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A Comparative Analysis of Pollutant Levels at Bagsewania, Arera Colony and T.T. Nagar Areas of Bhopal (MP): A Case Study of March–April 2026

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Abstract

Air pollution has emerged as a major environmental and public health concern in rapidly urbanizing Indian cities. The present study investigates the spatial and temporal variation of major air pollutants at three urban locations of Bhopal—Bagsewania, Arera Colony and T.T. Nagar—during March–April 2026. Secondary data obtained from monitoring stations were analysed for six key pollutants: carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM_{10} and $PM_{2.5}$) and sulphur dioxide (SO_2). Mean concentrations were calculated for morning, afternoon and evening periods, followed by computation of overall mean values for inter-site comparison.

The results indicate significant diurnal and spatial variations in pollutant concentrations across the study areas. Bagsewania recorded the highest overall pollution load, particularly for CO and O_3, suggesting strong influence of vehicular emissions and traffic congestion. Arera Colony exhibited moderate pollution levels, while T.T. Nagar showed relatively higher particulate matter concentrations. Diurnal trends revealed peak levels of primary pollutants during morning and evening hours, whereas ozone concentrations were elevated during afternoon due to photochemical reactions. Fine particulate matter ($PM_{2.5}$) remained consistently high across all locations, indicating potential health risks for the urban population.

The study highlights transportation, road dust and urban land-use patterns as major contributors to air pollution in Bhopal. The findings emphasize the need for effective urban air quality management strategies, continuous monitoring and implementation of pollution control measures to safeguard public health.

Keywords: air pollution; Bhopal; carbon monoxide; diurnal variation; environmental monitoring; nitrogen dioxide; ozone; particulate matter; public health; urban air quality

1 Introduction

Air pollution has emerged as one of the most serious environmental and public-health challenges worldwide, particularly in rapidly urbanizing cities of developing countries. Rapid industrialization, increasing vehicular density, urban expansion and population growth have contributed significantly to the deterioration of ambient air quality. Exposure to polluted air is associated with respiratory diseases, cardiovascular disorders, ecological damage and increased mortality [1], [16]. Therefore, continuous monitoring and assessment of air quality have become essential for environmental planning, sustainable urban development and public health protection.

Ambient air quality monitoring focuses on major pollutants such as particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and ozone (O_3), which

originate mainly from vehicular emissions, industrial processes, domestic fuel combustion and construction activities. Early work in India highlighted the importance of monitoring urban air pollution, including studies on Bangalore that emphasized the need for systematic regional air-quality assessment [2]. Subsequent investigations across various Indian cities confirmed that urban air quality frequently exceeds permissible limits and poses serious environmental and health risks [3], [4].

Several researchers have conducted region-specific assessments of ambient air pollution in India. Studies in Puducherry reported increasing concentrations of major pollutants and highlighted the importance of continuous monitoring for urban management [5]. Investigations in Raipur and Jhansi revealed significant spatial and temporal variations in pollutant levels due to industrial and vehicular emissions [6], [7]. Similarly, studies conducted in the Himalayan region and Haridwar showed that rapid industrialization and urban development have led to noticeable deterioration in air quality [8], [9].

To simplify the interpretation of complex pollution data, the Air Quality Index (AQI) has been widely adopted as an effective communication tool that converts pollutant concentrations into a single value representing overall air quality and potential health risks [10]. AQI-based studies have demonstrated its usefulness in identifying pollution hotspots and communicating environmental risks to the public and policymakers [11], [12]. Further research in Udaipur also emphasized the importance of continuous monitoring and AQI assessment in rapidly growing urban centres [13].

Specific studies conducted in Bhopal have highlighted rising pollution levels and the need for continuous air-quality monitoring. Gupta [14] assessed the ambient air quality status of Bhopal and reported significant variations in pollutant concentrations across the city. More recently, machine-learning approaches have been applied to predict AQI in Bhopal, demonstrating the growing importance of advanced analytical tools in air-quality management [15]. Regional differences in the short-term effects of air pollution on daily mortality have also been investigated [16].

Despite the availability of previous studies, there remains a need for updated and location-specific comparative analysis of air pollution within Bhopal city. Rapid urbanization and increasing vehicular emissions necessitate continuous monitoring to understand spatial variations and identify pollution hotspots. Therefore, the present study integrates ambient air-quality monitoring and AQI assessment to evaluate spatial variations in pollutant concentrations across selected urban locations of Bhopal. The study aims to provide updated scientific evidence that can support environmental planning, pollution control strategies and public health protection.

The Air Quality Index scale defined by the US Environmental Protection Agency [17] is given in Table 1.

Table 1. Air Quality Index categories, levels of health concern and colour codes.

AQI value	Level of health concern	Health implications	Colour
0–50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk 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

AQI value	Level of health concern	Health implications	Colour
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 warnings of emergency conditions. The entire population is more likely to be affected.	Purple
301–500	Hazardous	Health alert: everyone may experience more serious health effects	Maroon

In this context, the present study focuses on a comparative analysis of pollutant levels in three distinct areas of Bhopal—Bagsewania, Arera Colony, and T.T. Nagar—during March–April 2026. These locations represent different urban characteristics such as residential zones, mixed land-use areas, and high-traffic regions. By examining variations in $PM_{2.5}$, PM_{10}, CO, SO_2, NO_2, and O_3 concentrations across these sites, the study aims to provide insights into spatial pollution patterns and their implications for environmental management and public health.

This research contributes to the growing need for localized air-quality assessments, which are crucial for designing targeted mitigation strategies, improving urban planning, and protecting the health of city residents.

2 Materials and methods

2.1 Study area

The present investigation was conducted in Bhopal, the capital of Madhya Pradesh, India, during March–April 2026. The city lies at approximately 23.25° N latitude and 77.41° E longitude, with an average elevation of ~527 m above mean sea level. Bhopal experiences a sub-tropical climate characterized by hot summers, mild winters, and a monsoon season. The study period corresponds to the late winter–early summer transition, typically marked by rising temperature, lower humidity, and increased dust suspension, which significantly influence ambient air pollution levels.

We chose Bagsewania, Arera Colony, and T.T. Nagar for air pollution comparison because they represent different levels of urban development and traffic density in Bhopal. Bagsewania is a developing residential area, Arera Colony is a planned residential-commercial area, and T.T. Nagar is a busy commercial and administrative center with heavy traffic. Comparing these locations helps us understand how human activities, traffic, and land use affect air quality and allows us to identify areas with higher pollution levels for better environmental management. The locations are shown in Figure 1.

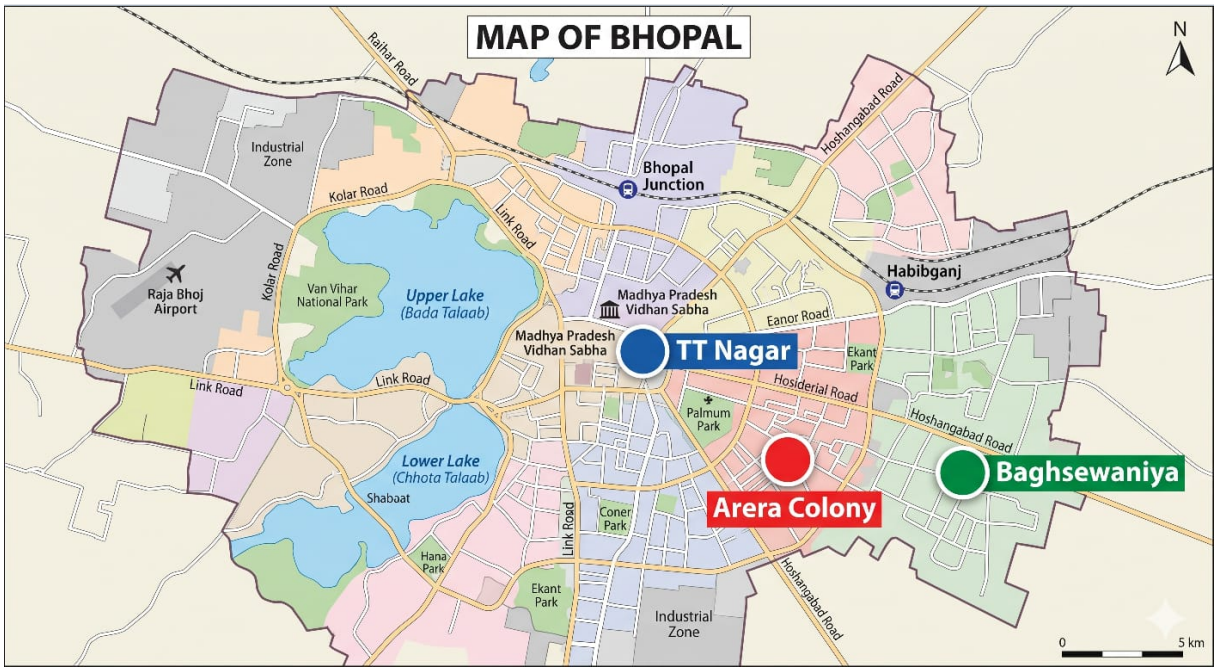


Figure 1. Map of Bhopal city showing the three study locations.

Bagsewania. Bagsewania is a rapidly developing residential locality situated in the southern part of the city. The area is characterized by:

- On-going construction and infrastructure expansion
- Increasing population density
- Moderate vehicular movement
- Dust emissions from unpaved roads and construction sites

This location represents a developing residential zone.

Arera Colony. Arera Colony is a well-planned residential and commercial area in central Bhopal. Major features include:

- Well-developed road network
- Commercial establishments and offices
- Moderate to high traffic density

This site represents a mixed land-use urban environment.

T.T. Nagar. T.T. Nagar is one of the primary administrative and commercial hubs of the city. Key characteristics include:

- Heavy vehicular traffic
- Government offices and marketplaces
- High pedestrian movement and roadside emissions

This location represents a traffic-dominated urban zone expected to exhibit comparatively higher pollution levels.

2.2 Data collection and analysis

The present research adopted a comparative analytical study design based on secondary air-quality data. The study utilized publicly available monitoring data obtained from the Central Pollution Control Board (CPCB) [18] air-quality monitoring stations for the selected locations in Bhopal during March–April 2026.

The collected dataset included pollutant measurements recorded at different time intervals of the day. The analysis was carried out to evaluate:

- Morning average concentrations (Time-9am to 11am)
- Afternoon average concentrations (Time-1.00pm to 3.00pm)
- Evening average concentrations (Time-6.00pm to 9.00pm)

The study focused on the following major criteria pollutants:

- Particulate Matter ($PM_{2.5}$ and PM_{10})
- Carbon Monoxide (CO)
- Nitrogen Dioxide (NO_2)
- Sulphur Dioxide (SO_2)
- Ground-level Ozone (O_3)

3 Results and discussion

3.1 Overall air quality characteristics

The present study evaluated the diurnal and spatial variation of major air pollutants ($PM_{2.5}$, PM_{10}, CO, SO_2, NO_2, and O_3) at three urban locations of Bhopal—Bagsewania, Arera Colony and T.T. Nagar—during March–April 2026 (Table 2). Mean concentrations were computed for morning, afternoon and evening periods and further integrated to obtain overall mean values for inter-site comparison.

The results clearly indicate noticeable temporal as well as spatial variation in pollutant concentrations, mainly influenced by traffic density, land-use pattern and atmospheric photochemical processes.

Table 2. Mean pollutant concentrations in the morning, afternoon and evening at the three locations of Bhopal, March–April 2026.

Site	Pollutant (unit)	Morning	Afternoon	Evening
Bagsewania	CO (ppb)	375	346.67	453
	NO_2 (ppb)	24	11.75	13.43
	O_3 (ppb)	66	54.50	56.71
	PM_{10} ($\mu g/m^3$)	42	29.75	31.71
	$PM_{2.5}$ ($\mu g/m^3$)	29	20.67	22.29
	SO_2 (ppb)	5	4.50	4.71
Arera Colony	CO (ppb)	343	316.73	397
	NO_2 (ppb)	25	16.18	14.43
	O_3 (ppb)	41	41.55	48.71

Site	Pollutant (unit)	Morning	Afternoon	Evening
	PM_{10} (µg/m^3)	44	29.91	33.00
	$PM_{2.5}$ (µg/m^3)	31	21.45	22.71
	SO_2 (ppb)	5	4.36	5.29
T.T. Nagar	CO (ppb)	458	285.82	385
	NO_2 (ppb)	22	13.36	13.43
	O_3 (ppb)	68	51.64	54.57
	PM_{10} (µg/m^3)	49	37.45	35.43
	$PM_{2.5}$ (µg/m^3)	31	22.64	21.57
	SO_2 (ppb)	5	4.30	3.71

3.2 Spatial comparison of overall mean concentrations

3.2.1 Carbon monoxide (CO)

The overall mean CO concentration followed the trend:

Bagsewania (438 ppb) > Arera Colony (361 ppb) > T.T. Nagar (≈385 ppb)

Bagsewania recorded the highest CO levels, indicating strong vehicular emissions and traffic congestion. CO is primarily emitted from incomplete combustion of fuel; therefore, its higher concentration in Bagsewania suggests intense morning and evening traffic activity. The relatively lower values in Arera Colony may be attributed to comparatively smoother traffic flow and residential land use. The diurnal variation at the three sites is shown in Figure 2.

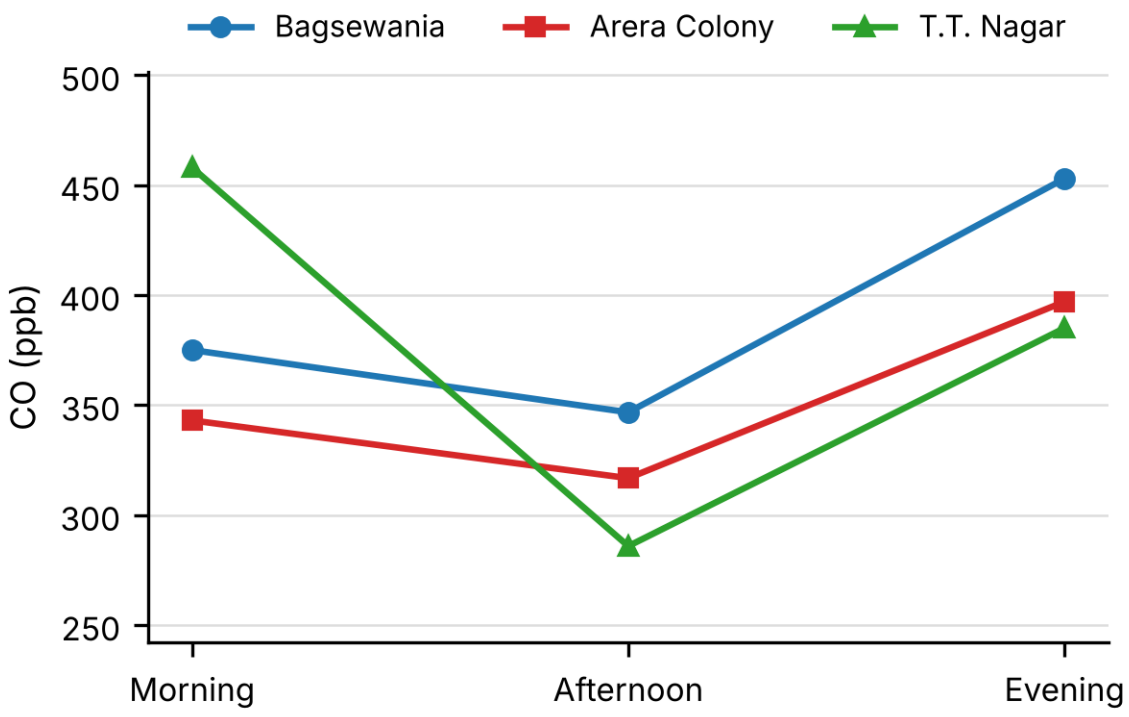


Figure 2. Diurnal variation of CO concentration (ppb) at the three study locations.

3.2.2 Nitrogen dioxide (NO_2)

NO_2 concentrations were almost similar across the study areas:

Bagsewania ≈ Arera Colony ≈ T.T. Nagar (≈17 ppb)

This uniformity suggests that vehicular emissions—common to all locations—are the dominant source of NO_2. The relatively moderate values indicate typical urban background pollution levels. The diurnal variation at the three sites is shown in Figure 3.

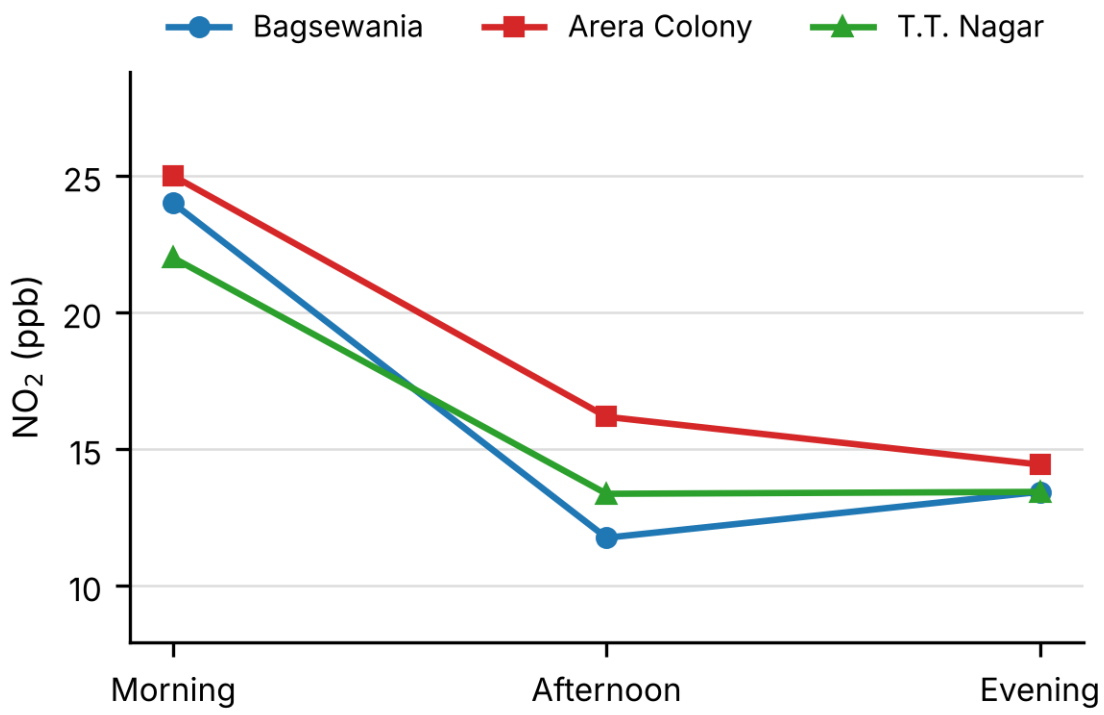


Figure 3. Diurnal variation of NO_2 concentration (ppb) at the three study locations.

3.2.3 Ozone (O_3)

Ozone (O_3) showed the pattern:

Bagsewania (57.6 ppb) > T.T. Nagar (≈54 ppb) > Arera Colony (48.2 ppb)

Higher ozone levels in Bagsewania and T.T. Nagar may be attributed to photochemical reactions involving NOx and volatile organic compounds under strong sunlight conditions. Since ozone is a secondary pollutant, its peak during daytime significantly contributed to higher overall mean levels. The diurnal variation at the three sites is shown in Figure 4.

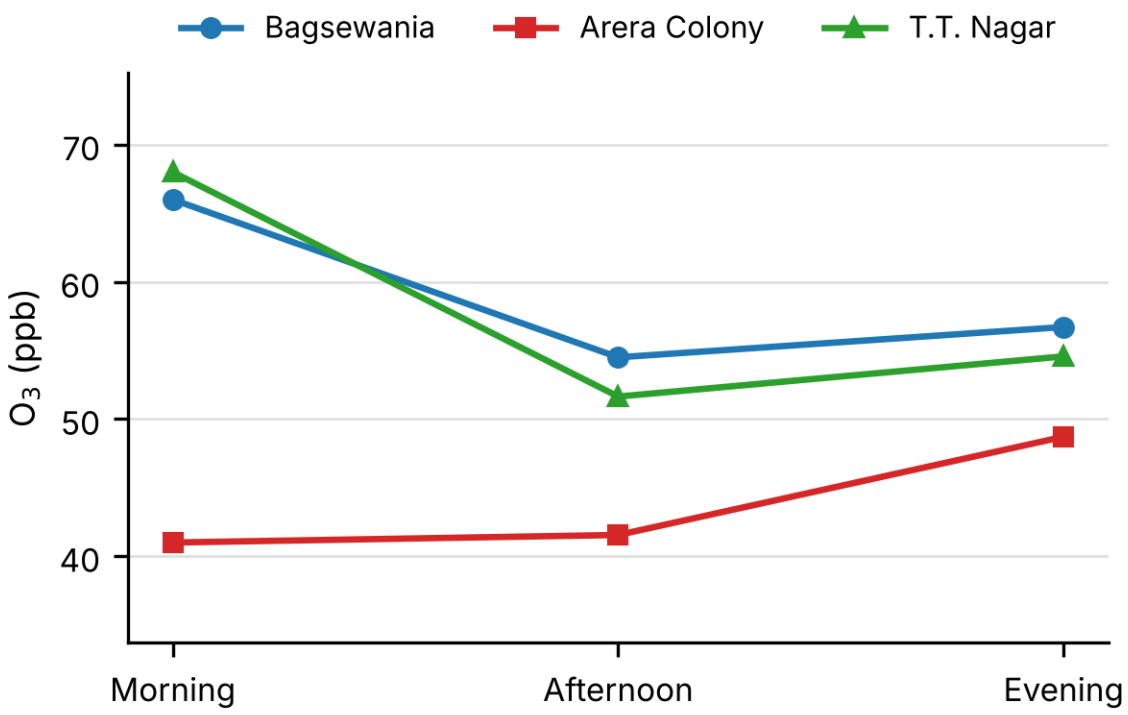


Figure 4. Diurnal variation of O_3 concentration (ppb) at the three study locations.

3.2.4 Particulate matter (PM_{10})

PM_{10} concentrations were found as:

Bagsewania (35.9 µg/m^3) ≈ T.T. Nagar (≈35 µg/m^3) > Arera Colony (34.7 µg/m^3)

The relatively high PM_{10} levels in Bagsewania and T.T. Nagar indicate the influence of road dust resuspension, traffic movement, and urban construction activities. The values are close to the recommended limits, highlighting the growing concern of coarse particulate pollution in Bhopal. The diurnal variation at the three sites is shown in Figure 5.

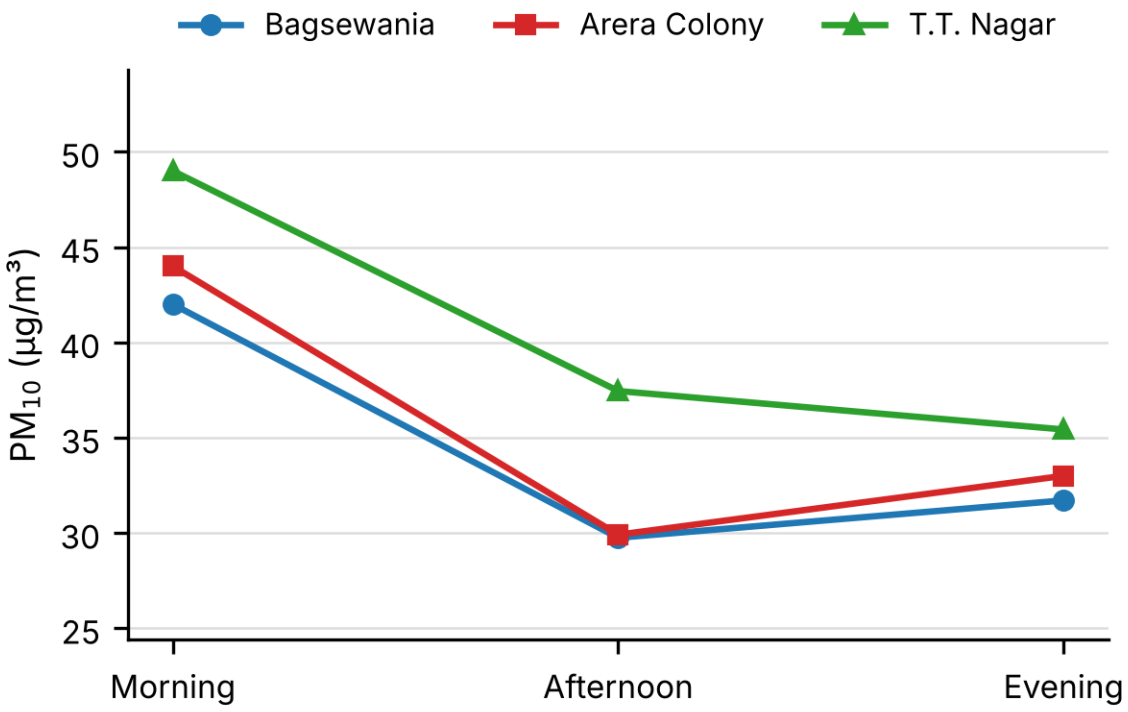


Figure 5. Diurnal variation of PM_{10} concentration ($\mu g/m^3$) at the three study locations.

3.2.5 Fine particles ($PM_{2.5}$)

$PM_{2.5}$ concentrations showed minimal spatial variation:

All areas ≈ 24–25 $\mu g/m^3$

These values exceed WHO recommended limits, suggesting persistent fine particulate pollution across the city. Fine particles are particularly harmful because they penetrate deep into the respiratory system and are associated with cardiovascular and pulmonary diseases. The diurnal variation at the three sites is shown in Figure 6.

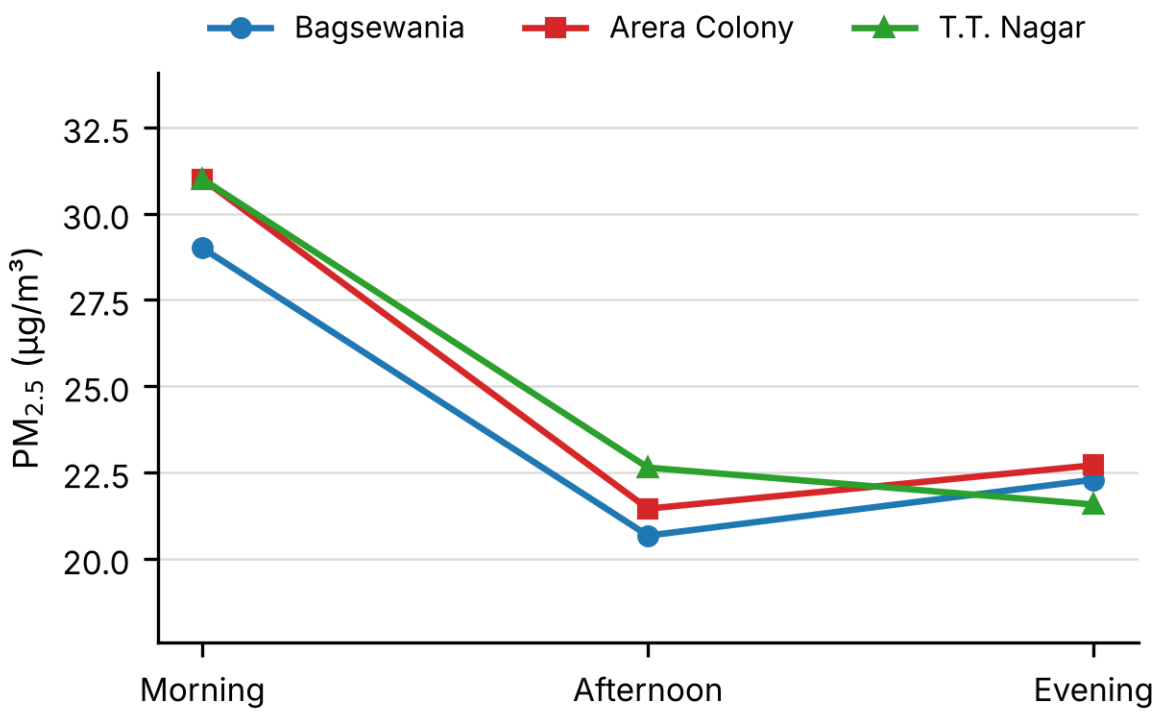


Figure 6. Diurnal variation of $PM_{2.5}$ concentration ($\mu g/m^3$) at the three study locations.

3.2.6 Sulphur dioxide (SO_2)

SO_2 showed the lowest concentrations among all pollutants:

All areas ≈ 4–5 ppb

The low SO_2 levels indicate limited influence of heavy industrial activities in the study zones. The primary source may be fuel combustion from vehicles and small-scale industries. The diurnal variation at the three sites is shown in Figure 7.

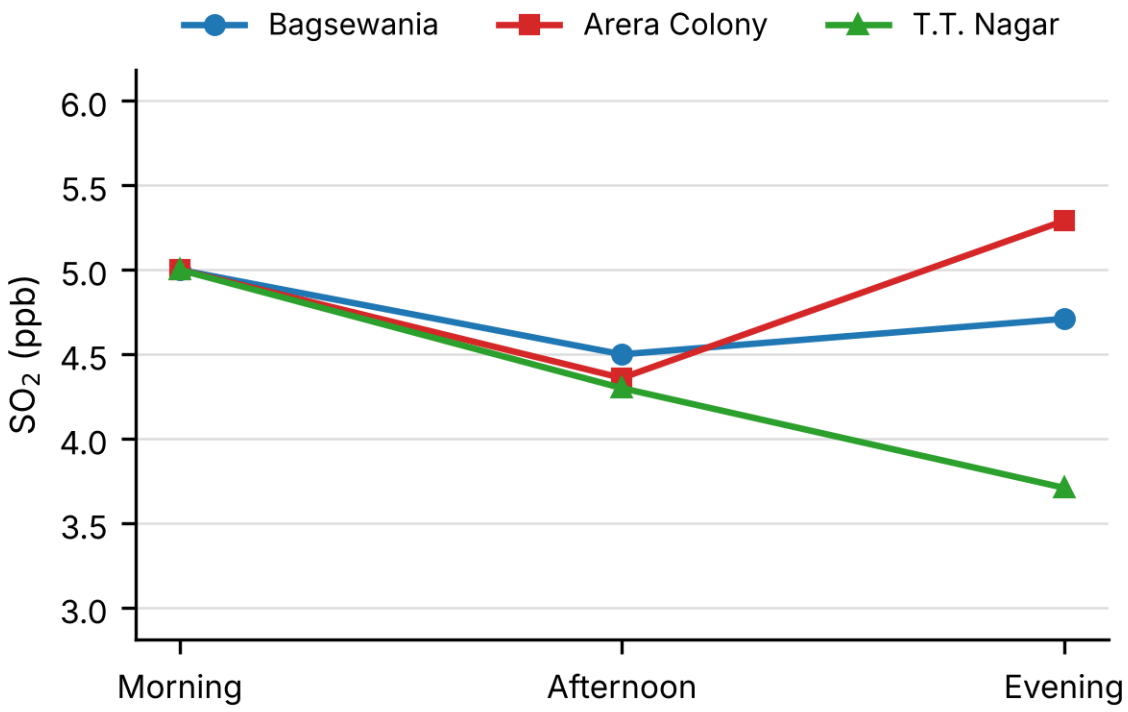


Figure 7. Diurnal variation of SO_2 concentration (ppb) at the three study locations.

3.3 Diurnal variation of pollutants

3.3.1 Morning period

Morning hours exhibited elevated concentrations of CO, NO_2 and particulate matter due to:

- Peak traffic congestion
- Lower atmospheric mixing height
- Reduced dispersion conditions

3.3.2 Afternoon period

A noticeable decline in primary pollutants was observed in the afternoon, which can be attributed to:

- Increased atmospheric mixing
- Higher wind speeds
- Enhanced dispersion of pollutants

However, ozone concentrations remained relatively high during this period due to active photochemical reactions.

3.3.3 Evening period

Evening levels again showed an increase in CO and NO_2 due to:

- Return traffic peak hours
- Lower mixing height after sunset
- Accumulation of pollutants in the atmosphere

3.4 Findings

The comparative analysis of air quality data collected from Bagsewania, Arera Colony, and T.T. Nagar areas of Bhopal during March–April 2026 revealed significant spatial variations in pollutant concentrations. Among the three study locations, Bagsewania emerged as the most polluted area overall, exhibiting higher concentrations of particulate matter and gaseous pollutants. The elevated pollution levels in this area may be attributed to increased traffic density, rapid urbanization, and local anthropogenic activities.

The study further indicated that vehicular emissions were the primary source of air pollution across all monitoring sites. Higher concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2), and particulate matter near traffic-dominated zones suggest the substantial contribution of motor vehicles to deteriorating air quality in Bhopal.

The presence of relatively high ozone (O_3) concentrations points towards active photochemical smog formation in the study area. Ground-level ozone is a secondary pollutant formed through photochemical reactions involving nitrogen oxides and volatile organic compounds in the presence of sunlight. The observed ozone levels indicate that photochemical processes significantly influence urban air quality, particularly during warmer periods.

Another important finding of the study is that $PM_{2.5}$ concentrations exceeded recommended health-based guidelines in all three areas. Fine particulate matter poses serious health risks due to its ability to penetrate deep into the respiratory system and enter the bloodstream. The consistently high $PM_{2.5}$ levels suggest potential adverse effects on public health, including respiratory and cardiovascular diseases among the urban population.

In contrast, sulphur dioxide (SO_2) concentrations remained comparatively low throughout the study period, indicating a relatively limited impact of industrial emissions in the selected areas. The low SO_2 levels suggest that industrial activities are not the dominant contributors to air pollution in these parts of Bhopal, and that vehicular and urban sources play a more significant role in determining overall air quality.

Overall, the study highlights the need for effective traffic management strategies, stricter vehicular emission controls, and continuous air quality monitoring to mitigate pollution levels and protect public health in Bhopal city.

3.5 Implications for urban air quality

The results demonstrate that Bhopal is experiencing typical urban air pollution driven primarily by transportation and urban activities. Persistent particulate pollution and rising ozone levels indicate the need for:

- Improved traffic management
- Promotion of cleaner fuels
- Dust control measures
- Expansion of green cover

The site with the highest mean level of each pollutant in each period is summarised in Table 3.

Table 3. Location with the highest mean concentration of each pollutant by period.

Pollutant	Morning	Afternoon	Evening
CO	**T.T. Nagar**	Bagsewania	Bagsewania
NO_2	**Arera Colony**	Arera Colony	Arera Colony
O_3	**T.T. Nagar ≈ Bagsewania**	**Bagsewania and T.T. Nagar**	Bagsewania and T.T. Nagar
PM_{10}	**T.T. Nagar**	**T.T. Nagar**	**T.T. Nagar**
$PM_{2.5}$	**T.T. Nagar ≈ Arera Colony**	**T.T. Nagar**	**T.T. Nagar**
SO_2	**Similar in all areas**	**Similar in all areas**	**Similar in all areas**

4 Conclusion

The present study provides a comparative assessment of air quality across Bagsewania, Arera Colony and T.T. Nagar in Bhopal during March–April 2026 by analysing diurnal variations and overall mean concentrations of major pollutants ($PM_{2.5}$, PM_{10}, CO, SO_2, NO_2, and O_3).

The findings reveal clear spatial and temporal variations in pollutant levels across the three monitoring locations. Among the study areas, Bagsewania recorded the highest overall pollution load, particularly for carbon monoxide and ozone, indicating strong influence of traffic congestion and urban activity. Arera Colony showed moderate pollution levels, while T.T. Nagar exhibited relatively high particulate matter concentrations, likely due to road dust resuspension and commercial activities.

Diurnal analysis demonstrated that morning and evening periods experienced elevated concentrations of primary pollutants such as CO and NO_2 due to peak traffic flow and reduced atmospheric dispersion. In contrast, afternoon hours showed reduced levels of primary pollutants but relatively higher ozone formation driven by photochemical reactions. Fine particulate matter ($PM_{2.5}$) remained consistently high across all areas, exceeding recommended health guidelines and indicating persistent exposure risks for the urban population.

Overall, the study highlights vehicular emissions, traffic density, and urban land-use patterns as the dominant contributors to air pollution in Bhopal. Although SO_2 levels remained low, the consistently elevated particulate matter and ozone concentrations pose significant public health concerns.

The results emphasize the urgent need for integrated air quality management strategies, including traffic regulation, promotion of cleaner transportation fuels, dust control measures, and expansion of urban green infrastructure. Continuous monitoring and long-term mitigation policies are essential to reduce pollution levels and protect public health in rapidly growing urban environments.

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