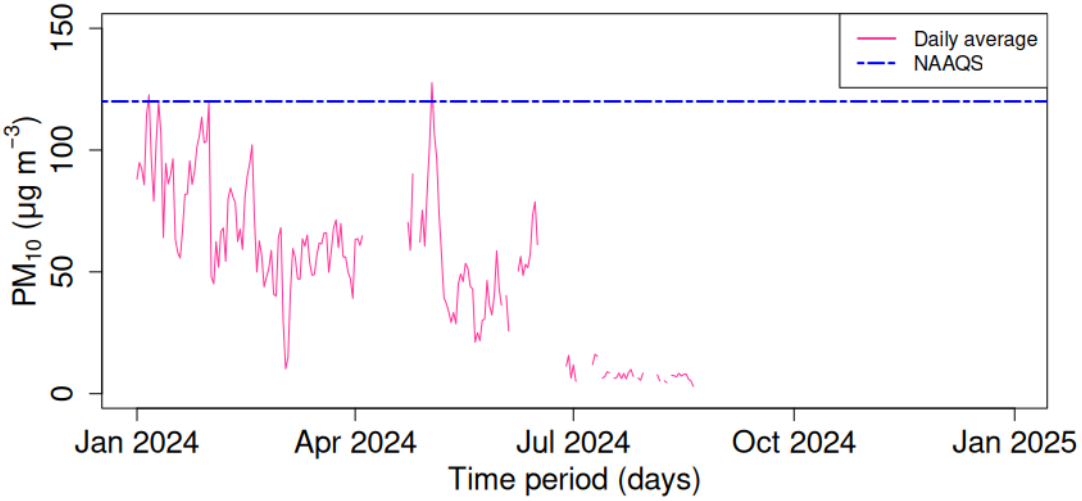

Figure A4-375: Daily Average of PM_{10} for Mahendranagar Station

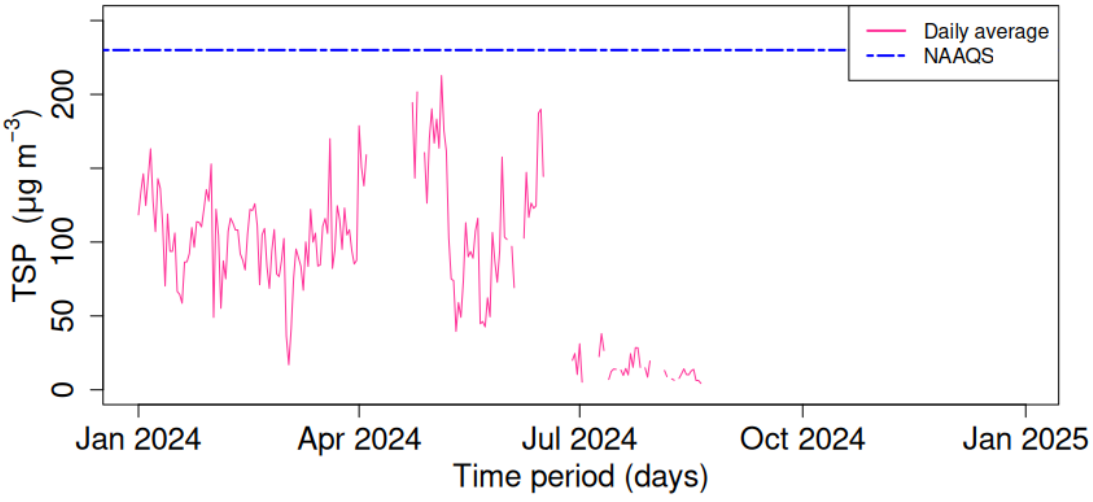

Figure A4-376: Daily Average of TSP for Mahendranagar Station

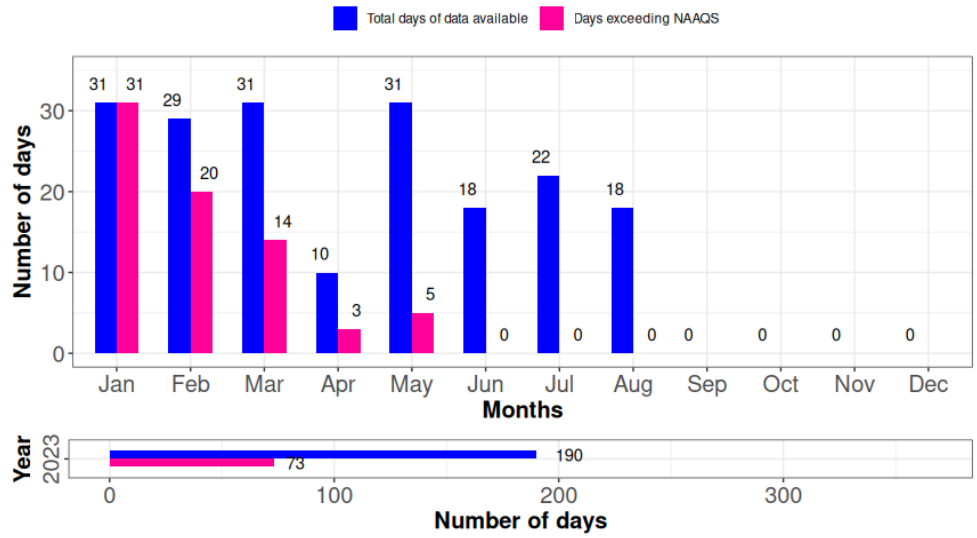

Figure A4-377: Compliance Status of $PM_{2.5}$ for Mahendranagar Station

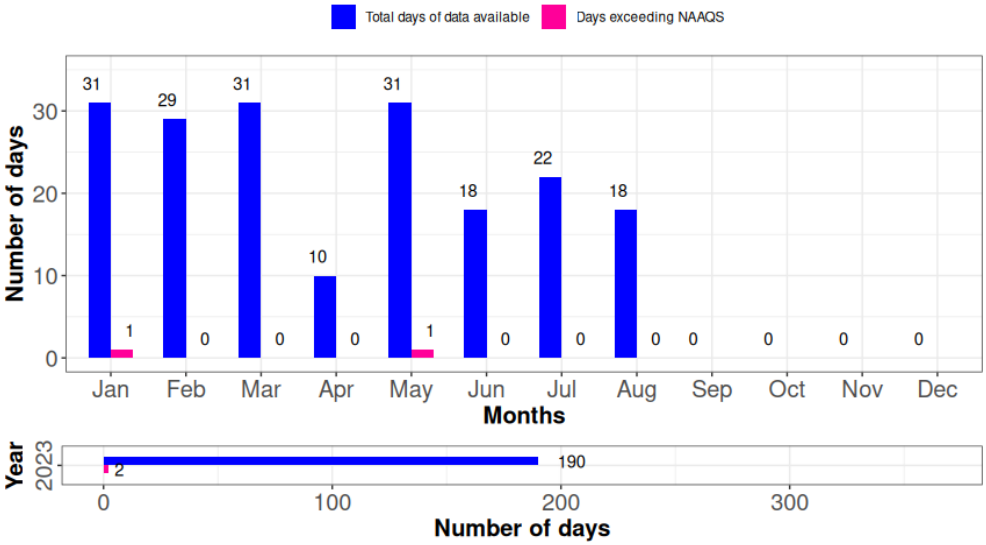

Figure A4-378: Compliance Status of PM_{10} for Mahendranagar Station

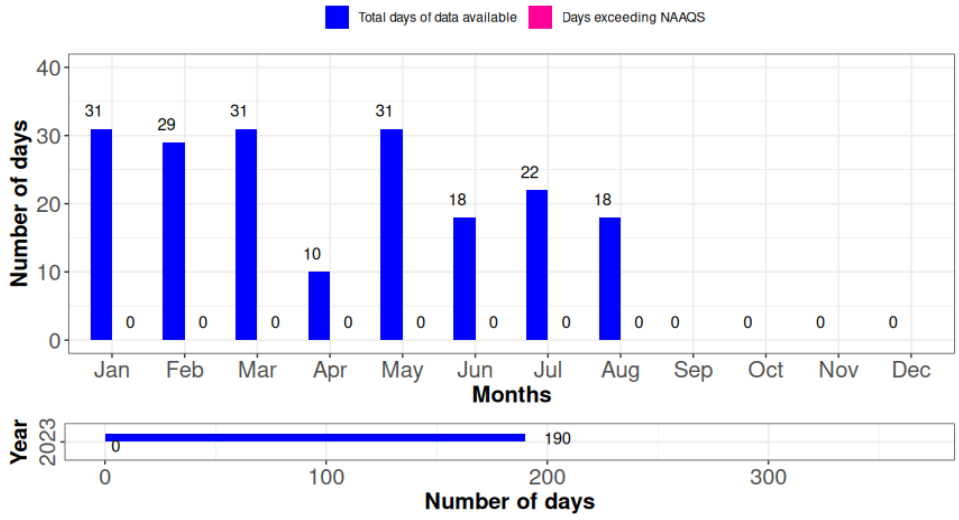

Figure A4-379: Compliance Status of TSP for Mahendranagar Station

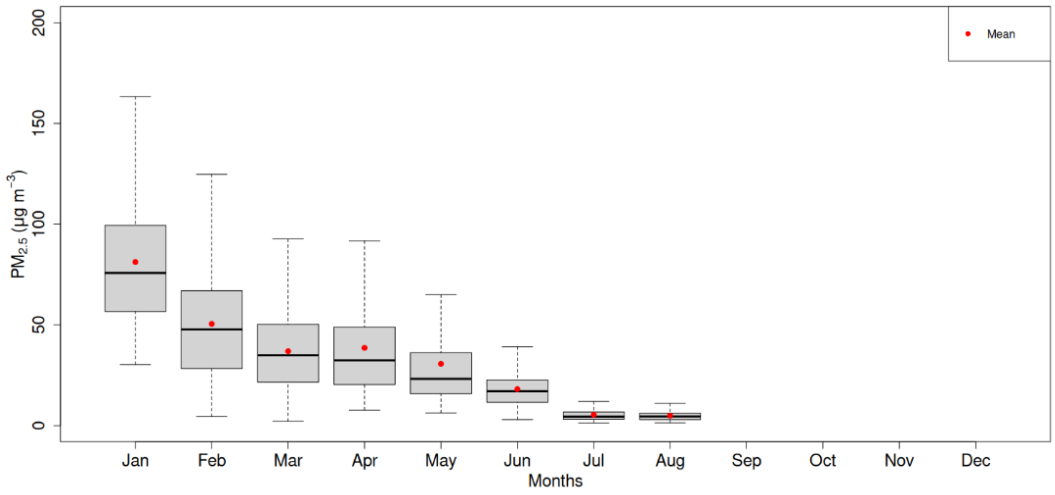

Figure A4-380: Monthly Variation of $PM_{2.5}$ for Mahendranagar Station

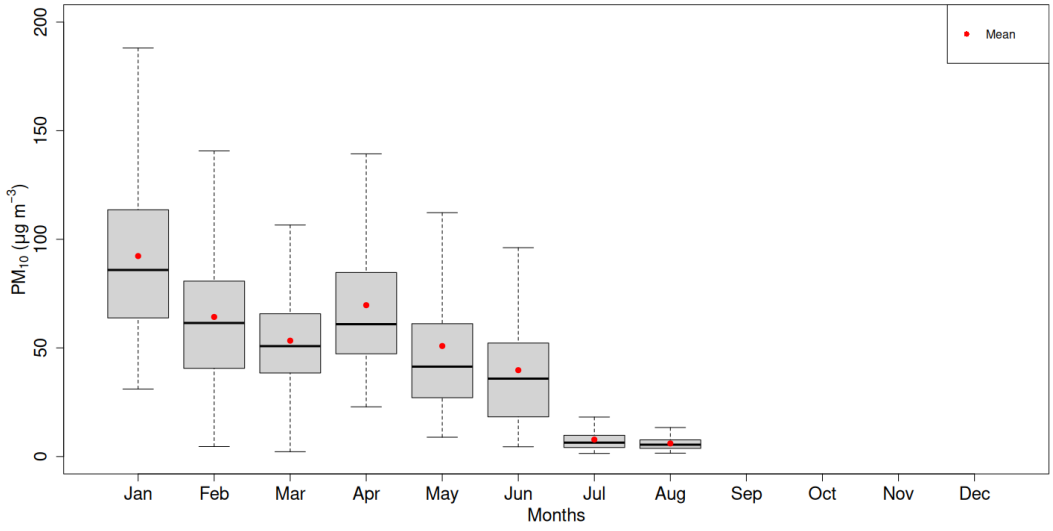

Figure A4-381: Monthly Variation of PM_{10} for Mahendranagar Station

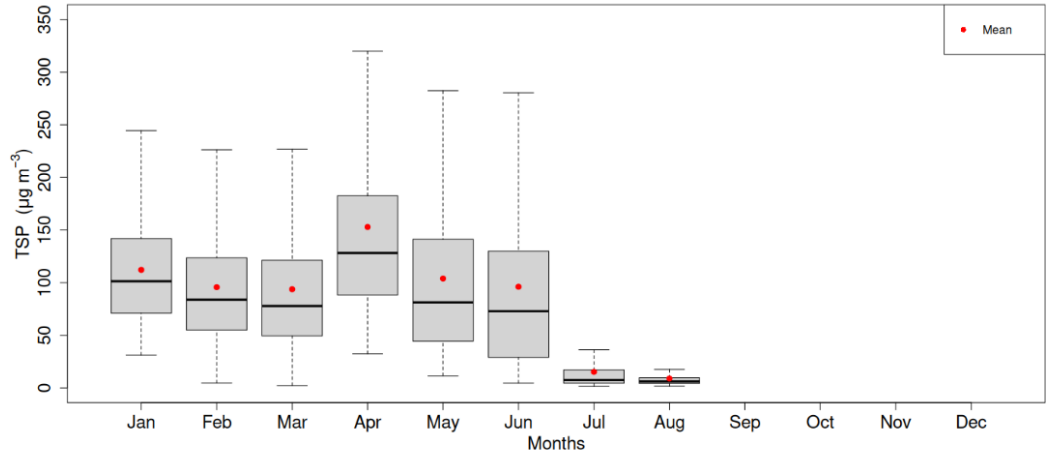

Figure A4-382: Monthly Variation of TSP for Mahendranagar Station

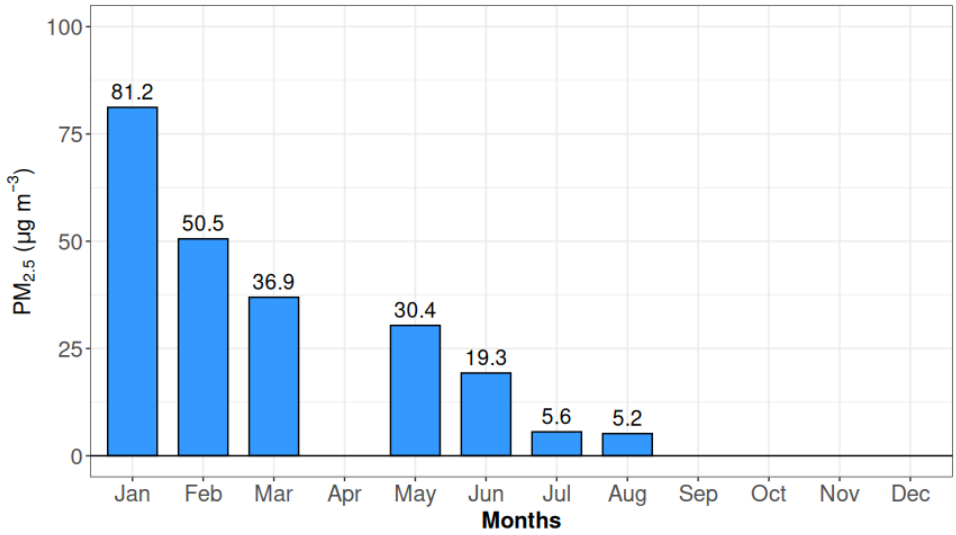

Figure A4-383: Monthly Average of $PM_{2.5}$ for Mahendranagar Station

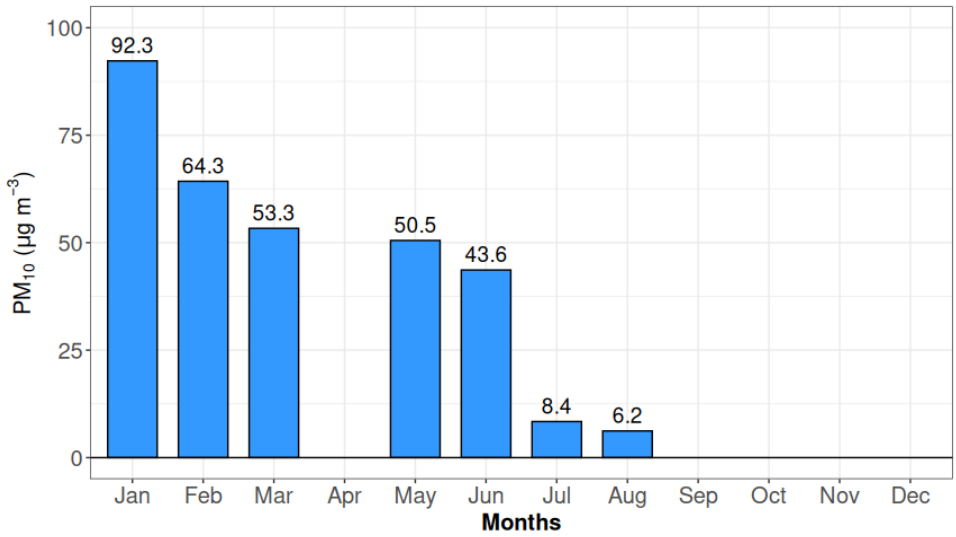

Figure A4-384: Monthly Average of PM_{10} for Mahendranagar Station

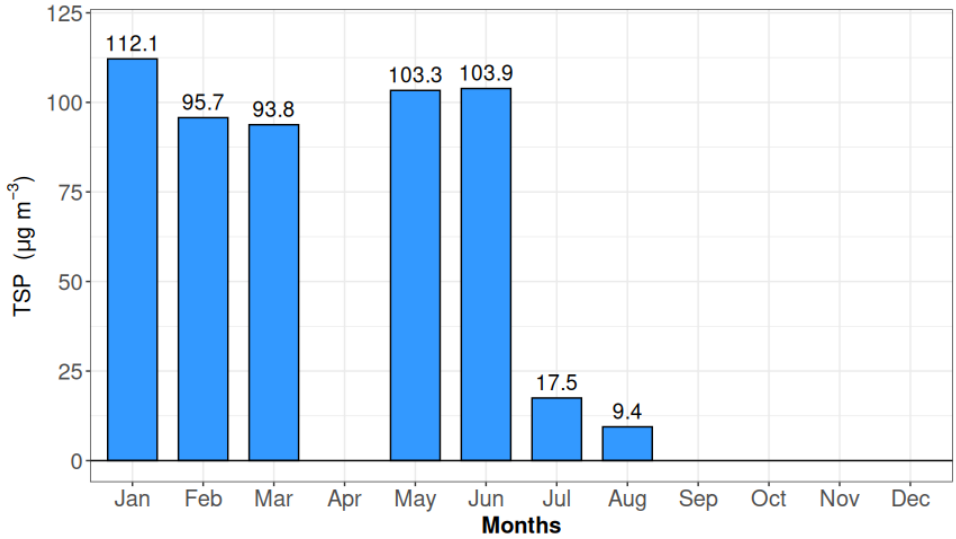

Figure A4-385: Monthly Average of TSP for Mahendranagar Station

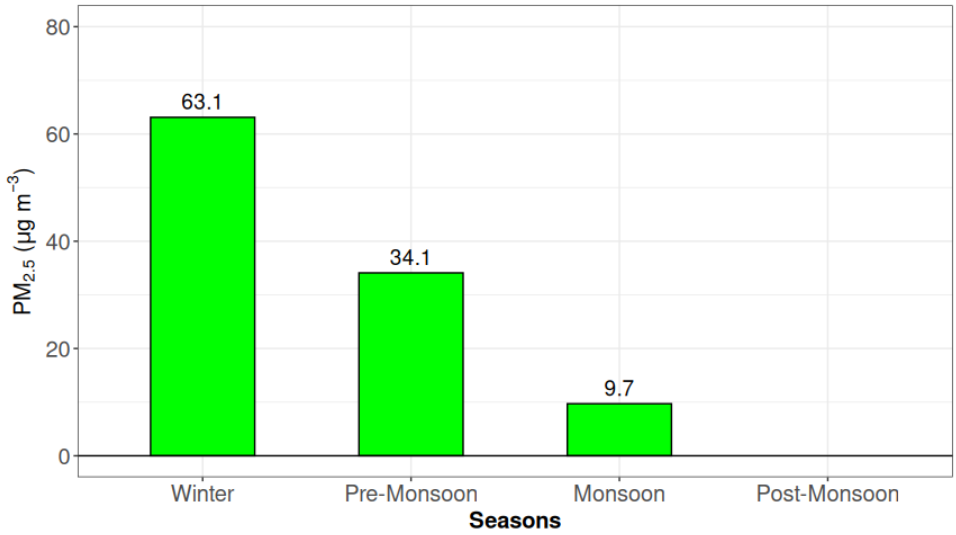

Figure A4-386: Seasonal Average of $PM_{2.5}$ for Mahendranagar Station

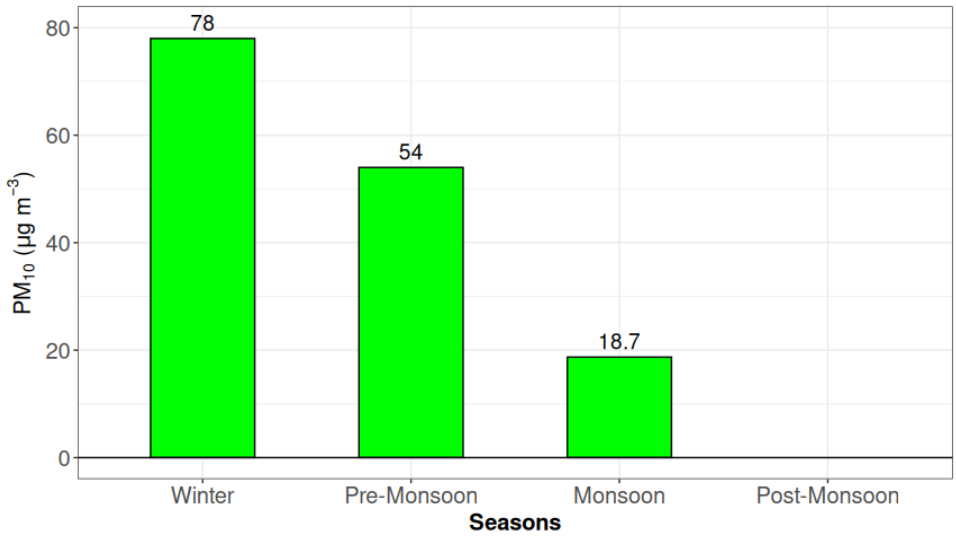

Figure A4-387: Seasonal Average of PM_{10} for Mahendranagar Station

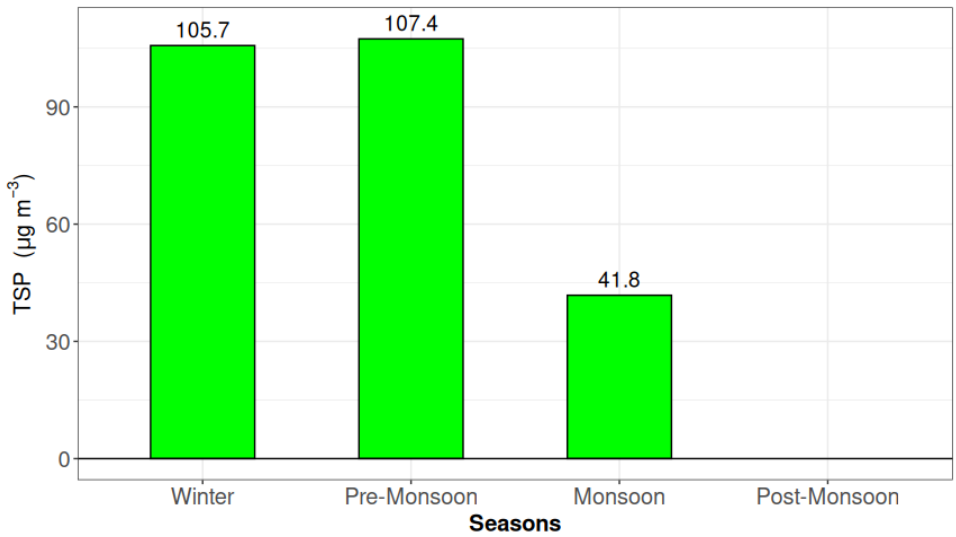

Figure A4-388: Seasonal Average of TSP for Mahendranagar Station

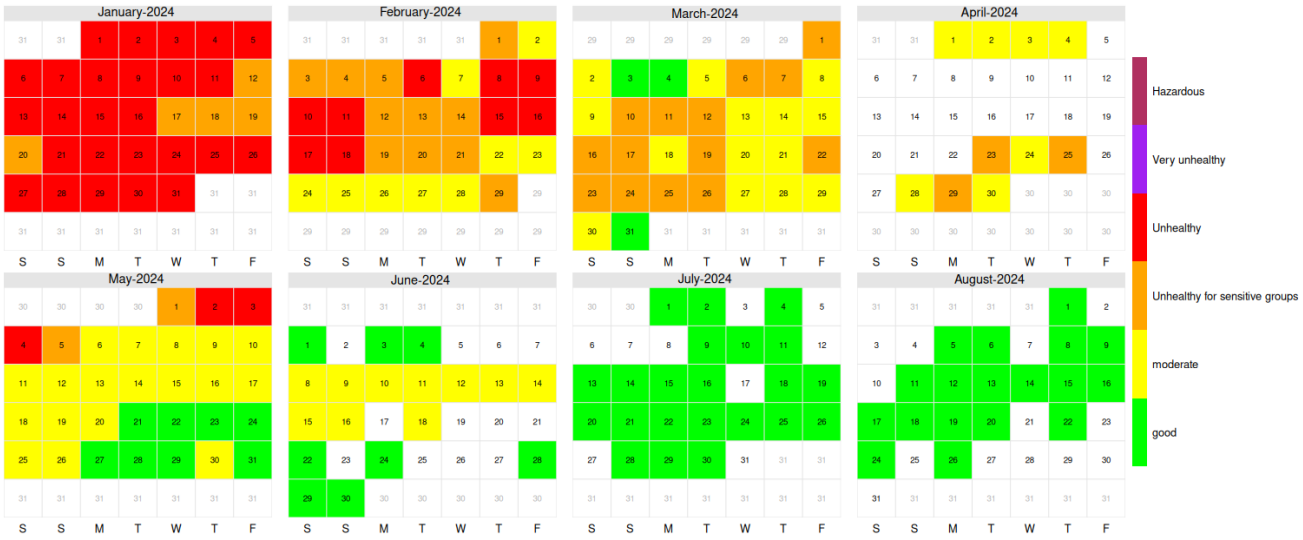

Figure A4-389: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Mahendranagar Station

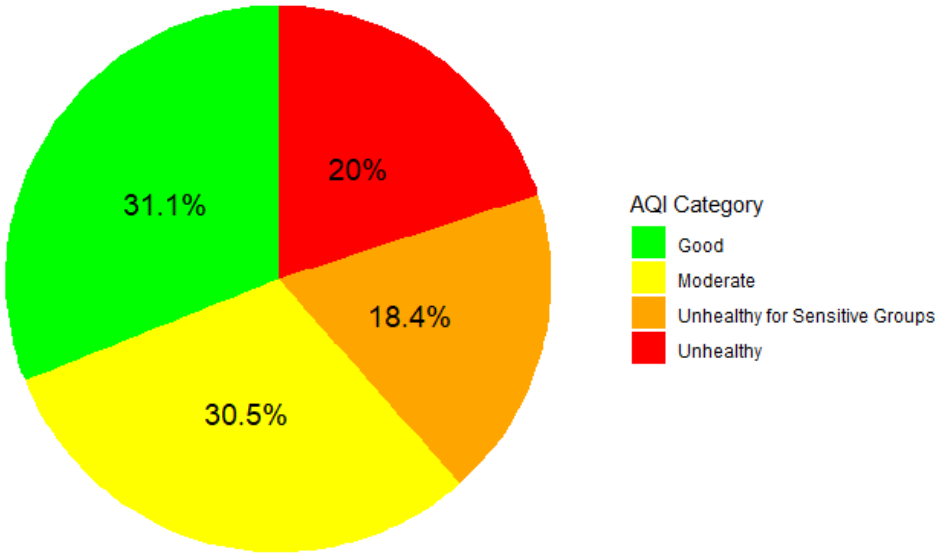

Figure A4-390: AQI Category Distribution for Mahendranagar Station

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