# Ambient Air Quality in Bangladesh

## (2018-2023)


**Department of Environment**

Ministry of Environment, Forest & Climate Change

Government of the People's Republic of Bangladesh

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# FOREWORD

Bangladesh has been experiencing increased level of air pollution particularly in dry season, which is being compounded with transboundary air pollution in Indo-Gangetic Plain (IGP) for country's specific geographical location and meteorological conditions. So, proper assessment and monitoring of air quality is critical to understand its dynamic situation, and taking them into account relevant authorities can take up appropriate measures to abate the air pollution.

In this report, an extensive analysis of air quality data has been performed captured in 31 (thirty-one) Continuous Air Quality Monitoring Stations (CAMS) operated by the Department of Environment during 2018 – 2023, which are located in different divisional cities and district towns of the country. Statistical parameters of the prime pollutants (PM2.5 and PM10) have been analyzed and illustrated. At the same time seasonal and diurnal trends are examined and presented. In the report, the whole country has been divided into 5 regions (middle, north to west, south, southeast and east) to examine regional status of air pollution in the country. The middle region includes Dhaka, Gazipur, Narayanganj, savar and Narsindi, north to west region includes Mymensingh, Rangpur and Rajshahi, south region includes Barisal and Khulna, southeast region includes (Chattogram and Cumilla) and the east region contains Sylhet cities.

It is to be noted that the Department of Environment started disseminating real-time Air Quality Index (AQI) in DoE website analyzing data and information of 16 CAMS across the country since 2023, and keep updating the AQI of 16 CAMS every one hour.

I would like to thankfully acknowledge the contributions of Md Ziaul Haque, Director (Air Quality) and his team in Air Quality Wing as well as Mr. Masud Rana, Air Quality Expert for preparing this important and useful report.

**Dr. Md. Kamruzzaman, ndc**
Director General
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# CONTENTS

# ABBREVIATIONS

| | |
|---|---|
| AQI | Air Quality Index |
| AQM | Air Quality Monitoring |
| BARC | Bangladesh Agricultural Research Corporation |
| BARI | Bangladesh Agricultural Research Institute |
| BNAAQS | Bangladesh National Ambient Air Quality Standard |
| BRRI | Bangladesh Rice Research Institute |
| BS | Bangladesh Standard |
| BSMRAU | Bangabandhu Sheikh Mujibur Rahman Agricultural University |
| CAMS | Continuous Air Monitoring Station |
| CAP | Criteria Air Pollutants |
| CASE | Clean Air and Sustainable Environment Project |
| CDS | Central Data Station |
| CNG | Compressed Natural Gas |
| COPD | Chronic Obstructive Pulmonary Disease |
| DCC | Dhaka City Corporation |
| DoE | Department of Environment |
| DTCA | Dhaka Transport Coordination Authority |
| FCK | Fixed Chimney Kiln |
| GDB | Global Burden of Disease |
| GDP | Gross Domestic Product |
| GoB | Government of Bangladesh |
| GPRS | General Packet Radio Service |
| IR | Infrared |
| NCDC | National Climatic Data Centre |
| NOAA | National Oceanic and Atmospheric Administration of the United States of America |
| NDIR | Non-Dispersive Infrared |
| NSTI | National Institute of Standards and Technology |
| PAN | Peroxyacetyl Nitrate |
| PM | Particulate Matter |
| PMT | Photo Multiplier Tube |
| QA/QC | Quality Control/Quality Assurance |
| SQL | Structured Query Language |
| SRO | Statutory Regulatory Order |
| USEPA | United States Environment Protection Agency |
| UV | Ultra Violet |
| WB | World Bank |
| WHO | World Health Organization |

## SYMBOLS

| | |
|---|---|
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| $HNO_3$ | Nitric Acid |
| NO | Nitrogen Oxide |
| $NO_2$ | Nitrogen Dioxide |
| NOx | Oxides of Nitrogen |
| $O_3$ | Ozone |
| $OH^-$ | Hydroxyl Radical |
| Pb | Lead |
| PM | Particulate Matter |
| $PM_{10}$ | Particulate Matter with Aerodynamic Diameter less than 10 Micrometer |
| $PM_{2.5}$ | Particulate Matter with Aerodynamic Diameter less than 2.5 Micrometer |
| $SO_2$ | Sulfur Dioxide |
| $SO_3$ | Sulfur Trioxide |
| SOx | Oxides of Sulfur |

## UNITS

| | |
|---|---|
| ppb | parts per billion |
| ppm | parts per million |
| $\mu g/m^3$ or $\mu g\ m^{-3}$ | microgram per cubic meter |
| $^oC$ | Degree Centigrade |
| % | Percent |
| hPa | Hecto Pascal |
| $W\text{-}m^{-2}$ | Watt per square meter |
| mm | millimeter |

# 1 Executive Summary

Bangladesh has been suffering from heightened level of air pollution from a decade. Despite taking several measures in controlling the pollution, the situations have worsened in recent years, especially due to development works, and adverse meteorology resulting from climate changes; some researches also pointed to the trans-boundary particulate matters responsible for this calamity. Department of Environment (DoE) has been tirelessly acting to get rid of the situation. As part of its air quality management programs, it has been expanding the air quality monitoring network throughout the country; the network now covers 31 monitoring sites at 23 districts compared to only 06 in 2010; the present network ensures covering all the regions of the country, from north to south and east to west. Sixteen sites out of those 31 are equipped with robust type continuous air monitoring stations (CAMS) while the other fifteen are with compact type continuous air monitoring stations (C-CAMS); all of the stations are monitoring the criteria air pollutants ($PM_{10}$, $PM_{2.5}$, $NO_x$, $SO_2$, $O_3$ and CO) using Federal Equivalent Methods (FEMs) developed by the United States Environmental Protection Agency (USEPA). Some of the meteorology parameters (WS, WD, T, P, RH, etc.) are also continuously monitored at the stations. Air and meteorology data captured every 15 minutes at the stations are dispatched to the central server at the DoE head office in Dhaka where the data are gone under quality checks and are finally stored.

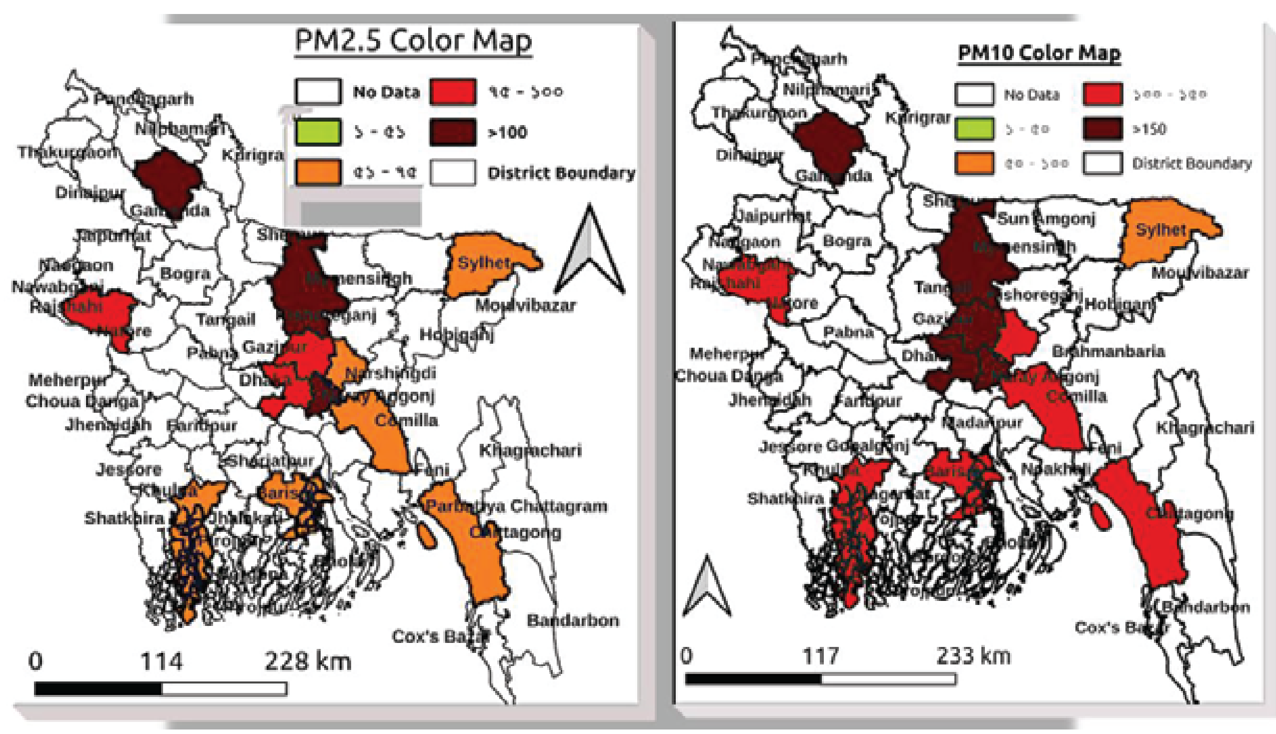
In this report an extensive analysis of air quality data captured at the stations during 2018 – 2023 has been performed. Statistical parameters of the prime pollutants ($PM_{2.5}$ and $PM_{10}$) have been analyzed and illustrated and at the same time seasonal and diurnal trends are examined, the directional influences of especially $PM_{2.5}$ at the stations are also studied. Sufficient valid data availability was strictly ensured during calculating daily (70% availability) and annual (65% availability) averages of $PM_{2.5}$ and $PM_{10}$ concentrations. The Air Quality Index (AQI) categories calculated using USEPA scale are also shown for the cities.

The whole country has been divided into 5 regions (middle, north to west, south, southeast and east) to examine regional status of air pollution in the country. The middle region includes Dhaka, Gazipur, Narayanganj, savar and Narsindi, north to west region includes Mymensingh, Rangpur and Rajshahi, south region includes Barisal and Khulna, southeast region includes (Chattogram and Cumilla) and the east region contains Sylhet cities. In the following section a summary of this analysis has been provided;

(i) The population-weighted $PM_{2.5}$ concentration of the country was primarily calculated at 79.4 µg-m$^{-3}$ (based on urban measurement only)

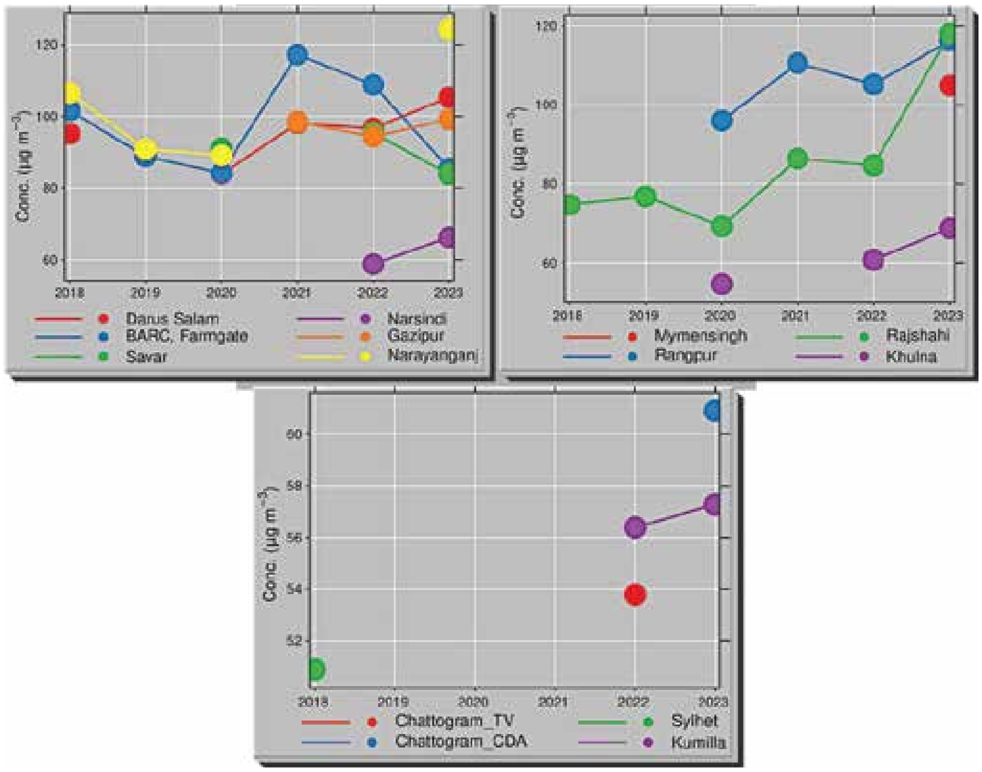
(ii) The north and northwest districts of the country experienced the highest level of both $PM_{2.5}$ and $PM_{10}$ concentrations while the Sylhet district experienced the lowest; status of annual particulate matter concentrations for all the regions are shown in Fig. i.

**Fig. i Period-average $PM_{2.5}$ (left) and $PM_{10}$ (right) concentrations (µg-m$^{-3}$) shown for different regions of the country**



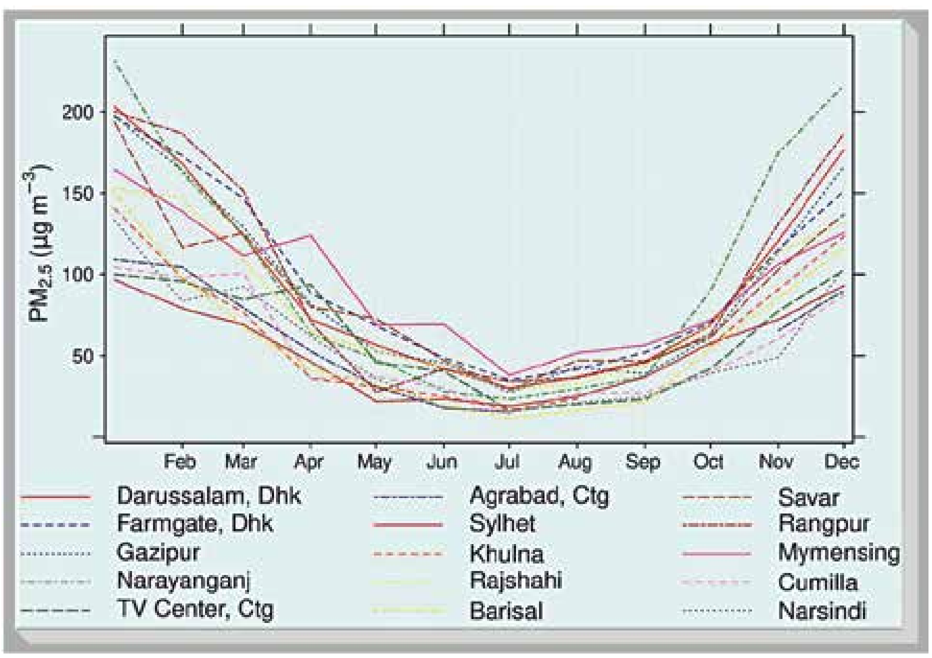

(iii) Trends in annual $PM_{2.5}$ concentrations at all of the stations (except Savar and Farmgate) have been found increasing in recent years (Fig. ii); the concentration in Farmgate fell from 2021 due to relocation of the station.

## Fig. ii Trends in annual $PM_{2.5}$ Concentrations at different cities during 2018 to 2023



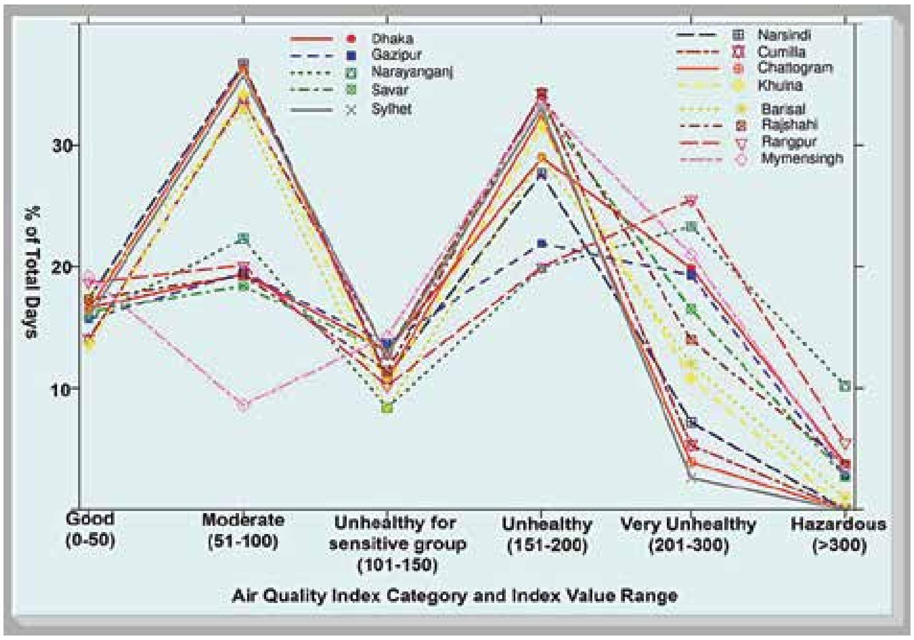

(iv) Seasonal variations in $PM_{2.5}$ concentrations in all the cities were similar, with the lowest concentrations in July and the highest in January, although in couple of cities (i.e. Narsindi, Cumilla) December, February and March were found exceptionally high compared to other cities.

## Fig. iii Monthly trends in $PM_{2.5}$ concentrations in the cities.



(v) Most of the days in a year $PM_{2.5}$ concentrations level remained at unhealthy category (in terms of health impact index) in the cities. "Moderate" level is the second most of the categories for the less impacted cities like Khulna, Narsindi, Cumilla, Chattogram, etc.; however for the cities located in the middle and north of the country "very unhealthy" days were comparatively greater with suppression of the "moderate" days.

**Fig. iv Percent of the period days with Air Quality Index (AQI) and value range shown for the cities of the country**




(vi) The other observations found from the analysis are as follows;

a) Irrespective of the regions and seasons, nighttime $PM_{2.5}$ concentrations were found greater than the daytime concentrations, and the amount of increment was found to vary with the stations and seasons. However on an average, ~40.0% increased $PM_{2.5}$ concentrations were observed at nighttime compared to daytime.

b) $PM_{2.5}$ to $PM_{10}$ ratio was found high in both winter and summer.

c) Very distinctive seasonal trends were observed for the particulate matter concentration in all of the regions of the country. On an average, 50% increase in $PM_{2.5}$ concentration was observed in winter season compared to summer season at the stations of Dhaka Division while that for other regions of the country were as, 12.0% in southeastern region and 20.0% in northwest regions. Wet seasonal $PM_{2.5}$ concentrations were about 50.0% lower than those in summer season.

d) Gaseous pollutants, especially $O_3$ and CO were found to breach the respective national standards in several stations; $O_3$ concentrations were found higher in Narsindi, Savar, Khulna and Rangpur stations while CO concentrations were higher in Agargaon, BARC, Khulna, Noakhali and Mymensingh stations.

# 2 INTRODUCTION

Air pollution has become a matter of grave concern for Bangladesh in recent years. The continued expansion of urbanization and industrialization as a result of high economic growth has resulted increased activities of emissions in the country. Climate changes and over-the-boundary pollution may also exacerbate the situation. The World Bank (WB), in a report, has claimed air pollution to be the second largest risk factor, causing most deaths and disability in the country in 2019[1]; about 80000 deaths and 1.0 billion days lived with illness were estimated in 2019. The University of Chicago has also revealed that the people of Bangladesh, on an average, are losing 6.8 years from their normal life-span due to exposure to polluted air[2]. The economic burden of this pollution is alarming, about 4.2% of national Gross Domestic Product (GDP)[1] in a year, estimated by the WB. The main pollutant behind this calamity is $PM_{2.5}$ (particulate matter with aerodynamic diameter less than 2.5µm) which has potentiality to enter the bloodstream and reach to heart, brain and other organs of the body. The scientists have found these tiny particles even in the placenta and affecting a developing fetus.

The Department of Environment (DoE) under the Ministry of Environment, Forests and Climate Change (MoEFCC) has been constantly endeavoring to contain the air pollution in the country. Induced by the source apportionment study conducted in 2012 by the Norwegian Institute for Air Research (NILU), DoE completed countywide inventory of brick kilns and steel mills and undertook massive drive against illegal brick kilns throughout the country. Government Acts and Rules have been revised to further tighten the standards of industrial and vehicular emissions. Enforcement on the high emitting sources is periodically taken place throughout the country. It is believed that were those controlling measures not taken place in time, the air pollution level throughout the country would have been skyrocketed; the air pollution, in recent years, was found not to wane especially due to the increase in construction works and long-range transport of pollutants; climate change may also be attributed to this undeterred air pollution. The recent publication from the WB has shown that the local sources of Dhaka accounted for only one third of the pollution in the city[3]-meaning that the majority of the pollution coming from distant sources. Thus, besides controlling the urban sources,

1 World Bank (2022) Breathing heavy – new evidence of air pollution & health in Bangladesh (p.p xi)
2 https://aqli.epic.uchicago.edu/reports/ Bangladesh factsheet
3 World Bank (2022) Striving for Clean Air: Air Pollution and Public Health in South Asia

tracking down the pollution movement in the regional scale could be a determining step for the air quality management.

As a consequence of government policy implementations and socio-economic changes the source apportionment of air borne $PM_{2.5}$, especially in Dhaka, has changed much in last 20 years. While the vehicle emissions were the main causes, with contributions of nearly 50.0% to $PM_{2.5}$ before the year 2005, the brick kilns started dominating the scenario afterwards because of the clustering of traditional brick kilns around Dhaka city, and on the other hand phasing out of two stroke taxies as well as massive use of cleaner fuel compressed natural gas (CNG) in vehicles in Dhaka city. For a long time, the cities of Bangladesh have not gone for complete source apportionment studies based on mathematical modeling (receptor/dispersion); although in the meantime, some researches/studies from educational institutes are published. The result shown in a study on the in-situ metal analysis of PM samples conducted jointly by the Bangladesh Council of Scientific and Industrial Research (BCSIR) and North South University (NSU) in 2020-2021 revealed dust sources as the dominant sector of PM pollution in Dhaka[4] . It is a matter of great concern that most of the studies[5,6] that chemically analyzed the $PM_{2.5}$ of Dhaka found very high degree of both organic carbon (OC) and elemental carbon (EC), which are the products of burning biomass and fossil fuel, and can travel long distance.

With a view to study the characteristics of the air quality trends throughout the country as well as to understand the regional pollution flow over Bangladesh DoE has been expanding the air quality monitoring network in the country. The network is now covering 23 districts compared to only 06 in 2010. The criteria air pollutants ($PM_{10}$, $PM_{2.5}$, $NO_x$, $SO_2$, $O_3$ and CO) are continuously measured in those monitoring sites using the Federal Equivalent Methods (FEMs) developed by the United States Environmental Protection Agency (USEPA). Some of the meteorology parameters (WS, WD, T, P, RH, etc.) are also monitored in the stations.

In this report, temporal and spatial trend characteristics of the pollutant concentrations retrieved from those stations from 2018 to 2023 are extensively analyzed, regional comparison of the pollution has been mapped; the pollutions were converted to index value to show extent of health danger the cities suffered during the period.

## 2.1 Objectives

Air quality Monitoring is an important tool of the air quality management system. It informs us the level of air quality and the responsible components for the pollution (if any) in a region, which leads us taking appropriate steps on its management. The characteristics of the trends are effective tools for making any plan on controlling the air quality. The degree of air quality improvement/decrement during any event in an area may provide the relation between the local sources and the air quality of the area; for example, the air quality improvement, calculated from the air monitoring results, during a complete shut-off day or during a long vacation (when most of the local sources are off) gives an idea of the strength of contribution of the local sources to the air quality. The air monitoring data is able to evaluate the impact of a policy implementation in the region and also serve the purpose of validating the simulation results got from any run of the air dispersion models. Thus, the main objective of this report is to present, analyze and make available the air quality data generated at 16 Continuous Air Monitoring Stations (CAMS) and 15 Compact Continuous Air Monitoring Stations (C-CAMS) installed throughout the country under the DoE. The specific objectives are:

- To explore the spatial and temporal trends of air quality throughout the county;
- To evaluate air quality compliance of the cities with respect to national standards;

4 Seasonal changes and respiratory deposition flux of $PM_{2.5}$ and $PM_{10}$ bound metals in Dhaka, Bangladesh. Chemosphere, 309, p.136794

5 Air pollution by fine particulate matter in Bangladesh. Atmospheric Pollution Research, 4 (1), pp.75-86.

6 Wintertime air quality in megacity Dhaka, Bangladesh strongly affected by influx of black carbon aerosols from regional biomass burning. Environmental Science & Technology, 55 (18), pp.12243-12249

- To understand the contribution of the most harmful components, $PM_{2.5}$ and $O_3$;
- To compare air quality among various types of the stations;

## 2.2 Air Quality Monitoring Network

The Department of Environment is now monitoring air quality of all the regions of Bangladesh. A total of 16 continuous air monitoring stations (CAMS) and 15 compact continuous air monitoring stations (C-CAMS) are functioning in 23 districts of the country; the equipment and the methods of operation of both CAMS and C-CAMS are the same, the only difference lies in their sizes and compactness; the inner arrangements and the parts of the C-CAMS are designed in such a way to make it compact and portable while keeping the principles of operation and functions of the analyzers and monitors the same. The air monitoring network has been designed as such that the busy and populated cities get included, and at the same time it can map the pollution tracks according to the wind direction.

Dhaka being the capital of the country, most populated and located middle of the country has got 05 monitoring stations (03 CAMS, 02 C-CAMS); two more stations have been installed very near to Dhaka city, one CAMS in Savar, only ~25km northwest from Dhaka, and one C-CAMS in Tongi only ~20km north from the city; both the areas are industrial in nature. The other cities, their positions and number of active monitoring stations within the cities are given in Table 1, while the positions of the station sites with respect to population distribution and land elevation of the country are shown in Fig.1 and Fig. 2.

**Table 1 Locations, types and capacity of the air monitoring stations**

| City | ID | Location | Lon/Lat | Monitoring Capacity | Type | Inlet & Met tower Height (m) |
|---|---|---|---|---|---|---|
| Dhaka | CAMS -1 | DoE, Agargaon, Dhaka | 90.372617; 23.7774 44 | $PM_{10}$, $PM_{2.5}$, $SO_2$ CO, $O_3$ & $NO_x$ with Meteorological Parameters | UB, R, C | 4.8 & 8 |
| | CAMS -2 | BARC, Farmgate | 90.389319; 23.760883 | | UB, C | 4.8 & 11 |
| | CAMS -3 | Darus-Salam, Mirpur | 90.355783; 23.782167 | | UB, C | 8.8 & 11 |
| Gazipur | CAMS -4 | Gazipur | 90.422315; 23.9 94128 | | SUB | 8.8 & 11 |
| Narayanganj | CAMS -5 | Narayanganj | 90.5072; 23.626079 | | UB, I | 8.8 & 11 |
| Chattogram | CAMS -6 | TV Station, Khulshi | 91.800454; 22.360487 | | UB, R | 4.8 & 7 |
| | CAMS -7 | Agrabad | 91.802242; 22.323068 | | UB, R | 8.8 & 11 |
| Khulna | CAMS -8 | Boyra | 89.529056; 22.835775 | | UB | 6.8 & 10 |
| Rajshahi | CAMS -9 | Sapura | 88.607837; 24.383221 | | UB, R, Rd | 6.8 & 10 |
| Sylhet | CAMS -10 | Red Crecent Campus | 91.867317; 24.888381 | | UB, R, Rd | 13.8 & 15 |
| Barishal | CAMS -11 | DFO Office Campus | 90.362565; 22.71023 | | UB, R | 6.8 & 10 |
| Mymensingh | CAMS -12 | DoE Office, Divisional Headquarter | 90.402041; 24.76239 | | UB | 8.8 & 11 |

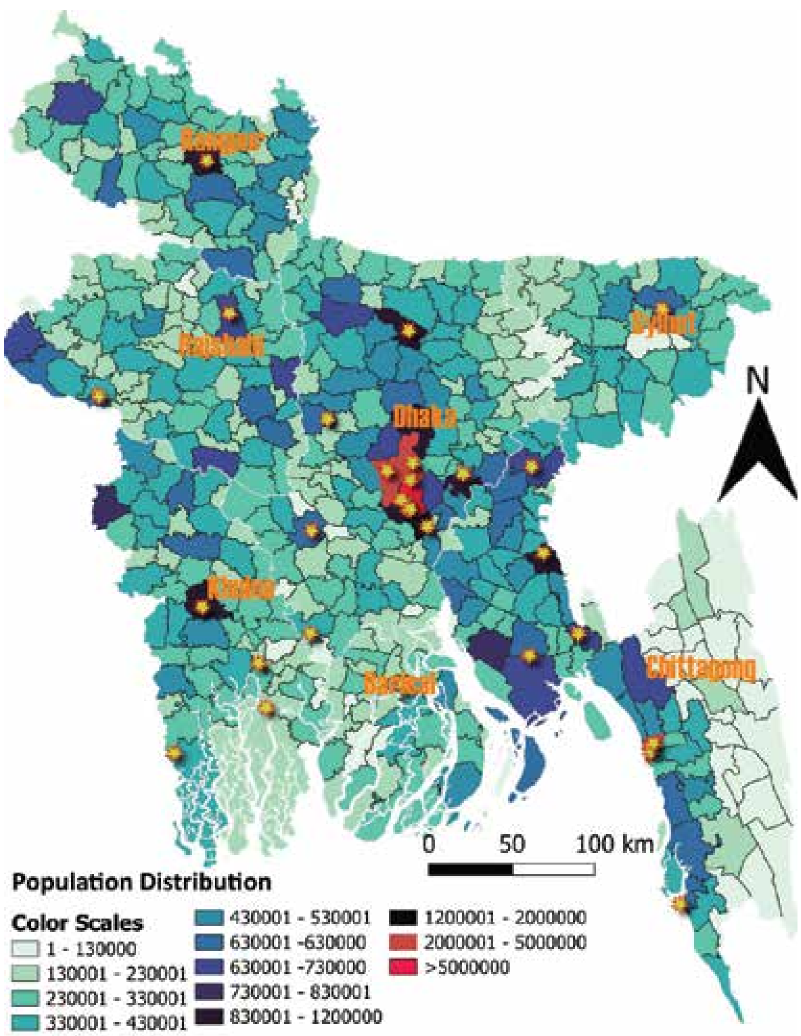
| | | | | | | |
|---|---|---|---|---|---|---|
| Rangpur | CAMS -13 | BTV Rangpur Station | 89.228931; 25.747371 | | UB | 8.8 & 11 |
| Savar | CAMS -14 | Atomic Energy Research Institute | 90.279617; 23.953726 | | SUB, I | 10.8 & 14 |
| Narsingdi | CAMS -15 | Sadar Upazila Complex | 90.716542; 23.932465 | | SUB, I | 8.8 & 11 |
| Cumilla | CAMS -16 | Court Area | 91.180671; 23.472988 | | UB | 8.8 & 11 |
| Faridpur | C -CAMS -17 | Sadar, Faridpur (Municipal Office) | 89.83871; 23.60624 | $PM_{10}$, $PM_{2.5}$, $SO_2$, CO, $O_3$ & NOx with Meteorological Parameters | SUB | 9 & 11 |
| Jashore | C -CAMS -18 | Sadar, Jashore (circuit house) | 89.20638; 23.162142 | | SUB | 12 & 14 |
| Satkhira | C -CAMS -19 | Shyamnagar, Satkhira | 89.04317; 22.315996 | | RUR | 5 & 7 |
| Bagerhat | C -CAMS -20 | Rampal, Bagerhat | 89.554563; 22. 595599 | | RUR, I | 5.7 & 7.7 |
| Gopalganj | C -CAMS -21 | Sadar, Gopalganj | 89.829035; 23.008615 | | SUB | 22 & 24 |
| Tangail | C -CAMS -22 | Sadar, Tangail (DoE office) | 89.929425; 24.249696 | | SUB | 15 & 17 |
| Bogura | C -CAMS -23 | Sadar, Bogura (DoE Office) | 89.361225; 24.86175 | | SUB | 9 & 11 |
| Tongi | C -CAMS -24 | BSCIC, Tongi, Gazipur | 90.41121; 23.894174 | | C, I | 18 & 20 |
| Dhaka | C -CAMS -25 | BUET, Dhaka | 90.392797; 23.727591 | | UB, R | 10 & 12 |
| Brahmanbaria | C -CAMS -26 | Sadar, B.Baria (municipal Office) | 91.109769; 23.974371 | | SUB | 18 & 20 |
| Feni | C -CAMS -27 | Sadar, Feni (DoE Office) | 91.381305; 23.006297 | | SUB | 18 & 20 |
| Noakhali | C -CAMS -28 | Maijdi Bazar, Noakhali (DoE Office) | 91.096979; 22.88097 | | SUB | 15 & 17 |
| Chattogram | C -CAMS -29 | BSRM, Nasirabad, Chattogram | 91.818054; 22.372838 | | UB, I, C | 12 & 14 |
| Cox's Bazar | C -CAMS -30 | Cox 's-Bazar (DoE Office) | 91.971083; 21.442208 | | SUB | 9 & 11 |
| Dhaka | C -CAMS -31 | Nagar Bhaban, DSCC, Dhaka | 90.409272; 23.726078 | | UB | 13 & 15 |

UB=Urban, R=Residential, C=Commercial, SUB=Sub-Urban, I=Industrial
RUR=Rural

## 2.3 Population Distributions of Bangladesh

Bangladesh is highly populous country; about 165.16 million people living in an area of 148,460 km$^2$, as per the national census of 2022, which also reveals that 31% of those people are now urban. Dhaka and its neighboring districts (Gazipur, Narayanganj) are the most populous area while the Chattogram Hill Tracts to the southeast and the Sundarban to the south are the least populous. The divisional cities (Khulna, Barisal, Mymensingh, Rajshahi, Sylhet, Rangpur, etc.) have also comparatively high populations (Fig.1) compared to the district or upazila sadar cities. The locations of the air monitoring station relative to high population zones of the country are shown in Fig.1;

**Fig. 1 Population Distribution of Bangladesh and the locations of Monitoring Stations (marked with yellow stars)**

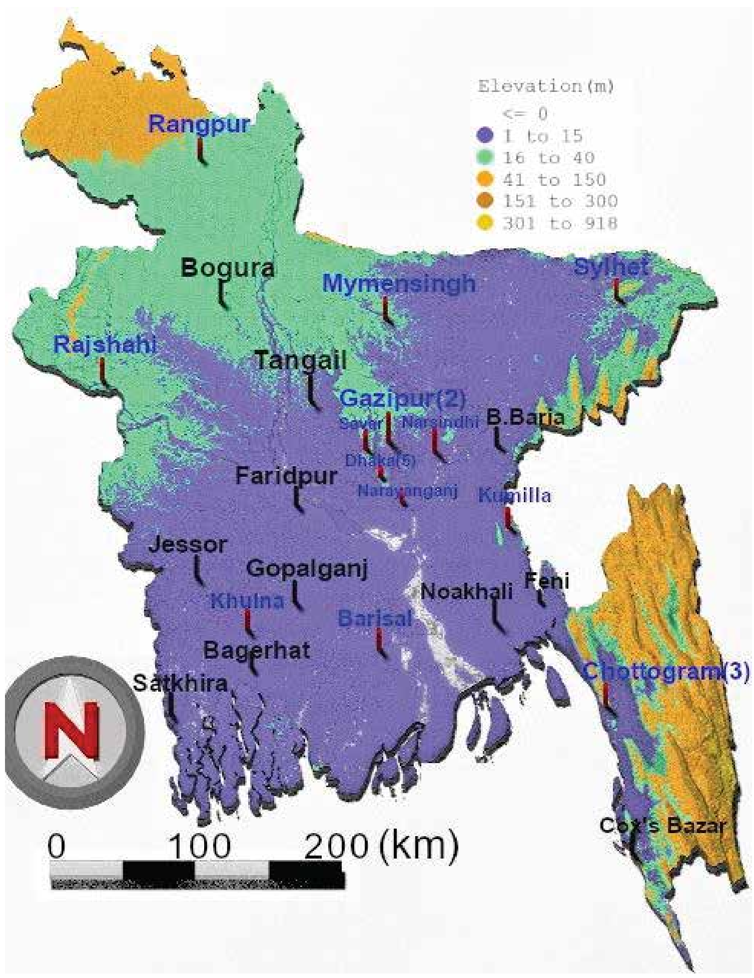



## 2.4 Topography of Bangladesh

The country of Bangladesh is although small in size (~148,460.0 km$^2$), it has considerable topographic diversity. There is main three distinctive features of the topography: (i) a broad alluvial plain subject to frequent flooding, (ii) a slightly elevated relatively older plain, and (iii) a small hill region drained by flashy rivers. The alluvial plain is part of the larger plain of Bengal, which is sometimes called the Lower Gangetic Plain. Elevations of this plain is less than 10m above the sea level; elevation furthers decline to near sea level in the coastal south. The hilly areas of the southeastern region of Chattogram, the northeastern hills of Sylhet and highlands in the north and northwest are of low elevations (Fig.2). The Chattogram Hills constitute the only significant hill system in the country. It rises steeply to narrow ridgelines (average 36m wide), with elevation ranges between 600 and 900m above mean sea level.

The country is surrounded by large hills and mountains from two sides; the great Himalaya is standing hard on the north while the Hills of Assam and Myanmar are locating across the northeast and eastern boundary of the country. The air moving to the east along the Himalayan valley during the winter season is thus forced to spread over Bangladesh. The large part of the country being almost plain, the flow of air (wind speeds and directions) throughout the country does not get much influenced by any large obstructions.

**Fig. 2 The elevation map of Bangladesh with the positions of the air monitoring stations. Number in first bracket shows total stations within it (the black towers are showing C-CAMSs while the red ones are showing CAMS mostly, except for Dhaka and Gazipur where C-CAMS are also included)**




## 2.5 Criteria Air Pollutants

Six pollutants [i.e., particulate matters ($PM_{10}$ & $PM_{2.5}$), sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$ = $NO_2$ + NO), ozone ($O_3$), carbon monoxide (CO) and lead] are termed as the criteria air pollutants (CAPs) for their abundances as pollutants in the atmosphere and ability to harm human health, plants, and properties. The Government of Bangladesh (GoB) has set standards for each of the CAP for controlling their presence in air. The DoE monitors all of the CAPs, except lead, in the air of the major cities of the country. The table below gives short notes on the CAPs:

**Table 2 Criteria Air Pollutants, their sources and health impacts**

| Component | Introduction | Sources | Health Impacts |
|---|---|---|---|
| $PM_{10}$ | Particulate Matters with diameter less than 10 µm. These include dusts, pollen, spores, fly ash, plant & insect parts, etc. | Produced mainly from mechanical processes. | Exposures to $PM_{10}$ is associated primarily with worsening of respiratory diseases, including asthma and COPD, leading to hospitalization and emergency department visits. |
| $PM_{2.5}$ | Particulate Matters with diameter less than 2.5 µm, thinner than a human hair by a factor 20-25. Different types of chemical components (both solid and aqueous) like organic and elemental carbon, salts, sulfuric acid mists, etc. fall within this category. | Produced mainly from chemical processes. | $PM_{2.5}$ is associated with premature mortality, increased hospital admissions for heart or lung causes, acute and chronic bronchitis, asthma attacks, respiratory symptoms, etc. These adverse health effects have been reported primarily in infants, children, and older adults with preexisting heart or lung diseases. $PM_{2.5}$ is also responsible for COPD, dementia, and autism. |
| $SO_2$ | Sulfur Dioxide, colorless gas with pungent odor, soluble in water. | Forms when fossil fuel with high sulfur content is burnt. The oxidation of sulfur compound like hydrogen sulfide ($H_2S$) also produce $SO_2$. Coal burning in brick kilns, and metal smelter industries are the main sources. | Sulfur dioxide gas is corrosive and severe irritant. Some individuals especially children, the elderly, and those who suffer from asthma are extremely sensitive to the effects of sulfur dioxide. Exposure to high concentrations of $SO_2$ for several minutes produces respiratory paralysis and pulmonary edema with a risk of death. |
| $NO_x$ | Nitrogen Oxides – consists mainly of Nitric Oxide (NO) and Nitrogen Dioxide ($NO_2$) gases. NO is a colorless and tasteless gas; $NO_2$ is a yellowish-orange to reddish-brown gas with a pungent, irritating odor, and is a strong oxidant. | $NO_x$ is emitted when something burns. More than 90% of $NO_x$ is released as NO, and 5 – 8 % as $NO_2$. Vehicles, Power Plants, brick kilns are good source of $NO_x$ | Exposure to high levels of $NO_x$ can cause collapse, rapid burning and swelling of tissues in the throat and upper respiratory tract, difficult breathing, throat spasms, and fluid build-up in the lungs. It can interfere with the blood's ability to carry oxygen through the body, causing headache, fatigue, and dizziness |

| | | | |
|---|---|---|---|
| $O_3$ | Ozone is highly reactive and corrosive gas. Its presence in the stratosphere is benign for the living species on earth, while in the troposphere its presence is malignant. The tropospheric ozone is both an air pollutant and a green house gas. | Ozone is not directly emitted to the air; it is formed from the chemical interactions of the precursor gases (i.e hydrocarbons, NOx) under the influence of sunlight, | When inhaled, ozone can damage lung tissues. Ozone is harmful to all types of cells. It may create more frequent attacks on individuals with asthma, cause eye irritation, chest pain, coughing, nausea, headaches and chest congestion. It can worsen heart disease, bronchitis, and emphysema. |
| CO | Carbon monoxide is a colorless, odorless & tasteless gas. It is flammable and is quite toxic to humans and other oxygen-breathing organisms. | Carbon monoxide is a product of fossil fuel combustion, biomass burning and the oxidation of volatile hydrocarbons. It is often a product of incomplete combustion – when something burns in a system with little oxygen, or more carbon, CO produces. | Someone breathing air with high CO can have their hemoglobin saturated with it, making it impossible for the blood to deliver oxygen to their cells. This might cause headache, fatigue, dizziness, etc. Breathing too high CO may even cause death. |

## 2.6 National Ambient Air Quality Standards

The government of Bangladesh has revised the ambient air quality standards in 2022, applicable for all over the country, vide the Air Pollution (Control) Rules - 2022" (S.R.O 255 Law/2022); the standards are shown in Table 3.

**Table 3 Limit values of air pollutants in Bangladesh**

| Pollutant | Limit Value | Averaging Time |
|---|---|---|
| CO | [a]5.0 mg/m$^{-3}$ | 8-hour |
| | [a]20.0 mg/m$^{-3}$ | 1-hour |
| $NO_2$ | [b]40 µg/m$^{-3}$ | Annual |
| | [a]80 µg/m$^{-3}$ | 24-hour |
| $PM_{10}$ | [b]50 µg/m$^{-3}$ | Annual |
| | [a]150 µg/m$^{-3}$ | 24-hour |
| $PM_{2.5}$ | [b]35 µg/m$^{-3}$ | Annual |
| | [a]65 µg/m$^{-3}$ | 24-hour |
| $O_3$ | [a]100 µg/m$^{-3}$ | 8-hour |
| | [a]180 µg/m$^{-3}$ | 1-hour |
| $SO_2$ | [a]80 µg/m$^{-3}$ | 24-hour |
| | [a]250 µg/m$^{-3}$ | 1-hour |

[a]The mean value will not cross more than once in a year.
[b]Target will be achieved when annual average will remain within this.

## 2.7 Meteorology of the Country

Meteorology plays an important role in building up pollutants in air. The wintertime meteorology of Bangladesh is characterized with low wind speed, minimum downpour, foggy nights, weak sun, all of which are very congenial to mounting air pollution. Although wind speed increases and strong sun assist in wide atmospheric mix-up during summertime (March – April), excessive dryness with dusty surroundings prevails all over the country. Rainy seasonal meteorology (from May to October) in Bangladesh is helpful for good quality air, the downpour amount all over the country is not the same though. The northeastern part (Sylhet) of the country experiences maximum rainfall (annual avg. ~5500mm) while the western region (Natore, Pabna) finds the minimum (annual avg. ~1500mm). The areas locating middle to south and southeast usually experience higher rainfall compared to the areas to the north and west. Wind patterns are completely opposite in dry season (November to April) and wet season (May to October); while strong marine wind with lot of moisture blows from the southeast directions during the wet season, dry continental wind from the northwest direction blows during the dry season. Several low-pressure systems inflict the country during wet season, while in contrast, comparatively high-pressure system acts over the country during dry season.

# 3 METHODOLOGY

## 3.1 Instrument and Data Quality Control

Quality control is an important part of the work to which additional focus was given to ensure generating and disseminating valid information. While the instrument engineers were given the charge of maintaining the instrument following prescribed quality checks, the data managers were responsible for collecting, processing, screening & analyzing the data with proper care and expertise. Data quality control, especially, was performed in two steps: non-numeric invalid fields which were generated from sudden electric voltage disruptions or during calibrations, etc. were cleaned up in the first stage while in the second stage thorough checks of the data were performed manually to examine the validity of the data in terms of chemical-physical characteristics of air pollution, typical seasonal & diurnal patterns of the pollutants (understood from published articles), etc. Aggregation of data for coarser time average (i.e. 24-hour, month, annual, etc.) was performed only when at least 70% data were available for daily average and 65% for annual average. In the following sections, the process of instrument quality control and data quality control is described;

### 3.1.1 Instrument QA/QC

DoE has awarded contracts to the certified local representatives of the instrument manufacturers for the maintenance of the stations. The contractors have sufficient resources of trained engineers and easy access to the manufacturers for spare parts and calibration gases. The engineers are entrusted with servicing, preventive maintenance, repair and calibrations of the stations. They also perform fortnightly site inspections to examine equipment operational status, site safety, security and calibration. They serve with rapid engagement in a station in any place of the country if it undergoes any kind of malfunction.

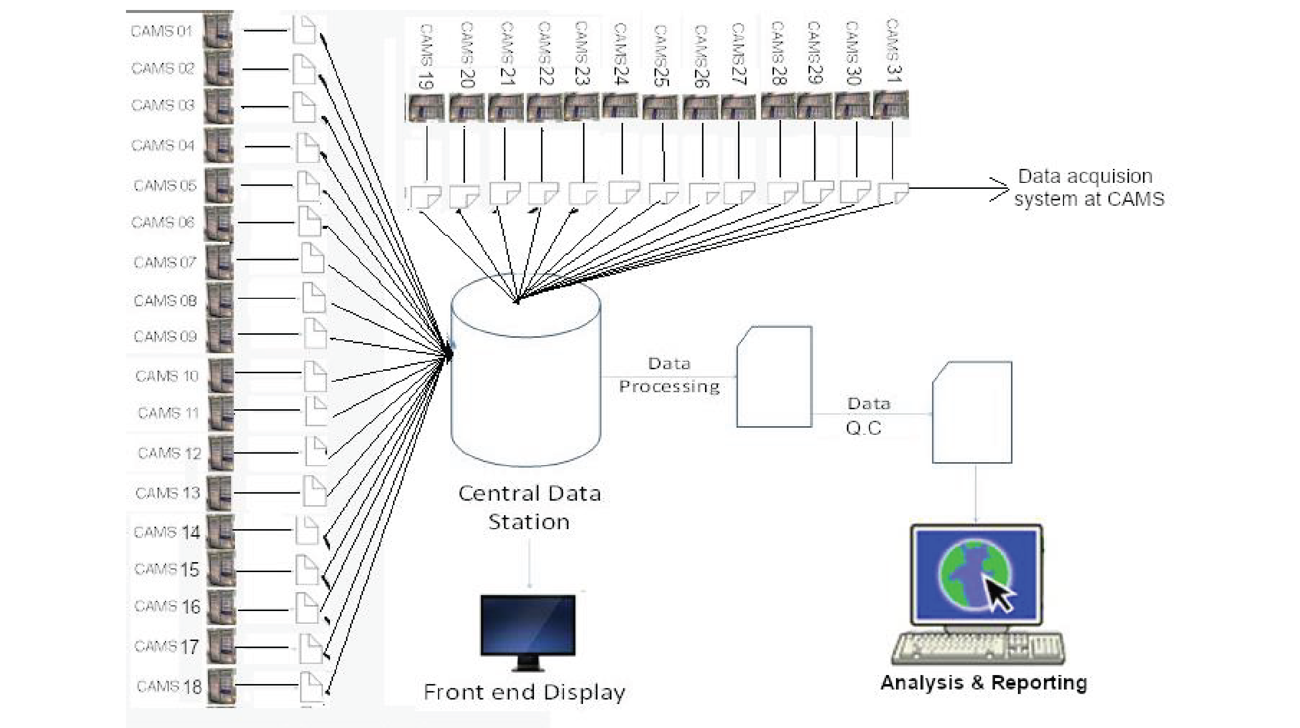
The DoE officials involved in the operations of the stations have been trained up time to time. A checklist and log book are maintained in each station to run the stations in a prescribed way and to note down the health conditions of the stations, including the ZERO/SPAN gases. The validity of the calibration of each of the analyzers is properly documented and carried out. Pre-calibration check, zero check, span check, post calibration checks are also performed regularly. The contents of the portable scrubber (hopcalite, activated charcoal, purafil and drierite) are changed when necessary or at least every six months.

The analyzers are calibrated using NIST traceable calibration gases. Standard foils with specified areal mass densities are used to calibrate particle monitors.

### 3.1.2 Data Flow and Data Management

All of the CAMSs and C-CAMSs are connected using GPRS system to a server placed at the Central Data Station (CDS) at the head office of DoE in Agargaon, Dhaka. The air quality and meteorology data generated every 15 minutes at the stations are retrieved as database using XR-Premium 6.4 software at the server system of the CDS. Although the XR Premium 6.4 software has the ability of aggregating data in other averaging periods like 1-hour, 8-hour, etc., it is programmed to retain data primarily at a 15-minute average. However, the data are transferred as 1-hr average to the local computer where it is gone through a rigorous quality check manually, used for calculating the Air Quality Index (AQI), and finally analyzed for reporting.

**Fig. 3 Air quality data flow from stations to desktop for analysis.**




### 3.1.3 Data Quality Control

All of the 31 stations generate data of 07 air quality parameters ($PM_{10}$, $PM_{2.5}$, $NO_2$, NO, $SO_2$, CO and $O_3$) and 07 meteorology parameters (WS, WD, T, RH, SR, Rain and BP). Running incessantly puts the instrument and its software in the risk of malfunction as they are made with high sensitivity to be able to measure minute levels (ppb) of air pollutants in air. Although data is stored in the server as 15-minute average, overall volume of the data in a month or in a year is very high, and after several years the volume becomes gigantic. Special care needs to be taken to manage, transfer and screening of the data.

Primary level screening of the data is done regularly while in-depth screening is performed every month. Despite operating the instrument as per the prescribed procedures, there are lot of causes for the instrument to fail to produce valid data; and the main causes are

(a) Electricity disruptions;

(b) During calibration or zero gas run;

(c) Trouble in operating software of the instruments or data acquisition system;

(d) Malfunctions of the instrument, especially bad signal from the PMT sections;

1-hourly aggregated data are transferred to the client computers where it is saved in MS Excel software. Following conditions were applied during checking the validity of a dataset of a station;

(i) $PM_{2.5}$ is a constituent of $PM_{10}$, so its value cannot be greater than $PM_{10}$;

(ii) The value of the parameters should not be unusually high or low compared to its adjacent ones; in such cases, instrument malfunctions or encroached new sources are assumed. To study the usual trends of air quality in an area this type of value should be kept aside if there are no records of causes for such extra pollution.

(iii) The value of NOx should be the sum of NO and $NO_2$;

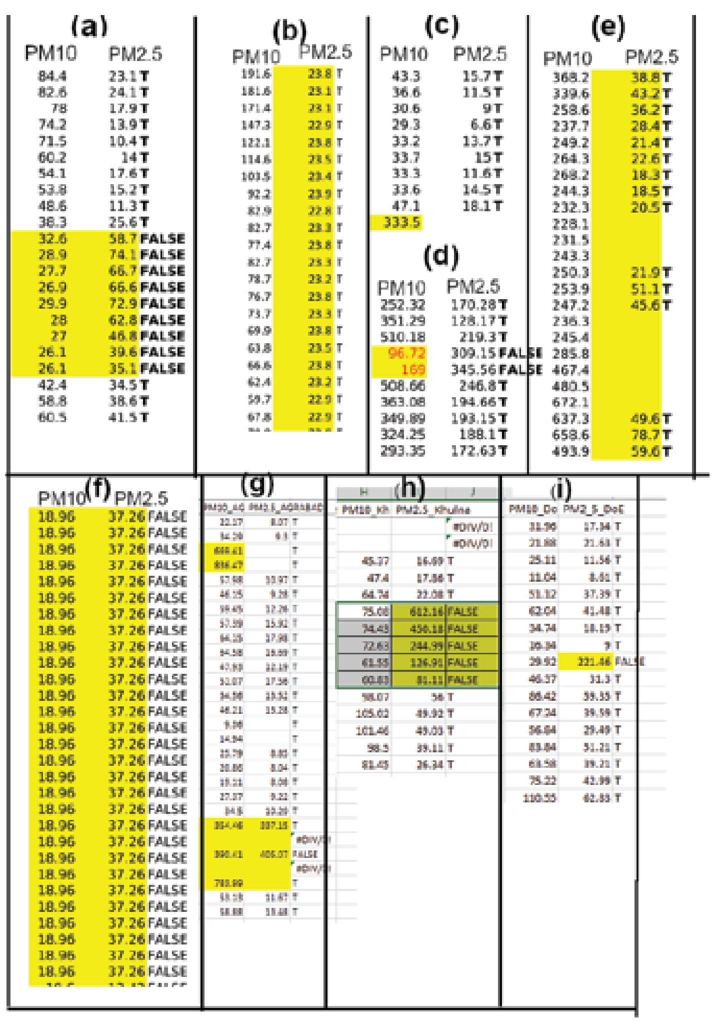
(iv) Data of a parameter should not be stick to a value for more than two hours;

(v) The ozone data should follow its urban/non-urban and day/night characteristics;

(vi) The data should follow seasonal characteristics;

Some examples of invalid data identifications are shown in Fig. 4; suspected data were screened out from the database before doing analysis.

**Fig. 4 (a) $PM_{2.5}$ were greater than $PM_{10}$, (b) $PM_{2.5}$ values stuck in a narrow band, (c) Sudden high value of $PM_{10}$, (d) Sudden low value of $PM_{10}$, (e) $PM_{2.5}/PM_{10}$ ratio suddenly become much lower than its typical seasonal values, (f) the values stuck on a value for hours, (g) Sudden very high values compared to the adjacent, (h) Exceptionally high values for $PM_{2.5}$, (i) Sudden high value for $PM_{2.5}$**



### 3.1.4 Data Analysis

This report is prepared based on analysis of air quality data generated from 2018 to 2023 in 31 stations running throughout the country. Microsoft Excel and R were used to manage and analyze the data. For being the pollutants of main concern in the whole country, $PM_{10}$ and $PM_{2.5}$ concentrations were extensively analyzed with illustrations. The trends were analyzed using both line and box-whisker plots of the 24-hour averaged $PM_{10}$ and $PM_{2.5}$ concentrations. Data aggregations to the coarser average (i.e. 24-h from hourly data) were performed with 70% data availability for daily averages and 65% for annual averages; For example, daily averages were calculated only for those days that have at least 17 hourly data. Those days having less than 17 hourly data were excluded from trend analysis and statistical calculations. Thus, monthly averages were calculated only for those months that have at least 21 daily data and annual averages for the year having at least 237 daily data. For gaseous parameters, data aggregations were done according to the averaging period for which standards are available.

Stations were grouped as per their positions within the boundary of the country; 12 stations (Dhaka – 5, Tongi, Savar, Gazipur, Narayanganj, Narsindi, Tangail & Faridpur) were grouped as located in the middle of the country, 06 stations (Gopalganj, Jashore, Khulna, Bagerhat, Satkhira & Barisal) were grouped as located to the southern region, 07 stations (Kumilla, Noakhali, Feni, Chattogram – 3 & Cox's Bazar) were grouped as located to the southeastern region, 04 stations (Rajshahi, Bogura, Mymensingh and Rangpur) were grouped as located to the north to western region, and Sylhet and Brahmanbaria were grouped as northeastern region.

In most of the stations, data analysis of the C-CAMS has been shown separately for the data capture rates of these type of stations not found very satisfactory.

## 3.2 Principles of Air Quality Monitoring

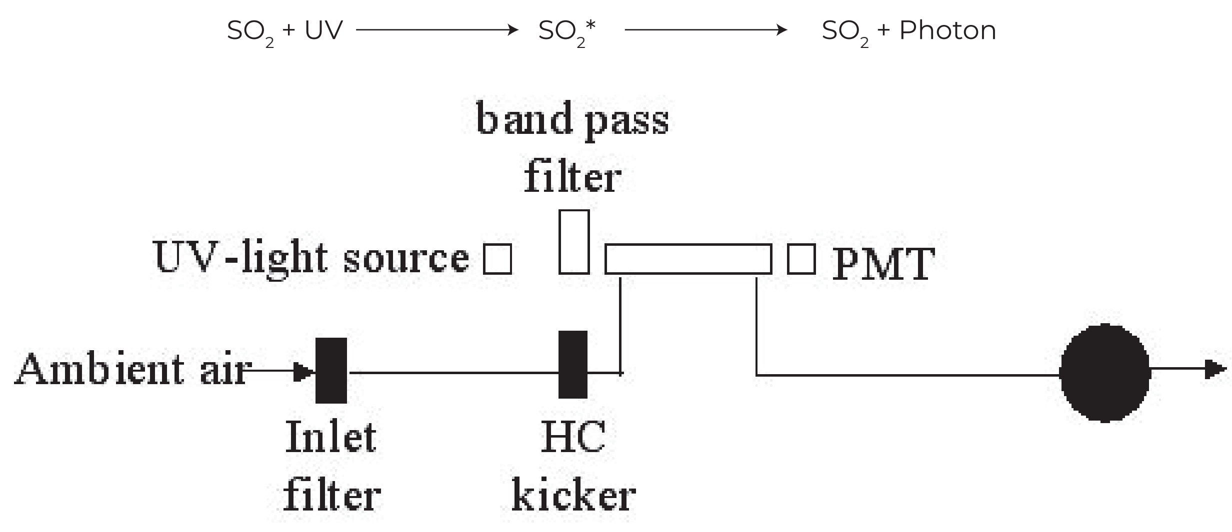
Department of Environment has deployed air monitoring systems, which are automated and equivalent grade system as per the USEPA guideline, at all of the stations in the country, although the size of the systems is different for CAMS and C-CAMS. PM monitors and the gas analyzers of all of the CAMSs and C-CAMSs run on the principles that are internationally acceptable for air quality monitoring. The data thus generated are certified for getting published and referenced. The method of analysis of the analyzers are shortly briefed with diagram in the following;

### 3.2.1 Sulfur Dioxide ($SO_2$)

The sulfur dioxide analyzer measures the concentration of sulfur dioxide present in the ambient air by Ultraviolet Fluorescence method. The analyzer works as follows:

1. Sample air passes through a particulate filter. This particulate filter removes particu-lates and other contaminants from the sample air.
2. The sampled air then goes through the hydrocarbon kicker, which removes hydrocar-bon from the sample.
3. After that, the sample enters into the fluorescence cell.
4. A zinc lamp is used as a UV source. This UV lamp supplies UV light of 214 nm wave-length which passes through an optical filter and enter in to the fluorescence cell.
5 In the fluorescence cell, $SO_2$ molecules absorb the UV light and become excited.
6. $SO_2$ molecules emit radiation as they return to ground state from the excited state. This radiation produces small electric current which is detected by a Photo Multiplier Tube [PMT]. The intensity of this current is directly proportional to the concentration of $SO_2$.

**Fig. 5 Simple flow diagram of $SO_2$ analyzer**



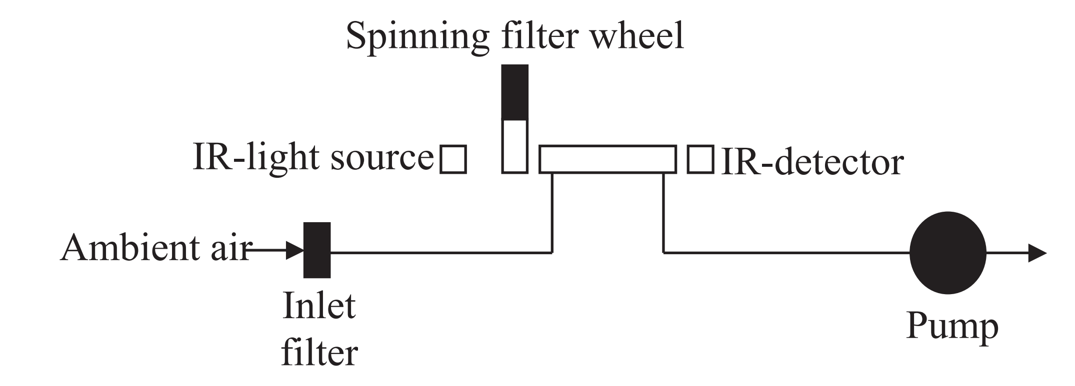

### 3.2.2 Carbon Monoxide (CO)

CO analyzer measures the concentration of carbon monoxide in the ambient air by **Non-Dispersive Infrared Radiation [NDIR] method.** It is also called Gas Filter Wheel Correlation method. The analyzer works as follows:

1. Sample air passes through a particulate filter which removes particulates and other contaminants from the sample air.
2. The sampled air goes to the measurement cell through a pre-heater that warms the air.
3. There is also an Infrared (IR) light source that generates infrared radiation.
4. After the IR source, a gas filter correlation wheel is present which rotates by a motor. This gas filter correlation wheel includes two gas-filled chambers: (i). A reference chamber which is filled with CO [500,000 ppm], and (ii) A measure chamber which is filled with nitrogen.
5. When IR radiation pass through the reference chamber it removes all of the CO sensi-tive wavelengths (centered at 4.7 microns) and allow the CO insensitive wavelengths to pass the reference chamber.
6. The IR then enters into the measurement cell and absorbed by sample air. Finally, it reaches the IR detector and the detector measures the amount of absorption as voltage signal.
7. Again, the IR radiation passes through the measure chamber which is filled with nitro-gen and passes the CO sensitive wavelengths.
8. Then this IR enter into the measurement cell and absorbed by sample air i.e., CO. Fi-nally, it reaches the IR detector and the detector measure the amount of absorption as voltage signal.

The difference between these two signals is used to compute the concentration of CO.

**Fig. 6 Simple flow diagram of CO analyzer**




## 3.2.3 Nitrogen Oxides ($NO_x$)

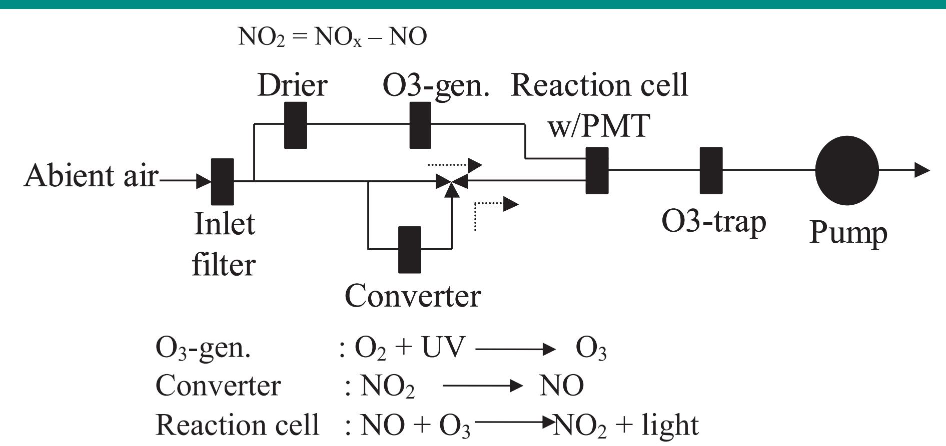
The NOx analyzer measures the concentration of oxides of nitrogen present in the ambient air by Chemiluminescence method. The analyzer works as follows:

1. The sample air pass through a micron filter which removes the unwanted particulates from the sample air.
2. Then the sample goes to the chemiluminescence reaction cell through one way. In the cell, NO molecules present in the sample react with ozone to form excited $NO_2$*.

   $NO + O_3 \longrightarrow NO_2^* + O_2$ [Chemiluminescence Reaction]

   The ozone comes to the cell from ozone generator which produces10,000 ppm ozone.
3. This excited $NO_2$* molecule returns to the ground state and emits radiation. This radi-ation is detected by Photo Multiplier Tube [PMT] that produces a small electric cur-rent. This current is directly proportional to the concentration of NO.
4. On the other way sample air goes to the molycone converter which converts $NO_2$ to NO.
5. Then this sample air which contains NO and $NO_2$ [as converted NO] goes to the measurement cell. Again react with ozone and create a chemiluminescence reaction, produce radiation and current. The intensity of current is directly proportional to the total concentration of NO i.e., NOx
6. $NO_2$ concentration is measured by the subtraction of NO concentration from NOx concentration.

**Fig. 7 Simple flow diagram of NOx analyzer**

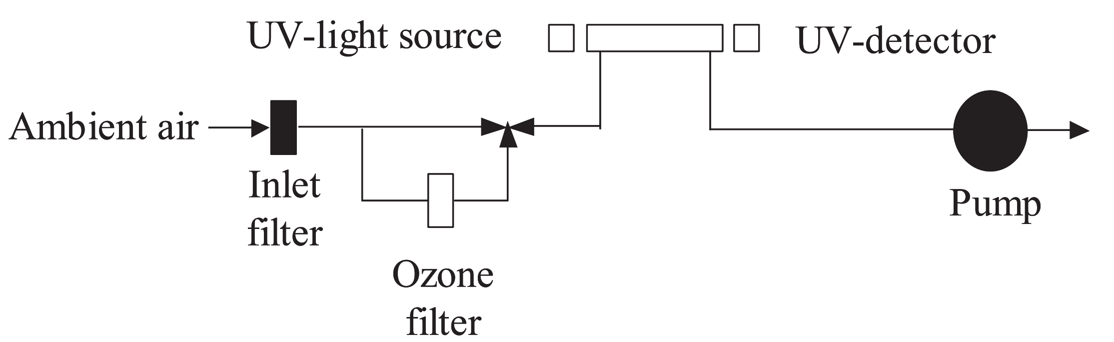


## 3.2.4 Ozone ($O_3$)

The $O_3$ analyzer measures the concentration of ozone present in the ambient air by Ultra Violet Absorption method. It is also called UV Photometry. The analyzer works as follows:

1. The sample air goes through the particulate filter to remove particulates and other con-taminants from the sample air.
2. Then the sample enters into the measurement cell.
3. A mercury vapor lamp is used to emit UV light at 254 nm wave length. In the measurement cell this UV light is absorbed by the sample.
4. After absorption, the intensity of UV light is measured.
5. Again the sample enters into the measurement cell through an ozone scrubber. The ozone scrubber contains manganese dioxide which removes only ozone from the sample air. This scrubbed sample absorbs UV light in the measurement cell and intensity of UV light is measured again.
6. Finally, the difference between the two intensity of UV light (absorption by non-scrubbed sample and absorption by scrubbed sample) is used to determine the ozone concentration.

**Fig. 8 Simple flow diagram of $O_3$ analyzer**




## 3.2.5 Particulate Matter ($PM_{10}$ & $PM_{2.5}$)

When beta rays pass through a material, they can be absorbed, reflected or pass directly through. The attenuation of intensity in beta rays is proportional to the amount of material present. The attenuation through most materials is relatively consistent and is based on the electron density of the material (calculated by dividing the atomic number by the atomic mass).

The attenuation for most materials is about 0.5, except for hydrogen and heavy metals. Beta attenuation has been used in production lines as a quality control check of product thickness for more than 40 years. For example, in the production of cellophane plastic wrap, a beta gauge is used to ensure that the thickness of the cellophane remains within specification.

The principle behind beta attenuation particulate sampling instruments (beta gauge) is that energy is absorbed from beta particles as they pass through PM collected on a filter media. Beta gauge instruments have been designed to take advantage of this scientific principle to monitor/measure PM concentrations. The attenuation due to only the PM is measurable if a baseline beta count through just the filter can be established prior to sampling. The difference between the baseline beta count and the beta count after sampling is directly proportional to the mass of PM in the sample.

The two main components of a beta attenuation measuring system are the beta source and the detector. The beta source must be selected so that: it has an energy level high enough for the beta particles to pass through the collection media (i.e., the filter tape) and the particulate, it has enough source material so that a high count rate is present, it is stable over long periods of time, and it does not present a danger to the health of personnel that come into contact with the instrument. The source of choice has been Carbon-14 because: it has a safe yet high enough energy level, it has a half-life of 5,568 years, and it is relatively abundant. Many different types of detectors can quantify beta particle counts, but the ones most widely used are the Geiger Mueller counter or a photodiode detector.

The beta gauge works by measuring beta counts before and after collecting PM on a filter media. The instrument will measure a clean area of the filter media for a fixed period to determine the baseline (e.g., 2 minutes), then it will advance that area of the filter to a sampling apparatus for another set period of time (e.g., 50 minutes), and finally return that area of the filter to the detector for the same period used to establish the baseline reading. The difference in the beta count can be directly correlated to particulate mass through calibration of the instrument using a filter media containing a known mass of a particulate-like material.

The beta gauge instrument is designed to provide a mass concentration. The instrument measures the volume of gas extracted through the stack/duct for each sample interval and calculates mass concentration in the specified units (e.g., $\mu g/m^3$)

## 3.3 Air Quality Index (AQI)

Air Quality Index (AQI) is a value calculated directly from the range of the concentrations of the pollutants. To make the people aware of the status of the air quality in their region, AQI is publicized along with the associated health impact and cautions for the vulnerable people. AQI is caluculated based on the concentrations of 5 criteria pollutants, PM ($PM_{2.5}$ & $PM_{10}$), $NO_2$, CO, $SO_2$ and $O_3$. AQI value tells how much clean or polluted the air is at a certain time and the associated health impacts are informed alongside the value. It is a number ranging from 0 to 500. The higher the AQI, the greater is the risk from the air pollution, and thus indicates greater public health concern.

The following equation (eq. 1) adopted by the United States Environment Protection Agency (USEPA) is used to calculate the AQI in Bangladesh too.

$$I_p=I_{Lo}+(C_p-BP_{Lo})*(I_{Hi}-I_{Lo})/(BP_{Hi}-BP_{Lo}) \quad \text{...eq. 1}$$

Where,

$I_p$ = The Index Value for Pollutant P

$C_p$ = Concentration of Pollutant P

$BP_{Hi}$ = The Break Point that is greater than or equal to Cp

$BP_{Lo}$ = The Break Point that is less than or equal to Cp

$I_{Hi}$ = The AQI value that is corresponding to $BP_{Hi}$

$I_{Lo}$ = The AQI value that is corresponding to BPLo

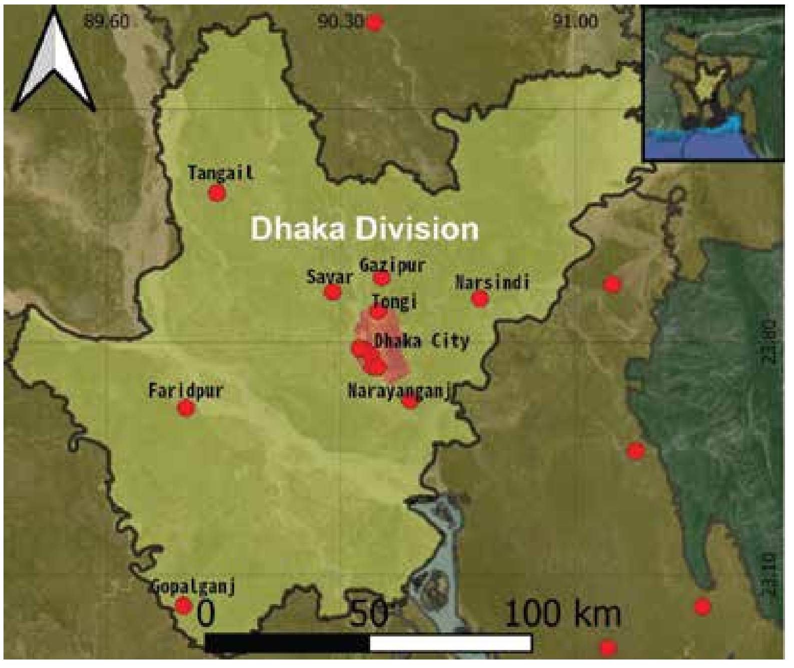
An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, which is the level that set by the mandated Environment Protection Agency (e.g., for Bangladesh Department of Environment) to protect public health. AQI values below 100 are generally thought of as satisfactory. When AQI values are between 101 and 150, air quality is considered to be unhealthy for certain sensitive groups of people. Then as AQI values get higher the categories of AQI changes its level upto hazardous mode. The AQI Categories for Bangladesh is given in Table 4.

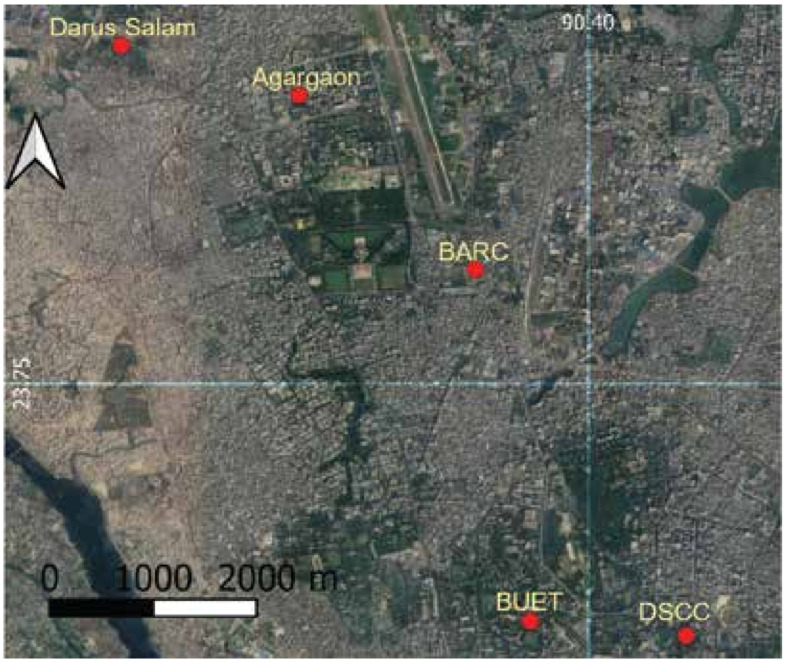
**Table 4 Air Quality Index (AQI) for Bangladesh**

| AQI Value | Level of Health Concern | | Colour |
|---|---|---|---|
| | Status | Health Implication | |
| 0-50 | Good | Air quality is considered satisfactory, and air pollution poses little or no risk. | Green |
| 51-100 | Moderate | Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution. | Yellow |
| 101-150 | Unhealthy for Sensitive Groups | Members of sensitive groups may experience health effects. The general public is not likely to be affected. | Orange |
| 151-200 | Unhealthy | Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects. | Red |
| 201-300 | Very Unhealthy | Health warning of emergency condition. The entire population is more likely to be affected. | Purple |
| 301-500 | Hazardous | Health alert: everyone may experience more serious health effect. | Maroon |

# 4 Data Analysis Results Dhaka Division

**Maps of Dhaka division (top) and Dhaka city (bottom) with positions of air monitoring stations (red balls)**



## 4.1 Introduction

Dhaka division is located in the middle of Bangladesh; with its geographical extent from 22.85N to 24.79N latitude and 89.30E to 91.25E longitude, the division has an area of 20,508.8 $km^2$ and population of 44215759. The land is mainly flat with average topography height of 9.0m. Tree cover of this region is about 6.9% (www.globalforestwatch.org). Major sources of air pollution are brick kilns, cement & still mills, power plants, vehicles, dust sources, etc.

Overall 13 stations are running within the boundary of Dhaka division; air quality data from 12 stations is analyzed in this chapter; Gopalganj station being located at the southern most boundary of this division is studied with the south zone stations.

Dhaka city has 3 CAMS and 2 C-CAMS. The city extends from latitude 23.69N to 23.89N and longitue 90.33E to 90.44E, having an area of ~306$km^2$ and population of 10295786. The city has only 2.0% of tree cover, reported in the Daily Financial Express on 28 Aug. 2023. Major air pollution sources are brick kilns, vehicles, cement & still mills, dusts, etc.

Gazipur and Narayanganj are neighboring districts of Dhaka; both the cities are industrial in nature. Gazipur city has an area of 329 $km^2$ and population more than 4.0 million. The site with CAMS is approximately 15 meters from a small road with little traffic and 0.5 kilometers from a national rail line. Apart from some local buildings, surroundings of this area is mostly open.

With 1.5 million inhabitants, the city of Narayanganj stands at about 30 km southeast of the capital Dhaka. The city has a busy river port. It serves as a center of commerce and industry, especially the jute trade and processing plants, and the textile sector of the country.

Narsindi is a district with an area of ~1,150.14 square kilometers and population of 224,944. It is a densely industrial area; many industries like textile, flour, jute, ice factories, etc. are located around the air monitoring station.

Tangail is a district with area of 3414.28 $km^2$ and population of 3.6 million. Agriculture is the prime business in this region, but some industries are also established in recent days. The district is located to the northwest from Dhaka and has a tropical climate.

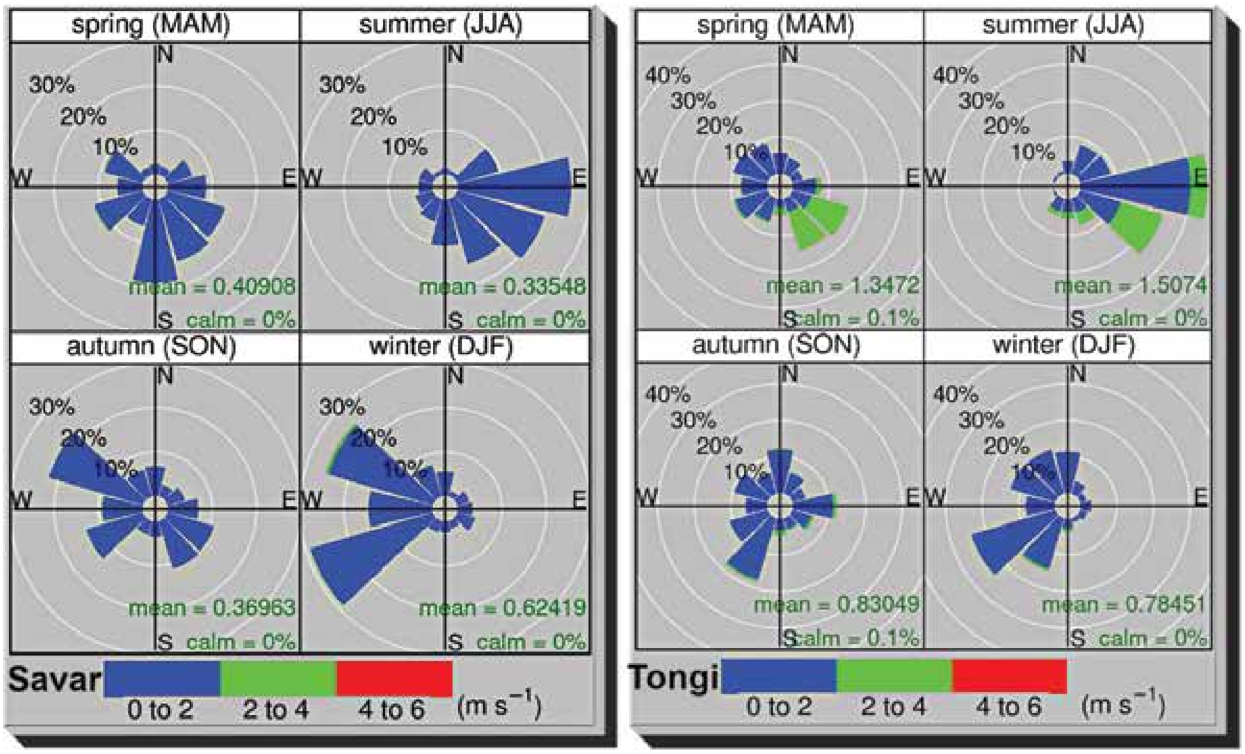
## 4.2 Meteorology

The topography of Dhaka being mostly flat, meteorology throughout the division could be considered almost the same, the urban effect although may cause some deviations in the Dhaka city area. The meteorology parameters captured at the Darus Salam, Savar and Tongi stations are shown in the following;

### 4.2.1 Wind Rose

Seasonal wind roses drawn on Savar and Tongi stations show mostly similar wind pattern, may be considered typical for Dhaka (Fig. 4-1). Wind roses show clear distinction in wind pattern in dry and wet season; while the air dominantly blows from the south and southeast directions during the month of April to September, it blows from the north and northwest directions during November to March. October and November months are characterized with low wind speeds while April to August with high speeds.

**Fig. 4-1 Seasonal wind-roses at Savar (left) and Tongi (right) Stations**




## 4.2.2 Temperature, Relative Humidity, Atm. Pressure & Solar Radiation:

Dhaka experiences high temperature (with max at~42ºC) from March to September. The temperature starts falling from the month of October till January (with min. at~8.5ºC), and starts rising again from February (Fig.4-2a). March to April is characterized with low cloud cover, high solar radiation, high temperature and low relative humidity. Rainy season in Bangladesh (May–October) is characterized with high temperature and high relative humidity with large cloud cover and heavy rainfall; excess downpour during this time helps wash-out the pollutants from the atmosphere. Calm weather, low solar radiation and rare rainfall are characteristic meteorology of winter (December–January); lower mixing height and strong temperature inversion at night aid in increasing pollution level during the winter season. Mixing height at night in Dhaka in the month of January may come down to a height of 31m. High relative humidity in December and January (Fig. 4-2b) is the result of saturation near ground due to lowering temperature.

Fig. 4-2 (a) hourly temperature (°C), (b) weekly relative humidity (%), (c) daily solar radiation (W/m²), and (d) hourly atm. Pressure (hPa) at Darus Salam Station, Dhaka

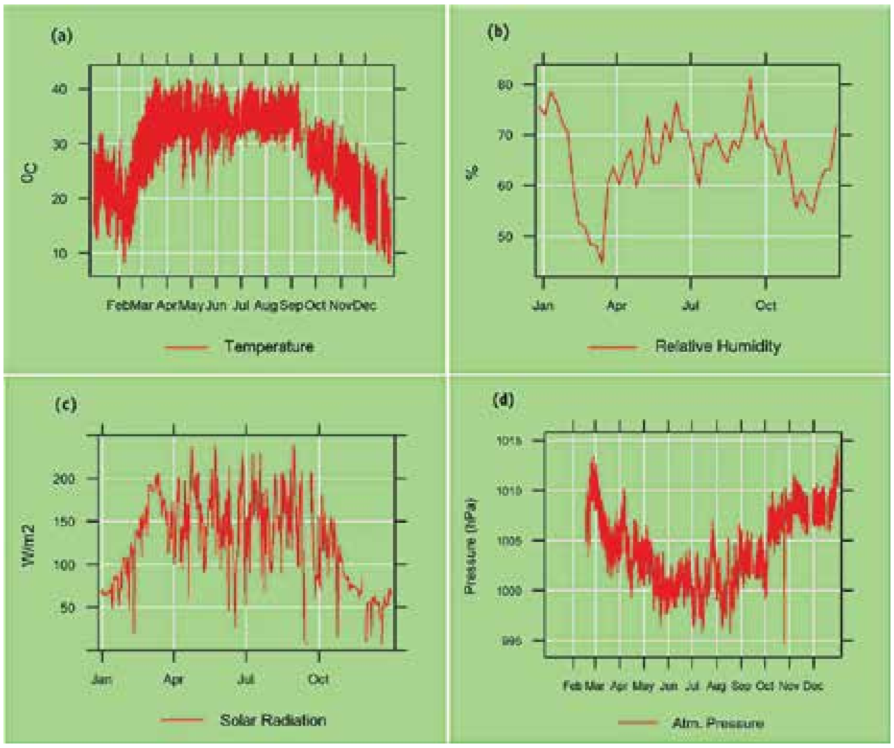
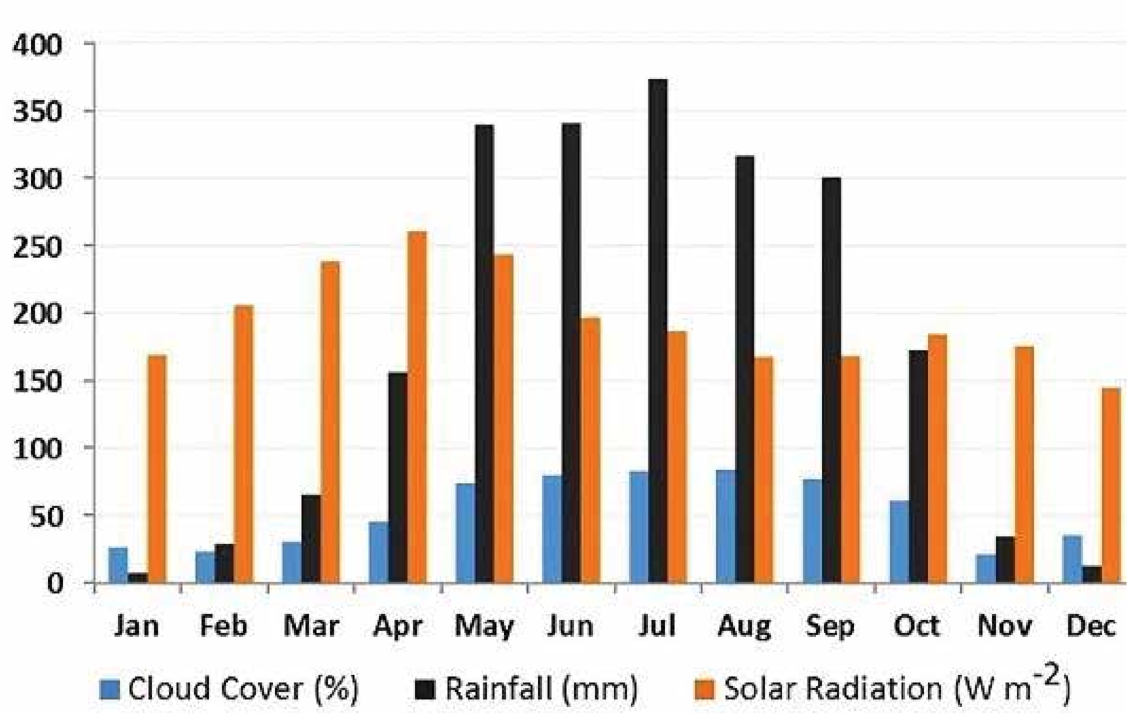



Fig. 4-3 Typical monthly Cloud Cover, Rainfall and Solar Radiation in Dhaka



## 4.3 Criteria Air Pollutants

### 4.3.1 Particulate Matters ($PM_{2.5}$ & $PM_{10}$)

Table 4-1 and Table 4-2 show the year-wise overview of the daily $PM_{2.5}$ and $PM_{10}$ concentrations at the stations; the daily concentrations were calculated only when at least 17 hourly concentration data were available in a day. In these tables statistical parameters were determined when annual data capture rates were greater than 65%.

Among those stations Narayanganj was found the most polluted with average annual $PM_{2.5}$ conc. of 103.4 µg/m$^3$ and $PM_{10}$ conc. of 200.0 µg/m$^3$, while Narsindi with annual $PM_{2.5}$ conc. of 61.6 µg/m$^3$ and $PM_{10}$ conc. of 128.6 µg/m$^3$ was the least polluted. Narsindi is only 40 km away to the northeast direction from Narayanganj but was enjoying air with PM concentrations about half of that in Narayanganj which experienced annual $PM_{2.5}$ concentrations greater than the national limit value by a factor of eight or more in 2023. It was horrifying to observe that daily $PM_{2.5}$ concentrations in Narayanganj were more than 3 times of the national limit value in about 90 days (mostly dry season) of the year 2023. $PM_{2.5}$ emissions from the busy city of Dhaka and industrial areas of Savar and Gazipur might have impacted the building-up of the $PM_{2.5}$ concentration during dry season in Narayanganj. Average annual $PM_{2.5}$ concentrations in other stations like Agargaon, BARC, Darus Salam, Savar, Gazipur are almost the same with annual $PM_{2.5}$ concentrations of 79.79 µg/m$^3$, 97.9 µg/m$^3$, 95.7 µg/m$^3$, 91.6 µg/m$^3$ and 98.3 µg/m$^3$ respectively.

The yearly data shown in the tables are certifying almost steady status of the PM concentrations in Dhaka and the surroundings for the last 06 years, the values changed to some extent from year to year though. Sudden increase in the concentrations in any year at a station could be attributed to increased activities of constructions around and favorable meteorology.

Within the Dhaka city Agargaon station is located in less traffic area while the BARC and Darus Salam stations are located near busy roads, which might be the cause Agargaon station was getting 10–15% less PM concentrations compared to the other two.

Compared to Dhaka Gazipur has small population size and less traffic flow; the station is also located in some remote areas and upwind (dry seasonal) from Dhaka city; still, $PM_{2.5}$ concentrations at this station were very similar to those at the stations of Dhaka.

Similar interpretations of the statistics of both $PM_{2.5}$ and $PM_{10}$ for other stations can be made from Table 4-1 and Table 4-2.

**Table 4-1 Overview of the daily $PM_{2.5}$ Concentrations ($\mu g/m^3$) captured at the stations of Dhaka Divisions**

| Station | Par | Year | Data capture (%) | Mean | 25 percentiles | 50 percentiles | 75 percentiles | Max. |
|---|---|---|---|---|---|---|---|---|
| Darus-Salam, Dhaka | $PM_{2.5}$ | 2018 | 83.6 | 94.0 | 37.67 | 71.61 | 142.3 | 314.1 |
| | $PM_{2.5}$ | 2019 | 65.7 | 98.4 | 43.0 | 82.2 | 141.3 | 288.3 |
| | $PM_{2.5}$ | 2020 | 87.7 | 80.8 | 31.4 | 52.3 | 125.6 | 293.2 |
| | $PM_{2.5}$ | 2021 | 80.0 | 98.6 | 39.0 | 75.6 | 153.4 | 303.8 |
| | $PM_{2.5}$ | 2022 | 90.4 | 96.9 | 41.8 | 65.7 | 143.2 | 366.3 |
| | $PM_{2.5}$ | 2023 | 93.4 | 105.8 | 48.0 | 85.0 | 149.3 | 422.5 |
| BARC, Farmgate, Dhaka | $PM_{2.5}$ | 2018 | 85.5 | 99.8 | 48.1 | 76.9 | 132.8 | 381.3 |
| | $PM_{2.5}$ | 2019 | 88.2 | 89.3 | 44.3 | 77.9 | 129.4 | 248.5 |
| | $PM_{2.5}$ | 2020 | 81.6 | 84.4 | 22.2 | 62.7 | 146.5 | 260.7 |
| | $PM_{2.5}$ | 2021 | 92.9 | 119.4 | 53.4 | 102.1 | 175.0 | 355.4 |
| | $PM_{2.5}$ | 2022 | 91.0 | 108.6 | 55.9 | 87.3 | 149.6 | 357.9 |
| | $PM_{2.5}$ | 2023 | 78.9 | 86.0 | 42.6 | 62.2 | 106.0 | 387.6 |
| Agargaon, Dhaka | $PM_{2.5}$ | 2023 | 77.0 | 79.7 | 34.0 | 64.0 | 105.0 | 335.8 |
| Savar | $PM_{2.5}$ | 2020 | 88.5 | 94.4 | 37.4 | 64.2 | 130.9 | 364.0 |
| | $PM_{2.5}$ | 2021 | 32.0 | – | – | – | – | – |
| | $PM_{2.5}$ | 2022 | 84.0 | 96.5 | 44.6 | 74.4 | 144.2 | 317.6 |
| | $PM_{2.5}$ | 2023 | 83.3 | 84.0 | 39.2 | 71.6 | 115.4 | 243.7 |
| Gazipur | $PM_{2.5}$ | 2018 | 36.4 | – | – | – | – | – |
| | $PM_{2.5}$ | 2019 | 52.2 | – | – | – | – | – |
| | $PM_{2.5}$ | 2020 | 38.9 | – | – | – | – | – |
| | $PM_{2.5}$ | 2021 | 85.5 | 98.9 | 38.7 | 81.5 | 155.6 | 322.8 |
| | $PM_{2.5}$ | 2022 | 68.0 | 96.1 | 44.0 | 76.7 | 140.0 | 284.6 |
| | $PM_{2.5}$ | 2023 | 80.0 | 100.0 | 45.3 | 81.6 | 145.9 | 352.6 |
| Narayanganj | $PM_{2.5}$ | 2018 | 67.4 | 108.0 | 29.0 | 73.2 | 190.6 | 343.3 |
| | $PM_{2.5}$ | 2019 | 75.0 | 90.7 | 25.6 | 53.3 | 153.5 | 325.4 |
| | $PM_{2.5}$ | 2020 | 75.0 | 87.3 | 24.6 | 51.9 | 142.3 | 311.5 |
| | $PM_{2.5}$ | 2021 | 60.0 | – | – | – | – | – |
| | $PM_{2.5}$ | 2022 | 57.0 | – | – | – | – | – |
| | $PM_{2.5}$ | 2023 | 81.9 | 127.5 | 46.2 | 57.2 | 198.6 | 412.3 |
| Narsindi | $PM_{2.5}$ | 2020 | 46.8 | – | – | – | – | – |
| | $PM_{2.5}$ | 2021 | 64.1 | – | – | – | – | – |
| | $PM_{2.5}$ | 2022 | 84.7 | 57.4 | 19.8 | 41.7 | 93.0 | 180.0 |
| | $PM_{2.5}$ | 2023 | 79.7 | 65.8 | 18.4 | 49.1 | 105.6 | 227.0 |

-Statistics not shown for low data availability (< 65.0%)

**Table 4-2 Overview of the daily $PM_{10}$ Concentrations ($\mu g/m^3$) captured at the stations of Dhaka Divisions**

| Station | Par | Year | Data capture (%) | Mean | 25 percentiles | 50 percentiles | 75 percentiles | Max. |
|---|---|---|---|---|---|---|---|---|
| **Darus-Salam, Dhaka** | $PM_{10}$ | 2018 | 83.8 | 173.0 | 80.8 | 143.4 | 239.0 | 560.3 |
| | $PM_{10}$ | 2019 | 83.8 | 144.2 | 62.9 | 113.3 | 203.6 | 481.2 |
| | $PM_{10}$ | 2020 | 77.8 | 122.0 | 55.9 | 100.1 | 179.1 | 373.5 |
| | $PM_{10}$ | 2021 | 69.6 | 133.0 | 59.4 | 110.6 | 202.8 | 374.3 |
| | $PM_{10}$ | 2022 | 83.6 | 134.7 | 72.2 | 110.9 | 183.2 | 438.4 |
| | $PM_{10}$ | 2023 | 78.9 | 171.5 | 81.4 | 134.1 | 249.6 | 601.0 |
| **BARC, Farmgate, Dhaka** | $PM_{10}$ | 2018 | 89.3 | 168.6 | 75.3 | 133.9 | 214.5 | 652.0 |
| | $PM_{10}$ | 2019 | 89.3 | 157.8 | 99.3 | 149.8 | 207.7 | 485.9 |
| | $PM_{10}$ | 2020 | 87.4 | 117.0 | 38.6 | 90.4 | 197.7 | 343.0 |
| | $PM_{10}$ | 2021 | 94.8 | 191.3 | 104.4 | 172.3 | 265.2 | 523.3 |
| | $PM_{10}$ | 2022 | 78.4 | 177.1 | 112.1 | 154.4 | 228.9 | 481.9 |
| | $PM_{10}$ | 2023 | 32.1 | – | – | – | – | – |
| **Agargaon, Dhaka** | $PM_{10}$ | 2023 | 81.6 | 139.9 | 61.4 | 112.5 | 196.5 | 537.3 |
| **Savar** | $PM_{10}$ | 2020 | – | – | – | – | – | – |
| | $PM_{10}$ | 2021 | 44.9 | – | – | – | – | – |
| | $PM_{10}$ | 2022 | 77.8 | 146.5 | 73.1 | 118.3 | 206.2 | 481.1 |
| | $PM_{10}$ | 2023 | 81.4 | | | | | |
| **Gazipur** | $PM_{10}$ | 2018 | 71.2 | 161.7 | 62.6 | 133.3 | 256.4 | 511.3 |
| | $PM_{10}$ | 2019 | 65.8 | 166.2 | 69.1 | 144.6 | 263.1 | 451.2 |
| | $PM_{10}$ | 2020 | – | – | – | – | – | – |
| | $PM_{10}$ | 2021 | 40.3 | – | – | – | – | – |
| | $PM_{10}$ | 2022 | 83.3 | 145.6 | 64.3 | 106.1 | 224.2 | 441.2 |
| | $PM_{10}$ | 2023 | 89.0 | 175.2 | 77.6 | 150.9 | 268.4 | 523.0 |
| **Narayanganj** | $PM_{10}$ | 2018 | 77.3 | 230.8 | 112.7 | 204.3 | 340.0 | 564.9 |
| | $PM_{10}$ | 2019 | 68.8 | 177.9 | 82.9 | 147.1 | 258.0 | 535.4 |
| | $PM_{10}$ | 2020 | 87.1 | 184.3 | 76.1 | 140.2 | 290.1 | 495.3 |
| | $PM_{10}$ | 2021 | 52.3 | – | – | – | – | – |
| | $PM_{10}$ | 2022 | 60.0 | – | – | – | – | – |
| | $PM_{10}$ | 2023 | 80.8 | 209.1 | 96.7 | 187.6 | 318.6 | 555.3 |
| **Narsindi** | $PM_{10}$ | 2020 | 56.4 | – | – | – | – | – |
| | $PM_{10}$ | 2021 | 76.0 | 133.0 | 50.6 | 111.6 | 184.8 | 460.7 |
| | $PM_{10}$ | 2022 | 82.0 | 124.7 | 48.8 | 88.9 | 203.8 | 430.8 |
| | $PM_{10}$ | 2023 | 74.8 | 128.1 | 51.4 | 103.9 | 178.6 | 444.4 |

-Statistics not shown for low data availability (< 65.0%)

For the purpose of air quality study the season of Bangladesh can be divided into three categories, i.e. winter season (November to January), summer season (February to April) and wet season (May to October) based on the meteorological conditions that influence the air quality greatly. Table 4-3 below shows PM level for different seasonal and diurnal scenarios, $PM_{2.5}$ to $PM_{10}$ ratio is also determined and shown. Winter was the most notorious season found for air pollution in the country. The increase in $PM_{2.5}$ concentrations in winter season compared to summer season varied from 28% in Agargaon to 77.6% in Narayanganj. Savar station experienced about 63% increase in $PM_{2.5}$ concentration in winter compared to summer season while in the other stations the concentrations of $PM_{2.5}$ gained about 40.0% in winter compared to summer season. Similarly, $PM_{2.5}$ concentrations in the stations were found 40–60% lower in wet season compared to summer season. It is also important to notice that the nighttime PM concentrations are all the season higher than the daytime concentrations. However, the increase in PM concentrations at night varied at different stations. The highest increase was found in Gazipur station where $PM_{2.5}$ and $PM_{10}$ concentrations at night in winter were found to increase respectively by about 66 and 85% compared to daytime concentrations, nighttime concentration increase in summer were 35 and 41% and in wet season 25 and 35% respectively. BARC station observed the lowest increase of PM concentrations at night compared to daytime concentrations (only 15% $PM_{2.5}$ and 14.1% $PM_{10}$ in winter, 2.6% $PM_{2.5}$ and 4.1% $PM_{10}$ in summer). For Savar and Narsindi stations, ~20% increase in $PM_{2.5}$ and 25-30% increase in $PM_{10}$ concentrations at night were observed during winter season. In most of the stations, the rates of increase in $PM_{10}$ concentrations at night were found higher than those in $PM_{2.5}$ concentrations all the season.

$PM_{2.5}$ to $PM_{10}$ ratio in winter season was found higher than summer and wet season. Darus Salam station had the highest ratio (0.76) in winter season while Narsindi station had the lowest (0.52). Compared to summer and wet season, the ratios at the stations in winter season were found greater by about 20-30%. Day and nighttime ratios in the stations irrespective of the seasons were found almost the same.

**Table 4-3 Seasonal and Diurnal statistics of PM concentrations (µg/m³) at the stations**

| Station | Pollutant | Winter[5] | | | Summer[6] | | | Wet[7] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean[1] | Day[2] | Night[3] | Mean[1] | Day[2] | Night[3] | Mean[1] | Day[2] | Night[3] |
| **Agargaon, Dhaka** | $PM_{2.5}$ | 136.0 | 116.7 | 158.8 | 106.0 | 98.8 | 115.4 | 42.0 | 39.7 | 45.4 |
| | $PM_{10}$ | 225.8 | 196.9 | 259.2 | 197.8 | 180.2 | 218.2 | 77.0 | 73.5 | 82.8 |
| | [4]$PM_{2.5}/PM_{10}$ | 0.60 | 0.60 | 0.60 | 0.55 | 0.55 | 0.56 | 0.50 | 0.50 | 0.503 |
| **BARC, Farmgate** | $PM_{2.5}$ | 159.0 | 148.5 | 171.4 | 113.8 | 112.4 | 115.4 | 58.2 | 58.1 | 58.3 |
| | $PM_{10}$ | 269.4 | 252.7 | 288.3 | 208.7 | 202.6 | 216.2 | 114.8 | 113.2 | 116.5 |
| | $PM_{2.5}/PM_{10}$ | 0.71 | 0.72 | 0.71 | 0.55 | 0.55 | 0.55 | 0.52 | 0.54 | 0.5 |
| **Darus-Salam** | $PM_{2.5}$ | 174.4 | 151.8 | 201.1 | 125.6 | 112.0 | 141.4 | 52.4 | 48.4 | 57.0 |
| | $PM_{10}$ | 231.0 | 196.0 | 272.8 | 196.2 | 173.7 | 222.7 | 86.3 | 80.0 | 93.6 |
| | $PM_{2.5}/PM_{10}$ | 0.76 | 0.76 | 0.76 | 0.60 | 0.60 | 0.60 | 0.60 | 0.61 | 0.59 |
| **Gazipur** | $PM_{2.5}$ | 159.1 | 121.8 | 201.5 | 120.0 | 103.0 | 139.0 | 48.7 | 43.6 | 54.5 |
| | $PM_{10}$ | 254.4 | 182.5 | 337.4 | 214.0 | 179.4 | 253.2 | 82.9 | 71.4 | 96.1 |
| | $PM_{2.5}/PM_{10}$ | 0.618 | 0.645 | 0.59 | 0.58 | 0.583 | 0.577 | 0.615 | 0.62 | 0.61 |
| **Narayanganj** | $PM_{2.5}$ | 222.0 | 192.4 | 255.7 | 125.0 | 109.5 | 143.0 | 51.3 | 47.3 | 56.2 |
| | $PM_{10}$ | 321.0 | 270.3 | 380.3 | 239.6 | 210.7 | 273.6 | 108.8 | 99.2 | 120.6 |
| | $PM_{2.5}/PM_{10}$ | 0.675 | 0.68 | 0.67 | 0.55 | 0.54 | 0.56 | 0.415 | 0.42 | 0.41 |
| **Savar** | $PM_{2.5}$ | 155.9 | 144.8 | 168.9 | 93.9 | 90.7 | 97.7 | 55.4 | 54.1 | 56.8 |
| | $PM_{10}$ | 219.0 | 198.9 | 242.7 | 173.0 | 159.2 | 189.5 | 86.8 | 82.8 | 91.5 |
| | $PM_{2.5}/PM_{10}$ | 0.725 | 0.74 | 0.70 | 0.585 | 0.60 | 0.57 | 0.625 | 0.64 | 0.61 |
| **Narsindi** | $PM_{2.5}$ | 116.6 | 106.0 | 128.5 | 82.2 | 75.3 | 89.6 | 29.1 | 27.1 | 31.5 |
| | $PM_{10}$ | 226.2 | 197.6 | 259.1 | 184.5 | 162.8 | 210.1 | 65.1 | 61.8 | 69.0 |
| | $PM_{2.5}/PM_{10}$ | 0.515 | 0.52 | 0.49 | 0.46 | 0.46 | 0.46 | 0.435 | 0.44 | 0.43 |
| **BUET, Dhaka** | $PM_{2.5}$ | 110.5 | 101.8 | 120.8 | 123.4 | 108.5 | 141.1 | 53.5 | 49.1 | 58.6 |
| | $PM_{10}$ | 154.3 | 147.1 | 162.6 | 164.1 | 147.5 | 183.7 | 76.2 | 71.4 | 81.6 |
| | $PM_{2.5}/PM_{10}$ | 0.705 | 0.68 | 0.73 | 0.76 | 0.74 | 0.78 | 0.725 | 0.72 | 0.73 |
| **Faridpur** | $PM_{2.5}$ | 127.9 | 104.2 | 154.9 | 87.8 | 77.6 | 100.3 | 50.7 | 46.4 | 55.7 |
| | $PM_{10}$ | 169.7 | 146.4 | 196.6 | 119.9 | 109.9 | 132.0 | 77.0 | 70.0 | 85.1 |
| | $PM_{2.5}/PM_{10}$ | 0.725 | 0.69 | 0.76 | 0.695 | 0.68 | 0.71 | 0.62 | 0.62 | 0.62 |
| **Tangail** | $PM_{2.5}$ | 198.4 | 188.7 | 209.5 | 150.2 | 137.3 | 165.1 | 67.0 | 64.3 | 76.9 |
| | $PM_{10}$ | 268.3 | 262.5 | 275.1 | 224.5 | 210.1 | 241.9 | 92.0 | 88.2 | 97.0 |
| | $PM_{2.5}/PM_{10}$ | 0.715 | 0.68 | 0.75 | 0.655 | 0.64 | 0.67 | 0.735 | 0.70 | 0.77 |

1 Seasonal means were calculated from the daily concentrations which were calculated from hourly concentrations, forcing 75% data availability.
2 Daytime considered the hours from 6:00 am to 18:00 pm
3 Nighttime considered the hours from 19:00 pm to 5:00 am
4 $PM_{2.5}$ to $PM_{10}$ ratio was calculated from the hourly values
5 November to January;
6 February to April;
7 May to October;

**Fig. 4-4 Time-series plots of daily $PM_{2.5}$ and $PM_{10}$ concentrations at the CAMS in Dhaka division; red horizontal lines indicate national limit value for $PM_{2.5}$ while the blue ones indicate $PM_{10}$ limit**

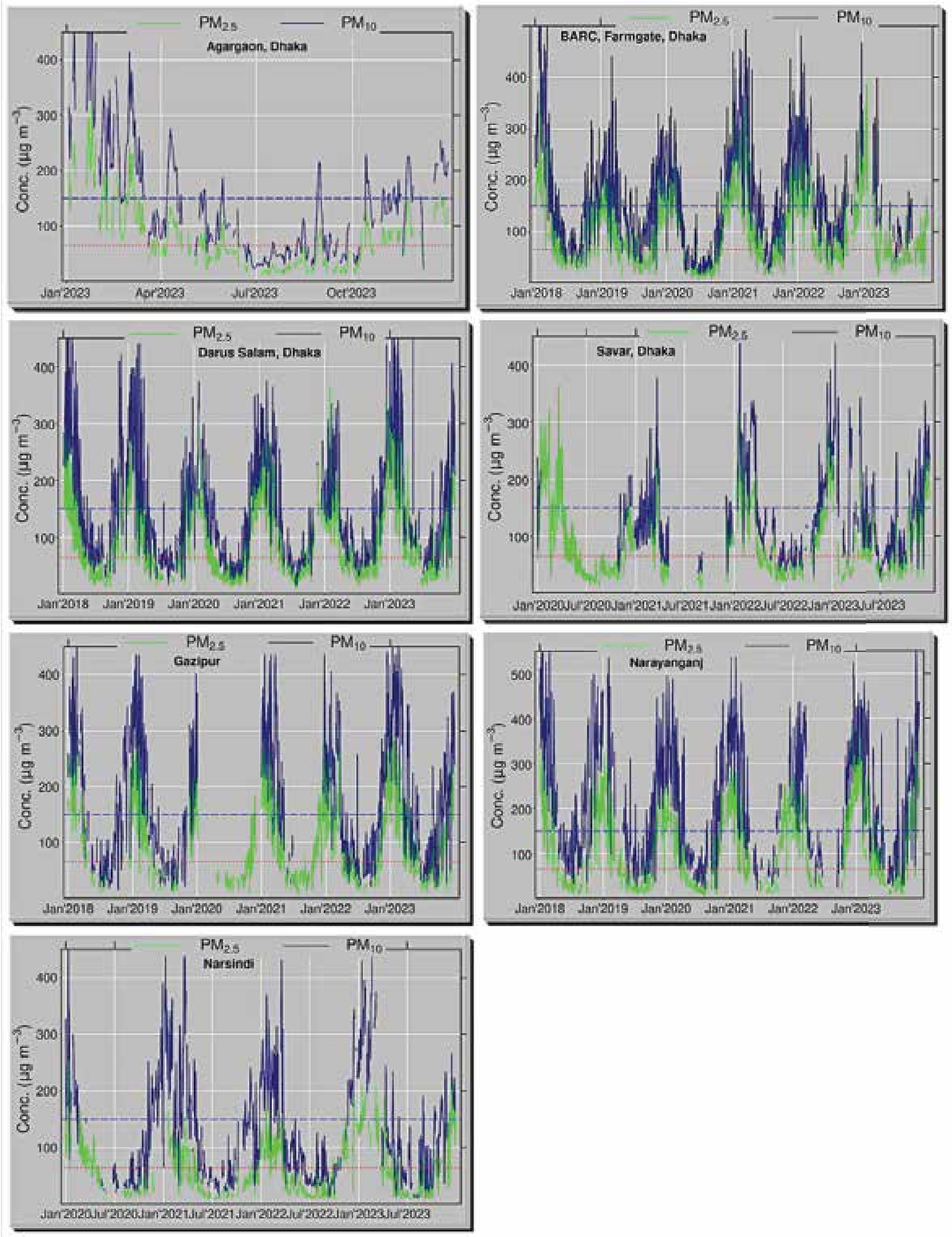


**Fig. 4-5 Time-series plots of daily $PM_{2.5}$ and $PM_{10}$ concentrations at the C-CAMS; the red horizontal lines indicate national limit value for $PM_{2.5}$ while the blue ones indicate $PM_{10}$ limit**

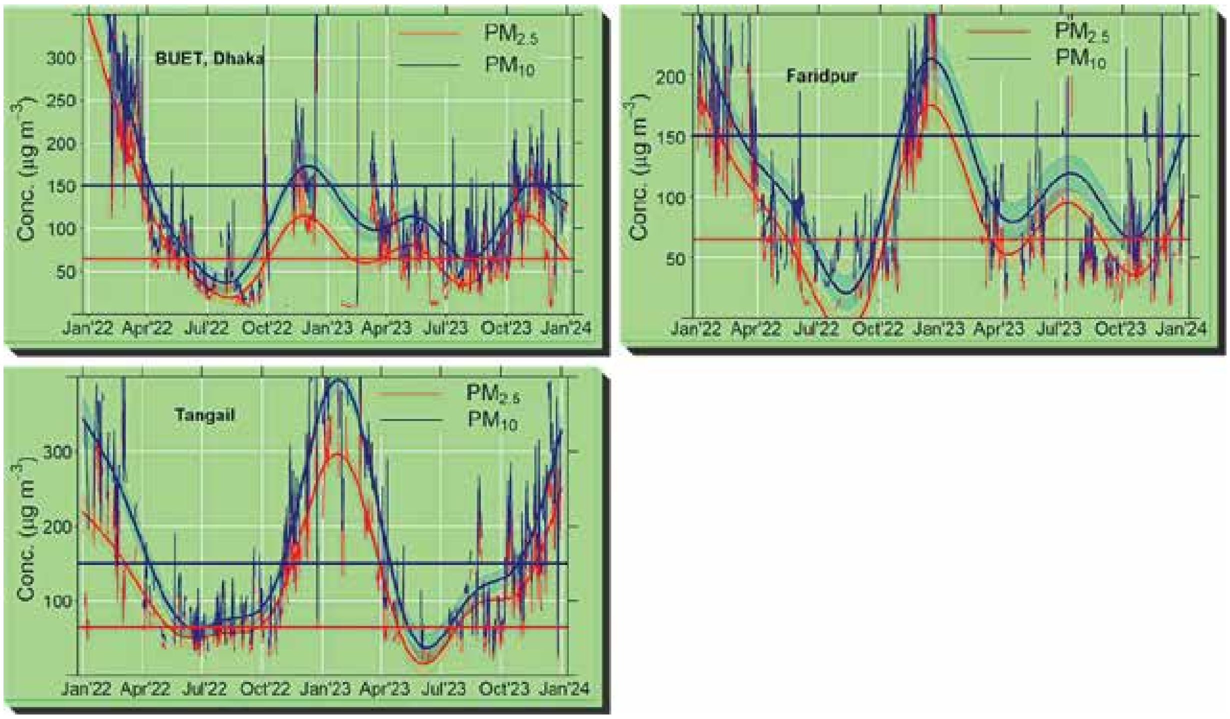
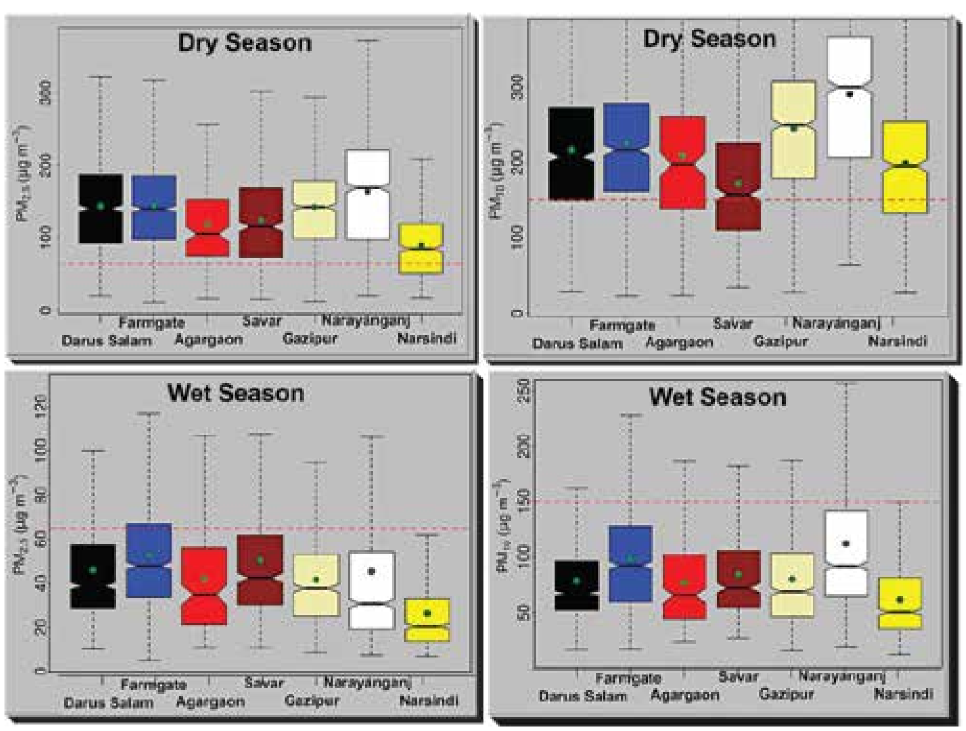



**Fig. 4-6 Box-Whisker plots of $PM_{2.5}$ and $PM_{10}$ concentrations in dry and wet seasons at the stations, green balls showing mean values while red lines show the national limit value**

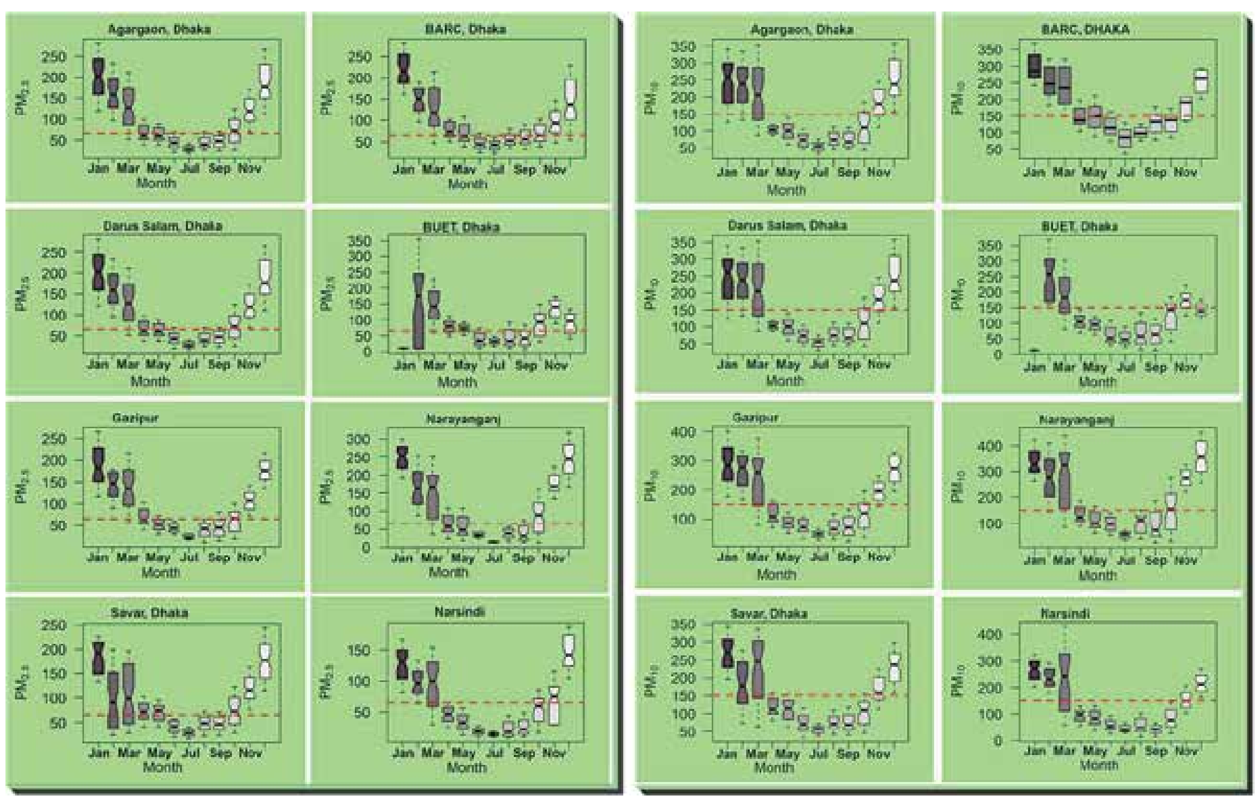


Monthly variations of $PM_{2.5}$ and $PM_{10}$ were almost similar in the cities (Fig.4-7); the box-whisker plots for every month shown in Fig.4-7 were drawn with the daily $PM_{2.5}$ and $PM_{10}$ concentrations at the stations. It is observable that daily $PM_{10}$ concentrations from April to October in most of the stations were keeping below the national limit value of 150 µg/m$^3$, with some difference at BARC and Narayanganj where daily $PM_{10}$ concentrations in some days of the wet season, especially in the month of April, May and October, were found violating the standard line (Fig.4-7). Contrasted to the wet season, dry seasonal months (November to March) were mostly violating due to exceeding $PM_{10}$ concentrations.

The month of January was found to be the most polluted month at the stations followed by February and December in terms of $PM_{10}$ concentrations although pollution level in March was also very acute and in Narayanganj, Savar and Narsindi stations March was found to be the second most polluted month.

$PM_{2.5}$ has some different characteristic compared to $PM_{10}$– January and December were the most polluted months followed by February and March (Fig.4-7). Unlike $PM_{10}$ concentrations, $PM_{2.5}$ concentrations were found to exceed about 50% of the wet seasonal days.

**Fig. 4-7 Box-whisker plots of monthly $PM_{2.5}$ concentrations (µg/m$^3$) (left) and $PM_{10}$ concentrations (µg/m$^3$) (right) at the stations; red line shows the Bangladesh Standard**



**Diurnal Variations** $PM_{10}$ concentrations at the stations decreased remarkably over the night hours during dry season (Fig. 4-8) although $PM_{2.5}$ concentrations did not fall that much over the night hours, except at Gazipur and Narsindi stations. However, both $PM_{10}$ and $PM_{2.5}$ concentrations got a peak at 9:00 am, perhaps as an impact of office going vehicle rush, then fell sharply up to 6:00 pm from when both the concentrations rose greatly up to 9:00 – 11:00 pm, the extents of evening hike in PM concentrations were although not similar at the stations; Narayanganj, Gazipur and Darus Salam stations were found having stronger hike while the sub-urban stations (Narsindi, Savar) having comparatively mild peak (Fig. 4-8).

Darus Salam, BARC, Agargaon, Gazipur and Savar stations showed similar pattern in weekday $PM_{2.5}$ concentrations during dry season; all of the stations experienced comparatively higher pollution in Tuesday and Thursday, and lower in Friday and Saturday, the weekly holidays, and also in Wednesday.

Steady decrease in $PM_{2.5}$ concentration at daytime was also found in wet season, but somewhat different picture was noticed for $PM_{10}$ concentrations that did not decrease proportionately (Fig. 4-9).

**Fig. 4-8 Diurnal and weekday variations in $PM_{2.5}$ and $PM_{10}$ concentrations in dry season at the stations of Dhaka division**

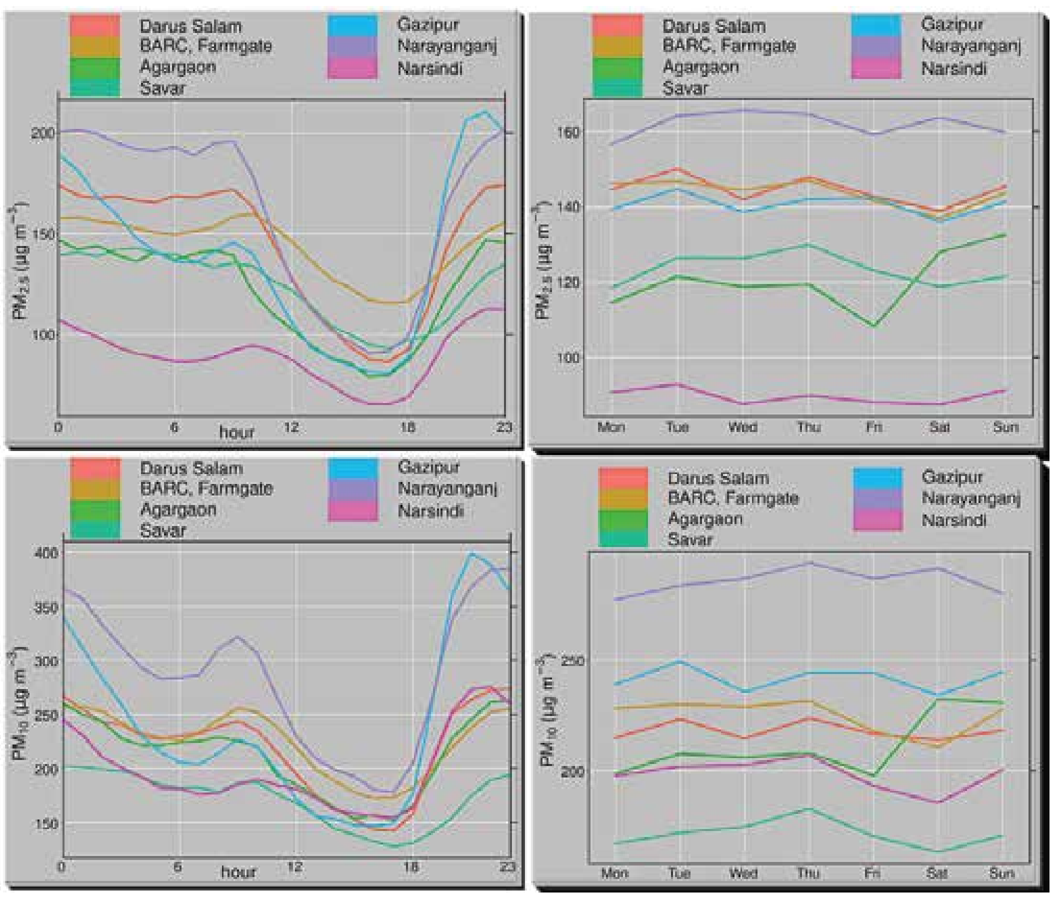
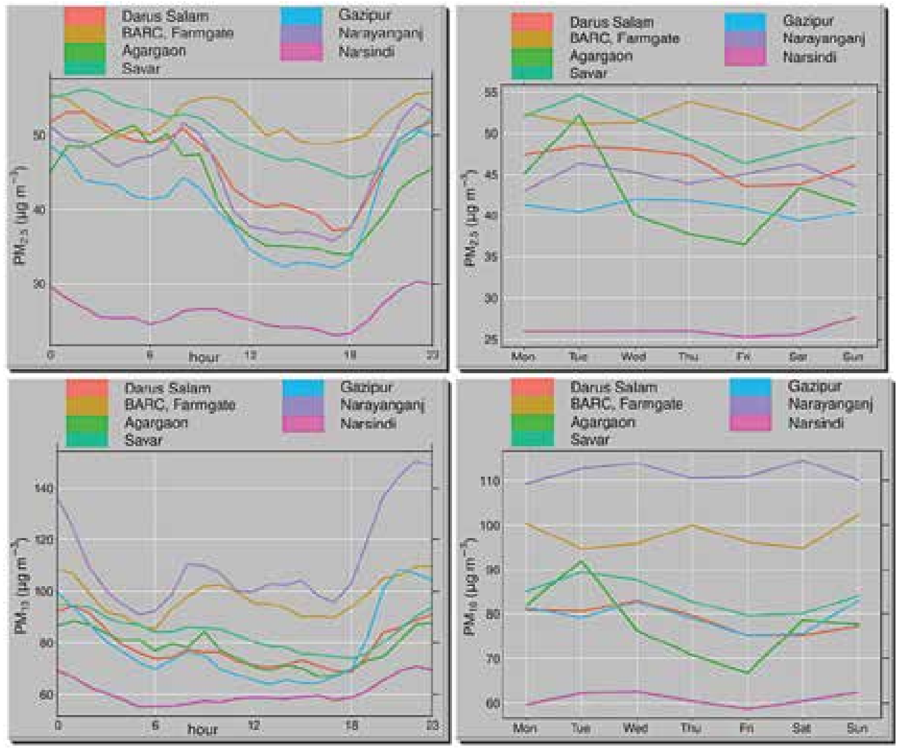


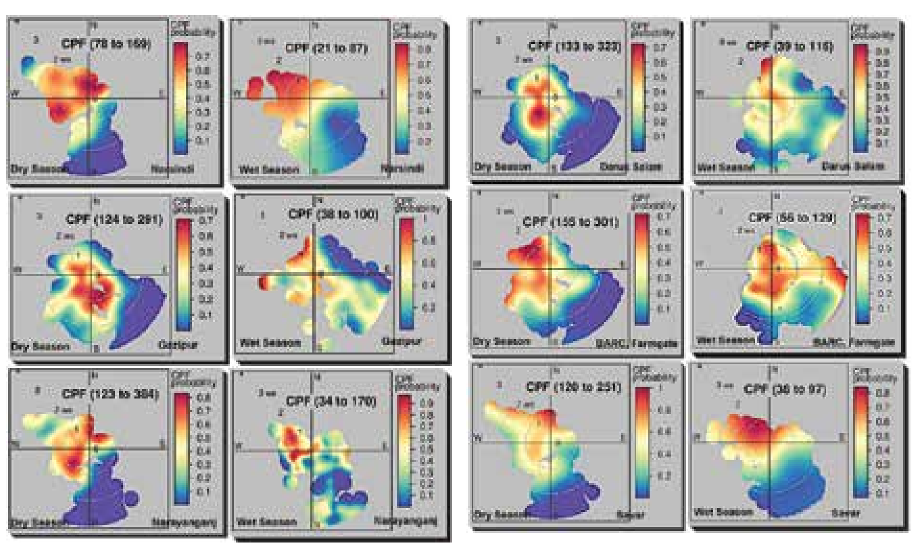
Fig. 4-9 Diurnal and weekday variations in $PM_{2.5}$ and $PM_{10}$ concentrations in wet season at the stations of Dhaka division




## Directional Influences

The plots of conditional probability functions (cpf) for the high $PM_{2.5}$ concentrations (>50 percentiles) are revealing the fact that irrespective of the seasons the stations were prone to receive high $PM_{2.5}$ from the north and west directions (Fig. 4-10), and most of the time high pollution scenarios happened in low wind speeds. Gazipur and Narayangnj stations had also high chance of getting extra pollutions from the east.

**Fig. 4-10 Conditional Probability Functions (cpf) for 50 percentile and above of $PM_{2.5}$ concentrations at the stations in Dhaka division; the values within bracket show the $PM_{2.5}$ concentration range for which the cpfs are drawn.**

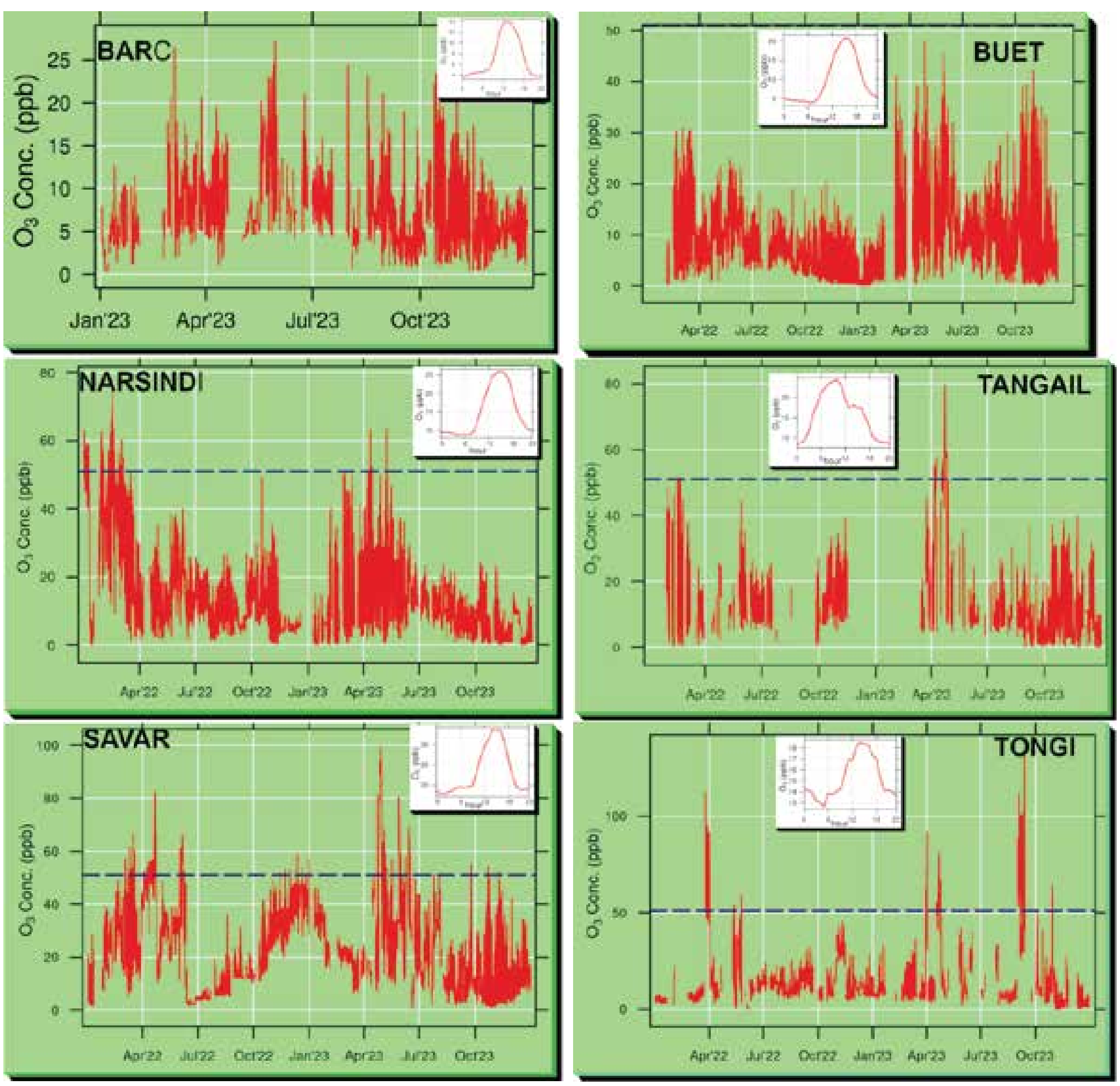


### 4.3.2 Gaseous Pollutants

#### Ozone

Ozone concentrations were found comparatively higher in the sub-urban areas (Savar, Narsindi) than that in Dhaka City. The maximum 8 hourly ozone concentration at the BARC station was found at ~28 ppb whereas the maximum concentrations at Savar and Narsindi were found at ~98.0 and ~68.0 ppb respectively; the national limit value for the same time average is 51 ppb. The trends also revealed that February to April in Bangladesh was the ideal time for ozone formation due to low cloud cover and high solar radiation (Fig. 4-3). Diurnal variations of ozone (insets at the Fig. 4-11) show the stations getting peak concentrations at around 3:00 pm and lowest at night, certifying dependency of ozone productions on sunlight. However, Tangail station was found to get higher ozone concentrations at night and in the morning hour (9:00-10:00 am); the Savar station also received comparatively high values at night hours, which might be the effect of the transport of ozone from Dhaka to Savar.

**Fig. 4-11 Trends in 8 hourly ozone concentrations at the stations, with diurnal variations given as insets; the horizontal blue lines showing the limit value.**



## Nitrogen Dioxide

The government of Bangladesh set in 2022 the limit value for $NO_2$ concentrations in ambient air at 80 µg/m$^3$ or ~43 ppb in 24-h average. Among the CAMSs the BARC station was found to detect high values of $NO_2$ concentrations which at times crossed the national limit value (Fig.4-12); Darus-Salam had also experienced violating level of $NO_2$ at times. Seasonal variations are as usual for $NO_2$ concentrations, high values in dry season and low values in wet season. Diurnal variations of $NO_2$ concentrations at the stations were mostly the same as those for $PM_{2.5}$ concentrations – decreasing trends at daytime and increasing at nighttime (Fig.4-13).

**Fig. 4-12 Trends in 24-h average $NO_2$ concentrations at the stations of Dhaka division.**

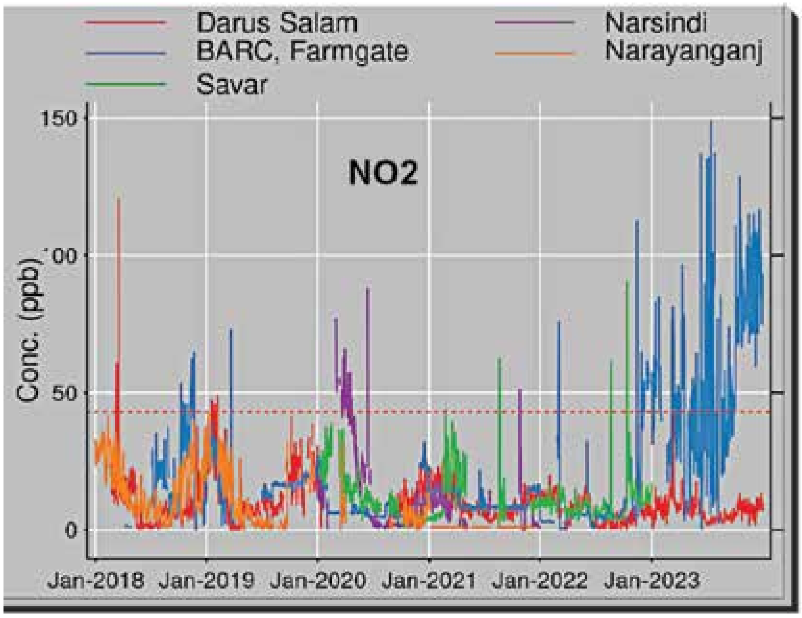
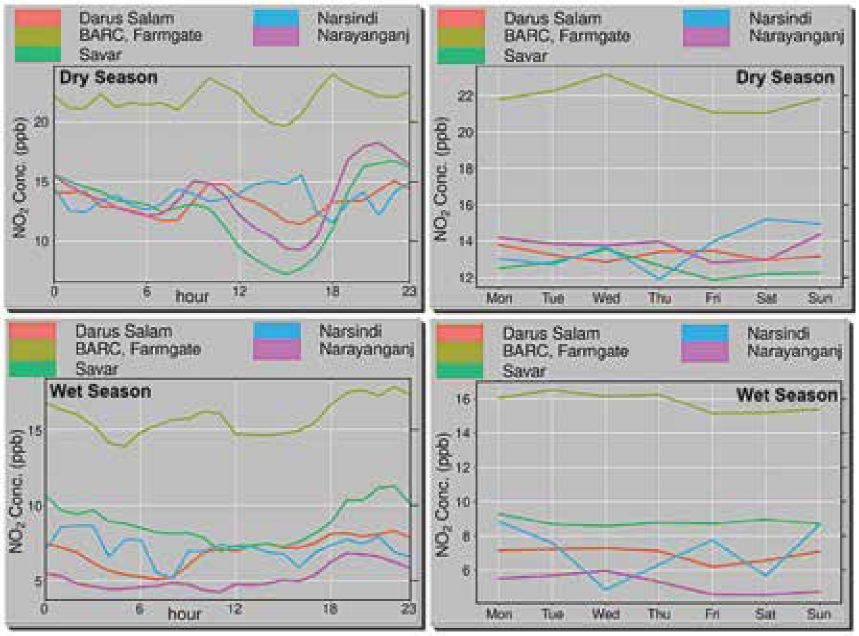



**Fig. 4-13 Diurnal and weekdays variations of $NO_2$ concentrations at Dhaka stations**

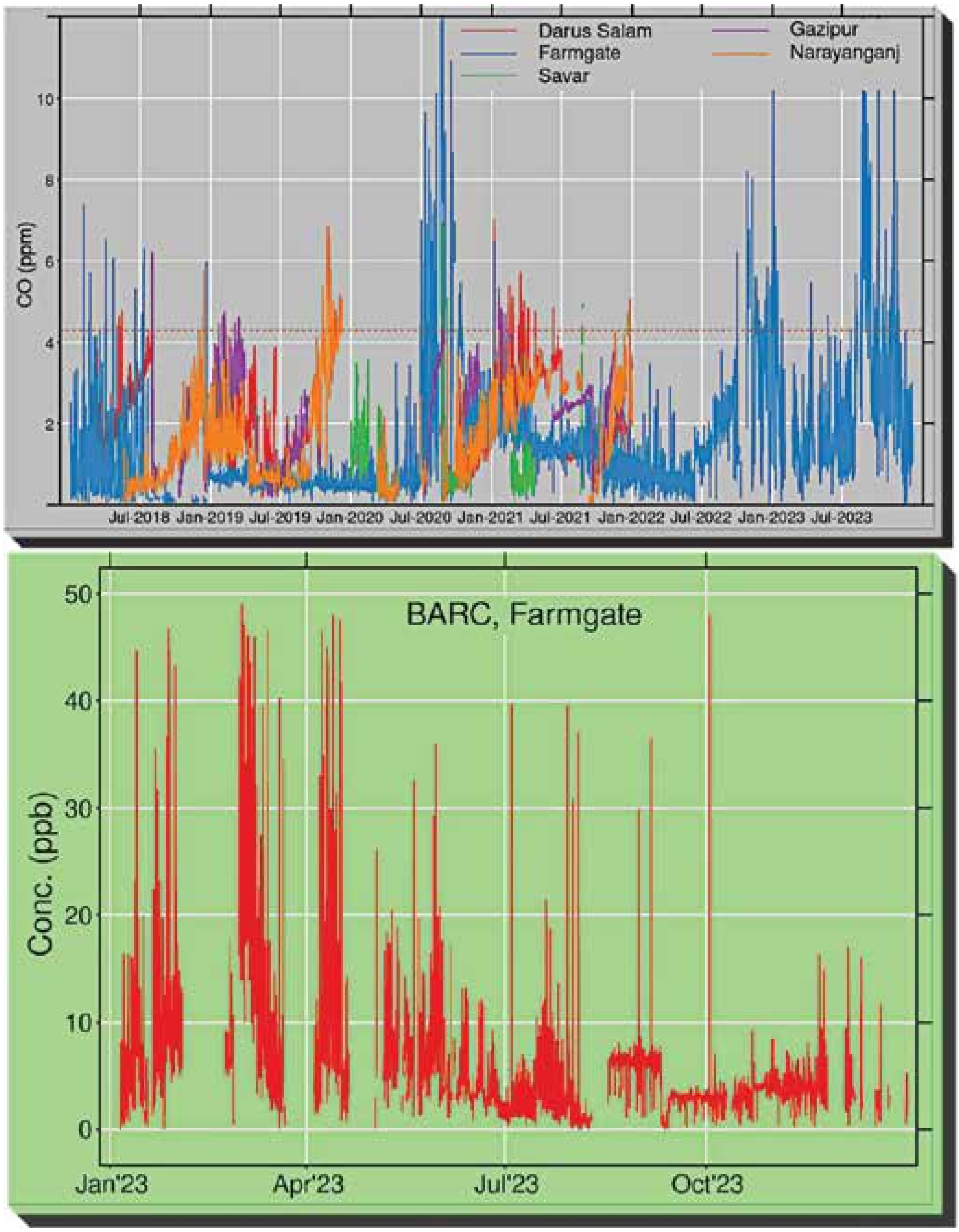


## Carbon Monoxide and Sulfur Dioxide

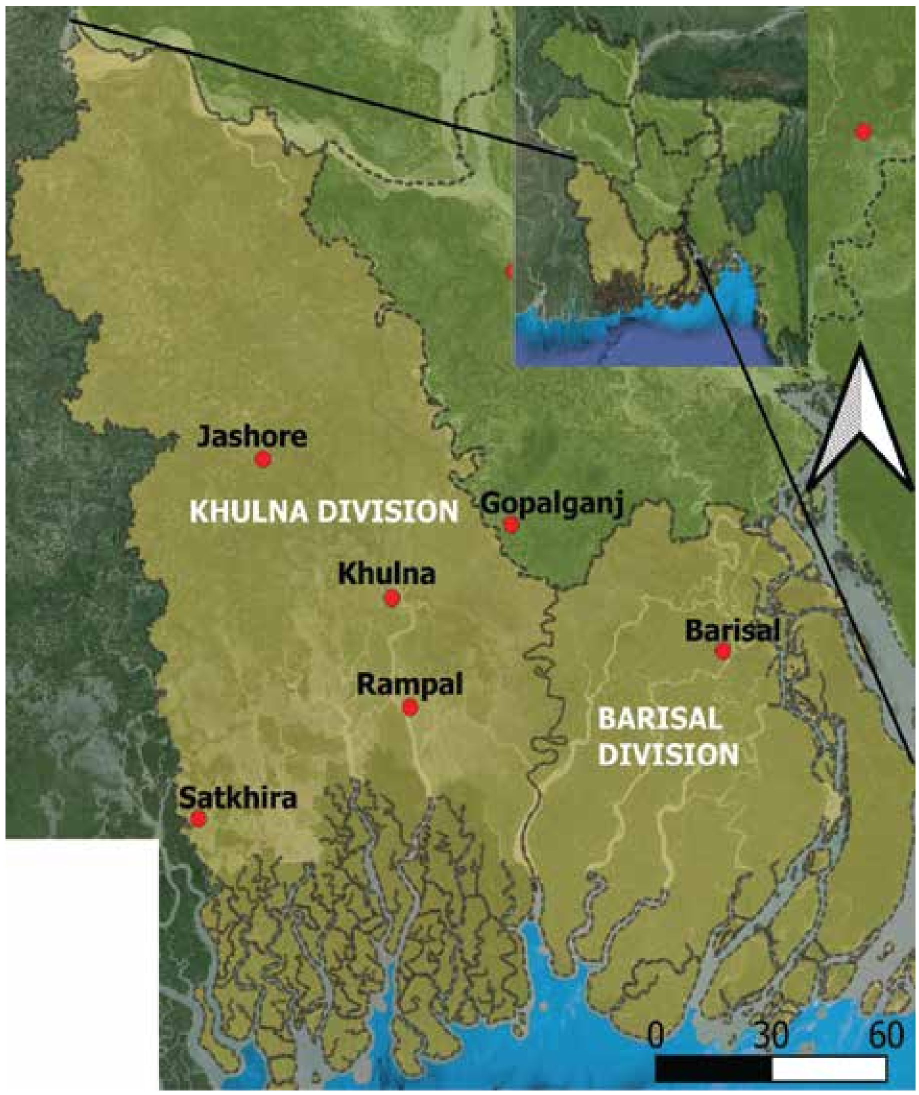
Carbon monoxide (CO) concentrations at the stations (except BARC, Farmgate) were found to follow seasonal trends, with higher values at dry season and lower at wet season. The CO concentrations at the stations were found frequently violating the new limit value set in 2022 at 5.0 mg/m$^3$ (~4.4 ppm) for 8-h average. The station at BARC, Farmgate had very high traffic movement in two directions and consequently got higher CO values throughout the year (Fig.4-14).

Trends in $SO_2$ concentrations at BARC, Farmgate station were found agreeable to the national limit value of 95 ppb in 1-h time average (Fig. 4-14).

**Fig. 4-14 8-h average CO concentrations (upper) and 1-h average $SO_2$ concentrations (bottom) at the stations mentioned in the figures.**



# 5 Data Analysis Results South & Southwest Region




## 5.1 Introduction

Barisal and Khulna divisions are located to the south and southwest of the country. DoE operates only one CAMS in Barisal City and another one CAMS and three C-CAMSs in Khulna division. Although Gopalganj district is within the administrative boundary of Dhaka Division, it is studied with the southern stations for its location at the extreme south of Dhaka division, bordering

Khulna division; one C-CAMS is running in Gopalganj. Some introductory information of the cities/areas possessing the CAMS and C-CAMSs are given in the following;

Barisal is a metropolitan city, situated in the southern region of Bangladesh. The city has a population of about 3.28 million within an area of 58 $km^2$. The city is one of the biggest river ports of Bangladesh; large number of diesel-powered water vessels operate from this port. The economy of Barisal is mainly agriculture based and there are no significant industries around the city.

Khulna is the third largest city of Bangladesh, located in south-western part of the country and on the banks of the river Rupsha and Bhairab. It is part of the largest delta in the world. The population of the city, under the jurisdiction of the Metropolitan Area is 770498, living in an area of about 40.79 $km^2$. Khulna is one of the country's most important industrial and commercial area; the second seaport of Bangladesh "Mongla" is located about 40 km south of the Khulna City.

Jashore is a district under Khulna division. The district encompasses 2606.98 $km^2$ with populations of 3.1 million, of them 0.21 million live in Jashore pourosova where the C-CAMS is collecting air quality data. Jashore is mainly an agriculture-based district; however for it has the largest land port (Benapole) with India for its proximity to the Mongla seaport, some small to medium size industries have been established in the district, and the city of Jashore has some business of heavy transport movement for the purpose of export and import goods.

Rampal is a very remote area located near the world's largest mangrove forest "the Sundarban", in Bagerhat district of Khulna Division. Recently, a coal based power station with a capacity of 1320 MW (2x660 MW) has been established there.

Satkhira is a district under Khulna Division, located to the southwest part of Bangladesh. The district has a population of 2.2 million, living in an area of about 3,817 square kilometres. The monitoring Station is located at a village of Harirampur under Noor Nagar Union Parisad of Shyamnagar Upajila which is actually an agriculture based village, located at the border with India.

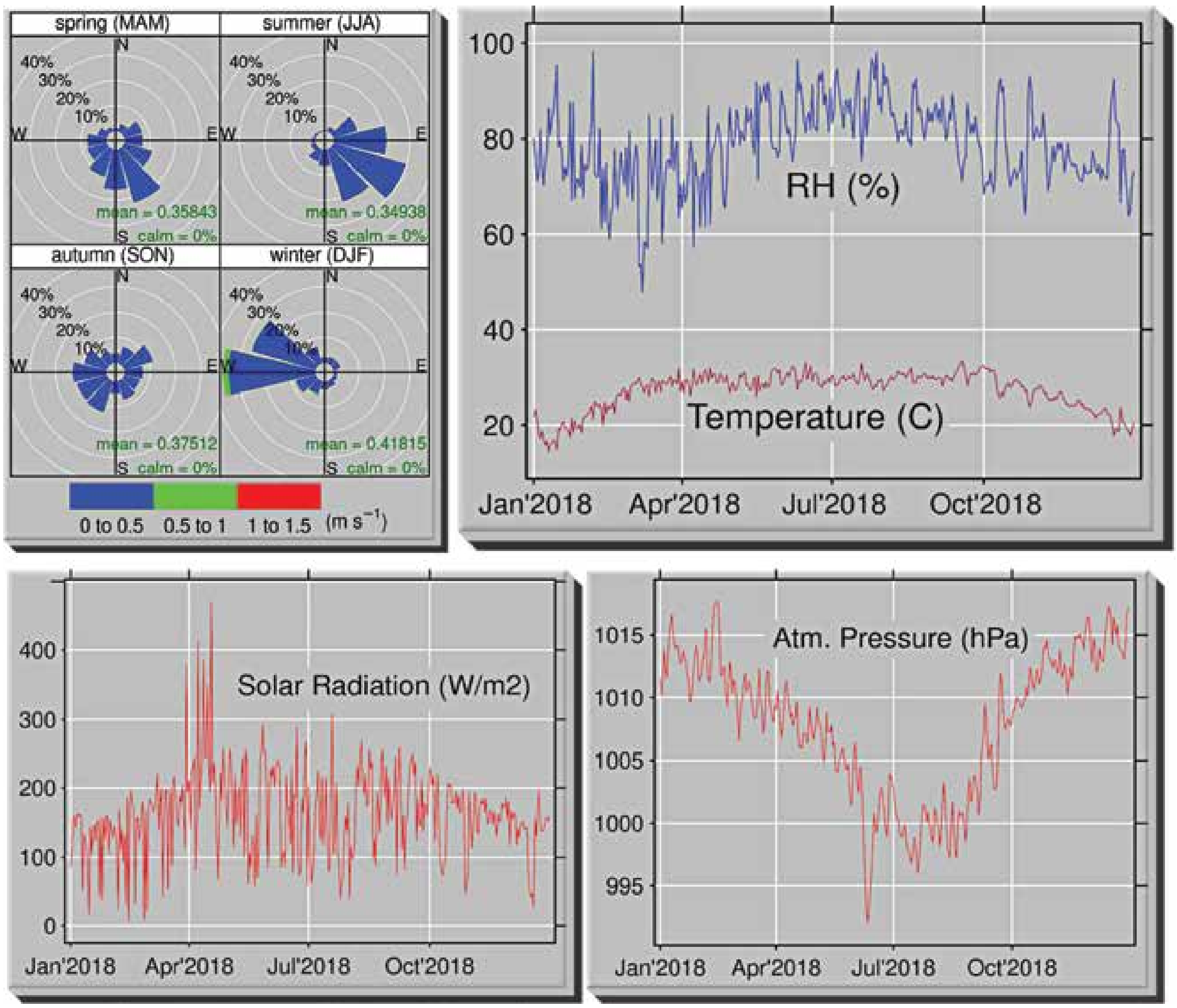
Gopalganj district in under Dhaka Division, having about 1.29 million people within an area of 1,490 $km^2$. This is primarily an agricultural based region with minimal industrialization.

## 5.2 Meteorology

The meteorology of the southern part of the country is typically similar to that of the country – with lowest temperature in January when the daily temperature falls up to 11 $^0$C and highest during April to June when the daily temperature rises up to 37 $^0$C. June to August is the time of high relative humidity (RH) that frequently crosses 90% (daily avg.), and March-April is characterized with low relative humidity that can fall up to 48% (daily avg.) during this time. March to May is also characterized with high solar radiation and moderate atmospheric pressure while January is the month of low solar radiation and high atmospheric pressure.

The wind roses at the Barisal station (Fig.5-1) shows that the station largely gets wind from the southeast direction from March to August, and from the west and northwest directions (Fig. 5-1) during December to February.

**Fig. 5-1 Seasonal wind roses (upper-left), trends in daily temperature and relative humidity (upper-right), daily solar radiation and atm. Pressure (bottom) at Barisal**




## 5.3 Criteria Air Pollutants

### 5.3.1 Particulate Matters (PM)

Yearly $PM_{2.5}$ concentrations in the major city area (Khulna & Barisal) of the south and southeast region of the country were around 65.0 µg/m³. Although this value is much lower than that of Dhaka region it is still 85.7% greater than the national limit value and greater than the WHO limits by a factor of 13. Fifty percent of the days of a year in both Khulna and Barisal the $PM_{2.5}$ concentrations were below the national limit values and 25% of the days the concentrations were greater than the limit value by a factor between 1.5 to 3 (Table 5-1). On the other hand, yearly $PM_{10}$ concentrations in this region were around 115 µg/m³, and more than 50% of the days the $PM_{10}$ concentrations were compliant to national limit value (Table 5-2).

An overview of the daytime and nighttime concentrations has been demonstrated in Table 5-3; nighttime PM concentrations are typically found comparatively high. Khulna and Jashore stations experienced high increase in PM concentrations at night in wintertime; increase in 43.5% $PM_{2.5}$ and 65.7% $PM_{10}$ concentrations were found in Khulna while 52.2% and 27.8 % increase in $PM_{2.5}$ and $PM_{10}$ concentrations were noticed at nighttime in Jashore. Nighttime PM concentrations in winter in Gopalganj and Barisal were not found to vary much from its daytime values (Table 5-3).

On the other hand, all the stations and parameters (except $PM_{10}$ at Khulna) were found to show moderate increase at night time in Summer season; $PM_{2.5}$ increased by a range from 25 to 41 % while $PM_{10}$ increased by a range from 26 to 31 % at the stations.

During wet season, nighttime $PM_{10}$ concentrations increased by around 18.1, 8.8 and 25.5% at the Khulna, Gopalganj and Jashore stations respectively while nighttime $PM_{2.5}$ concentrations at those stations increased by around 19.8, 16.1, 34.8 % respectively compared to daytime concentrations. PM concentrations at Barisal station did not experience changes at night in wet season.

**Table 5-1 Overview of the daily $PM_{2.5}$ Concentrations ($\mu g/m^3$) in the stations in south zone**

| Station | Par | Year | Data capture (%) | Mean | 25 percentiles | 50 percentiles | 75 percentiles | Max. |
|---|---|---|---|---|---|---|---|---|
| **Khulna** | $PM_{2.5}$ | 2018 | 51.5 | – | – | – | – | – |
| | $PM_{2.5}$ | 2019 | 40.0 | – | – | – | – | – |
| | $PM_{2.5}$ | 2020 | 59.7 | – | – | – | – | – |
| | $PM_{2.5}$ | 2021 | 54.2 | – | – | – | – | – |
| | $PM_{2.5}$ | 2022 | 68.7 | 62.9 | 62.9 | 46.6 | 94.0 | 208.7 |
| | $PM_{2.5}$ | 2023 | 66.6 | 69.6 | 69.6 | 54.7 | 105.4 | 203.7 |
| **Barisal** | $PM_{2.5}$ | 2018 | 47.4 | – | – | – | – | – |
| | $PM_{2.5}$ | 2019 | 60.3 | – | – | – | – | – |
| | $PM_{2.5}$ | 2020 | 37.0 | – | – | – | – | – |
| | $PM_{2.5}$ | 2021 | 30.0 | – | – | – | – | – |
| | $PM_{2.5}$ | 2022 | 35.6 | – | – | – | – | – |
| | $PM_{2.5}$ | 2023 | 66.3 | 63.3 | 63.3 | 61.4 | 88.0 | 190.4 |

-data capture rate less than 65%

**Table 5-2 Overview of the daily $PM_{10}$ Concentrations (µg/m³) in the stations in south zone**

| Station | Par | Year | Data capture (%) | Mean | 25 percentiles | 50 percentiles | 75 percentiles | Max. |
|---|---|---|---|---|---|---|---|---|
| **Khulna** | $PM_{10}$ | 2018 | 37.2 | – | – | – | – | – |
| | $PM_{10}$ | 2019 | 37.0 | – | – | – | – | – |
| | $PM_{10}$ | 2020 | 64.4 | – | – | – | – | – |
| | $PM_{10}$ | 2021 | 50.4 | – | – | – | – | – |
| | $PM_{10}$ | 2022 | 62.7 | – | – | – | – | – |
| | $PM_{10}$ | 2023 | 71.8 | 122.5 | 46.2 | 91.0 | 181.5 | 445.7 |
| **Barisal** | $PM_{10}$ | 2018 | 80.0 | 111.5 | 43.3 | 80.1 | 176.6 | 341.0 |
| | $PM_{10}$ | 2019 | 49.9 | – | – | – | – | – |
| | $PM_{10}$ | 2020 | 14.0 | – | – | – | – | – |
| | $PM_{10}$ | 2021 | 36.0 | – | – | – | – | – |
| | $PM_{10}$ | 2022 | 32.1 | – | – | – | – | – |
| | $PM_{10}$ | 2023 | 62.5 | – | – | – | – | – |

-data capture rate less than 65%

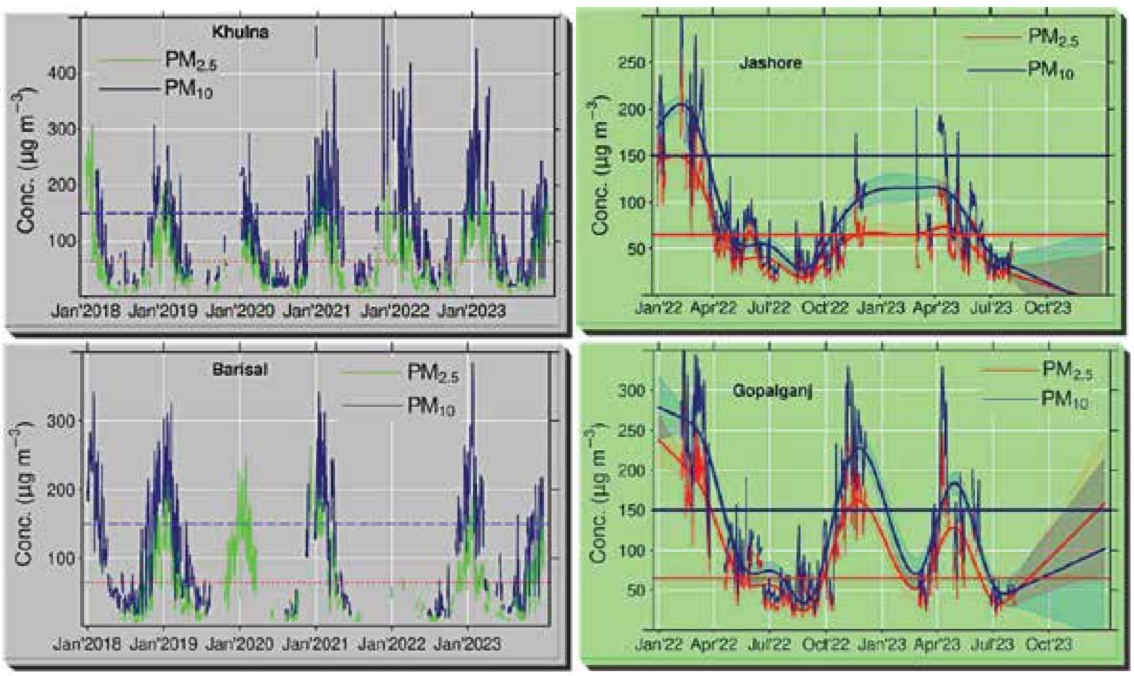
**Table 5-3 Seasonal and Diurnal statistics of PM concentrations (µg/m³) at the stations**

| Station | Pollutant | Winter | | | Summer | | | Wet | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Day[1] | Night[2] | Mean | Day[1] | Night[2] | Mean | Day[1] | Night[2] |
| **Khulna** | $PM_{2.5}$ | | 96.4 | 138.4 | | 63.1 | 89.0 | | 26.3 | 31.7 |
| | $PM_{10}$ | | 143.7 | 238.2 | | 178.3 | 189.0 | | 49.7 | 58.7 |
| | $PM_{2.5}/PM_{10}$ | | 0.72 | 0.66 | | 0.47 | 0.507 | | 0.56 | 0.54 |
| **Barisal** | $PM_{2.5}$ | | 88.2 | 103.2 | | 50.9 | 63.8 | | 24.3 | 23.6 |
| | $PM_{10}$ | | 164.0 | 196.0 | | 133.5 | 174.3 | | 49.4 | 49.3 |
| | [3]$PM_{2.5}/PM_{10}$ | | 0.56 | 0.58 | | 0.434 | 0.44 | | 0.48 | 0.50 |
| **Gopalganj** | $PM_{2.5}$ | | 121.1 | 120.9 | | 111.8 | 151.6 | | 52.8 | 61.3 |
| | $PM_{10}$ | | 174.5 | 184.5 | | 157.8 | 199.9 | | 79.4 | 86.4 |
| | $PM_{2.5}/PM_{10}$ | | 0.67 | 0.64 | | 0.70 | 0.76 | | 0.68 | 0.74 |
| **Jashore** | $PM_{2.5}$ | | 62.7 | 95.3 | | 78.6 | 109.3 | | 34.5 | 46.7 |
| | $PM_{10}$ | | 99.3 | 126.9 | | 120.0 | 155.7 | | 51.0 | 64.4 |
| | $PM_{2.5}/PM_{10}$ | | 0.62 | 0.73 | | 0.65 | 0.69 | | 0.67 | 0.71 |

1 Daytime considered the hours from 6:00 am to 18:00 pm
2 Nighttime considered the hours from 19:00 pm to 5:00 am
3 $PM_{2.5}$ to $PM_{10}$ ratio was calculated from the hourly values

Seasonal trends in the PM concentrations in all the stations were very typical, with higher trends at dry season and lower at wet season. Of those four stations shown in Fig. 5-2 Jashore was comparatively cleaner while the other three stations (Khulna, Barisal and Gopalganj) were moderately the same.

**Fig. 5-2 Trends in daily $PM_{2.5}$ and $PM_{10}$ concentrations at Khulna and Barisal (left), and Jashore and Gopalganj (right).**




January was the month of high pollution, followed by December and February in both Khulna and Barisal stations. The trends show that the $PM_{2.5}$ concentration level is decreasing in recent years in Basial, although we can not make any concluding remarks right now on this as data capture rate was not good for these two stations, and further investigations needed.

**Fig. 5-3 Trends in Monthly $PM_{2.5}$ (left) and $PM_{10}$ concentrations (right) in Khulna and Barisal**

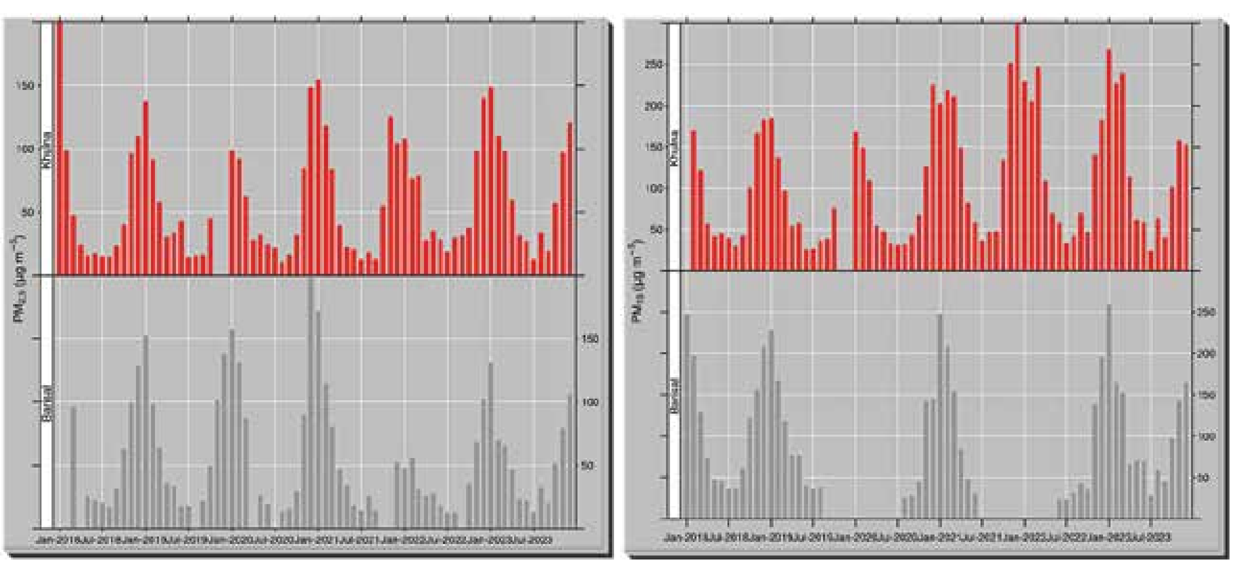
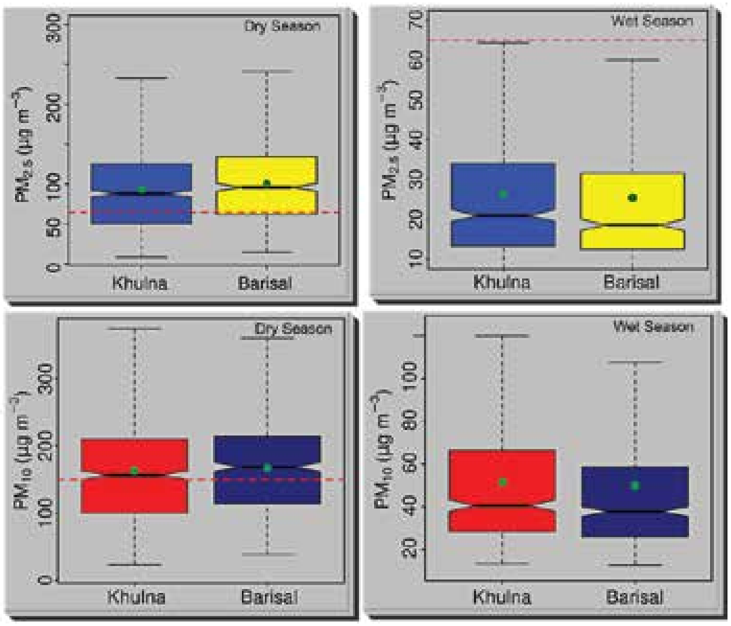


**Fig. 5-4 Box-Whisker plots of $PM_{2.5}$ and $PM_{10}$ during dry and wet season in Khulna and Barisal; red lines indicate national limit values while green circles showing the average.**




Diurnal trends in $PM_{2.5}$ and $PM_{10}$ concentrations in dry season in both Khulna and Barisal follow about the same pattern – down trends throughout the night (10:00 pm – 6:00 am) and throughout the day (9:00 am – 6:00 pm), and two concentration peaks, one in 8:00 am-9:00 am and another in 6:00 pm-10:00 pm in the dry season were observed. However, the wet seasonal daytime trends were opposite to those in dry season – concentrations to some extent increased throughout the day during wet season. The concentration peaks at the evening and the nighttime downtrends were similar to those in dry season (Fig. 5-5; Fig. 5-6).

**Fig. 5-5 Diurnal (left) and weekday (right) trends in $PM_{2.5}$ concentrations at Khulna and Barisal stations in dry and wet season**

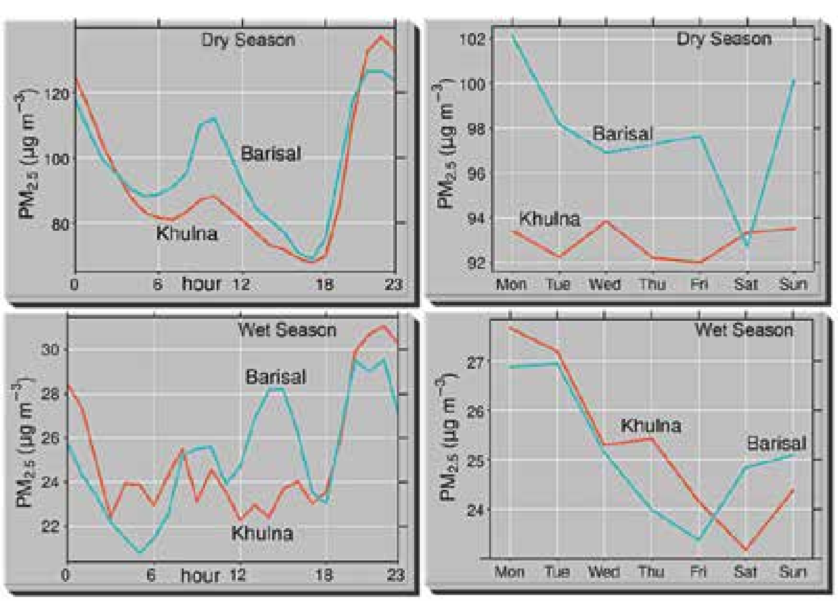
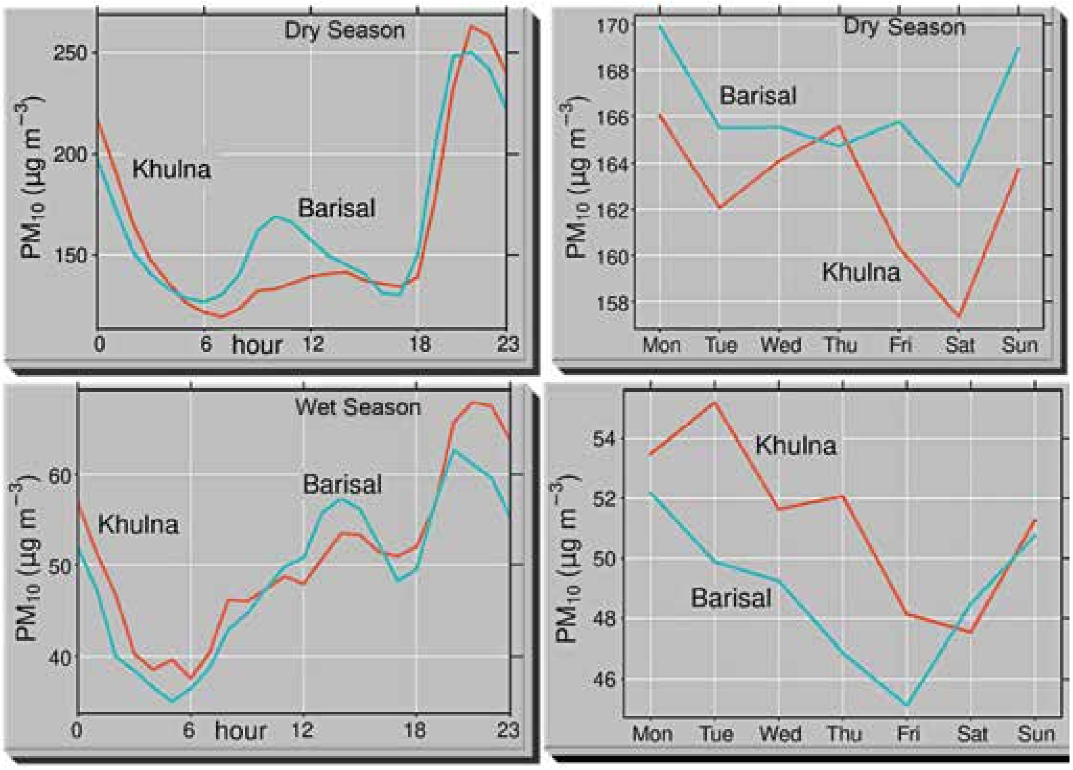
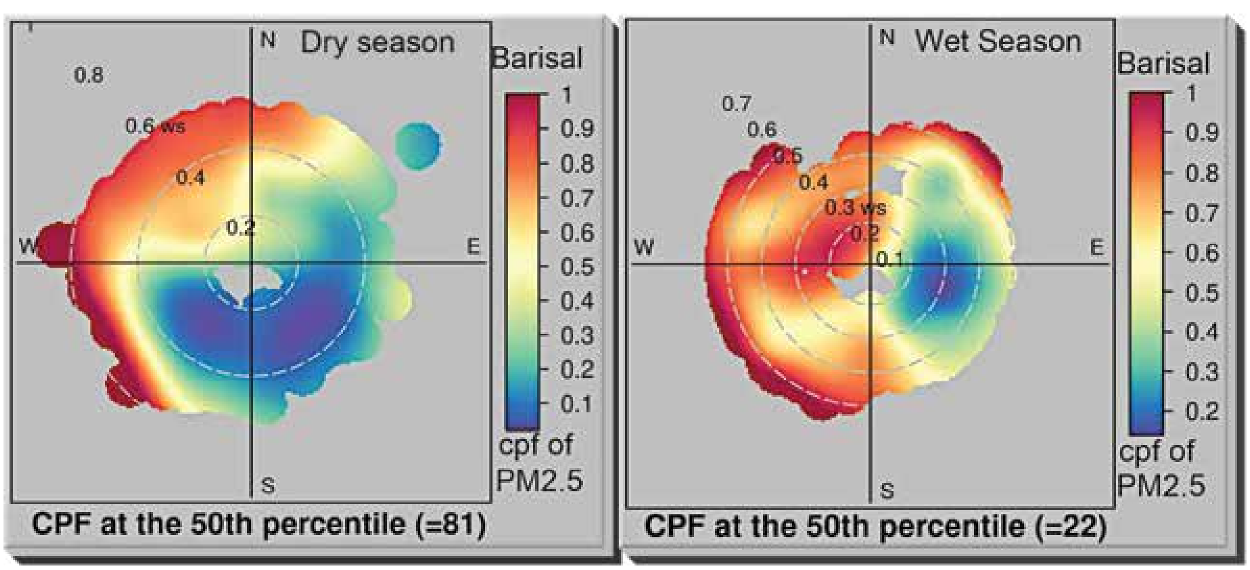


**Fig. 5-6 Diurnal (left) and weekday (right) trends in $PM_{10}$ concentrations at Khulna and Barisal stations in dry and wet season**




Barisal station was found to achieve comparatively high $PM_{2.5}$ from north to northwest directions in all the season, although wind blew from south and southeast directions during wet season (fig. 5-1), high pollutions still achieved from the northwest and southwest directions (fig. 5-7).

**Fig. 5-7 Directional influence of $PM_{2.5}$ on the Barisal station**



### 5.3.2 Gaseous Pollutants

Khulna being comparatively bigger and busier city in this region experienced little high $SO_2$ concentrations which were still far below the national standard. The maximum hourly $SO_2$ concentration at Khulna was found at 50 ppb (Fig. 5-8) whereas the national standard for that time period is 95 ppb. While the frequently reaching level of $SO_2$ concentration at Khulna station was around 30 ppb, those at Jashore and Gopalganj stations were around 15 ppb and 10 ppb respectively.

CO concentrations were found frequently crossing the national limit value of 4.4 ppm in Khulna (Fig. 5-9), while those at Jashore station were much low from the limit value. The CO concentrations were also influenced by the seasonal meteorology; higher concentrations were observed in dry season while lower concentration in wet season (Fig. 5-9).

**Fig. 5-8 Hourly variations of $SO_2$ concentrations at Khulna, Jashore and Gopalganj stations; Bangladesh Standard ~ 95 ppb**

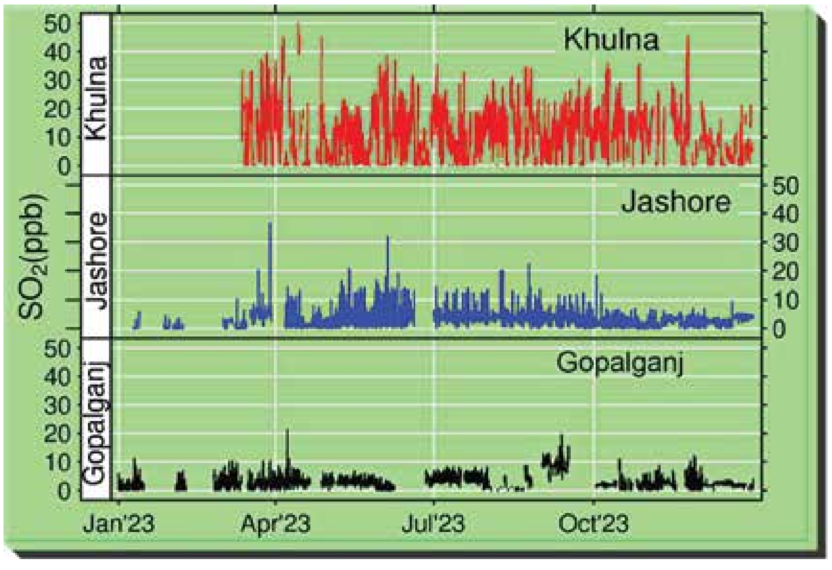
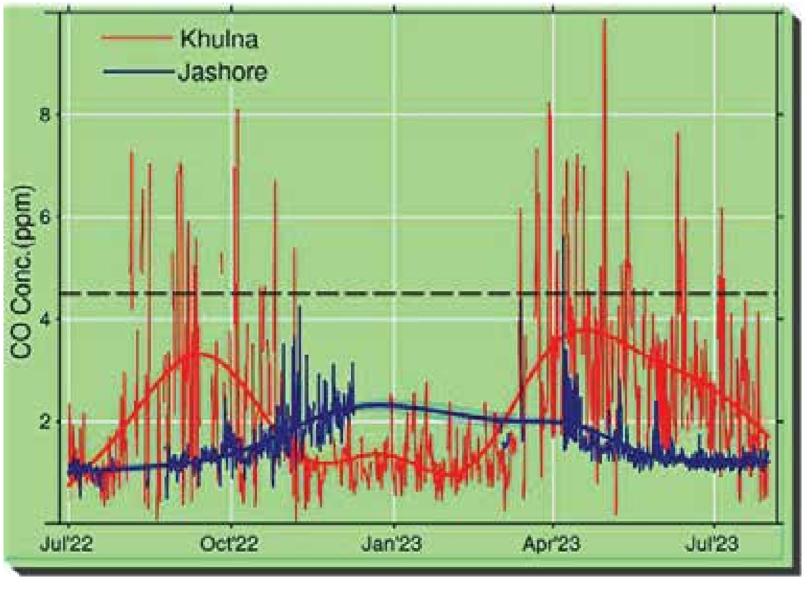
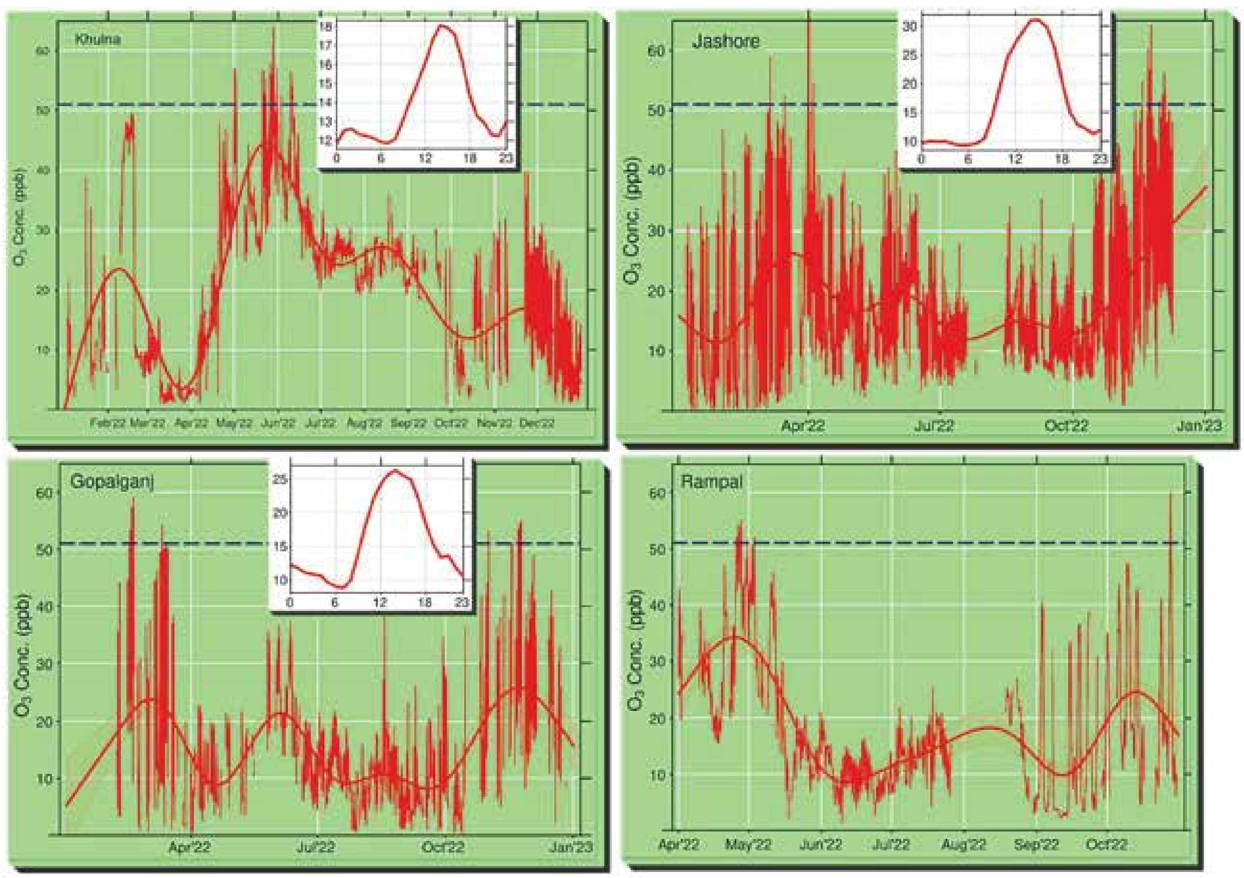



**Fig. 5-9 Trends in 8-hourly CO concentrations at Khulna and Jashore stations; black line shows the national standard.**



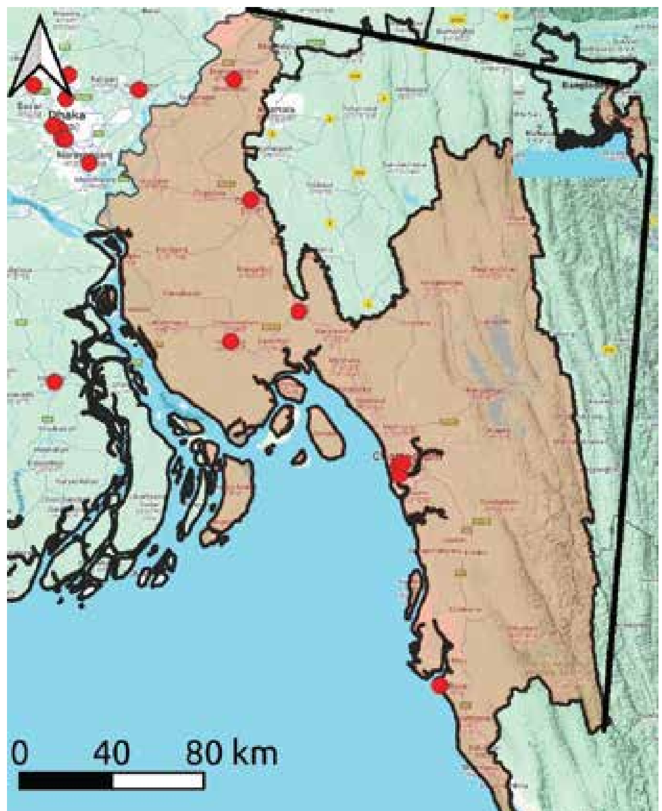
In contrast to the $SO_2$ and CO concentrations, $O_3$ concentrations were found comparatively higher in Jashore and Gopalganj stations, and also found to follow the seasonal pattern (Fig 5-10). In dry season, 8-hourly $O_3$ concentrations in Gopalganj and Jashore frequently crossed the level of 40 ppb; several times the concentrations violated the national standard line at 51 ppb. Diurnal patterns of $O_3$ concentrations at the stations were very typical – got the peaks in the afternoon and lower values at nighttime; however, it seems that the southern stations were observing comparatively greater $O_3$ level at nighttime.

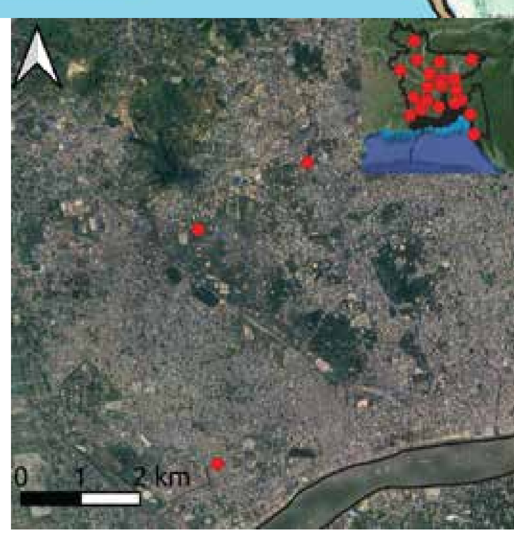
**Fig. 5-10 Trends in 8-hourly $O_3$ concentrations at Khulna, Gopalganj, Jashore and Rampal stations; Diurnal variations of $O_3$ concentrations given as insets.**



# 6 Data Analysis Results South East Region

**Maps of Chattogram Division (top) and Chattogram City (bottom); Red dots mark the locations of monitoring stations**



## 6.1 Introduction

The area of Chattogram division spreads from the east to the southeast directions of the country. There are 8 air monitoring stations (3 CAMS and 5 C-CAMS) functioning in this division, and the locations of the stations are, Brahmanbaria, Cumilla, Noakhali, Feni, Chattogram City (3) and Cox's Bazar. Of these stations, Brahmanbaria being located to the eastern part of the country is studied with the stations to the east and northeast directions. This chapter will only deal with the stations located to the southeast direction. A glimpse of the cities studied here is given below;

Chattogram city has an area of 155.4 square kilometer, loaded with population of 3.23 million. Three stations are installed in this city – one CAMS is located at the Chattogram Television Station Campus in Khulshi, which is functioning on a hilltop, about 2.5 kilometers northwest from the city center and roughly 100 meters above the surrounding region; the area is comparatively serene and away from notable sources. Another CAMS is located at the CDA residential area near the "Hatekhary" School at Agrabad. One C-CAMS is located at BSRM Steel Re-rolling Mill Area at Nasirabad, the area is mainly industrial where some heavy industries are running.

Cumilla CAMS is located in the court area at the District Office of the Department of Environment. The City Corporation of Cumilla has a population of 0.44 million, living in an area of 53.04 square kilometer. The city is a significant financial and educational hub of Eastern Bangladesh, and is characterized with mainly flat land.

Noakhali District is surrounded by the Meghna River to the west and the Bay of Bengal to the south, has an area of 4,202 $km^2$ and population of 3.1 million. The economy of Noakhali is predominately agricultural based with little industrial activities. The district also experiences tropical climate and has significant rainfall in most of the time, with a short dry season.

The southeastern district of Feni has an area of 928.34 square kilometer, with population of 1.5 million, of which 0.5 million live in the Feni Pourosova area. The city has very limited industrial activities.

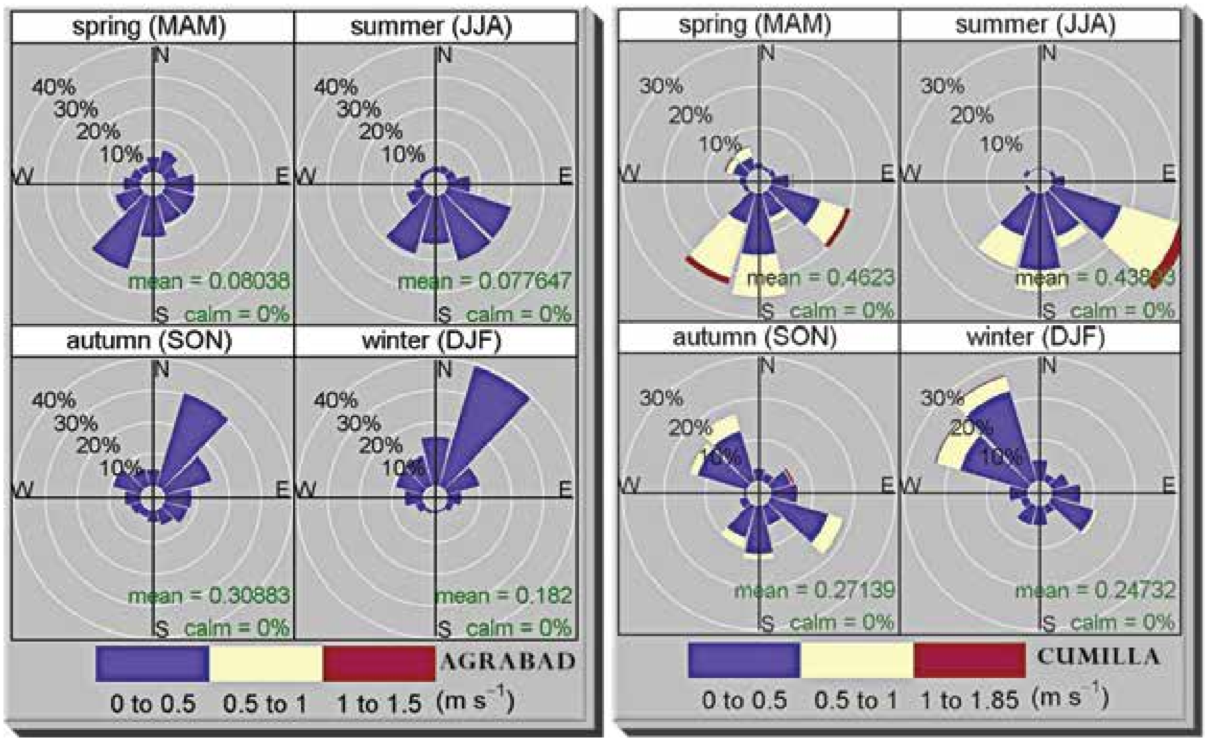
Cox's Bazar is a tourism center with its iconic long beach along the Bay of Bengal. The city covers an area of 23.4 $km^2$ with a population of nearly 0.2 million. The area is mainly dependent on fishing and tourism, has very little industrial activities.

Air quality of the cities of Noakhali, Feni and Cox's Bazar are being monitored with C-CAMS.

## 6.2 Meteorology

The wind roses over Agrabad, Chattogram and Cumilla stations shown at Fig. 6-1 reveal that both the stations during spring and summer seasons received almost similar wind although the speeds of the air at Cumilla station were comparatively violent. In addition to the southeastern wind, both the stations were getting substantial wind from southwest direction during spring and summer times. However, the wintertime wind directions experienced at those stations were little different from each other; while Agrabad was getting wind predominantly from the northeast direction, Cumilla was experiencing mostly northwesterly wind during this time (Fig. 6-1).

**Fig. 6-1 Season-wise wind roses in Agrabad (Chattogram) and Cumilla. MAM, JJA, etc. constitute with the first letters of a month name, i.e. MAM = March, April, May**




The trends in temperature were almost similar in the stations (Fig. 6-2). On the other hand, the differences in the relative humidity (RH) at the stations are obvious; the most northern position, the highest RH was found at the stations. Thus, Cumilla had the highest levels of RH while the Chattogram City station experienced the lowest levels (Fig. 6-2).

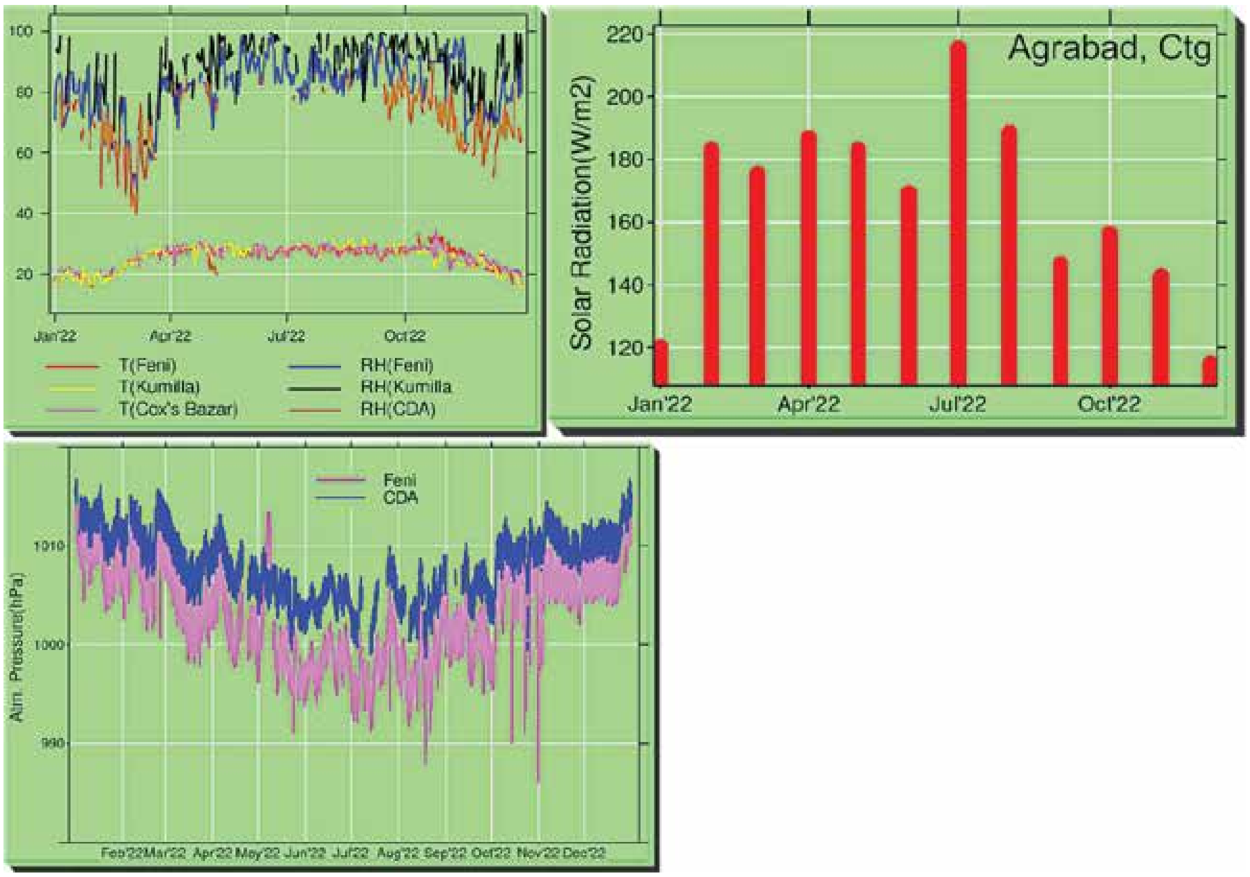
April-May was the month of highest temperature in the cities, and the high temperature continued up to October from when it dropped to get the lowest point in January.

February-April was the time of low relative humidity, when the RH sometimes came down to 40%; the month of November was also characterized with low RH. In other months, especially from July to October and December-January the RH were high.

July was the month the Chattogram City experienced highest level of solar radiation; the months of February to May and August were also highly sunny in compared to December-January which were the months of least solar insolation.

Wet season (May – October) was also characterized with low atmospheric pressure while the dry season (November – April) with high pressure (Fig. 6-2).

**Fig. 6-2 Daily temperature (°C) and Relative Humidity (%) at Feni, Cumilla and Cox's Bazar stations (topleft), Hourly Atmospheric Pressure (hPa) at Feni and Agrabad (bottom) and Monthly Solar Radiation at CDA, Chattogram station (topright)**




## 6.3 Criteria Air Pollutants

### 6.3.1 Particulate Matters (PM)

Due to lower data capture rates yearly trends in both $PM_{2.5}$ and $PM_{10}$ concentrations could not be shown for the stations. However, from the three yearly data points of $PM_{10}$ concentrations at the Agrabad station it can be guessed that the concentration trends in recent years were almost the same. Agrabad station was experiencing higher pollution than the TV center area, and the pollution level at Cumilla was also the same as that in the Chattogram City.

More than 50% of the days in a year PM concentrations were found good at the stations; 25% of the days $PM_{2.5}$ concentrations were about 24.6, 57.0 and 23.0 % greater than the national limit values at TV Center, Agrabad and Cumilla stations (Table 6-1). But for $PM_{10}$ concentrations this figure was even better; 25% of the days $PM_{10}$ concentrations were about 2.6, 16.6 and 6.7 % greater than the national limit values at TV Center, Agrabad and Cumilla stations respectively (Table 6-2).

**Table 6-1 Overview of the daily $PM_{2.5}$ Concentrations (µg/m³) in the stations in southeast zone**

| Station | Par | Year | Data capture (%) | Mean | 25 percentiles | 50 percentiles | 75 percentiles | Max. |
|---|---|---|---|---|---|---|---|---|
| **Television Center, Chattogram** | $PM_{2.5}$ | 2018 | 46.8 | – | – | – | – | – |
| | $PM_{2.5}$ | 2019 | 36.7 | – | – | – | – | – |
| | $PM_{2.5}$ | 2020 | 56.7 | – | – | – | – | – |
| | $PM_{2.5}$ | 2021 | 45.7 | – | – | – | – | – |
| | $PM_{2.5}$ | 2022 | 70.0 | 55.2 | 55.2 | 40.6 | 80.8 | 195.2 |
| | $PM_{2.5}$ | 2023 | 61.4 | – | – | – | – | – |
| **CDA, Chattogram** | $PM_{2.5}$ | 2018 | 14.5 | – | – | – | – | – |
| | $PM_{2.5}$ | 2019 | 45.4 | – | – | – | – | – |
| | $PM_{2.5}$ | 2020 | 59.2 | – | – | – | – | – |
| | $PM_{2.5}$ | 2021 | 21.9 | – | – | – | – | – |
| | $PM_{2.5}$ | 2022 | 47.4 | – | – | – | – | – |
| | $PM_{2.5}$ | 2023 | 67.1 | 63.6 | 63.6 | 47.4 | 102.2 | 195.0 |
| **Cumilla** | $PM_{2.5}$ | 2020 | 56.7 | – | – | – | – | – |
| | $PM_{2.5}$ | 2021 | 53.2 | – | – | – | – | – |
| | $PM_{2.5}$ | 2022 | 68.8 | 56.6 | 56.6 | 37.6 | 86.3 | 206.6 |
| | $PM_{2.5}$ | 2023 | 70.4 | 55.8 | 55.8 | 46.9 | 73.3 | 218.8 |

-Statistics not shown for low data availability (< 65.0%)

**Table 6-2 Overview of daily $PM_{10}$ concentration (µg/m³) at different stations of southeast region**

| Station | Par | Year | Data capture (%) | Mean | 25 percentiles | 50 percentiles | 75 percentiles | Max. |
|---|---|---|---|---|---|---|---|---|
| **Television Center, Chattogram** | $PM_{10}$ | 2018 | 46.0 | – | – | – | – | – |
| | $PM_{10}$ | 2019 | 35.9 | – | – | – | – | – |
| | $PM_{10}$ | 2020 | 69.6 | 114.1 | 55.0 | 95.5 | 154.1 | 460.2 |
| | $PM_{10}$ | 2021 | 37.3 | – | – | – | – | – |
| | $PM_{10}$ | 2022 | 24.7 | – | – | – | – | – |
| | $PM_{10}$ | 2023 | 46.3 | – | – | – | – | – |
| **CDA, Chattogram** | $PM_{10}$ | 2018 | 47.7 | – | – | – | – | – |
| | $PM_{10}$ | 2019 | 65.0 | 126.3 | 70.5 | 119.6 | 174.7 | 340.3 |
| | $PM_{10}$ | 2020 | 66.0 | 116.8 | 42.3 | 101.6 | 175.4 | 339.6 |
| | $PM_{10}$ | 2021 | 55.1 | – | – | – | – | – |
| | $PM_{10}$ | 2022 | 57.3 | – | – | – | – | – |
| | $PM_{10}$ | 2023 | 80.0 | 116.4 | 51.0 | 83.0 | 180.8 | 349.9 |
| **Cumilla** | $PM_{10}$ | 2020 | 35.9 | – | – | – | – | – |
| | $PM_{10}$ | 2021 | 49.9 | – | – | – | – | – |
| | $PM_{10}$ | 2022 | 69.3 | 112.6 | 52.2 | 81.3 | 159.7 | 381.4 |
| | $PM_{10}$ | 2023 | 24.4 | – | – | – | – | – |

-Statistics not shown for low data capture rate (< 65.0%)

Seasonal and diurnal statistics of the stations in the southeast region revealed that both $PM_{2.5}$ and $PM_{10}$ concentrations were higher in wintertime than summertime at the stations with some exception in Cumilla where $PM_{2.5}$ concentrations were higher in summertime. The increase in $PM_{2.5}$ concentrations during winter compared to summer at most of the stations were found by a range from 8 to 14%, with exceptions at CDA, Chattogram and Feni stations where wintertime concentrations were higher by 33.5 and 32.0% respectively from summertime concentrations. Reductions in $PM_{2.5}$ concentrations in wet season compared to summer time was as usually high, >50.0% in most of the stations. Almost similar scenario was found for $PM_{10}$ concentrations; in most cases the concentrations were greater in winter than summer by a range between 1.5% in Cox's Bazar to 17.0% in Feni, with exceptions in TV center and Noakhali station where the wintertime increase in $PM_{10}$ concentrations than in summertime were 32.9 and 23.7 % respectively. The wet seasonal reductions in $PM_{10}$ concentrations compared to summertime concentrations were typically high, >50% (Table 6-3).

Nighttime $PM_{2.5}$ concentrations in winter season were greater than daytime concentrations by 34.0, 60.0, 51.0, 48.0, 11.3, 67.3, & 38.0 % at the stations of Cumilla, Agrabad, TV Station, Feni, Noakhali, BSRM & Cox's Bazar respectively, while the nighttime increase in summertime at the stations were 34.6, 21.8, 15.5, 34.2, 30.1, 34.0 & 36.5 % respectively (Table 6-3).

January was the most polluted month found from the station data, followed by December and February. However in recent years February and March were found more polluted than even January in Agrabad and Cumilla (Fig. 6-5, Fig. 6-6).

**Table 6-3 Seasonal and Diurnal statistics of PM concentrations (μg/m³) at the stations**

| Station | Pollutant | Winter[5] | | | Summer[6] | | | Wet[7] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean[1] | Day[2] | Night[3] | Mean | Day[2] | Night[3] | Mean | Day[2] | Night[3] |
| Cumilla | $PM_{2.5}$ | 80.5 | 69.4 | 93.5 | 91.1 | 78.6 | 105.3 | 29.7 | 27.7 | 32.1 |
| | $PM_{10}$ | 195.5 | 153.0 | 248.1 | 140.4 | 115.0 | 169.9 | 64.9 | 57.9 | 73.0 |
| | $PM_{2.5}/PM_{10}$ | 0.68 | 0.71 | 0.65 | 0.60 | 0.60 | 0.59 | 0.63 | 0.66 | 0.60 |
| CDA, Chattogram | $PM_{2.5}$ | 95.1 | 74.6 | 118.3 | 71.2 | 64.6 | 78.3 | 25.7 | 22.9 | 28.0 |
| | $PM_{10}$ | 175.1 | 139.5 | 214.2 | 158.3 | 145.8 | 172.0 | 61.9 | 55.2 | 69.2 |
| | $PM_{2.5}/PM_{10}$ | 0.60 | 0.57 | 0.62 | 0.46 | 0.43 | 0.48 | 0.37 | 0.35 | 0.39 |
| TV station, Chattogram | $PM_{2.5}$ | 87.2 | 70.8 | 106.4 | 76.4 | 71.5 | 82.0 | 24.1 | 21.7 | 26.7 |
| | $PM_{10}$ | 157.9 | 130.3 | 190.0 | 118.8 | 110.3 | 128.1 | 51.8 | 48.1 | 56.2 |
| | $PM_{2.5}/PM_{10}$ | 0.50 | 0.48 | 0.52 | 0.535 | 0.52 | 0.55 | 0.425 | 0.42 | 0.43 |
| Compact- Continuous Air Monitoring Station | | | | | | | | | | |
| Feni | $PM_{2.5}$ | 116.7 | 95.5 | 141.7 | 88.4 | 75.9 | 102.8 | 44.7 | 37.9 | 52.2 |
| | $PM_{10}$ | 153.8 | 134.2 | 176.8 | 131.4 | 116.1 | 149.3 | 67.1 | 60.0 | 75.3 |
| | $PM_{2.5}/PM_{10}$ | 0.73 | 0.69 | 0.78 | 0.625 | 0.60 | 0.65 | 0.665 | 0.63 | 0.70 |
| Noakhali | $PM_{2.5}$ | 111.8 | 106.4 | 118.7 | 94.5 | 83.5 | 108.7 | 49.3 | 48.9 | 49.9 |
| | $PM_{10}$ | 170.1 | 170.0 | 170.3 | 137.4 | 127.9 | 149.8 | 85.6 | 86.0 | 85.1 |
| | $PM_{2.5}/PM_{10}$ | 0.60 | 0.59 | 0.61 | 0.71 | 0.67 | 0.75 | 0.595 | 0.60 | 0.59 |
| BSRM, Chattogram | $PM_{2.5}$ | 184.2 | 141.6 | 236.6 | 170.3 | 147.7 | 197.6 | 81.5 | 69.9 | 95.1 |
| | $PM_{10}$ | 244.9 | 192.4 | 307.3 | 229.8 | 206.8 | 257.6 | 109.4 | 95.8 | 125.0 |
| | $PM_{2.5}/PM_{10}$ | 0.76 | 0.74 | 0.78 | 0.725 | 0.69 | 0.76 | 0.76 | 0.74 | 0.78 |
| Cox's Bazar | $PM_{2.5}$ | 132.7 | 113.0 | 156.0 | 121.7 | 104.2 | 142.1 | 52.3 | 43.0 | 63.0 |
| | $PM_{10}$ | 172.1 | 152.8 | 195.6 | 169.6 | 151.5 | 192.0 | 77.8 | 66.4 | 90.9 |
| | $PM_{2.5}/PM_{10}$ | 0.715 | 0.69 | 0.74 | 0.76 | 0.73 | 0.79 | 0.70 | 0.69 | 0.71 |

1 Seasonal means were calculated from the daily concentrations which were calculated from hourly concentrations, forcing 75% data availability.
2 Daytime considered the hours from 6:00 am to 18:00 pm
3 Nighttime considered the hours from 19:00 pm to 5:00 am
4 $PM_{2.5}$ to $PM_{10}$ ratio was calculated from the hourly values
5 November to January;
6 February to April;
7 May to October;

**Fig. 6-3 Seasonal variations in daily averaged PM concentrations captured using CAMS in the southeastern stations.**

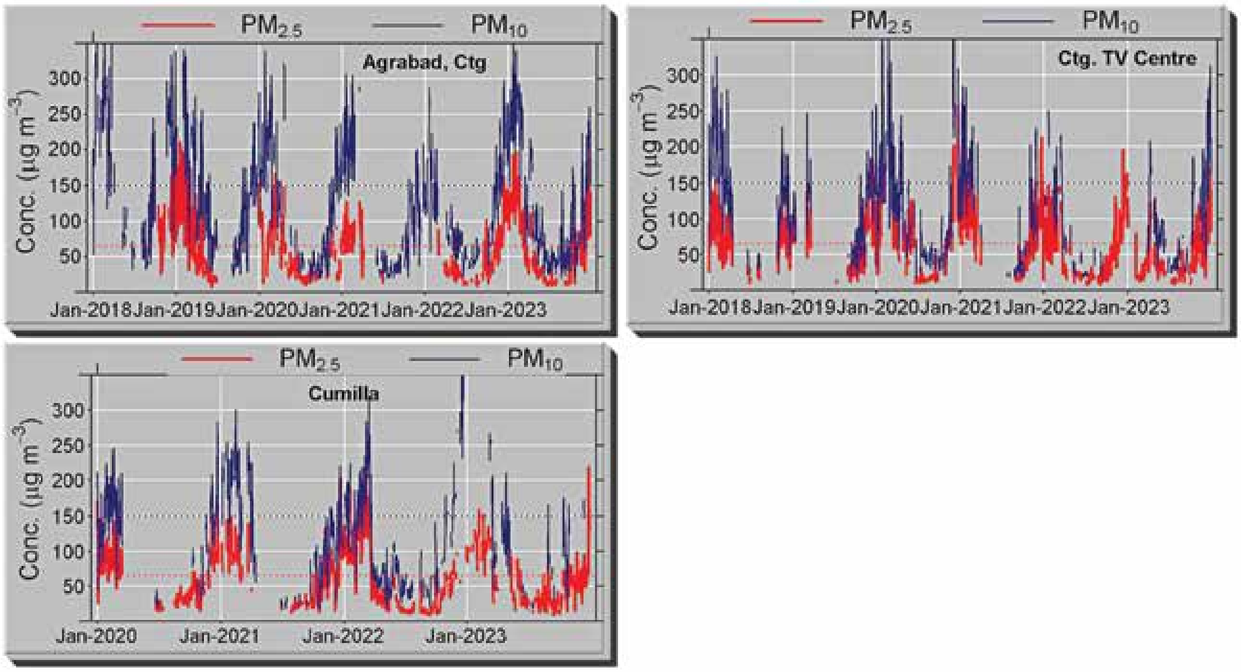
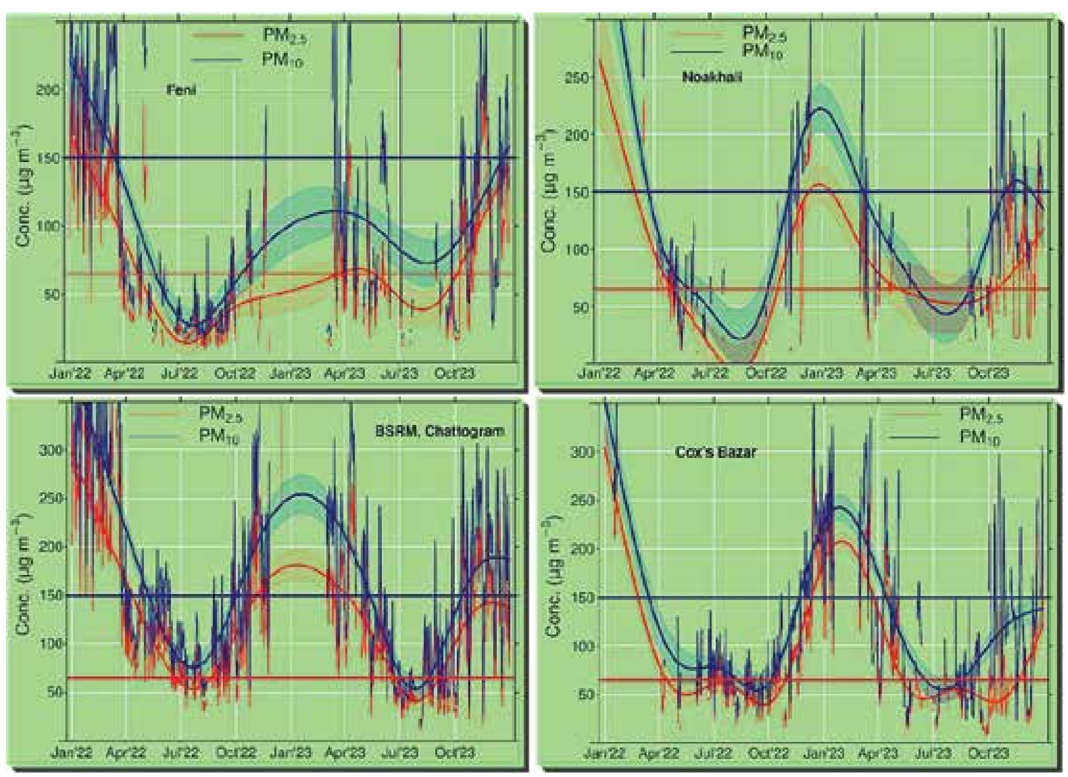
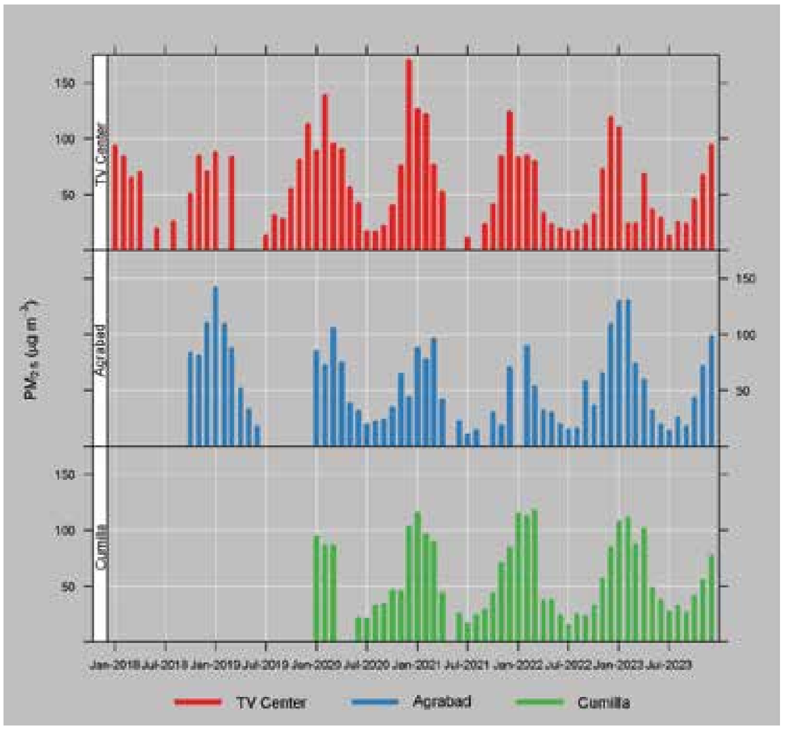


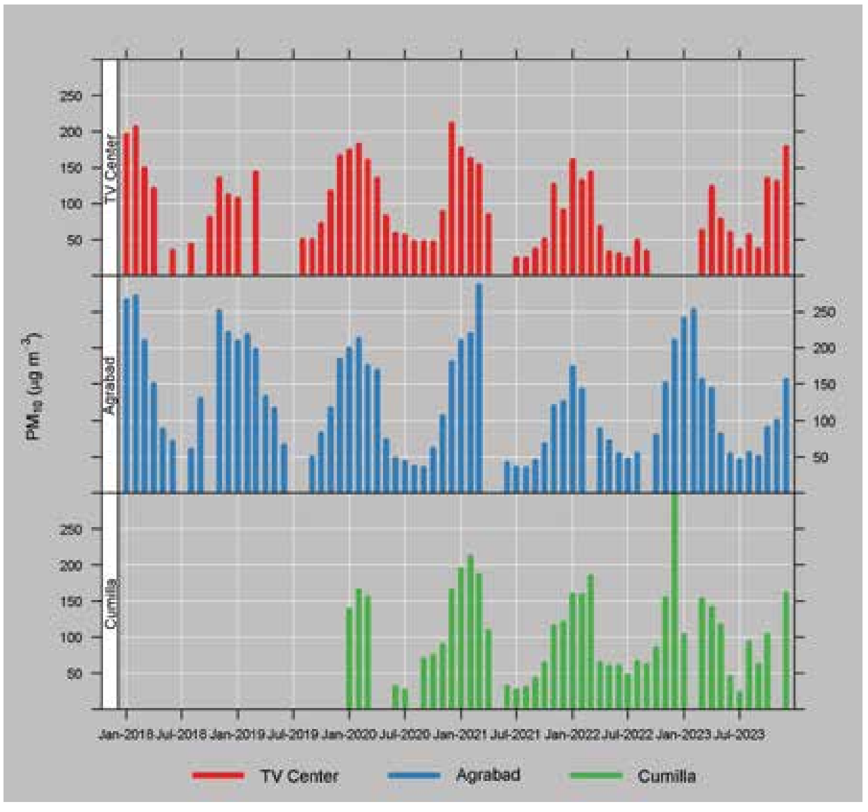

**Fig. 6-4 Seasonal variations in daily averaged PM concentrations captured using C-CAMS in the southeastern stations.**



## Fig. 6-5 Trends in monthly $PM_{2.5}$ concentrations in southeast region



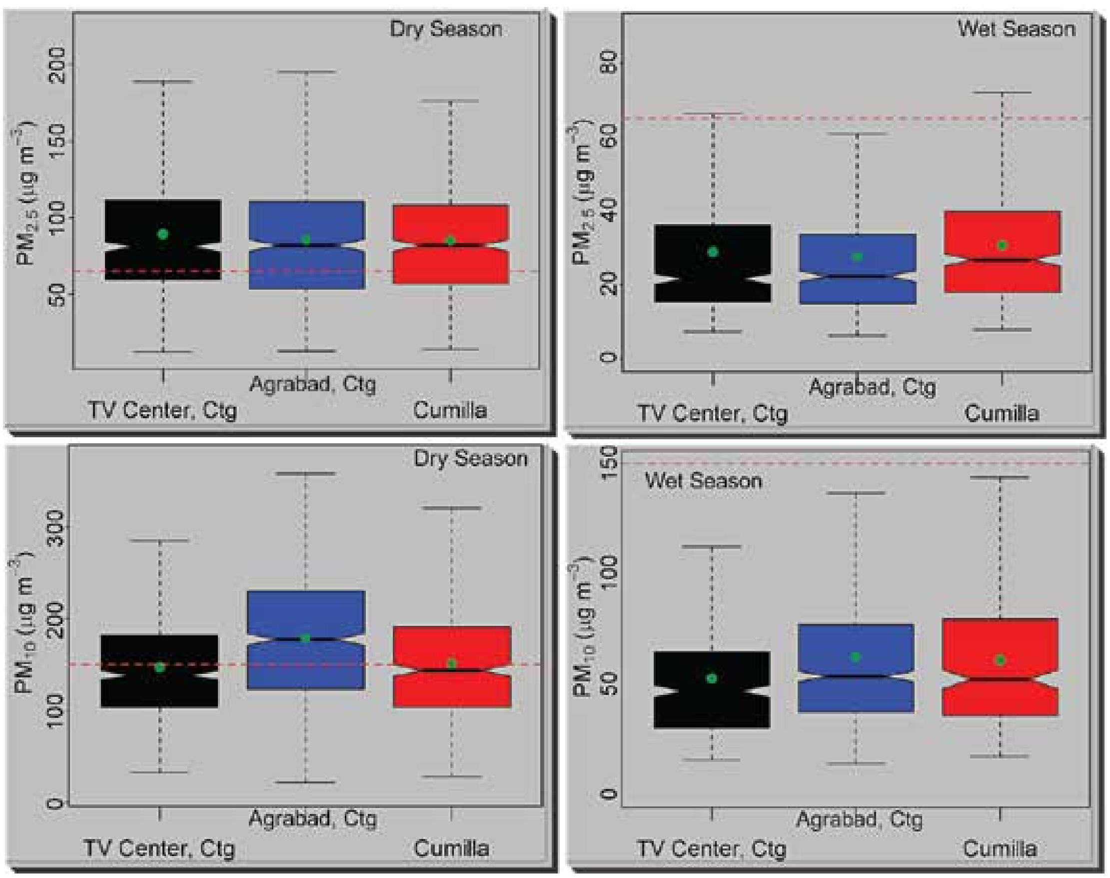

## Fig. 6-6 Trends in monthly $PM_{10}$ concentrations in southeast region



The box-whisker plots of daily averaged $PM_{2.5}$ and $PM_{10}$ concentrations in different seasons are showing that most of the days (~75%) in the dry season $PM_{2.5}$ concentrations exceeded the national limit values whereas number of exceeding days for $PM_{10}$ concentrations at the stations during dry season were relatively low (~50%) (Fig. 6-7). Dry seasonal average $PM_{10}$ concentrations (green balls on the box of Fig. 6-7) at the stations were also marginal to the national limit value, whereas those for $PM_{2.5}$ concentrations were remarkably high (Fig. 6-7).

During wet season, both the $PM_{2.5}$ and $PM_{10}$ concentrations at all of the stations were compliant in most of the days (Fig. 6-7).

**Fig. 6-7 Box-whisker plots of daily averaged $PM_{2.5}$ and $PM_{10}$ concentrations in dry (left) and wet (right) season at the CAMS located southeastern Bangladesh. Horizontal red lines are the respective national limit values, and the green balls on the box showing the means.**




Particulate matter (both $PM_{2.5}$ & $PM_{10}$) concentrations at Cumilla, CDA, TV Center and Noakhali during dry season (Fig. 6-8) were found to rise only once in the whole day, from 6:00 pm to 9:00 pm, from when the concentrations incessantly drop until 6:00 pm. It is noticeable that the concentrations fell sharply in the morning hour at BSRM, Feni and Cox's Bazar stations. In general, $PM_{2.5}$ concentrations in dry season were found to increase in Tuesday and fall in Saturday at the stations.

**Fig. 6-8 Diurnal variations in $PM_{2.5}$ concentrations at the stations.**

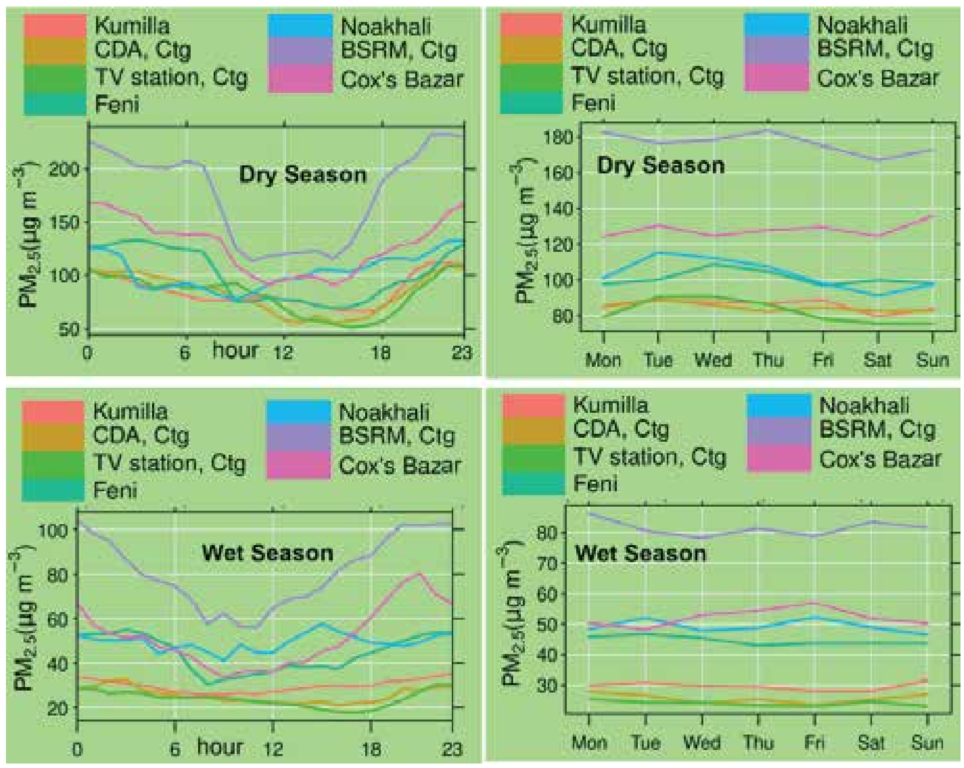
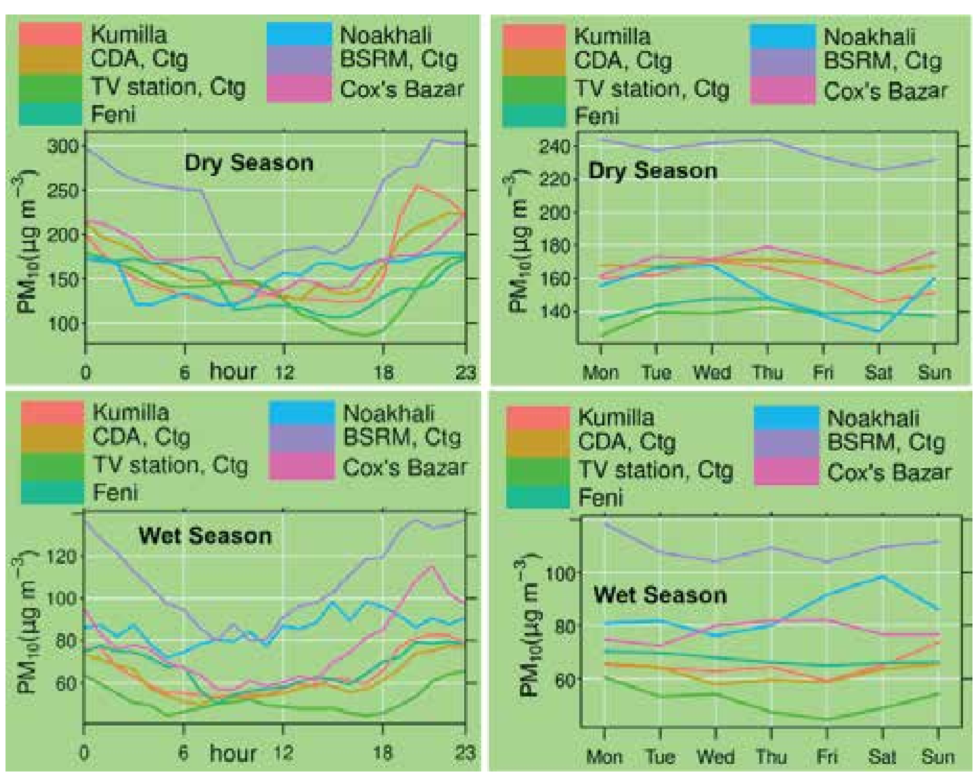


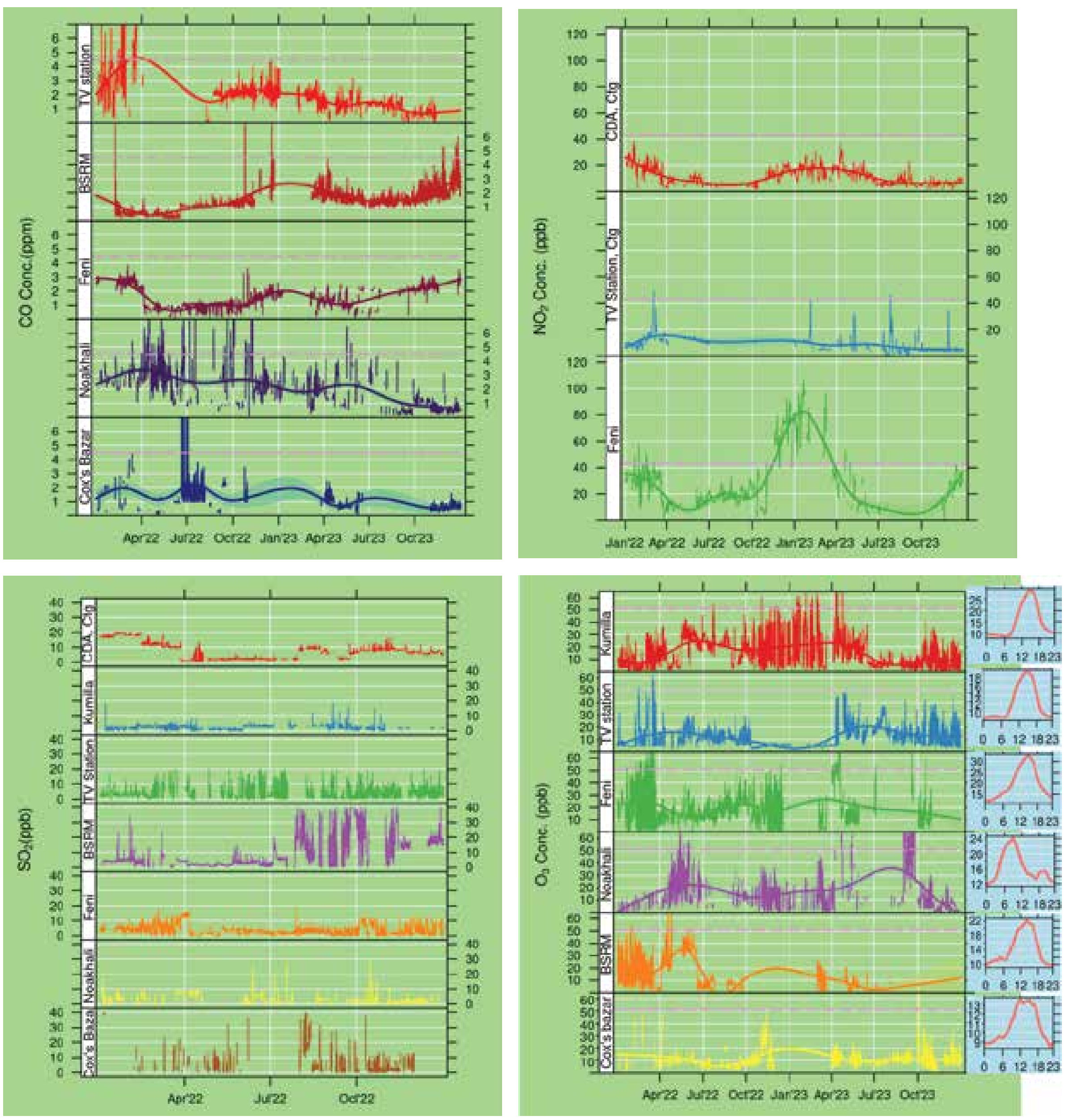

**Fig. 6-9 Diurnal variations in $PM_{10}$ concentrations at the stations.**



## 6.3.2 Gaseous Parameters

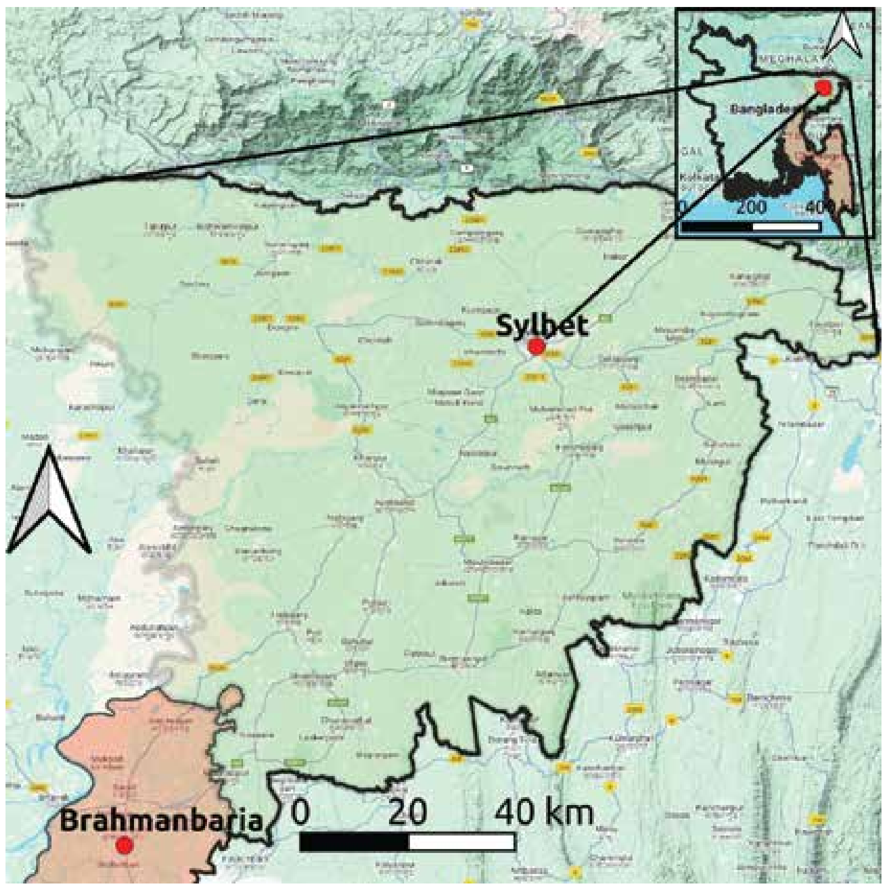
The gaseous parameters at the stations also found to follow seasonal variations, with higher values at dry season and lower at wet season. However, in most of the stations the gaseous parameters were very compliant with the national limit values except in several cases like the Feni station experienced higher $NO_2$ concentrations during January' 2023, and the Noakhali station frequently violated with higher CO concentrations in the year 2022. $SO_2$ concentrations in all of the stations were much lower from the limit value. But the stations, especially Cumilla and Noakhali were polluted with higher $O_3$ concentrations; Nighttime $O_3$ concentration at Noakhali station could also be a worrying matter.

**Fig. 6-10 8-h average CO concentrations (top-left), 24-h average $NO_2$ concentrations (top-right), hourly $SO_2$ concentrations (bottom-left) and 8-h average $O_3$ concentrations with diurnal variations in inset (bottom-right) at the stations. Horizontal dotted lines are respective limit values.**



# 7 Data Analysis Results North East Region

Northeast regions of Bangladesh; red ball shows the air monitoring stations




## 7.1 Introduction

Sylhet division and the northern part of Chattogram division are the areas of the northeast region of Bangladesh. This area is blocked by high mountains to both the north and east sides. One CAMS in Sylhet and one C-CAMS in Brahmanbaria are collecting air quality data in this region.

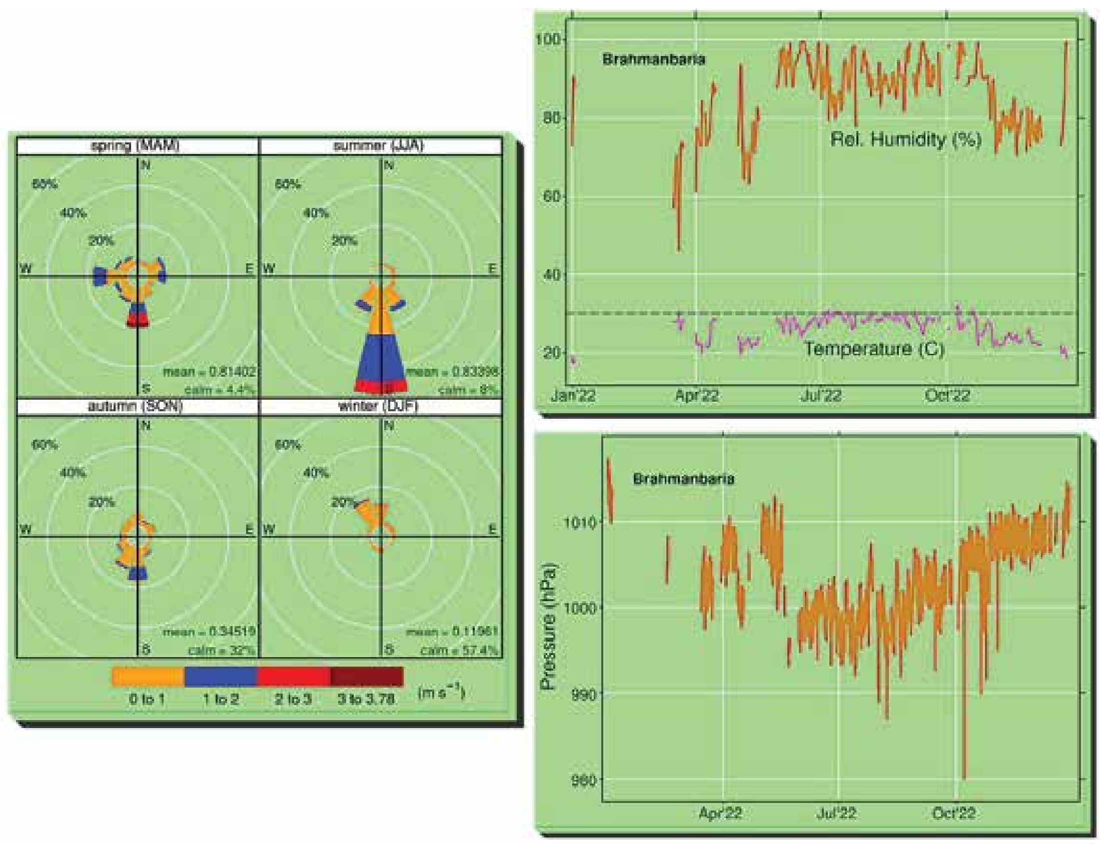
Sylhet has a topography characterized with hills and basins, located on the banks of the river Surma. Sylhet is the hub of tea industry and also the major reservoir of oil and gas. The metropolitan city of Sylhet (latitude 24˚ 53' 18.95" N, longitude 91˚ 51' 58.82" E) with its area of 26.50 $km^2$ is housing about 0.5 million people.

Brahmanbaria is a district under Chattogram Division. The major industries of Brahmanbaria District have been: agriculture, fishing, power and electricity generation, and natural gas. Brahmanbaria's Titas gas is the largest gas field of Bangladesh. Population of the Brahmanbaria city is only 33067.

## 7.2 Meteorology

The meteorology of this region is very typical to that of Bangladesh – northern and northwestern calm winds prevail in winter season and the southern strong wind dominated in summer season (Fig. 7-1); very calm environment persists during October and November months. The months from June to October are characterized with high temperature, high relative humidity and comparatively low atmospheric pressure; temperature starts waning from November and reached at the lowest in January when atmospheric pressure are comparatively remains high. The region usually observes high level of relative humidity (RH>70%) except during February to April when the RH frequently gets below 70% (Fig.7-1).

**Fig. 7-1 Seasonal wind roses at Brahmanbaria (leff), trends in daily Temperature & Relative humidity (upper-right) and trends in hourly Atm. Pressure (bottom-right) in Brahmanbaria**



## 7.3 Criteria Air Pollutants

### 7.3.1 Particulate Matters (PM)

Data capture rates at the stations being very low, annual conclusion cannot be drawn for most of the years except 2018; however, the discussions on the seasonal and diurnal trends have been made in the following sections to depict an approximations of the air quality in this region.

On the basis of a full year data captured in 2018 it is found that the annual mean $PM_{2.5}$ and $PM_{10}$ concentrations in Sylhet were about 52.2 and 94.1 $\mu g/m^3$ respectively. Only 25% of the days in a year in this station were severely polluted with high concentrations of particulate matter.

**Table 7-1 Overview of the daily $PM_{2.5}$ Concentrations ($\mu g/m^3$) in Sylhet**

| Station | Par | Year | Data capture (%) | Mean | 25 percentiles | 50 percentiles | 75 percentiles | Max. |
|---|---|---|---|---|---|---|---|---|
| Sylhet | $PM_{2.5}$ | 2018 | 81.1 | 52.2 | 21.6 | 44.0 | 74.0 | 180.3 |
| | $PM_{2.5}$ | 2019 | 62.7 | – | – | – | – | – |
| | $PM_{2.5}$ | 2020 | 6.3 | – | – | – | – | – |
| | $PM_{2.5}$ | 2021 | 32.3 | – | – | – | – | – |
| | $PM_{2.5}$ | 2022 | 39.7 | – | – | – | – | – |
| | $PM_{2.5}$ | 2023 | 47.7 | – | – | – | – | – |

-Not applicable due to data capture rate less than 65%

**Table 7-2 Overview of the daily $PM_{10}$ Concentrations ($\mu g/m^3$) in Sylhet**

| Station | Par | Year | Data capture (%) | Mean | 25 percentiles | 50 percentiles | 75 percentiles | Max. |
|---|---|---|---|---|---|---|---|---|
| Sylhet | $PM_{10}$ | 2018 | 88.8 | 94.1 | 47.5 | 81.1 | 130.8 | 279.2 |
| | $PM_{10}$ | 2019 | 54.2 | – | – | – | – | – |
| | $PM_{10}$ | 2020 | 18.9 | – | – | – | – | – |
| | $PM_{10}$ | 2021 | 35.3 | – | – | – | – | – |
| | $PM_{10}$ | 2022 | 45.5 | – | – | – | – | – |
| | $PM_{10}$ | 2023 | 51.2 | – | – | – | – | – |

-Not applicable due to data capture rate less than 65%

Unlike other regions of the country, eastern region was found to get highest level of particulate matter concentration in summer season which experienced $PM_{2.5}$ concentration greater by about 19.4 and 5.4% than those in winter season, and $PM_{10}$ concentrations about 16.5 and 9.6% than those in winter season in Sylhet and Brahmanbaria respectively. The wet season as usually enjoyed fresh air with $PM_{2.5}$ and $PM_{10}$ concentrations about half of the levels found in winter season (Table 7-3).

Nighttime pollutions worsened much from the daytime pollutions during all the season in both the stations. During winter season, the increases in $PM_{2.5}$ and $PM_{10}$ concentrations at night compared to those at day were 82.2 and 70.0 % in Sylhet, and 26.5 and 36.6 % in Brahmanbaria respectively. On the other hand during summer season, the increases in $PM_{2.5}$ and $PM_{10}$ concentrations at night compared to those at day were 38.7 and 36.6 % in Sylhet, and 17.4 and 16.8 % in Brahmanbaria respectively. Nighttime PM concentrations at the stations during wet season were, on an average, greater by 30.0% than daytime concentrations (Table 7-3).

Particulate pollutions in Sylhet was also found characterized with low contributions of $PM_{2.5}$ to $PM_{10}$; the highest contribution was found at 56% during the summer season. However, the contributions of $PM_{2.5}$ to $PM_{10}$ were found comparatively high in all the seasons (Table 7-3) in Brahmanbaria.

**Table 7-3 Seasonal and Diurnal statistics of PM concentrations at the stations**

| Station | Pollutant | Winter | | | Summer | | | Wet | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Day[1] | Night[2] | Mean | Day[1] | Night[2] | Mean | Day[1] | Night[2] |
| **Sylhet** | $PM_{2.5}$ | 75.3 | 54.6 | 99.5 | 83.9 | 71.1 | 98.6 | 32.2 | 27.0 | 37.9 |
| | $PM_{10}$ | 142.2 | 107.8 | 182.3 | 165.7 | 141.5 | 193.4 | 73.8 | 62.3 | 86.4 |
| | [3]$PM_{2.5}/PM_{10}$ | 0.34 | 0.33 | 0.35 | 0.56 | 0.55 | 0.57 | 0.46 | 0.44 | 0.48 |
| **Brahmanbaria** | $PM_{2.5}$ | 136.7 | 121.5 | 153.7 | 144.0 | 133.4 | 156.6 | 85.9 | 75.8 | 97.4 |
| | $PM_{10}$ | 190.7 | 153.9 | 210.3 | 209.0 | 194.0 | 226.6 | 114.1 | 103.5 | 126.8 |
| | $PM_{2.5}/PM_{10}$ | 0.68 | 0.66 | 0.70 | 0.645 | 0.63 | 0.66 | 0.675 | 0.65 | 0.70 |

1 Daytime considered the hours from 6:00 am to 18:00 pm
2 Nighttime considered the hours from 19:00 pm to 5:00 am
3 $PM_{2.5}$ to $PM_{10}$ ratio was calculated from the hourly values

Seasonal variations of PM concentrations in Sylhet was obvious and follow the typical pattern for the country. However instead of July, the month of June was found to be the cleanest time while January was as usually the most polluted time (Fig. 7-2). Although a general conclusion couldn't be drawn for Sylhet due to poor data capture rate, it is presumed from Fig. 7-2 that the daily concentrations in recent times have increased compared to 2018-19.

**Fig. 7-2 Trends in daily (top) and monthly $PM_{2.5}$ and (bottom) $PM_{10}$ concentrations in Sylhet**

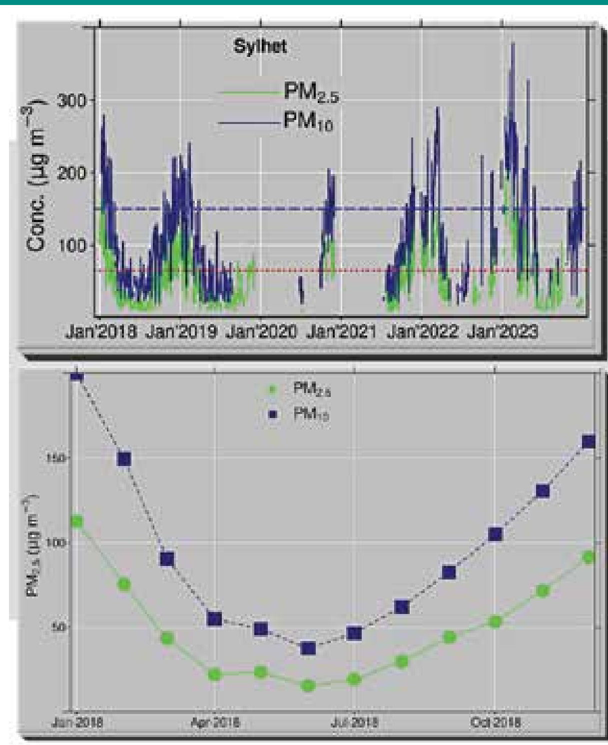
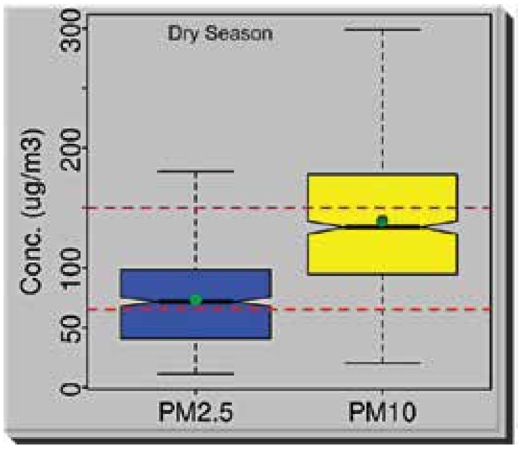
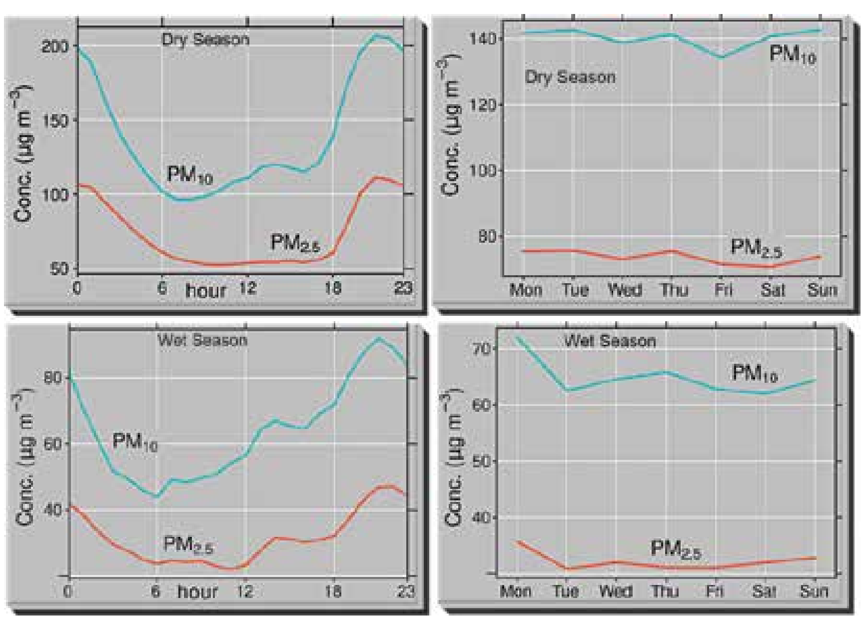


**Fig. 7-3 Box-Whisker plots of daily $PM_{2.5}$ and $PM_{10}$ concentrations in dry season (left) and wet season (right) in Sylhet horizontal lines are corresponding national standards; and the green circles show the average.**



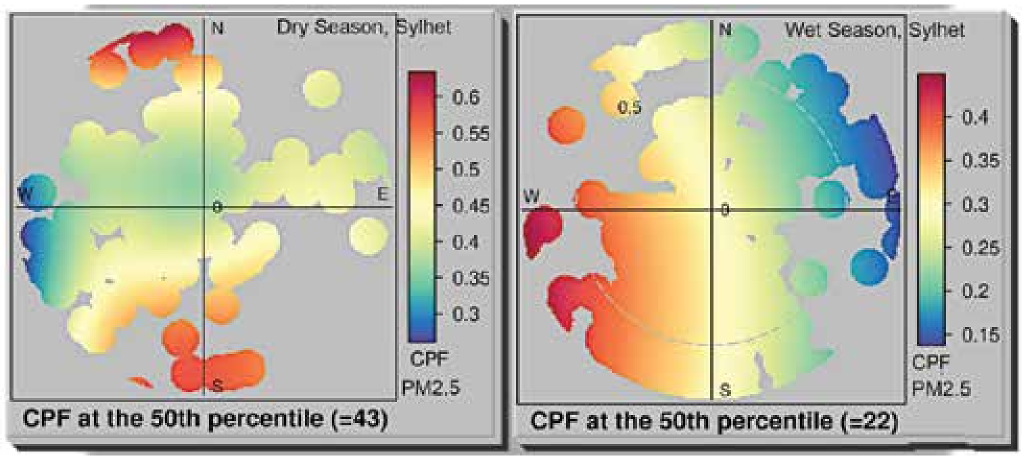

Diurnal variations in both $PM_{2.5}$ and $PM_{10}$ concentrations in Sylhet were found little from those in other regions. The concentrations got peaks value at around 9:00 pm from when incessantly dropped until 11:00 am for $PM_{2.5}$ and 7:00 am for $PM_{10}$ in dry season in Sylhet station; $PM_{10}$ concentrations had shown an increasing trends even at daytime during dry season while $PM_{2.5}$ concentrations were mostly flat during daytime. Sylhet station was getting low PM concentrations during week-off days and also in Wednesday, and in line with the other regions of the country Tuesdays of dry season were found getting higher pollutions in Sylhet too (Fig. 7-4).

**Fig. 7-4 Diurnal and weekday trends in $PM_{2.5}$ and $PM_{10}$ concentrations during dry (upper) and wet (bottom) seasons in Sylhet**




Sources to the southwest directions from the station were contributing highly to $PM_{2.5}$ concentrations in Sylhet station during both dry and wet season. In addition, the northwest sources were also important, particularly in dry season (Fig. 7-5).

**Fig. 7-5 Directional influences of $PM_{2.5}$ concentrations during dry (left) and wet (right) seasons in Sylhet**




## 7.3.2 Gaseous Pollutants

Very small amount of gaseous data was got from the Sylhet station, although in contrast, the Brahmanbaria station generated sufficient amount of data of CO, $SO_2$ (Fig. 7-6), and $NO_2$ and $O_3$ concentrations (Fig. 7-7). It was found that the gaseous pollutants in Brahmanbaria station were not at that level to be concerned for; only $O_3$ concentrations were found crossing the national limit value in several times (Fig. 7-7).

**Fig. 7-6 Trends in 8-h CO (left) and 24-h $SO_2$ (right) concentrations in Sylhet and Brahmanbaria stations.**

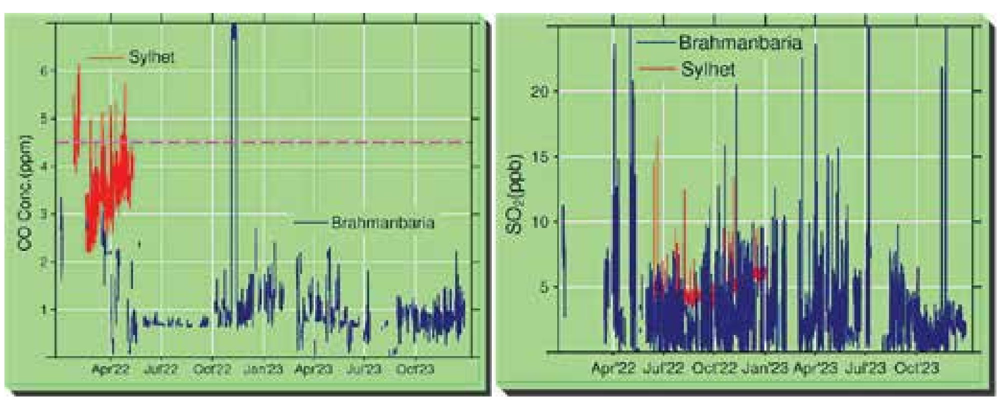
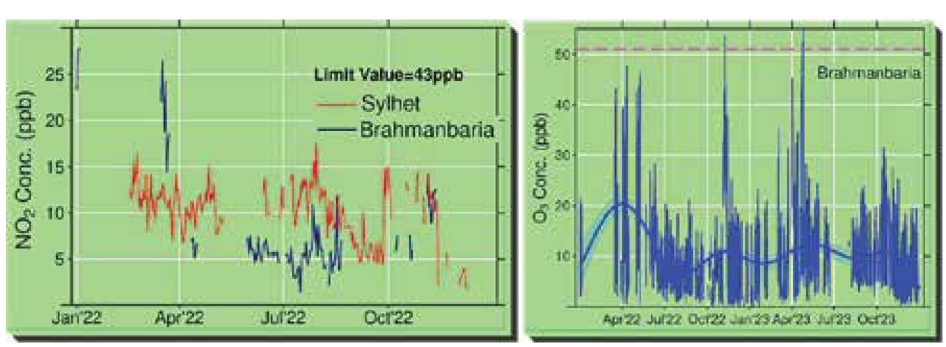
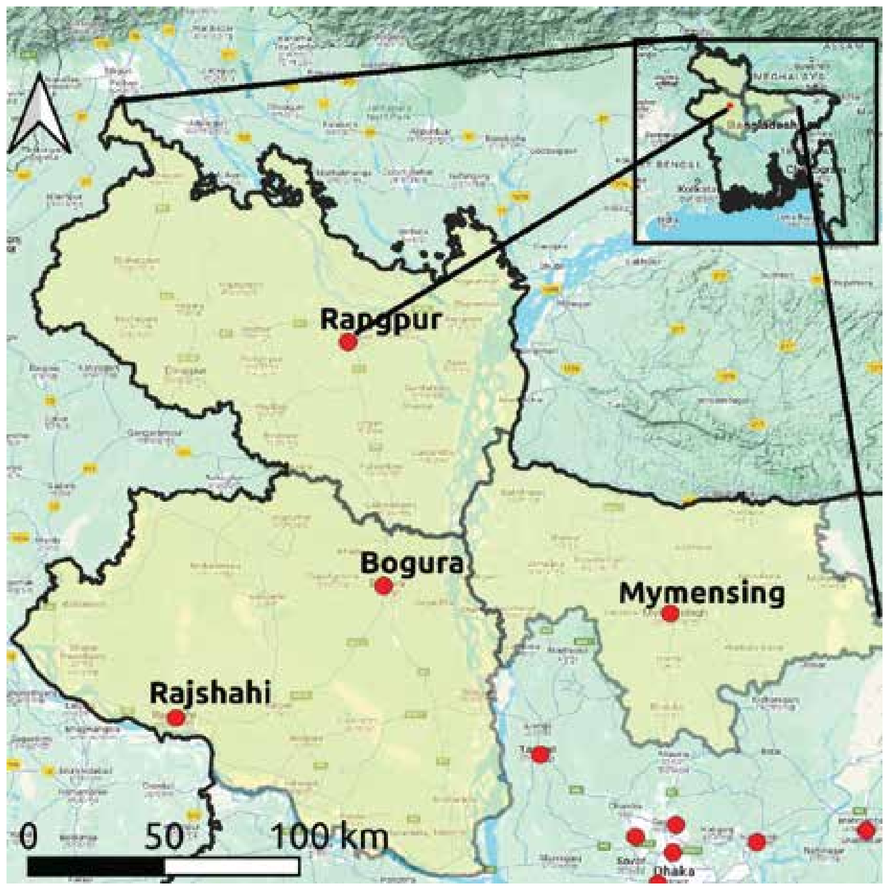



**Fig. 7-7 Trends in daily $NO_2$ and 8-hourly $O_3$ conc. in Sylhet and Brahmanbaria stations**



# 8 Data Analysis Results North West Region

**Maps with stations of North West region of Bangladesh**




## 8.1 Introduction

The north and west parts of Bangladesh are very important for the study of air pollution as the wind enters through these zones during dry season. This region is mostly agricultural; industrial growth is very limited. Department of Environment operates 3 CAMS and 1 C-CAMS in this region; the cities under monitoring are Rajshahi, Rangpur, Mymensingh and Bogura.

Rajshahi a metropolitan city, is situated in the northwest region of Bangladesh (monitoring site position is at latitude 24˚ 22′ 58.33″ N, longitude 88˚ 36′ 27.42′ E) and near the border with India. The metropolitan area has a population of 3.8 million with an area of 95.56 km$^2$. The monitoring station is located beside the Rajshahi – Naogaon highway.

Rangpur is the divisional city, located to the northwest region. It has also border with India. Rangpur City Corporation has an area of 205.76 square kilometers with population approximately 7,96,556. The climate is humid subtropical.

Mymensingh is about 120 km north from the capital city of Dhaka. It is a major financial center and educational hub of the north-central Bangladesh. The population density of Mymensingh city is 44,458/km$^2$, making it the second most densely populated city in Bangladesh. Mymensingh, lies on the north bank of the Old Brahmaputra River. The climate of Mymensingh is little cooler than Dhaka, as it is closer to the Himalayas.

The Bagura district has a humid subtropical climate, situated at the northwest part of country. This district area is 2,899 km$^2$ with 3.7 million civilians. The analyzer is located 2.0 m above the roof and close to a region with light traffic and sparse population.

## 8.2 Meteorology

The meteorology of this region is illustrated in Fig.8-1 and Fig.8-2. Winter season of this region is characterized with low temperature, high relative humidity, high atmospheric pressure and low solar radiation; north-western calm wind blows over this area during winter season. On the other hand, the summer season is characterized with high temperature, low relative humidity, moderate pressure and high solar radiation (Fig. 8-2). The wind roses for Rangpur station is mostly the same as the other parts of the country – wind blows from the north and northwest during dry season and from south and southeast during wet season. However, the roses drawn on the Mymensingh station is found quite different; wind is blown mostly from northwest directions all the year round, which needs to be investigated further.

**Fig. 8-1 Seasonal wind-roses at Rangpur and Mymensingh stations**

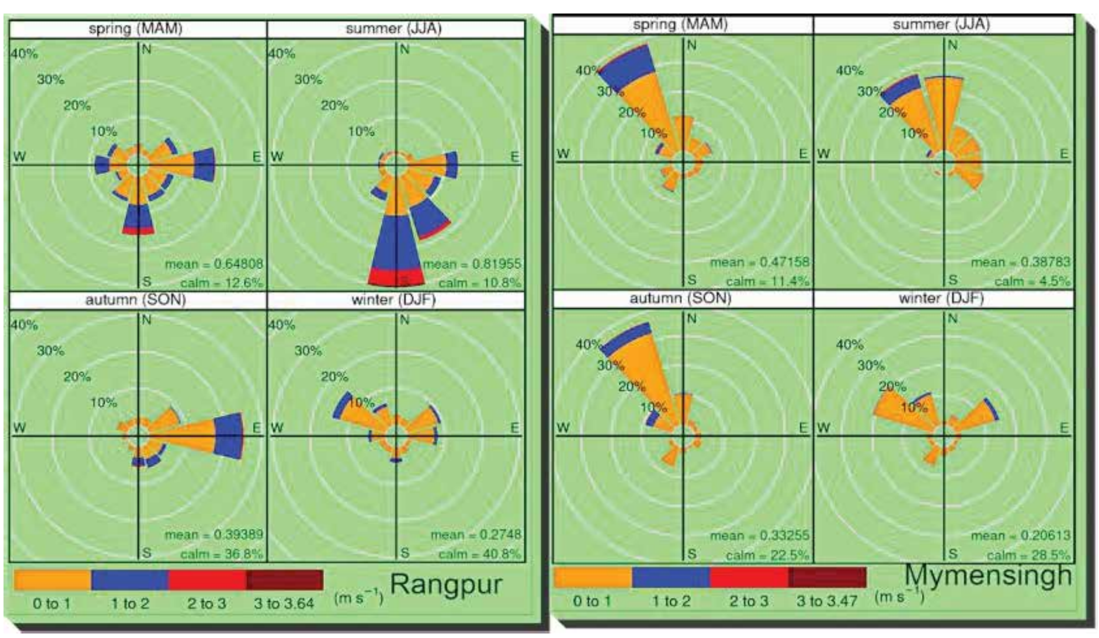
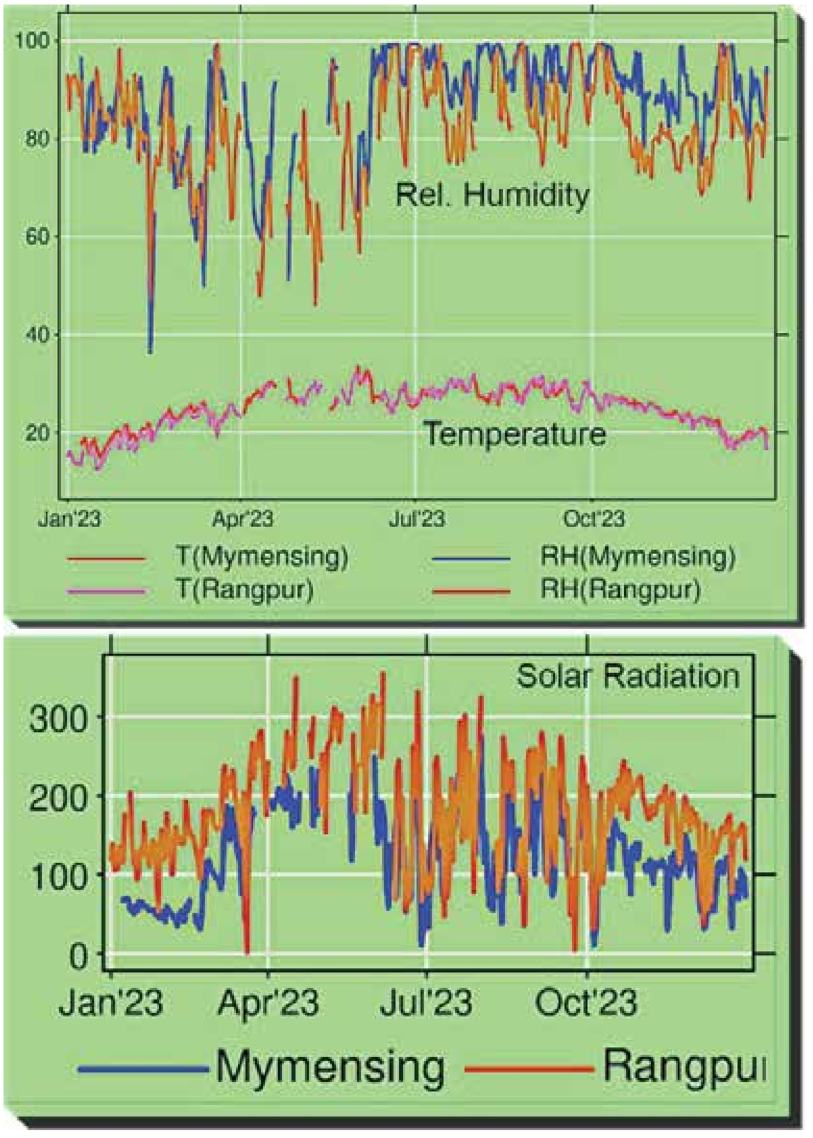


**Fig. 8-2 Trends in daily temperature ($^{0}C$) and relative humidity (%) at Mymensingh and Rangpur stations (upper); Trends in daily solar radiation ($W/m^2$)**




## 8.3 Criteria Air Pollutant

### 8.3.1 Particulate Matters (PM)

Northwestern regions were found having comparatively high PM concentrations – annual $PM_{2.5}$ concentrations at Mymensing, Rangpur and Rajshahi stations in 2023 were respectively 105.9, 116.0 and 116.1 µg-m$^3$ which were greater than the national limit value by a factor of 3 and the annual $PM_{10}$ concentrations at the stations in recent years were respectively 227.1, 170.0 and 165.0 µg-m$^3$, which are greater than the national limit value by a factor of 4.5. The data shows (Table 8-1), only 25% days of a year at the stations daily $PM_{2.5}$ concentrations could satisfy the national limit value of 65 µg-m$^3$. The data also reveals that pollution levels in recent years in the stations have increased (Table 8-1).

**Table 8-1 Overview of the daily $PM_{2.5}$ Concentrations (µg/m³) in the stations in northwest zone**

| Station | Par | Year | Data capture (%) | Mean | 25 percentiles | 50 percentiles | 75 percentiles | Max. |
|---|---|---|---|---|---|---|---|---|
| **Rajshahi** | $PM_{2.5}$ | 2018 | 92.3 | 75.2 | 33.6 | 56.3 | 112.9 | 244.5 |
| | $PM_{2.5}$ | 2019 | 66.6 | 76.5 | 32.1 | 66.2 | 110.6 | 275.6 |
| | $PM_{2.5}$ | 2020 | 74.2 | 70.3 | 28.2 | 63.7 | 101.4 | 241.1 |
| | $PM_{2.5}$ | 2021 | 81.9 | 86.3 | 35.3 | 77.9 | 126.2 | 285.8 |
| | $PM_{2.5}$ | 2022 | 91.0 | 85.1 | 44.8 | 74.2 | 108.9 | 285.6 |
| | $PM_{2.5}$ | 2023 | 84.1 | 116.0 | 42.1 | 95.9 | 173.4 | 395.2 |
| **Rangpur** | $PM_{2.5}$ | 2018 | – | – | – | – | – | – |
| | $PM_{2.5}$ | 2019 | – | – | – | – | – | – |
| | $PM_{2.5}$ | 2020 | 80.0 | 95.2 | 28.5 | 44.5 | 166.7 | 330.9 |
| | $PM_{2.5}$ | 2021 | 91.2 | 111.0 | 42.3 | 98.0 | 168.4 | 311.8 |
| | $PM_{2.5}$ | 2022 | 70.1 | 108.2 | 43.5 | 87.6 | 167.8 | 287.5 |
| | $PM_{2.5}$ | 2023 | 79.7 | 116.4 | 51.0 | 103.2 | 168.8 | 359.2 |
| **Mymensingh** | $PM_{2.5}$ | 2020 | 45.5 | – | – | – | – | – |
| | $PM_{2.5}$ | 2021 | 53.1 | – | – | – | – | – |
| | $PM_{2.5}$ | 2022 | 38.1 | – | – | – | – | – |
| | $PM_{2.5}$ | 2023 | 88.8 | 105.8 | 45.9 | 91.6 | 143.2 | 324.1 |

-Not applicable due to data capture rate less than 65%

**Table 8-2 Overview of the daily $PM_{10}$ Concentrations (µg/m³) in the stations in northwest zone**

| Station | Par | Year | Data capture (%) | Mean | 25 percentiles | 50 percentiles | 75 percentiles | Max. |
|---|---|---|---|---|---|---|---|---|
| **Rajshahi** | $PM_{10}$ | 2018 | 78.6 | 147.0 | 81.6 | 122.9 | 203.5 | 434.3 |
| | $PM_{10}$ | 2019 | 78.9 | 126.1 | 67.9 | 99.8 | 159.8 | 459.2 |
| | $PM_{10}$ | 2020 | 77.8 | 123.0 | 64.0 | 99.0 | 149.8 | 454.3 |
| | $PM_{10}$ | 2021 | 90.7 | 160.0 | 70.0 | 118.0 | 229.7 | 566.0 |
| | $PM_{10}$ | 2022 | 73.4 | 168.7 | 102.6 | 163.3 | 222.1 | 417.2 |
| | $PM_{10}$ | 2023 | 49.3 | – | – | – | – | – |
| **Rangpur** | $PM_{10}$ | 2018 | – | – | – | – | – | – |
| | $PM_{10}$ | 2019 | – | – | – | – | – | – |
| | $PM_{10}$ | 2020 | 68.2 | 158.3 | 65.2 | 113.8 | 240.2 | 493.7 |
| | $PM_{10}$ | 2021 | 75.9 | 188.2 | 87.4 | 189.8 | 253.1 | 559.7 |
| | $PM_{10}$ | 2022 | 59.4 | – | – | – | – | – |
| | $PM_{10}$ | 2023 | 60.3 | – | – | – | – | – |
| **Mymensingh** | $PM_{10}$ | 2020 | 9.0 | – | – | – | – | – |
| | $PM_{10}$ | 2021 | 64.1 | – | – | – | – | – |
| | $PM_{10}$ | 2022 | 32.9 | – | – | – | – | – |
| | $PM_{10}$ | 2023 | 83.6 | 227.7 | 137.6 | 222.5 | 308.2 | 556.1 |

-Not applicable due to data capture rate less than 65%

The winter season was affected greatly with particulate matter pollution; compared to summer season, winter season experienced about 14.5, 30.0, 23.0 % greater $PM_{2.5}$ concentrations in Mymensing, Rangpur and Rajshahi respectively, and about 18.2, 18.4, 7.5 % greater $PM_{10}$ concentrations at the stations respectively. However, the PM concentrations at Bogura station did not change at all in winter and summer season. On the other hand, the wet season experienced about 50.0 to 60 % less PM concentrations compared to summer season at the stations (Table 8-3).

All the stations, irrespective of the season, were found to observe high pollution at night hours – compared to day-hours, the night-hours were receiving 16.6, 65.0, 30.0 % higher $PM_{2.5}$ concentrations in Mymensing, Rangpur and Rajshahi stations in winter season; the values at summer season were 26.1, 39.0 and 26.1 % and at rainy season were 21.0, 25.0 and 18.0 %. On the other hand, $PM_{10}$ concentrations at nighttime were higher than the concentrations at daytime by 37.7, 79.0 and 44.8 % in winter, 31.9, 32.3 and 37.6 % in summer and 30.0, 38.8 and 22.4 % in rainy season in the stations respectively (Table 8-3).

$PM_{2.5}$ contribution to $PM_{10}$ concentrations was received higher at daytime during winter season in Rangpur, followed by summer and wet season. Compared to other regions, Mymensing was experiencing lower $PM_{2.5}$ contribution to $PM_{10}$ concentrations in dry season (Table 8-3).

**Table 8-3 Seasonal and Diurnal statistics of PM concentrations (µg/m³) at the stations**

| Station | Pollutant | Winter[5] | | | Summer[6] | | | Wet[7] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean[1] | Day[2] | Night[3] | Mean | Day[2] | Night[3] | Mean | Day[2] | Night[3] |
| **Mymensing** | $PM_{2.5}$ | 142.4 | 119.5 | 139.4 | 124.7 | 111.4 | 140.3 | 62.0 | 56.6 | 68.4 |
| | $PM_{10}$ | 292.1 | 251.9 | 347.2 | 247.6 | 216.6 | 285.6 | 149.9 | 131.2 | 171.5 |
| | $PM_{2.5}/PM_{10}$ | 0.49 | 0.50 | 0.49 | 0.51 | 0.53 | 0.49 | 0.44 | 0.45 | 0.43 |
| **Rangpur** | $PM_{2.5}$ | 181.6 | 139.8 | 231.6 | 139.5 | 118.6 | 164.6 | 52.8 | 48.2 | 60.2 |
| | $PM_{10}$ | 238.5 | 176.1 | 315.4 | 201.4 | 166.3 | 243.3 | 95.0 | 80.9 | 111.2 |
| | $PM_{2.5}/PM_{10}$ | 0.68 | 0.70 | 0.66 | 0.61 | 0.63 | 0.60 | 0.60 | 0.62 | 0.58 |
| **Rajshahi** | $PM_{2.5}$ | 159.2 | 139.6 | 181.3 | 129.4 | 115.0 | 145.8 | 53.9 | 49.8 | 58.4 |
| | $PM_{10}$ | 215.2 | 174.9 | 252.5 | 200.1 | 170.1 | 234.8 | 109.0 | 98.4 | 120.5 |
| | $PM_{2.5}/PM_{10}$ | 0.61 | 0.62 | 0.59 | 0.45 | 0.45 | 0.45 | 0.56 | 0.56 | 0.56 |
| Compact- Continuous Air Monitoring Station | | | | | | | | | | |
| **Bogura** | $PM_{2.5}$ | 196.7 | 167.9 | 232.0 | 196.2 | 162.0 | 235.5 | 55.6 | 48.8 | 63.6 |
| | $PM_{10}$ | 252.8 | 218.7 | 294.0 | 249.3 | 211.9 | 293.3 | 86.0 | 76.0 | 97.6 |
| | $PM_{2.5}/PM_{10}$ | 0.77 | 0.74 | 0.80 | 0.78 | 0.76 | 0.80 | 0.68 | 0.68 | 0.69 |

1 Seasonal means were calculated from the daily concentrations which were calculated from hourly concentrations, forcing 75% data availability.
2 Daytime considered the hours from 6:00 am to 18:00 pm
3 Nighttime considered the hours from 19:00 pm to 5:00 am
4 $PM_{2.5}$ to $PM_{10}$ ratio was calculated from the hourly values
5 November to January;
6 February to April;
7 May to October;

Particulate Matter concentrations were greatly influenced by the seasonal factors – very high pollution level during winter and summer seasons and low in rainy season (May – October) (Fig. 8-5). Rangpur station was affected highly compared to Rajshahi and Mymensingh in dry season. $PM_{2.5}$ levels during the episode periods were much higher in Rangpur, followed by Mymensingh and Rajshahi (Fig. 8-4). During wet season, more than 75% of the daily $PM_{2.5}$ concentrations were within the national limit value in Rajshahi and Rangpur; however in Mymensingh more than 25% daily $PM_{2.5}$ concentrations were found greater than the national limit (Fig. 8-4). $PM_{10}$ concentrations, on the other hand, were fully compliant throughout the wet season.

**Fig. 8-4 Box-whisker plots of daily $PM_{10}$ and $PM_{2.5}$ concentrations during dry and wet season at the stations; green circles showing the average.**

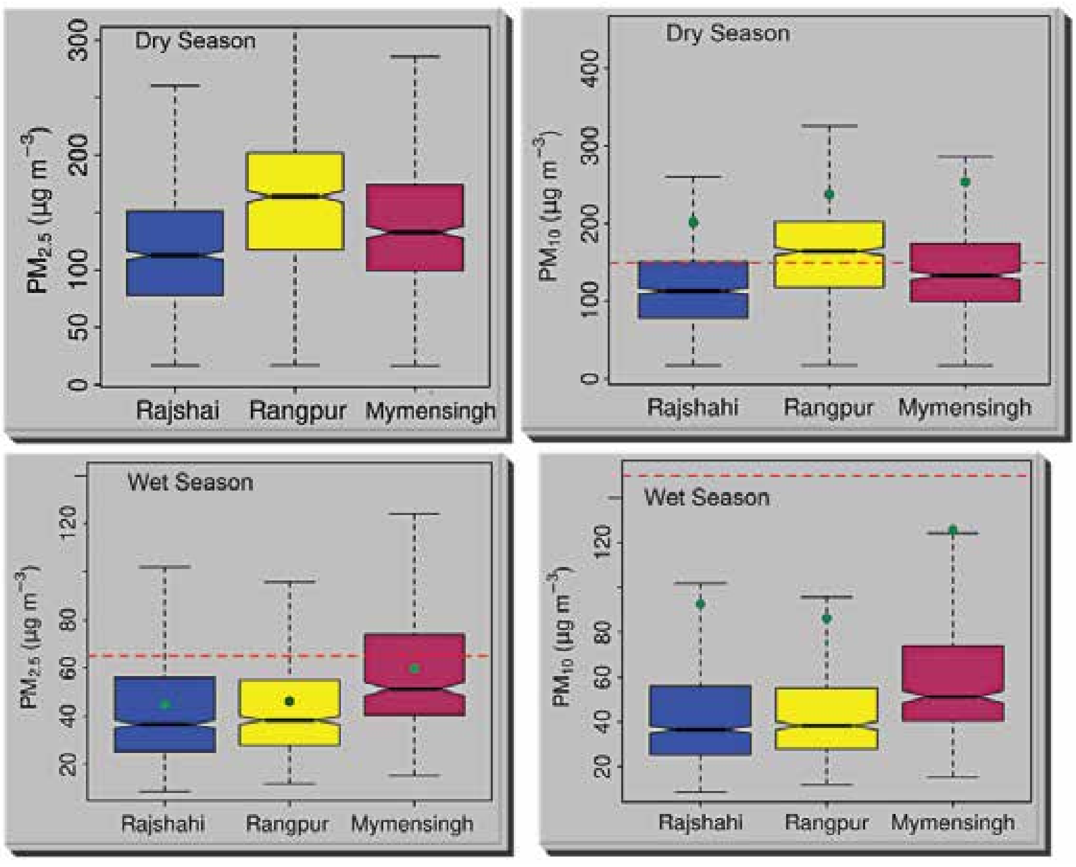
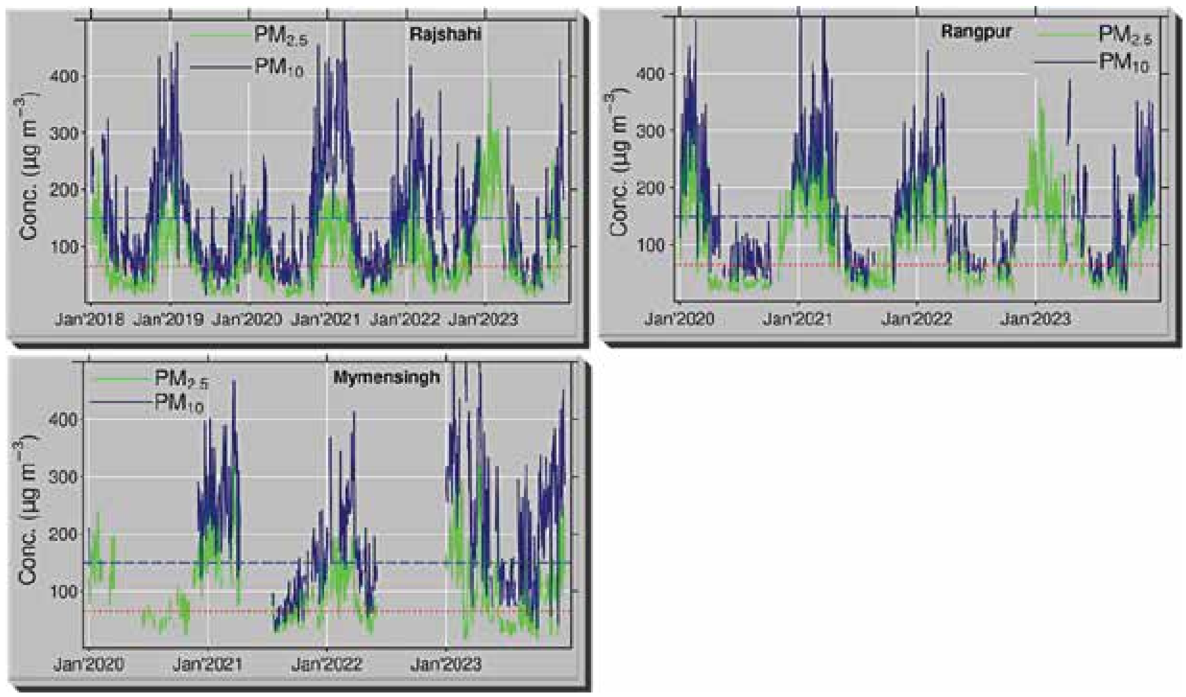
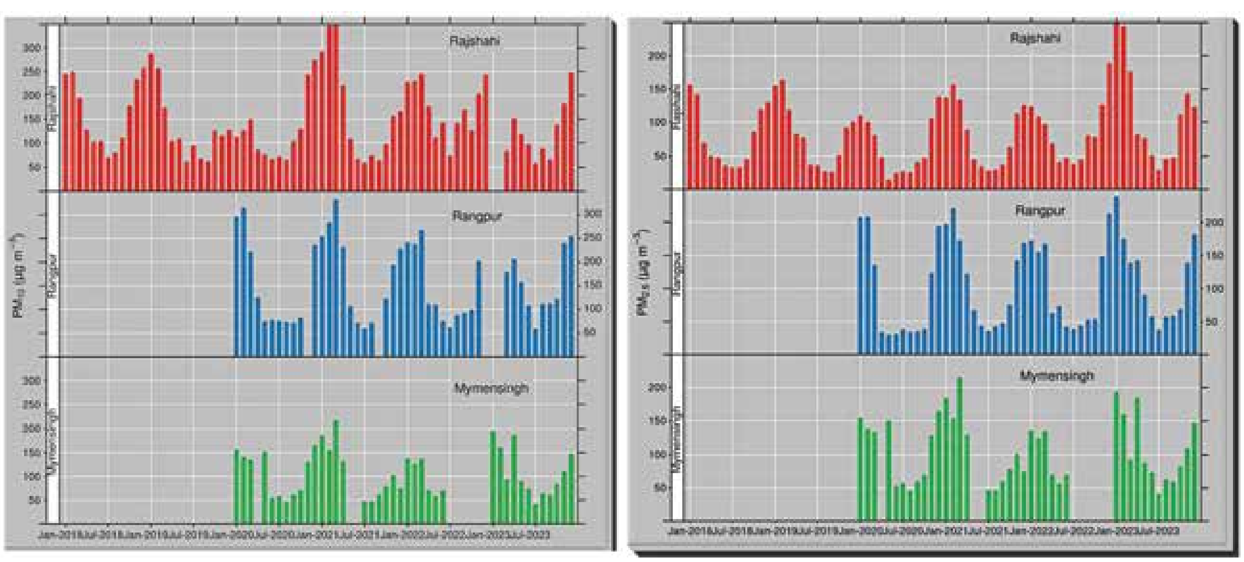


**Fig. 8-5 Trends in 24-h average $PM_{2.5}$ and $PM_{10}$ concentrations at the north-west stations**




While the month of January in other parts of the country was found the most polluted followed by December and February, all those three months were almost similarly critical in the northern stations (Fig. 8-6). Sometimes, the month of March (March'2021) were also found mostly polluted with $PM_{2.5}$.

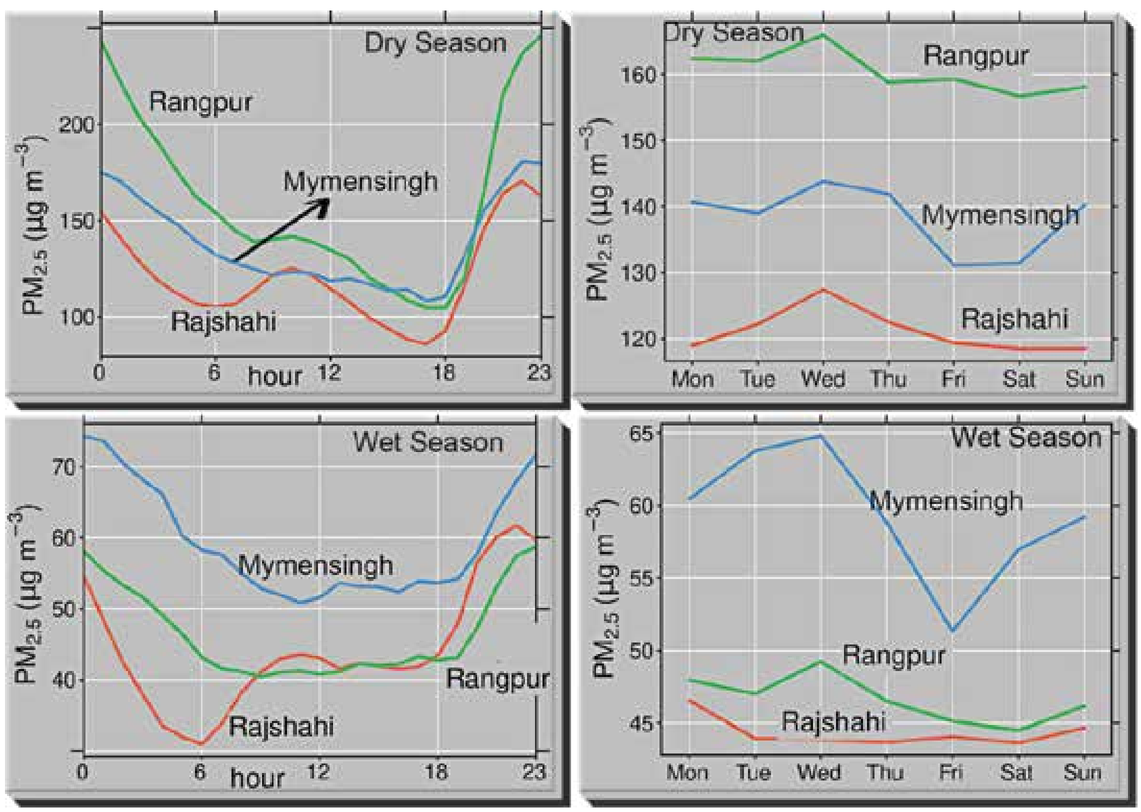
**Fig. 8-6 Trends in monthly $PM_{10}$ (left) and $PM_{2.5}$ (right) concentrations at the stations**



Diurnal trends in $PM_{2.5}$ concentration at the northwestern districts were as usual, with peak concentrations at 9:00 – 10:00 pm from when the concentrations plummeted whole night until 7:00 am. The main difference in the diurnal trends of the stations was that the Rajshahi station observed some concentration-peak at 9:00-10:00 am but in contrast, the Mymensingh and Rangpur stations got no such remarkable hike in PM concentrations at that time; rather the concentrations continuously fell through the daytime until 6:00 pm from when started to rise to the major peaks. On the other hand, diurnal trends in the PM concentrations at wet season were mostly the same for nighttime changes, but the daytime behavior of the trends were not similar to those at dry season – PM concentrations did not fall continuously at daytime during wet season (Fig. 8-7).

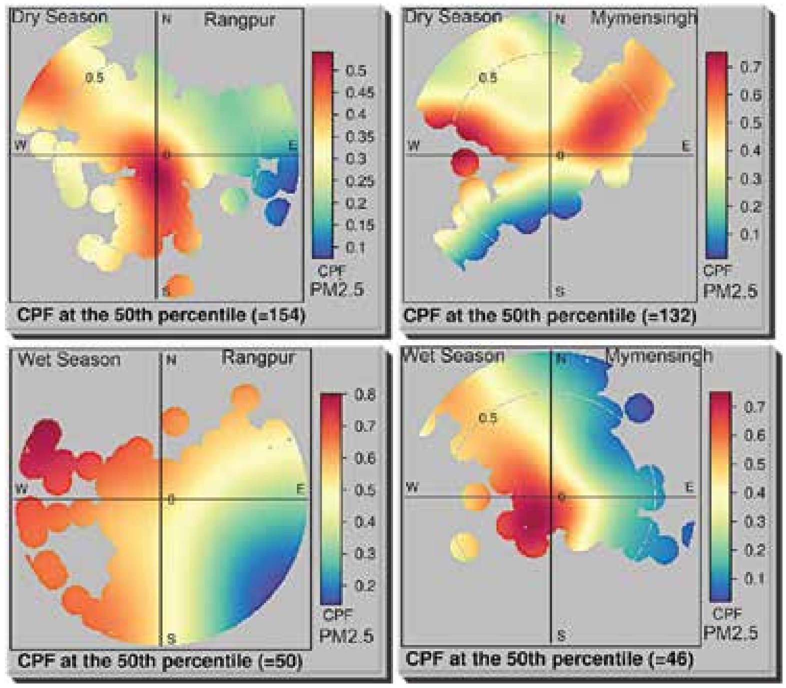
$PM_{2.5}$ concentrations were found to wane in weekend (Friday) during dry season, although the decrease in $PM_{10}$ concentrations was not much profound (Fig. 8-7). In general, the concentrations were found to increase in Wednesday.

**Fig. 8-7 Diurnal and weekday trends in $PM_{2.5}$ concentrations at dry (upper) and wet (bottom) seasons at the stations.**




The polar plots shown in Fig. 8-8 were drawn only for the high $PM_{2.5}$ concentrations. The plots show that during dry season, the Rangpur station was hit by very high level of $PM_{2.5}$ concentrations in calm weather and the pollution seemed coming mainly from the south; the station was also influenced greatly by the northwestern sources. Mymensingh station was influenced by both the northeastern and northwestern sources in dry season. During wet season both the stations were affected by the southwestern sources (Fig. 8-8).

**Fig. 8-8 Directional influences of the high level of $PM_{2.5}$ concentrations at Rangpur and Mymensingh stations during dry and wet season**




## 8.3.2 Gaseous Pollutants

Both the CO and $SO_2$ concentrations at the Mymensingh and Rangpur stations were very compliant with the national standards, although the Rajshahi and bogura stations were found susceptible to CO concentrations – dry seasonal CO concentrations at those stations crossed the national standards very frequently (Fig. 8-9).

Rangpur was also polluted with $O_3$, especially during April to July when the 8-hour $O_3$ concentrations crossed the respective standard line at 51 ppb.

**Fig. 8-9 Trends in hourly $SO_2$ concentrations (left) and 8-h CO concentrations (right) at the northwestern stations of the country.**

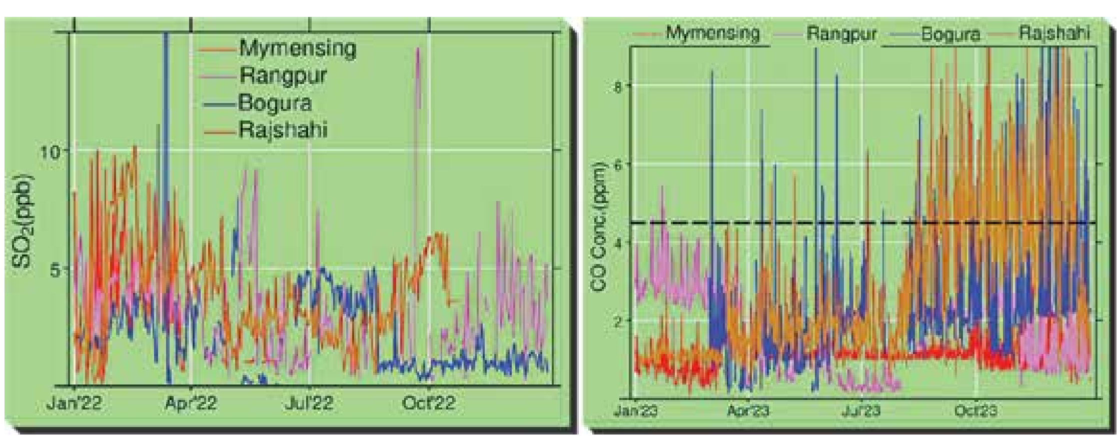
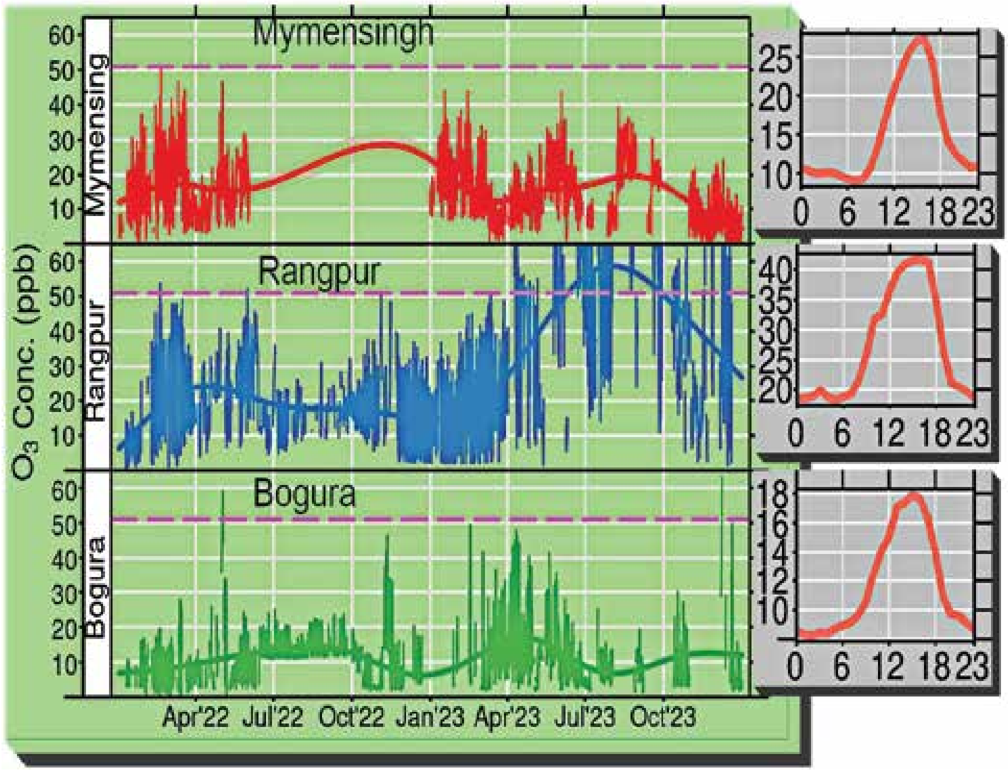


**Fig. 8-10 Trends in 8-h $O_3$ concentrations at the stations with diurnal $O_3$ conc. shown as insets**



# 9 Recommendations

After scrutinizing and analyzing the air quality monitoring database produced by the Department of Environment from 2018 to 2023, it was found that improvement can be done in several steps; some of the recommendations intended to make further improvement in data generation and analysis are given below;

a. QA/QC system in the stations can be built up and maintained strictly to increase data capture rate;

b. Regular scrutiny of the database should be performed to screen out the invalid data;

c. Air Quality Index (AQI) should be published based on screened data;

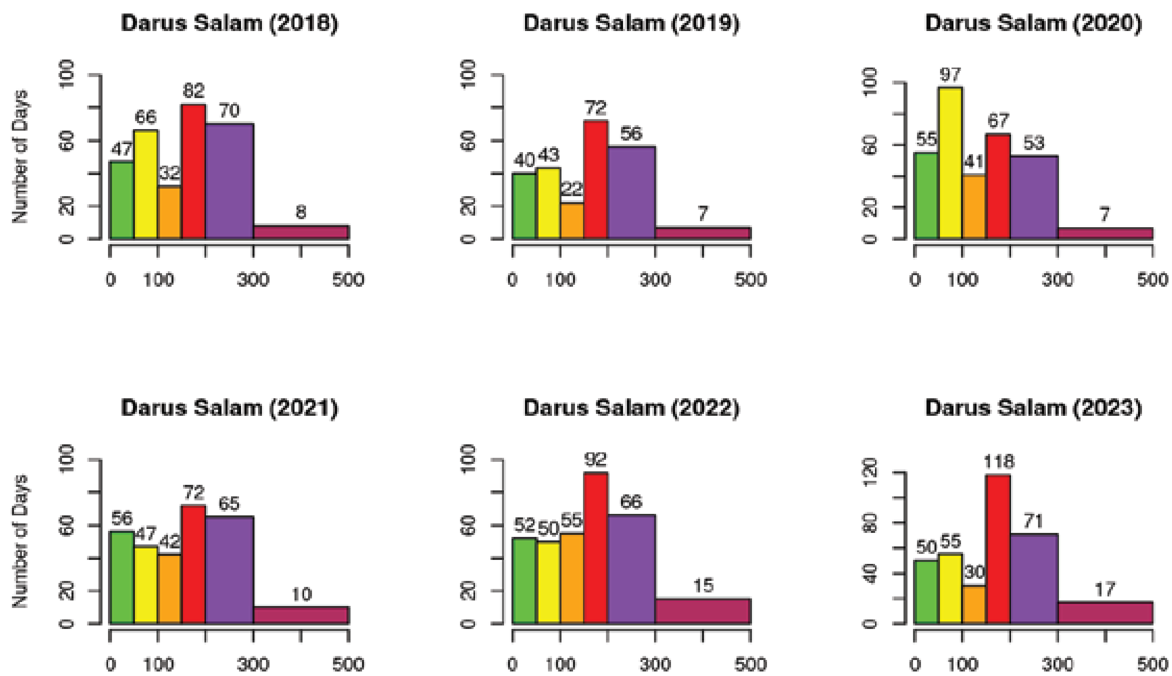
d. Monthly and annual reports should be published regularly to understand trends of the pollutants;

e. More training on data quality checks, data screening, management, and analysis are needed;

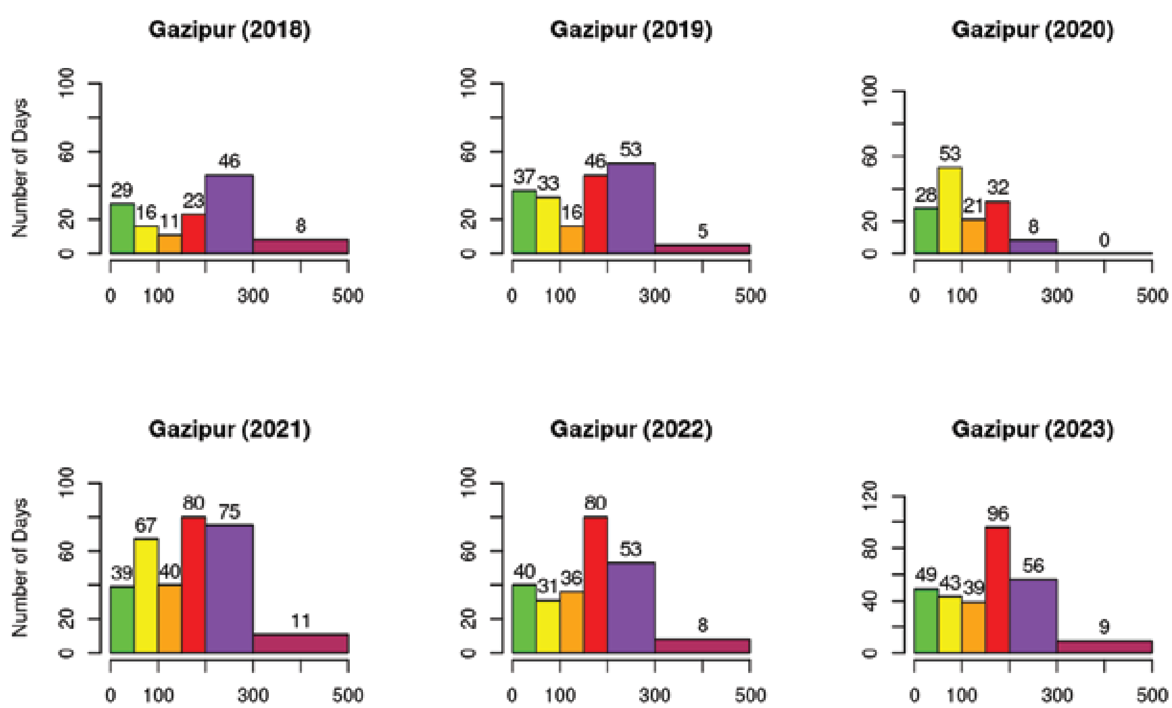
# Annex – A: Year-wise Air Quality Index (U.S scale) at the Stations

(Invalid days are not shown; bars' color codes represent corresponding index's color codes)

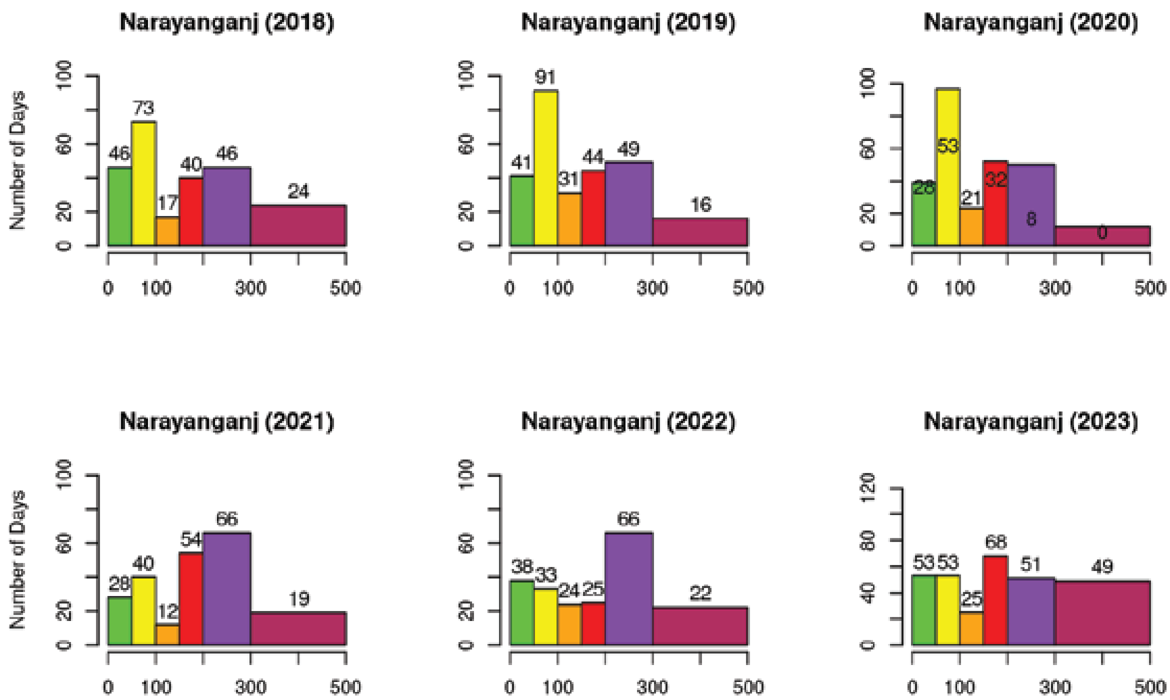
## (1) Dar es Salam, Mirpur, Dhaka



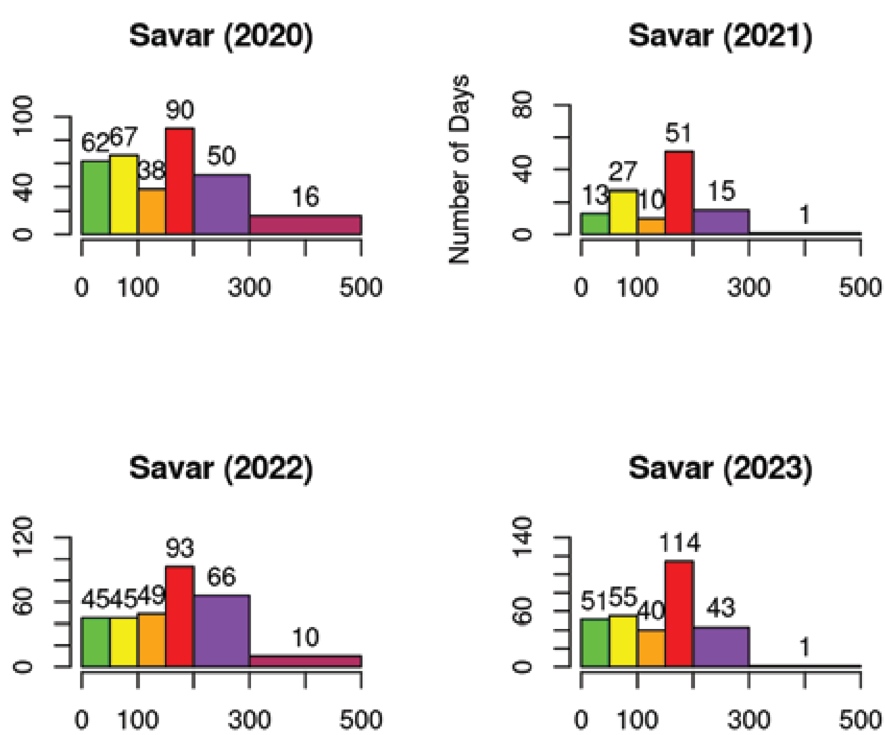

## (2) Gazipur



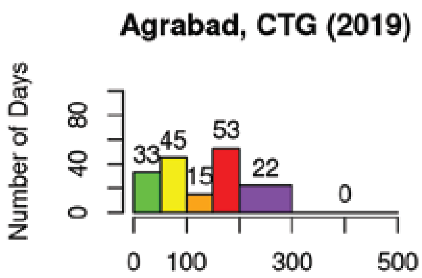
## (3) Narayanganj

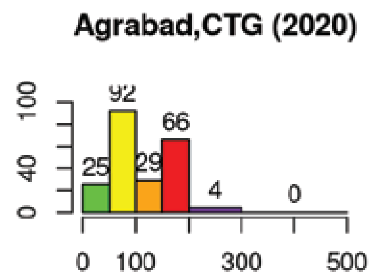


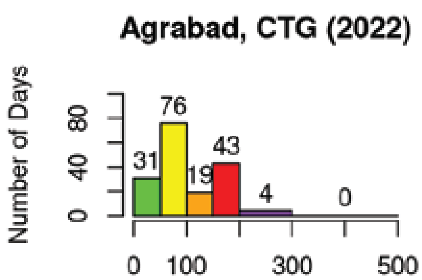

## (4) Savar

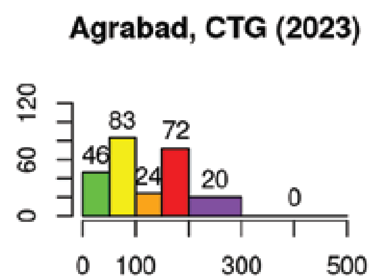


## (5) Chattogram

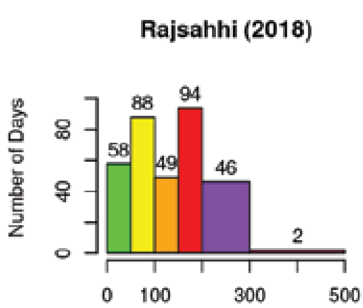


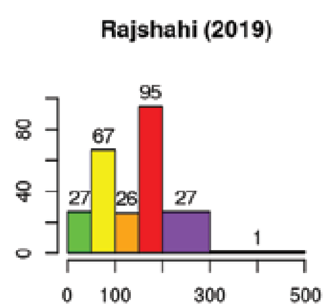



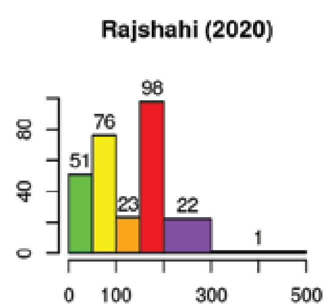



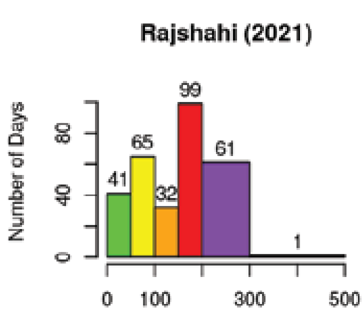



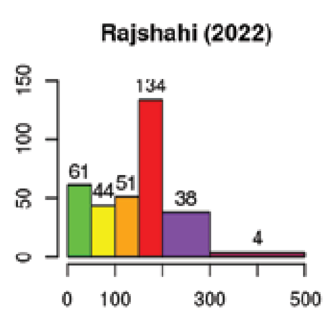

## (6) Rajshahi

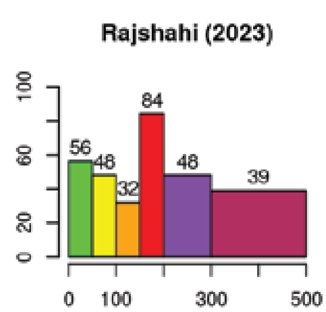


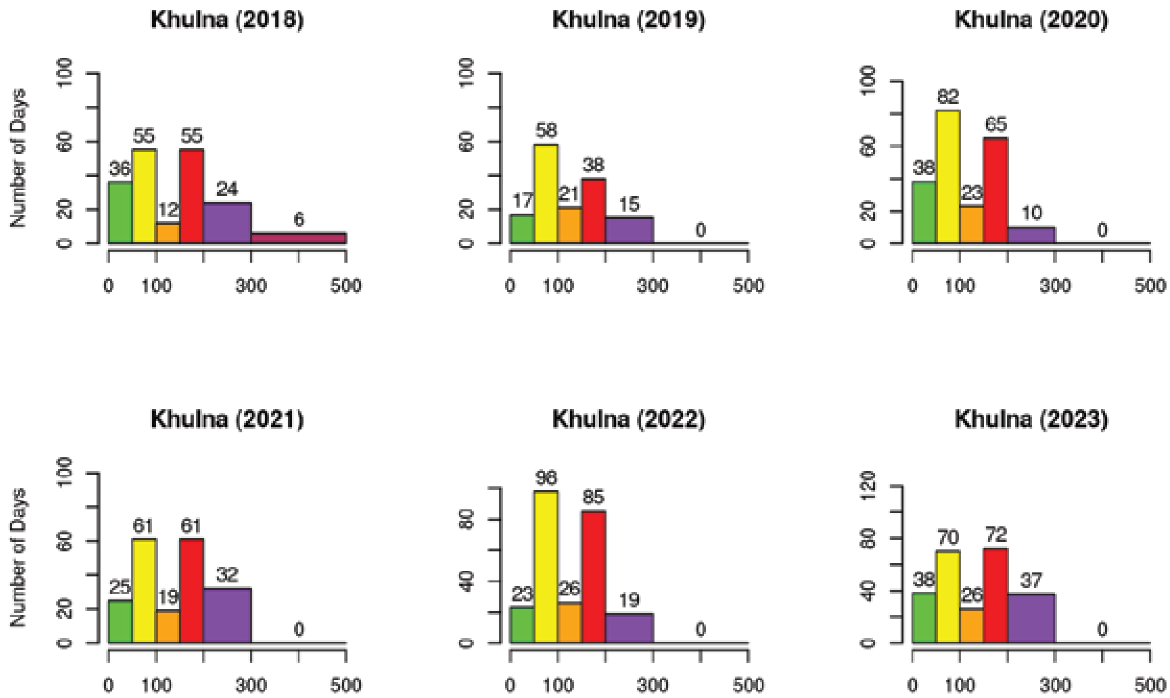



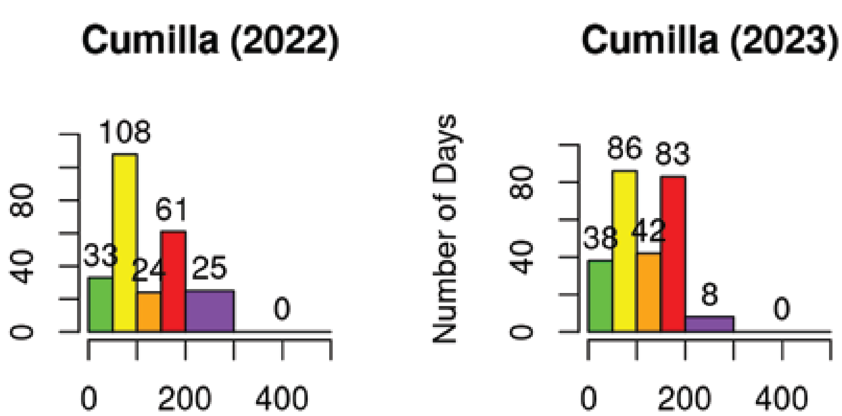



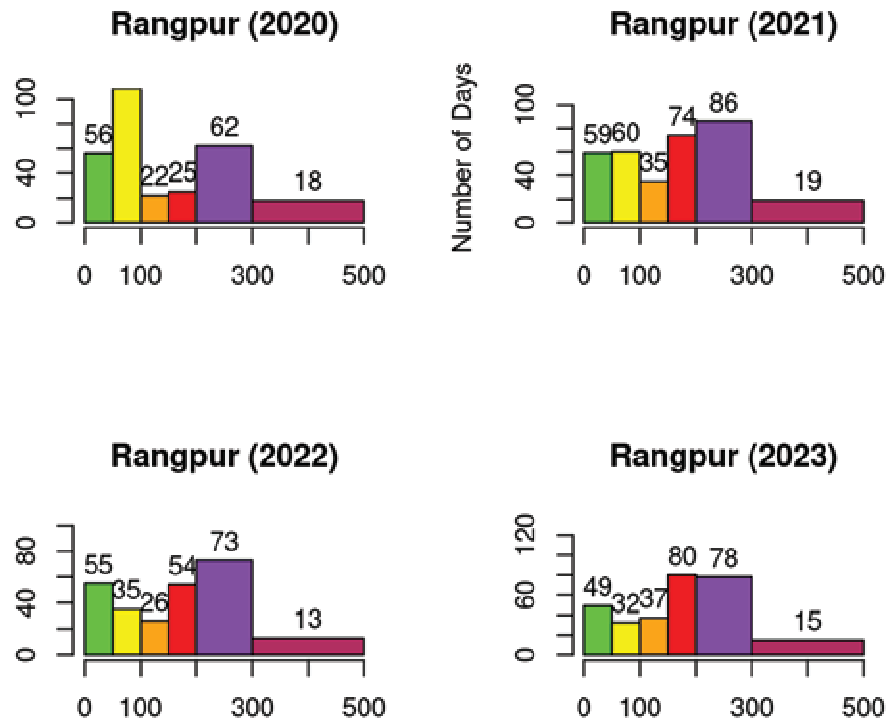
## (7) Khulna



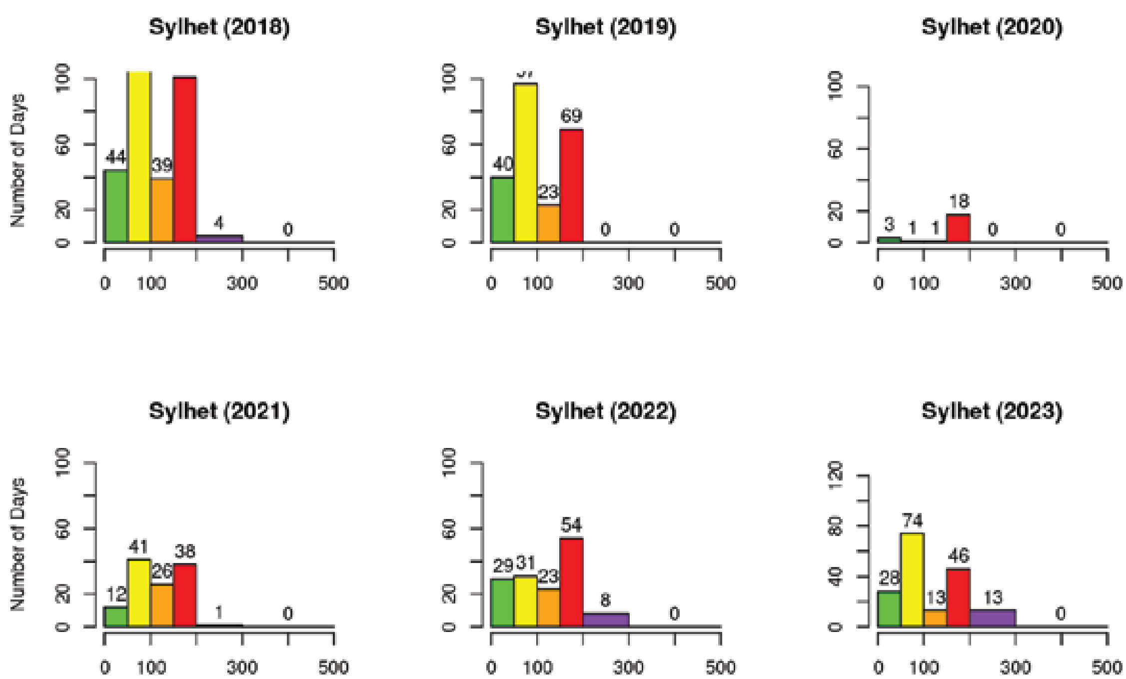

## (8) Cumilla



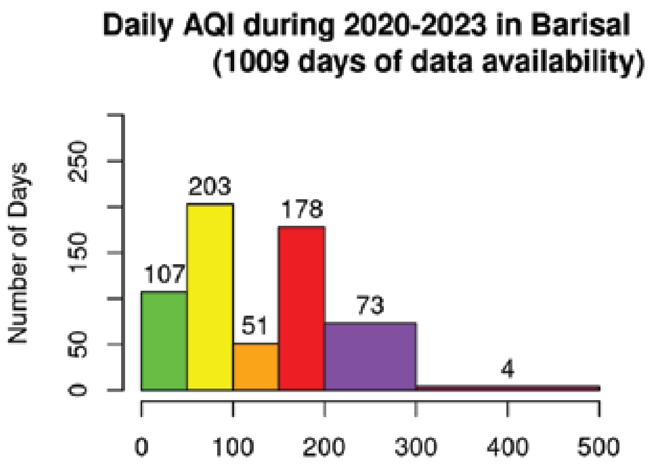
## (9) Rangpur



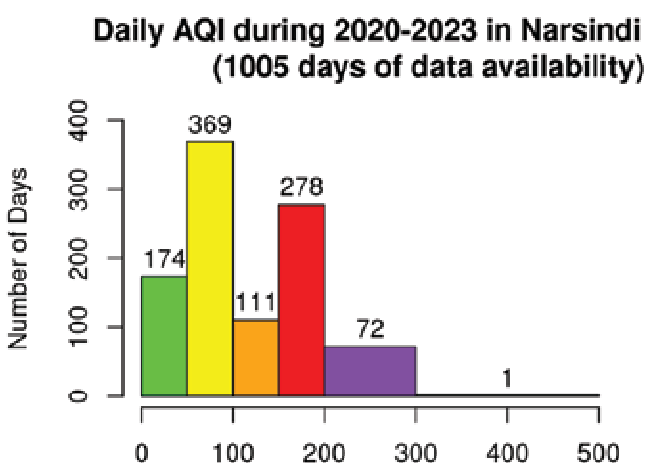

## (10) Sylhet



## (11) Barisal




## (12) Narsindi



**Department of Environment**