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Increasing Community Participation in Air Pollution Mitigation in Indore, India

August 2022

THRIVE NETWORKS

International Organization for Migration (IOM)
The UN Migration Agency

URBAN INSTITUTE

Contents

Note: Annexes are available in a separate supplementary report.

Acronyms

AQI	air quality index
BHC	Building Healthy Cities
CAG	Clean Air Guide
CII	Confederation of Indian Industries
CPCB	Central Pollution Control Board
EPA	Environmental Protection Agency
IMC	Indore Municipal Corporation
ISCDL	Indore Smart City Development Limited
ISSW	Indore School of Social Work
LCS	low-cost air quality sensors
LGP	liquefied petroleum gas
MPPCB	Madhya Pradesh Pollution Control Board
NAAQS	National Ambient Air Quality Standards
PM	particulate matter
$PM_{2.5}$	particulate matter 2.5 micrograms/cubic meter
PM_{10}	particulate matter 10 micrograms/cubic meter
USAID	United States Agency for International Development

Building Healthy Cities

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Introduction

The United States Agency for International Development (USAID)-funded Building Healthy Cities (BHC) project aims to refocus city policies, planning, and services with a health equity lens while improving data-driven decision-making for Smart Cities in India, Indonesia, Nepal, and Vietnam. Planning for a Smart City is intrinsically linked to health: transportation, the environment, sanitation, education, recreation, technology, and the built environment all influence the health of an urban population. When decision-making across these areas is harmonized, people will benefit from improved access to health services, decreased environmental and lifestyle risk factors for chronic diseases, a lower burden of infectious diseases, and an increased availability of useful data for decision-making.

BHC engages with sectors that contribute, directly or indirectly, to citizens' (particularly women and children) health and quality of life. This multisector engagement, the first core value of BHC, aims to provide all municipal sectors a common understanding of how they contribute to health. The second BHC core value is to strengthen community engagement in municipal decision-making, especially for those most vulnerable to health shocks. BHC's third core value is supporting the use of data for planning and decision-making. Informed by these three core values, BHC partnered with Indore Smart City Development Limited (ISCDL) to improve healthy urban planning.

The purpose of this study was to assess the feasibility and effectiveness of community participation in identifying main sources of air pollution and the measures required for its mitigation using community-based local data from low-cost air quality sensors (LCS). BHC conducted this study with support from the Indore School of Social Work (ISSW) and Skymet Weather Services.

Background

Air pollution exposure is the second most important risk factor for ill-health in South Asia, contributing to between 13 and 22 percent of all deaths and approximately 58 million disability-adjusted life years due to chronic and acute respiratory and cardiovascular illnesses (Gakidou et al. 2017). In 2015, particulate matter (PM) air pollution from several major sources was responsible for approximately 1.1 million deaths, or about 11 percent of the total number of deaths in India (Health Effects Institute 2018). High levels of PM affect both the environment and human health; very fine particles can penetrate the lungs, causing cardiovascular and neurological problems (Amaral et al. 2015). Ultrafine particles, measured as PM 2.5 micrograms/cubic meter ($PM_{2.5}$), are often cited as the primary cause of air pollution-related health issues (World Bank 2015). If no action is taken, deaths attributable to ambient $PM_{2.5}$ are projected to rise to 3.6 million in India

(Health Effects Institute 2018)). Children are the most vulnerable to air pollution; it harms healthy brain development and contributes to diseases that account for almost 1 in 10 of all deaths of children under the age of 5 (UNICEF 2016). Air pollution is also an equity issue; families living in poverty have a higher risk of being exposed to deadly air pollutants than families that live above the poverty line (Mikati et al. 2018).

For decades, air quality in Indian cities has deteriorated. This has increased health issues such as respiratory infections, cardiovascular diseases, and asthma incidence and severity. Indore is a fast-expanding city with a population of nearly 2.8 million people. Around 30 percent of the population live in informal settlements, which is the highest in the state of Madhya Pradesh (Agarwal 2018) (Times of India 2013). The annual average air quality in Indore has improved in recent years due to city efforts, and in 2019 was below the Indian National Ambient Air Quality Standards (NAAQS) threshold for $PM_{2.5}$ of 40 ug/m3 (Central Pollution Control Board 2020). However, the World Health Organization recommends lower thresholds for $PM_{2.5}$ and PM 10 micrograms/cubic meter (PM_{10}): 10 µg/m3 annual mean and 20 µg/m3 annual mean respectively. When compared to those measures, Indore was around seven times above the recommended PM_{10} level and nearly two times above recommended levels for $PM_{2.5}$. With population growth in Indore at 5 percent per year, pollution is bound to increase.

The Madhya Pradesh Pollution Control Board (MPPCB) is the state agency that operates the official reference air monitoring stations in Indore, resulting in high-quality data for policy and regulatory applications. At present, the MPPCB operates six official air quality measurement stations in the city, and four report real-time data. These are highly sophisticated monitoring stations that can report on multiple pollutants, but none are located in informal settlements or settlements where urban poor populations reside. There are also not enough stations to get a full picture of the range of air pollution across neighborhood types in the city. An information ecosystem analysis done by Earth Journalism Network in Indore found that 32 percent of Indore's citizens did not know where to access information about air pollution (Goswami, Bhogelkar, and Jat 2022). Therefore, citizens also may not be aware of pollution levels, local sources of pollutants, and precautions they should take to limit exposure to air pollution.

There are a growing number of companies that offer wireless LCS that can help to democratize air quality data (Bowles 2018). Many of these companies were founded by residents who felt the effects of poor air quality in their own neighborhoods. Indore's mix of pollution sources, incomes, and neighborhood types provide a rich testing ground to understand how LCS might address some gaps in air quality data and action in the city.

LCS are emerging as a complementary tool to supplement the reference air monitoring network, but do have some shortcomings that can be addressed by good study design and operations. Namely, LCS must be placed next to reference instruments to develop a calibration equation for the LCS, ensuring the most accurate measurements. In addition, LCS data are not accepted as official reference data but can be used for general awareness building and understanding how pollution changes and varies spatially. They also only measure PM levels well; it is harder to find LCS that can accurately measure other pollutants such as sulfur dioxide, nitrogen dioxide, ozone, and others.

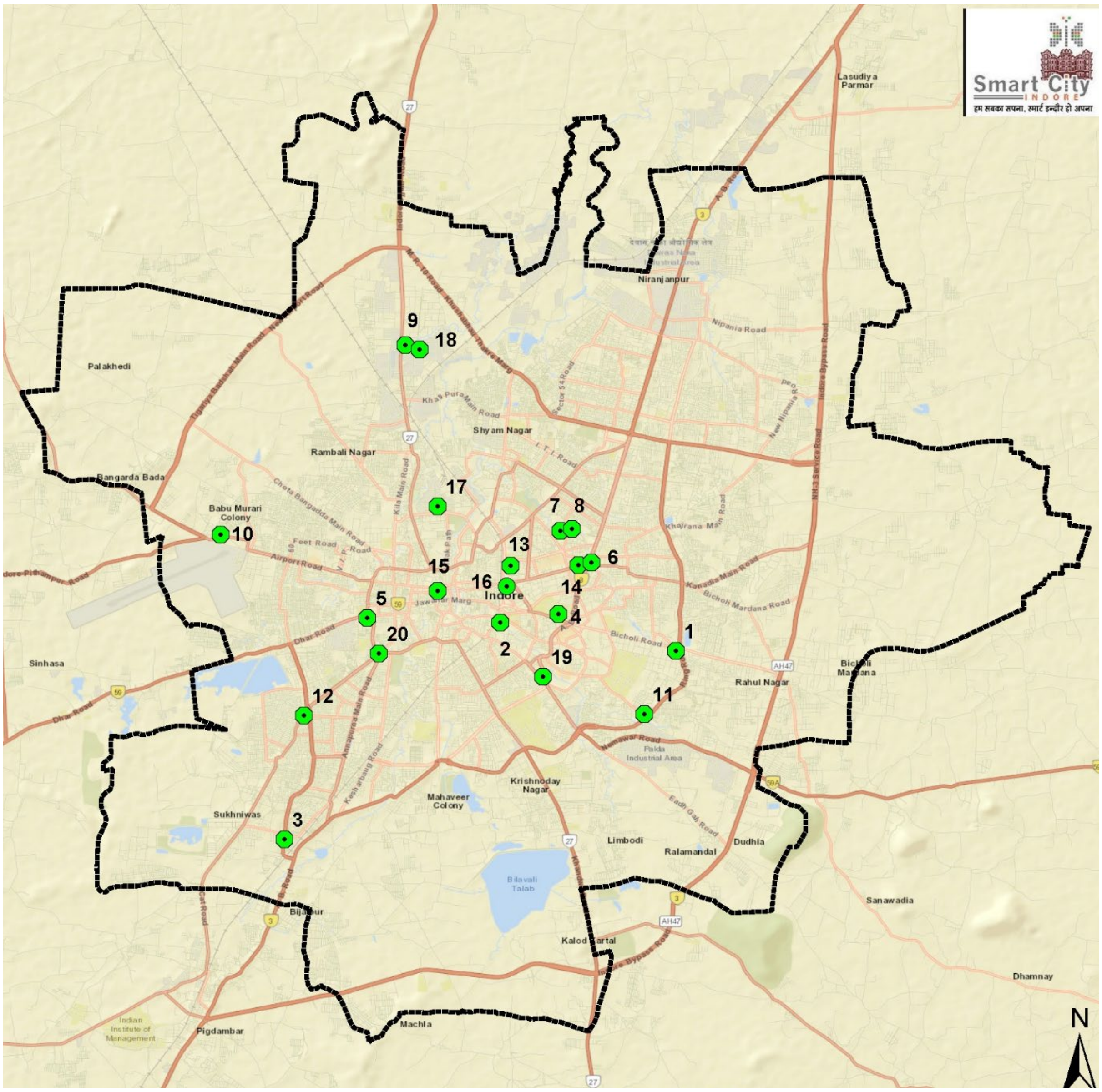
Indore is one of the 100 Indian cities funded by the Smart Cities Mission under the Ministry of Housing and Urban Affairs. Indore has been recognized as one of the cleanest cities in the country because of various city government interventions including solid waste management through active community participation, improved traffic management, and mechanical night sweeping of streets. BHC previously shared how Indore's efforts led to winning India's cleanest city award multiple years in a row, and how this may already have had an impact on air pollution (Bachani, Pomeroy-Stevens, and Gupta 2018). However, BHC also documented continuing air pollution concerns in our Health Needs Assessment, Policy Brief on Low-Cost Real-Time Sensors for Air Quality Monitoring, and Journey Map on Air Pollution (Pomeroy-Stevens et al. 2018, Building Healthy Cities project 2019, Building Healthy Cities project 2020).

To address air quality concerns, BHC planned this one-year study in partnership with MPPCB and ISCDL. Implementation support was provided by ISSW and Skymet Weather Services (for purchase, training, and support of the LCS). Twenty strategic locations were identified in consultation with city authorities covering residential, industrial, commercial, and traffic locations. For each site, a local community volunteer was identified and trained as a Clean Air Guide (CAG) with the responsibilities of monitoring air quality using LCS data; engaging and educating communities about levels of air pollution; gathering data on local sources of pollutants; and interacting with the local officials for interventions wherever required to reduce emissions and exposure to air pollutants. See Annex 1 in the separate Annex Supplement[1] for a full job description. Twenty LCS were procured, calibrated, and installed at strategic locations. However, air quality data for this study was collected from 19 sites. MPPCB asked to move the location of the twentieth sensor from Mhow Naka to the Regional Park after a CAG was already appointed for Mhow Naka. This CAG worked for three months without a sensor before this decision was finalized, and then a new CAG for the Regional Park was not assigned until January 2022. The sensor itself was not reporting data during this time, and therefore was not included in the study.

[1] Bachani, Damodar, Tim Dye, Minakshi Kar, Neeraj Mishra, Alsa Bakhtawar, and Amanda Pomeroy-Stevens. 2022. *Annex Supplement: Increasing Community Participation in Air Pollution Mitigation in Indore, India*. Arlington, VA: Building Healthy Cities (BHC) project.

The final list of LCS sites with their GPS coordinates and corresponding CAGs is provided in Annex 2 (see Annex Supplement). A map showing the location of LCS sites is shown below in Figure 1.

Figure 1. Study Locations



No.	Location name	No.	Location name
1	Pipliyahana Square	11	Indira Ekta Nagar
2	Luniyapura	12	Footi Kothi Square
3	Reti Mandi Square	13	ISCDL office campus
4	M.Y. Teaching Hospital campus	14	56 Dukaan food street
5	Gangwal bus stand	15	Near Rajwada
6	Palasia Square	16	Chhoti Gwaltoli DIG office
7	Amar Tekri, primary school	17	IPCA, industrial area
8	Amar Tekri, Anganwadi center	18	Narwal, Sanwer Road, primary school
9	Narwal, Sanwer Road, Anganwadi center	19	Navlakha Square
10	In front of airport (Panchsheel Nagar)	20	Regional park

Clean Air Guides

The CAGs were appointed in January 2021 as part-time volunteers and received a monthly stipend for their work. Each CAG lived near the location where a LCS was installed. All the CAGs were graduates and had experience working with the communities. However, they did not have any working knowledge of air pollution or air quality data prior to joining the study. To address this, they were trained on basic concepts related to air pollution and air quality data.

The CAGs had three main functions:

- **Maintain and read the LCS.** This included collation and interpretation of data; understanding basic air quality data; observing variations over time; recording air quality readings; checking the real-time dashboard on their phone; completing basic analysis; maintaining the LCS with basic cleaning and operation; and notifying ISSW if the sensor appeared to be malfunctioning.
- **Educate the community.** This included educating and empowering citizens and communities about air quality and its effects on health; using air pollution facts and resources to convey the general concepts of what air pollution is; and increasing community awareness about local $PM_{2.5}$ readings, sources of air pollution, and actions needed to reduce emissions and exposure to local pollutants.
- **Organize and support advocacy efforts.** This included identifying and suggesting measures required at the community level and by each government sector/system to reduce air pollution in Indore, and participating in activities organized by the government to make Indore a clean and green city.

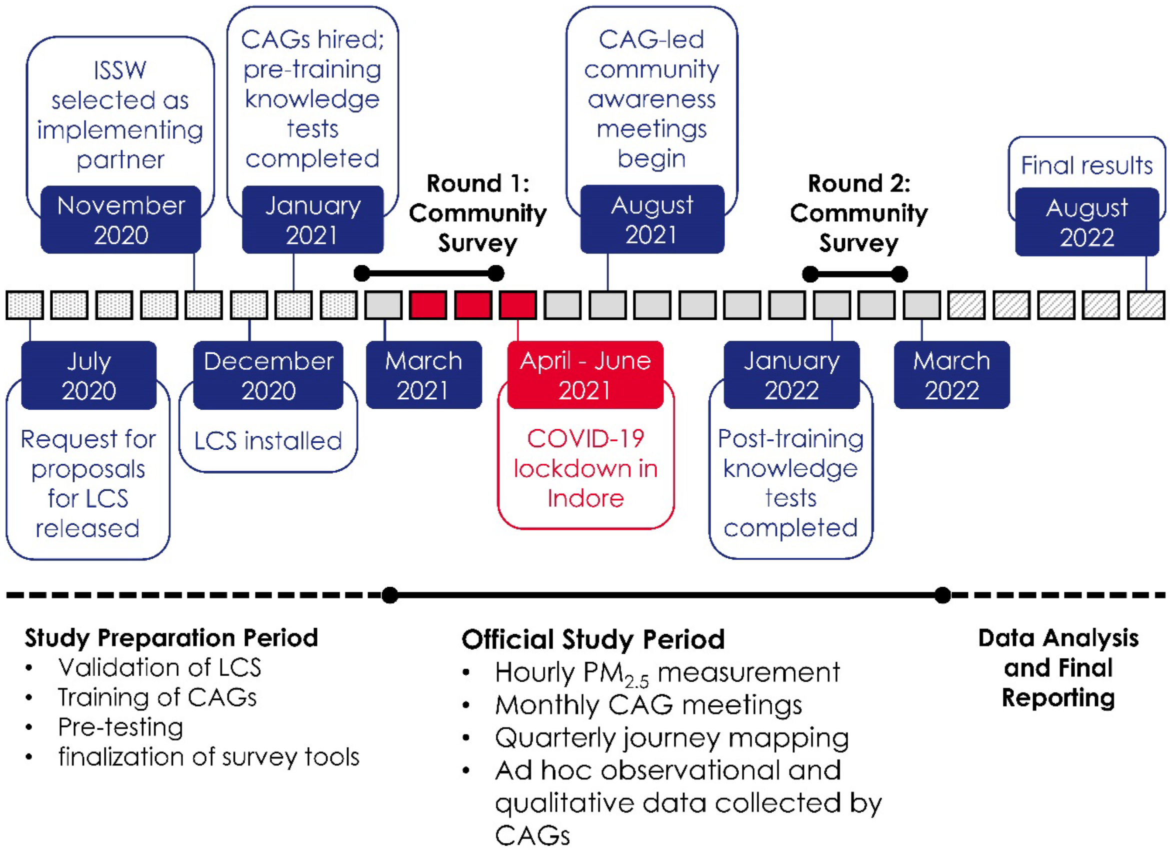
BHC held monthly meetings with all CAGs as a group to address any issues. These meetings also acted as refresher sessions and helped the CAGs to better analyze the data received from the sensors.

The main issue that this cadre faced was that this was only a part-time work opportunity; student CAGs who had completed their studies looked for better-paying full-time jobs once they graduated. This meant that 6 out of 20 CAGs left during the study and had to be replaced. However, the majority stayed until the end of the study.

Methods

This mixed-method participatory action research study was carried out in Indore, India from 2020-2022, with active data collection occurring between March 2021 and March 2022 (see Figure 2 for a detailed timeline). The quantitative portion included community survey and air quality data from 19 neighborhoods. Pre- and post-training knowledge tests were also collected from the CAGs. The qualitative data included group discussions with community members, in-depth interviews of individuals including city officers and service managers, and information collected through journey maps. For all types of data, analysis allowed for disaggregation by type of site: residential (4), commercial (5), industrial (4), and traffic congestion points (6).

Figure 2. Study Timeline



The objective of the study was to understand whether LCS can be successfully deployed to empower low-income communities to measure air pollution, understand the results and what it means for their health, and use those data to suggest measures to city governments to reduce emissions and exposure to air pollutants. The secondary purpose was to test the acceptability of LCS data to the city authorities. The objectives were broken down into the following research questions:

1. How have LCS been used by low-income communities in Indore to effectively monitor air quality in their neighborhood?

2. Did these data make any difference in the knowledge, attitudes, and/or practices relating to air pollution creation or avoidance, first in the CAGs, and then in their communities?

3. Have the LCS been effective in identifying locations with higher pollution across the city and potentially identifying sources of air pollutants? How does the air quality data lead to action by CAGs or the community?

4. Have the sensor data been accepted by the official groups as valid and relevant? How does the air quality data lead to action by the government?

The information collected to answer these questions is described below.

Knowledge Tests

After community volunteers were selected as CAGs, an introductory session was organized on January 8, 2021 covering an overview of air quality, an introduction to LCS and their calibration and application, and CAG roles and responsibilities. A CAG training was conducted on January 29, 2021 covering technical aspects and standards of air quality, health effects of pollution, and common sources of pollution. Using a questionnaire containing 10 questions (see Annex 3 in the Annex Supplement), BHC assessed the CAG's knowledge before and after the training. Questions focused on those topics most relevant to the CAG job description. Some CAG positions turned over during the study and a second round of pre- and post-training tests was held on January 8, 2022. All knowledge tests were assessed together for results across all 25 CAGs who participated at some point in the study.

Community Survey

The CAGs conducted a community survey in two rounds—the first in April-May 2021 and the second in January-February 2022—to understand the views of community members on air quality-related issues. Each CAG interviewed 50 individuals in the first round (950 subjects total) and 25 individuals in the second round (450 subjects total). CAGs were asked to randomly sample residents, shopkeepers, and other community members using a pre-tested questionnaire (see Annex 4 in the Annex Supplement). In the second round, the CAGs were asked to go back to the same types of people, plus frontline workers where available, including Anganwadi workers, teachers, and accredited social health activists. The questionnaire for the second round (see Annex 4 in the Annex Supplement) included questions relating to COVID-19 and opinions on trends over time relating to air pollution and health. Due to the COVID-19 situation and other logistical issues, the final sample was not random, and so should be treated as more of a convenience sample. In addition, in the CAG review meeting held on April 30, 2021, it was decided that during the lockdown period imposed due to an increase in COVID-19 cases, CAGs could conduct 50 percent of interviews in the first round (25 interviews per CAG) over the phone. This may have effected completeness of data in this round and excluded persons who did not have access to telephones. The rest of the interviews were conducted face-to-face after COVID-19 restrictions were lifted in June-July 2021.

Air Quality Data

Quantitative data were collected via the LCS for 19 neighborhoods for the duration of the official study period. The LCS selected for this study was a sensor system produced by Skymet Weather Services (see Figure 3). This device measures PM by using a small laser to detect particles as they flow through the device. The LCS measures $PM_{2.5}$ and PM_{10} every minute, averages the data into hourly measurements, and transmits data to a cloud database system. These devices are solar powered and operate continuously.

BHC used the following steps to calibrate the LCS:

1. Collocated two LCS at the reference monitor operated by the MPPCB to develop a calibration equation for the reference sensor (Figure 3).
2. Set up the remaining 18 sensors for a two-week collocation at ISSW.
3. Moved one of the LCS from the MPPCB reference site to the ISSW collocation for the two-week collocation.
4. Compared LCS data after the two-week collocation and calibrated all LCS.

Figure 3. Close-up View of an LCS (left) and LCS Collocated with MPPCB Site at Chhoti Gwaltoli (right)

Next, the CAGs were trained on the operation of the air sensors and how to interpret the data. Then, Skymet and the CAGs deployed the air sensors at each community location.

During the study period, BHC performed the following activities to ensure data quality:

- CAGs reviewed the data frequently and used it for outreach to the community.
- Skymet monitored the sensors and addressed several minor issues with solar panels, cellular SIM cards, and sensor performance.
- TD Environmental (BHC's air quality consultant) reviewed data every quarter to examine completeness and accuracy. In addition, data were analyzed to identify trends and unique features.
- BHC collocated one air sensor at the reference station (Chhoti Gwaltoli) for the entire study. Results from this collocation show that the LCS were accurate and performed very well when compared to the reference $PM_{2.5}$ data.

These data were analyzed using Excel to assess trends in air quality over the study period, diurnal and seasonal variations, and variations due to local weather conditions, social/cultural events, and festivals. Maps and visualizations were constructed in Python to identify clean and polluted periods in each neighborhood.

Clean Air Guide Qualitative Data

CAGs collected qualitative data during small group meetings, in-depth interviews, and direct observation. After the COVID-19 situation in the city improved, from August 2021 to February 2022 each CAG organized small group meetings with the community members to raise air quality awareness. CAGs used hand-made color-coded sheets depicting ranges of $PM_{2.5}$ in different colors, as shown in Figure 4. Levels were calibrated to the NAAQS National Air Quality Index Indian 24-hour $PM_{2.5}$ and PM_{10} thresholds (Figure 5) (Central Pollution Control Board 2020).

CAGs also conducted in-depth interviews with community leaders and government officials on issues and measures required to improve air quality. Quotes from citizens, photographs, and materials used to share results on air quality were collected from the CAGs. These were shared with ISSW and BHC team members every month in review meetings organized by ISSW.

Figure 4: Handwritten Chart Prepared by CAGs to Illustrate Categories

Figure 5: Air Quality Category Based on Levels of $PM_{2.5}$ and PM^{10}

AQI Category	PM2.5 (ug/m3)	PM10 (ug/m3)	Health Impact
Good (0-50)	0-30	0-50	Minimal
Satisfactory (51-100)	31-60	51-100	Minor Breathing discomfort to sensitive people.
Moderately polluted (101-200)	61-90	101-250	Breathing discomfort to asthma patents, elderly and children.
Poor (201-300)	91-120	251-350	Breathing discomfort to all
Very poor (301-400)	121-250	351-430	Respiratory illness on prolonged exposure.
Severe (401-500)	250+	430+	Health impact even on light physical work. Serious impact on people with heart/lung disease.

Source: Central Pollution Control Board 2020

Journey Maps

Using ethnographic methods, BHC developed "journey maps" as monitoring tools to follow air pollution issues specific to each of the CAG neighborhoods over time. Data were inputted quarterly and mapped against the LCS data monthly. For this purpose, our team developed a qualitative guide to collect repeated cross-sectional data from communities, city officials, and other stakeholders. Convenience sampling was used to select two to three respondents per quarter who agreed to participate in the conversation. City officials and service managers were purposively selected each quarter so that the appropriate officers overseeing each issue were briefed and then asked to comment. Journey maps described each neighborhood with key issues, local sources of pollution (household, vehicular, industrial, or commercial source), direct observation by CAGs captured in pictures, data from sensors, variations due to weather conditions or social and cultural events, and quotes from respondents. Information on actions taken by CAGs to increase public awareness was also included. These journey maps were intended to socialize information with the community, get their feedback, and increase awareness about air quality. CAGs also shared information with local government officials including zonal municipal officers, transport officials, and traffic police, and with community leaders. On a few occasions, city government leaders (such as the CEO of ISCDL) attended review meetings where measures that city authorities should take were discussed and decisions were made. Additional analysis across these journey maps was done by type of site, e.g., residential, commercial, industrial, and traffic congestion points. This was done to summarize information on some research questions and understand any themes that might emerge from these site types that could inform broader city planning.

Results

Results are organized by research question, synthesizing across data streams to give an accurate picture of what we were able to learn from the study.

1. How have LCS been used by low-income communities in Indore to effectively monitor air quality in their neighborhood?

BHC found that in general, the participating communities were interested in, and accepting of, the sensors and the CAGs, particularly in the residential areas. At the beginning, a few CAGs in the commercial and industrial areas noted that there was some hesitancy/confusion about the purpose of the sensors. One way that CAGs were able to overcome this hesitation was to begin the practice of color coding the data and sharing it with people on a regular basis. One resident of MY Hospital campus said, "It is easy to differentiate and understand the air quality with color zones." A shopkeeper living close to Gangwal bus stand said, "I am surprised to see that most of the air quality readings are in red zone and pollution level remains high during the days of festival and other special occasions of the city." Citizens cooperated extensively during the study, though initially there was hesitancy to reveal their personal information. All CAGs were given a photo ID signed by the ISSW Principal and BHC Project Officer, which helped to facilitate introductions of CAGs to the citizens. Initially, they enquired about the purpose of installing sensors, but when CAGs explained their utility in measuring air quality, they were generally receptive.

Another issue was that at first some community members were confused about what constituted air pollution, which led to them to think the sensor readings were not correct. In addition, some citizens mentioned that foul smell is a sign of air pollution or that only a haze means poor air quality.

One consideration for use of LCS in these communities is where to install them, and who makes that decision. BHC negotiated placement with the city officials, and they wanted to spread the LCS around multiple neighborhood types. The Skymet guidelines indicated that the sensors needed to be placed about 2 meters above the nearest horizontal obstruction (e.g., a rooftop) and at least 20 meters from trees, walls, or other obstructions. Ideally, the inlet of the sensor should be unobstructed for 360 degrees around it, but some situations, such as pole mounting, prevented this. In these situations, unobstructed airflow for 270 degrees around the inlet is acceptable if the unobstructed direction is in the direction of the prevailing wind. BHC was able to identify appropriate sites meeting these technical parameters within neighborhoods identified in consultation with senior city officers.

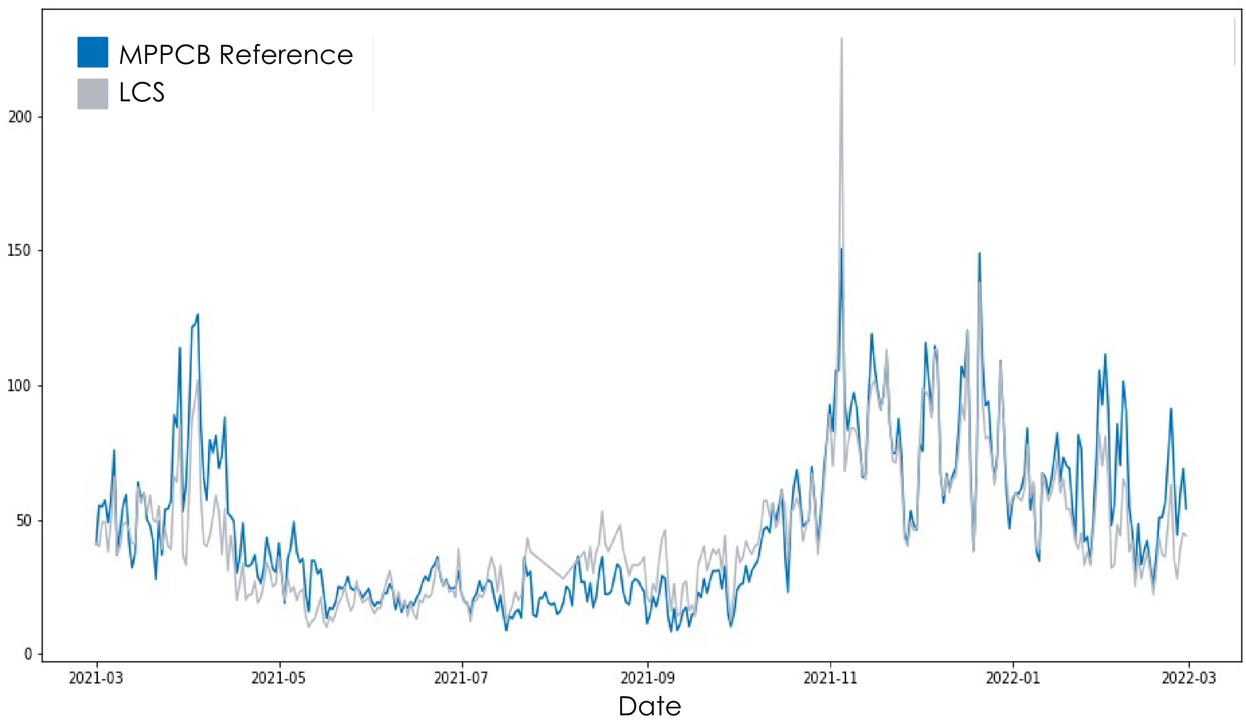
Functionally, once collocation was completed the LCS worked well for these local settings. Table 1 shows that performance assessments of the Skymet LCS relative to the MPPCB's reference instrument at Chhoti Gwaltoli indicated the LCS met or exceeded the U.S. Environmental Protection Agency's (EPA) performance targets for air sensors.

Table 1. Value from Collocation MPPCB Site versus EPA Target Value

U.S. EPA metric	EPA target value	Value from MPPCB collocation site (Chhoti Gwaltoli)	Result
Bias slope	1.0 ± 0.35	0.85	✓ Meets target
Intercept (b)	$-5 \leq b \leq 5$ µg/m^3	+4.55 ug/m^3	✓ Meets target
Linearity coefficient of determination (R^2)	> 0.70	0.85	✓ Meets target
Normalized root mean square error	<30%	27%	✓ Meets target
Data completeness	>75%	93%	✓ Meets target

Figure 6 shows a time series of daily $PM_{2.5}$ concentrations collected by the LCS collocated with the MPPCB reference instrument for the one-year measurement period. It shows that the LCS followed the general trend of $PM_{2.5}$. Higher values of $PM_{2.5}$ that occurred in April and November 2021 were recorded both by the MPPCB reference instrument and the LCS. This matched with qualitative information from the CAGs mentioning a higher number of deaths—leading to more cremations—during the second wave of the COVID-19 pandemic in April 2021 and the use of firecrackers during the Diwali festival in November of that same year.

Figure 6. Daily Average $PM_{2.5}$ from LCS and MPPCB Reference during the Study Period



There were some gaps in the continuous data in 8 out of 19 LCS, due to technical reasons such as malfunctioning SIM cards and Wi-Fi connectivity. Skymet provided support to get each LCS back online as quickly as possible when errors occurred. BHC aimed to have two sets of data: one set reported via Wi-Fi and the other a handwritten record from the CAGs. Annex 6 (see Annex Supplement) shows the data collection sheet used by CAGs to record PM levels. In analysis of the paper records, there were some cases where the CAGs captured data not recorded through the automated system, but only about one percent of the data for the high missingness neighborhoods were recovered through imputation from these paper data sheets. This is because most CAGs read the PM values off their phones rather than off the sensors, and this method still relied on the Wi-Fi connectivity of the device. The study team did a data quality check of the first 10 days of each month for approximately 60 percent of the paper records against the automated sensor dataset. On average, the CAGs had accurately reported their data 80 percent of the time; two CAGs in particular had issues with record keeping, which dropped the overall average by about 6 percentage points. Other mismatches were by one or two points, or was due to the additional data recorded by the CAGs that was not reported into the main database due to connectivity issues; adjusting for these situations improved the match rate an additional 3 percentage points.

As a cadre, the CAGs appeared to provide a useful service. Based on $PM_{2.5}$ levels, CAGs prepared color-coded charts to illustrate the air quality for each day of the month, with examples shown in Figures 4 and 5 above, and in Annex 6 (see Annex Supplement). They also described variations due to climate conditions, festivals, and ceremonies. Community members were able to understand air quality better using color-coded charts rather than numeric values. CAGs used these charts in group sessions with community members and during public awareness campaigns.

In the monthly review meetings with BHC, CAGs were asked to describe the effectiveness of the methods used to improve public awareness of sources and mitigation of air pollution. CAGs found group discussions better than one-on-one communication as these led to more interaction and questions related to sources of pollutants, health hazards, and measures to reduce them. They found public awareness rallies to be useful but also suggested other ways of communication including: banners/billboards at public places; mass media (newspaper or television); informative animation videos; jingles played by garbage collection vehicles; social media; street plays; educating students through quizzes or poster competitions; organizing marathons/cyclothons; and educational messages on MPPCB information panels.

2. Did these data make any difference in the knowledge, attitudes, and/or practices relating to air pollution creation or avoidance, first in the CAGs, and then in their communities?

CAG Knowledge, Attitudes, and Practices

Across the data collected for this study, there was evidence that both the CAGs and citizens gained knowledge about air pollution and air quality in their neighborhood.

Comparison of CAG pre-test and post-test knowledge scores showed that the percentage of CAGs scoring increased from 9 to 65 percent (Table 2). Overall, 84 percent of all CAGs across the study period improved on their test scores from pre- to post-training. The average knowledge score increased from 68 to 86 percent after training ($P<0.05$). We observed improvement in responses to all questions except question 10, which asked CAGs to identify the best visualization (graph) to depict changes in air quality over time. That said, as described elsewhere in this report, CAGs developed a very reader-friendly data visualization tool in the color-coded wheel, showing good data literacy and comprehension. While more than 80 percent of CAGs gave correct answers to most questions after training, only about half of the CAGs gave the correct answer to question five, even after training. This True or False question was, "Air inside a home is never as polluted as air outside a home" (the correct answer is False).

Table 2: Distribution of CAGs Based on Pre- and Post-training Assessment

Number of correct answers	≤5 (poor)	6-8 (fair)	9-10 (good)
CAGs (pre-training)	26%	65%	9%
CAGs (post-training)	4%	30%	65%

The monthly meetings that BHC held with CAGs also provided insights into their changing perspectives. In one meeting, CAG Pooja Raghuvanshi mentioned, "I get goosebumps when I think [of the] damage caused by the present air condition." Vani Joshi, CAG for the air sensor placed at the Gangwal bus stand, mentioned that she learned about the composition of air pollutants and that dust, which she encounters daily, contributes to air pollution. With data from her sensor, Vani is able to "compare the data from days with more traffic to days when there was less traffic and show community members how stark the difference is." Vani said, "though [community members] were not able to understand the technical terms, they still got the idea that their practices directly impact the air quality in their area."

Community Survey

The community survey provided evidence on changes in general citizen knowledge and attitudes between the beginning and end of the study. Recognizing that the final sample was not truly random, we did not run statistical comparisons, but the results can still be considered as part of the full set of evidence for this study.

In round 1 of the survey, the sample was 57 percent male; in round 2 it was 56 percent. The percent of respondents living in their settlements for more than 5 years was 91 percent in round 1, and 92 percent in round 2. The average length of residence was 20 years; only about 3-4 percent had been there less than 1 year. When asked to rate the place where they lived, 58 percent in round 1 and 57 percent in round 2 described it as good; 3 percent in both rounds considered it poor. Only 6-10 percent of residents across both rounds thought of moving out of their settlement.

Additional results from both rounds of the community survey are detailed below.

Knowledge

In both rounds, respondents thought air pollution was generally worse in the summer and winter. This does not match $PM_{2.5}$ readings; as shown in Figure 14 on page 23, the fall had the highest average $PM_{2.5}$ readings, followed by winter and spring.

More than 60 percent of respondents in both rounds thought of air pollution as heavy dust around them. Forty-nine percent (round 1) and 38 percent (round 2) thought of air pollution as a bad smell, and 29 percent (round 1) and 23 percent (round 2) thought it was a heavy fog. This opinion did not change much over time.

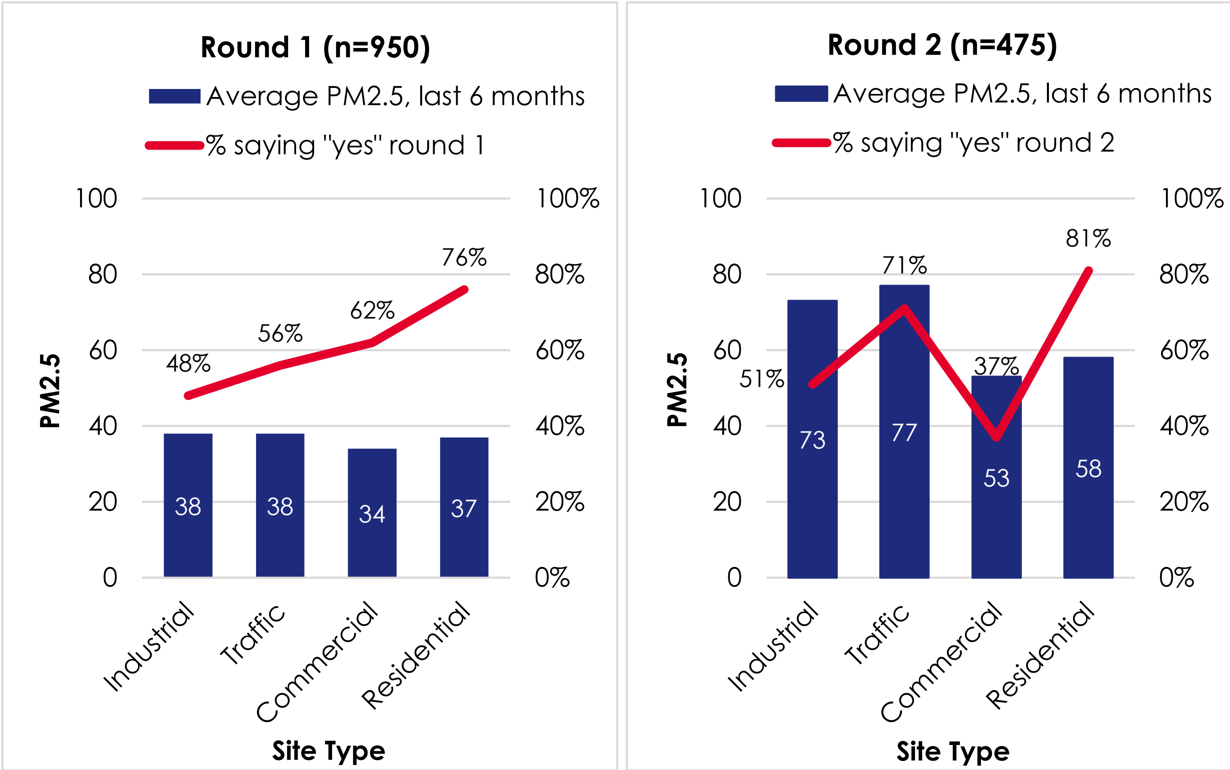
The average ranking of air pollution as a serious issue hovered in the middle of the scale for both rounds (Table 3). These rankings were not related to the average actual amount of air pollution in round 1 but did seem to align somewhat more to actual pollution levels in round 2.

Table 3. In your opinion, how serious is the problem of air pollution? (N=950)

	Round 1	Round 2
Level of air pollution (annual average)	Average ranking of air pollution (1 = not a serious issue; 5 = a very serious issue)	
Below 40ug	2.6	2.8
40-49 ug	2.6	3.2
50 ug and above	2.5	3.2
Total	**2.5**	**3.2**

When asked if they thought there was air pollution in their community any time during the year, residents differed in their opinion by type of neighborhood (Figure 7). When compared to the average $PM_{2.5}$ levels in the six months before the survey, there was somewhat better correlation between opinions and actual readings in round 2. However, residential areas always had a higher perception of air pollution than other groups, regardless of actual air quality.

Figure 7. In your opinion, is there air pollution in your community?



Perception of Air Quality

When asked if pollution bothers them, most said it was somewhat of a bother, but very few said they were highly bothered (Table 4).

Table 4. If you think there is air pollution in your community any time during the year, does it bother you?

	Not bothered	Somewhat bothered	Highly bothered
Round 1	39%	53%	8%
Round 2	31%	62%	7%

When we look at this by level of actual $PM_{2.5}$ pollution (Table 5), there is a pattern of greater concern (percent saying "yes") with greater pollution. However, the level of "bother" does not follow the same pattern.

Table 5. Does air pollution bother you? If so, how much?

Level of air pollution (annual average)	Percent saying yes	Percent somewhat/ highly bothered	Percent saying yes	Percent somewhat/ highly bothered
	Round 1		Round 2	
Below 40ug	53%	50%	46%	62%
40-49 ug	60%	46%	55%	60%
50 ug and above	61%	62%	66%	41%

In total, 66 percent of respondents thought efforts were being made to change air quality in round 1, while nearly 80 percent thought the same in round 2 (Table 6). In nearly all site types, a greater percentage of people thought this was true in the second round than the first, except for those in commercial areas; here the number of people that perceived changes in air quality decreased by nearly 10 percentage points in the second round.

Table 6. Do you think efforts are being made to change air quality?

Site type	Percent saying yes	Percent saying yes
	Round 1 (N=950)	Round 2 (N=475)
Residential	57%	82%
Commercial	74%	65%
Industrial	75%	95%
Traffic	61%	77%
Total	**66%**	**79%**

<u>Knowledge and Perception of Health Effects of Pollution</u>

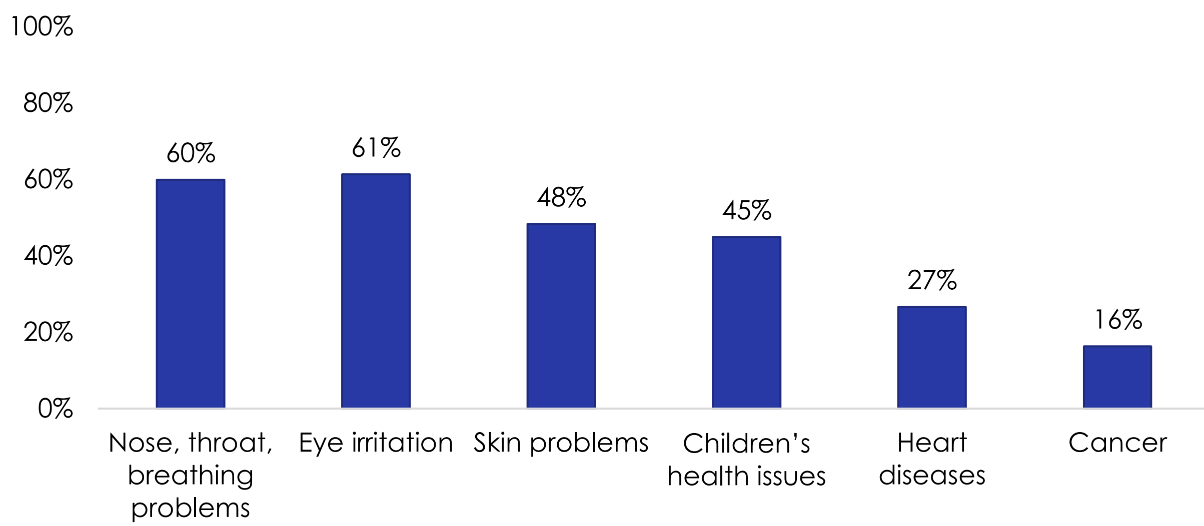
Most of the respondents (92 percent) in round 1 thought air pollution had an adverse effect on health (Table 7). This dropped to 78 percent in the second round, which is surprising given the addition of frontline health workers to the round 2 sample. Disaggregating by actual air quality did not explain this change.

Table 7. In your opinion, does air pollution adversely affect health?

Level of air pollution (annual average)	Percent saying yes	Percent saying yes
	Round 1 (N=950)	Round 2 (N=475)
Below 40ug	100%	58%
40-49 ug	83%	70%
50 ug and above	97%	88%
Total	**92%**	**78%**

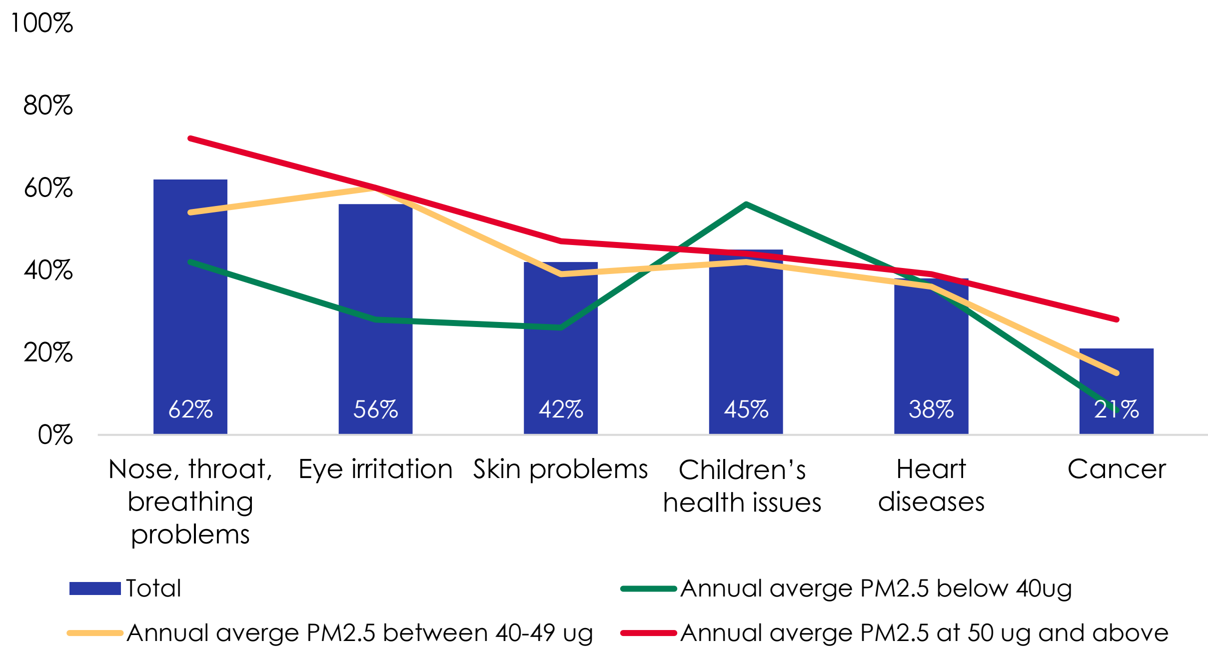
In the first round, most respondents knew that air pollution could cause nose, throat, and breathing problems or eye irritation. Less than 50 percent knew that it could also cause other health issues (Figure 8).

Figure 8. What health problems can arise from air pollution? (Round 1, N=950)



In round 2, 20 percent of respondents mentioned that their health problems not related to COVID-19 had increased over the last year, while 47 percent said they had decreased; the remainder had no change. As seen in Figure 9, the most common health issues experienced in the last year (January 2021-January 2022) were nose, throat, and breathing problems (62 percent), eye irritation (56 percent), and children's health issues (45 percent). There were higher rates of nose, throat, and breathing problems, eye irritation, skin issues, and cancer in the areas with higher $PM_{2.5}$ values.

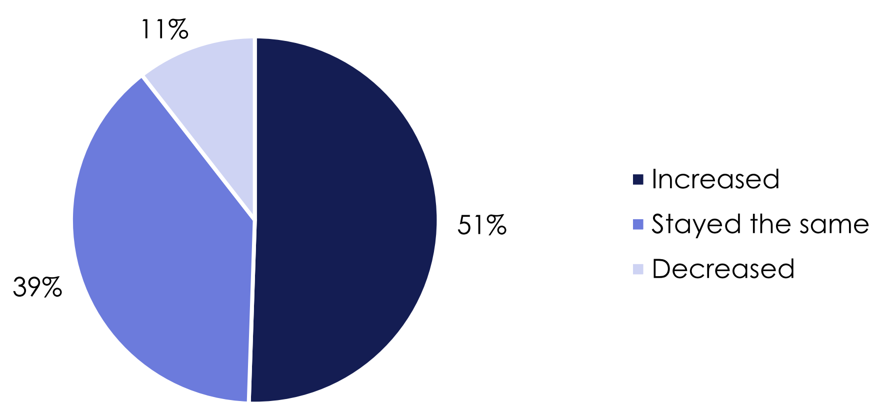
Figure 9. Have you or your household family members experienced any of the following (non-COVID related) health problems in the last year? (Round 2, N=475)



Practices

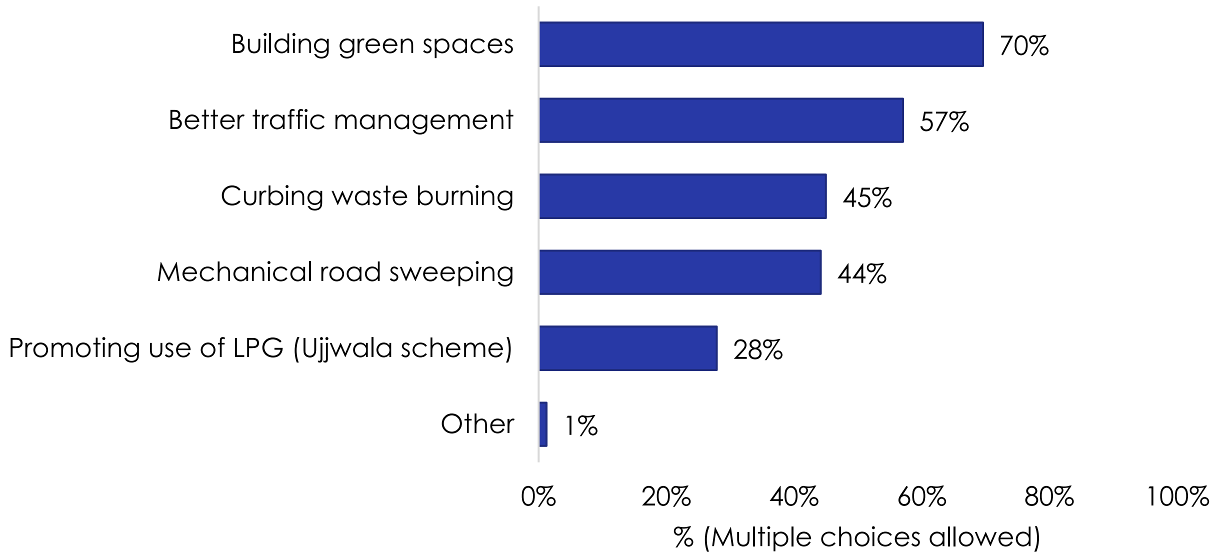
We saw some promising results around changing practices in the second round of the survey. When asked if citizens saw any greater efforts to control air pollution since January 2021 (near the start of the study), 51 percent said they did see an increase (Figure 10). Only 11 percent thought efforts had decreased, and 70 percent of those who answered as such were located in four neighborhoods: ISCDL office campus, Amar Tekri Anganwadi center, Narwhal primary school, and the Gangwal bus stand.

Figure 10. Since January 2021, what change have you observed in efforts to control air pollution? (Round 2, N=450)



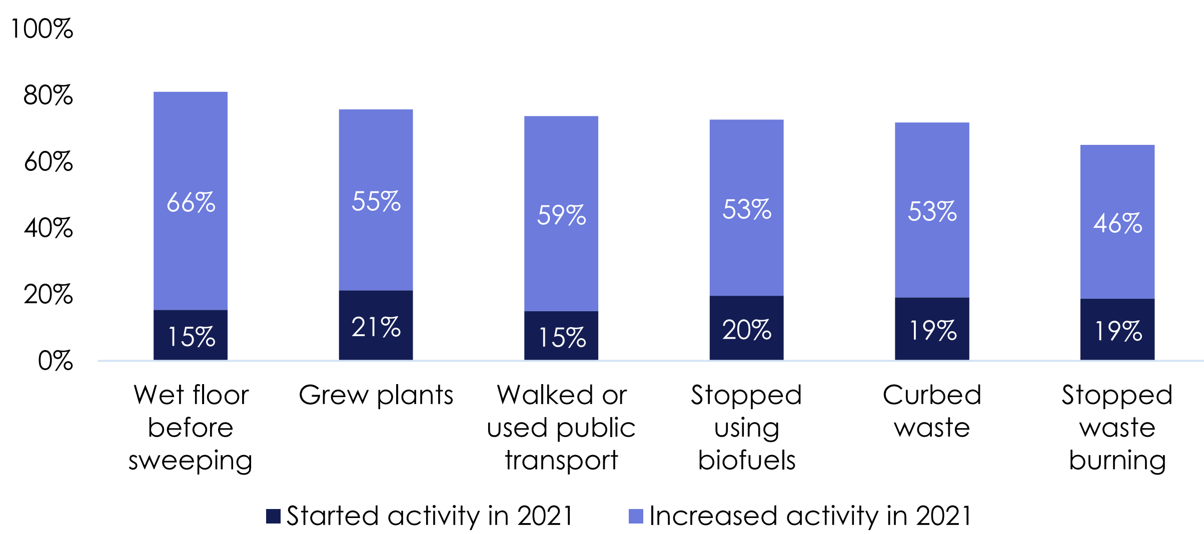
Among those who said that efforts had increased (N=240), nearly 70 percent said those efforts included building green spaces (Figure 11). The next most common answer was better traffic management, followed by curbing waste burning, sweeping of roads, and promotion of liquefied petroleum gas (LPG) through the Ujjwala scheme.

Figure 11. What efforts are being made to control air pollution? (Round 2, N=240)



In the second round, the community members were asked whether in 2021 they had started or increased activities that affect air quality. Nearly a quarter (15-21percent) of respondents had started various activities, and 46-66 percent had increased these activities (Figure 12).

Figure 12. Measures Initiated or Increased by Citizens during the Year 2021 to Control Air Pollution (round 2, N=450)



Through journey mapping and direct observation, the CAGs observed that the community members adopted many practices that could reduce air pollution. Across the 19 active study sites:

- **Four CAGs saw reductions in use of biofuels for cooking/warming.** CAGs located in a famous food street (56 Dukaan) worked with management of the association of food handlers to stop the use of biofuels in the street.
- **Nine CAGs saw and heard about reductions in burning of waste.** In Luniyapura and Narwal, Sanwer Road, residents burned waste because the lanes were too narrow for municipal vehicles to travel through to collect garbage. CAGs conducted awareness activities, and the amount of burned waste decreased.
- **Eleven CAGs participated in activities to get more people to switch off vehicle engines at red lights and encourage green transport.** The CAG in Palasia Square successfully encouraged his friends and community members to ride bicycles after concluding that vehicle traffic was the major source of air pollution in his locality. The CAG in Gangwal bus stand worked with bus stand authorities and drivers to get them to turn the bus engine off while waiting for commuters.
- **Six CAGs conducted tree-planting activities.** In Reti Mandi, the CAG distributed 25 free tree saplings to community members to encourage planting.

Advocacy by CAGs also led to government authorities taking some measures, which are described in results section 4.

3. Have the LCS been effective in identifying locations with higher pollution across the city and potentially identifying sources of air pollutants? How does the air quality data lead to action by CAGs or the community?

Formal source apportionment studies are effective at identifying sources of pollution, but can be expensive and time consuming. One question this study aimed to answer was how much information on sources of pollution can be gleaned by triangulating data from LCS, community members who live in those environments, and visual observations by the CAGs.

As a first step, we analyzed the sensor data to get a better understanding of patterns of air quality across the study sites to understand variations due to weather, time, type of site, and events that could deteriorate air quality. Figure 13 shows average diurnal variation (cumulative hourly $PM_{2.5}$ data for 24 hours) across the city. Diurnal variation suggested lower $PM_{2.5}$ during the day in all types of sites due to atmospheric mixing. Air quality worsened from the evening onward and $PM_{2.5}$ remained high during the nighttime. This may be due to waste burning (e.g., tires in industrial areas are burnt at night to escape penalties), cooking (e.g., more consumers in food streets including Sarafa night bazaar), and lower temperature leading to inversion, which traps pollutants near the ground. The industrial and traffic sites were higher at night than the residential (informal settlement) and commercial sites. One exception was that the residential (informal settlement) sites had high $PM_{2.5}$ during the evening hours, which likely was the result of cooking.

Figure 13. Diurnal Variation in Average Concentration of $PM_{2.5}$ by Type of LCS Site

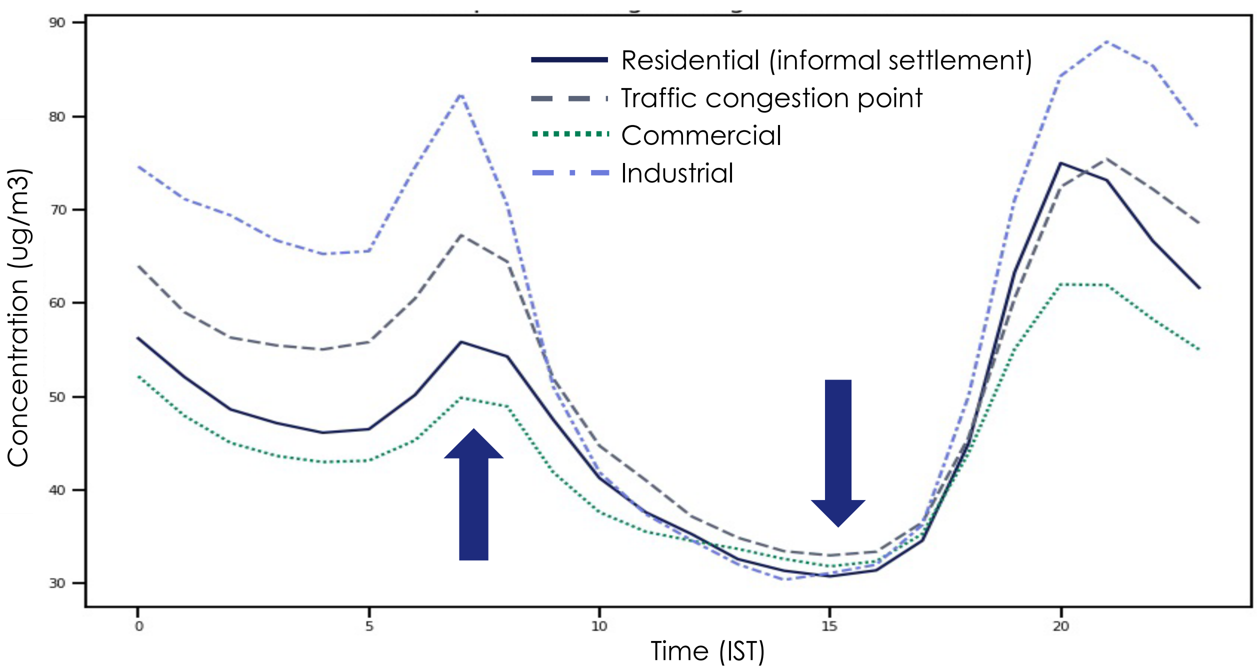


Figure 14. Average Daily Concentration of $PM_{2.5}$ by Type of LCS Site

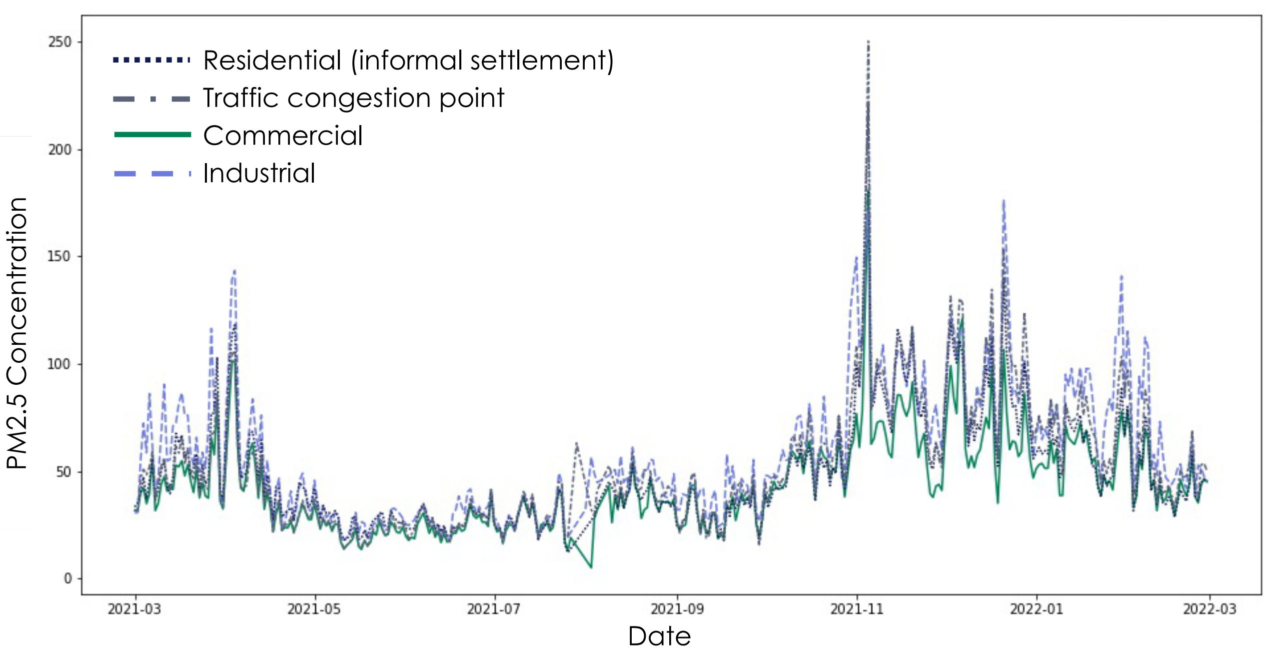


Figure 14 shows that $PM_{2.5}$ levels were higher in winter (November-March) as compared to summer (May-June) and the rainy season (July-September). Even in the winter months, residential sites showed lower $PM_{2.5}$ levels compared to industrial areas and traffic congestion points.

Figure 15 summarizes all the data and indicates that the industrial and traffic sites were 12 and 23 percent higher on average than the residential (informal settlement) sites.

Figure 15. Summary of $PM_{2.5}$ Concentrations by Type of LCS Site

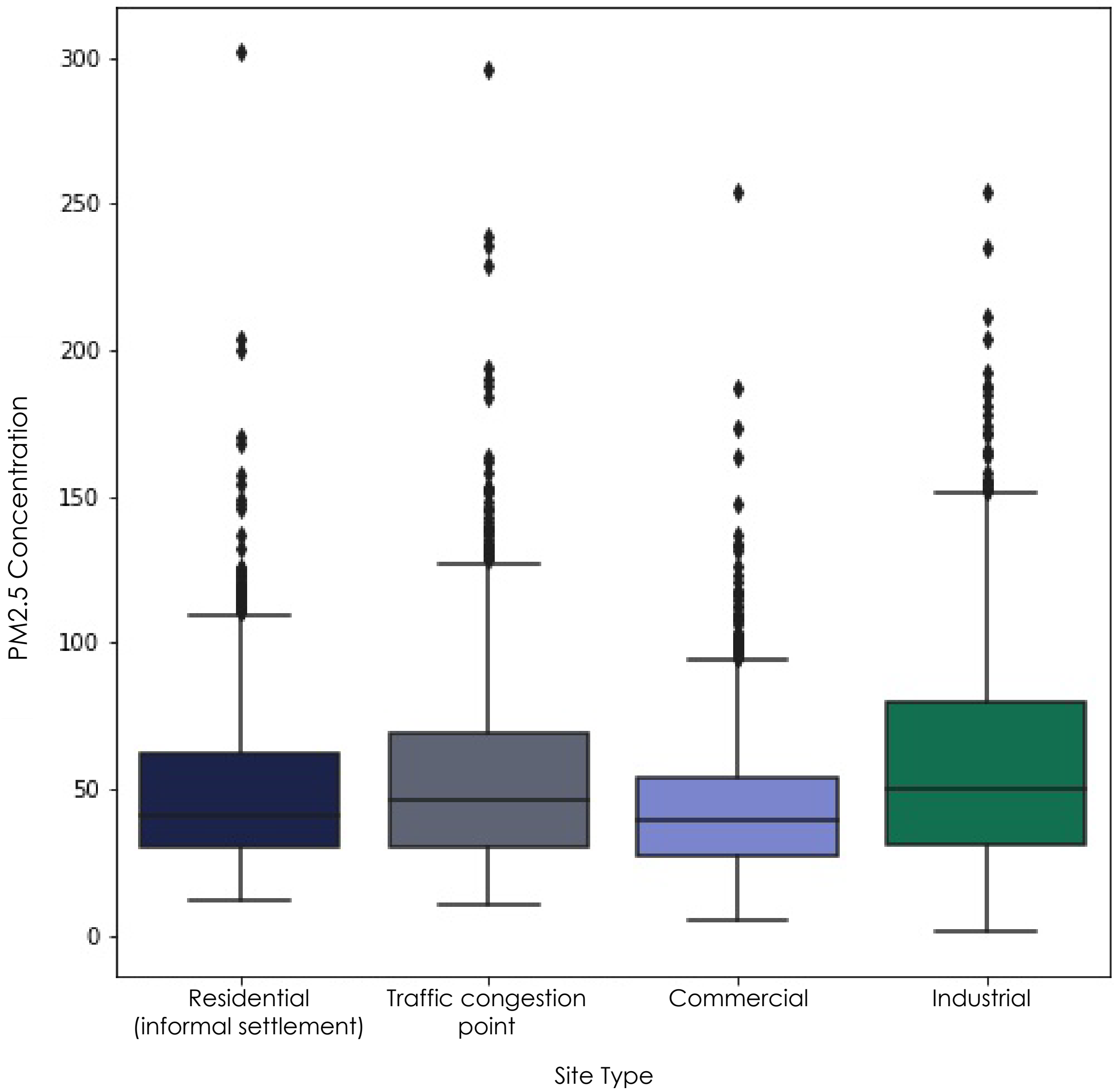
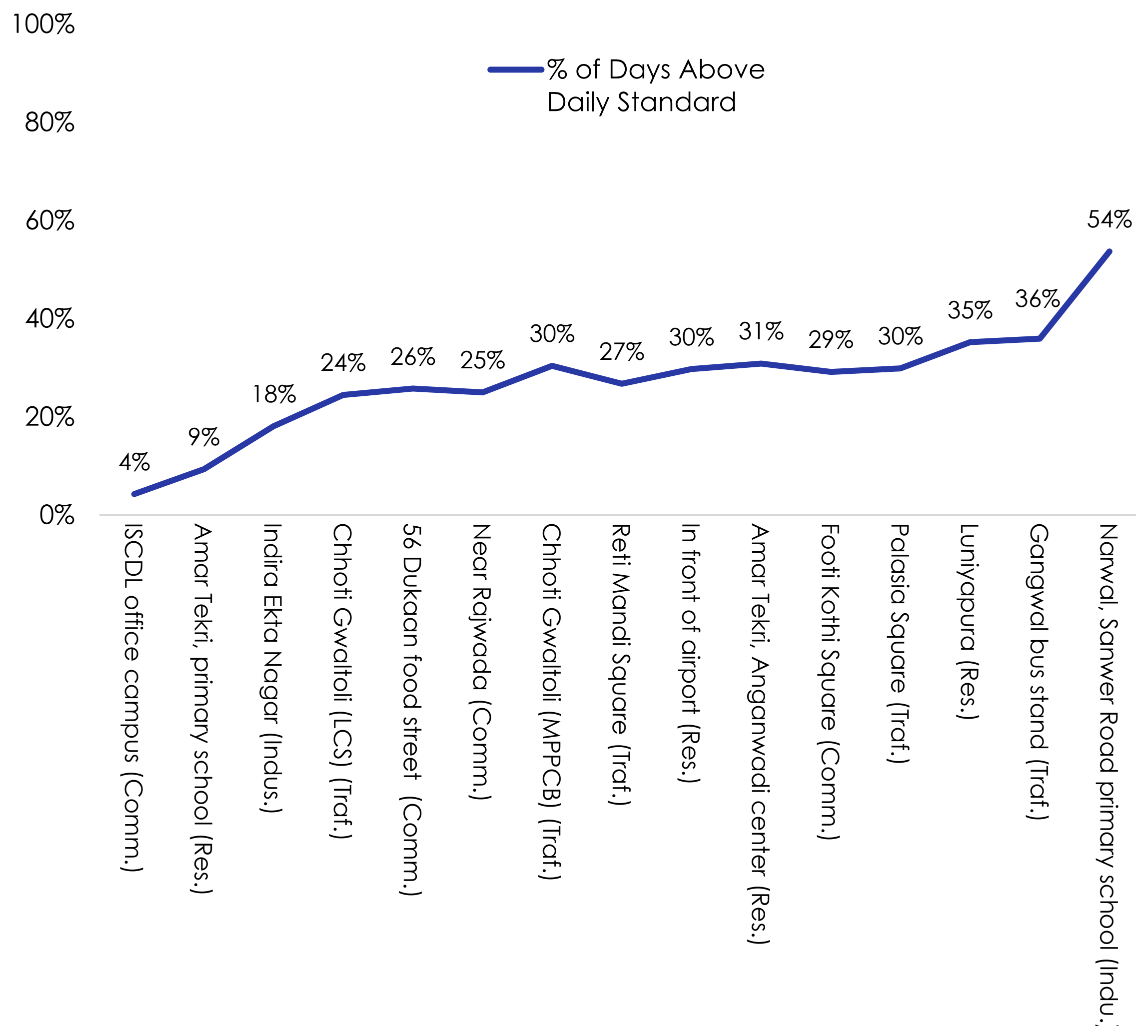


Figure 16 indicates that sites close to industrial zones and traffic congestion points had more days with moderate to very poor air quality. On average, those living at the study sites spent 30 percent of their days at or above the Indian national daily threshold for air quality.

Figure 16. Percent of Days above the Daily Indian National Air Quality Standard, by Location



Irrespective of seasonal variations, the industrial sites generally had a higher concentration of $PM_{2.5}$, whereas commercial sites had lower concentrations. This did generally align with the community perceptions of air quality in these sites. There were more outliers (high values) in sites in informal settlement areas, showing wider variation in air quality.

The community survey also provided data on perceived sources of pollution. About half of those in traffic areas perceived vehicular emissions as the biggest source of pollution in the first round, while in the second round 75 percent of respondents named that as a main source. In industrial areas, during the first round of data collection most respondents cited burning of waste as the biggest source (61 percent). By the second round, the most common choices were vehicular emissions (58 percent) and emissions from industry (57 percent). Vehicular emissions were the most common choice for both rounds in the residential areas, and in the first round in the commercial areas.

Figure 17. Perceived Sources of Air Pollution

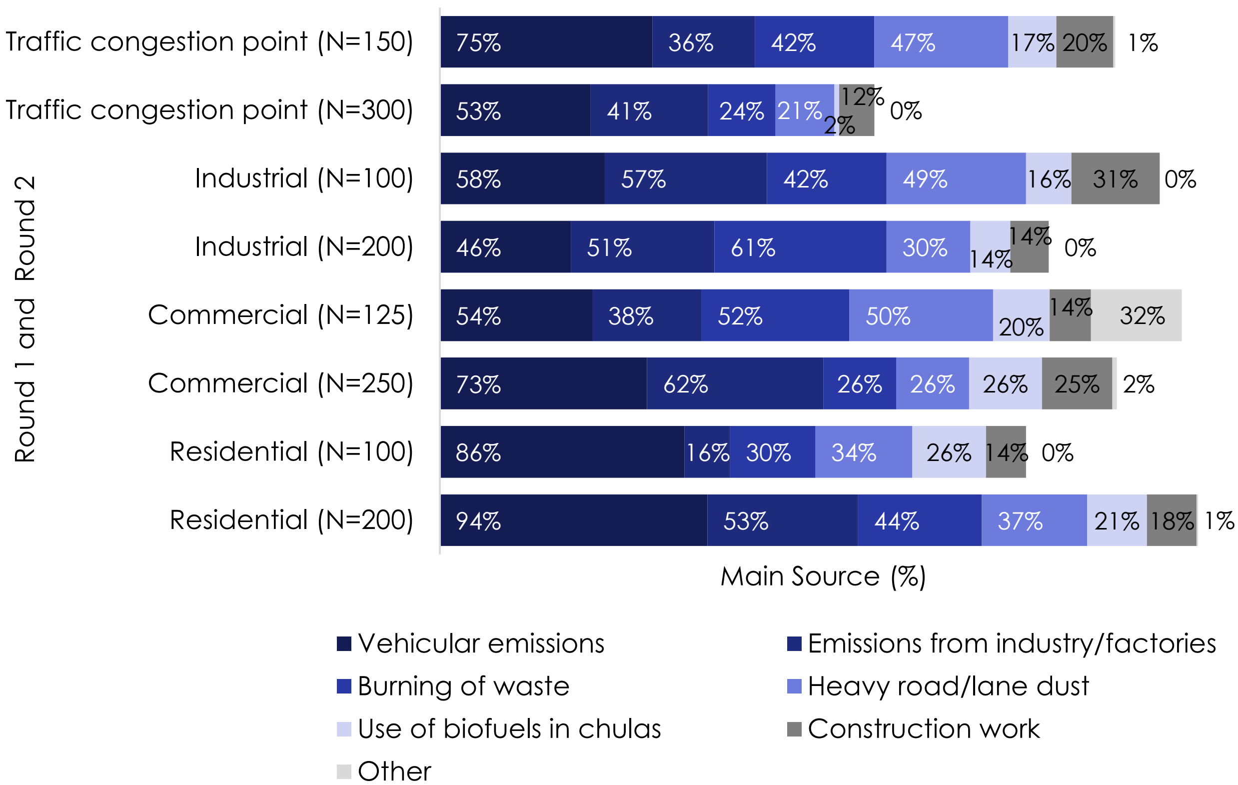


Table 8 shows a comparison of the main sources identified by our qualitative and quantitative data. Based on this, the results from the first round of community data generally aligned with the sources identified by the qualitative observations. This should still be verified externally but could provide useful ground level information to help with source identification.

Table 8: Primary Sources of Air Pollution based on Community Survey and Observations Made by CAGs

Site	Observed primary sources (journey maps)	Survey round 1 primary sources (at or above 50%)
Pipliyahana Square	Dust from construction/industrial sites, vehicles	Vehicles, industry
Luniyapura	Crematorium, vehicles, waste burning	Vehicles, road dust
Reti Mandi Square	Trucks ferrying sand, waste burning	Vehicles

M.Y. Teaching Hospital campus	Vehicles, debris/dust from demolition sites	Vehicles, road dust
Gangwal bus stand	Vehicles	Vehicles
Palasia Square	Biofuels, waste burning	Construction
Amar Tekri, primary school	Vehicles	Vehicles, industry
Amar Tekri, Anganwadi center	Use of repellant coils	Vehicles
Narwal, Sanwer Road, Anganwadi center	Industry, waste burning	Waste burning, road dust, vehicles
In front of airport (Panchsheel Nagar)	Vehicles	Vehicles, industry, waste burning, road dust
Indira Ekta Nagar	Industry processing pulses, waste burning	Industry
Footi Kothi Square	Vehicles	Vehicles
ISCDL office campus	Waste burning	Industry
56 Dukaan food street	Use of biofuels	Vehicles, industry
Near Rajwada	Vehicles, road construction	All categories; vehicles and industry both 96%
Chhoti Gwaltoli DIG office*	Waste burning (old tires)	Industry
IPCA, industrial area	Waste burning, use of large generators	Waste burning
Narwal, Sanwer Road, primary school	Industry, vehicles	Industry, vehicles, waste burning
Navlakha Square	Vehicles	Industry, waste burning

While these data are helpful, it is important to note what functions these data cannot perform. One is to identify a specific causal link between a particular source and the air quality readings in the sensors. In addition, because the sensors only read PM data, other types of pollution will be missed. This may affect industrial areas in particular, where sulfur dioxide and nitrogen dioxide are more prevalent pollutants. As of the writing of this report, LCS are still not equipped to measure these pollutants.

Beyond sources, these data helped to identify events that may trigger poor air quality. Spot air quality index (AQI) maps were used to illustrate variation across sites and the impact of specific events on air quality. For example, during the Diwali festival on November 4-5, 2021, all sites recorded poor air quality (Figure 18). However, we observed rapid improvement within a few days.

May 11, 2021 was recorded as the cleanest day, with all sites were in the green zone, indicating good to satisfactory air quality. Outside of the Diwali festival, December 22, 2021 was the most polluted day as none of the sites were in the green zone (Figure 19). During discussions about journey maps, CAGs mentioned that air quality worsens during other festivals besides Diwali, including Holika Dahan, Navratra, Dusshara, Eid, and other ceremonies like marriages.

Figure 18. AQI Maps Depicting Air Quality Levels During Diwali Festival

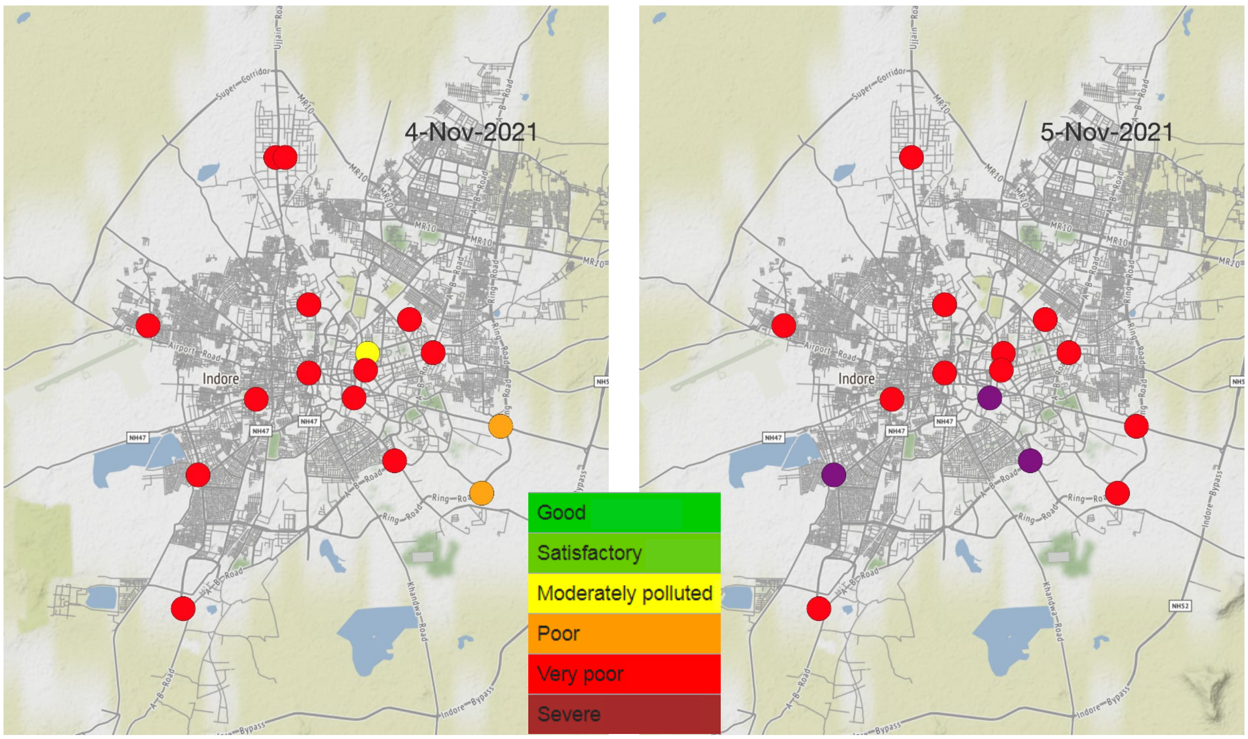
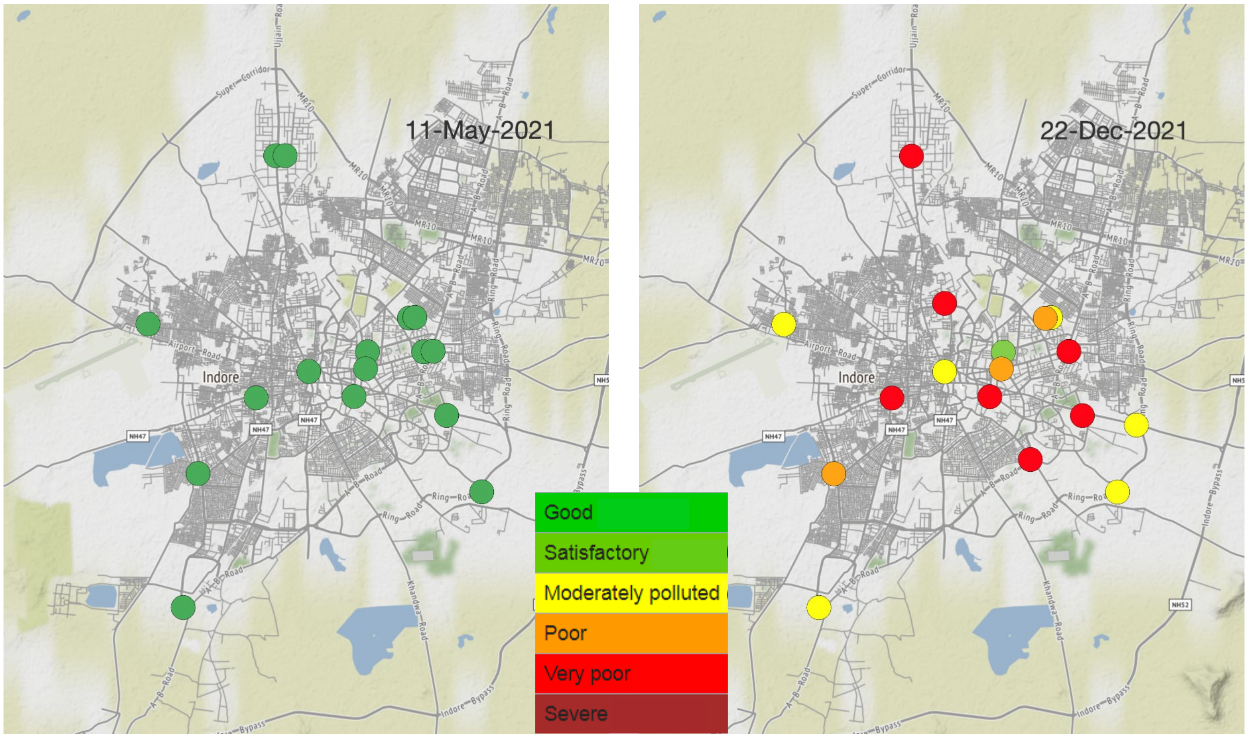


*Figure 19. AQI Maps Depicting the Cleanest and the Most Polluted Day**



*Excluding Diwali

4. Have the sensor data been accepted by the official groups as valid and relevant? How does the air quality data lead to action by the government?

As noted under the first research question, the LCS data passed all relevant checks on quality and completeness needed for ISCDL. The BHC team had several meetings with the MPPCB officials since the inception of the project. MPPCB shared city data generated from MPPCB equipment on air pollutants from previous years that were analyzed to study trends of air quality before and during the project period. MPPCB follows guidelines from the Central Pollution Control Board (CPCB) and had some reservations about using data from unofficial sensors. However, the CEO of ISCDL was convinced that data from LCS could be used to identify and address local sources of air pollution in selected communities, industrial and commercial areas, and traffic congestion points.

The ISCDL Board of Directors approved this study and therefore Indore Municipal Corporation (IMC) and ISCDL were supportive of the use of the LCS for the study. Based on the strength of the study results, ISCDL agreed in August 2021 to integrate the real time LCS data in their Integrated Command Control Center dashboard, and make these data accessible to the public.

The air quality data, along with the qualitative data and advocacy from the CAGs, led to interesting increases in action for air quality by the government. CAGs used the LCS data during discussions on the air quality situation and related issues with government officials and other stakeholders. Some of the important issues discussed by CAGs with government authorities included:

1. **Reducing burning of waste by community and/or IMC workers.** CAGs observed this issue in Luniyapura, Palasia Square, Indira Ekta Nagar, Narwal Sanwer Road, Reti Mandi Square, and Chhoti Gwaltoli, especially the burning of tires. In addition, although the city uses mechanical sweeping of major roads, there are narrow lanes where manual sweeping by sanitary workers continues. The workers would then burn the dry waste in the neighborhood. Following interactions with CAGs, the city authorities banned the burning of waste and advised sprinkling water before sweeping lanes to reduce road dust.

2. **Use of electric crematorium.** Luniyapura is located close to a crematorium, which has facilities for traditional cremation using wood, as well as an electric crematorium. Due to traditional rituals and beliefs, community members mainly use wood for cremation. CAGs took up this issue with the authorities to promote the use of the electric crematorium, though the response was lukewarm. Further work will be needed on this issue.

3. **Better traffic management.** CAGs in Pipliyahana Square (during the weekly market), MY Teaching Hospital campus, and near Rajwada raised the issue of poor traffic management and parking of vehicles as key sources of air pollution. The city authorities took action to improve traffic flow, and earmarked parking spaces in some important marketplaces to reduce vehicle pollution.

4. **Compliance with guidelines at construction sites.** In Pipliyahana Square, construction of a big hotel and sports stadium did not comply with guidelines for reducing construction dust. The CAG in that location raised this issue with government authorities, who then ensured that the construction contractors began using wet green curtain sheets at these sites to trap dust particles. The CAG at MY Teaching Hospital campus reported dumping of debris and waste generated from demolition of old buildings on the campus. After repeated requests from the CAG, the hospital authorities took action and removed the debris from the campus. There is now also a citywide policy that a monetary fine will be imposed if waste is dumped at construction or other sites.

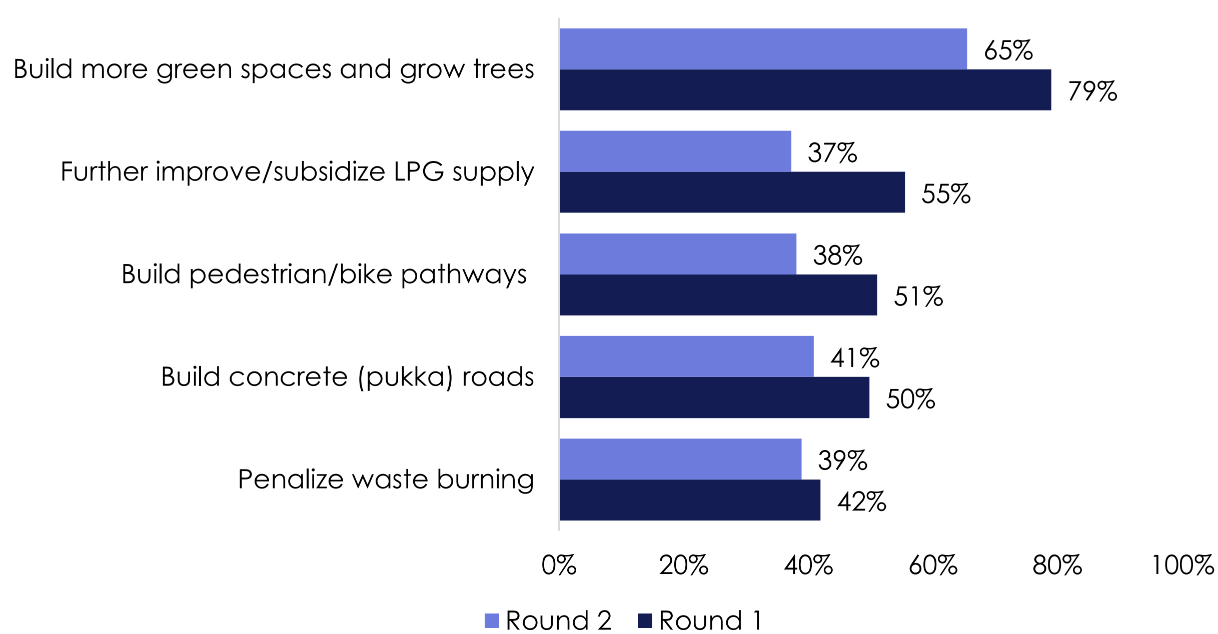
5. **Reducing vehicle pollution.** Running bus engines before departure from bus stands was a common problem in two major bus stands (Gangwal bus stand and Navlakha Square). CAGs met with bus stand officials and drivers of public buses and informed them about pollution caused by running the engines. The

situation has since improved. The city government and public worked together to start a major campaign to switch off vehicle engines at red lights.

6. **Reducing industrial pollution.** CAGs met with industry managers, environment officers, and safety officers to present issues faced by the industrial workers and the surrounding communities. Industrial leadership agreed to promote the use of public transport or biking for commuting to the workplace and also initiate tree planting to reduce pollution. A specific example in Indira Ekta Nagar is the CAG shared observations and sensor data that suggested a pulse processing factory nearby was emitting pollution. The self-help group in the community took up this issue and are now working with the owners of the factory to decrease emissions.

Further work is always needed to stay ahead of air pollution. In the community survey, respondents listed additional measures they would like to see the government enact to control air pollution. Building more green spaces and growing trees received the highest ranking in rounds 1 and 2 (79 and 66 percent respectively), followed by improving LPG supply, building pedestrian and bike pathways, and building more concrete roads/lanes. Respondents also suggested penalizing those who burn waste (38 percent in round 1 and 42 percent in round 2).

Figure 20. Additional Measures Required from the Government to Control Air Pollution



Discussion

This study adds to a small but growing body of evidence linking strategic community action to change in air and other types of pollution in urban settings. This type of work is not without its shortcomings, but can be a powerful, affordable way to expand the monitoring network for air pollution across cities, identify pollution sources that bother residents the most, mobilize residents and city authorities to act on pollution issues, and create citywide awareness of the issue.

This study has shown that LCS can produce data of acceptable quality for tracking $PM_{2.5}$, that CAGs can understand and use these data to mobilize their communities, and that communities can engage in and provide ideas for solutions to the sources of pollution they care about most. While we did not find an overall high level of concern about air quality in the community, we did see some correlations between the level of air pollution and concern, and some awareness of the relationship between air quality and health. Further work is needed to ensure residents (and in particular frontline health workers) are oriented to the dangers air pollution poses to health. The sources of pollution identified by this study should also be checked against more formal sourcing studies, while keeping in mind that this information represents those sources of most concern or that were most apparent at the community level.

Sharing community-based data with citizens is an important step in seeking their involvement in identifying and solving problems related to air pollution, but it is not the only step. It was critical to diversify the ways the community participated across the timeline of the study, including through the formal community survey interviews, informal group discussions, discourse with CAGs, and awareness rallies. As communities observed the benefits of such interventions in their environment and understood the relationship between air pollution and their health, their participation became more active and sustainable. In this way, the CAGs were catalysts in creating awareness, and identifying problems and solutions, and were able to use data to convince city authorities to implement appropriate solutions.

Indore has previously succeeded in implementing a community-based approach under *Swachh Bharat Abhiyan* (Clean India Mission), so this study did benefit from the established culture of active community engagement in the city. CAGs have become a valuable cadre for addressing air pollution in Indore. Similar participatory action research needs to be replicated not only in the area of air pollution, but also in other issues related to public health to test its value in effective implementation of healthy public policies.

There was special interest shown in this study by senior city officers including the District Collector, Indore Municipal Commissioner, CEO of ISCDL, and senior Traffic Police officers, many of whom participated in various CAG meetings and events. The CEO of ISCDL ensured that data from LCS were not only integrated with the Integrated Command Control Center, but were also made available to the public on the ISCDL website.

The CAGs have been welcomed by ISCDL as a helpful cadre, and IMC has now included air quality as one of the goals of its Clean India (Swachh Bharat) campaign for 2022-23. Two of the CAGs (Ms. Manjit Garg and Mr. Jugal Kishore Chauhan) were recognized with "air warrior" awards for their contributions, and seven CAGs were recognized with the MP Gaurav Ratna Samman award by Rashtriya Nari Sashaktikaran Sangh (National Women Empowerment Group). Another CAG, Ms. Puja Raghuvanshi, won first prize in a competition for a tagline for a Clean Air campaign.

Figure 21. Clean Air Guides Receiving Awards

Now that this study and the BHC project have ended in Indore, the LCS have been handed over to ISCDL. In order to sustain this work, ISCDL signed a memorandum of understanding with the Confederation of Indian Industries (CII). CII will continue our air quality approach of using LCS data in monitoring air quality, engaging community volunteers (now called Clean Air Champions) and expanding the network of LCS (30 more sensors were added by CII). In support of this, BHC also signed a memorandum of understanding with CII to share all data, job descriptions, and other technical information from this study. In addition, the USAID-funded Clean Air Catalyst project is also actively working in Indore to make Indore cleaner and greener, and will add three sensors of their own to the Indore context.

Limitations

This participatory action approach was different from a traditional academic study, and while it brought many benefits, it also had some shortcomings. While the CAGs were advised to follow a randomized design for the community survey, their comfort level during the COVID-19 time period and complications of the lockdowns meant the final survey sample was more of a convenience sampling. In future studies that have a survey component, it may be useful to either pair CAGs with official enumerators, or increase CAG training (and remuneration for such work) to ensure their comfort level with a more representative sample.

There were a few other issues encountered during the course of the study. The study period included a major second wave of the COVID-19 pandemic, which peaked in April/June 2021 and adversely affected or delayed some qualitative parts of the study, including in-person interviews, monthly CAG meetings, and group discussions with the community members. However, the study team and CAGs were able to modify and adjust to continue data collection, and as restrictions were lifted in the second half of 2021, the CAGs were able to return to the formal study structure.

There were also some technical problems with the LCS leading to gaps in recording data, but timely intervention and remedial action by Skymet reduced these gaps to the minimum possible. Finally, as previously noted, some CAG positions turned over during the study, and some CAGs were more successful than others at engaging the community. Future study of this work should include more measures of level of engagement to better understand the best uses of the CAG cadre.

Recommendations

The CAGs (now Clean Air Champions) should continue as a regular, paid cadre to help mobilize residents and city authorities toward clean air activities. In order to sustain them, the city will need to better understand what remuneration is needed, whether these would be part- or full-time positions, and how to retain their advocacy role within the community, even if they are being paid by the government.

Indore is taking the lead in adding clean air to its definition of a clean city. The National Clean India Mission should consider how to integrate data from LCS as part of their monitoring and evaluation framework for the Swachh Bharat campaign.

The current CPCB rules limit the ability of cities to use LCS for more widespread pollution control activities. Many major cities worldwide already allow for visualization of private LCS and official monitoring stations. CPCB should consider revising its guidance to allow for more integration of these two types of pollution data sources, while still fully acknowledging the official sensors as "gold standard" data.

Cities should consider how best to connect CAGs with frontline health workers including accredited social health activists, Anganwadi workers and auxiliary nurse midwives. This can also include coordination with Mahila Arogya Samiti under the National Urban Health Mission. While there should not be duplication of efforts, regular communication between CAGs and frontline health workers about poor air quality days is advised. A potential result of this communication is a local monitoring and alert system for groups most vulnerable to poor air quality, such as pregnant mothers, children under 5, and people with asthma, heart disease, and respiratory illnesses. This coordination could also inform a larger cross-city effort to develop automatic mechanisms to alert citizens when pollution levels rise.

Air quality data should be integrated into existing information systems and networks. In Indore, these data have already been incorporated in the Smart City Integrated Command and Control Centre. There are also potential benefits for the planning and prevention of illness when these data are integrated into selected health management information systems such as the Integrated Disease Surveillance Project and databases of NCDs and their risk factors.

Conclusions

Addressing air pollution is key to a healthy environment. It is heartening to observe that the Government of India's Clean India Mission has decided that in addition to solid and liquid waste management and other sanitation parameters, air quality is an important area of intervention. This study is an important step toward these new clean Indore air quality goals. We hope that continued engagement of the CAGs and expanding the LCS network will continue to help the Indore Municipal Commissioner and city authorities meet their new targets and keep air quality as a top priority area in 2022 and beyond.

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Annex List

The following annexes are available in a separate Annex Supplement:

Annex 1: Clean Air Guide Job Description

Annex 2: Low-cost Air Quality Sensor Installation Sites and Clean Air Guide Details

Annex 3: Clean Air Guide Knowledge Assessment Questionnaire

Annex 4: Questionnaires for Community Survey: Rounds 1 and 2

Annex 5: Clean Air Guide Journey Maps

Annex 6: Clean Air Guide Air Quality Data Collection Sheet, with Examples

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