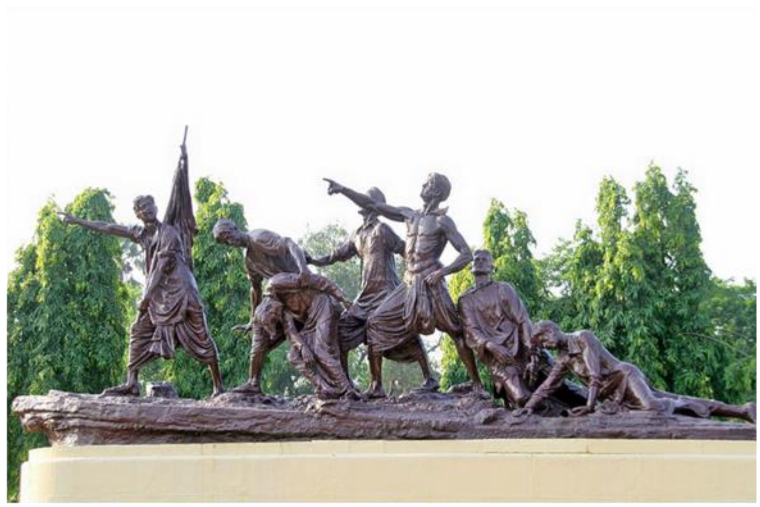
Local Air Quality Management Plan (LAMP) for Indian Cities

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Local Air Quality Management Plan (LAMP) for Indian cities

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Background

India is dealing with multiple environmental issues, with the most pressing being air pollution. The poor quality of air that citizens are forced to breathe, especially in heavily polluted cities, harms their health and well-being. About 0.6 million mortalities and a heavy loss in agriculture are attributed to poor ambient air quality in India. World Bank estimated that the damage cost of outdoor air pollution in India was about 2-4% of the total GDP. Energy consumption in different sectors is linked to emissions of various air pollutants that deteriorate air quality at different scales. Some of the pollutants are linked to inefficiency in the combustion processes and others are due to inadequate tail-pipe controls required for their treatment. Continued exposure to polluted air is causing diminished lung function, and acute and chronic respiratory symptoms like cough, wheezing, and asthma.

The issue of air pollution is not just limited to degrading the health of Indian citizens and the economy, but it also poses dangers to cultural heritages. It has been scientifically proven that continuous exposure to air pollutants both gaseous and particulate matter have damaged the historical monuments in India and across the world. A case in point will be the discoloration of the Taj Mahal in Agra on which the number of studies and interventions have been analyzed. Multiple factors have been attributed to the discoloration out of which first and foremost has been air pollution caused by various industries, vehicular movements, burning of biomass, crop residue burning, and various construction activities within and outside the Taj Trapezium Zone (TTZ). The pollution becomes so pervasive in the TTZ area that the Taj Mahal becomes obscured by thick smog during post-monsoon and winter seasons.

Several steps are being taken to preserve this white beauty of India, but India is filled with several cultural heritages spread across the country that have not received any attention as the Taj Mahal. These heritages tell tales of the great Indian past and are in danger of degradation due to various air pollutants. It is observed that seasonal fluctuations in the outdoor climate and increased human activities in the vicinity of the museums have plausible impacts on the immediate changes in indoor air quality as well. Hence the clear and present danger from air pollution is not limited to just the outer walls of the monumental structures. There is a need to analyze the ambient air quality near the major museums to save the artifacts that are celebrated remnants of bygone India for future generations. It has been observed that seasonal fluctuations in the outdoor climate and increased human activities in the vicinity of the museums have plausible impacts on the immediate changes in indoor air quality.

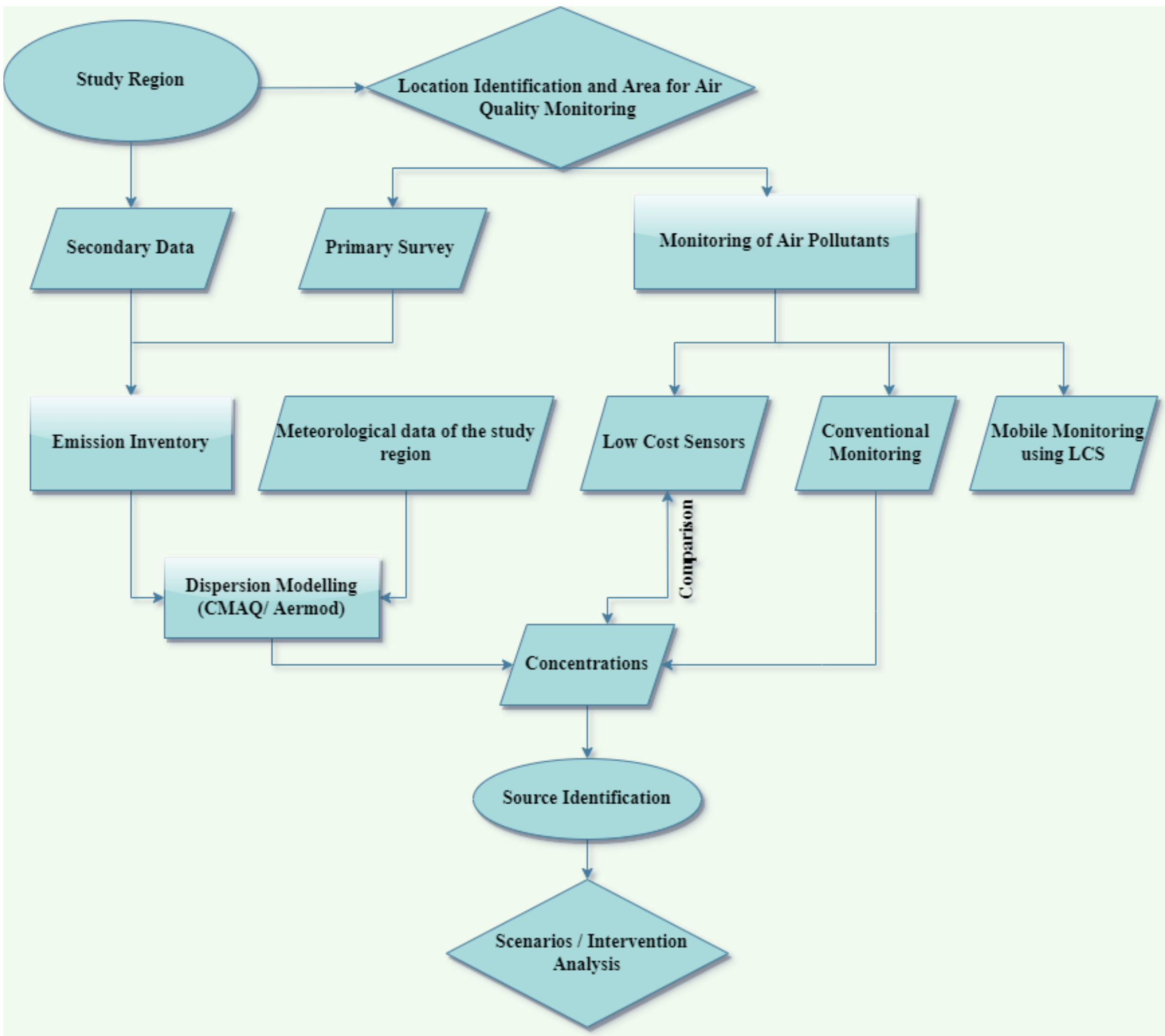
To save these national treasures first step is to study and analyze the ambient concentrations of pollutants in the region and their species. Further assessment and prioritization of government's policies already in place along with suggesting new measures based on the scientific assessment. In this context, the Environmental Defense Fund (EDF) has awarded a project "Local Air Quality Management Plan (LAMP)" to TERI to conduct a scientific study to measure the ambient concentration levels of particulate matter along with conducting source apportionment around four national monuments across the country. Further, analyze seasonal fluctuations of these pollutants and calibrate low-cost sensors for regular real-time monitoring. Also, raising awareness of the issue among those who live close to these national treasures is crucial in addition to scientific research to reduce air pollution. As a result, informational communication educational material in simplified local languages should be used to raise awareness among these people about the issue, its effects, and personal activities that can aid in decreasing the health effects and, ultimately, the impact of air pollution.

Objectives

- To prepare emission inventory using a combination of primary surveys and recent secondary literature searches for all major sectors (Domestic, Power, Industry, Transport, Open Burning, Construction, Refuse Burning, DG sets, Crematoria, Road Dust) around 2.5 km radius of each cultural monument or commercial hub
- Conduct ambient air quality monitoring using conventional monitoring techniques and air quality sensors (AQS) in the vicinity of the selected study area and CAAQMS, for 2 seasons (summer and winter).
- Use the monitored and validated modeled concentrations for calibrating low-cost sensor concentration.
- To conduct mobile monitoring using AQS for different routes surrounding each of the selected monuments and hubs for both seasons for 5-7 days each.
- To validate and simulate air pollution concentration and assess contributions of each sector for source apportionment using WRF-CAMQ and/or AERMOD models.
- To design a communications campaign to raise awareness of air pollution’s immediate impacts and share the same with EDF.
- Design micro action plans for each city, for each season, based on the scientific analysis to mitigate the impact of air pollutants in the study area.
- Conduct two capacity-building workshops, in collaboration with EDF for each city, at mutually agreed times during the study period.

Selection of study area and methodology

The Environmental Defense Fund (EDF) was solely responsible for selecting the study locations for the project. Given that TERI had established connections with the Bihar State Pollution Control Board (BSPCB), Patna was chosen as one of the study locations. After detailed discussions with BSPCB and the Patna Municipal Corporation (PMC), Golghar was identified as the central point for the study, with a 2.5 km radius around it. In addition, based on suggestions from BSPCB officials, a reference location free from any immediate visible sources of air pollution was also selected. Shaheed Smarak, along with a 2.5 km surrounding radius, served as this reference point. Indore and Dewas, in the state of Madhya Pradesh, were selected as the second and third study areas. The actual study area in Indore was 2.5 km around Choti Gwaltoli, while in Dewas, it was a 2.5 km radius around the Continuous Ambient Air Quality Station (CAAQS) of the National Air Monitoring Programme (NAMP), as recommended by the Dewas Municipal Corporation. Due to challenges in finalizing the fourth location, EDF revised the study's scope to focus on the three selected locations. The overall methodology adopted is shown in Figure.



The sensor selection process, technical details, installation, Performance matrix, and mobile monitoring route

As part of the study, a co-location study was conducted to select air quality sensors for hyperlocal air quality assessment. The goal was to identify commercially available sensors capable of measuring $PM_{2.5}$, NO_2, temperature, and humidity under Indian conditions. The study followed a structured approach to sensor selection, technical evaluation, and installation. A list of potential sensors was prepared, considering factors like parameters, cost, and feedback from technical teams. Six models from different vendors namely S1, S2, S3, S4, S5, and S6 were shortlisted. The sensors were subjected to a rigorous testing process at two locations in phases. During phase 1 assessment, the sensors were installed at the rooftop of TERI, Lodhi Road, New Delhi, and compared with data from two Continuous Ambient Air Quality Monitoring Stations (CAAQMS). The testing period spanned nine days in May, covering summer conditions. A manual reference-grade monitor was also set up for cross-verification. In phase 2 assessment, the sensors were tested at TERI Gram, Gurgaon, during the pre-monsoon period (June 13-24). This site had higher dust concentrations due to its proximity to kerb-side emissions. Descriptive analysis was conducted to assess the sensors' performance, and the data from the CAAQMS served as a reference. The study used descriptive and visual analysis methods to compare sensor data with reference-grade monitors. Key statistical parameters, such as mean, standard deviation, and range, were used for performance evaluation. The descriptive analysis of phase 1 showed that the S3 sensor was closest to the CAAQMS in terms of accuracy, followed by S2. S1 and S4 performed poorly, while S5 and S6 provided incomplete or no data. The advanced statistical analysis in Phase 2 further refined the results. S3 and S2 were the top-performing sensors, with S3 being marginally better in terms of hourly data accuracy. Based on the performance both S3 and S2 were invited for discussions, and based on performance, logistics, cost, and vendor reputation, S3 was selected for installation. The selected sensors were then installed in predefined locations around Patna, Indore, and Dewas for hyperlocal air quality monitoring, with technical parameters aligned with the project's goals for assessing $PM_{2.5}$ and NO_2 levels around key monuments/commercial hubs. To identify the hotspots within the study area, a mobile monitoring exercise was carried out covering all major roads in the three selected study areas. A road stretch of approximately 14km was taken for mobile monitoring and the same route was repeated two times a day (morning and evening peak hours) for 7 continuous days.

Results

Hyperlocal variation in pollution levels based on fixed and mobile sensor data

The hyperlocal variation in pollution levels was analyzed using both fixed monitoring stations and mobile monitoring data across the three study areas. The data was gathered over a year, with insights into $PM_{2.5}$ concentrations and the relationship with factors like humidity. Fixed stations provided long-term data, while mobile monitoring helped identify hotspots in real-time. The data reveals significant spatial and temporal variations, offering insights into localized pollution sources and trends.

Fixed Monitoring Data

The data collected from the two locations in Patna, Indore, and Dewas showed higher concentrations during cooler months due to stagnant atmospheric conditions. In contrast, warmer months showed a decrease in $PM_{2.5}$ levels, attributed to better atmospheric dispersion. The spatial variation between locations was notable, with no strong correlation between relative humidity and $PM_{2.5}$ levels, periods of higher humidity did coincide with elevated $PM_{2.5}$ levels in some areas, suggesting that other factors such as emissions from industry and traffic were more influential in determining pollution levels. The data revealed significant daily fluctuations in $PM_{2.5}$ concentrations across monitoring stations, with certain outlier days linked to specific meteorological or human-induced events. The data highlighted substantial spatial variation in pollution levels with some locations consistently recorded higher $PM_{2.5}$ concentrations.

Mobile monitoring data

Mobile monitoring in Patna identified hotspots, particularly along high-traffic roads. Mobile monitoring provided high-resolution data on hyperlocal pollution variations. It highlighted roads and intersections where $PM_{2.5}$ levels were particularly high during peak traffic hours, offering insights into traffic-related pollution spikes. The hyperlocal variation in pollution levels from the mobile monitoring data of Indore likely captures differences in air quality across specific locations within the city, highlighting how factors such as traffic density, local emissions, and geography contribute to fluctuating pollutant concentrations like $PM_{2.5}$ and PM_{10}. The mobile monitoring data from major roads in Indore identified intersections and commercial areas as key pollution hotspots. Mobile monitoring in Dewas revealed clear pollution hotspots, particularly along industrial corridors and busy traffic intersections.

Emission Inventory

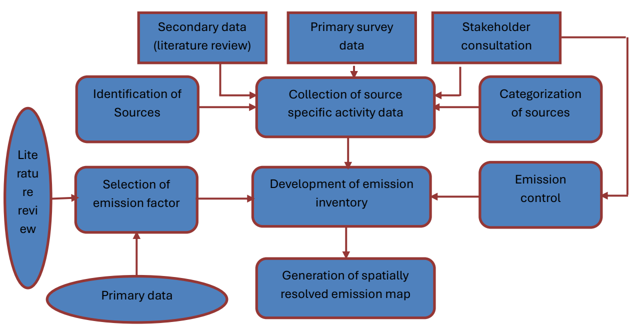
Apart from the measurement of the ambient concentrations of different air pollutants, the development of a comprehensive emission inventory is an important step in the air quality management process. 2 × 2 km^2 grid-wise emission inventory of air pollutants like PM_{10}, $PM_{2.5}$, NOx, SO_2, CO, and NMVOCs was prepared for different point, line, and area sources for the year 2023 in the study area through ground-level surveys and the acquisition of activity data from various departments. Secondary information was supplemented by primary surveys specific to each sector. EF are selected from a detailed review of published literature.

Equation used for emission estimation

$$E = A \times EF \times (1 - \alpha),$$

Where E = Emissions, A = Activity data, EF = Emission Factor, α = Efficiency of control

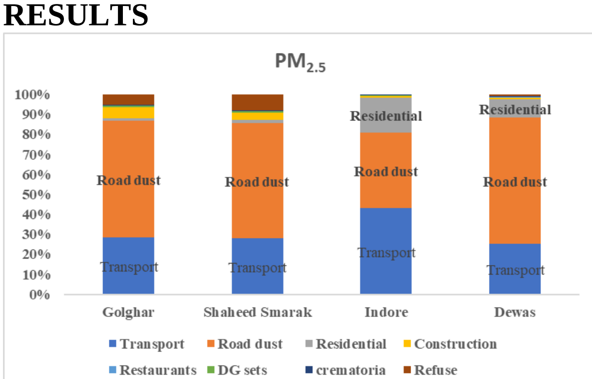
METHODOLOGY

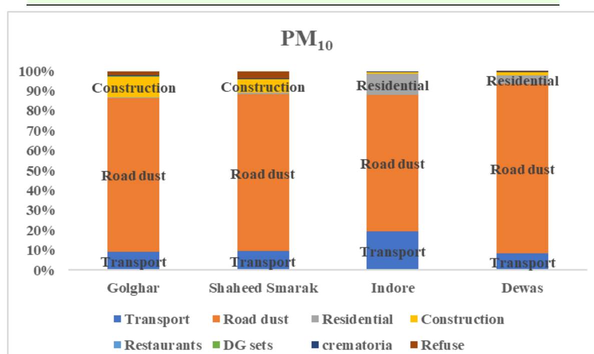


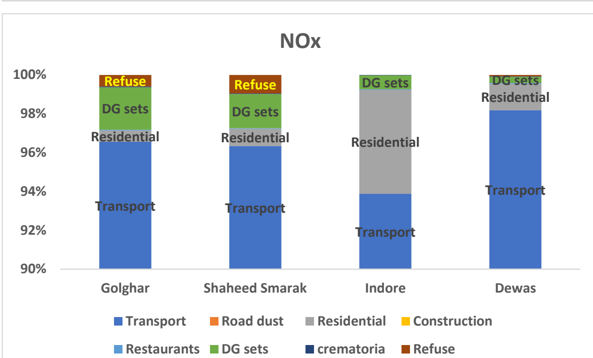
PRIMARY SURVEY

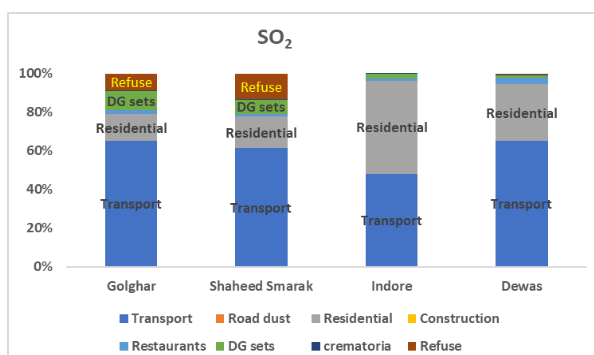
S.No	Sector	Type of survey
1	Transport	Vehicles counts surveys / Parking Lot surveys
2	Domestic	Fuel use pattern of different households
3	DG sets	Commercial /Households fuel consumption
4	Road dust	Road dust monitoring
5	Open burning	Quantity of residue burnt
6	Hotels/restaurants/open eat outs	Fuel use pattern

RESULTS





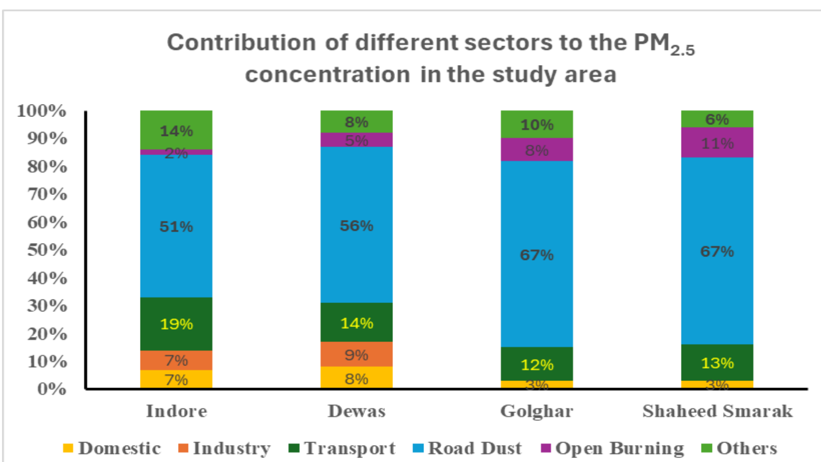




Air quality modelling

The study employed the WRF-CMAQ (Weather Research and Forecasting - Community Multiscale Air Quality) modeling system to simulate PM_{10} and $PM_{2.5}$ concentrations at Golghar, Shaheed Smarak (Patna), Indore, and Dewas. The WRF model generated meteorological inputs, while the CMAQ model estimated the pollutant transport, considering both primary and secondary pollutants. Emission inventories at a fine resolution (1x1 km) for local emissions and 36x36 km for regional transport were used. International pollutant inflow data was sourced from the NCAR CAM-chem model. The model validation was conducted by comparing simulated $PM_{2.5}$ concentrations against observed data from the CAAQS at each of the locations under the NAMP. The simulated values were found to be in satisfactory agreement with observed data, with an average ratio of 1.2 between modeled and measured values.

The results of the dispersion modeling indicate that external sources dominate air pollution in all four locations: Golghar, Shaheed Smarak, Indore, and Dewas. The annual contribution of $PM_{2.5}$ from outside the study areas ranged between 65% and 80% across these locations, showing a significant influence of regional and long-range pollutant transport. For the remaining contributions from within the study areas road dust, transport and refuse burning consistently emerged as the primary contributors to $PM_{2.5}$ pollution at all the four locations.



Based on the winter season average spatial distribution of $PM_{2.5}$ concentrations in the study area (both mobile monitoring and simulated concentrations), the top five hotspot locations (grids) were identified in each of the study areas. Road dust was the major contributor in these hotspots, followed by waste burning, residential and transport. Contributions from other sectors were minimal.

Proposed solutions and their potential in reducing $PM_{2.5}$ levels

To combat the alarming levels of air pollution in Golghar, Shaheed Smarak, Indore, and Dewas, a set of robust and targeted interventions have been proposed. These solutions are designed to address key pollution sources—road dust, transport emissions, refuse burning, while offering the potential for significant emissions reduction.

Transport Sector Solutions The transport sector, especially road dust and vehicle tail pipe emissions, is a major contributor to $PM_{2.5}$ pollution, accounting for over 38% - 67% of road dust emissions across different locations. The tail pipe emissions from vehicles across the four locations ranged between 9% and 43%.

Phasing out old diesel vehicles: By 2030, 100% of 15-year-old private and 20-year-old commercial vehicles would be scrapped, reducing $PM_{2.5}$ emissions by up to **56%**.

Electrification of vehicles: Encouraging electric two-wheelers and city buses (50% by 2025 and 100% by 2030) could reduce emissions by **30%**.

Congestion management: Improving traffic flow and reducing on-road emissions can cut $PM_{2.5}$ emissions by up to **54%**.

Road dust: Mechanized Road sweeping and roadside plantation: Regular cleaning and greenery can lower road dust emissions by up to **58%** by 2030.

Waste Burning Solutions: Refuse burning contributes significantly to air pollution in Patna. For other two locations Indore and Dewas, its contribution is very minimal. Enhancing collection rates from 60% to 71% can reduce emissions by 44% by 2025 in some areas. Sustained efforts would lead to a further 35% reduction in refuse burning emissions.

Construction Sector Solutions: Construction dust is another major pollutant, contributing 4-6% of $PM_{2.5}$ levels in Patna. Proposed interventions include: The use of blue sheets and green mesh to cover sites and materials could reduce PM emissions by **53%** by 2030. Implementing precast materials could lead to a **42-58%** reduction in $PM_{2.5}$ emissions by 2030.

Residential sector: Residential sector contributed 9% and 18% of the total $PM_{2.5}$ emissions in Dewas and Indore respectively. Considering the current LPG penetration growth in Indore, there could lead to a reduction of 35% and 66% of $PM_{2.5}$ emissions by 2025 and 2030 respectively. But in Dewas assuming an annual LPG growth rate of 7.57%, could lead to reduction of $PM_{2.5}$ emissions by 26% and 92% by 2025 and 2030 respectively. If effectively implemented, these measures together can deliver up to **70% reduction** in $PM_{2.5}$ levels.

Conclusion, Learning from LAMP methodology and way forward

The Local Air Quality Management Plan (LAMP), focusing on Patna, Indore and Dewas, is a comprehensive initiative aimed at addressing air pollution at a hyperlocal level. This plan integrates scientific assessments, emission inventories, source apportionment studies, and targeted interventions. The study's findings are crucial for sustainable urban development and air quality improvement in non-attainment cities like Patna, Indore and Dewas. The results of ambient air quality monitoring carried out at the study area using different monitoring methods indicate that there is a concerning issue with $PM_{2.5}$ levels in Patna, particularly during winter months. For Indore and Dewas, the levels were in general within the standard. The emission inventory identified road dust, refuse burning, transport, residential and transport as the primary contributors to $PM_{2.5}$. Source apportionment carried out in these four study areas indicated that major share of $PM_{2.5}$ is from sources outside the study area. Road dust, transport and residential sectors are the major contributors of $PM_{2.5}$ at all the identified hotspots in these study areas and different city specific action plans were suggested to improve the air quality in these areas. The study recommended a regional scale approach along with city specific action plans for most effective results.

The LAMP project emphasized the importance of localized, high-resolution air quality monitoring and source identification for targeted intervention. This initiative, leveraging both conventional monitoring methods and low-cost sensors, showcased the effectiveness of combining real-time data collection with community-based awareness and engagement strategies. The success of this methodology demonstrates its potential for replication in other non-attainment cities in India to meet the targets set by the National Clean Air Program (NCAP).

Way Forward

Targeted Interventions: Key strategies, such as the reduction of road dust, waste management improvements, and stricter vehicular emissions control, should be implemented. Measures like non-motorized transport, congestion pricing, and better waste collection will have a significant impact.

Policy Support and Community Engagement: Strengthening policies at the regional level, especially through coordinated efforts across Patna, Indore and Dewas, is essential. Additionally, raising community awareness through Information, Education, and Communication (IEC) strategies will be key in fostering long-term behavioral changes.

Broader Regional Approach: Addressing air pollution in Patna, Indore and Dewas requires a regional strategy that not only focuses on local sources but also considers external factors contributing to pollution in the area. This should align with the state-level action plans under NCAP to achieve more sustainable results.

Conclusively, the LAMP project has laid the groundwork for replicating similar localized interventions across India, supporting both air quality improvement and heritage conservation efforts.

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About TERI

A unique developing country institution, TERI is deeply committed to every aspect of sustainable development. From providing environment-friendly solutions to rural energy problems to helping shape the development of the Indian oil and gas sector; from tackling global climate change issues across many continents to enhancing forest conservation efforts among local communities; from advancing solutions to growing urban transport and air pollution problems to promoting energy efficiency in the Indian industry, the emphasis has always been on finding innovative solutions to make the world a better place to live in. However, while TERI's vision is global, its roots are firmly entrenched in Indian soil. All activities in TERI move from formulating local- and national-level strategies to suggesting global solutions to critical energy and environment-related issues. TERI has grown to establish a presence in not only different corners and regions of India, but is perhaps the only developing country institution to have established a presence in North America and Europe and on the Asian continent in Japan, Malaysia, and the Gulf.

TERI possesses rich and varied experience in the electricity/energy sector in India and abroad, and has been providing assistance on a range of activities to public, private, and international clients. It offers invaluable expertise in the fields of power, coal and hydrocarbons and has extensive experience on regulatory and tariff issues, policy and institutional issues. TERI has been at the forefront in providing expertise and professional services to national and international clients. TERI has been closely working with utilities, regulatory commissions, government, bilateral and multilateral organizations (The World Bank, ADB, JBIC, DFID, and USAID, among many others) in the past. This has been possible since TERI has multidisciplinary expertise comprising of economist, technical, social, environmental, and management.

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