

Escalation of Urban Air Pollution in Ghaziabad: A Comparative Analysis of 2024-2025

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Abstract: Air pollution has taken a disastrous form in NCR region of India. The effect of increasing and prolonged concentration of air pollutant in atmosphere is affecting people's health. One of such region which is highly affected with this problem is "Ghaziabad", one of the important cities of NCR, India. There are four measuring sites working in Ghaziabad. This paper presents a study of spatio-temporal variations of atmospheric pollutants recorded at all four sites during 2024-25 by CPCB. In comparison to 2024, the year 2025 observed increased values of pollutants $PM_{2.5}$ (~20%), PM_{10} (~20%), NO_2 (~12%), SO_2 (~22%), and CO (~13%). On the other hand, a decrease of (~35%) is recorded in Benzene. The study shows that in 2024, $PM_{2.5}$ shows a strong correlation with NO_2 ($r = 0.67$) and benzene ($r = 0.69$), which is highlighting a noteworthy effect of vehicles while 2025 shows a reduced $PM_{2.5}$ - NO_2 correlation ($r = 0.43$) and a bit enhanced correlations with CO ($r = 0.47$) and SO_2 ($r = 0.42$), that reflects a shift towards from combustion and secondary processes.

Keywords: spatio-temporal variation, PM and Air Quality.

1. Introduction

Growing urbanization, vehicular emission and industrialization has led to poor to very poor air quality in many cities, causing substantial health effect not only in all ages of humans but also affecting to pregnant women. As far as the health effects due to air pollution in humans are concerned, the presence of particulate matter in the air, specially $PM_{2.5}$ (fine) and PM_{10} (fine and coarse), are mainly responsible. Many studies have been conducted showing a strong relation of air pollution with health effects¹⁻⁶. Studies that have been conducted in India and abroad shows that health effects get worsen with the protracted and intense exposure of air pollutants and result to minor eye irritations, affected respiratory symptoms, diminished lung and heart

function⁷⁻¹¹ Increased pollution levels cause sensitive health risks. A study conducted by Directorate of Economics and Statistics (New Delhi, India) between 2000 to 2009 reveals that there was an increase in deaths from cardiovascular diseases from 11.4% ~ 20.4% and due to respiratory diseases from 3.8% ~ 4.6% which in turn are directly related to air pollution. (DoES, 2010). According to an assessment done (monitoring data) by Cropper *et al.*¹² in 1990, an increase of 100 mg/m³ in total suspended PM concentrations results to 1385 deaths and loss of 51,400 life years.

A report published by WHO reveals that 7 million people are killed due to air pollution every year in which respiratory diseases are the dominant factor¹³. An estimation done by Global Burden of Disease Report¹⁴ long time exposure of particulate matter PM_{2.5} and PM₁₀ to the patients of Asthma, chronic obstructive pulmonary disease (COPD), lung cancer, and other respirational disorders turns into chronic disease and deaths. Airborne pollutants are especially detrimental in urban environments due to the prevalence of emissions from traffic congestion and industrial activities. Nitrogen dioxide (NO₂), sulphur dioxide (SO₂), carbon monoxide (CO), and ground-level ozone (O₃) are among the most detrimental pollutants that exacerbate respiratory inflammation and accelerate the decline in lung function. Exposure to PM_{2.5} and NO₂ has been linked to diminished lung function and heightened hospital admissions for respiratory complications¹⁵.

The most recent transition necessitating attention in India is the environmental transition. The declining ambient air quality in extensive regions of the country, along with continuous exposure to household air pollutants, has been identified as a recent risk factor for the increasing disease burden in India¹⁶. Household air pollution has been linked to birth weight and respiratory infections¹⁷ in India, but ambient air pollution and cardiovascular disease need further study. The Centre for Cardio-metabolic Risk Reduction in South Asia (CARRS) study used ensemble modelling to assess exposure to ambient PM_{2.5}. The study found that annual average PM_{2.5} concentrations in Delhi ranged from 87 to 138 µg/m³, indicating seasonal and geographical variations¹⁸. Some researches indicate that air pollution may increase the risk of cardiovascular disease through inflammation, lipid peroxidation, endothelial dysfunction, elevated blood pressure, and heart rhythm irregularities¹⁹.

Traffic-related air pollution plagues Delhi-NCR commuters. Study conducted in Ghaziabad for delivery workers' PM and VOC exposure and probabilistic health risk assessment shows average exposure levels while riding was to be 516, 180, and 113 µg/m³ for PM₁₀, PM_{2.5}, and PM₁ and the multiple path particle dosimetry model showed 2.5 and 3.7 times more PM₁₀ in the

respiratory tract than $PM_{2.5}$ and PM_{10} . VOC concentrations on traffic intersections, while riding, and in restaurant were 172, 50, and 16 $\mu g/m^3$, respectively. Benzene was the biggest carcinogen and non-carcinogen²⁰.

In Ghaziabad, industrial, construction, and vehicular emissions contributed to both indoor and outdoor air pollution. This paper presents a comparative analysis of spatio-temporal variations in air pollution in Ghaziabad for the years 2024 and 2025, elucidating and contrasting their status in the ambient air.

1.1 Study Area

The Ghaziabad Municipal Corporation is ideally located at the entrance of Uttar Pradesh, India. Ghaziabad, near New Delhi, is a major NCR city. Ghaziabad is in the Ganga-Yamuna Doab center. It borders Meerut to the north, Bulandshahr and Gautam Budh Nagar to the south, Delhi to the southwest, and Jyotiba Phule Nagar to the east. Ghaziabad regularly fail national ambient air quality standards. It has four seasons: a warm and agreeable spring (February to April) with sporadic dust storms; a hot and humid summer (May to June) with temperatures rising to 45°C; a monsoon period (late June to September) with intermittent thunderstorms and strong winds; and a post-monsoon phase (late September to early October) with a cool breeze and clear skies. Increased air pollution in the festive season (Diwali) and as a result of crop burning (late October to mid-November); followed by cold and foggy winter conditions (late November to early February) with temperatures falling below 10°C. The volume of emissions and seasonal meteorological conditions increase air pollution in Ghaziabad.



Fig.1: Source: <https://indiahousing.com/ghaziabad/map.gif>

It has repeatedly been named one of the world's most polluted cities²¹. India has a background PM concentration five to 10 times greater than US and European norms²². The recommended break concentrations in India have been changed²³. Noncompliance causes higher PM_{10} and particulate matter

concentrations. Between 2013 and 2018, yearly PM concentrations consistently exceeded 250 ($\mu\text{g}/\text{m}^3$) (AQI bad). Air quality declines in winter due to pollutant dispersion circumstances such temperature inversion, although the monsoon season lowers particle matter²⁴. As they come from similar sources, $\text{PM}_{2.5}$ and PM_{10} levels are tightly related²⁵. Ghaziabad's average $\text{PM}_{2.5}$ concentrations ($\mu\text{g}/\text{m}^3$) in the Delhi-NCR region changed from orange/yellow ($\sim 60\text{--}80 \mu\text{g}/\text{m}^3$) in 1998-1999 to maroon ($\sim 125\text{--}160 \mu\text{g}/\text{m}^3$) in 2020-2021, classified as hazardously polluted²⁶⁻²⁷.

1.2 Sampling sites

Presently there are four monitoring stations are working in Ghaziabad, Indirapuram, Vasundhara, Loni and Sanjay Nagar. All four stations are focussed in this study. These sites are being continuously monitored and real-time updated (online) by the Central Pollution Control Board (CPCB), New Delhi for measurement of various air quality parameters.

1.3 Data set used

Continuous datasets for ambient fine particulate matter, oxides of nitrogen and sulphur, carbon monoxide, ozone, and benzene, along with temperature (average temperature 24 hrs average), relative humidity, wind speed, and wind direction, for the period from January 2024 to December 2025, were sourced from the Continuous Ambient Air Quality Monitoring (CAAQM) repository of the CPCB²⁸, New Delhi, India. While processing the data, there were some gaps in the data at the different locations or data was either not accessible or discontinuous for a few to several days. In this case, the approach was that such data sets were filled with the average value before and after the missing day or data was taken from the closest CPCB station if it was available. The selection of eleven parameters, $\text{PM}_{2.5}$, PM_{10} , NO, NO_2 , SO_2 , CO, O_3 , and Benzene along with temperature, relative humidity, wind speed, and wind direction, is planned to broadly evaluate urban air quality and atmospheric processes. The excess presence of particulate matter reflects the major health-risk component and indicates both primary emissions and secondary aerosol formation. The presence of Nitrogen and Sulphur oxides serve as key combustion markers and precursors for ozone and secondary particles. Presence of CO in air acts as a tracer of incomplete combustion, while presence of benzene signifies toxic VOC emissions. Level of Ozone signifies photochemical activity in the atmosphere. The role of Meteorological parameters is to include and understand pollutant dispersion, transport, chemical transformation, and seasonal variability. Together, these parameters enable assessment of source characteristics, atmospheric chemistry, and their combined environmental and health impacts. To achieve

quality results, the daily concentration values were assessed and represented as their monthly mean rather than directly obtaining averaged values.

This study aims to compare interphase and temporal variations in pollutant concentrations over the corresponding durations of both years.

2. Results and Discussions

This study compared levels of selected ambient air quality parameters and meteorological parameters from 2024 to 2025 by analysing the monthly mean of 24-hour daily data. On comparing data of two years 2024-2025, a noteworthy increase in the concentrations of the selected air pollutants is observed during the stated period.

2.1 Variation of PM_{2.5}

Fig. 2 represents the comparison of monthly average of PM_{2.5} concentrations for the two years 2024 and 2025 recorded at four sites of Ghaziabad, Indirapuram, Loni, Sanjay Nagar and Vasundhara. This is obvious from the fig 2 that concentration of pollutants differed in different seasons and noteworthy changes are observed for two years as well. Comparative study of Seasonal variability shows that concentration of pollutants in winter is increased by 150–220% in Loni, 120–180% in Vasundhara, 100–160% in Indirapuram, and 90–140% in Sanjay Nagar from monsoon season. This is due to the fact that in monsoon season rain washout the pollutants while in winter season due to low temperature there is low dispersion, more biomass burning, less wind speed, and temperature inversion are responsible for increased concentration.

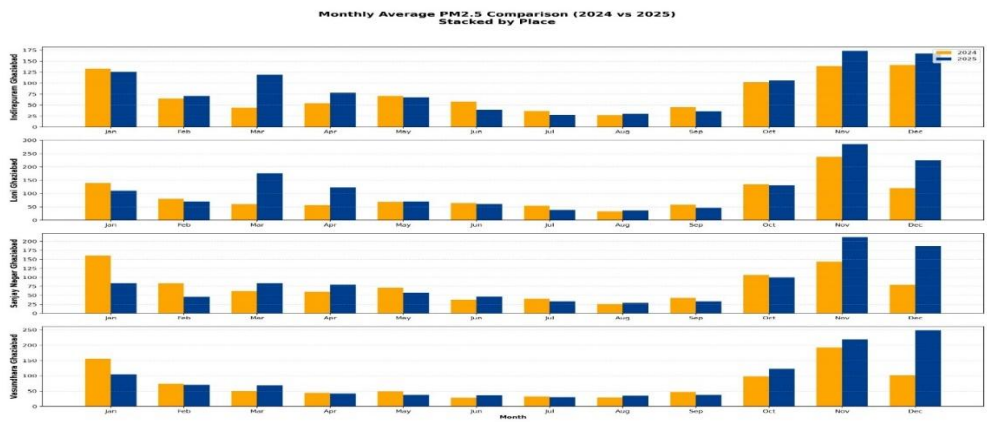


Fig.2: PM_{2.5} (µg m⁻³) comparison for 2024(yellow) and 2025(blue)

Annual comparison of two years shows increased concentration of pollutants in 2025 compared to 2024. Winter months (Nov-Dec) showed an

increase of 20~25% in Indirapuram, Sanjay Nagar 30–35%, and Vasundhara with PM_{2.5} increased by 25~30% as compared to 2024. Loni showed annual average level of PM_{2.5} increased by 15~20% and Vasundhara showed ~20% as compared to 2024.

Among all four measuring sites, highest concentration (monthly average) of PM_{2.5} was recorded in Loni in Nov 2025 (~300). It may be due to increased traffic density, industrial activity, parali burning and local construction activities. On the other hand, Vasundhara and Indirapuram faces the problem during winer months. Monsoon season of Ghaziabad, recorded lowest concentration of PM_{2.5} at all four measuring sites. Seasonal improvements did not help in improving the air pollution of Ghaziabad as PM_{2.5} concentrations surpassed set thresholds on many times.

2.2 Variation of PM₁₀ (2024–2025)

Fig. 3 represents the comparison of monthly average of PM₁₀ concentrations for the two years 2024 and 2025 recorded at four sites of Ghaziabad, Indirapuram, Loni, Sanjay Nagar and Vasundhara. From the fig 3 it is obvious that pre monsoon period of 2025(January–May) shows an improvement in PM₁₀ concentration (low by 20~40%) as compared to 2024 at all four sites of Ghaziabad. Maximum drop of PM₁₀ concentration is seen in the month of January. The month of May also recorded a good decline (25~40) at all four sites. In both the years PM₁₀ concentration was recorded minimum in monsoon season with inter-year change remained limited (≤10–15%) due to precipitation and rain fall.

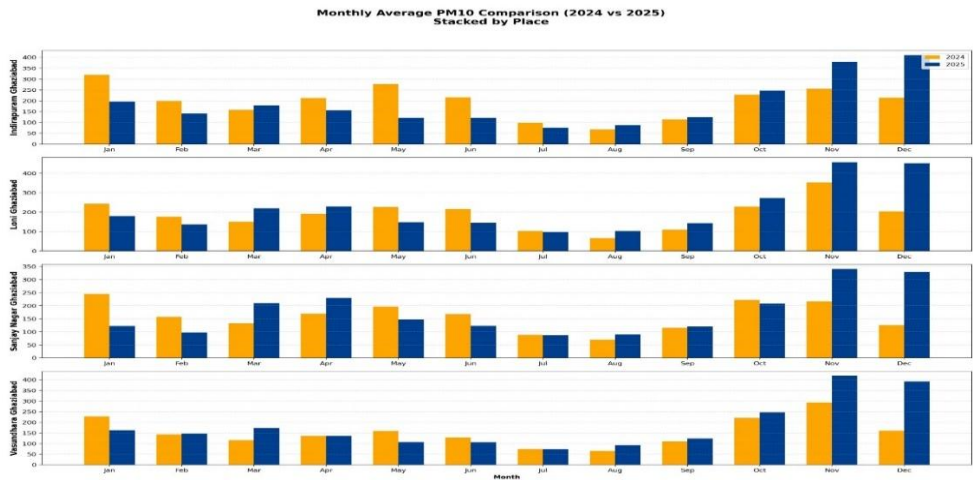


Fig.3: PM₁₀ (µg m⁻³) comparison for 2024 (yellow) and 2025 (blue)

It is clear from the Fig.3 that the variation in PM₁₀ follow the PM_{2.5} trend and hence post monsoon and winter months are noticeable worsen in air quality.

Specially a hike in October 2025 is observed (~20-30%) at all sites in comparison to 2024. Similar to PM_{2.5} November 2025 observed hike PM₁₀ concentration as ~65%, ~30%, ~55%, and ~45% at Indirapuram, Loni, Sanjay Nagar and at Vasundhara respectively and gets double in December 2025(~95%-160%). Out of four sites Indirapuram and Loni constantly showed higher PM₁₀ concentration all through the year while other two, Vasundhara and Sanjay Nagar showed more prone in winter season, which in turn reflects that spatially they have significant influence of seasonal meteorology, local emission and winter inaction.

2.3 Variation of NO₂ (2024–2025)

Fig. 4 represents the comparison of monthly average of NO₂ concentrations for the two years 2024 and 2025 recorded at four sites of Ghaziabad, Indirapuram, Loni, Sanjay Nagar and Vasundhara. It is obvious from the fig 4 that NO₂ concentrations vary spatially, seasonally and also interannual variation is observed. Concentration of NO₂ during the winter months of 2025 shows a significant rise, especially in Loni (~180–250%), which reflects a strong effect of traffic and combustion. Analysis from fig.4 shows ~20–60% increase in NO₂ in pre-monsoon months (March-May) in 2025 at Loni and Sanjay Nagar while Indirapuram showed a slight decrease ~10–20%. Again, minima in the NO₂ concentration are observed in rainy season (July-August) with annual differences of two years lies within ±10–15%. On comparing post monsoon and winter months of 2024 and 2025, we find increased concentration of NO₂ ~15–30%, ~20–70%, and ~10–40% in October, November and December respectively, which reveals direct effect of localized emission sources and seasonal weather on the variation of NO₂.

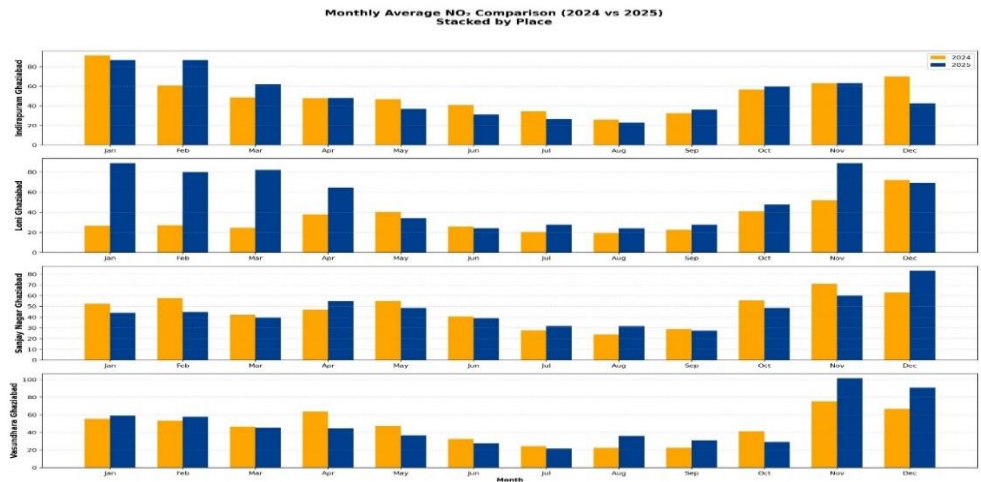


Fig.4: NO₂ (µg m⁻³) comparison for 2024(yellow) and 2025(blue)

2.4 Variation of SO₂ (2024–2025)

Fig. 5 shows the comparison of monthly average of SO₂ concentrations for the two years 2024 and 2025 recorded at four sites of Ghaziabad, Indirapuram, Loni, Sanjay Nagar and Vasundhara. Comparing annual variation of winter and pre-monsoon period of two years, it is clear from Fig. 5 that two sites Indirapuram and Vasundhara shows a decline in the concentration of SO₂ in 2025 by ~15–45%, while other two sites Loni and Sanjay Nagar showed a modest increase of ~10–35% in March & April. Lowest concentrations are aligned with monsoon months which reflects pollutants removal and atmospheric dispersion due to rain. In 2025, in comparison to monsoon season, a noticeable rise in SO₂ concentration is observed (~25–60%) at all four sites during September-October while ~30–70% rise in November-December is recorded.

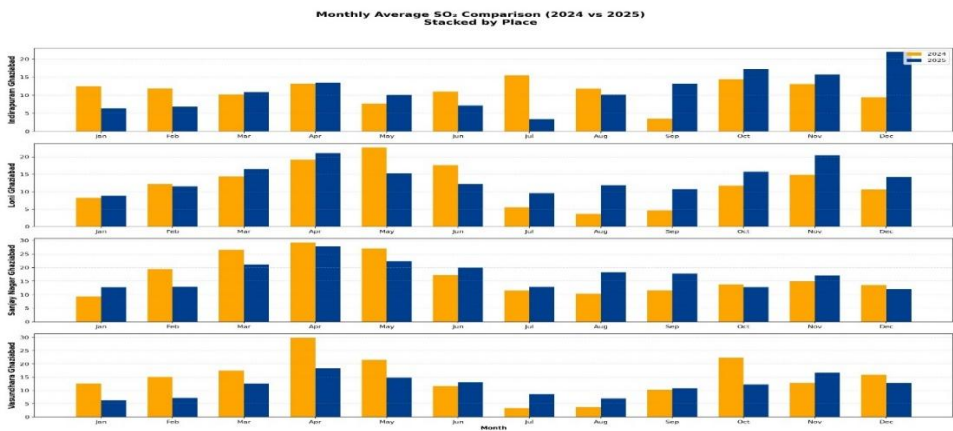


Fig.5: SO₂ (µg m⁻³) comparison for 2024(yellow) and 2025(blue)

2.5 Variation of CO (2024-2025)

Fig. 6 shows the comparison of monthly average of CO concentrations for the two years 2024 and 2025 recorded at four sites of Ghaziabad, Indirapuram, Loni, Sanjay Nagar and Vasundhara. Increase in the concentration recorded at different sites in (2025 vs 2024) were, Indirapuram (~20–30%), Loni (~15–25% annual rise), Sanjay Nagar (~10–25%), and Vasundhara (35–40%) in October–December months with highest peak occurring in November. Annual comparison of two years shows an increase of ~10–35% in the concentration of CO in 2025 during post-monsoon and winter months. Both the year exhibit minimum concentration of CO in monsoon season but 2025 remains constantly elevated. Increased concentration of CO reflects heightened anthropogenic emissions, poorer dispersion conditions in 2025 during winter season.

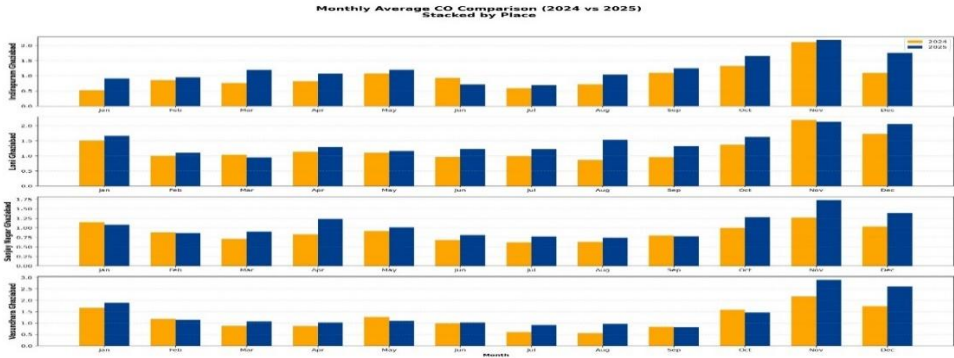


Fig.6: CO ($\mu\text{g m}^{-3}$) comparison for 2024(yellow) and 2025(blue)

2.6 Variation of O₃ (2024-2025)

Fig. 7 shows the comparison of monthly average of O₃ concentrations for the two years 2024 and 2025 recorded at four sites of Ghaziabad, Indirapuram, Loni, Sanjay Nagar and Vasundhara. This is obvious from the fig.7 that maxima in O₃ is observed from April-June in both the years. Ozone concentration of Indirapuram shows ~15–30% hike (approx. double) in 2025 from 2024 during pre-monsoon season, whereas Loni, observed an increase of ~20–35%. Both these sites observed a slight decline in winter months which reflects decreased photochemical production. In contrast, Sanjay Nagar showed higher concentration in winter months in 2025 (~20–40%), and significantly lower maxima in comparison to 2024. The fourth site Vasundhara showed considerably higher values in April-May, (April~50% higher than 2024) whereas winter months shown a decline in comparison to 2024. The trend reflects that pre-monsoon 2025 sees a greater photochemical O₃ formation and decline in winter months shows strong NO titration and limited solar radiation.

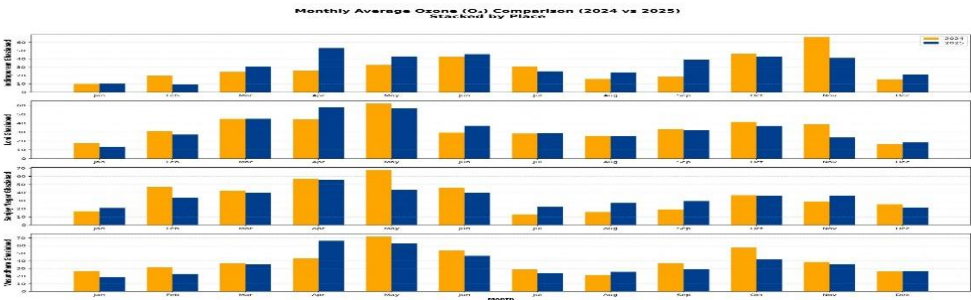


Fig.7: O₃($\mu\text{g m}^{-3}$) comparison for 2024(yellow) and 2025(blue)

2.7 Variation of Benzene (2024-2025)

Fig. 8 shows the comparison of monthly average of Benzene concentrations for the two years 2024 and 2025 recorded at four sites of

Ghaziabad, Indirapuram, Loni, Sanjay Nagar and Vasundhara. Annual comparison reflects an improvement in concentration of Benzene in 2025.

Site-wise, Indirapuram observed continuous decrease in benzene concentration in 2025 (~40–60%) from January to September. The maxima occurred in 2025 in November (~0.70 $\mu\text{g m}^{-3}$), which is (~20%) more than November 2024, which may be due to localized post-monsoon emission influence. Loni experienced highest concentration of benzene in May and October 2024 (~6.5–7.2 $\mu\text{g m}^{-3}$), but 2025 showed a markable reduction throughout the year, with a decrease ~55–75%, mainly in summer and post monsoon months. Sanjay Nagar also showed the improved benzene concentrations in 2025 with a substantial decrease ~40% to 70%. Winter months showed a remarkable decrease of ~65–70% reflecting improvement in local reduced vehicular and evaporative emissions during the study period.

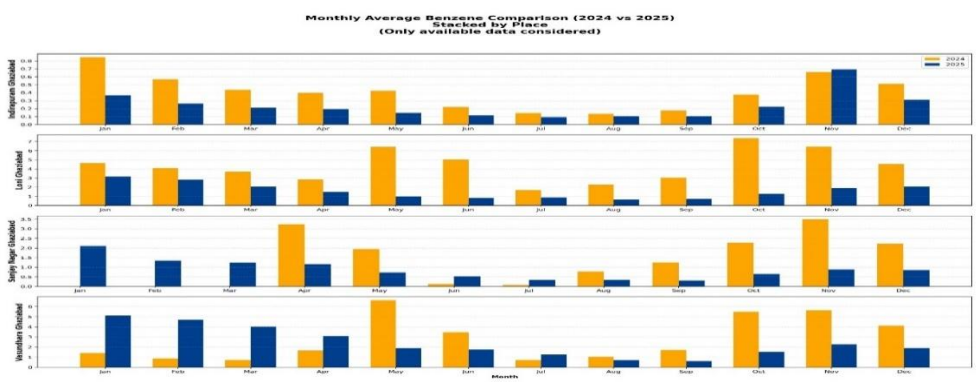


Fig.8: Benzene ($\mu\text{g m}^{-3}$) comparison for 2024(yellow) and 2025(blue)

Annual averages of $\text{PM}_{2.5}$, PM_{10} , NO_2 , SO_2 , CO , O_3 and Benzene are summarised in the below table 1.

Table 1: Annual averages of $\text{PM}_{2.5}$, PM_{10} , NO_2 , SO_2 , CO , O_3 and Benzene

Year	$\text{PM}_{2.5}$ $\mu\text{g m}^{-3}$	PM_{10} $\mu\text{g m}^{-3}$	NO_2 $\mu\text{g m}^{-3}$	SO_2 $\mu\text{g m}^{-3}$	CO $\mu\text{g m}^{-3}$	O_3 $\mu\text{g m}^{-3}$	Benzene $\mu\text{g m}^{-3}$
2024	79.96	174.17	44.66	13.74	1.08	34.17	2.34
2025	93.2	189.96	49.81	13.60	1.28	34.01	1.27

3. Metrological parameters (2024-2025)

Fig. 9 shows the comparison of monthly average of temperature (Temp) and relative humidity (RH) for the two years 2024 and 2025 recorded at Ghaziabad. It is obvious from the fig.9 that higher temperature corresponds to lower humidity and therefore winter months show higher RH which reflects the significant role of temperature-controlled moisture in atmosphere.

Though 2024 was recorded warmer year than 2025 but January and February of 2025 are recorded slight warmer with temperature an increase of ~13% and ~3%. Highest temperature is observed in May 2024 which has ~10% increase from May 2025. Rest of the months have a very little difference.

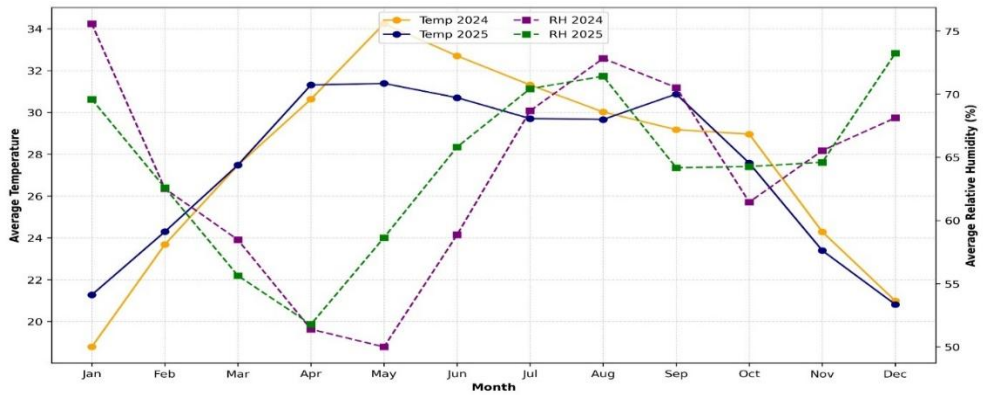


Fig.9: Temperature and relative humidity variation (monthly average) during 2024 and 2025

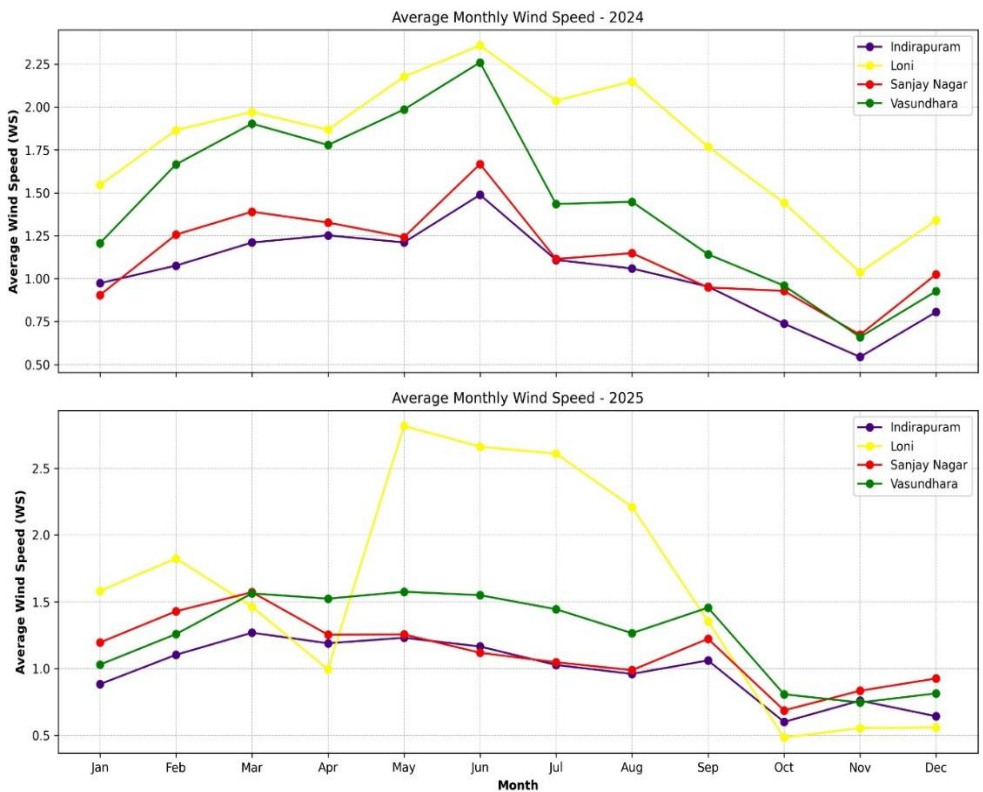


Fig. 10: Wind speed variation (monthly average) during 2024 and 2025

Inter annual comparison of RH reveals greater variation than temperature. Data shows that relative humidity in January 2024 has a hike of ~8–10% than 2025 while pre-monsoon season (April–May) observe ~10–12% increase in RH in 2025 which reflects better climatic conditions in 2025. Monsoon season of two years are comparable, but post monsoon season (November–December) shows ~7–9% increase in RH in 2025, signifying winter months of 2025 to be more humid than 2024.

Fig. 10 shows the variation of wind speed (monthly average) for the stated study period (2024 &2025) of Ghaziabad, recorded at four sites of Ghaziabad, Indirapuram, Loni, Sanjay Nagar and Vasundhara. Data of wind speed 2024 shows that wind speed becomes maximum in June at all measuring sites and peak value occurred at Loni (~2.3 m s⁻¹) while wind speed becomes minimum in winter month (~0.6–1.2 m s⁻¹) which reflects low atmospheric mixing. Wind speed data 2025 reflects higher wind speeds in 2025 in comparison to 2024. Maximum speed observed in Loni in May–June (~2.6–2.8 m s⁻¹). Both the year shows a steeper decline in wind speed during post monsoon season. Winter months of the two years see comparable wind speed which results in stagnation of air pollutants.

3.1 Correlation of PM_{2.5} and Wind Speed (Scatter Plots)

Fig. 11 shows the scatter plots with linear regression of PM_{2.5} concentration and wind speed for the two years 2024 and 2025 recorded at four sites of Ghaziabad, Indirapuram, Loni, Sanjay Nagar and Vasundhara. It clearly reflects a inverse correlation between PM_{2.5} concentration and wind speed at all measuring centres proving that particulate pollution is highly wind dependent.

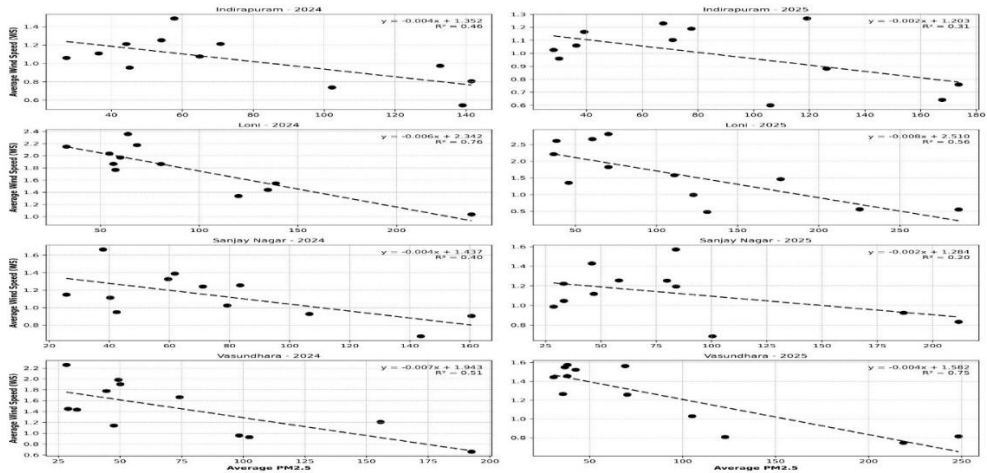


Fig. 11: Correlation between PM_{2.5} and wind speed in 2024 and 2025 at all four measuring sites.

Out of the four sites Loni shows highest inverse relationship ($R^2 = 0.76$), signifying that $\sim 76\%$ of $PM_{2.5}$ concentration depends on wind speed. While Vasundhara shows a moderate negative correlation ($R^2 = 0.51$), followed by Indirapuram ($R^2 = 0.46$) and Sanjay Nagar ($R^2 = 0.40$). Loni and Vasundhara have steeper negative slopes, signifying that these areas are more prone to ventilation conditions. 2025 also shows the inverse relationship but there is more variation locally. Vasundhara exhibits highest correlation ($R^2 = 0.75$) in 2025, Loni a modest ($R^2 = 0.56$). Indirapuram ($R^2 = 0.31$) and Sanjay Nagar ($R^2 = 0.20$) reflects a feebler relationship, that suggest $PM_{2.5}$ in this area is highly related to local emissions and does not depend upon non-meteorological factors on contrast Loni and Vasundhara benefit more from natural ventilation.

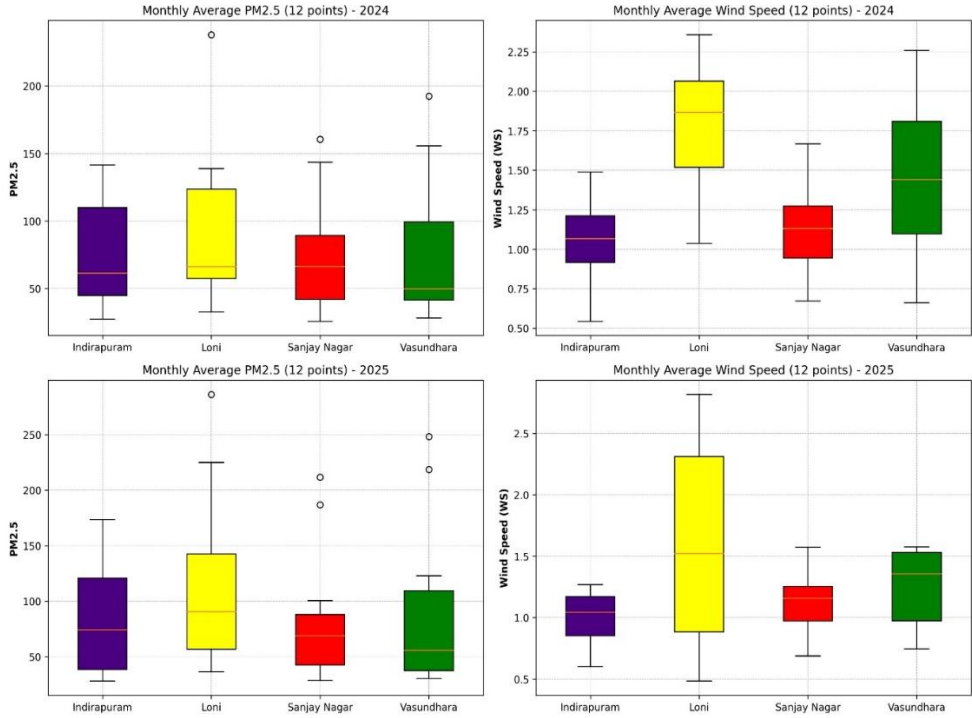


Fig. 12 $PM_{2.5}$ and wind speed (Box and Whisker plot) for 2024 and 2025 at all four measuring sites.

Fig. 12 shows the box-whisker analysis of $PM_{2.5}$ concentration and wind speed for the study period recorded at four sites of Ghaziabad, Indirapuram, Loni, Sanjay Nagar and Vasundhara. In 2024, median $PM_{2.5}$ concentrations were $\sim 60 \mu g m^{-3}$ at Indirapuram, $65-70 \mu g m^{-3}$ at Loni, $\sim 65 \mu g m^{-3}$ at Sanjay Nagar, and $\sim 50 \mu g m^{-3}$ at Vasundhara. In 2025, medians increased to $\sim 75 \mu g m^{-3}$ (Indirapuram), $\sim 90-95 \mu g m^{-3}$ (Loni), $\sim 65-70 \mu g m^{-3}$ (Sanjay Nagar),

and $\sim 55\text{--}60\text{ }\mu\text{g m}^{-3}$ (Vasundhara), indicating an overall 15–30% rise in $\text{PM}_{2.5}$, with Loni showing the highest variability and extreme values.

Median wind speeds in 2024 were $\sim 1.05\text{ m s}^{-1}$ (Indirapuram), $\sim 1.9\text{ m s}^{-1}$ (Loni), $\sim 1.1\text{ m s}^{-1}$ (Sanjay Nagar), and $\sim 1.45\text{ m s}^{-1}$ (Vasundhara). In 2025, medians remained similar at Indirapuram and Sanjay Nagar ($\sim 1.1\text{ m s}^{-1}$) but showed greater variability at Loni ($\sim 1.5\text{ m s}^{-1}$, range up to $\sim 2.8\text{ m s}^{-1}$) and Vasundhara ($\sim 1.3\text{ m s}^{-1}$). Locations with higher median wind speeds and wider ranges (Loni and Vasundhara) correspond to stronger negative $\text{PM}_{2.5}$ –wind speed correlations, while lower wind regimes (Indirapuram and Sanjay Nagar) exhibit weaker correlations, confirming wind speed as a key control on $\text{PM}_{2.5}$ dispersion.

3.2 Wind Rose Analysis for 2024 and 2025

Figs. 13-14 represents wind rose analysis of Ghaziabad region of 2024 and 2025 respectively. The fig. (13-14) we find the domination of southerly to south-easterly (S–SSE–SE) wind direction in both the year. From fig. (13-14), it is clear that wind speed in winter months gets lower ($\leq 2\text{ m s}^{-1}$), this produces decline in dispersion and increases accumulation of pollutants in the study area, on contrary pre-monsoon and early summer months (March–June) finds greater wind speed which results to less accumulation of $\text{PM}_{2.5}$. Comparing the two years, though 2024 finds high speeds more frequent ($>3\text{ m s}^{-1}$), yet both the years follow the same trend throughout the year i.e. accumulation of pollutants in winter months and less pollution in summer and pre-monsoon months.

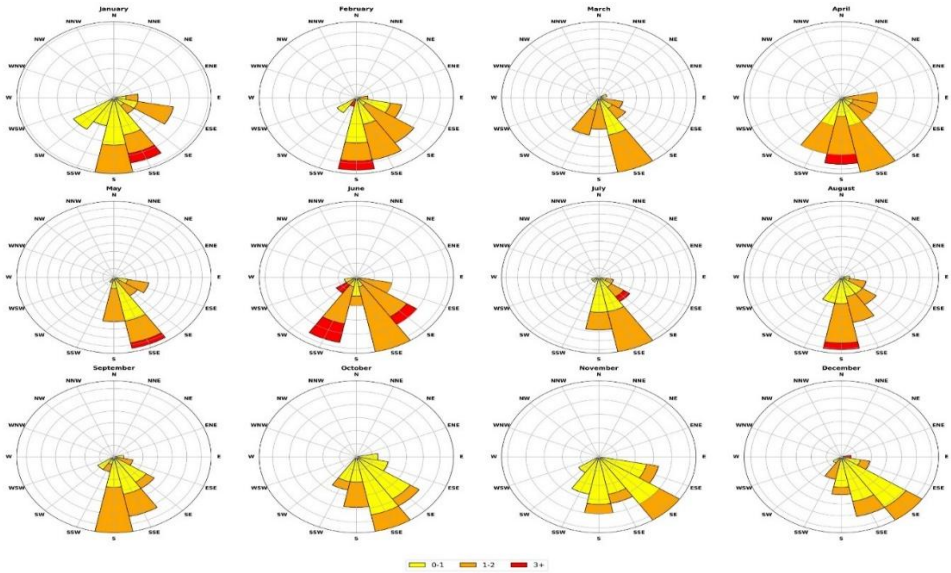


Fig. 13: Month-wise wind rose plot for 2024 for the study area WR 2024

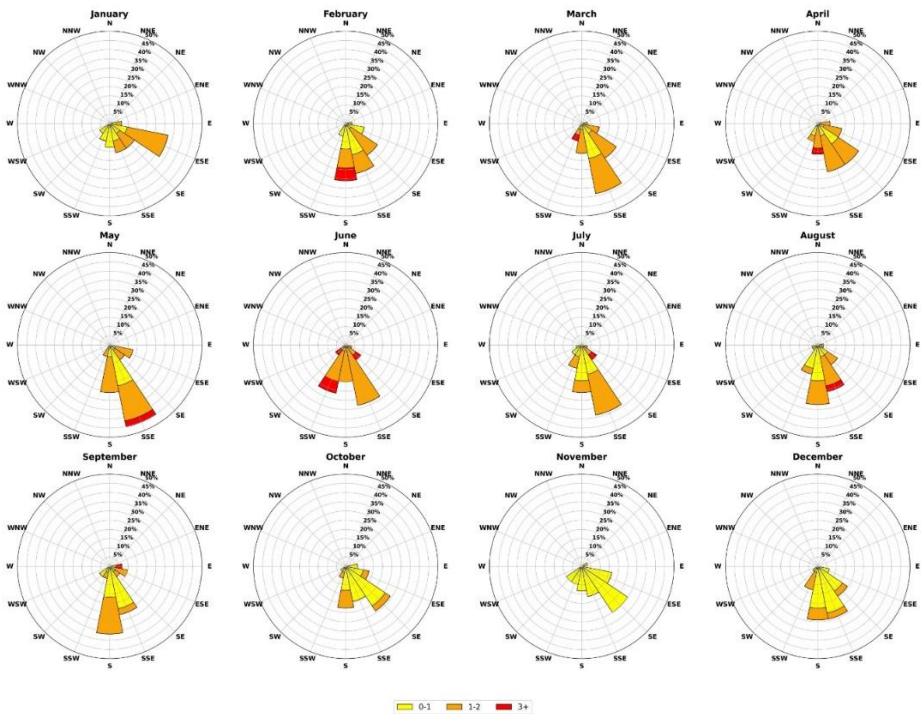


Fig.14: Month wise wind rose plot for 2025

4. Statistical Analysis (Correlation between selected variables)

Table 2 shows the correlations among all selected pollutants for the year 2024 in Ghaziabad. All pollutants having strong correlation are represented in bold. It is clear from the table 1 that PM_{2.5} and PM₁₀ are strongly correlated ($r=0.79$) which signify that they are originating from common sources. In 2024, PM_{2.5} also has higher correlation with NO₂ ($r = 0.67$) and benzene ($r = 0.69$), which indicates towards vehicular impact.

Table 3 shows the correlations among all selected pollutants for the year 2025 in Ghaziabad. All pollutants having strong correlation are represented in bold. In 2025, correlation of PM_{2.5} and PM₁₀ increases than 2024 ($r = 0.79 \rightarrow 0.81$), CO ($r = 0.42 \rightarrow 0.47$) and SO₂ ($r = .08 \rightarrow 0.42$) but gets weaken in PM_{2.5}–NO₂ coupling ($r = 0.67 \rightarrow 0.43$). PM₁₀ correlation increases with CO ($r = 0.66$ vs 0.37 in 2024) and SO₂ ($r = 0.56$ vs ~ 0.01) which reflects that coarse particles are affected by combustion related and secondary sources. Correlation of ozone with temperature also increase in 2025 ($r = 0.26 \rightarrow 0.51$) but becomes negative with NO₂ and RH, reflecting increased photochemical activity in 2025.

The present work is based on secondary data obtained from monitoring stations run by CPCB, so it has some limitations. The first limitation of the

work is, it includes uncertainties related to instrumentation and data gaps. The spatial variability is limited to fixed monitoring locations (Indirapuram, Vasundhara, Loni and Sanjay Nagar) and may not capture micro-scale variability. The second limitation of the study is that meteorological analysis was confined to surface parameters only.

Table 2: Correlation matrix 2024

	PM _{2.5}	PM ₁₀	NO ₂	SO ₂	CO	Ozone	Benzene	Temp	RH	WS
PM _{2.5}	1	0.785933	0.667673	0.084563	0.426388	0.153142	0.687871	-0.45216	0.14848	-0.49603
PM ₁₀		1	0.665615	0.008001	0.36893	0.161296	0.734436	-0.21547	-0.26603	-0.26505
NO ₂			1	0.160529	0.33387	-0.01732	0.749541	-0.57415	0.027046	-0.39149
SO ₂				1	0.053029	0.25709	0.104383	-0.09216	-0.04694	-0.15233
CO					1	0.502411	0.327064	0.07018	-0.10604	-0.47902
O ₃						1	-0.01461	0.258444	-0.26337	-0.15364
BENZENE							1	-0.59158	0.058777	-0.44367
TEMP								1	-0.48079	0.229426
RH									1	-0.32072
WS										1

Table 3: Correlation matrix 2025

	PM _{2.5}	PM ₁₀	NO ₂	SO ₂	CO	Ozone	Benzene	Temp	RH	WS
PM _{2.5}	1	0.805969	0.43416	0.421338	0.473455	-0.05396	0.474788	-0.59236	0.029694	-0.26086
PM ₁₀		1	0.376763	0.561795	0.657627	0.008037	0.468754	-0.51179	0.07779	-0.42013
NO ₂			1	0.096067	0.36162	-0.26721	0.395821	-0.47102	-0.14428	-0.22154
SO ₂				1	0.486025	0.284116	0.110786	-0.17085	-0.10279	-0.31302
CO					1	0.118723	0.298112	-0.17913	-0.01453	-0.40074
O ₃						1	-0.12815	0.50828	-0.45214	-0.00288
BENZENE							1	-0.34323	0.028003	0.022657
TEMP								1	-0.38552	0.177961
RH									1	-0.26728
WS										1

5. Conclusion

The study conducted in this paper for the stated period finds that variation in air pollutants and atmospheric parameters is correlated. It has been found that concentration of pollutants varies with location and season. Correlation tables shows that year 2024 exhibit vehicular effect while year 2025 relates to combustion and secondary processes. According to correlation table 2025,

correlation of PM₁₀ reveals that coarse particle is affected by combustion-related and secondary sources. Though Meteorological parameters improved in 2025 (temperature and wind speed showing negative correlations with pollutants) which result in improvement in dispersion of pollutants. The study reveals that year 2024 shows traffic dominated pollution while 2025 shows pollution from combustion-related and secondary sources. Hence it has been suggested that winter months which are more prone to pollution, policy makers should focus more on control of vehicular emission and traffic management, and also regulation of combustion sources to reduce PM₁₀, CO, and SO₂. Therefore, seasonal, meteorology-based action plans and dust-control measures are essential to address winter stagnation and summer ozone episodes. Traffic volume is increasing not only in Ghaziabad but also increasing in all over the NCR region, particularly after GST rates on the vehicles are revised. The effect of increased traffic volume and rapid urban expansion will further elevate NO₂, CO, and secondary O₃ concentrations, particularly in high-density corridors, which in turn will increase the pollutant levels in the coming future deteriorating urban air quality.

Future scope- From the future perspective, this work with the integration of satellite observations and advanced statistical or machine learning models can add improved predictive capability which will help policy makers to develop policy accordingly. Secondly, the work in combination with health outcome records would provide stronger evidence of public health impacts and support policy-level interventions.

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