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IMPACT ASSESSMENT OF AIR POLLUTION AT URBAN CONSTRUCTION SITES: A CASE STUDY OF BHOPAL

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ABSTRACT

Construction activities have emerged as significant contributors to air pollution in urban India, especially in mid-sized cities like Bhopal. This study evaluates air pollution at two active construction sites—the GSP Trainers Hostel and the Girls Hostel—selected based on construction intensity and proximity to residential areas. Air quality was monitored using CPCB-approved instruments, measuring PM10, PM2.5, SO_2, NO_2, and O_3. While pollutant levels remained within CPCB limits, PM10 and PM2.5 concentrations spiked during active construction, particularly during material handling and vehicular movement, indicating potential health risks from prolonged exposure.

To incorporate human experience, structured surveys and interviews were conducted with laborers and nearby residents. Common health complaints included coughing, eye irritation, and fatigue, coupled with limited awareness and use of protective gear. The study highlights the gap between environmental regulations—such as the Construction and Demolition Waste Management Rules (2016)—and their implementation, especially in small- to mid-scale projects where basic mitigation practices are often ignored.

The research concludes with actionable recommendations including regular air monitoring, mandatory PPE enforcement, waste management protocols, and worker training. It calls for stronger policy enforcement and increased awareness, urging stakeholders to recognize the hidden environmental cost of urban growth.

1. Introduction

Urban construction is a symbol of progress, reflecting a city's growth, ambition, and modernization. However, behind the scaffolding and cement mixers lies an invisible yet dangerous by-product: air pollution. The dust clouds raised by heavy machinery, the emissions from diesel-powered equipment, and the scattering of fine particles during material handling all contribute to the degradation of ambient air quality at construction sites.

India, with its rapid urbanization and infrastructure boom, is witnessing an unprecedented surge in construction activity. Bhopal, a city that balances ecological heritage and urban expansion, is no exception. As flyovers, hostels, apartments, and smart city projects continue to rise, so does the concern for environmental sustainability—especially the quality of air that workers and residents breathe daily.

Unlike industrial air pollution, which is relatively constant and more regulated, construction-site air pollution is intermittent, unpredictable, and often ignored. This poses unique challenges in both detection and regulation. The particulate matter released—PM10 and PM2.5—along with gases like sulfur dioxide (SO2), nitrogen dioxide (NO2), and ozone (O3), are not only environmental hazards but also serious health threats.

This thesis focuses on two real construction sites in Bhopal, where air quality data was collected and analyzed in collaboration with Krishna Digital Material Testing Laboratory. But beyond the numbers, this study explores the human side of the problem. It brings forth the voices of site workers, supervisors, and nearby residents, providing a deeper understanding of how air pollution affects not just statistics but lives.

As an M.Tech student in Environmental Engineering, I have tried to merge academic rigor with field-based realism in this study. The intent is to produce not just a technical document but a narrative that can influence how future construction is planned and executed—with both development and health in mind.

2. Methods and material

2.1 Study Location and Selection Criteria

The study was conducted at five active construction sites within the campus of Global Skill Park, Bhopal, Madhya Pradesh, India. The selection of these sites was based on ongoing civil activities, accessibility for sampling, and their proximity to residential buildings and classrooms, ensuring realistic exposure conditions. The sites monitored were:

- Trainers Hostel
- Girls Hostel
- Steel Yard
- Academic Block A
- Boys Hostel

Each of these locations represented a different type of construction activity, such as tiling, welding, concrete mixing, excavation, and bricklaying.

2.2 Air Sample Collection

Air sampling was conducted using CPCB-approved instruments from Krishna Digital Material Testing Laboratory, which is NABL-certified. Sampling was carried out at each site for 24 hours continuously, between 3 to 5 meters above ground level, adhering strictly to CPCB and APHA guidelines.

Two main instruments were used:

- Respirable Dust Sampler (Envirotech APM 460) – for PM_{10} measurement
- Fine Dust Sampler (Envirotech APM 550 MFC) – for $PM_{2.5}$ and gaseous pollutants

Photographic documentation of sample collection was maintained (Fig. 5 & Fig. 6 in thesis).

2.3 Parameters Monitored

The air quality parameters recorded during sampling included:

- Particulate Matter (PM_{10} and $PM_{2.5}$)
- Sulphur Dioxide (SO_2)
- Nitrogen Dioxide (NO_2)
- Ozone (O_3)

These pollutants were chosen based on their significant presence in construction-related air pollution and known respiratory and cardiovascular impacts as per WHO and CPCB data.

Pollutant	Unit	Limit (CPCB)
PM_{10}	µg/m³	100
$PM_{2.5}$	µg/m³	60
SO_2	µg/m³	80
NO_2	µg/m³	80
O_3	µg/m³	180

2.4 Sampling Period

Sampling was scheduled based on project timelines to ensure diverse construction phases were captured. The period and conditions for each location are summarized below:

Site	Date	Temperature	Humidity
Trainers Hostel	29–30 Nov 2024	24°C	40–50%
Girls Hostel	31 Jul–1 Aug 2024	32°C	40–50%
Steel Yard	25–26 May 2024	28°C	25–28%
Academic Block A	13–14 Mar 2024	29°C	26–28%
Boys Hostel	5–6 Jan 2024	31°C	40–50%

All samples were collected in dry weather with minimal external wind disturbance, thereby isolating the influence of onsite construction activities on ambient air quality.

2.5 Data Analysis and Interpretation

After sampling, pollutant concentrations were tabulated and compared against the National Ambient Air Quality Standards (NAAQS). Both descriptive and comparative analysis were employed:

- Tabular data to reflect raw values
- Graphical representations (bar charts, pollutant-wise site comparisons)
- Compliance checks against CPCB standards
- Trend interpretation across sites to identify pollutant hotspots

For example, Steel Yard recorded the highest SO_2 and PM2.5, while Boys Hostel showed minimal pollutant presence, indicating either low construction activity or better dust control.

2.6 Human Survey and Observational Method

A qualitative survey was conducted with 40+ individuals including:

- 25 construction workers
- 15 residents living/working near the sites

The survey involved:

- Structured interviews
- Informal conversations
- Health symptom reporting (cough, fatigue, throat irritation)
- Site condition documentation (e.g., use of PPE, water sprinkling)

Participants were informed of the research purpose, and all data were anonymized. Field notes also documented weather conditions and construction intensity.

2.7 Ethics and Documentation

All data collection was conducted ethically under the supervision of qualified faculty. Consent was obtained before interviews. Observations and survey findings were cross-referenced with technical data to enrich the analysis with ground-level human perspectives.

3. Results and Discussion

The study was conducted to evaluate the ambient air quality across five active construction zones located within the Global Skill Park (GSP) campus in Bhopal. Air quality monitoring was performed over a 24-hour period at each location using CPCB-certified instruments, measuring concentrations of PM_{10}, $PM_{2.5}$, SO_2, NO_2, and O_3.

The results presented in this section highlight the site-wise pollutant levels, followed by a comparative and interpretive analysis. Although all measured values were within the CPCB permissible limits, particulate concentrations were consistently elevated during construction activities, underscoring potential health risks associated with prolonged exposure.

3.1 Particulate Matter (PM_{10} and $PM_{2.5}$)

Across all five construction sites, PM_{10} concentrations ranged from 48.46 to 77.57 µg/m³, while $PM_{2.5}$ levels ranged from 19.16 to 36.25 µg/m³. The highest concentrations were observed at the Steel Yard, attributed to welding operations, material handling, and vehicular movement on unpaved surfaces. Conversely, the Boys Hostel site recorded the lowest values, indicating minimal activity during the sampling period or better dust control.

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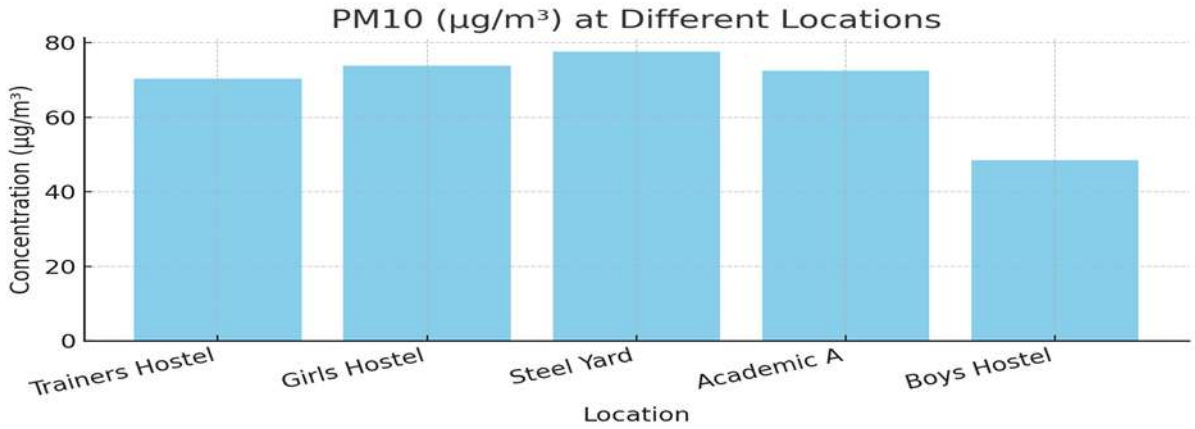
PM2.5 at Different Locations

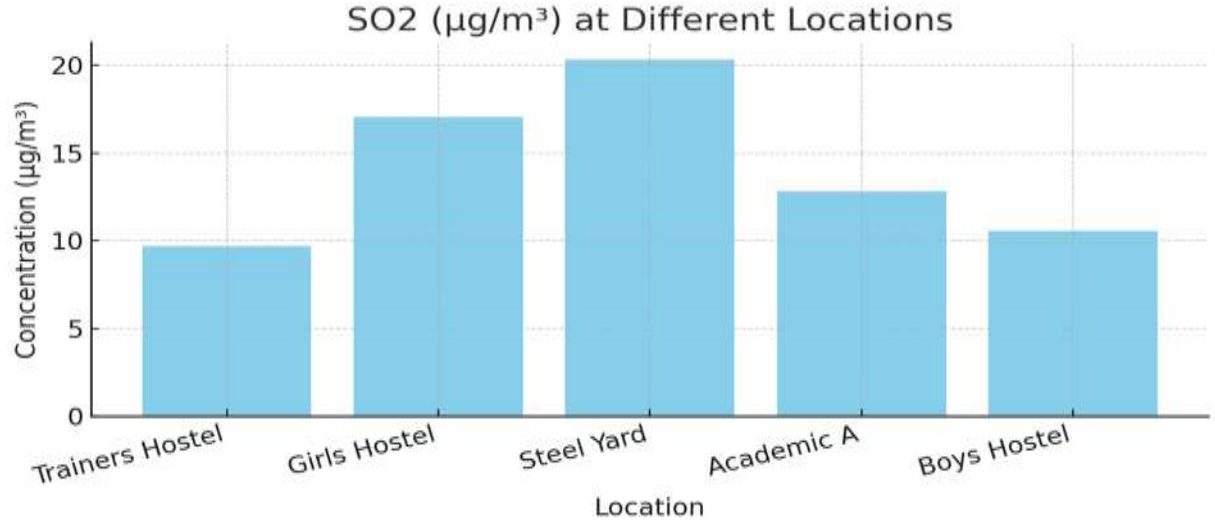


PM10 at Different Locations

These figures illustrate that particulate pollution is directly correlated with the intensity and type of on-site activities. Sites with active material transport, steel cutting, and excavation consistently showed higher PM levels.

3.2 Sulphur Dioxide (SO_2)

SO_2 concentrations ranged from 9.68 to 20.32 µg/m³. The Steel Yard again recorded the maximum level, likely due to fuel combustion during welding and cutting operations. The Girls Hostel also reported elevated SO_2 values, pointing toward similar sources of combustion-based emissions.



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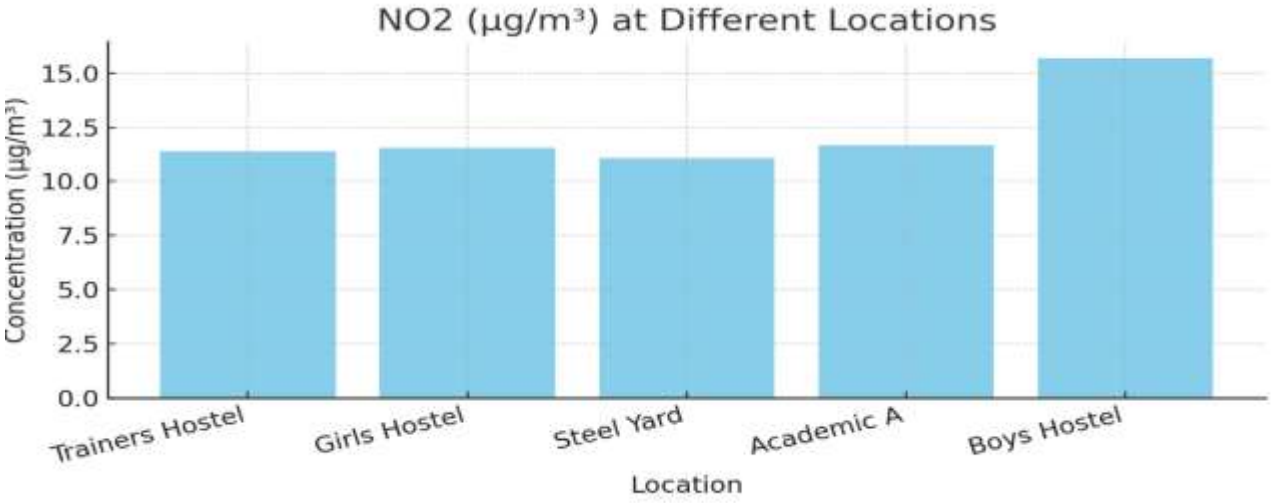
SO_2 at Different Locations

While within the safe limits, these levels suggest a consistent presence of combustion-related air pollutants, particularly in areas with heavy machinery and non-electric equipment use.

3.3 Nitrogen Dioxide (NO_2)

NO_2 levels were relatively stable across all five locations, ranging from 11.07 to 15.68 µg/m³. The Boys Hostel showed the highest NO_2, possibly due to nearby vehicle emissions rather than site activity alone.



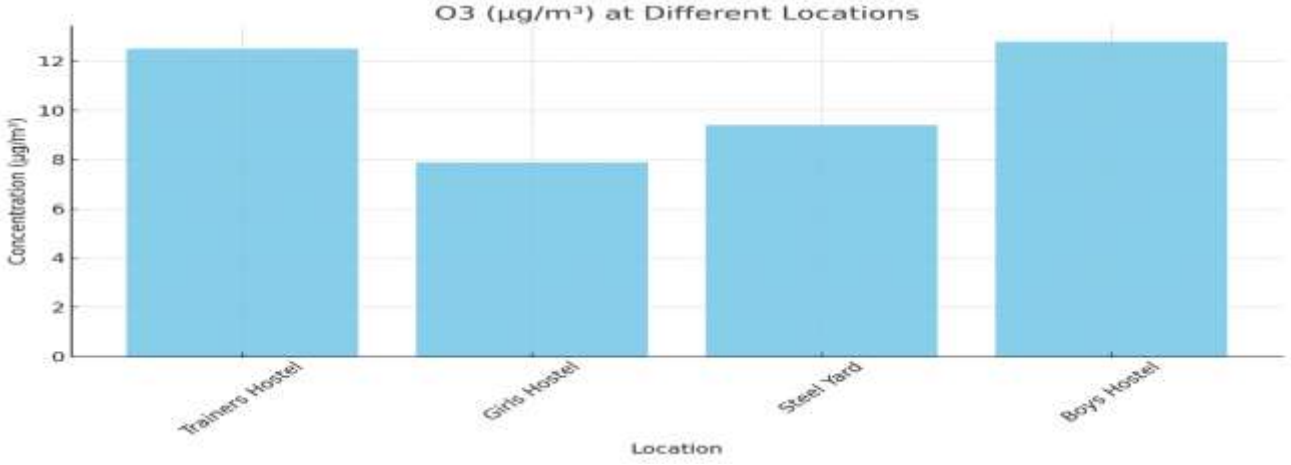
NO_2 at Different Locations

Even modest levels of NO_2, if sustained over time, can contribute to respiratory issues—especially in a mixed-use campus environment.

3.4 Ozone (O_3)

O_3 concentrations varied between 7.82 to 12.71 µg/m³, with the highest reading at the Boys Hostel. Ozone levels remained significantly below the CPCB threshold of 180 µg/m³. O_3 formation at ground level can result from complex photochemical reactions involving NO_2 and VOCs in sunlight, indicating secondary pollution patterns.

This parameter, while generally low, reflects the need to monitor background pollution processes in addition to direct construction emissions.



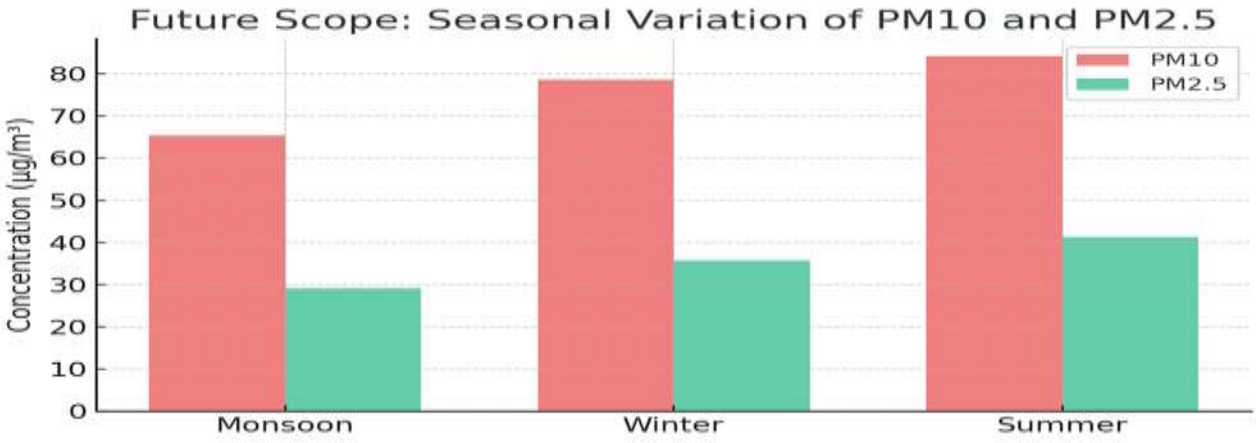
O_3 at Different Locations

3.5 Seasonal Trends in Particulate Levels

The analysis also explored seasonal variation for PM_{10} and $PM_{2.5}$ levels across different timeframes. Notably, particulate concentrations were higher during summer and dry months, correlating with windier, dust-prone conditions and peak construction activity.

This trend confirms the need for site-specific control strategies such as frequent water sprinkling, dust

nets, and reduced open material storage, especially during dry spells.



Seasonal Variation of PM10 and PM2.5

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