J. Adv. Res. Alternative Energy, Environment and Ecology
Volume 5, Issue 4 - 2018, Pg. No. 23-28
Peer Reviewed Journal

Research Article

Reducing Air Pollution - Towards making Indore a Smart, Clean, and Healthy City

Damodar Bachani[1], Amanda Pomeroy Stevens[2], RK Gupta[3]

[1]Deputy Project Director, Building Healthy Cities Project, John Snow India Private Limited, New Delhi, India.
[2]Project Director, Building Healthy Cities Project, JSI Research & Training Institute, Inc., USA.
[3]Regional Officer, M.P. Pollution Control Board, Indore, Madhya Pradesh, India.
DOI: https://doi.org/10.24321/2455.3093.201804

Abstract

Introduction: The Government of India initiated the Smart City Mission in 2015 with the aim of comprehensive urban development for 100 cities. Swachh Bharat Mission was also launched nationwide in 2014 with the goal of advancing universal sanitation coverage. Indore was selected as a Smart City; it was also declared the cleanest city in India in 2017 and in 2018 under Swachh Bharat. Indore is also participating in the United States Agency for International Development (USAID) - funded Building Healthy Cities Project, with the objective of improving the health of the city environment. As part of that objective, a closer examination of air pollution levels was conducted.

Methodology: Annual average concentrations for sulphur dioxide, nitrogen oxides, and particulate matter ($PM_{2.5}$ and PM_{10}) from three air pollution measuring stations located in Indore's Polo Ground (industrial), Kothari Market (commercial), and Kanodia Road, Vijay Nagar (residential) were analysed for trends during the last five years (2013-2017). For 2017, month-wise data were analysed for seasonal variations.

Results: The annual average concentration of sulphur dioxide and nitrogen oxides did not change during the preceding five years. A declining trend was observed at all sites in concentration of PM_{10} from a range of 118-187 μg/m^3 in 2013 to 77-81 μg/m^3 in 2017. The $PM_{2.5}$ concentration was measured only since 2016; 2017 levels were less when compared to the preceding year. Lower values were observed during the rainy season (July to September) for all pollutants. It was observed that, during the period, declining trend for PM_{10}, various interventions were initiated in Indore, including night mechanical sweeping of city roads, free left loop roads to reduce traffic congestion, and an efficient systematic collection and disposal of solid waste.

Conclusion: Declining trends of air pollution in particulate matter in Indore is evident, possibly due to various measures taken by the Municipal Corporation and Indore Smart City Mission. Further analysis is needed to understand how these trends can be sustained and how they may impact the respiratory health of Indore citizens.

Keywords: Air pollution, Healthy city, Smart city

Introduction

Air pollution exposure is the second most important risk factor for ill health in South Asia, contributing to between 13 percent and 21.7 percent of all deaths and approximately 58 million disability adjusted life years (DALYs) due to chronic and acute respiratory and cardiovascular illnesses.[1] In 2015, particulate matter (PM) air pollution from several major sources was responsible for approximately 1.1 million deaths, or 10.6 percent of the total number of deaths in India.[2] High levels of PM effect both the environment and human health - very fine particles can penetrate the lungs, causing cardiovascular and neurological problems.[3] Ultrafine particles, measured as $PM_{2.5}$, are often cited as the primary cause of air pollution-related health issues.[4]

Corresponding Author: Dr. Damodar Bachani, Building Healthy Cities Project, John Snow India Private Limited, New Delhi, India.
E-mail Id: damodar_bachani@in.jsi.com
Orcid Id: https://orcid.org/0000-0001-5588-3929
How to cite this article: Bachani D, Stevens AP, Gupta RK. Reducing Air Pollution - Towards making Indore a Smart, Clean, and Healthy City. *J Adv Res Alt Energ Env Eco* 2018; 5(4): 23-28.

If no action is taken, deaths attributable to ambient $PM_{2.5}$ are projected to rise to 3.6 million in India.[5]

The Government of India initiated various schemes to improve air quality by addressing emissions from vehicles, thermal power plants, and household energy use. The Clean India Mission (Swachh Bharat Abhiyan) was also launched in October 2014, both in rural and urban areas. In Indore, Swachh Bharat is led by the Indore Municipal Corporation. Indore was declared India's cleanest city in both 2017 and 2018, based primarily on solid waste management infrastructure and good public outreach to raise awareness.[9]

Smart City Mission was launched in June 2015 with the aim of comprehensive urban development to improve the quality of life for the citizens, create employment, and enhance incomes for all, especially the poor and the disadvantaged in 100 cities of the country, including Indore. Indore's Smart City efforts, organized by Indore Smart City Development Limited (ISCDL), have included additional solid waste management, improved traffic management, and encouraged mass and non-motorized transport, all of which should help reduce air pollution, one of the city's key impact areas.[10]

In 2017, Indore also began participating in a multi-country Building Healthy Cities Project, funded by the United States Agency for International Development (USAID). This project is being implemented in close coordination with the ISCDL to embed a health equity lens into city planning. The objective of this project is to improve the city environment and health of the citizens, especially for vulnerable populations. A healthy city environment includes clean air, soil, and water, as well as access to city services. As part of this project, and in collaboration with the Madhya Pradesh (MP) Pollution Control Board, this study assessed whether the above-mentioned initiatives implemented in the city of Indore had any effect on the level of air pollution since 2015.

Materials and Methods

The MP Pollution Control Board set up a regional centre in Indore to monitor air and water pollution in the city. Concentrations of SO_2, NO_2 and particulate matter (PM_{10}) are measured from three air pollution measuring stations in Indore, located in the Polo Ground (Industrial area), Kothari Market (commercial area), and Kanodia Road, Vijay Nagar (residential area). Only the station at the polo ground measures and reports air pollution in real time, while the remainder must be measured manually. The measurement of $PM_{2.5}$ was started in 2016 for all three stations. Average annual concentrations of SO_2, NO_2, and PM_{10} from each site were analysed in Excel for trends over the last five years (2013–2017). $PM_{2.5}$ could only be analysed for the last two years. Detailed month-wise data were also analysed in Excel for 2017 to identify any possible seasonal variations in air pollution across all four measures.

Results

Table 1.Annual Concentration of air pollutants in indore city: 2013-2017

Year	2013			2014			2015			2016			2017		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
Sulphur dioxide															
Polo Ground	5	13	11	10	11	11	9	12	11	9	12	11	11	12	11
Kothari Market	5	13	11	10	11	11	7	12	11	10	11	11	10	12	11
Kanodiya Road	5	27	11	10	11	11	10	12	11	10	12	11	10	11	11
Nitrogen oxides															
Polo Ground	10	24	19	19	20	20	17	22	20	18	22	20	20	23	21
Kothari Market	10	23	19	19	20	20	18	22	20	19	22	20	19	21	20
Kanodiya Road	9	23	19	19	20	20	18	21	20	18	24	20	19	21	20
PM 10 µg															
Polo Ground	27	298	118	47	313	138	50	187	100	40	164	96	49	100	81
Kothari Market	23	443	187	50	324	135	45	173	93	69	127	96	48	102	79
Kanodiya Road	15	355	158	50	311	157	56	202	98	43	154	94	46	96	77

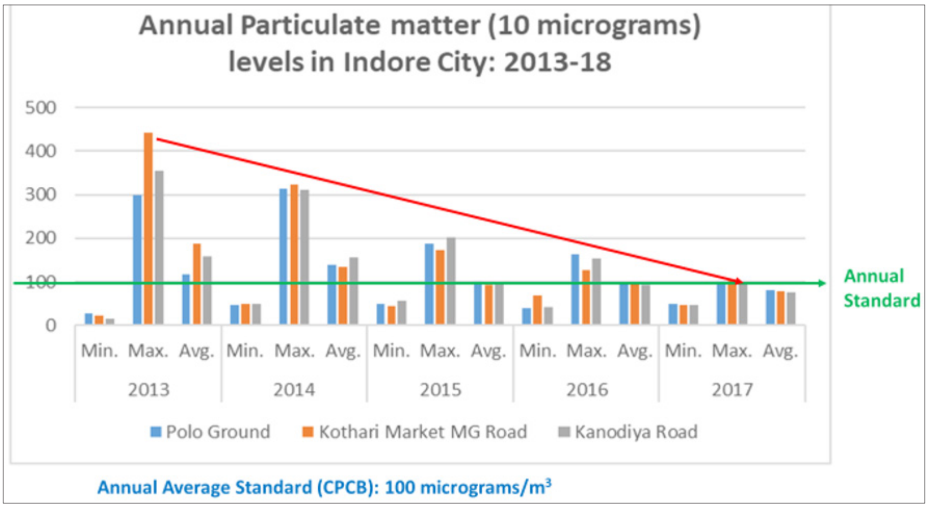

Figure 1.Annual particulate matter (10 micrograms) levels in indore city: 2013–2018

Table 2.Annual particulate matter (2.5 Microgram) concentration in Indore City: 2016–2017

Monitoring Station	2016			2017		
	Min.	Max.	Avg.	Min.	Max.	Avg.
Polo Ground	21	122	55	34	52	45
Kothari Market	36	84	56	7	52	36
Kanodiya Road	22	114	50	34	62	46

Table 3.Month-wise concentration of air pollutants in indore city: 2017

Sulphur Dioxide	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
Polo Ground	10.97	10.80	10.76	10.90	11.11	10.85	10.79	11.44	11.93	10.70	10.90	10.98	11.01
Kothari Market	11.53	10.83	10.64	10.70	10.79	10.57	10.57	10.07	10.17	10.34	10.87	10.99	10.67
Kanodiya Road	10.83	10.87	10.93	11.00	10.88	10.73	10.36	10.09	10.10	10.74	10.83	10.73	10.67
Nitrogen Oxides													
Polo Ground	20.98	20.60	20.84	20.80	21.29	20.89	20.78	20.35	20.37	20.88	22.77	21.05	20.97
Kothari Market	21.33	21.20	20.28	21.10	20.64	20.50	20.73	19.32	19.54	20.08	21.01	21.18	20.58
Kanodiya Road	20.70	20.41	21.11	20.90	20.91	20.83	19.88	19.46	19.55	20.64	20.77	19.96	20.43
PM 10 µg													
Polo Ground	100.06	87.71	93.01	95.70	95.61	83.48	68.18	48.79	50.43	78.50	81.68	93.20	81.36
Kothari Market	94.47	83.41	88.59	99.00	90.20	84.68	68.55	49.13	48.44	60.60	73.61	102.15	78.57
Kanodiya Road	96.23	89.11	85.50	93.30	95.35	80.19	70.15	46.53	46.72	62.00	74.69	88.15	77.33
PM 2.5 µg													
Polo Ground	50.24	48.19	51.43	51.90	50.23	42.04	33.53	*NA*	*NA*	38.18	39.18	45.43	45.04
Kothari Market	51.81	46.04	47.36	50.30	44.61	6.79	33.60	*NA*	*NA*	33.08	34.90	10.76	35.93
Kanodiya Road	47.44	50.26	48.77	45.80	49.36	40.61	33.98	*NA*	*NA*	61.58	37.68	47.62	46.31

ISSN: 2455-3093
DOI: https://doi.org/10.24321/2455.3093.201804

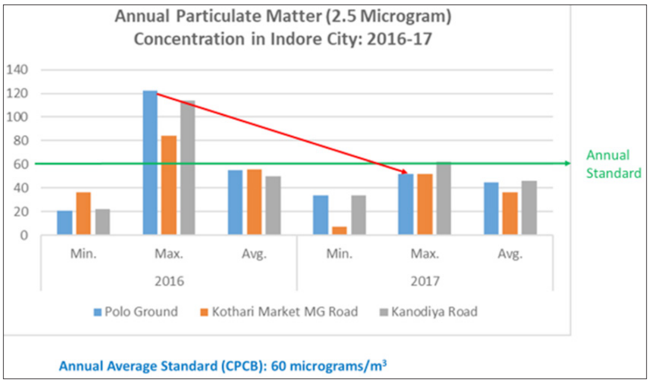

Figure 2. Annual particulate matter (2.5 micrograms) concentration in indore city: 2016-2018

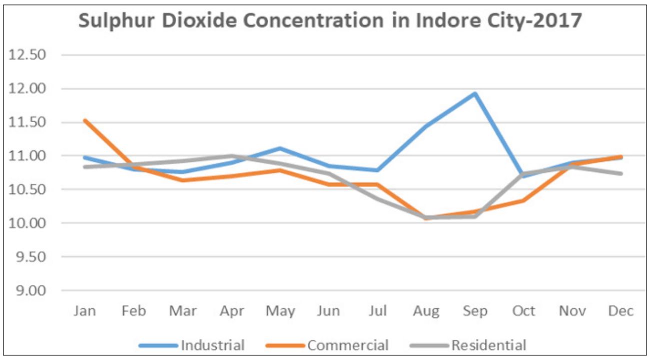

Figure 3(A).Month-wise concentration of air pollutants (sulphur dioxide concentration) - indore: 2017

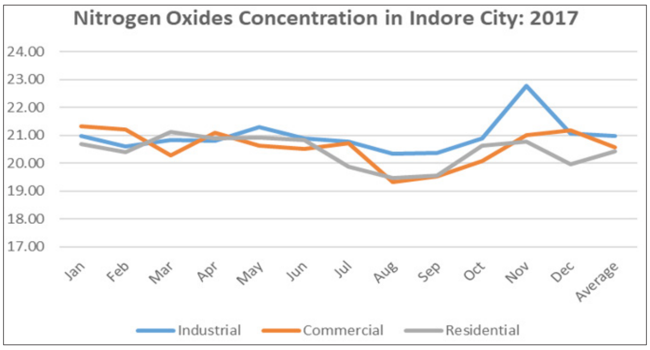

Figure 3(B).Month-wise concentration of air pollutants (nitrogen oxides concentration) - indore: 2017

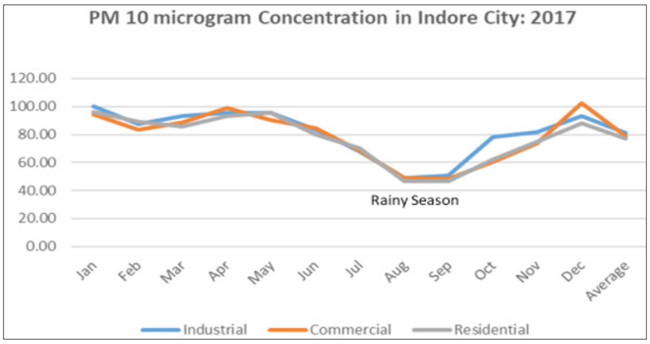

Figure 3(C).Month-wise concentration of air pollutants (PM 10 microgram concentration) - indore: 2017

No change was noted in the annual average concentration of SO_2 and NO_2 during the preceding five years. The average annual concentration of SO_2 was 11 μg/m^3 in each of the last five years. This was well within the Central Pollution Control Board (CPCB) standard of 50 μg/m^3. Average annual concentration of NO_2 ranged between 19 and 21 μg/m^3 against the CPCB standard of 40 μg/m^3 (Table 1).

A downward trend was observed at all three sites in concentrations of PM_{10}, decreasing from a range of 118-187 μg/m^3 in 2013 to 77-81 μg/m^3 in 2017. While in 2013-2015, these values were higher than the annual average standard (CPCB) of 100 μg/m^3; PM_{10} declined below 100 in 2016 (range 94-96) and dropped further to 77-81 μg/m^3 in 2017, showing a downward trend (Table 1 and Figure 1).

The $PM_{2.5}$ concentration was measured only since 2016 and the 2017 levels were less, compared to the preceding year. Average concentration of $PM_{2.5}$ was 50-56 μg/m^3 in 2016 which further decreased to 36-46 μg/m^3 in 2017. These values were within annual average standard (CPCB) of 60 μg/m^3 (Table 2 and Figure 2).

Month-wise data of all pollutants were studied for 2017. Lower values were observed in the rainy season (July to September) for all pollutants (Table 3 and Figure 3). Most of the observations of various pollutants throughout the year at all three sites were within the standards prescribed for each pollutant, showing a persistent control of air pollution in the city during 2017.

Discussion

India has some of the highest levels of outdoor air pollution in the world. The most comprehensive air pollution estimates available from both satellite and Indian ground-level measurements of fine particulate matter (PM2.5) indicate that 99.9 percent of the Indian population is estimated to live in areas where the World Health Organization (WHO) Air Quality Guideline of 10 μg/m3 for PM2.5 was exceeded in 2015. Nearly 90 percent of people live in areas that exceed the WHO Interim Target-1 (35 μg/m3). Similarly, the population in most Indian states (21) and union territories (6) was exposed to PM2.5 levels above the Indian annual standard of 40 μg/m3 in 2015. Trends in outdoor air pollution levels are not promising. Air pollution estimates indicate that, in the last 25 years, average exposure for India increased from about 60 μg/m3 in 1990 to 74 μg/m3 in 2015. The steepest increases occurred during the last 10 years.[5]

Although the air pollution levels for the Indian population can vary substantially, depending on where people live, these levels are unusually high compared with WHO guidelines and Indian standards. In 2016, of the top 30 cities in the world with the poorest air quality, 17 are in South Asia.6 The cities include Delhi, Varanasi, Kanpur, Faridabad, Gaya, Patna, Agra, Muzaffarpur, Srinagar, Gurgaon, Jaipur, Patiala, and Jodhpur.

While Indore was not in the list of most polluted Indian cities, the concentration of air pollution in the Indore city was high before 2015. In a study conducted by Panday and

Dohare7, an attempt was made to express the ambient air quality of Indore city using the IND-AQI procedure.8 The results showed that breathable PM concentrations exceeded the permissible limits, while sulphur dioxide (SO2), nitrogen oxide (NO2), atmospheric ammonia (NH3), and lead (Pb) levels were under the prescribed Indian limits. The concentrations of ground-level ozone (O3) were higher than the standard limits during the summer season in the city.

Quantitative data on Swachh Bharat and Smart City activities near each of the air pollution measuring stations were not available to statistically correlate the changes seen in PM_{10} and $PM_{2.5}$ to initiatives in Indore. However, qualitative data suggest a correlation between the scale-up of interventions under Swachh Bharat and activities carried out by ISCDL during 2015 to 2017.

In interviews conducted for the Building Healthy Cities baseline health needs assessment, Indore respondents discussed several interventions that these campaigns have brought to Indore. Since 2015, mechanical street sweeping has been done on alternate days on roads, and roads are washed every night by pressure jets to keep the city dust free.[11] In addition, free left loop roads reduce traffic congestion at key intersections, and improvements to the public transport system have helped limit traffic-related pollution, although private car ownership continues to rise. Finally, systematic collection and disposal of solid waste throughout the city has helped reduce burning of trash by households. These activities were implemented on such a scale that, combined, they may have contributed to a reduced level of air pollutants during this time.

During discussions with city officials by the team implementing the USAID-funded Building Healthy Cities Project, the following issues were discussed and recommendations were made to strengthen the efforts of the city in making Indore a clean, healthy, and smart city:

- Only three air pollution monitoring stations are located within the city, and only one is in a residential neighborhood. Indore is quickly expanding and would need additional stations to monitor city-wide air pollution trends.
- Lack of real-time air quality measurement: currently only one is equipped to monitor in real-time. All stations should be real-time and able to easily transmit their data to city officials, including publicly accessible displays to communicate information on current air quality.
- There is no facility and capacity to conduct source appropriation studies. It will be difficult to take containment measures unless the sources of air pollutants are studied.
- The effects of air pollution levels on health in Indore has not been studied; currently, health sector data is not in a form, or at a level, to allow for city or neighborhood-level statistical analyses. Medical colleges in Indore could be engaged to further investigate this association.

Conclusion

This study is a first step toward identifying effective interventions to reduce air pollution in Indore. Declining trends of air pollution in particulate matter in Indore is evident, and may be the result of various measures taken by the Municipal Corporation and Indore Smart City Mission. Strengthening monitoring data on Swachh Bharat and Smart City implementation, and increasing the number of air quality monitoring stations, could help confirm this association. A reduction in emissions and exposure to citizens from biomass combustion, agricultural waste burning, vehicles, industries, and construction sites would be required to sustain high air quality standards. If it is confirmed that the aggressive actions Indore has taken have led to the improvements in air quality, then other Indian cities can follow this example to avoid additional air pollution-related mortality.

Acknowledgments

The authors would like to acknowledge MP Pollution Control Board, Indore, for providing data on air pollution for the last five years, and Indore Smart City Development Limited and Indore Municipal Corporation for pollution control initiatives in the city.

Author's Note

Building Healthy Cities is a three-year cooperative agreement funded by the United States Agency for International Development (USAID) under Agreement No. AID-OAA-A-17-00028, beginning September 30, 2017. Building Healthy Cities is implemented by JSI Research & Training Institute, Inc. (JSI), with partners Urban Institute, International Organization for Migration, and PricewaterhouseCoopers Pvt Ltd.

This study is made possible by the generous support of the American people through USAID. The contents are the responsibility of Building Healthy Cities and do not necessarily reflect the views of USAID or the United States Government.

Conflict of Interest: None

References

1. Gakidou E, Afshin A, Abajobir A et al. Risk factors collaborators. global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2016: a systematic analysis for the global burden of disease study 2016. *The Lancet* 2017; 390: 1345-422.
2. Global Burden of Disease 2015 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2015: a systematic analysis for the global burden

ISSN: 2455-3093
DOI: https://doi.org/10.24321/2455.3093.201804

of disease study 2015. *The Lancet* 2016; 388: 1659-724.
3. Amaral S, de Carvalho J, Costa M et al. An overview of particulate matter measurement instruments. *Atmosphere* 2015; 6(9): 1327-45.
4. The World Bank. Understanding air pollution and the way it is measured. The World Bank, Washington, D.C. 2015. Cited 2018 August 16. Available from: http://www.worldbank.org/en/news/feature/2015/07/14/understanding-air-pollution-and-the-way-it-is-measured.
5. Health Effects Institute. Burden of disease attributable to major air pollution sources in India. Special Report 21. Health Effects Institute, Boston. 2018.
6. World Health Organization (WHO). WHO global urban ambient air pollution database (Update 2016). WHO, Geneva.
7. Panday V, Dohare D. Assessment of present ambient air quality of Indore city using Indian air quality index - a case study. *International Journal of Science Technology & Engineering* 2016; 3(6): 153-7.
8. Mamta P, Bassin JK. Analysis of ambient air quality using air quality index - a case study. *International Journal of Advanced Engineering Technology* 2010; 1: 106-14.
9. Saldanha A, Rao O. India's cleanest cities: citizen engagement drives the rankings. 2017. Cited 2018 August 9. Available from: https://scroll.in/article/837901/indias-cleanest-cities-citizen-engagement-drives-the-rankings.
10. Indore Municipal Corporation. Smart City Proposal-Indore, India. Ministry of Housing and Urban Affairs, Government of India. 2016. Available from: http://smartcities.gov.in/upload/uploadfiles/files/Indore_SCP.pdf.
11. Anjuli B. How Indore became garbage-free and beat every other city to it. The Better India, Delhi, India. 2017. Cited 2018 August 17. Available from: https://www.thebetterindia.com/114040/indore-madhya-pradesh-clean-garbage-free-india/.

Date of Submission: 2018-09-07
Date of Acceptance: 2018-11-09