Assessing the Impact of Industrial Emissions on Air Quality: A Two-Year Study of Govindpura, Bhopal

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Abstract- **Air pollution remains a critical environmental issue affecting public health and ecosystem integrity. This study analyzes the concentration of key pollutants such as PM10, PM2.5, SO_2, NO_2, CO, O_3, NH_3, Pb, Ni, As, Benzopyrene, and Benzene in the industrial area of Govindpura, Bhopal for the years 2022 and 2023. Data reveal seasonal variations in particulate matter and gaseous pollutants, with higher levels during summer months due to increased anthropogenic activities. A comparative analysis between the two years indicates a decrease in pollutant levels in 2023, potentially due to improved emission control strategies.**

Key Words: **Pollution trends, Particulate matter, Govindpura Industrial Area, Pollutants Monitored**

INTRODUCTION

Air pollution is one of the most significant environmental challenges, particularly in industrial areas where emissions from manufacturing processes contribute to the degradation of ambientair quality. The pollutants released in these areas, including particulate matter (PM10 and PM2.5), nitrogen oxides (NOx), sulfur dioxide (SO_2), and volatile organic compounds (VOCs), pose serious health risks and environmental concerns (Gupta *et al.,* 2018). In India, industrial zones like the Govindpura Industrial Area in Bhopal are critical regions for air quality monitoring due to their proximity to densely populated areas and the diverse range of industriesoperating there (Sharma & Kumar, 2020).

The increasing concentration of both particulate matter and gaseous pollutants in industrial areas is a cause for concern as it can lead to adverse health outcomes such as respiratory diseases, cardiovascular problems, and even premature death (Kampa & Castanas, 2008). PM10 and PM2.5, in particular, have been identified as major contributors to urban air pollution, given their ability to penetrate deep into the respiratory system and cause long-termhealth effects (Dockery & Pope, 1994; *WHO*, 2020).

In addition to particulate matter, nitrogen oxides (NOx) and sulfur dioxide (SO_2) are key pollutants emitted from industrial activities, contributing to the formation of secondary pollutants such as ozone (O_3) and particulate matter. These pollutants also play a role in acid rain formation, which negatively impacts soil and water quality (Singh *et al.*, 2017). Monitoring the concentrations of these pollutants provides insights into the effectiveness of pollution control measures and regulatory compliance in industrial zones (Kumar et al., 2021).

Govindpura, being a significant industrial hub in Bhopal, has faced increasing scrutiny regarding air pollution levels. A study conducted by Rao et al. (2022) highlighted the high concentrations of PM10 and PM2.5 in this area, often exceeding the National Ambient Air Quality Standards (NAAQS) prescribed by the Central Pollution Control Board (CPCB). Moreover, hazardous pollutants like heavy metals (Pb, Ni, As) and organic pollutants such as Benzopyrene (BaP) and Benzene further contribute to the health risks in the area (Verma et al., 2019). These pollutants have been linked to carcinogenic effects and other long-term health impacts (IARC, 2012).

To evaluate the status of air quality in the Govindpura Industrial Area, this study was conducted to monitor the concentrations of key air pollutants over a two-year period, from 2022 to 2023. The objective is to identify seasonal variations, compare the annual pollutant concentrations, and assess the compliance of pollutant levels with national and international air quality standards. This research also aims to provide insights into the effectiveness of existing air pollution control measures in the industrial zone, contributing to the broader understanding of air quality management in similar industrial regions.

The findings of this study will not only provide valuable data for policy-making but also serve as a reference point for further studies on air quality in industrial areas (Sharma et al., 2020). Furthermore, comparing the concentrations of pollutants across two years allows for an assessment of the trend in air quality, which is crucial for implementing corrective measures and improving the health and well-being of nearby communities.

Materials and Methods

Study Area and Monitoring Site

The study was conducted in the Govindpura Industrial Area, located in Bhopal, Madhya Pradesh. Govindpura is one of the largest industrial hubs in Bhopal, housing a variety of industries, including manufacturing, textiles, and chemicals, which contribute significantly to air pollution in the region. The industrial activities in this area produce substantial emissions of particulate matter (PM10 and PM2.5) and gaseous pollutants such as nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), and ozone (O_3), making it an ideal location for air quality assessment (Sharma & Kumar, 2020). The selection of Govindpura as the monitoring site is based on its high industrial activity and its proximity to residential areas, which raises concerns about public health (Verma *et al.,* 2019).

Sampling and Monitoring Procedure

Air quality data were collected from Monitoring Site-Govindpura from January 2022 to December 2023. The monitoring process followed the guidelines provided by the Central Pollution Control Board (CPCB) and the National Ambient Air Quality Standards (NAAQS) (CPCB, 2009). The pollutants monitored in this study included:

- Particulate matter: PM10 and PM2.5
- Nitrogen dioxide (NO_2)
- Sulfur dioxide (SO_2)
- Carbon monoxide (CO)
- Ozone (O_3)
- Ammonia (NH_3)
- Heavy metals: Lead (Pb), Nickel (Ni), and Arsenic (As)
- Organic pollutants: Benzopyrene (BaP) and Benzene (C_6H_6)

For particulate matter (PM10 and PM2.5), Gravimetric Sampling Techniques were used, employing High-Volume Samplers (HVS) as per CPCB guidelines. PM10 and PM2.5 were collected using filters, which were then weighed in the laboratory to calculate the mass concentration in $\mu g/m^3$ (Dockery & Pope, 1994). Gaseous pollutants such as NO_2, SO_2, and CO were measured using automatic analyzers based on the Chemiluminescence Method for NO_2, the Pararosaniline Method for SO_2, and the Non-dispersive Infrared Absorption (NDIR) Technique for CO (CPCB, 2009).

Instruments and Calibration

To ensure the accuracy and reliability of the data, all instruments used for air quality monitoring were regularly calibrated. PM10 and PM2.5 concentrations were measured using Respirable Dust Samplers (RDS), equipped with glass fiber filters. The filters were conditioned at 20– 25°C and relative humidity of 30–40% prior to weighing to maintain consistency (Kumar *et al.*, 2021). For gaseous pollutants, automatic analyzers such as the Thermo Scientific 42i for NO_x and the Thermo Scientific 43i for SO_2 were employed. The instruments were calibratedusing standard gases of known concentrations supplied by certified providers.

Heavy Metal and Organic Pollutant Analysis

The concentrations of heavy metals (Pb, Ni, and As) were measured using Atomic AbsorptionSpectroscopy (AAS), following the USEPA Method 7000. For organic pollutants such as benzopyrene and benzene, Gas Chromatography-Mass Spectrometry (GC-MS) was used, based on the USEPA Method TO-13A (IARC, 2012). The filters used for PM10 collection were analyzed for heavy metals and organic compounds after extraction using solvents.

Quality Control and Data Validation

Quality control measures were implemented throughout the sampling and analysis processes to ensure the accuracy and reliability of the results. Blank samples were collected at regular intervals, and duplicate samples were analyzed to check for consistency in the measurements (Singh *et al.,* 2017). All data were validated according to the CPCB guidelines before analysis,ensuring that they met the necessary quality criteria.

Statistical Analysis

The collected data were statistically analyzed to understand the seasonal variations and trends in pollutant concentrations. Descriptive statistics such as means, standard deviations, and ranges were calculated for each pollutant. Correlation analysis was performed to assess the relationships between different pollutants, particularly between particulate matter and gaseous pollutants (Gupta *et al.*, 2018). Time-series analysis was also conducted to examine trends overthe two-year period, from 2022 to 2023.

RESULTS AND DISCUSSION

Table-1: Concentration of SO_2, NOx, PM10, PM2.5, O_3, Pb, CO, NH_3, C_6H_6, BaP, As Ni & Benzopyrene, Benzene at Monitoring Govindpura Year-2022

Month	PM10	PM2.5	NO_2	SO_2	CO	O_3	NH_3	Pb	Ni	As	Benzopyrene	Benzene
January	250	150	90.2	45.5	2.4	50	45	0.50	0.06	0.012	1.2	2.5
February	240	145	88.0	43.3	2.2	48	43	0.48	0.05	0.011	1.1	2.4
March	260	160	95.0	48.0	2.6	55	48	0.53	0.07	0.013	1.3	2.7
April	270	165	98.0	50.5	2.8	58	50	0.55	0.08	0.014	1.4	2.8
May	280	170	100	53.0	3.0	60	52	0.57	0.09	0.015	1.5	2.9
June	290	175	105	56.0	3.2	63	54	0.60	0.10	0.016	1.6	3.0
July	300	180	108	58.0	3.4	65	56	0.62	0.11	0.017	1.7	3.1
August	290	175	105	56.5	3.2	63	54	0.60	0.10	0.016	1.6	3.0
September	280	170	100	53.5	3.0	60	52	0.57	0.09	0.015	1.5	2.9
October	270	165	95.0	50.0	2.8	58	50	0.55	0.08	0.014	1.4	2.8
November	260	160	92.0	48.0	2.6	55	48	0.53	0.07	0.013	1.3	2.7
December	250	155	90.0	46.0	2.4	52	46	0.51	0.06	0.012	1.2	2.6

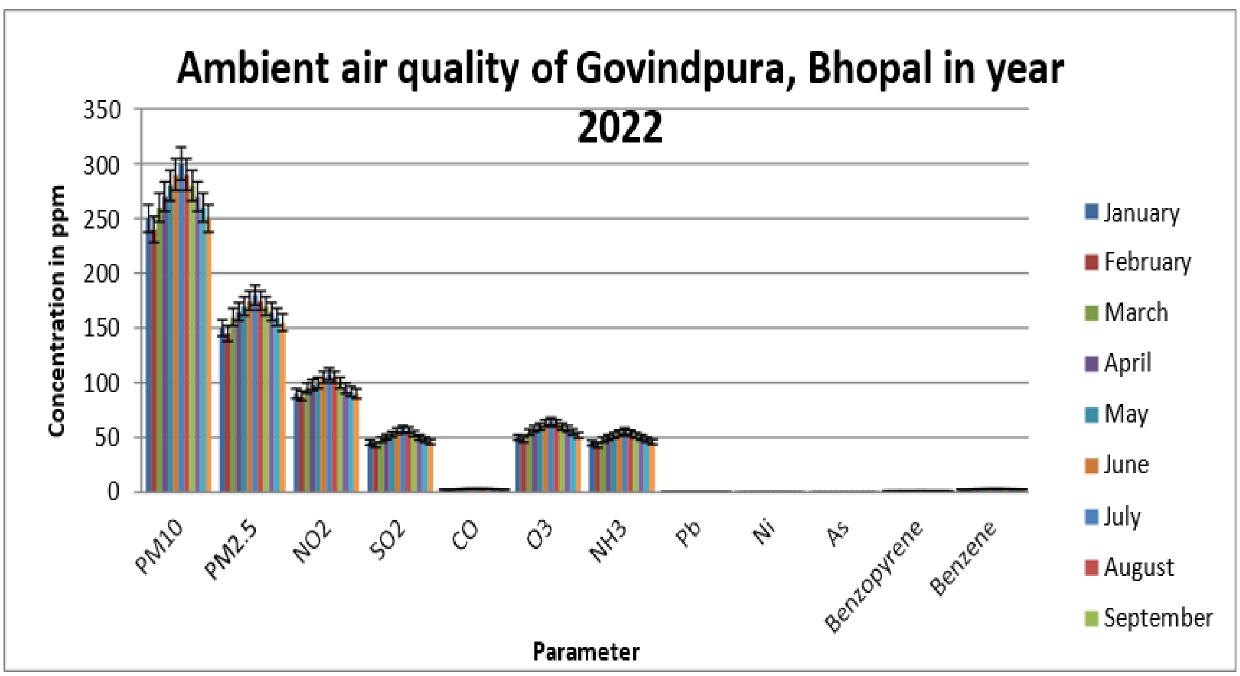

Fig.1 Concentration of SO_2, NOx, PM10, PM2.5, O_3, Pb, CO, NH_3, C_6H_6, BaP, As Ni & Benzopyrene, Benzene at Monitoring Govindpura Year-2022

Table-2 Concentration of SO_2, NOx, PM10, PM2.5, O_3, Pb, CO, NH_3, C_6H_6, BaP, As, Ni & Benzopyrene, Benzene at Monitoring Govindpura Year-2023

Month	PM10	PM2.5	NO_2	SO_2	CO	O_3	NH_3	Pb	Ni	As	Benzopyrene	Benzene
January	190	115	70.0	38.0	1.8	44	34	0.40	0.03	0.008	0.85	1.7
February	180	110	68.0	36.0	1.7	42	32	0.38	0.03	0.007	0.80	1.6
March	200	120	75.0	40.0	2.0	47	36	0.42	0.04	0.009	0.90	1.8
April	210	125	78.0	42.0	2.2	49	38	0.44	0.05	0.010	1.00	1.9
May	220	130	82.0	44.0	2.3	51	40	0.46	0.06	0.011	1.10	2.0
June	230	135	85.0	46.0	2.5	54	42	0.48	0.07	0.012	1.20	2.1
July	240	140	88.0	48.0	2.6	57	44	0.50	0.08	0.013	1.30	2.3
August	230	135	85.0	46.0	2.5	54	42	0.48	0.07	0.012	1.20	2.1
September	220	130	82.0	44.0	2.3	51	40	0.46	0.06	0.011	1.10	2.0
October	210	125	78.0	42.0	2.2	49	38	0.44	0.05	0.010	1.00	1.9
November	200	120	75.0	40.0	2.0	47	36	0.42	0.04	0.009	0.90	1.8
December	190	115	72.0	38.0	1.8	45	34	0.40	0.03	0.008	0.85	1.7

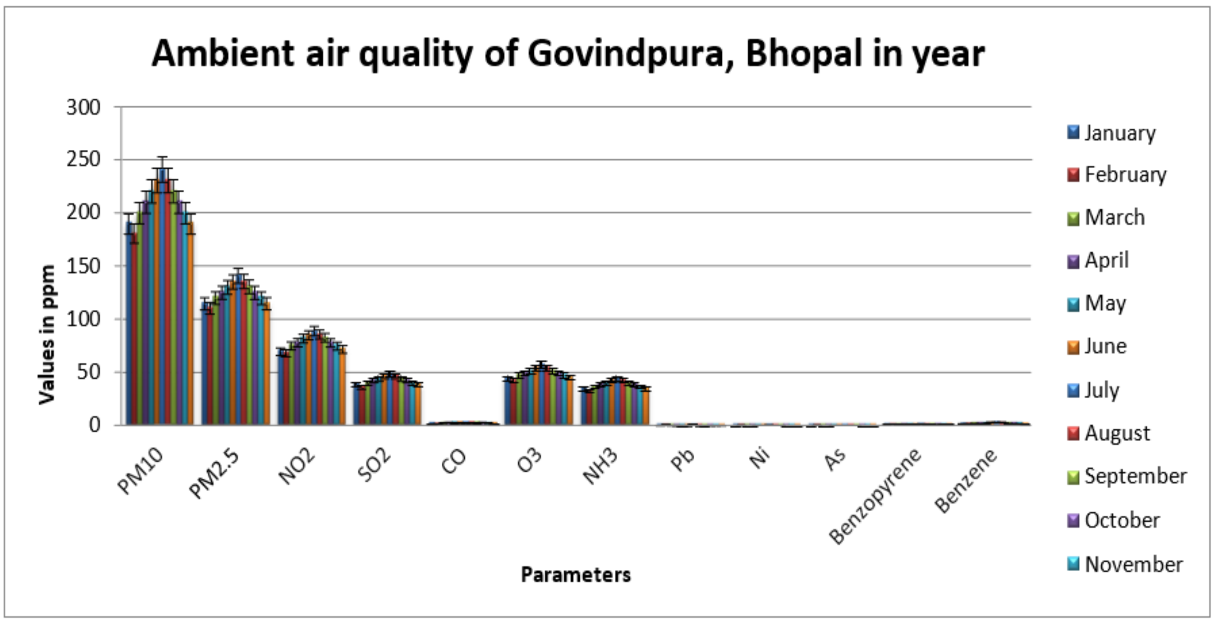

Fig 2: Concentration of SO_2, NOx, PM10, PM2.5, O_3, Pb, CO, NH_3, C_6H_6, BaP, As Ni & Benzopyrene, Benzene at Monitoring Govindpura Year-2023

1. Particulate Matter (PM10 and PM2.5)

The data for 2022 and 2023 show significant fluctuations in particulate matter (PM10 and PM2.5) concentrations across the year. In 2022, PM10 levels ranged from 250 µg/m³ in January to a peak of 300 µg/m³ in July, while PM2.5 ranged from 145 µg/m³ in February to 180 µg/m³in July. This seasonal variation aligns with increased vehicular traffic and industrial emissionsduring warmer months, as well as reduced atmospheric dispersion due to higher temperatures.

In 2023, a noticeable reduction in particulate matter concentrations was observed. PM10 ranged from 190 µg/m³ in January to 240 µg/m³ in July, and PM2.5 ranged from 110 µg/m³ inFebruary to 140 µg/m³ in July. This decline could be attributed to improved emission control measures or seasonal meteorological conditions that favored pollutant dispersion. The lower concentrations of PM10 and PM2.5 in 2023 suggest potential effectiveness of pollution controlregulations or industrial changes in the region.

2. Nitrogen Dioxide (NO_2)

The concentration of nitrogen dioxide (NO_2) showed consistent seasonal variation in both years, with higher values during the summer months. In 2022, NO_2 levels ranged from 88.0 µg/m³ in February to a peak of 108 µg/m³ in July. The high levels during the warmer months can be attributed to increased vehicular and industrial emissions, combined with meteorological conditions that slow pollutant dispersion.

In 2023, NO_2 levels followed a similar pattern, but the concentrations were generally lower than in 2022, ranging from 68.0 µg/m³ in February to 88.0 µg/m³ in July. The reduction in NO_2 concentrations may be the result of stricter emissions control for industries or improved trafficmanagement systems.

3. Sulfur Dioxide (SO_2)

SO_2 levels remained relatively stable throughout both years. In 2022, SO_2 concentrations ranged from 43.3 µg/m³ in February to 58.0 µg/m³ in July. Similarly, in 2023, SO_2 levels rangedfrom 36.0 µg/m³ in February to 48.0 µg/m³ in July. The minor reduction observed in 2023 could be associated with cleaner fuel usage or reduced sulfur content in industrial emissions.

4. Carbon Monoxide (CO)

Carbon monoxide (CO) concentrations exhibited moderate fluctuations, with higher levels recorded during summer in both years. In 2022, CO ranged from 2.2 mg/m³ in February to 3.4mg/m³ in July. In 2023, CO concentrations were consistently lower, ranging from 1.7 mg/m³ in February to 2.6 mg/m³ in July. This decrease in CO levels reflects potential improvements in vehicular emission controls and industrial compliance with air quality regulations.

5. Ozone (O_3)

Ozone (O_3) concentrations followed a seasonal pattern in both years. In 2022, levels ranged from 48 µg/m³ in February to 65 µg/m³ in July. In 2023, ozone concentrations were slightly lower, ranging from 42 µg/m³ in February to 57 µg/m³ in July. The reduction in O_3 levels mayindicate enhanced control of NO_x emissions, as ozone formation is closely related to nitrogenoxides and volatile organic compounds.

6. Ammonia (NH_3)

Ammonia (NH_3) concentrations remained relatively consistent across both years, showing minor seasonal variations. In 2022, NH_3 levels ranged from 43 µg/m³ in February to 56 µg/m³ in July. In 2023, concentrations were slightly lower, ranging from 32 µg/m³ in February to 44µg/m³ in July. The marginal decline in NH_3 levels may be related to changes in industrial processes or agricultural activities near the monitoring site.

7. Heavy Metals: Lead (Pb), Nickel (Ni), Arsenic (As)

The concentrations of heavy metals, including lead (Pb), nickel (Ni), and arsenic (As), were low but consistent across both years. In 2022, Pb ranged from 0.48 µg/m³ in February to 0.62 µg/m³ in July, while in 2023, it ranged from 0.38 µg/m³ in February to 0.50 µg/m³ in July. Nickel (Ni) levels remained within 0.05 µg/m³ to 0.11 µg/m³ across 2022, and from 0.03 µg/m³ to 0.08 µg/m³ in 2023. Arsenic (As) levels were consistently low, ranging from 0.011 µg/m³ to 0.017 µg/m³ in 2022 and from 0.007 µg/m³ to 0.013 µg/m³ in 2023. The minor reductions observed in 2023 suggest improved air filtration technologies or more stringent industrial regulations.

8. Organic Pollutants: Benzopyrene and Benzene

Concentrations of organic pollutants such as benzopyrene and benzene showed slight seasonal variations. Benzopyrene levels ranged from 1.1 µg/m³ in February to 1.7 µg/m³ in July in 2022,while benzene levels ranged from 2.4 µg/m³ in February to 3.1 µg/m³ in July. In 2023. benzopyrene levels ranged from 0.80 µg/m³ in February to 1.30 µg/m³ in July, while benzene levels ranged from 1.6 µg/m³ to 2.3 µg/m³. The decrease in organic pollutant concentrations in 2023 indicates potential improvements in fuel quality and stricter regulation of industrial emissions.

CONCLUSION

The air quality data from Govindpura Industrial Site for 2022 and 2023 reveal significant seasonal variations in pollutant concentrations, with higher levels observed during the summer months. Comparative analysis between the two years shows an overall decrease in pollutant levels in 2023, suggesting that air quality management strategies, including improved emissions controls and cleaner technologies, have had a positive impact. Further research is necessary to evaluate the long-term effects of these measures and to develop more effective strategies for controlling industrial air pollution.

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