SHORT ARTICLE

Evaluation of Particulate matter and air pollutants level in the ambient air of Bengaluru city

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ABSTRACT

Background: Air pollution has been a global environmental concern, and its effects on human health in the past have played an important role. Thus, this study investigated the concentrations of particulate matter (PM10, PM2.5), nitrogen dioxide (NO2), sulfur dioxide (SO2), and carbon monoxide (CO) in four distinct areas of Bengaluru over one year. **Materials and Methods**: It is a descriptive cross-sectional design, utilizing secondary data from the Central Pollution Control Board's National Air Quality Monitoring Programme. Data analysis was conducted using SPSS software, expressing descriptive statistics such as mean, standard deviation, and maximum concentrations. **Results**: The study reveals varying air quality levels, with PM10 peaking at 102 µg/m³ in Silk Broad (August 2023) and NO2 spiking in February 2023. SO2 peaks at Majestic (March 2023), while CO poses health risks, peaking in January 2023. Silk Broad shows highest PM10; Majestic has elevated NO2, SO2, and CO. **Conclusion**: The study reveals fluctuating air quality, with PM10 peaking at 102 µg/m³ in Silk Broad station (August 2023) and NO2 spiking in February 2023. SO2 and CO levels also vary, posing health risks, particularly at Majestic station. Regional disparities highlight the need for targeted pollution control.

KEYWORDS

Air Pollution, Particulate Matter, Nitrogen Dioxide, Sulfur Dioxide, Carbon Monoxide

INTRODUCTION

Air pollution has been a global environmental concern, and its effects on human health in the past have played an important role and have been considered by researchers and people. Particulate matter or PM is the term for particles found in the air, including liquid droplets, dirt, dust, soot, and smoke. According to a report by the United Nations Environment Program (UNEP), particulate matter are most important pollutant in the world's cities.(1) Among the pollutants in the air today ambient air pollutants include complex mixtures of particles and gases such as particulate matter (PMs2.5 and PM10), carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), and sulfur dioxide (SO2).(2,3) Especially in cities, high concentrations of airborne particles, are serious problems for air quality.(4)

In recent years, numerous epidemiological studies have shown a relationship between the concentration of particle matter in urban air and respiratory diseases, pulmonary damage, and mortality in the population.(5-8) Short-term exposure to PM10 can irritate the lungs and perhaps cause immune responses; lung constriction, producing shortness of breath, and cough. Long-term, lower-level PM10 exposure may cause cancer and premature deaths.(9) Exposure to PM2.5 is associated with several serious health effects like premature death, respiratory-related hospital admissions emergency room visits, and aggravated asthma. It is also responsible for acute respiratory symptoms, including aggravated coughing and difficult or painful breathing; chronic bronchitis; decreased lung function that can be experienced as shortness of breath; and work and school absences.(10)

CO is another toxic gas in the atmosphere that is primarily produced due to the incomplete combustion of carbon-containing fuels such as gasoline, natural gas, oil, coal, and wood. Breathing high concentrations of CO can reduce O2 transportation and cause health effects, including headaches, chest pain, heart disease, etc.(11) To minimize health effects, an appropriate level of CO must be below 10.5 µg/m3 for an 8 h average time, and possibly as low as 4.6–5.8 µg/m3. The next pollutants are NO2 and SO2 where the primary source for the anthropogenic emission is a combination of the burning of fossil fuels, biomass, and emissions from cars, trucks, buses, power plants, and off-road equipment. Most of the atmospheric NO2 is emitted by NO, which is then rapidly oxidized by O3 to become NO2. Both NO2 and SO2 easily mix with rainwater, creating acid rain, which is very harmful to animals and plant life. Breathing with a high concentration can cause asthma, coughing, and wheezing.(12,13) The standard value of NO2 is 40 µg/m3 annual averaging time and 200 µg/m3 1 h averaging time, and for SO2 the standard values are 20 µg/m3 24 h averaging time and 500 µg/m3 10 min averaging time.

All these adverse health effects have been associated with exposures to PM over both short periods (such as a day) and longer periods (a year or more). World Health Organization (WHO) study showed that increased 10 micrograms of aerosols, the mortality rate of 1 to 3 percent increases.(14) Particulate matter of heavy metals, asbestos, and aromatic hydrocarbons are carcinogenic.(15) On the other hand, aerosols cause reduced visibility, and adverse effects on ecosystems and plant growth can be reduced or stopped. Climate change and air pollution are deeply interconnected because the chemical species that lead to a degradation in air quality are frequently co-emitted with greenhouse gases.(16)

Atmospheric particles originate from various sources and possess different physical and chemical properties.(17,18) Very little is known about the concentration of particulates and gaseous pollutants. Thus, there is a need to study the properties of particulate matter and their distribution to determine their origin in different areas to control air pollution in cities. Thus, the purpose of this study was to evaluate the average concentration of PM10, PM2.5, NO2, SO2, and CO in four different areas in Bengaluru city during a year.

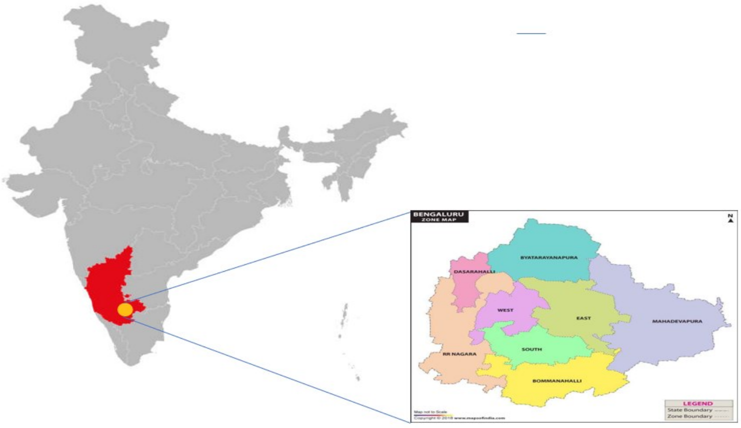
MATERIAL & METHODS

Study Area

Bengaluru, located in the southeastern part of Karnataka, India, is the focus of this study. It includes four key areas (Figure 1):

- Hebbal (northern Bengaluru): Known for its lake, parks, and flyover.
- Majestic (central Bengaluru): Also known as Kempegowda Bus Station.
- Saneguruvahalli (western Bengaluru): A residential area.
- Silk Board (southern Bengaluru): A major junction connecting the Outer Ring Road and Hosur Road.

Figure 1: Study area (Bengaluru).



Data Collection

The study utilized a descriptive cross-sectional design and secondary data from the Central Pollution Control Board (CPCB), which monitors air quality nationwide through the National Air Quality Monitoring Programme (NAMP). Data were collected for one year (October 2022 to September 2023) from four monitoring stations in Bengaluru.

Sampling Protocol:

- Gaseous Pollutants (NO2, SO2, CO): Sampled every four hours.
- Particulate Matter (PM10): Sampled every eight hours.

The data were obtained in Excel format, detailing the concentrations of the pollutants over the specified period.

Data Analysis

Data were analyzed using SPSS software, employing descriptive statistics (mean, standard deviation, maximum concentrations) to express the results. This approach helped identify the variations and peak concentrations of pollutants across different months and stations.

Enhancing Reliability Assessment

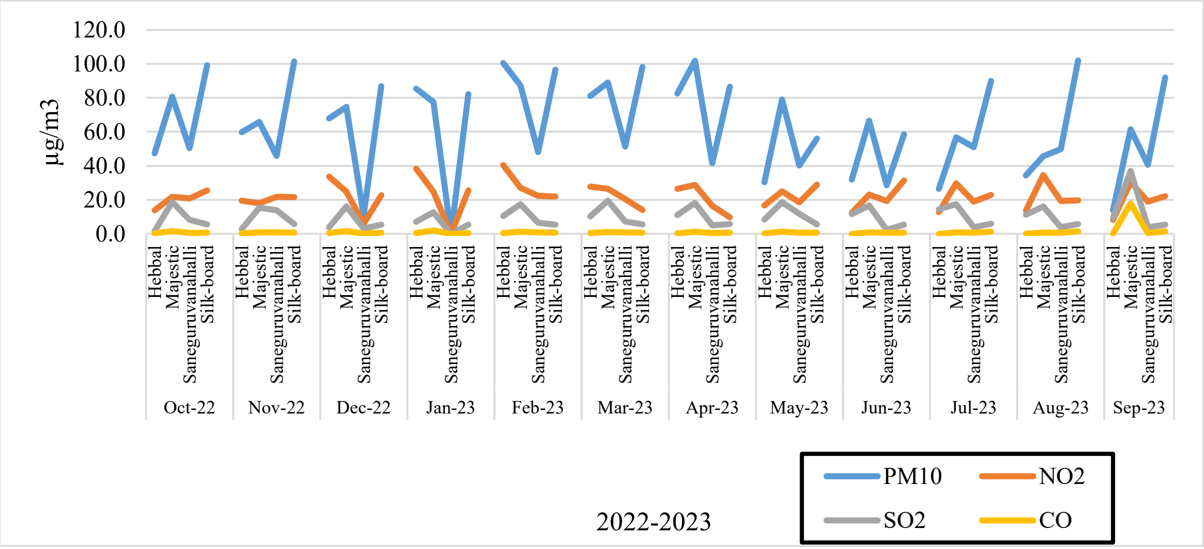
To enhance the reliability of the data collection and analysis, the following Quality Assurance and Quality Control measures were implemented: Regular calibration of monitoring instruments was conducted to ensure accurate measurements. Calibration followed the CPCB guidelines and manufacturer's recommendations. Data were cross-checked for anomalies and outliers. Any abnormal values were flagged and verified against raw data logs or re-measured if necessary. Data consistency checks were performed to ensure continuity and reliability over the monitoring period. Strict adherence to SOPs for sampling and analysis ensured uniformity and reduced variability in data collection. Use of statistical methods to identify trends, correlations, and anomalies in the data. Descriptive statistics (mean, standard deviation, maximum) provided insights into the variability and distribution of pollutants.

RESULTS

Figure 2 shows the distribution of particulate matter and air pollutants across various stations in each month in a year from October 2022 to September 2023. It indicates varying levels of air quality over time, the PM10 levels, represented by an orange line, show fluctuations across the months. The peak level of PM10 of about 102 µg/m3 is seen in August 2023 in Silk Broad station followed by April 2023 PM10 of about 101.7 µg/m3 in Majestic Station. However, it appears that PM10 levels are not consistently high, indicating that particulate pollution varies significantly over time. The next pollutant NO2, shown in blue, has the most pronounced spikes, suggesting episodes of high NO2 concentration. The peak level of NO2 of about 40.5 µg/m3 is seen in February 2023 in Silk Broad station followed by January 2023 NO2 of about 38.4 µg/m3 in Silk Broad station. The next pollutant SO2, shown in a gray line representing SO2 shows moderate variability. The peak level of SO2 of about 19.6 µg/m3 is seen in March 2023 in

Majestic Station followed by October 2022 SO2 of about 18.7 µg/m3 in Majestic Station. The trend does not show extreme highs or lows, suggesting stable sources of SO2 over the period. The CO levels, indicated by the yellow line, seem to have lower overall concentrations compared to the other pollutants. The peak level of CO of 1.9 µg/m3 is seen in the month of January 2023 in Majestic Station followed by October 2022 CO of 1.5 µg/m3 in Majestic Station.

Figure 2: Distribution of particulate matter and air pollutants across various stations in each month in a year.



The Distribution of particulate matter and air pollutants across various months in a year of all four stations in Bengaluru. The maximum value of the PM10 is 240.4 µg/m3, found to be in December 2022 followed by April 2023 where PM10 is found to be 101.7 µg/m3 (Table 1). Table 2 shows the distribution of particulate matter and air pollutants across four stations in a year (October 2022 to September 2023). The Silk Board station is found to have the Highest PM 10 of 85.2 µg/m3 in a year. The majestic station is found to have the highest level of NO2 is 26.2 µg/m3, SO2 is 18.7 µg/m3, and CO is 2.5 µg/m3.

Table 1: Distribution of particulate matter and air pollutants across various months in a year.

Months	Variables	PM10	NO2	SO2	CO
October 2022	Mean	69.41	20.50	8.53	0.78
	Maximum	99.18	25.50	18.74	1.53
	SD	24.89	4.84	7.29	0.54
November 2022	Mean	68.28	20.23	9.42	0.68
	Maximum	101.5	21.69	15.36	0.87
	SD	23.67	1.75	6.19	0.24
December 2022	Mean	60.11	21.78	7.14	0.71
	Maximum	240.47	87.14	28.57	2.87
	SD	85.78	30.9	10.94	1.09
January 2023	Mean	81.70	29.56	8.37	0.97
	Maximum	85.48	38.36	12.68	1.93
	SD	40.98	16.04	5.22	0.83
February 2023	Mean	83.15	27.92	9.98	0.77
	Maximum	100.52	40.48	17.38	1.22
	SD	23.96	8.67	5.39	0.32
March 2023	Mean	79.90	22.23	10.72	0.76
	Maximum	98.3	27.82	19.56	1.14
	SD	20.31	6.31	6.2	0.30
April 2023	Mean	78.09	20.33	10.01	0.64
	Maximum	101.7	28.67	18.23	1.16

Months	Variables	PM10	NO2	SO2	CO
	SD	25.75	8.79	6.12	0.36
May 2023	Mean	51.43	22.3	11.03	0.71
	Maximum	79.09	28.8	18.48	1.23
	SD	21.27	5.61	5.60	0.4
June 2023	Mean	46.40	21.52	9.02	0.52
	Maximum	66.54	31.46	16.67	0.81
	SD	18.97	7.95	6.38	0.36
July 2023	Mean	56.09	21.06	10.38	0.68
	Maximum	90.01	29.7	17.34	1.28
	SD	26.15	7.12	6.55	0.52
August 2023	Mean	57.99	21.81	9.2	0.73
	Maximum	102.02	34.59	16.1	1.43
	SD	30.05	8.96	5.57	0.53
September 2023	Mean	52.02	19.95	9.02	0.68
	Maximum	91.98	30.52	17.78	1.39
	SD	33.01	9.20	6.24	0.52

Table 2: Distribution of particulate matter and air pollutants across four stations in a year (October 2022 to September 2023).

Stations	PM10(μg/m3)	NO2(μg/m3)	SO2(μg/m3)	CO(μg/m3)
Hebbal	54.6	21.7	8.4	0.2
Silk-board	85.2	21.6	5.4	0.8
Majestic	73.9	26.2	18.7	2.5
Saneguruvanahalli	36.5	16.1	5.5	0.5

DISCUSSION

This comprehensive study was conducted in Bengaluru, to evaluate the average concentrations of particulate matter (PM10, PM2.5), nitrogen dioxide (NO2), sulfur dioxide (SO2), and carbon monoxide (CO) in four distinct areas in a year, it also provides a significant insight into the varying levels of air pollutants particles.

The observed fluctuations in PM10 levels, with a peak of 102 μg/m3 in Silk Broad station in August 2023, raise concerns about short-term exposure impacts on respiratory health. The variation in PM10 levels over the months emphasizes the dynamic nature of particulate pollution in urban environments. This finding aligns with the well-established link between PM exposure and adverse respiratory effects reported in numerous epidemiological studies.(5-8) The study also highlights the pronounced spikes in NO2 levels, in Silk Broad station in February 2023. High NO2 concentrations are associated with respiratory diseases, consistent with the outcomes of previous research. The findings underscore the urgent need for targeted interventions to mitigate NO2 emissions, especially in specific areas identified as hotspots. The moderate variability in SO2 levels, with a peak in Majestic station in March 2023, suggests relatively stable sources of SO2 over the study period. The lower overall concentrations of CO compared to other pollutants indicate that, while CO levels are relatively lower, they still reach levels that can pose health risks. The peak in January 2023 in Majestic station aligns with the known health effects of CO exposure, emphasizing the need for continued efforts to minimize combustion-related emissions.

As per Indian National Air Quality Standards (NAQS), the average value is 60 μg/m3 for PM2.5, 100 μg/m3 for PM10, 80 μg/m3 for NO2, and 80 μg/m3 for SO2.(20) The values are expressed in μg/m3. The study highlights regional disparities in pollutant levels, with Silk Board station recording the highest PM10 concentration, and Majestic station exhibiting elevated levels of NO2, SO2, and CO. Though the pollutant concentration is less than the NAQS, understanding these variations is crucial for targeted policy interventions tailored to specific areas, acknowledging the diverse sources of pollution in different city sectors

The study on air pollution levels in Bengaluru could be enriched by critically analyzing potential confounders and discussing specific urban activities contributing to pollution. Meteorological conditions such as wind speed, direction, temperature inversions, humidity, and precipitation can significantly influence pollutant dispersion and concentration. Diurnal and weekly traffic patterns, with rush hours and reduced weekend traffic, along with industrial activities that vary in intensity, also impact pollution levels. Construction activities contribute to particulate matter, particularly PM10, while biomass burning during festivals or for agricultural purposes can cause seasonal spikes in pollutants. Transportation, including vehicular emissions and inadequate public transport, remains a major pollution source, exacerbated by traffic congestion. Industrial emissions, particularly from manufacturing and brick kilns, add to the pollutant load. Domestic activities, such as biomass cooking and waste burning, along with emissions from commercial kitchens and markets, further contribute to air quality degradation. Understanding these confounders and activities can lead to more targeted and effective policy interventions to mitigate pollution.

CONCLUSION

In conclusion, the study underscores the critical role of air quality monitoring in assessing environmental health risks. The identified pollutant hotspots, such as Silk Board for NO2 and Majestic for PM10, SO2, and CO highlight specific areas requiring targeted interventions. The findings contribute valuable information for policymakers, guiding the development of evidence-based strategies to improve air quality and public health in Bengaluru.

RECOMMENDATION

Based on the quantified levels of pollutants in different areas and times in Bengaluru, several specific recommendations can be made to guide policy and intervention. Given the high PM10 levels in the Silk Board area, particularly in August 2023, implementing stricter emissions controls on construction sites and promoting the use of dust suppressants could mitigate particulate matter. For Majestic, which exhibited elevated NO2 and CO levels, enhancing public transportation infrastructure and promoting cleaner fuel alternatives for vehicles can reduce traffic-related emissions. During months with peak pollution levels, such as January and February, implementing temporary restrictions on vehicular movement, like odd-even schemes or carpooling incentives, could be beneficial. Continuous monitoring and real-time data dissemination through public platforms can also empower citizens to take precautionary measures, such as using masks or avoiding outdoor activities during high pollution periods. Additionally, increasing green spaces and urban vegetation can help absorb pollutants, improving overall air quality. These targeted interventions, tailored to specific pollutant patterns and sources, can effectively reduce pollution levels and safeguard public health in Bengaluru.

LIMITATION OF THE STUDY

Despite its contributions, the study has certain limitations. The study's focus on specific pollutants may not fully capture the complexity of the air quality scenario, necessitating future research incorporating a broader range of pollutants and sources.

RELEVANCE OF THE STUDY

This comprehensive study underscores the critical role of air quality monitoring in assessing environmental health risks. Identified pollutant hotspots necessitate targeted interventions, providing valuable information for evidence-based policymaking. The findings emphasize the urgent need for continuous monitoring and multifaceted interventions to improve air quality, safeguard public health, and contribute to overall well-being in Bengaluru.

AUTHORS CONTRIBUTION

All authors have contributed equally.

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Nil

CONFLICT OF INTEREST

There are no conflicts of interest.

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DECLARATION OF GENERATIVE AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors haven't used any generative AI/AI assisted technologies in the writing process.

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