Air Pollution in Pune

RESEARCH AND EVIDENCE FOR DEVELOPING THE PUNE AIR INFORMATION & RESPONSE (AIR) PLAN

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Indian Institute of Tropical Meteorology
Centre for Environment and Education
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The Ministry of Earth Sciences (MoES), Government of India, introduced a major national initiative, System of Air Quality and Weather Forecasting and Research (SAFAR), for greater metropolitan cities of India to provide location specific information on air quality in near real time and its forecast 1-3 days in advance for the first time in India. The SAFAR system was developed by the Indian Institute of Tropical Meteorology, Pune, along with ESSO partner institutions, namely the India Meteorological Department and the National Centre for Medium Range Weather Forecasting. The implementation of SAFAR is made possible with an active collaboration with local municipal corporations and various local educational institutions and governmental agencies in that metro city. safar.tropmet.res.in

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SECTION 1

Introduction

To mitigate the human health problems associated with air pollution, policymakers need to take informed actions to better manage sources of pollution using monitoring data that tracks pollutant trends over time. This issue brief highlights current air quality conditions in Pune and associated risks to human health. It then describes recommended actions that the city and stakeholders can take to better protect residents and to address underlying emissions that drive air pollution.

Air Pollution and Health

GLOBAL

The World Health Organization (WHO) estimates that globally, air pollution contributes to 4.9 million premature deaths and 149 million years of healthy life lost annually (3.4 million deaths and 90 million years of healthy life lost from ambient air pollution and 1.5 million deaths and 59 million disability adjusted life years annually from household air pollution in year 2017).[1]

Of this staggering total, about half of the burden falls in two countries, India and China, where levels of fine particulate matter (PM2.5) are highest.[2] The WHO estimates that 92% of the world's population lives in places where average annual air quality levels exceed health-based ambient air quality guidelines for fine particulate matter (PM2.5, see text box).[3,4]

While air quality standards vary in coverage and stringency across countries and global regions, the WHO guidelines provide evidence-based reference points for evaluating potential health risks.

INDIA

Air pollution is a growing public health concern around the world, but especially in India. The country's National Clean Air Programme (NCAP), launched in early 2019, provides a roadmap to prevent, control, and reduce unhealthy levels of air pollution (see text box on next page).

With the alarming air pollution levels across India, the urgency of the NCAP is clear. India is severely affected by air pollution; it led to 1.24 million or 12.5% of the total deaths recorded in the country during 2017 alone.5 In

The Health Risks of Fine Particulate Matter

Over the past two decades, research in air pollution epidemiology has increasingly focused on the harmful effects of exposure to particulate matter (PM, depicted in Figure 1). PM is mixture of solids and liquids in the air that can be emitted directly or formed by chemical reactions in the atmosphere.

Coarse particulate matter (PM10) is comprised of substances that are between 2.5 and 10 micrometers (μm) in diameter stems primarily from motor vehicles, dust and construction. Fine particulate matter (PM2.5) measures ≤2.5μm in diameter. PM2.5 pollution is the harmful byproduct of combustion, including vehicles, power plants, industry, waste burning, agricultural burning and cooking.

PM2.5 can rapidly penetrate deep into airways, lungs and the respiratory system causing adverse health effects, even at low levels.[1]

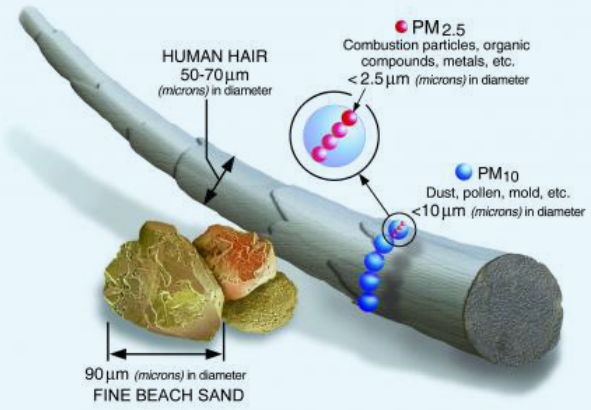


Figure 1: Size comparisons of particulate matter (Credit: U.S. Environmental Protection Agency).[3]

2019, the Central Pollution Control Board of India (CPCB) determined that 122 cities across the country, including Pune, exceed the permissible national ambient air quality standards.[6] In response to the significant health risks posed by air pollution, the CPCB, state leaders, and city officials are taking actions to mitigate the complex and widespread challenges of air pollution.

It is important that successful strategies for addressing air pollution are highlighted and scaled effectively.

PUNE

Over the past five years, the air quality in the Indian city of Pune has deteriorated significantly. Data collected by the Indian Institute of Tropical Meteorology (IITM) indicates that 2018 was reportedly the second most polluted year since 2013.[7]

By 2018, the average annual concentration of PM2.5 had increased by about 60% over the past five years – jumping from 29 µg/m^3 in 2013 to 47 µg/m^3 in 2018—exceeding the country's annual national ambient air quality standard for PM2.5 of 40 µg/m^3.[8] IITM-led continuous air quality monitoring data shows that about 73 days in 2017 exceeded annual pollution standard, increasing to 94 days in 2018.[9]

A recently published analysis of annual air quality trends in Pune by the Urban Emissions Air Pollution Knowledge Assessment (APnA) program[10] demonstrates that air quality in Pune remains an urgent public health issue in the city. That analysis, based on global chemical transport models and satellite monitoring, indicates that annual levels of PM2.5 air pollution in Pune consistently exceed health-based pollution limits.

India's National Clean Air Programme (NCAP)

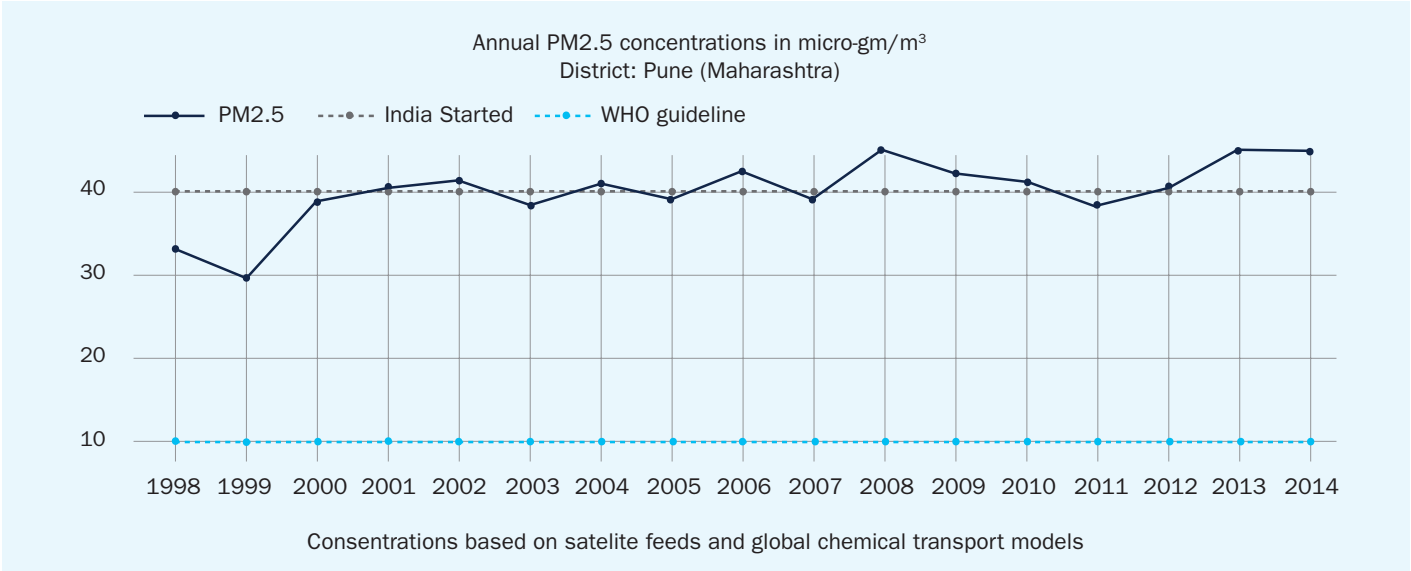
Launched in 2019, India's National Clean Air Programme (NCAP) is an initiative to reduce the amount of PM2.5 and PM10 in cities 20%-30% by 2024.1 The NCAP provides a framework to cities to reduce air pollution based on a sectoral approach and coordination amongst multiple government agencies (Figure 2). The NCAP targets towards 122 cities that exceed national air quality standards. Maharashtra is the state with the largest number of nonattainment cities, including Pune and Nagpur.

Figure 2: National Clean Air Programme Goals

The NCAP lays out 3 pillars to support cities in achieving air quality targets: knowledge augmentation, implementation of pollution mitigation actions, and long-term institutional strengthening. City actions can help to expand the national air quality monitoring network, build capacity for pollution management, and strengthen public awareness about dangerous air pollution.

Specifically, the group estimated a 2014 annual city average ambient PM2.5 concentration of 44.8µg/m^3, a level above the national standard (40) and more than four times the corresponding WHO guideline of 10 µg/m^3 (Figure 3). Other pollutants, including coarse particulate matter (PM10), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) have also exceeded annual national standards in recent years, according to this analysis.

Figure 3: Estimated annual PM2.5 concentrations for Pune, 1998-2014 (Credit: Urban Emissions).[11]



These high levels of air pollution are triggering adverse respiratory health impacts in Pune residents.

Air Quality Monitoring Stations in Pune

Pune currently has a total of 15 air pollution monitoring stations across the city, operated by three separate systems. The Maharashtra Pollution Control Board (MPCB) operates a system of five monitoring stations, and IITM (through its System of Air Quality and Weather Forecasting and Research, SAFAR) program operates an additional 10 monitoring stations. The Pune Smart City Development Corporation also maintains an independent network of 50 environmental monitoring stations, which measure air pollution, temperature, humidity, noise, and radiation levels.[12]

The MPCB station is operated in partnership with the Central Pollution Control Board. In the CPCB system, one continuous air quality monitoring station operates at Karve Road.[13] In addition, four manual air quality monitoring stations maintained by MPCB provide observations on coarse particles (PM_{10}), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) twice each week.

The IITM-SAFAR program operates 11 continuous air quality monitoring stations in Pune (Figure 4). The green markers on the map represent stations operated through the SAFAR program.[14,15]

IITM and the India Meteorological Department (IMD) developed SAFAR in 2013, and the system provides location-specific AQI in near real-time and forecasts the daily AQI up to two days in advance. IITM-SAFAR was conceived as a major national initiative for greater metropolitan cities in India to provide local information on air quality and health risks, in collaboration with the National Centre for Medium Range Weather Forecasting.[16] The IITM-SAFAR monitors represent the first networks in India that continuously monitors and forecast air pollution levels. Continuous monitors sample air at a height of three meters from the ground and characterize air quality

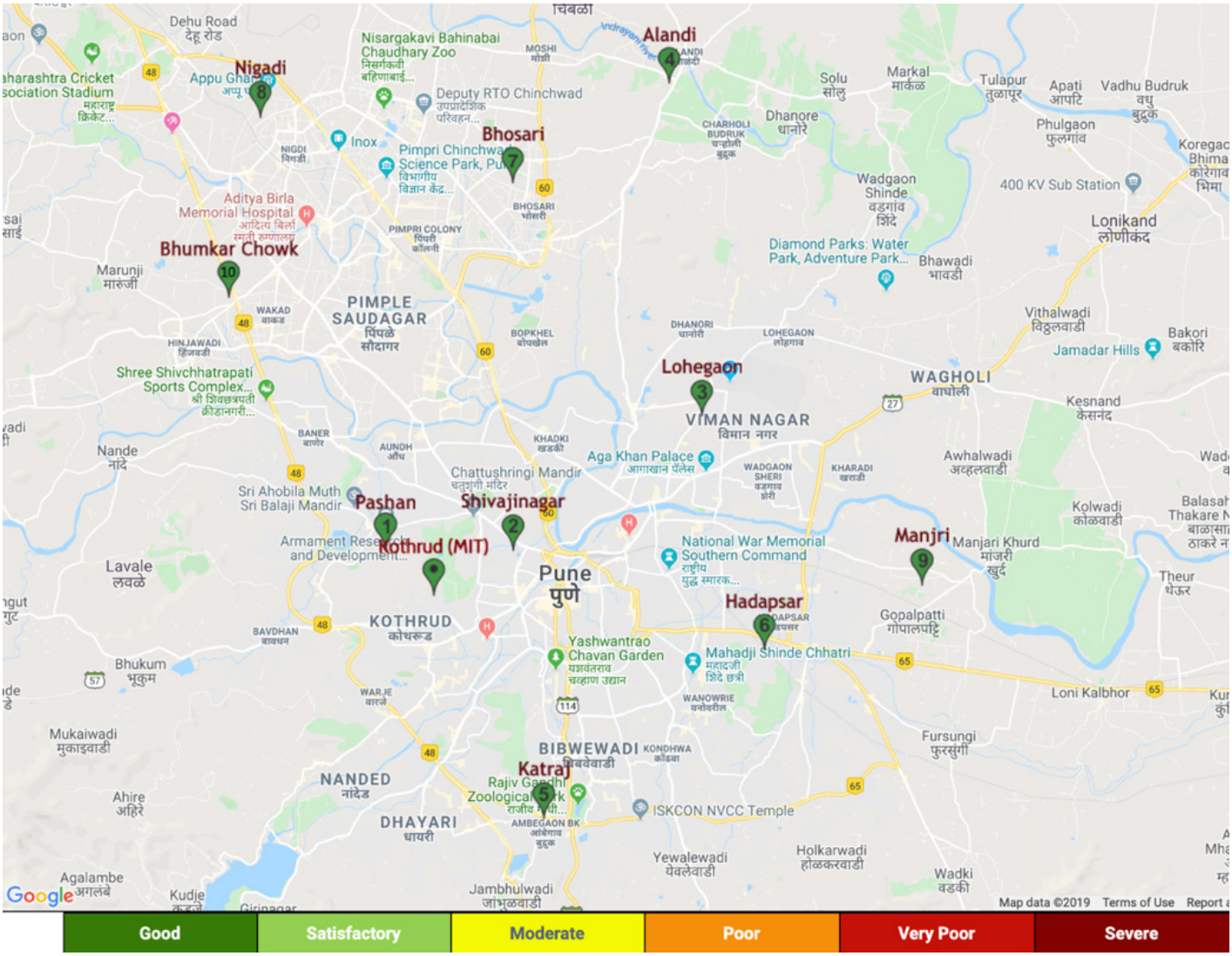


Figure 4: Map of IITM-SAFAR continuous air monitoring stations in Pune (2019) (Credit: IITM-SAFAR).[16]

Actions To Reduce Air Pollution in Pune

The Pune Municipal Corporation (PMC) takes the threat of air pollution seriously and is engaged in actions to reduce the health burden of air pollution within the city. Recently, PMC floated a tender for 500 electric buses (Figure 5) and procured 8000 bicycles, with the goal of eventually making 20,000 such cycles available.

Pune is also improving street design to include by cycle-only tracks a pedestrian movement policy. To curb waste burning, Pune has completely banned open dumping. Pune has also adopted 20 bio-methanation plants that help reduce trash burning and polluting emissions from landfills and generate clean energy. To reduce dust particles generated during construction activities, the PMC is providing ready-mix concrete.

Figure 5: Four of 25 new electric buses used by Pune Mahanagar Parivahan Mahamandal Limited (PMPML) for public transport (Credit: Pune Municipal Corporation).

for the entire city by incorporating information from sites in industrial corridors, residential areas, urban centers, agricultural zones, and areas that represent background level concentrations.

These monitors measure fine and coarse particles ($PM_{2.5}$ and PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), and carbon monoxide (CO). The stations also monitor key meteorological parameters (ultraviolet radiation, rainfall, temperature, humidity, wind speed and direction).[17]

IITM-SAFAR monitors are deployed in accordance with Central Pollution Control Board and World Meteorological Organization standards[18] and continuously collect data at 5- minute intervals. IITM-SAFAR has also adopted the U.S. Environmental Protection Agency (U.S. EPA) Standard Operating Procedures for instrument calibration and maintenance. The IITM-SAFAR system deploys state-of-the-art monitoring instruments, manufactured in France by Environnement SA,[19] which are ISO standard compliant[20] and certified by the U.S. EPA for their PM_{10} and $PM_{2.5}$ sampling technology.

IITM-SAFAR publishes an Air Quality Index (AQI) based on its raw monitoring data that largely corresponds to the CPCB AQI calculation methodology.[21] IITM-led air monitoring also informs a comprehensive, computationally intense modeling apparatus that is used to develop SAFAR's dynamic, city-level air quality forecasts for one and two days in advance.

Understanding Air Pollution Sources through Pune's Emissions Inventory

Many sectors (e.g., transportation, power generation, agriculture, solid waste burning) contribute to the air pollution problem in India and quantifying the relative contributions of each sector is key for shaping efforts to reduce polluting emissions at the local level. An emissions inventory is a comprehensive list, by source, of the amount of air pollution emitted in a particular area over a specified time period. These lists are representative of long-term average conditions and as such, capture general determinants of air quality rather than causes of short-term local peaks in emissions.

During 2015-2016, IITM-SAFAR research compiled a comprehensive emissions inventory for Pune. The inventory covers the metropolitan region for key health-damaging pollutants like small particles ($PM_{2.5}$ and PM_{10}), but also other pollutants that threaten health: ozone precursors like nitrogen oxides (NO_X) and volatile organic compounds (VOCs), carbon monoxide (CO), and sulfur dioxide (SO_2).

IITM's emissions inventory relied on a major data collection effort to quantify air pollution sources directly through on-the-ground field surveys and indirectly from reviews of government and industry records. Researchers also retrieved data from local authorities like the PMC city government, state- level Maharashtra State Pollution

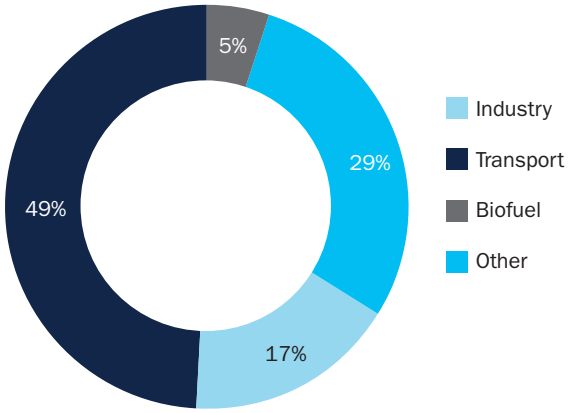


Figure 6: Relative contributions to PM2.5 emissions from different sectors in the Pune Municipal Region, 2015 (Credit: IITM-SAFAR)

Control Board, and individual industrial site operators, such as local power plants.

The key results from Pune's emissions inventory for fine particles ($PM_{2.5}$) indicate that, during 2015, the transportation sector was responsible for almost half of primary emissions, the air pollution emitted directly from combustion or other sources (Figure 6). The other contributors to airborne $PM_{2.5}$ were resuspended dust (29%), industrial operations (17%), and solid fuel combustion (5%). The emissions inventory includes a sectoral breakdown for each pollutant of concern, to allow for a detailed, spatially- defined understanding of local air pollution sources.

Air Quality Linked to Adverse Health Impacts in Pune

Given its detrimental health effects, air pollution needs to be addressed in the context of its significant adverse health effects on people. Leading policy makers in Pune should take a health-focused approach when deciding which initiatives to prioritize in efforts to mitigate air pollution.

Several studies document pollution-related health effects in Pune. In 2016, Dr. Kamal Jyoti Maji, a scholar at the Indian Institute of Technology-Bombay, led a health risk assessment on the effects of NO_2, SO_2 and PM based on data from 2005-2013 from monitoring stations operated by the CPCB in Pune.[22] That study estimated 733 excess deaths per million people in Pune due to cardiovascular diseases from air pollution exposures (PM_{10} and SO_2) each year. The author team estimated 901 annual hospital admissions for respiratory disease per million people in the city due to polluted air, and 348 excess hospital admissions for cardiovascular disease per million people. Another study relying on an emissions inventory published by the CPCB in 2010 and monitoring data from five stations in the city estimated that 2009-10 average exposure to PM_{10} (90.8 $\mu g/m^3$) caused 3,600 premature deaths in 2010 due to exposures above WHO guideline level ($\mu g/m^3$).[23,24]

Exposure to air pollution is an established risk factor for contracting various cardiovascular and respiratory diseases, and there is evidence of such effects in the Pune.[25] For example, a 2014 study in Pune examined the link between the risk of contracting tuberculosis in children under the age of 5 and other factors such as malnourishment and exposure to indoor air pollution, which itself exacerbates outdoor air pollution levels in India.[26] Jubulis et al. (2014) reported a statistically-significant increase (more than a doubling of the baseline disease rate) in the incidence of tuberculosis in children exposed to higher levels of indoor air pollution, compared to those not exposed.[27]

Epidemiologic evidence of health effects caused by air pollution is currently limited in Pune (and India generally) due to a lack of comprehensive, long-term, and transparent data. Improved integration of air quality monitoring and data reporting with public health research efforts can better illuminate the present-day health burden and better protect vulnerable populations from this harmful environmental exposure.[28]

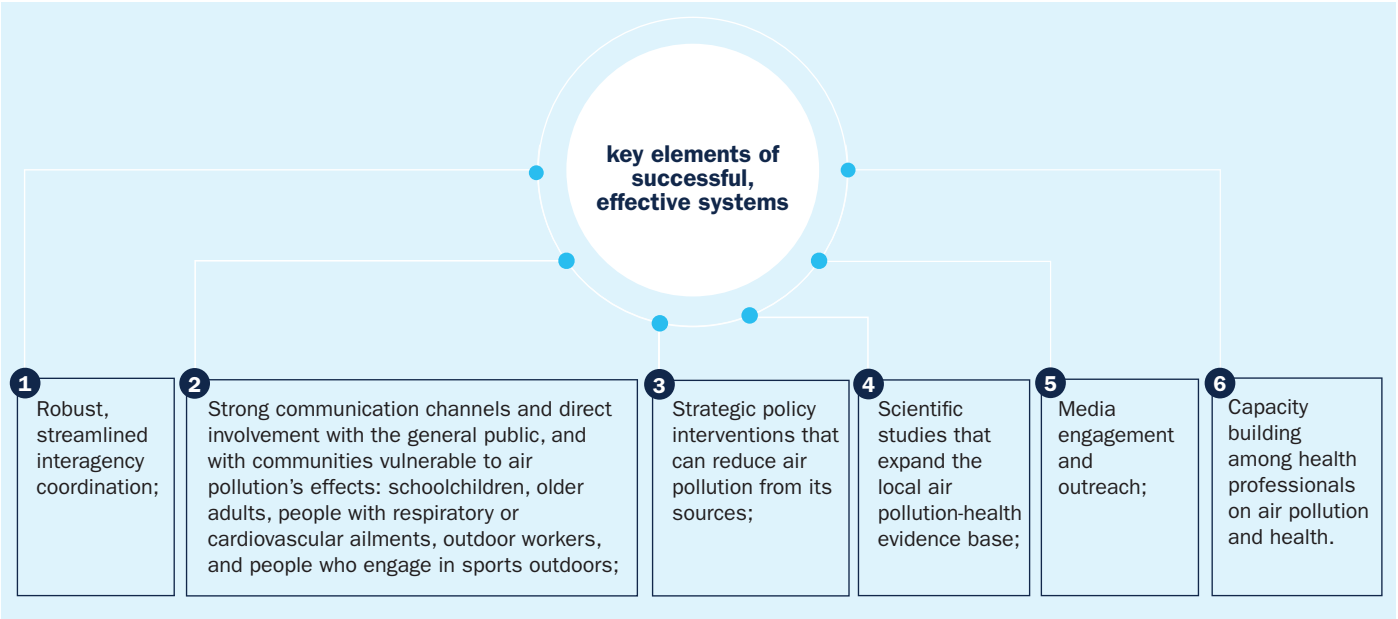
SECTION 2

Air Quality Index and Health Advisories

Cities around the world are increasingly working to disseminate information on air pollution levels and associated health risks with the aim of reducing harmful exposures at the population level. One key tool to communicate such data is the air quality index (AQI), a metric that summarizes air quality conditions in a single metric and distills information on associated health risks in a way that is accessible to the public. Recent research indicates that AQI systems, when accompanied by emissions reductions on the most polluted days, could help cities achieve cleaner air and tangible health benefits.[29]

Key Elements of Effective AQI Systems

AQI systems that have been effectively communicated to air pollution-affected communities are based on a strong foundation of epidemiology research on air pollution-health effects, well-designed and operated air quality monitoring programs, and effective government agency coordination air pollution management and public outreach. Based on the operation of AQI dissemination networks in India and globally, six of the key elements of successful, effective systems mentioned in a box below:



In sum, effective AQI systems require strong foundations of robust air pollution monitoring, effective communication of health risk information, and robust interagency coordination. The dual goals of protecting public health from air pollution in the near-term and improving city and regional air quality over a longer time horizon are strengthened by effective AQI systems, which provide the evidence base for municipal, state, and national agencies to take policy actions to reduce air pollution.

SECTION 3

Recommendations for a Pune Air Information & Response Plan

As part of a coordinated stakeholder effort, the Pune Municipal Corporation has requested a set of recommendations on developing a health risk communication-focused AIR Plan and broader strategies, including a mitigation-focused Clean Air Programme (CAP).[30] In terms of guiding principles for the recommendations, strong partnerships and community stakeholder engagement are critical to successful implementation.

Transparent, tested IITM-SAFAR technology for documenting and reporting air quality builds trust and allows for the establishment of a research base on which to craft informed air quality management policies. It is also important to design AQI-driven interventions that achieve near-term benefits while also laying the foundation for sustainable progress towards larger environmental and public health goals.

Based on experiences among cities in India and other countries,[31] the following section describes key recommendations, many of which IITM-SAFAR and partners have underway:

1. Health-Based AQI Warning and Interagency Coordination

To develop the Pune Air Information & Response (AIR) Plan, one key step is to create ahealth-based AQI warning system and interagency coordination plan, led by the PMC.[32] Examining lessons from the Ahmedabad AIR Plan and other similar plans, the PMC would develop a warning system with health alerts based on the AQI (Figure 8, next page). For example, a Health Advisory would be issued to groups vulnerable to air pollution when the air quality index is forecasted "Poor" (levels 201 – 300). Information about alerts should be coordinated and shared closely with the Maharashtra Pollution Control Board and Central Pollution Control Board.

An essential initial step to develop the AQI warning system is for the PMC to appoint a "nodal officer" in charge of AIR Plan coordination. The nodal officer's activities involve informing key departments and medical facilities of health-harming air quality and overseeing implementation of a school flags program.[33] The nodal officer also facilitates communication between the city, urban health centres, and private medical practitioners (including pulmonologists and pediatricians), alerting healthcare providers in situations when respiratory health problems in the city's population are expected to rise. In addition, the nodal officer informs local ambulance services of elevated air pollution levels as well as other city departments including transport, traffic police, estate department, schools & colleges, and environmental management. The nodal officer and the PMC are critical in engaging with media, by publishing the air quality Health

Ahmedabad's Air Information & Response Plan

Figure 7: 2018 Launch of Ahmedabad AIR Plan health risk communication materials (Credit: NRDC, 2018).

In 2017, Ahmedabad launched an air pollution monitoring and risk communication project, the Air Information and Response (AIR) Plan.1 The centerpiece of the plan is the AQI developed by IITM-SAFAR relaying information from 10 continuous air monitoring stations. This data helps people avoid harmful exposures, in tandem with city-led health risk communications (Figure 7) and longer-term policy strategies achieve cleaner air.

Ahmedabad was among the first cities in India where city leaders, state government, and civil society worked proactively together to address the country's air pollution challenge with a focus on public health. The lessons learned from the development and implementation of the AIR Plan in Ahmedabad serve as a template for Pune and other cities aiming to address the heavy burden of air pollution on public health.

Air Quality Index (AQI) Level	Health Advisory	Health Effect Statement	Overall Associated Health Impact with AQI Level
Good (0 – 100)	No cautionary action required	Air pollution poses little or no risk	Minimal impact
Moderate (101 – 200)	Unusually sensitive people should consider reducing prolonged or heavy exertion and heavy outdoor work	Air quality acceptable for general public but moderate health concern for sensitive people	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults.
Poor (201 – 300) **Triggers "Health Warning" to Vulnerable Groups**	Children and adult with heart or lung disease, should reduce prolonged or heavy exertion and limit outdoor activity	Children and adult people at risk. Higher chance of precipitating respiratory symptoms in sensitive individuals.	May precipitate severe attack on short term exposure in high risk individuals and respiratory symptoms (breathing discomfort) in normal individual on long term exposure.
Very Poor (301 – 400) **Triggers "Health Alert"**	Everyone should reduce prolonged or heavy exertion. More caution for children or adult with heart or lung disease.	Everyone may experience more health effects. Significant increase in respiratory effects in general population.	May cause mild respiratory problems in normal individual/ more pronounced in people with lung and heart disease.
Severe (401 – 500) **Triggers "Health Warning"**	Everyone should avoid all outdoor physical activity. Sensitive individual should remain indoor with minimal activity.	Should be declared as emergency conditions. Serious risk of respiratory effect in general population as high risk.	May cause respiratory effects even on healthy people and serious health impacts on people with lung and heart diseases. The health impacts may be experienced even during light physical activity.

Figure 8: AQI index value ranges (left), associated population risks (middle), and anticipated health effects (right) (Credit: IITM-SAFAR).[34]

Warnings and Alerts (Figure 8) in print and broadcast media, including newspapers, radio, television, and social media channels, such as WhatsApp.

An interagency coordination framework is key for ensuring effective AIR Plan implementation. The city and nodal officer would create a map of the key agencies and groups involved in responding to air emergencies to develop an inclusive communications framework (Figure 9). For communicating the AQI and days with unhealthy air quality to key groups, creating that type of communications and coordination map will be very useful.

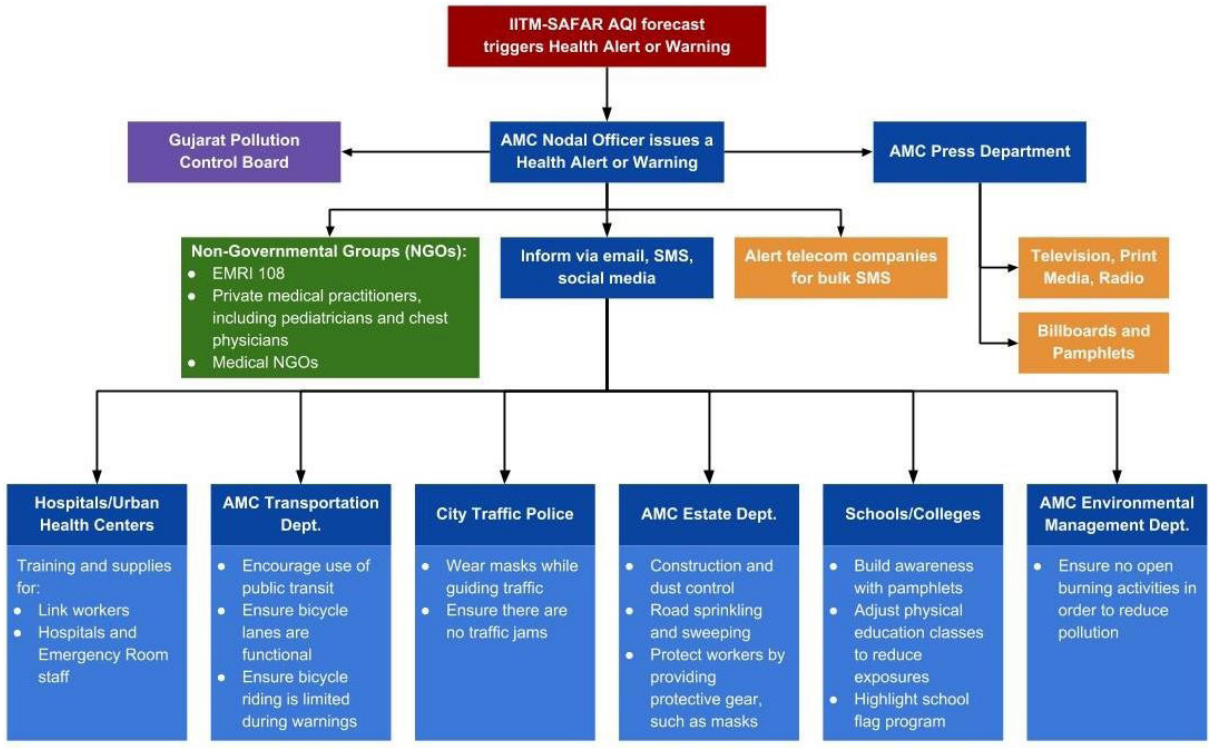


Figure 9: Flowchart demonstrating the array of interagency stakeholders necessary to disseminate and act on an AQI advisory in Ahmedabad (Credit: Limaye et al., 2018).[35]

Citywide programs such as the Smart Cities initiative and statewide plans for sustainable development goals could be useful for comprehensive planning that includes strategies to combat sources of air pollution. Successful implementation of the AIR Plan requires coordinated action between many diverse stakeholders, including government departments; health care professionals including emergency medical personnel, health center staff, and hospital staff; and community groups.

Combatting air pollution requires professionals and subject matter experts in many areas (such as scientists, data analysts, engineers, law-makers, politicians, economists, health officials, accountants, and many more). Because air pollution can arise from many different sources (such as the industrial, transportation, and agriculture sectors), it an interagency issue that demands a coordinated response.

As domestic and international experiences have shown, interagency coordination plays a pivotal part in reducing air pollution as well as informing and protecting the public from its effects. Because air pollution sources can affect large geographic areas and encompass different sectors, city and statewide coordination of government agencies is an important mechanism to effectivelycombat air pollution.[36]

REGIONAL AND STATE-LEVEL COORDINATION

Since emissions and outdoor pollutant levels are affected by regional and long-range pollution transport, air pollution is a regional and state issue. Air pollution can affect large geographic areas and impact many different sectors, making statewide coordination of agencies an effective mechanism to combat this far-reaching problem.

One international example of a regional cooperation is the Southern California Association of Governments (SCAG) in the United States. SCAG's Transportation Conformity Working Group (TCWG) works to facilitate interagency coordination for to ensure that approved infrastructure projects conform to air quality goals and targets in Southern California.[37] Specifically, the group meets monthly to address and resolve regional issues regarding transportation conformity focusing on PM_{10} and $PM_{2.5}$ hot spots in non-attainment areas.

The TCWG developed a "PM Conformity Hot Spot Analysis–Project Summary Form for Interagency Consultation" to help provide information to SCAG on whether a proposed project needs a detailed PM air pollution "hot spot" analysis.

Often, development of specific projects can have profound impacts on air quality during construction in addition to long-term effects on air quality. Coordinated interagency discussions on a project's potential impacts on air quality have been effective in addressing air-related issues and working out ways to mitigate the project's impact on air quality. For example, one Memorandum of Agreement (MOA) from the United States, the Washington State MOA on Fugitive Dust, could be relevant for some of Indian cities' long-range pollution problems.[38] In addition, the MOA outlines roles for both agencies and deadlines for deliverables such as training programs for best management practices for controlling fugitive dust.[39]

2. Public Awareness and Community Outreach

To build public awareness and community outreach, the PMC could identify a series of activities as part of the AIR Plan's efforts on health risk communication.[40] These activities could include updating its website with the AQI and AIR Plan; engaging media on the AQI and AIR Plan; and developing information, education and communication (IEC) materials (Figure 10). Such materials could be disseminated in multiple languages to ensure broad and equitable accessibility. The PMC and partners would focus on disseminating and updating IEC materials for hoardings, pamphlets and videos for general public awareness; and engaging media on the AQI and AIR Plan for regular broadcast of AQI in newspapers and posting associated health advisories, alerts or warnings whenever issued by PMC.

Figure 10: Information, education, and communication (IEC) materials illuminating air quality- related health risks, developed for the Ahmedabad Air Information and Response Plan (Credit: NRDC).[41]

The media in India have been covering the nation's deteriorating air quality and play a critical role in raising public awareness of air pollution's effects on health. For example, in March 2015, India Today published an article titled, "Choking on the Truth: How the Air that Sustains our Life is also Slowly Killing Us."[42] The story paints a vivid

image of the reality faced by Delhi's 25 million residents, who are subject to the city's pervasive smog and discusses scientific and statistical studies that have confirmed the dangers associated with prolonged exposure to airborne pollutants.

The Indian Express has media campaign called, Death by Breath: What's Happening to Delhi Air will have You Gasping for Breath.[43] The article investigates Delhi's deteriorating air quality despite the growing evidence base on the effects of pollution. PM_{10} levels in Delhi rose to 316 $\mu g/m^3$ in 2015, more than 15 times the corresponding WHO annual air quality standard.[44]

Proactively engaging with the media in efforts to raise public awareness and reduce air pollution is essential and ensuring that the AQI is communicated effectively to reach communities is vital to protecting public health. The AQI should be easy to associate with health effects and provide additional information relating to potential health symptoms and advice as to what action to take. Improvements in air quality depend on the support of citizens who are well-informed about local and national air pollution problems and about the progress of mitigation efforts.

Many air pollution guidelines consider the importance of alerts when air pollution becomes serious and action needs to be taken. The public should be involved in developing risk communication from the outset and can contribute to the assessment and management of risk. Involving the public as stakeholders helps establish effective communication and reciprocal exchange of information and is conducive to finding innovative solutions, thus moving away from one-way communication models. Essential elements for effective risk communication are information quality, transparency, the simplicity and coherence of the message, receptivity to public concerns and timing.

Communication approaches should be participatory and integrate sociological methods into traditional public health-oriented ones. While this may increase effort and cost, it is useful in managing controversy, when and if it develops during high air pollution emergencies. Including organizations who advocate for the health of people with particular illnesses can help reach some of the most health- vulnerable people, for example organizations who represent people with asthma or those with other respiratory diseases, or groups representing patients with heart disease.

Including air pollution as part of environmental education programs can increase awareness among school children, who are particularly vulnerable to the health impacts. SAFAR currently uses multiple approaches to reach the public with their AQI alerts, as discussed above, including its website, the SAFAR-app for smart phones, toll-free telephone numbers, email alerts, and digital display boards (Figure 11).[45]

Public Dissemination of the Air Quality Index

Figure 11: IITM-SAFAR digital display boards summarize real-time air quality conditions in Pune (Credit: NRDC).

Even with all these multiple, complementary pathways, there are more promotion options available, worthy of continued discussion by PMC for possible adoption in Pune. Some cities offer phone text messages or text alert sign-ups like the NotifyNYC system in New York City that helps make the public aware of emergencies of all types (heat, air pollution, accidents, etc.) or planned large-scale activities.[46]

The U.S. EPA AQI system also facilitates online access to trainings and tools for teachers,[47] weathercasters,[48] and health care providers.[49] An online Air Compare tool lets people compare the air quality of different US cities or find out about air quality trends in specific areas.[50] People can also access web cameras online, to see real-time pictures of visibility at locations across the US. Combating air pollution can also be done by the public on a citizen-to-citizen basis. For example, the Clean Air New York Public Education Campaign (CANY) focuses on marketing and outreach programs that educate New Yorkers on manageable changes that residents can make in their transportation choices to reduce their vehicle miles traveled and affect air quality.[51] This includes Air Quality Action Day notifications by the New York State Department of Transportation when O_3 and PM levels are

expected to be at levels that could threaten the health of sensitive populations.[52] The Program Advisory Committee for CANY includes members from state, regional, and local health departments, transportation councils, and city and state governments.

3. Focused Activities for Vulnerable Groups

Because children are extremely vulnerable to air pollution with their developing lungs and bodies, focused activities on health risk communication to protect children are critical. SAFAR-IITM along with the PMC and partners have already launched a "school flags program" in Pune (Figure 11).[53] As part of the program, the PMC will develop a program to disseminate pamphlets, hoardings, videos, text messages to increase awareness of vulnerable groups, especially children in schools.[54]

For the school flags program, the PMC and partners would focus on coordinating with schools to display colored flags corresponding to AQI levels for each day; studying chronic respiratory illness patients and children sensitization programs with the help of government and private doctors; develop specific sensitization programs for communities living in high level AQI communities in the city; conducting asthma clinics & pulmonary health promotion program; and sending text messages and WhatsApp Alerts to school officials and asthma/chronic obstructive pulmonary disease patients.

The air pollution U.S. EPA School Flags Program uses the color coding of the AQI to fly highly visible flags in school areas, corresponding to the day's air quality, since schoolchildren are especially vulnerable to air pollution.[55] The program also has informational materials for teachers, students and parent on air pollution and health protection. The U.S. EPA has developed a number of other outreach tools that could potentially be adapted for use in India. There are online brochures, games, and videos on different aspects of air pollution and health protection.

Figure 12: PMC and IITM- SAFAR Flyer for School Flags Programme. (Credit: NRDC)

4. Capacity Building for Medical Professionals

Building capacity among medial professions on the health impacts of air pollution, including asthma and respiratory infections, is vital to protecting public health. As part of the AIR Plan, the PMC would engage with private and public medical professionals to build health awareness and protection strategies on air pollution.[56]

The PMC and partners would focus on: trainings of medical and paramedical workforce to build their capacity on air pollution, health and mitigations measures; engage with private and public medical professionals to build health awareness and protection strategies on air pollution; and work with institutions specializing in public health and medical sciences to conduct epidemiological studies to ascertain impact of air pollution on health. Specifically, the AIR Plan could integrate with related activities, such as the lead physician in Maharashtra working with the group "Doctors for Clean Air."[57]

Health professionals can provide specific information on personal health risks of air pollution information. As trusted messengers and health experts, and people who are on the front lines of advising, diagnosing and treating respiratory and cardiovascular illnesses worsened by air pollution, local health professionals can encourage vulnerable people to take health-protective actions. Involvement of health care professionals can also support stronger policy solutions.

A study among nearly 34,000 people in the United States showed that receiving advice from a health professional to reduce outdoor activity during poor air quality periods dramatically increased the impact of media alerts and AQI reports, especially among people with asthma.[58] While 31% of adults with asthma reportedly reduced their outdoor activity after hearing a media AQI alert, 75% of people reduced time outdoors after hearing advice from a health professional.

Medical and health professionals should consider routinely advising patients, especially those with asthma and other respiratory or cardiovascular illness, to avoid strenuous outdoor activity when the AQI is high. In addition to supporting individual patients' health, the same health professionals have the research and clinical practice expertise that informs local interventions and policy strategies to reduce air pollution sources.

5. Set Priorities for Air Pollution Mitigation

Reducing pollution is critical to improving air quality in Pune. Fortunately, the MPCB has a draft pollution control plan for Pune. The PMC is also working on a city Clean Air Plan (CAP) as part of the National Clean Air Programme (NCAP), which includes a target to achieve a reduction of air pollution by 20-30% by 2024. The NCAP will be implemented in 122 cities nationally, including Pune.[59]

The PMC has already demonstrated leadership with programs to reduce air pollution, such as electric buses. In addition, IITM-SAFAR has already convened local experts as an informal Pune Expert Working Group.

To set priorities on air pollution mitigation, the PMC and partners would engage and draw upon expertise of local institutions and experts support developing of the city CAP; develop air quality improvement recommendations for the city; analyze 1-2 key sectors in more depth and detail interventions required to reduce pollution.[60]

An additional element critical to advancing a health-based plan is robust scientific research. Developing local scientific studies to build a local evidence base on environment-health connections provide the foundation for taking action.

Some of the types of scientific studies that could serve to build this evidence base include: epidemiologic studies to examine possible relationships between levels of daily air pollution and respiratory hospitalizations or emergency department visits in Pune; evaluation of data from air quality monitoring sites that are near schools, and investigation into school children's respiratory health; exploration of the long-term effects of air pollution exposures amongst pregnant mothers and their newborns, and estimation of the long-term effects and costs to society; and further illuminating the range of air pollution exposures and health effects relevant highly-exposed outdoor workers, such as traffic police.[61]

Another key element of a health-based air response plan is the development of a range of policy interventions that aim to reduce air pollution. For example, a road space rationing plan in Delhi in January 2016, in which odd versus even license plates had access to roadways on alternate days, resulted in uncertain effects on air quality overall but may be attempted again.[62]

Plans to reduce vehicle, industrial, construction, agricultural and other air pollution sources will be a necessary complement to air pollution monitoring and health risk communication managed through the AIR Plan. Other programs, like planting trees in order to reduce fine particulate air pollution, could help to address multiple environmental health risks in Indian cities. For example, one recent modeling study estimated that tree planting could appreciably lower both $PM_{2.5}$ concentrations and urban temperatures in cities worldwide.[63] By combining several of these approaches, air pollution sources can be reduced at the same time that AQI programs help people adjust their behavior to protect themselves from current levels of air pollution.

SECTION 4

Future Air Pollution Management in Pune

Given current air quality conditions in Pune and a strong pollution monitoring program led by IITM- SAFAR, better integrating public health protections into the city's response strategy is critical to protecting public health. The seven steps identified in Figure 13 provide a suggested path forward for the city and partners on developing the Pune AIR plan.

Figure 13: Proposed process for development of a Pune Air Information and Response (AIR) Plan.

1. **PMC Engagement and Nodal Officer Appointment**
   Once the city identifies a responsible nodal officer for air pollution management, it can centralize its response strategy and facilitate more effective interagency coordination, especially for the AQI warning systems as part of the Pune AIR Plan.

2. **Stakeholder Discussions**
   Engagement and consultation with a broad group of air pollution stakeholders, including vulnerable groups, medical professionals, the media, civil society, IITM-SAFAR, and government authorities at the city, state, and central levels will allow PMC to develop effective air pollution response strategies and communication tools.

3. **Development of Draft AIR Plan**
   Based on the initial round of stakeholder discussions, the PMC can develop a plan to enhance air pollution risk communication in the city. Potential strategies include locally-tailored information, education, and communication (IEC) materials, medical professional training, outreach to vulnerable populations, and a school flag program.

4. **Tabletop Exercise on Draft AIR Plan**
   Based on the draft plan, stakeholders responsible for AIR Plan implementation can gather to identify hurdles and opportunities for cross-sector partnerships for effective execution and develop standard operating procedures to standardize AIR Plan implementation across responsible city agencies.

5. **Stakeholder Discussions**
   Key stakeholders will have an opportunity to respond to the draft plan and standard operating procedures and brief the PMC on their recommendations. These experts can continue their engagement with local air pollution management through an expert working group structure.

6. **PMC Adoption and Release of the AIR Plan**
   Once the city has reviewed the AIR Plan, it can formalize its implementation across responsible city agencies.

7. **AIR Plan Implementation**
   Execution of plan objectives will require coordinated efforts across a range of stakeholders.

Throughout this process, the city should integrate its work on health risk communication into its pollution mitigation efforts through the NCAP.

References

1 Institute for Health Metrics and Evaluation. 2018. "GBD Results Tool | GHDx." 2018. http://ghdx.healthdata.org/gbd- results-tool.

2 Cohen, Aaron J., et al. "Urban air pollution." Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors 2 (2004): 1353-1433.

3 U.S. Environmental Protection Agency. "Particulate Matter (PM) Basics." Overviews and Factsheets. US EPA, April 19, 2016. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics.

4 International Energy Agency, Word Energy Outlook Special Report on Energy and Air Pollution, 2016, http://www.worldenergyoutlook.org.

5 Balakrishnan, K., Dey, S., Gupta, T., Dhaliwal, R. S., Brauer, M., Cohen, A. J., et al. (2019). The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: the Global Burden of Disease Study 2017. The Lancet Planetary Health, 3(1), e26–e39. https://doi.org/10.1016/S2542-5196(18)30261-4.

6 CPCB, Air Quality: "National Air Quality Monitoring Program", https://cpcb.nic.in/list-of-non-attainment-cities/.

7 Times of India, "Pune's Air Quality Continues To Worsen Over The Years", https://timesofindia.indiatimes.com/city/pune/air-quality-continues-to-worsen-over-the-years/articleshow/68086815.cms. 8 Times of India, "Pune's air quality continues to worsen over the years", https://timesofindia.indiatimes.com/city/pune/air-quality-continues-to-worsen-over-the-years/articleshow/68086815.cms. 9 Times of India, https://punemirror.indiatimes.com/pune/cover-story/out-of-breath/articleshow/70425100.cms, https://punemirror.indiatimes.com/pune/cover-story/out-of-breath/articleshow/70425100.cms.

10 Urban Emissions. "Air Pollution Knowledge Assessment (APnA) - City Profile (Pune, India)," 2019. http://www.urbanemissions.info/india-apna/pune-india/.

11 Satellite-derived Surface $PM_{2.5}$ Concentrations for Pune from 1998-2014, available online at: http://www.urbanemissions.info/india-apna/pune-india/.

12 Pune Smart City Development Corporation Limited. "Smart Elements (Environmental Sensors)," 2018. https://punesmartcity.in/project/smart-elements/.

13 Central Pollution Control Board, "List of Air Quality Stations", www.cpcb.gov.in/caaqm/frmStationdetails.aspx?cityID=312.

14 Indian Institute of Tropical Meteorology. "SAFAR - India (Pune Observational Network)," 2019. http://safar.tropmet.res.in/MONITORING%20SYSTEM-10-3-Details.

15 Sachin Patil, Sagar Gawande, "Ambient Air Quality Monitoring in Pune City", International Journal of Science and Research, May 2015. https://www.researchgate.net/publication/277405292_Ambient_Air_Quality_Monitoring_In_Pune_City.

16 World Meteorological Organization. GAW Report No. 217, System of Air Quality and Weather Forecasting and Research (SAFAR-India); World Meteorological Organization: Geneva, Switzerland, 2015.

17 Central Pollution Control Board (CPCB). About National Air Quality Index. Available online: http://cpcb.nic.in/About_AQI.pdf.

18 World Meteorological Organization. GAW Report No. 217, System of Air Quality and Weather Forecasting and Research (SAFAR-India); World Meteorological Organization: Geneva, Switzerland, 2015; Central Pollution Control Board (CPCB). Guidelines for the Measurement of Ambient Air Pollutants, Volume-I

(National Ambient Air Quality Series: NAAQMS/36/2012-13). Available online: http://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvMjdfMTQ1ODExMDQyNl9OZXdJdGVtXzE5Nl9OQUFRTVNfVm9sdW1lLUkucGRm. 19 Environnement SA. MP101M—Continuous, Automatic PM10, PM2.5, PM1, TSP Particulate Monitor.

Available online: http://www.environnement-sa.com/products-page/en/air-quality-monitoring-en/mp 101m-continuous-automatic-pm10-pm2-5-pm1-tsp-particulate-monitor/.

20 International Organization for Standardization. ISO 10473:2000—Ambient Air—Measurement of the Mass of Particulate Matter on a Filter Medium—Beta-ray Absorption Method. Available online: https://www.iso. org/standard/32943.html.

21 Central Pollution Control Board (CPCB). About National Air Quality Index. Available online: http://cpcb.n ic.in/About_AQI.pdf.

22 Kamal Joyti, Anil Kumar Dikshit, and Ashok Deshponde. "Human health risk assessment due to air pollution in 10 urban cities in Maharashtra, India", Cogent Environmental Science, May 2016, https://www.tandfonline.com/doi/full/10.1080/23311843.2016.1193110.

23 Sarath K. Guttikunda, Puja Jawahar "Application of SIM-air modeling tools to assess air quality in Indian cities" Atmospheric Environment, Volume 62, December 2012, 551 - 561 http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1027.5207&rep=rep1&type=pdf.

24 World Health Organization. "Air Quality Guideline Values," 2018. https://www.who.int/news-room/fact- sheets/detail/ambient-(outdoor)-air-quality-and-health.

25 Prabhakaran, Dorairaj, Panniyammakal Jeemon, Meenakshi Sharma, Gregory A Roth, Catherine Johnson, Sivadasanpillai Harikrishnan, Rajeev Gupta, et al. "The Changing Patterns of Cardiovascular Diseases and Their Risk Factors in the States of India: The Global Burden of Disease Study 1990–2016." The Lancet Global Health 6, no. 12 (December 2018): e1339–51. https://doi.org/10.1016/S2214-109X(18)30407-8.

[26] Balakrishnan, K., Cohen, A., & Smith, K. R. (2014). Addressing the Burden of Disease Attributable to Air Pollution in India: The Need to Integrate across Household and Ambient Air Pollution Exposures. Environmental Health Perspectives, 122(1). https://doi.org/10.1289/ehp.1307822

[27] Jubulis, J., et al, "Modifiable risk factors associated with tuberculosis disease in children in Pune, India", International Union Against Tuberculosis and Lung Disease, Volume 18, No 2 (February 2014), 198-207

[28] Gordon, T., Balakrishnan, K., Dey, S., Rajagopalan, S., Thornburg, J., Thurston, G., et al. (2018). Air pollution health research priorities for India: Perspectives of the Indo-U.S. Communities of Researchers. Environment International, 119,100–108. https://doi.org/10.1016/j.envint.2018.06.013; Limaye, V. S., Knowlton, K., Sarkar, S., Ganguly, P., Pingle, S., Dutta, P., et al. (2018). Development of Ahmedabad's Air Information and Response (AIR) Plan to Protect Public Health. International Journal of Environmental Research and Public Health, 15(7), 1460. https://doi.org/10.3390/ijerph15071460

[29] Mullins, J., & Bharadwaj, P. (2015). Effects of Short-Term Measures to Curb Air Pollution: Evidence from Santiago, Chile. American Journal of Agricultural Economics, 97(4), 1107–1134. https://doi.org/10.1093/ajae/aau081

[30] Pune Municipal Corporation, "PMC's efforts for Air Quality and Climate Resilience" Press Note (2019) https://www.pmc.gov.in/en/pmc-mou-air-pollution-control

[31] Ahmedabad Municipal Corporation, Indian Institute of Tropical Meteorology – SAFAR, Indian Institute of Public Health, Gandhinagar, Natural Resources Defense Council, "Protecting Health From Increasing Air Pollution in Ahmedabad: Supporting Research and Analysis for the Ahmedabad Air Information & Response (AIR) Plan" (2017) https://www.nrdc.org/sites/default/files/ahmedabad_aqi_-_final.pdf; Ahmedabad Municipal Corporation, Ahmedabad AIR Plan (2018 update) https://www.nrdc.org/sites/default/files/air_plan_2018_dec3_v2.pdf.

[32] Ahmedabad Municipal Corporation, Ahmedabad AIR Plan (2018 update) at 8-10 https://www.nrdc.org/sites/default/files/air_plan_2018_dec3_v2.pdf.

[33] Kaur, N. Flagging Air Pollution for School Children in Ahmedabad. 2017. Available online: https://www.nrdc.org/experts/nehmat-kaur/flagging-air-pollution-school-children-ahmedabad

[34] World Meteorological Organization. GAW Report No. 217, System of Air Quality and Weather Forecasting and Research (SAFAR-India); World Meteorological Organization: Geneva, Switzerland, 2015.

[35] Limaye, Vijay S., K. Knowlton, S. Sarkar, P. Ganguly, S. Pingle, P. Dutta, S. LM, et al. "Development of Ahmedabad's Air Information and Response (AIR) Plan to Protect Public Health." International Journal of Environmental Research and Public Health 15, no. 7 (July 10, 2018): 1460. https://doi.org/10.3390/ijerph15071460. [36] Sagar, A.; Balakrishnan, K.; Guttikunda, S.; Roychowdhury, A.; Smith, K.R. India Leads the Way: A Health-Centered Strategy for Air Pollution. Environ. Health Perspectives. 2016, 124.

[37] SCAG, Transportation Conformity Working Group, 2016, http://www.scag.ca.gov/programs/Pages/TCWG.aspx.

[38] Puget Sound Clean Air, Washington State Department of Transportation, Memorandum of Agreement- Fugitive Dust, 1999

[39] Puget Sound Clean Air, Washington State Department of Transportation, Memorandum of Agreement- Fugitive Dust, 1999.

[40] Ahmedabad Municipal Corporation, Ahmedabad AIR Plan (2018 update) at 11-12 https://www.nrdc.org/sites/default/files/air_plan_2018_dec3_v2.pdf.

[41] Limaye, Vijay S., and Anjali Jaiswal. "Getting the Word Out on Air Pollution and Health." https://www.nrdc.org/experts/vijay-limaye/getting-word-out-air-pollution-and-health.

[42] Amulya Gopalakrishnan, "Choking on the Truth: How the Air that Sustains Our Lives is also Slowly Killing Us," India Today, March 16, 2015.

[43] The Indian Express. "Death by Breath: What's Happening to Delhi Air Will Have You Gasping for Breath." The Indian Express (blog), April 4, 2015. https://indianexpress.com/article/india/india-others/death-by-breath-an-exhaustive- series-on-delhis-air-pollution/.

[44] World Health Organization. "Ambient (Outdoor) Air Quality and Health," 2018. https://www.who.int/news-room/fact- sheets/detail/ambient-(outdoor)-air-quality-and-health.

[45] Indian Institute of Tropical Meteorology. "System of Air Quality and Weather Forecasting And Research (SAFAR)." Accessed October 11, 2019. http://safar.tropmet.res.in/.

[46] New York City Department of Health and Mental Hygeine. "Outdoor Air Quality," 2019. https://www1.nyc.gov/site/doh/health/health-topics/air-quality-air-pollution-protection.page. [47] U.S. Environmental Protection Agency. "AirNow: Teacher's Air Quality Resources," 2018. https://airnow.gov/index.cfm?action=learning.forteachers.

[48] U.S. Environmental Protection Agency. "AirNow: For Weathercasters," 2018. https://airnow.gov/index.cfm?action=aqifor.weathercast.

[49] U.S. Environmental Protection Agency. "AirNow: Health Care Providers," 2018. https://airnow.gov/index.cfm?action=health_providers.index.

[50] U.S. Environmental Protection Agency. "AirCompare," 2019. https://www3.epa.gov/aircompare/.

[51] New York State Department of Transportation. "Clean Air New York." https://511nyrideshare.org/web/clean-air- ny/do-your-part.

[52] State of New York. "Air Quality Index (AQI) Forecast and Current Observations for New York State - NYS Dept. of Environmental Conservation." http://www.dec.ny.gov/chemical/34985.html.

[53] Jaiswal A., "Scaling Health-Based Air Plans and Cool Roofs in India: Pune" (2019) https://www.nrdc.org/experts/anjali-jaiswal/scaling-health-based-air-plans-and-cool-roofs-india-pune. [54] Ahmedabad Municipal Corporation, Ahmedabad AIR Plan (2018 update) at 11-12 https://www.nrdc.org/sites/default/files/air_plan_2018_dec3_v2.pdf.

55 U.S. Environmental Protection Agency. "AirNow: Air Quality Flag Program." https://airnow.gov/index.cfm?action=flag_program.index.

56 Ahmedabad Municipal Corporation, Ahmedabad AIR Plan (2018 update) at 12-13 https://www.nrdc.org/sites/default/files/air_plan_2018_dec3_v2.pdf.

57 The Breathe Life, "Doctors for Clean Air" (2018) https://breathelife2030.org/news/doctors-clean-air-leads-indias- medical-community-fight-air-pollution/.

58 Wen, X-J., L. Balluz, and A. Mokdad, "Association between media alerts of Air Quality Index and change of outdoor activity among adult asthma in six states, BRFSS, 2005," J. Community Health 34 (2009):40-46.

59 National Green Tribunal. "Original Application No. 681/2018," 2019. https://indiaaq.files.wordpress.com/2019/08/ngt- order-on-non-attainment-cities.pdf.

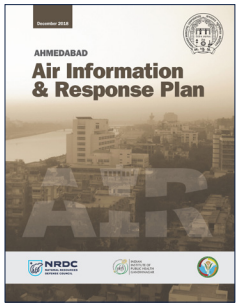
60 Ahmedabad Municipal Corporation, Ahmedabad AIR Plan (2018 update) at 13 https://www.nrdc.org/sites/default/files/air_plan_2018_dec3_v2.pdf.

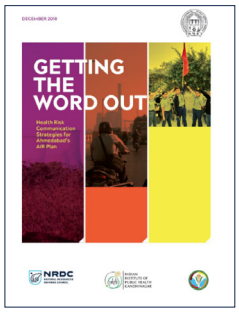
61 Raval, A., P. Dutta, A. Tiwari, P. Ganguly, S. LM, D. Mavalankar, and J. Hess. "Effects of Occupational Heat Exposure on Traffic Police Workers in Ahmedabad, Gujarat." Indian Journal of Occupational and Environmental Medicine 22, No. 3 (2018): 9.

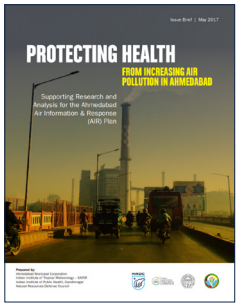
62 Kumar, P., Gulia, S., Harrison, R. M., & Khare, M. (2017). The influence of odd–even car trial on fine and coarse particles in Delhi. Environmental Pollution, 225, 20–30. https://doi.org/10.1016/j.envpol.2017.03.017

63 McDonald, Rob, Timm Kroeger, Tim Boucher, LongZhu Wang, and Rolla Salem. "Planting Healthy Air: A Global Analysis of the Role of Urban Trees in Addressing Particulate Matter Pollution and Extreme Heat." Planting Healthy Air: A Global Analysis of the Role of Urban Trees in Addressing Particulate Matter Pollution and Extreme Heat., 2016. https://www.nature.org/content/dam/tnc/nature/en/documents/20160825_PHA_Report_Final.pdf.

Resources, Issue Briefs and Blogs







Air Emergency in Delhi: A Health Crisis Hits Home, Polash Mukherjee, Anjali Jaiswal, Kim Knowlton, and Vijay Limaye, November 2019, https://www.nrdc.org/experts/vijay-limaye/air-emergency-delhi-health-crisis-hits-hom

Pune Expands City Efforts To Fight Dangerous Air Pollution, Vijay Limaye, Polash Mukherjee, Anjali Jaiswal, and Kim Knowlton, October 2019, https://www.nrdc.org/experts/vijay-limaye/pune-expands-city-efforts-fight-dangerous-air-pollution

Highlighting City Actions to Reduce Air Pollution in India, Anjali Jaiswal, Kim Knowlton, and Vijay Limaye, February 2019 https://www.nrdc.org/experts/vijay-limaye/highlighting-city-actions-reduce-air-pollution-india

Scaling Health-Based Air Plans and Cool Roofs in India: Pune, Anjali Jaiswal, July 2018, https://www.nrdc.org/experts/anjali-jaiswal/scaling-health-based-air-plans-and-cool-roofs-india-pune

India Launches a National Clean Air Program, Anjali Jaiswal, July 2019, https://www.nrdc.org/experts/anjali-jaiswal/india-launches-national-clean-air-program

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NATURAL RESOURCES DEFENSE COUNCIL