Looking beyond particulate matter in our cities' air

When the country grapples with high pollution levels in the winter months, it isn't just particulate matter that is a cause for concern. While the focus remains on PM levels during the period, high concentrations of other pollutants like PM2.5, PM10, NO2, SO2, CO, and Ozone add to the disease burden. This analysis attempts to bring attention to other pollutants in some major cities beginning with two months this year – January and February. We will routinely track the pollutants throughout this year to draw comparisons and understand the trends better.

Background:

The analysis focuses on assessing the air quality levels of seven major cities in India: **Delhi, Chandigarh, Lucknow, Varanasi, Patna, Kolkata, and Mumbai**. The study investigates the concentrations of key air pollutants, including PM2.5, PM10, NO2, SO2, CO, and Ozone, from January 01 to February 29, 2024.

Air pollution is a global environmental and public health concern, particularly in densely populated urban areas. It poses severe risks to human health, including respiratory diseases, cardiovascular problems, and premature mortality. The recent State of Global Air report found that air pollution caused 170k kids' deaths in India in 2021. Understanding the spatial and temporal variations in air pollutant concentrations is crucial for formulating effective air quality management strategies and mitigating the adverse impacts on public health and the environment. We chose January and February 2024 for our multipollutant analysis due to typically higher pollution levels during winter months, which can provide critical insights into peak air quality challenges and inform mitigation strategies.

NAAQS and WHO standards:

Pollutants	WHO standard	NAAQS standard
PM2.5 (mg/m³)	15	60
PM10 (mg/m³)	45	100
NO2 (mg/m³)	25	80
S02 (mg/m³)	40	80
CO (mg/m³)	4	NA (2 ;8-hour average)
Ozone (mg/m³)	NA (100 ;8-hour mean)	NA (100 ;8-hour average)

The selected cities represent diverse geographical locations, population densities, and industrial activities, offering insights into the different air quality dynamics across regions. As the capital city, Delhi often faces severe air pollution challenges due to various anthropogenic activities, vehicular emissions, industrial pollution, and geographical factors like stubble burning. Other cities such as Mumbai, Kolkata, and Lucknow are also known for their significant pollution levels, albeit influenced by different sources and factors.

The analysis aims to provide a comprehensive understanding of the temporal trends and spatial variations in air pollutant concentrations across the selected cities during the specified period. By examining the levels of PM2.5, PM10, NO2, SO2, CO, and Ozone, the study seeks to build a case and play a crucial role in informing public health decisions, shaping environmental policies, identifying pollution sources, addressing environmental justice issues, understanding climate change impacts, and advancing scientific knowledge. These insights are essential for creating sustainable and healthy urban environments.

Importance of the study:

Multipollutant analysis is crucial for understanding the complexities of air pollution and its impacts on public health and the environment. Air pollution consists of a mixture of pollutants emitted from various sources, including vehicles, industries, and natural sources. Multipollutant analysis allows us to examine the interactions and synergistic effects among different pollutants, providing a more comprehensive picture of air quality. Moreover, multipollutant analysis helps in identifying the sources and mechanisms contributing to air pollution. Different pollutants have distinct sources and emission patterns. For instance, particulate matter (PM) may originate from combustion processes and industrial activities, while nitrogen dioxide (NO_2) is often associated with vehicular emissions. Understanding the sources and mechanisms of pollution through multipollutant analysis is essential for designing effective regulatory measures and interventions to improve air quality and protect public health.

Methodology:

City	PM2.5 (µg/m³)	PM10 (µg/m³)	NO2 (µg/m³)	SO2 (µg/m³)	CO (µg/m³)	Ozone (µg/m³)
Delhi	155.6	268.1	48.70	12.3	1.4	24.2
Chandigarh	119.7	193.4	29.7	9.5	1.2	25.6
Kolkata	84.6	156.2	32.4	12.5	0.9	28.7
Lucknow	71.8	140.1	21.5	11.7	0.9	28
Mumbai	50.3	115.7	39.2	13.5	0.8	30.5
Patna	113.7	285.4	24.8	8.3	1.6	24.6
Varanasi	23.1	57.7	11.8	18.1	0.8	13.8

Table 1: City-wise pollution levels in January and February 2024

The methodology involved in this study begins with the collection of air quality data from the Central Pollution Control Board's (CPCB) website (www.cpcb.nic.in). The data includes measurements of various air pollutants, such as PM2.5, PM10, NO2, SO2, CO, and Ozone, recorded at monitoring stations in seven major cities of India: Delhi, Chandigarh, Lucknow, Varanasi, Patna, Kolkata, and Mumbai. The data span from January 1st to February 29th, 2024, providing a comprehensive dataset for baseline analysis. We selected January to February because during these months, pollution levels typically decrease significantly from very high to moderately high, allowing us to capture this declining trend. After collecting the data from the Central Pollution Control Board's (CPCB) website, the data was organized station-wise for each city. This involved grouping the measurements of various air pollutants, such as PM2.5, PM10, NO2, SO2, CO, and Ozone, recorded at different monitoring stations within each city. The next step involved calculating the average concentrations of these pollutants for each city. This was done by taking the mean of the pollutant measurements across all monitoring stations within the respective city. By averaging the data station-wise, we obtained a representative value for each pollutant for each city, providing an overall assessment of air quality in the selected urban areas.

Result:

From January to February, a declining trend in pollution levels was observed across various cities in the Indo-Gangetic Plain (IGP) region of India. While PM10 and PM2.5 emerged as the predominant pollutants in all cities, NO2, Ozone, SO2, and CO are under safe limits mostly, according to NAAQS. This consistent pattern suggests a common source of pollution across the region, likely stemming from industrial activities, vehicular emissions, and agricultural practices.

Delhi, as a major urban centre, exhibited relatively high pollution levels. With average pollution levels for **PM2.5, PM10, NO2, SO2, CO, and Ozone** at 155.6 μg/m³, 268.1 μg/m³, 48.70 μg/m³, 12.3 μg/m³, 1.4 μg/m³, and 24.2 μg/m³ respectively, it underscores the urgent need for stringent pollution control measures. Conversely, Varanasi displayed comparatively lower pollution levels across all parameters, with PM2.5, PM10, NO2, SO2, CO, and Ozone averaging at 23.1 μg/m³, 57.7 μg/m³, 11.8 μg/m³, 18.1 μg/m³, 0.8 μg/m³, and 13.8 μg/m³ respectively, suggesting more effective pollution management strategies or environmental initiatives in place.

Furthermore, specific factors such as ongoing construction in cities like Patna may have contributed to heightened PM10 levels, primarily emanating from dust and construction activities. This highlights the necessity for sustainable urban development practices and stricter regulations to minimize the adverse environmental impact of infrastructure projects. Overall, the data underscores the importance of continuous monitoring and proactive measures to address pollution challenges in the Indo-Gangetic Plain and ensure sustainable environmental stewardship.

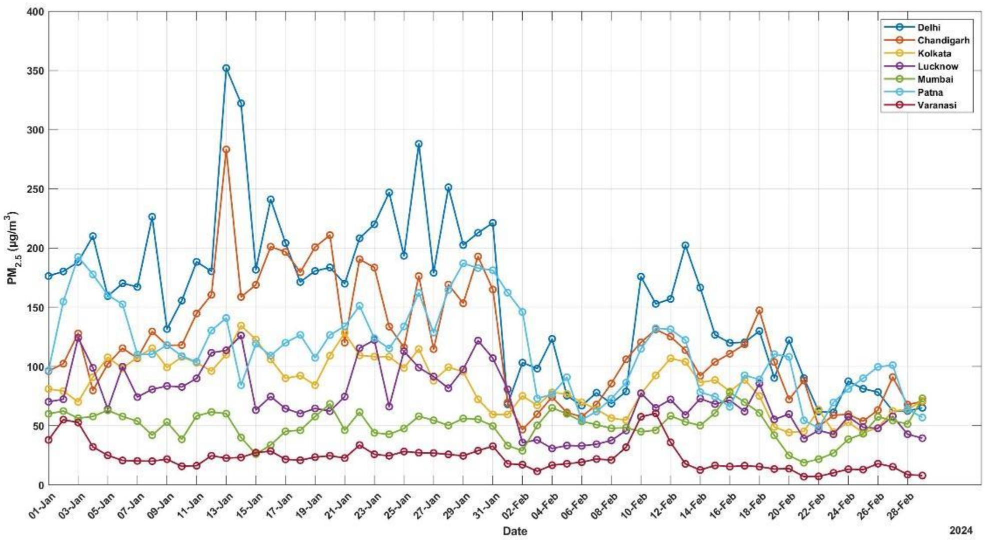

Figure 1: PM 2.5 variation for all selected cities: Daily variations of PM2.5 levels in different cities (listed in the plot) in two months (Jan & Feb 2024).

Varanasi and Mumbai PM 2.5 levels are mostly below the daily permissible limit (60 ug/m3) in Jan and Feb 2024. Lucknow also showed some clean days during the peak winter pollution months.

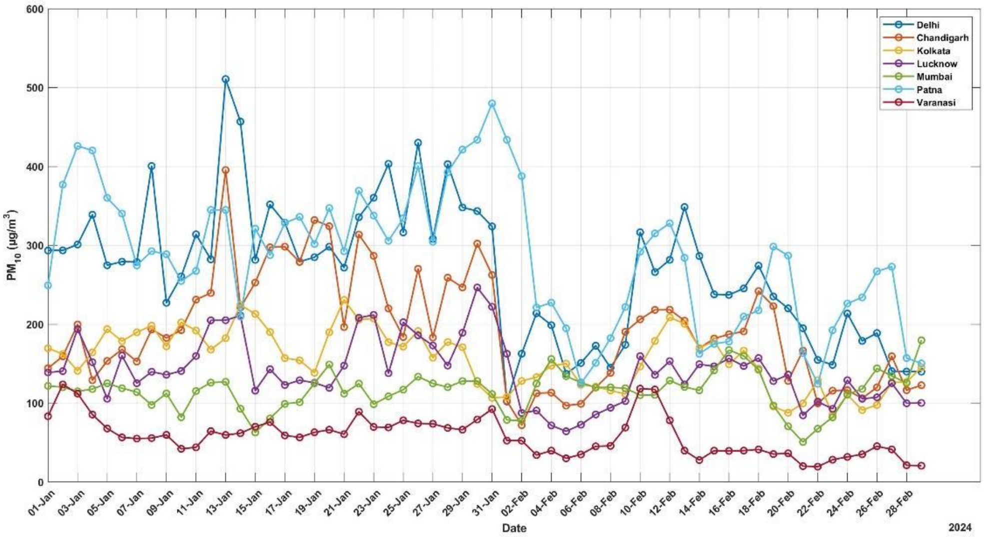

Figure 2: PM10 variation for all selected cities. Daily variations of PM10 levels in different cities (listed in the plot) in two months (Jan & Feb 2024).

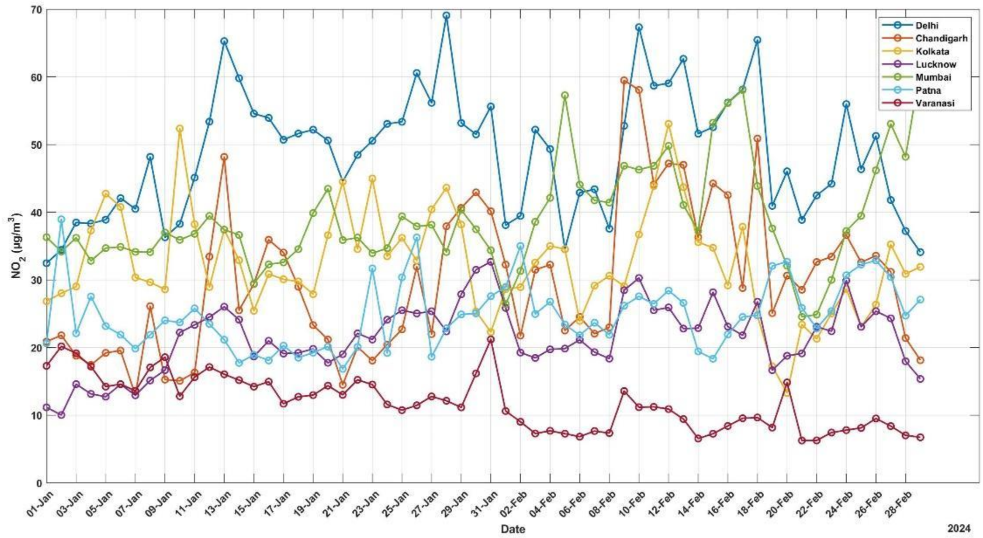

Figure 3: NO2 variation for all the selected cities

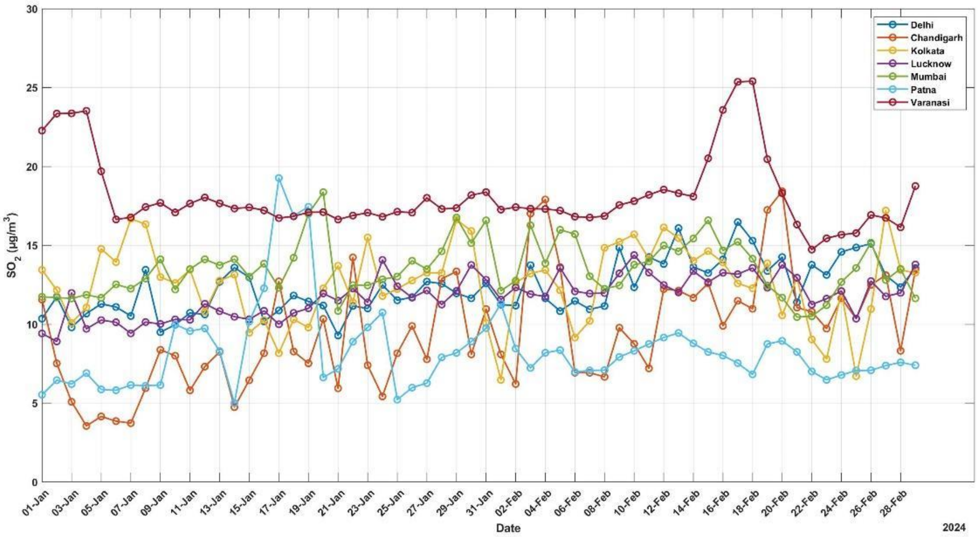

Figure 4: SO2 variation for all the selected cities

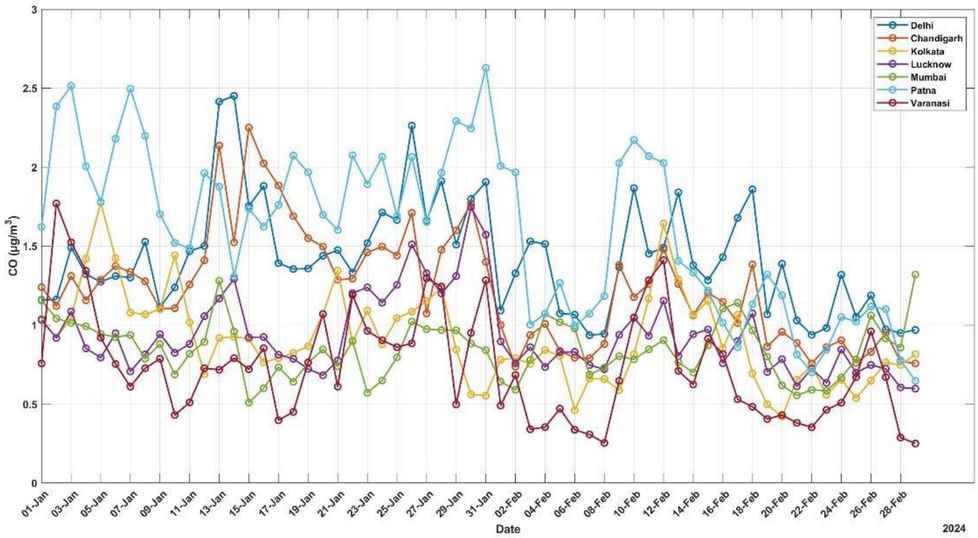

Figure 5: CO variation for all the selected cities

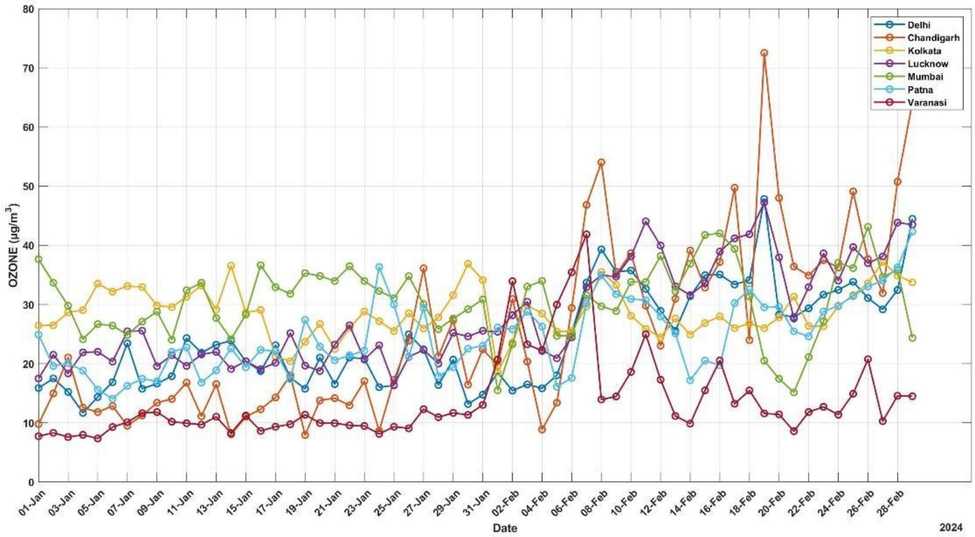

Figure 6: Ozone variation for all the selected cities

City wise variations:

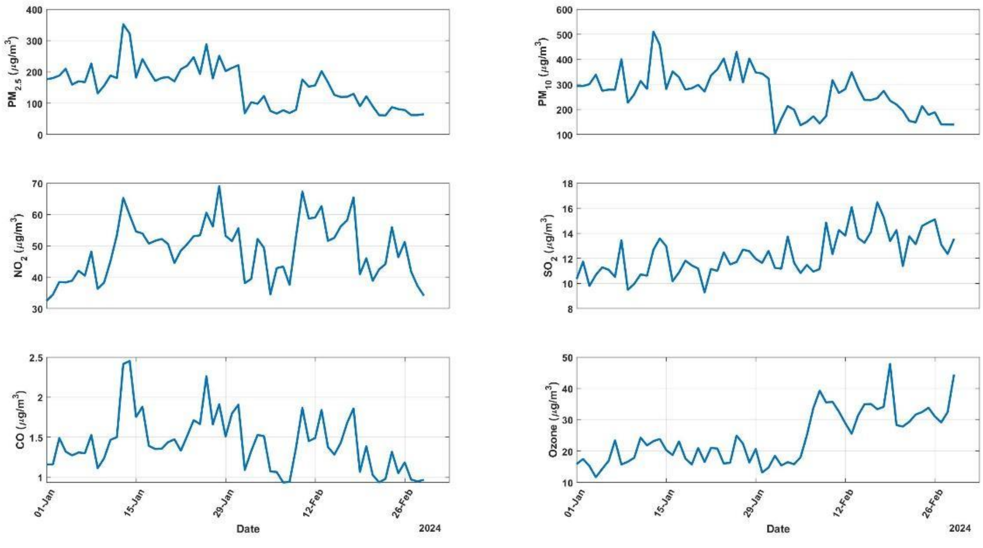

Figure 7: Delhi's multipollutant variation

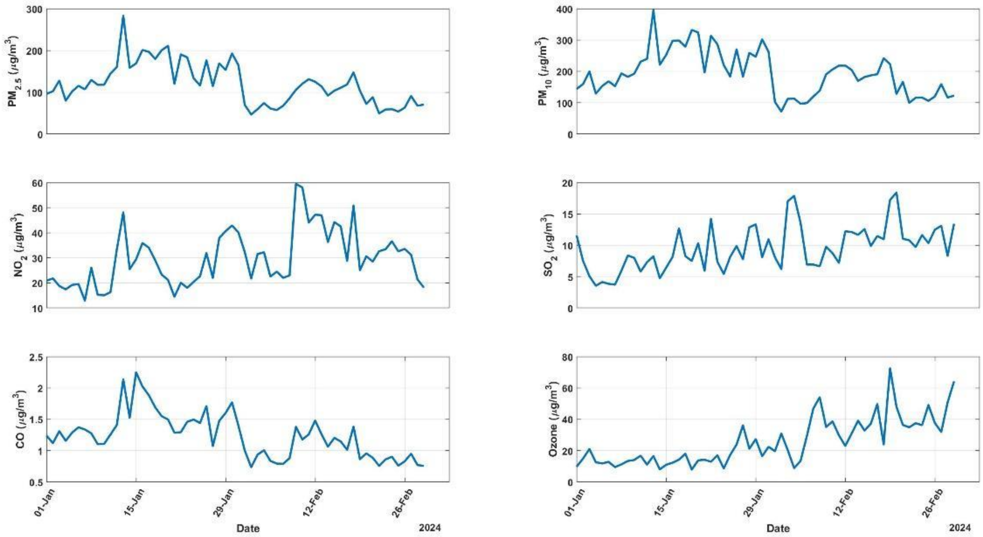

Figure 8: Chandigarh's multipollutant variation

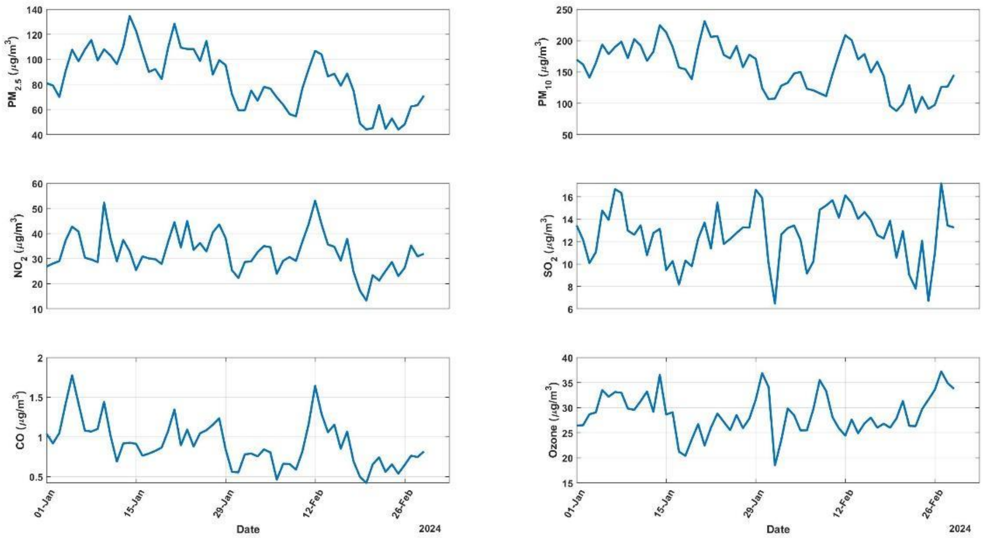

Figure 9: Kolkata's multipollutant variation

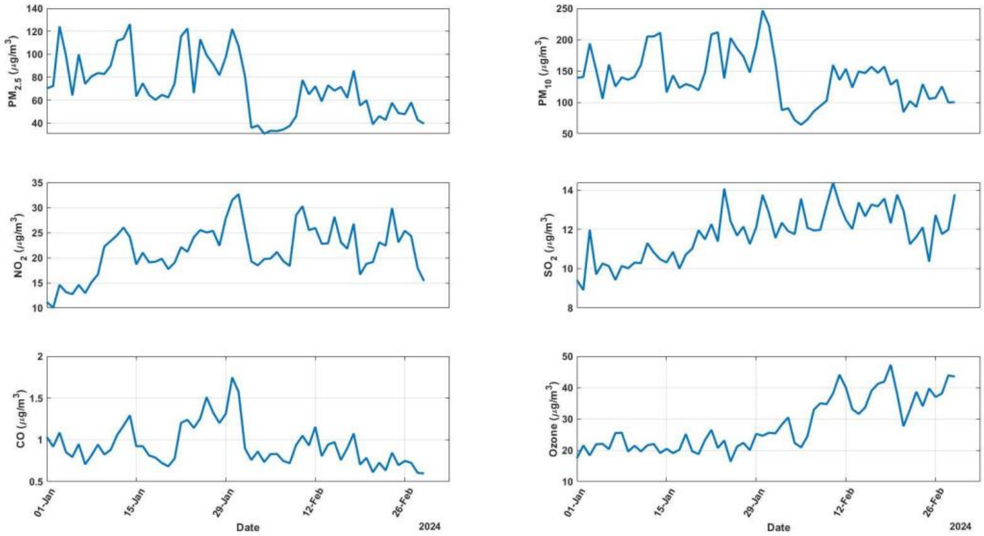

Figure 10: Lucknow’s multipollutant variation

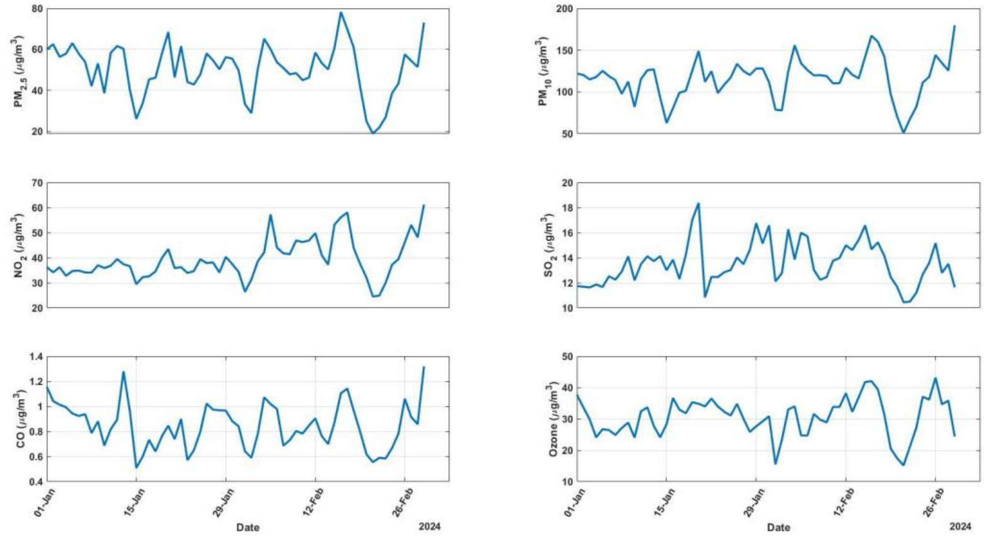

Figure 11: Mumbai’s multipollutant variation

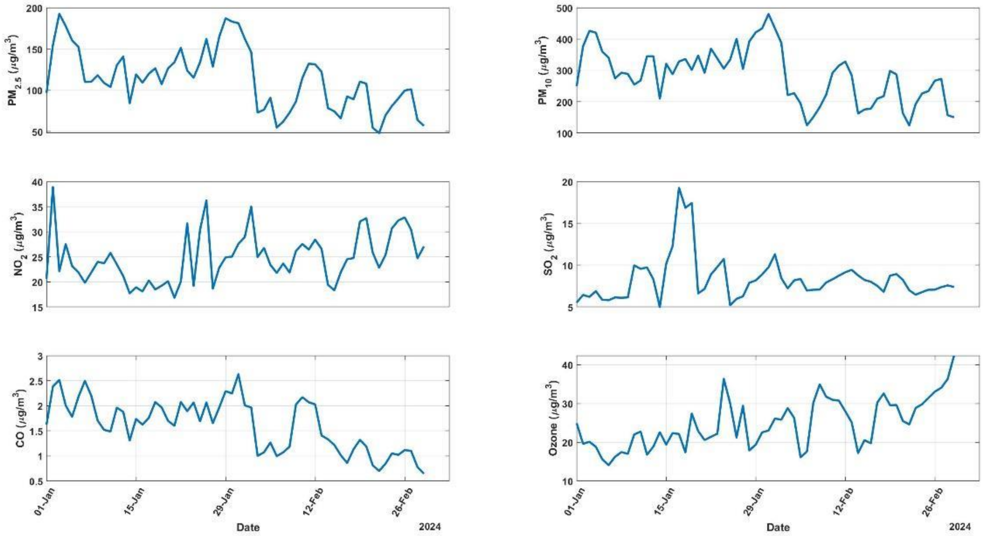

Figure 12: Patna's multipollutant variation

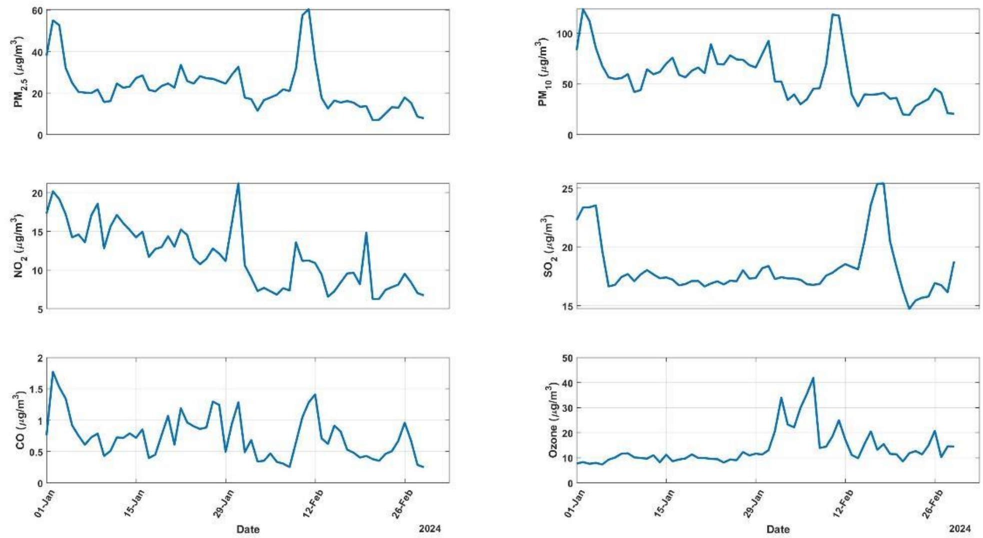

Figure 13: Varanasi's multipollutant variation

Some key observations based on the pollution levels for the specified cities:

PM2.5 and PM10 Levels: Delhi exhibits the highest average levels of PM2.5 (155.6 μg/m³) and PM10 (268.1 μg/m³), indicating severe particulate pollution. Patna follows with PM10 levels at 285.4 μg/m³, likely influenced by ongoing metro construction activities.

NO2 Concentrations: Delhi also records the highest average NO2 levels (48.70 μg/m³), reflecting significant vehicular emissions and industrial activities. Kolkata and Mumbai show moderate levels, while Varanasi displays the lowest NO2 concentration among the cities listed.

SO2 Levels: Varanasi exhibits the highest average SO2 level (18.1 μg/m³), possibly due to industrial emissions or combustion processes. Chandigarh and Lucknow also show relatively elevated SO2 levels compared to other cities.

CO Concentrations: CO levels are generally low across all cities, with Patna recording the highest average concentration (1.6 µg/m³), followed by Delhi and Chandigarh.

Ozone Levels: Mumbai exhibits the highest average ozone concentration (30.5 µg/m³), likely influenced by industrial emissions and atmospheric processes. Kolkata follows with relatively high ozone levels, while Varanasi displays the lowest average concentration.

Regional Disparities: Varanasi stands out with comparatively lower levels of PM2.5, PM10, and NO2 compared to other cities, indicating relatively better air quality in the region. On the contrary, Delhi and Patna experience significantly higher pollution levels across multiple parameters, highlighting the urgent need for pollution control measures.

Urban Development Impact: Ongoing metro construction in Patna probably contributes to heightened PM10 levels, indicating the environmental impact of infrastructure projects on air quality. These observations emphasize the critical need for targeted interventions and stringent regulatory measures to address air pollution challenges, particularly in heavily urbanized areas like Delhi and Patna, to safeguard public health and environmental well-being.

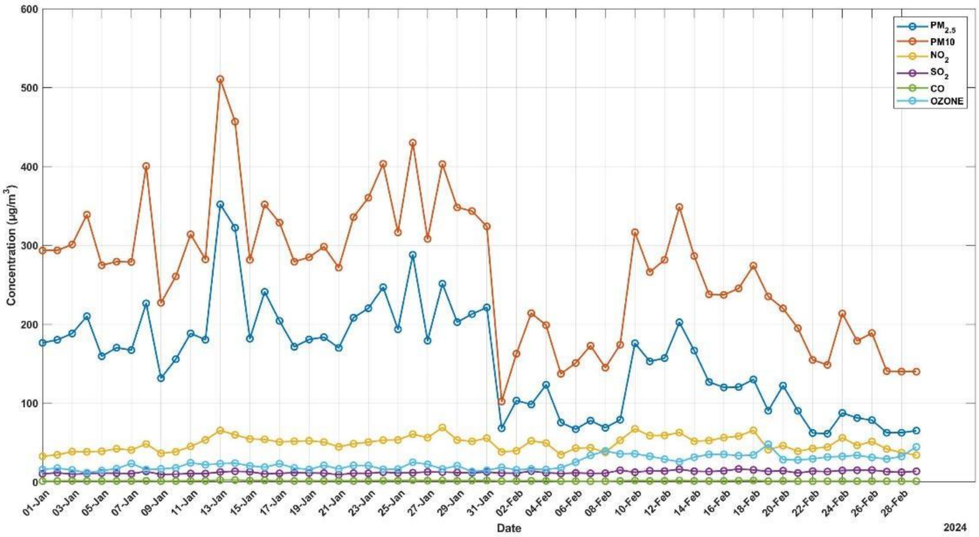

Figure 14: Delhi's pollution level from 1st Jan to 29th Feb 2024

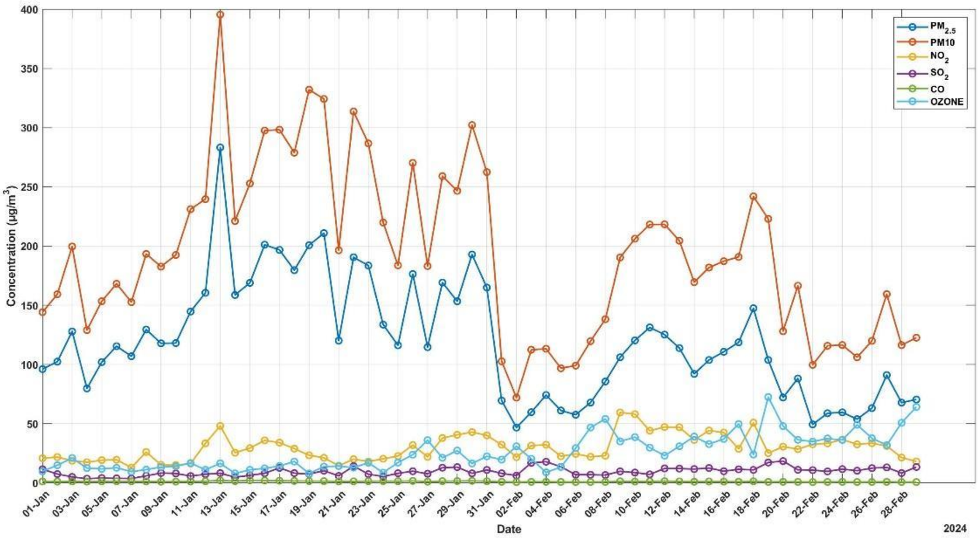

Figure 15: Chandigarh's pollution level from 1st Jan to 29th Feb 2024

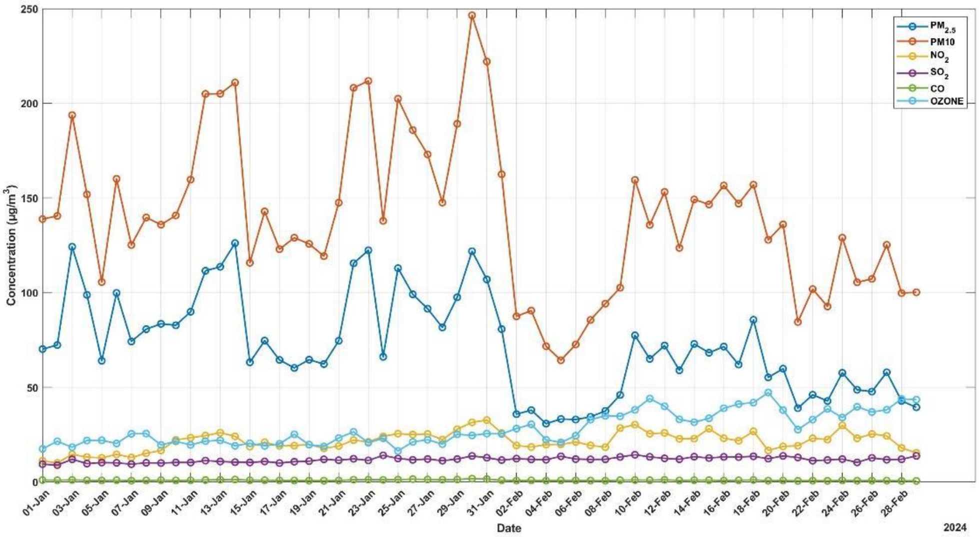

Figure 16: Lucknow's pollution level from 1st Jan to 29th Feb 2024

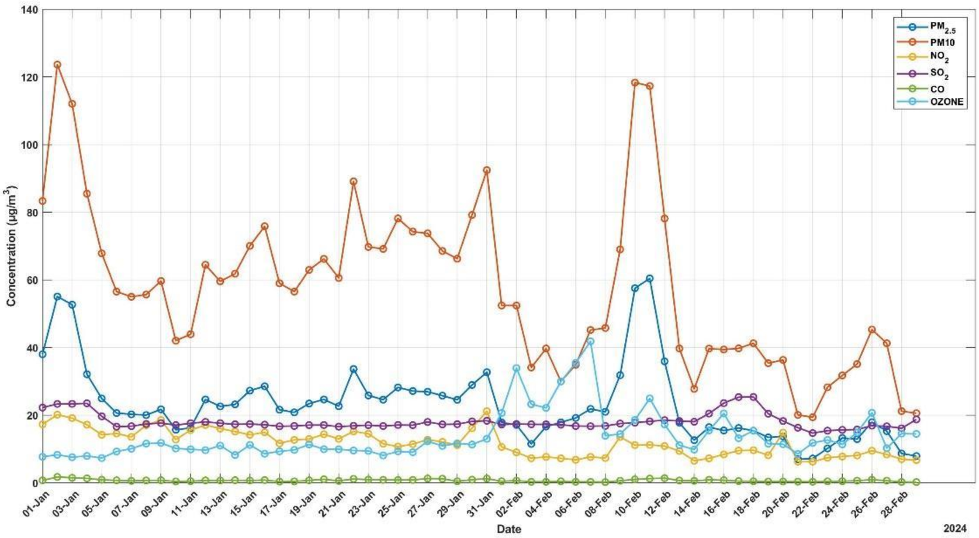

Figure 17: Varanasi pollution level from 1st Jan to 29th Feb 2024

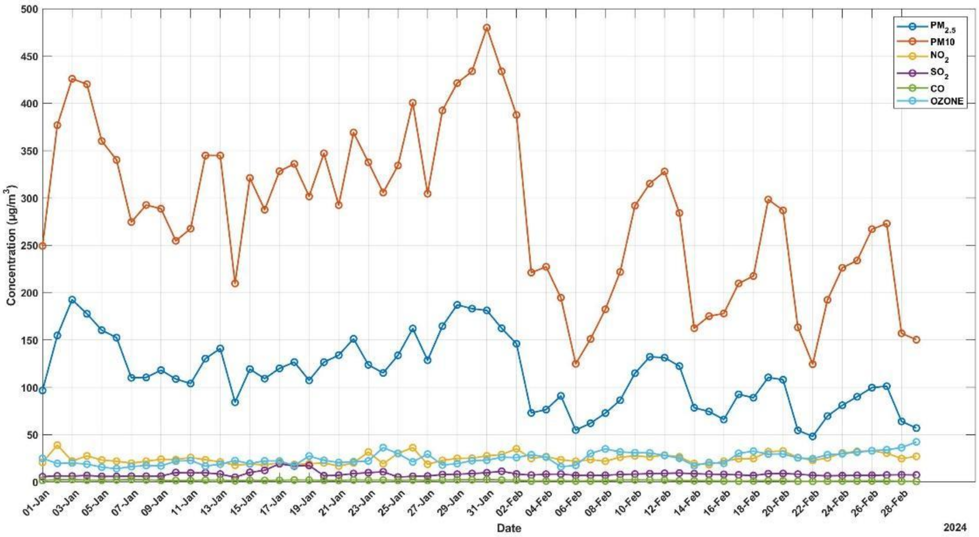

Figure 18: Patna's pollution level from 1st Jan to 29th Feb 2024

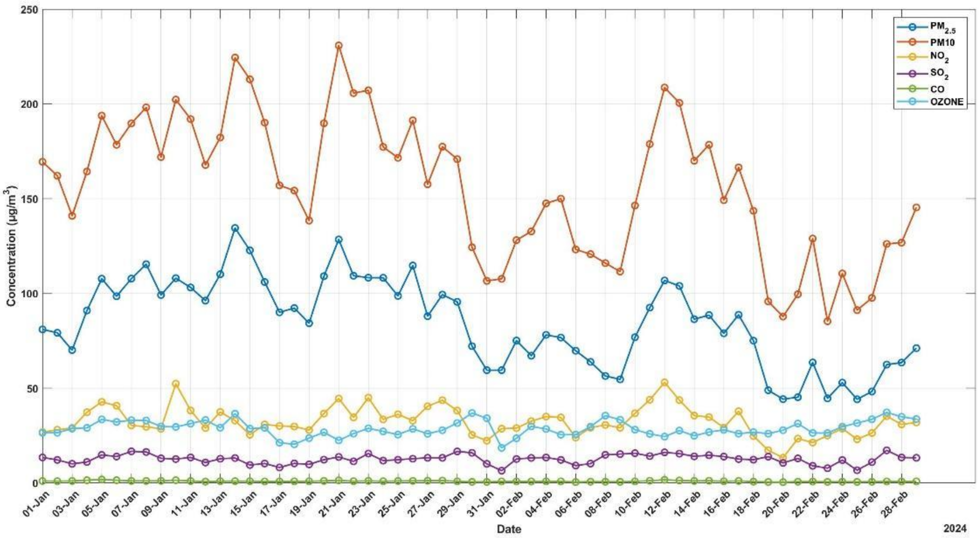

Figure 19: Kolkata's pollution level from 1st Jan to 29th Feb 2024

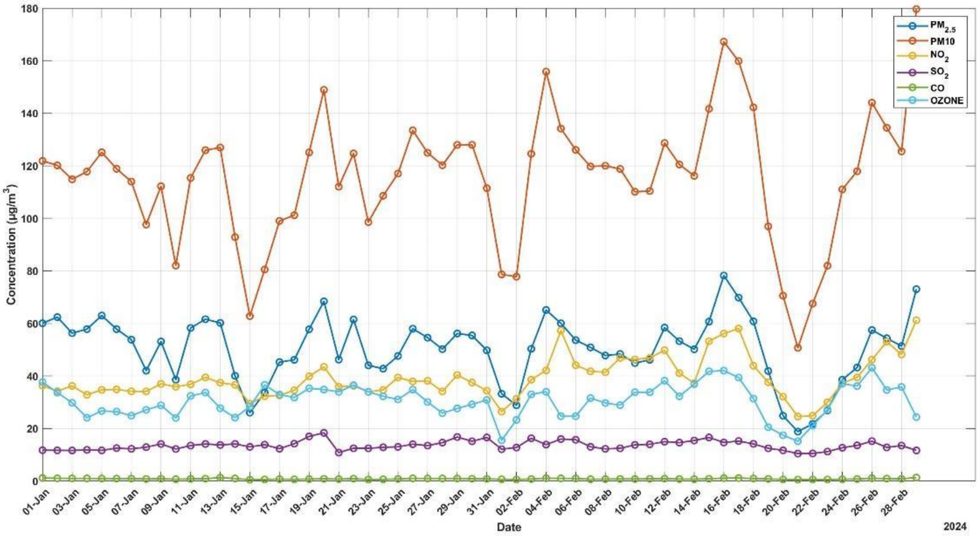

Figure 20: Mumbai's pollution level from 1st Jan to 29th Feb 2024

NAAQS Standard:

Pollutants	NAAQS standard (Annual)
PM2.5 (ug/m3)	40
PM10 (ug/m3)	60
NO2 (ug/m3)	40
S02 (ug/m3)	50
CO (mg/m3)	NA (02=8hrs & 04=1hrs)
Ozone (ug/m3)	NA (100=8hrs & 180=1hrs)

Why multi-pollutants?

Analysing the data for pollutants beyond PM2.5 and PM10 is crucial for understanding and addressing air quality issues comprehensively. Here's why each of these pollutants is important:

NO2 (Nitrogen Dioxide):

Source: NO2 primarily comes from combustion processes, including vehicles, power plants, and industrial activities.

Health Impacts: NO2 can irritate the respiratory system, leading to coughing, wheezing, and exacerbating asthma symptoms. Prolonged exposure may contribute to respiratory infections and reduced lung function.

Environmental Impact: NO2 contributes to the formation of ground-level ozone and particulate matter, exacerbating air quality issues.

Importance: Monitoring NO2 levels provides insights into traffic emissions and combustion-related pollution, helping identify areas with high vehicle density or industrial activity.

SO2 (Sulphur Dioxide):

Source: SO_2 is primarily emitted from industrial processes, power plants, and burning of fossil fuels containing sulphur, such as coal and oil.

Health Impacts: SO_2 can irritate the respiratory system, leading to coughing, shortness of breath, and aggravation of asthma and other respiratory conditions. Prolonged exposure may cause respiratory illnesses and cardiovascular effects.

Environmental Impact: SO_2 can contribute to the formation of fine particulate matter and acid rain, leading to ecological damage and deterioration of buildings and monuments.

Importance: Monitoring SO_2 levels helps track industrial emissions and assess the impact of combustion-related pollution on public health and the environment.

CO (Carbon Monoxide):

Source: CO is produced by incomplete combustion of fossil fuels, primarily from vehicles, industrial processes, and residential heating systems.

Health Impacts: CO can reduce the oxygen-carrying capacity of the blood, leading to headaches, dizziness, nausea, and in severe cases, unconsciousness, or death. Prolonged exposure may cause cardiovascular effects and exacerbate existing heart conditions.

Environmental Impact: While CO is not a significant contributor to particulate pollution or smog formation, it plays a role in atmospheric chemistry and contributes to the formation of secondary pollutants such as ozone.

Importance: Monitoring CO levels helps assess the efficiency of combustion processes, identify areas with heavy traffic congestion, and evaluate indoor air quality in poorly ventilated spaces.

Ozone:

Source: Ground-level ozone is formed through complex chemical reactions involving NO_x and volatile organic compounds (VOCs) in the presence of sunlight. Sources of VOCs include vehicle emissions, industrial processes, and vegetation.

Health Impacts: Ozone can irritate the respiratory system, leading to coughing, throat irritation, and exacerbation of asthma and other respiratory conditions. Prolonged exposure may cause lung inflammation and decrease lung function.

Environmental Impact: Ozone can damage vegetation, leading to reduced crop yields and forest productivity. It also contributes to the degradation of materials such as rubber and plastics.

Importance: Monitoring ozone levels helps understand the photochemical processes driving its formation and identify sources of precursor pollutants (e.g., NO_x and VOCs). It also helps assess the effectiveness of emissions control strategies in reducing ozone concentrations.

In summary, analysing data for NO_2, SO_2, CO, and ozone alongside $PM_{2.5}$ and PM_{10} provides a more comprehensive understanding of air quality, its sources, and associated health and environmental impacts. This holistic approach is essential for developing effective air quality management strategies and safeguarding public health and the environment in urban areas.

Quotes

Dr Vivek Panwar, Assistant Professor, Venkateshwara College, University of Delhi

"Improving air quality requires a comprehensive approach that goes beyond particulate matter, encompassing a variety of pollutants and their origins to protect public health and the environment effectively. Additionally, this approach aids in gaining a concise understanding of sources within the region."

Dr Palak Balyan, Research Lead, Climate Trends

"Over the past few years there has been increased attention on the particulate matter in the air and how it is impacting human life. We now have a very comprehensive national level programme to reduce PM levels. However, the source of other pollutants in the air may vary and it would require different interventions. We hence need to study the other pollutants along with tracking PM levels to ensure an overall reduction in pollution levels in the country. We hope our study can be a starting point in the process."