National Module on Advancing Air Quality

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The module is based on the Guidance Framework for Better Air Quality in Asian Cities developed by Clean Air Asia (2016)

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Acknowledgment and Credit

National Module on Advancing Air Quality intends to provide necessary guidance to Indian cities in implementing the National Clean Air Programme (NCAP) launched by the Ministry of Forest, Environment and Climate Change (MoEF&CC) on January 10, 2019. The module is based on the Guidance Framework for Better Air Quality in Asian Cities developed by Clean Air Asia (2016).

We wish to thank Clean Air Asia (CAA) for giving us this opportunity to work on the module which focuses on this year's World Environment Day theme – Beat Air Pollution.

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Foreword

For us at Clean Air Asia, having worked in over 1000 cities all over Asia, we have discovered that one of the key areas that cities need support in is Capacity Building. While most cities have the inclination to reduce air pollution, it is the lack of technical know- how and a comprehensive understanding of the integrated nature of the issue of air pollution that is a major challenge to addressing it.

The Guidance Framework is a voluntary and non- binding guidance document developed as an outcome of the biennial Governmental Meetings on Urban Air Quality in Asia, co-organized by Clean Air Asia and United Nations Environment Programme Regional Office for Asia Pacific. The development of the Guidance Framework is an important step in this direction as it serves as a guide for cities and countries to achieve this vision provides an overview of the status of air quality management across Indian cities. This framework details the key initiatives that can be undertaken at the national and city level, the progress cities are making to mitigate air pollution and its detrimental effects on the environment and the health of the people.

Our work in India involves supporting cities to prepare and implement air action plans. While we were assessing the air quality management needs of cities in India we felt that there is a need to look at local issues and prepare a module that can be used a basic toolkit for training of city officials so that they can comprehend the city needs and "discover" the areas of intervention required in order to create systems for advancing better air quality. It is in this background that Clean Air Asia India and the Centre for Environment Education, one of the leading institutions in training and capacity building in India has prepared the National Module for Advancing Air Quality. The module adapted from the Guidance Framework has been developed to help design cities define air quality management policy and strategize for implementation.

The National Module for Advancing Air Quality in India provides scope for defining recommended steps and actions to improve air quality through a range of targeted interventions, including knowledge-sharing platforms to strengthen regional collaboration, capacity building activities such as trainings, study tours and city twinning, and technical assistance. Since India is still at a nascent stage as far has air quality management in cities is concerned, one of the biggest learnings of this assessment has been identifying important initiatives already underway in many cities that create a positive impetus for assessing, monitoring and abating air pollution across cities and can be scaled up. The module also tried to look into national level policies and the institutional structures in India where enforcement mechanisms can be strengthened through strong public engagement. That said, there is also recommendations for enhancing certain areas to help and enable Indian cities to achieve the National Ambient Air Quality Standards in the future.

In the past one year we have been supporting air action plans for cities. We feel this document can be used as a guidance document to help strategize for the implementation of this plans. We hope that all those working in the better air quality space will find this a useful reference document to achieve better air quality and make Indian cities more liveable.

Prarthana Borah
India Director, Clean Air Asia

Preface

Air pollution is the world's single greatest environmental risk to health causing risk in terms of heart disease, stroke, lung cancer and other chronic diseases. Historically, indoor air pollution due to burning of wood and cow dung cakes has been a major cause of ill health. But while indoor pollution is decreasing with initiatives like better cook stoves and supply of LPG connections, outdoor pollution is still on the increase. At present, with the growth in urbanization in India, the cities are facing change in number of road vehicles and dusty construction sites which have multiplied, increase in industrial development have further contributed to air pollution and increased the threat on human life. Air pollution is also responsible for 50% of childhood pneumonia deaths.

According to World health statistics 2016, air pollution – both indoor and outdoor caused nearly 7 million deaths globally. India accounts for 1.2 million deaths due to air pollution and is amongst the top 10 countries with the highest mortality burden attributable to air pollution in 2017.

In recent years, small and medium towns as well as cities have witnessed a significant increase in air pollution. With decline in urban air quality, risk to people residing in these cities, which constitute to about 32 per cent of India' s population, increases. Therefore, active participation of cities through design, monitoring and implementation of air quality management plans is the need of the hour, in order to tackle air pollution at the local level.

CEE in partnership with CAA-India has prepared the National Module for Advancing Air Quality in line with the National Clean Air Programme (NCAP) based on the Guidance Framework for Better Air Quality in Asian Cities to provide Indian cities with a roadmap to take significant steps in attaining better air quality. The module lays emphasis on enhancing the knowledge base of key actors, and building the capacity of cities to mitigate air pollution, enabling participatory approaches for action plan development and enhancing the role of communication in improving air quality. The module also advocates strengthening multi-stakeholder, multi-sectoral approaches for improved air quality management.

We hope that the module will provide an impetus to address air pollution issues more seriously and inspire non-attainment cities to take strong actions for betterment of air quality.

Kartikeya V Sarabhai

Director, Centre for Environment Education

Abbreviations

AA-1981 : The Air (Prevention and Control of Pollution) Act 1981

AAQM : Ambient Air Quality Monitoring

AAQS : Ambient Air Quality Standards

AOD : Aerosol Optical Depth

APCD : Air Pollution Control Device

AQ : Air Quality

AQI : Air Quality Index

AQM : Air Quality Management

AQS : Air Quality Standards

AQSM : Air Quality Simulation Model

BaP : Benzo(a)Pyrene

BC : Black Carbon

BS VI : Bharat Stage VI

Ca++ : Calcium

CAA : Clean Air Asia

CAAP : Clean Air Action Plan

CAAQMS : Continuous Ambient Air Quality Monitoring Stations

CAM : Crustal + Alluvial + Marine constituents

CEE : Centre for Environment Education

CEMS : Continuous Emission Monitoring System

CSN : Chemical Speciation Network

Cl^- : Chlorine

CMB : Chemical Mass Balance

CO : Carbon Monoxide

COPD : Chronic Obstructive Pulmonary Diseases

CPCB : Central Pollution Control Board

CSIR : Council of Scientific & Industrial Research

CSR : Corporate Social Responsibility

DG : Diesel Generator

EC : Elemental Carbon

EFs : Emission Factors

EI : Emissions Inventory

EPA-1986 : Environment (Protection) Act, 1986

EPCA : Environmental Pollution (Prevention and Control) Authority

EPR : Extended Producer Responsibility

ESCOs : Energy Service Companies

EU : European Union

EV : Electric Vehicle

FGDs : Flue Gas De-Sulphurizations

GBD : Global Burden of Disease

GDP : Gross Domestic Product

GHGs : Greenhouse Gases

GR : Guaranteed Reagent

GRAP : Graded Response Action Plan

HCs : Hydro Carbons

HIA : Health Impact Assessment

IEA : International Energy Agency

IEC : Information Education and Communication

IIT : Indian Institute of Technology

ISRO : Indian Space Research Organization

KW : Kilowatt

LR : Laboratory Reagent

LTV : Long Term Vision for Urban Air Quality in Asia

MMSCMD : Million Metric Standard Cubic Metre per Day

MoA : Ministry of Agriculture

MoEF&CC : Ministry of Environment, Forest and Climate Change

MoH&FW : Ministry of Health and Family Welfare

MoHUA : Ministry of Housing and Urban Affairs

Na^+ : Sodium

NAAQM : National Ambient Air Quality Monitoring

NAAQS : National Ambient Air Quality Standards

NAMP : National Air Quality Monitoring Programme

NAPCC : National Action Plan on Climate Change

NATA : National Air Toxics Assessment

NCAP : National Clean Air Programme

NCR : National Capital Region

NDC : National Development Council

NEERI : National Environmental Engineering Research Institute

NGOs : Non-Governmental Organization

NH_4^+ : Ammonium

NO_3^- : Nitrate

NO_x : Oxides of Nitrogen

NPL-ICS : National Physical Laboratory-India Certification Scheme

OC : Organic Carbon

OCEMS : Continuous Emission/Effluent Monitoring System

PAH : Hydrocarbon Poly Aromatic

PM_{10} : Particulate Matter size less than 10 µm

$PM_{2.5}$: Particulate Matter size less than 2.5 µm

PUC : Pollution Under Control

QA : Quality Assurance

QC : Quality Control

RTO : Regional Transport Office

RWAs : Resident Welfare Associations

SA : Source Apportionment

SDGs : Sustainable Development Goals

SIA : Secondary Inorganic Aerosols

SIP : State Implementation Plans

SLAMS : State or Local Air Monitoring Stations

SO_2 : Sulphur dioxide

SOP : Standard Operating Procedure

SPCBs : State Pollution Control Boards

TC : Total Carbon

TERI : The Energy and Resources Institute

TPPs : Thermal Power Plants

UNEP ROAP : United Nations Environment Programme Regional Office of Asia and the Pacific

UNEP : United Nations Environment Programme

UNSDG : United Nations' Sustainable Development Goals

USEPA : United States Environmental Protection Agency

VKT : Vehicle Kilometers Travelled

VOCs : Volatile Organic Compounds

WHO : World Health Origination

Contents

Introduction

"In a country like India, it is inevitable that authorities and people soon take corrective measures or else quality of life diminish further. The need of the hour is to demand clean air."

1.1 Overview

Air pollution is now considered the world's largest environmental health risk. Seven billion people, more than 95% of the world's population, live in areas with unhealthy air and every year worldwide, 4.1 million deaths are attributed to long-term exposure to ambient $PM_{2.5}$ according to the State of Global Air Report 2018, a new global study by Health Effects Institute, a US based nonprofit research institute. As per a WHO report, air pollution kills an estimated 7 million people worldwide every year and 9 out of 10 people in the world breathe polluted air.

Air pollution for India is a national problem that is killing 1.2 million Indians every year and costing the economy an estimated 3% of GDP. If the country's development is important, fighting air pollution has to be a priority.

Again, as per the State of Global Air report - 2018 and WHO, air pollution is responsible for respiratory, heart, lungs, kidney and brain related diseases. Nearly 93% of all children under the age of 15 breathe polluted air, and hundreds of thousands of kids die of respiratory complications each year. Pollutants also have adverse effects on neurodevelopment in children, leading to low scores in cognitive tests. Air pollution is further responsible for acid rain and global warming.

As per WHO Urban Ambient Air Quality Database 2016, 10 out of the top 20 cities which have the highest annual average levels of $PM_{2.5}$ are from India.

With rapid urbanization - vis a vis continuing economic growth - comes a rise in the demand for road transport in urban areas, increased pollution from the surge in motor vehicle kilometers, and additional pressure on the existing limited supply of energy, predominantly fossil fuels such as oil and coal. Emerging Asian economies, notably China, India and, to a certain extent, South-East Asian countries - will account for more than 90% of net energy demand growth to 2035.

Environment Protection and the Constitution of India

The chapter on fundamental duties of the Indian Constitution clearly imposes a duty on every citizen to protect the environment. Article 51-A (g)

- Article 51-A (g), says that, "It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures."
- Article 48-A reads that "The State shall endeavor to protect and improve the environment and to safeguard the forests and wildlife of the country".

Environment protection is part of our cultural values and traditions. In Atharvaveda, it is said that "Man's paradise is on earth; this living world is the beloved place of all; it has the blessings of nature's bounties; live in a lovely spirit".

The demand for cleaner air is gaining momentum and the launch of the NCAP in January 2019 sets out an approach of cleaning up the air in India's cities, by reducing $PM_{2.5}$ and PM_{10} concentrations up-to 20-30% by 2024 in 102 non-attainment cities across the country, taking 2017 as the base year for the comparison of concentrations; the Indian cities are gearing up for advancing air quality. A steering committee has also been constituted by the MOEF&CC to ensure implementation of the NCAP across the country. The committee is planned to be under the chairmanship of its Secretary and would comprise of one chief secretary each from over 20 states and union territories, including Delhi, Jammu and Kashmir and Uttar Pradesh, as its members. The other members on the panel will include the additional secretary and joint secretary from the ministry, the Chairman of the Central Pollution Control Board (CPCB), the Director General of TERI and an IIT Kanpur professor. The committee would be headquartered in Delhi, will ensure inter-ministerial or organizational cooperation and sharing of information and resolve issues under the NCAP.

The National Module for Advancing Air Quality in Indian Cities (referred to as National Module in subsequent pages) is a framework meant to be a "living document" that will evolve with its users – offers guidance for policymakers and decision makers in key air quality management (AQM) components to help them progress through the development stages of AQM. CEE is developing this module based on the NCAP for Indian cities and referring to the Guidance Framework of CAA. This module will be orienting the cities to create their own City Specific Air Quality Management Plans, considering the varying pollutants and mitigation strategies for each city.

Sustainable Development Goals and Air pollution

SDGs is a way forward to improve well-being of people and the planet henceforth improving air quality also forms an integral part of SDGs. Goal 3, 7,11 and 13 and relevant targets are closely linked to air pollution. The targets include reduction in pollution, reducing related deaths and disabilities, change in fuels for reducing air pollution and other actions to combat climate change

3 GOOD HEALTH AND WELL-BEING	Goal 3. Target 3.9 - By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination Indicator 3.9.1: Mortality rate attributed to household and ambient air pollution
7 AFFORDABLE AND CLEAN ENERGY	Goal 7. Target 7.1- By 2030, ensure universal access to affordable, reliable and modern energy services Indicator 7.1.2: Proportion of population with primary reliance on clean fuels and technology
11 SUSTAINABLE CITIES AND COMMUNITIES	Goal 11. Target 11.6 - By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management Indicator 11.6.2: Annual mean levels of fine particulate matter (e.g. $PM_{2.5}$ and PM_{10}) in cities (population weighted)
13 CLIMATE ACTION	Goal 13. Take urgent action to combat climate change and its impacts

Air Pollution and Climate Change

Climate change and air pollution are closely related. The major source sectors for air pollution as well as GHG emission include road transport, thermal power plants, domestic and commercial sectors, industries and landfill sites. Mitigation actions for these sectors for air quality management will also lead to reduction in GHG emissions. Dovetailing of the existing policies and programmes including the National Action Plan on Climate Change (NAPCC) and other initiatives of the Government of India in reference to climate change will be done during the execution of NCAP.

1.2 The National Module for Advancing Air Quality in Indian Cities

The National Module for Advancing Air Quality in Indian Cities intends to provide guidance in implementing the NCAP and is inspired by the Guidance Framework for Better Air Quality in Asian Cities by CAA.

National Clean Air Programme for Indian Cities

Target: National level target of 20-30% reduction of $PM_{2.5}$ and PM_{10} concentration by 2024.

Objectives:

- Stringent implementation of mitigation measures for prevention, control and abatement of air pollution
- Augment and strengthen air quality monitoring network across the country
- Augment public awareness and capacity building measures

The module also encompasses a Long Term Vision for Urban Air Quality in Asia (LTV). The LTV describes the desired state of urban air quality in Asian cities by 2030

Long Term Vision for Urban Air Quality in Asia (LTV)

Vision: "Healthy people in healthy cities, which puts emphasis on the prevention of air pollution, and which implements effective strategies for the abatement of air pollution."

Indicator: "Asian cities have made significant progress towards achieving WHO air quality guideline values through the implementation of comprehensive AQM strategies."

The National Module also supports the realization of the United Nations' Sustainable Development Goals, (UNSDG) notably Goal 11: Make cities inclusive, safe, resilient, and sustainable; Goal 13: Take urgent action to combat climate change and its impacts; and Goal 3: Ensure healthy lives and promote wellbeing for all at all ages (Target: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination).

This national module focuses on ambient air quality and its management. Issues related to indoor air quality and occupational health also need to be addressed for better AQM, but they are beyond the scope of this module.

1.2.1 Target audience

The primary target audience of the National Module are policymakers and decision makers at the city level who are responsible for improving urban air quality. The module also provides information and recommendations to other relevant stakeholders who can support initiatives to improve air quality in cities: Development organizations, the private sector, nongovernmental organizations and other civil society groups, the media and academia.

1.2.2 Module Development process

The Guidance Framework developed by CAA is a result of discussions at the biennial Governmental Meetings on Urban Air Quality in Asia organized by UNEP ROAP and CAA to harmonize approaches in tackling urban air pollution and other related areas among Asian countries. Countries that have participated in the Governmental Meetings include Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Iran, Japan, Korea, Lao PDR, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Vietnam. In addition to these meetings, for adoption of the module in India, an expert engagement workshop was also organized by CEE at Ahmedabad. Table 1.1 provides an overview of the past Governmental Meetings

Table 1.1 Overview of Governmental Meetings and their outcome

Governmental Meeting	Date and Location	Outcome
First Governmental Meeting	13-14 December 2006 in Yogyakarta, Indonesia	The meeting recommended the development of a long term vision to help inspire Asian cities and countries in the establishment of their AQM policies and programmes.
Second Governmental Meeting	12-13 November 2008 in Bangkok, Thailand	The draft vision document was circulated to all participating countries and its contents were discussed during the meeting.
Third Governmental Meeting	8 November 2010 in Singapore	Experts deliberated on the way forward in achieving Asia's long term vision for improving urban air quality and priority areas were identified.
Fourth Governmental Meeting	6 November 2013 in Bangkok, Thailand	The participants agreed on developing a Guidance Framework which will provide a recognized guidance in implementing the long term vision.
Fifth Governmental Meeting	17-18 November 2014 in Colombo, Sri Lanka	The first draft of the Guidance Framework was presented. The meeting agreed that the Guidance Framework was useful for Asian cities and was comprehensive in terms of scope. The meeting also provided feedback on how to improve the draft document. The review and finalization process for the Guidance Framework was discussed.

Source: Guidance Framework for Better Air Quality in Asian Cities developed by Clean Air Asia (2016)

Expert engagement workshop in India

An expert engagement workshop was conducted by CEE on March 19, 2019 at Ahmedabad to receive inputs on the adapted module for Indian cities. The workshop comprised experts from CAA-India, CPCB, GPCB, National Environmental Engineering Institute (NEERI), Indian Institute of Public Health Gandhinagar (IIPHG), National Institute of Occupational Health (NIOH), Chest Research Foundation, Physical Research Laboratory (PRL) and Central University of Gujarat amongst others. The experts provided inputs on each of the modules to strengthen the implementation of action plans in cities, keeping in view the diversity in each city.

1.2.3 Air quality management framework

The National Module complements and operates within the framework of strategic AQM (Figure 1.1). This enables government authorities to set objectives to achieve and maintain good air quality, and minimize impacts on human health and the environment.

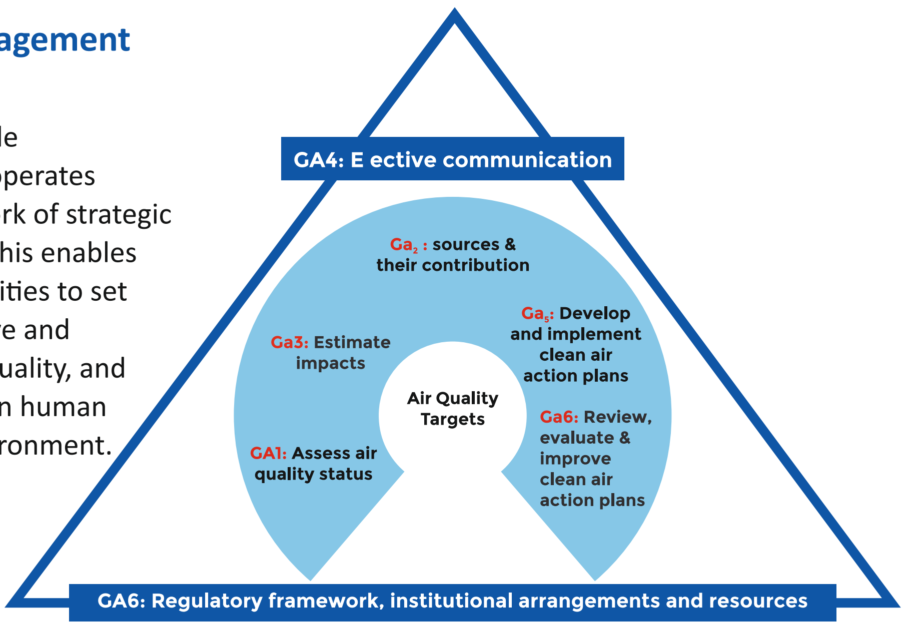


Figure 1.1 Air Quality Management Framework table 1.3 stages of air quality management

Note: GA = Guidance Area

Table 1.2 Overview of Modules

Priority areas of concern	Modules
Implementation and regulatory measures of national ambient air quality standards and improving air quality monitoring systems	Ambient air quality standards and monitoring
Developing and updating emissions inventories, source apportionment, air quality modeling	Emissions inventories and modeling
Linking air quality levels and emissions data with health impacts and their social and economic cost	Health and other impacts
Air quality improvement, setting objectives, mobilizing resources and collaborations for effectiveness of clean air action plans, policies and measures, covering compliance and enforcement and institutional frameworks	City-specific Air Quality Management Plan
Communicating air quality, health and information to government, city level organizations and the public; air quality indexes, mobile and web applications and other means. Communication for enabling participation in the formulation of city-specific AQM plan.	Air quality communication

Source: Guidance Framework for Better Air Quality in Asian Cities developed by Clean Air Asia (2016)

1.3 Structure of the National Module

The module is primarily organized around the five themes within the AQM framework based on the Guidance Framework prepared by CAA. Each chapter is provided as an individual document, which is a compilation of resources to support the implementation of the action points as part of the NCAP at the city level. Each chapter includes:

I) The objective of the module and an overview of key concepts,

ii) An account of the issues and challenges, and

iii) A roadmap with recommended steps to follow in order to improve air quality.

1.4 Development stages of air quality management

Cities can be classified according to their AQM capabilities. They could fall into any of these capability or development stages (Table 1.3 below): Underdeveloped, developing, emerging, maturing, or fully developed. These AQM development stages provide cities with the means to assess where they are on this continuum as well as work towards improving air quality and move upwards through the stages. The characteristics of each stage of AQM development are elaborated in the Guidance Framework developed by CAA through indicators on data, capacity, public awareness and participation, regulatory structure and framework. Indian cities are currently in the capacity of underdeveloped or developing stage of air quality management and need to move further in the stages to achieve the fully developed status. The module would focus on current stages of the Indian cities and facilitate the advancing of air quality.

Table 1.3: Stages of air quality management

Stages	Indicators
Underdeveloped	There is generally little/no capacity, policies, information on, and mechanisms for AQM. The city's air quality is deteriorating due to the lack of control systems and mechanisms in place.
Developing	There is some capacity, policies, information on, and mechanisms for AQM in place but this is insufficient. Consequently, while air pollution levels at this stage remain high with associated serious health and environmental impacts, these are stabilizing and the trajectory can be reversed.
Emerging	Air quality management activities, policies, and communications are starting to be put in place and are starting to be implemented more regularly and systematically. There is some data available and used and there is demonstrated capacity at the operational level of staff, stakeholders and institutions/structures that support implementation.
Maturing	Air quality management activities, policies, and systems are regularly implemented, with review and monitoring systems in place to ensure quality control and accuracy of information. These are supported by policies and governance processes that are more inclusive and varied to suit the different contexts at the national and subnational levels. There is a certain level of transparency such that information is communicated to a wider audience using different communication channels. The improvement of air quality is being achieved with the implementation of effective policies to reduce emissions.
Fully Developed	Where AQM activities, policies and processes are in place, the focus is on ensuring the sustainability of the measures undertaken, the quality of data and research studies generated, and continuous improvement to existing measures through the upgrading of review and monitoring processes, leading to further improvements in air quality. Public participation is strengthened and supported by transparency in governance processes, regulations, and frameworks.

Source: Guidance Framework for Better Air Quality in Asian Cities developed by Clean Air Asia (2016)

1.5 National Module roadmaps

The module encourages cities to actively consider long-term strategies and integrate them into development planning to achieve improved air quality. In order to achieve this, the module provides interrelated roadmaps with recommended steps or action points for cities to progress from the stage they are currently at to the next stage of AQM. The national module roadmap consists of steps categorized into:

Management processes	pertain to management capacities, resources and institutional arrangements (regulations, policies) that aid in decision-making;
Technical processes	involve scientific knowledge and technical skills, tools and equipment that are relevant to the implementation of identified measures; and
General considerations	identify factors (such as needed finance and human resources, stakeholder involvement, and others) that facilitate and may potentially hinder the attainment of goals and/or effective implementation

Case studies are provided along with the recommended steps to illustrate the specific actions and successful efforts undertaken by cities or countries to improve aspects of AQM relevant to each module. Each thematic area is provided as a separate chapter and are developed in such a way that they can be used separately to discuss and address a specific area or as a section of the document to tackle AQM issues in a holistic and more strategic manner.

1.6 National Module implementation

Cities need support to implement the National Module on advancing air quality. The module will serve as a guidance document for the National Clean Air Programme for implementation in other cities apart from Delhi. CAA and CEE are keen to support cities in implementing the module. The module will enable strengthening of knowledge platforms; facilitate collaboration, capacity building and technical assistance at city level to improve air quality. As part of the implementation, capacity building will be provided through designated training programmes for the city stakeholders.

Module 1:
Ambient air quality standards and monitoring

Ambient air quality standards and monitoring

2.1 About the module

Our country faces enormous challenges because of its exponential population growth and widespread poverty, in meeting its significant commitments associated with poverty and hunger eradication under the SDGs. Rapid industrialization and urbanization have added to the sources of air pollution - from industries, vehicles and human activities.

AQS are established by taking into account various factors: prevailing exposure levels, technical feasibility, source control measures, abatement strategies, social, economic and cultural conditions, and sensitivity of areas.

Air quality standards necessitate the setting up of a reliable Air Quality (AQ) monitoring system that evaluates trends in air pollution and compliance with these standards.

2.2 Objective of AQS

To establish and/or strengthen air quality standards that would protect public health and the environment, and sustainable national and local air quality monitoring programmes that would enrich the understanding of air quality status.

2.3 Overview of Legislation in India

The atmosphere has a number of air pollutants from a variety of sources that change the composition of the air and affect the biotic environment. The concentration of air pollutants depend not only on the quantities that are emitted from the sources of air pollution but also on the ability of the atmosphere to either assimilate or disperse these emissions. The concentration of pollutants vary spatially and temporarily, causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical conditions. The presence of air pollutants in the ambient air adversely affects the health of the people. In order to prevent and control air pollution, the Air (Prevention and Control of Pollution) Act was enacted in 1981(AA-1981). The responsibility has been further emphasized under the Environment (Protection) Act, 1986. It is necessary to assess the present and anticipated air pollution impacts through air quality survey/monitoring programmes. Therefore, CPCB started the National Ambient Air Quality Monitoring (NAAQM) Network during 1984-85 at the national level and gradually the number of stations have increased over the years. The programme was later renamed as National Air Quality Monitoring Programme (NAMP).

The ambient air quality monitoring network involves measurement of a number of air pollutants at different locations in the country. Air quality monitoring requires proper selection of pollutants, selection of locations, frequency and duration of sampling, sampling techniques, infrastructural facilities, manpower and operation and maintenance. The areas selected for monitoring are based on traffic density, industrial activities, human population and its distribution, emission source, public complaints, the land use pattern, etc. Generally, the basis of a network design are the pollution source and the pollutants present. Air pollution emission issues are associated with many sectors, which inter-alia include power, transport, industry, residential, construction and agriculture. The pollutants measured are $PM_{2.5}$, and $PM_{10,}$ Sulphur Dioxide (SO_2), Oxides of Nitrogen (NOx), Carbon Monoxide (CO), etc.

The methods prescribed in the notification for analyzing the respective Pollutants are a combination of gravimetric method, wet-chemical method and continuous online method. Therefore, to meet the NAAQS requirement, a combination of both manual and continuous method is invariably required at each monitoring location, besides a good a laboratory set-up and infrastructure.

The Government of India launched the NCAP in January 2019, a time-bound national level strategy to tackle increasing air pollution and address the emerging issues of air pollution in the cities of India. Its goal is to meet the prescribed annual average ambient air quality standards at all locations in the country in a stipulated timeframe.

2.4 Air quality standards

Ambient air quality refers to the condition or quality of air surrounding us in the outdoor. NAAQS are the standards for ambient air quality set by the CPCB that is applicable nationwide. CPCB has been conferred this power by the AA-1981. There are three different types of air quality standards in India, as described in the following pages.

2.4.1 National Ambient Air Quality Standards (NAAQS)

After the 1972 Stockholm Conference on the Human Environment, it became clear that the nation was in need of a uniform environmental law. As a result, AA-1981 was passed by the Parliament in 1981. Agencies responsible for air quality standard creation and monitoring include CPCB and several State Pollution Control Boards (SPCBs). All of these entities are under the control of the MoEF&CC.

The CPCB, working together with the SPCBs, provides technical advice and the set of responsibilities and relationships among central, state and local agencies, to MoEF&CC in order to fulfil the objectives outlined in the AA-1981.

The central government coordinates efforts through the CPCB, sets national air quality standards, and approaches to pollution mitigation so that it can provide a basic level of environmental protection to all individuals in the state and local governments, and subsequently develop, implement and enforce specific strategies and control measures to achieve the notified national standards and goals. These standards are fixed after taking into consideration various geographical conditions, background concentration of different air pollutants, types of technologies available for control of air pollution and the cost of treatment, international standards (WHO, Chinese, United States Environmental Protection Agency (USEPA), European Union (EU)) and the sensitivity/tolerance of the receptor (Table-1). The SPCBs/PCCs can set more stringent standards than the existing national standards in their respective states but do not have the powers to relax these standards. Such a process is similar to the local divisions used within the USEPA. With the goal of providing for the prevention, control and abatement of air pollution, the first ambient air quality standards were adopted in 1982 by the CPCB, revised in 1994, and again revised in November 18, 2009. These revised national standards aim to provide uniform air quality for all, irrespective of land use pattern, across the country.

2.4.1.1 Major objectives of NAAQS

- To indicate necessary air quality levels and appropriate margins required to ensure the protection of human, plant and animal lives and property
- To provide a uniform yardstick for the assessment of ambient air quality at the national level
- To indicate the extent and need of a monitoring programme. Annual standards are basically the annual arithmetic mean of a minimum of 104 measurements in a year at a particular site taken twice a week 24 hourly at a uniform interval and 24 hourly, 08 hourly or 01 hourly monitored values (time weighted average values), as applicable, which shall be complied with 98% of the time in a year. About 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Selection of standards and parameters for the development of an air action plan of a particular city will be based on the population, geological condition, types and extent of industrialization, number of vehicles, etc.

Table 2.1: Different air quality standards

Sr. No.	Pollutant	Time weighted average	Indian AQS		Chinese AQS		USEPA AQS	EU AQS	WHO AQS
			Industrial, Residential, Rural area	Ecological sensitive area	Natural Protection Area	Residential, Commercial, Industrial and Rural Area			
1	Particulate Matter PM_{10} (µg/m^3)	Annual	60	60	40	70	-	40	20
		24 hours	100	100	50	150	150	50	50
2	Particulate Matter $PM_{2.5}$ (µg/m^3)	Annual	40	40	15	35	12	-	10
		24 hours	60	60	35	75	35	25	25
3	Sulphur Dioxide SO_2 (µg/m^3)	Annual	50	20	20	60	75ppb (1 hour)	125	-
		24 hours	80	80	50	150	-	350	20
4	Nitrogen Dioxide NO_2 (µg/m^3)	Annual	40	30	40	40	53 ppb	200	40
		24 hours	80	80	80	80	100ppb (1 hour)	-	-
5	Ozone O_3 (µg/m^3)	8 hours	100	100	100	160	0.070 ppm	-	100
		1 hour	180	180	160	200	-	-	-
6	Lead Pb (µg/m^3)	Annual	0.5	0.5	-	-	-	-	-
		24 hours	1.0	1.0	-	-	0.15 (Rolling 3 month average)	-	-
7	Carbon Monoxide CO (mg/m^3)	8 hours	2.0	2.0	-	-	9.0	10	-
		1 hour	4.0	4.0	10	10	35.0	-	30
8	Ammonia NH_3 (µg/m^3)	Annual	100	100	-	-	-	-	-
		24 hours	400	400	-	-	-	-	-
9	Benzene C_6H_6 (µg/m^3)	Annual	5	5	-	-	-	5	-
10	Benzo(a)pyrene BaP (µg/m^3)	Annual	1	1	-	-	-	-	-
11	Arsenic As (ng/m^3)	Annual	6	6	-	-	-	-	-
12	Nickel Ni (ng/m^3)	Annual	20	20	-	-	-	-	-
13	Poly Aromatic Hydrocarbon PAH (ng/m^3)	Annual	-	-	-	-	-	1	-

2.4.1.2 Action Points/Suggestions

- The rationalization of the number of parameters need to be watched to attain compliance with air quality standard.
- Current status of non-attainment cities in the respective states (where training organized) need to be incorporated with their recent trends of air quality.
- Dominant air pollution sources and causes behind it need to be dealt with.
- Ways and means to motivate as well as mandate local authorities for achieving compliance of NAAQS through awareness and skill development programmes for all stakeholders on a regular basis with a system of review.
- Periodic review of NAAQS implementation and attainment in a city as well as industrial area.
- Institutional framework with roles and responsibilities covering local stakeholders and authorities – up to the apex authorities to be developed to ensure proper data generation.

2.4.2 Industry specific standards

In addition to the above, MoEF&CC, through CPCB, has notified 113 emission/effluent standards for different sectors of industries. Installation of online Continuous Emission/ Effluent Monitoring System (CEMS) for 17 categories of highly polluting industries have been made mandatory.

Monitoring Methods

Different methods are used to monitor ambient air quality i.e. continuous emission monitoring, intermittent monitoring (collection of samples over a period commonly ranging from one to 24 hours.) and mobile/manual air quality monitoring.

The instruments used for air quality monitoring shall be accurate (automatic instruments are preferred) and tamper proof. The personnel collecting samples must be knowledgeable and

2.4.3. National AQI

Table 2.2 AQI Categories and Health Breakpoints

AQI	Associated Health Impacts
Good (0-50)	Minimal Impact
Satisfactory (51-100)	May cause minor breathing discomfort to sensitive people
Moderate (101-200)	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)	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease with short exposure.
Very Poor (301-400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
Severe (401-500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

(Source: Control of Urban Pollution series CUPS/82/ 2014-15, Air Quality Index, CPCB)

The Hon'ble Prime Minister launched AQI in April 2015 starting with 14 cities and now extended to 57 cities. AQI is a tool for effective communication of air quality status to common people in terms which are easy to understand. It transforms ambient air quality data of various pollutants into a single number (index value), nomenclature and color. There are six AQI categories, namely, Good, Satisfactory, Moderately Polluted, Poor, Very Poor and Severe. Each category is decided based on the ambient concentration values of air pollutants and their likely health impacts (known as health breakpoints). AQ sub-index and health breakpoints are evolved for eight pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3 and Pb) for which short term (up to 24 hours) NAAQS are prescribed.

CPCB took the initiative for developing a national AQI for Indian cities. AQI is a tool to disseminate information on air quality in qualitative terms (e.g. good, satisfactory, poor) as well as its associated likely health impacts. An expert group comprising medical professionals, air quality experts, academia, NGOs and SPCBs developed the national AQI. The required technical information was provided by IIT Kanpur.

Taking into account the available international experiences and national studies, the tentative national level target of 20%–30% reduction of $PM_{2.5}$ and PM_{10} concentration by 2024 is proposed under the NCAP, keeping 2017 as the base year for the comparison of concentration.

The AQI is useful for: (i) the general public to know air quality in a simplified way, (ii) a politician to ensure quick actions, (iii) a decision maker to know the trend of events and to chalk out corrective pollution control strategies, (iv) a government official to study the impact of regulatory actions, and (v) a scientist who engages in scientific research using air quality data.

Whenever there is an increase in the concentration of $PM_{2.5}$ or PM_{10} from the category satisfactory to poorer quality, actions as per the customized Graded Response Action Plan (GRAP) similar to the plan operative in Delhi-National Capital Region are suggested.

2.4.3.1 Action Points

- Phase wise introduction of cleaner fuels and enforcement of new and stringent SO_2/ NO_x/$PM_{2.5}$ standards for industries using solid fuels based on the status of air quality in an area.
- City wise source apportionment study and action on major sources to curb the ambient pollutant levels.
- Evolve standards and norms for in-use Diesel Generator (DG) sets below 800 KW category.
- For DG Sets already operational, ensure usage of either of the two options: (a) use of retrofitted emission control equipment having a minimum specified PM capturing efficiency of at least 70%, the type approved by one of the CPCB-recognized labs; or (b) shifting to gas-based generators by employing new gas-based generators or retrofitting the existing DG sets for partial gas usage.
- Stringent compliance by all Thermal Power Plants (TPPs) with respect to the emission norms according to the timelines up to December 2022 and as per the action plan prescribed in the direction dated December 2017 issued under EPA 1986.
- Stringent norms for fuel and vehicles (Bharat Stage VI (BS VI), industrial standards, road to rail/ waterways, fleet modernization, Electric Vehicle (EV) policies, clean fuels and technology, bypasses, taxation policies, etc.

- NDC's target for an additional forest and tree cover of 2.5 to 3 billion tons of CO_2 equivalent by 2030 specifically focusing on the western regions of India (Rajasthan and Gujarat), which will reduce wind-blown dust within the country and will act as a barrier for trans-boundary dust.
- Enforcement of new and stringent SO_2/NO_x/$PM_{2.5}$ standards for industries using solid fuels and through continuous monitoring.

2.4.4 Role of air quality standards in air quality management

The standards as stated in item 2.4.1.1. are helpful in resource allocation, ranking of locations, enforcement of standards, trend analysis, public information and scientific research in the following manner:

- It provides guidance about the quality of air to be maintained for ambient air and at chimneys.
- It determines the methodology of treatment (types of APCD).
- It helps the authorities to determine the status of compliance and the impact of air pollutants on health.
- It indicates the levels of air quality necessary with an adequate margin of safety to protect public health, vegetation and property.
- It assists in establishing priorities for abatement and control of pollutants.
- It provides uniform yardstick for assessing air quality at national level;
- It indicates the need for and extent of a monitoring programme.

2.4.5 Establishing ambient air quality standards

WHO air quality guideline values are intended for worldwide use to achieve a safe air quality for public health. WHO recognizes that governments should consider their own local circumstances before directly adopting these guidelines as their own air quality standards.

In India, AAQS are determined after taking into consideration various factors such as sensitive receptors, pollutant behaviour in the atmosphere, pollutant behaviour in the environment, natural levels and fluctuations, technological feasibility, availability of resources for AQ monitoring, Available resources for monitoring of AAQS enforcement and compliance. One of the best examples was the MoEF&CC notified 'Environment (Protection) Amendment Rules, 2015' for TPPs on 07.12.2015, regarding standards for PM, SO_x, NO_x, mercury emissions and water consumption. As per the notification, all the existing stations were required to comply with the new standards within two years, that is, by December 2017, and the new stations, including all stations presently under construction were required to meet the new norms w.e.f. 01.01.2017. Subsequently, reviewing the representation from the Ministry of Power and Central Electricity Authority highlighting practical difficulties with respect to compliance with the prescribed TPP emission norms by December 2017, an earliest practical feasible plan extending up to December 2022 was prepared for the installation of Flue Gas De-Sulphurizations (FGDs) and other pollution control equipment at the identified coal-based TPP units, in consultation with the Regional Power Committees and the utilities, as notified by the Ministry in December 2017.

2.4.6 Reviewing the national ambient air quality standards

At present the ambient air quality standards of November 18, 2009 are being implemented. The developed countries like USA and others have a fixed time period (five years) to review and fix standards if required. Similarly, MoEF&CC/CPCB can decide the frequency for revision and fixation of standards based on the data regarding the existing air quality in the particular region, number of complaints received, directions from the courts and tribunals, based on the carrying capacity of the specific area, scenario analysis of the area, etc.

2.4.7 Action points/Suggestions

- The CPCB to come up with guidelines with respect to the periodicity of review of such standards.
- The existing standards need to be strengthened periodically and new standards need to be formulated for the sources where standards are not available, based on extensive scientific evidence with reference to protection of public health and environment (carrying capacity of the area).
- Study of volatile organic compounds in cities surrounded with dense industrial establishments in order to obtain the primary data which can be used in reviewing ambient standards.
- Capacity building for emerging techniques in air quality monitoring, source apportionment, carrying capacity assessment, scenario analysis, etc. at the regional level.
- Developing multi-disciplinary institutional framework at city level to fix the accountability for managing ambient air quality and research for ensuring better air quality.

2.4.8 Implementing national ambient air quality standards

Regulatory authorities need to undertake concrete measures to ensure that the standards are implemented and met, taking into account the existing air quality in the particular region, number of complaints received, directions from the courts, based on the carrying capacity of the specific area, the cost of control strategies, etc. The air pollution areas can be identified and designated as attainment and nonattainment areas. Two types of State Implementation Plans (SIP) can then developed— an attainment-maintenance SIP if the area is designated as attainment, and an attainment-demonstration SIP if designated as nonattainment.

2.5 Air Quality Monitoring

Another key component of effective AQ Monitoring is a sustainable and efficient AQ monitoring system. Routine monitoring of AQ provides data that allows monitoring of compliance with AAQS, assesses trends in air pollution levels and exposures, and evaluates progress and effectiveness of AQ policies and measures. Robust and credible AQ data contribute to effective decision-making in AQ Monitoring and this can be achieved only through an effective monitoring system.

- Well-planned and established monitoring network according to the monitoring requirements.
- Suitable implementation of Quality Assurance (QA) and Quality Control (QC) procedures. Maintainable operation of the air quality monitoring network.
- Effective communication of air quality information to the public and to policymakers.
- Strong commitment from authorities in terms of financial and human resource support.
- Sustainable operation of the air quality monitoring network.

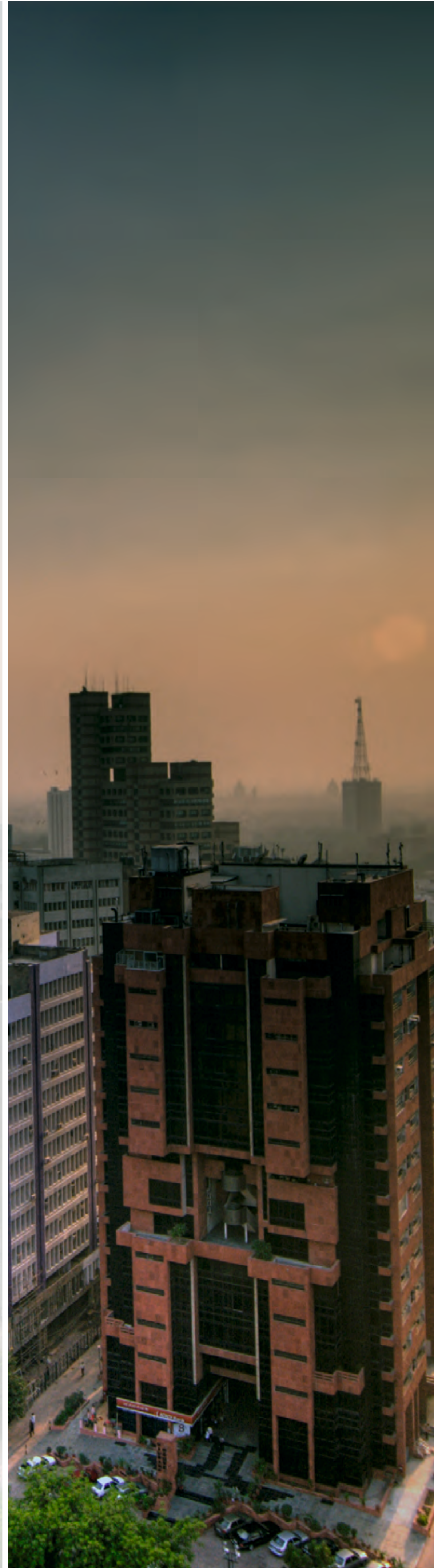
Monitoring systems/programmes also need to be cost-effective; have stable financial, operational and personnel resources; and adjusted to local needs and conditions (WHO, 1999). The design of an AQ monitoring programme is primarily defined by its purpose or objectives. The design will then determine: size and sophistication of the monitoring network (including equipment); location and number of sampling stations; duration and frequency of sampling; and, most importantly, the financial and manpower resources needed to operate and sustain the network.

Air quality monitoring activities can be grouped according to three broad types of objectives:

Timely public reporting | **Compliance** | **Research**

2.5.1 Objectives of AQ Monitoring

- Assess short-term pollution levels
- Identify non-attainment cities
- Develop an air quality index (or other tools for data communication)
- Generate data to evaluate forecasted pollution concentrations by modeling
- Determine compliance and levels of exceedances with respect to standards
- Observe pollution trends
- Formulate pollution control strategies
- Examine the extent and causes of elevated concentrations
- Enhance understanding of chemical and physical properties of atmospheric pollution and pollution sources
- Evaluate the effectiveness of pollution control strategies
- Comply with national and international agreements and initiatives
- Identify pollutant generation and behavioural characteristics
- Assess impacts on different groups of populations
- Assess impacts on visibility impairment, climate change and ecosystems
- Validate models
- Discover new contaminants
- Obtain the knowledge and understanding for developing preventive and corrective measures
- Understand the natural cleansing process happening in the environment through pollution dilution, dispersion, wind based movement, dry deposition, precipitation and chemical transformation of pollutants generated
- The AQM shall be dynamic, practical and one that can be reviewed.



2.5.2 Action points/Recommendations

- Precise strategy for the establishment of an air quality network and the number of monitoring stations in a city depending on pollution sources, potential, population density, existing air quality, sensitive area, etc. The location of the background monitoring station of a city to be declared by local authorities in consultation with SPCB and the state's department of environment.

- Every common infrastructure facility shall operate at least one monitoring station in the area and collect a minimum of two readings in the upwind and downwind direction.

- Improvement and strengthening of the inspection and maintenance system for vehicles through extension of I & C centres.

- Modify the existing Pollution Under Control (PUC) system to make it more authentic and ensure its stringent implementation through regular inspection and monitoring.

- Coordination with Indian Space Research Organization (ISRO) for regular availability of remote sensing monitoring data on crop burning by the farmers.

- Stringent implementation and monitoring for extended producer responsibility for e-waste and plastic waste.

- Regular monitoring of all petrol pumps of cities by regulatory authorities to check for adulteration of fuel and immediate stern punishment for defaulters.

- With reference to the existing 4000 cities in the country, 703 manual monitoring stations in 307 cities reflect a limited number and need augmentation. It is proposed to augment it to 1500 stations from the existing 703 stations; by the central government.

- Air pollution in India has regional ramifications - the Indo-Gangetic plain, covering approximately 45–50 cities spread across the states of Assam, Bihar, Haryana, Jharkhand, Madhya Pradesh, Punjab, Rajasthan, Uttarakhand, Uttar Pradesh and West Bengal is the main region impacted by air pollution. Presently in India, the 134 Continuous Ambient Air Quality Monitoring Stations (CAAQMS) in 71 cities and 17 states, should be expanded to mainly focus on this region and approximately 150 CAAQMS with an average of 2–3 stations in each city should be installed, based on population, industrial activities, etc.

- NCAP proposes Aerosol Optical Depth (AOD) from satellite-based observations, which is being widely accepted for the assessment of ambient particulate matter levels.

- CPCB will identify the process for developing/validating alternative cost-effective technology for source and ambient air quality monitoring in consultation with IIT, Council of Scientific & Industrial Research (CSIR), and other such institutes as NEERI.

- Air quality in the rural areas all over the world and particularly in the developing countries may be more polluted than some of the urban areas, and as rural areas have not been covered under the NAMP, it is proposed to set up about 100 such stations in rural areas.

- CPCB has issued a guideline for AAQM for assisting and taking decisions with respect to the setting up of monitoring stations. It is planned to review the existing guideline and issue a comprehensive protocol for setting up of monitoring stations and for the monitoring.

- Particulates especially $PM_{2.5}$ are the deadliest form of air pollutants due to their ability to penetrate deep into the lungs and blood streams unfiltered, causing various health issues. Accordingly, to evolve a comprehensive mechanism for the management of $PM_{2.5}$, it is proposed to augment the number of monitoring stations for $PM_{2.5}$ from the existing 167 in 80 cities to all stations under NAMP. A similar exercise for each city may be carried out by local authorities to arrive at the requirement of the number of monitoring stations.

- Setting up of the 10 cities' super network may capture the overall air quality dynamics of the nation, impact of interventions, trends, investigative measurements, etc. The cities may be identified for capturing possible variations (e.g., metro city, village, mid-level town, coastal town, controlled background location, industrial town, etc.). Each city may have one well-equipped monitoring station representing the city background. In addition to the notified 12 pollutants, constituents of PM_1, particle number, Volatile Organic Carbons (VOCs), hydrocarbons, etc., may be monitored along with meteorological data. It should generate high-quality data so that it will represent the national air quality dynamics. The plan for this network to be formulated and implemented in consultation with the CPCB.

- Super sites in cities and rural areas are to be selected to assess the background level and major sources to draw a scientific and statistically sound assessment of pollution and its impact on health.

- To operationalize the National Physical Laboratory-India Certification Scheme (NPL-ICS) at the central and regional levels to cater to the country's needs with respect to the online monitoring of air pollution.

- To evolve an action plan for the need of certification agencies for air pollution mitigation equipment in addition to monitoring equipment.

- Identification of an alternative technology for real-time monitoring with an impetus on low-cost indigenous real-time monitoring stations, and promoting real-time monitoring in other cities with these low-cost sensors. With an average of 10 sensors in each city, 1,000 sensors are being targeted. The sensor siting criteria and strict sensor calibration schedules should also be devised. The sensors shall be temper proof.

- Mobile air quality monitoring network to be made part of these alternative technologies. At least one mobile monitoring station for each city is to be considered. This will facilitate preliminary assessment in areas without conventional monitoring stations.
- Use of drones for monitoring in critically and highly polluted areas, remote areas and during accidents.
- Capacity development to ensure quality control at all the monitoring locations with defined traceability and mandatory assessment of uncertainty of generated data, quality flag for generated data and remarks with local events impacting air quality, along with analytical results.
- Development of computer simulations of dispersion phenomena.
- Report of potential public health risks.
- Development, execution and assessment of emission reduction programmes.
- Set up State or Local Air Monitoring Stations (SLAMS) Network.
- Set up $PM_{2.5}$ Chemical Speciation Network (CSN).
- Set up National Air Toxics Assessment (NATA).

2.5.3 Stages of ambient air quality standards and air quality monitoring:

In line with enabling cities to establish and strengthen AAQS to protect public health and the environment with sustainable national AQ monitoring programmes that enrich our understanding of air quality status and present indicators to aid cities or countries in identifying their current state of development in terms of AQS and monitoring, the following key indicators are to be considered:

1. Development of AAQS and alignment with other targets
2. Setting up an adequate AQ monitoring system
3. Check monitoring compliance
4. AAQS review process
5. Sustainability of AQ monitoring system

For strengthening the monitoring mechanism and ensuring the compliance of environmental standards, CPCB has directed 17 categories of highly polluting industries to install and provide connectivity to the CPCB server for Online Continuous Emission/Effluent Monitoring System (OCEMS). The CPCB, under Section 18(1) (b) of the Air Act, 1981, has directed the SPCBs/PCCs of the NCR and other states to install online continuous emission monitoring systems by the red category air polluting industries located in 23 districts of the NCR and Delhi in December 2017. So far, out of 3,531 industries, 2,743 industries have installed OCEMS and closure directions are in force for 740 non-complying units.

2.6 Issues and challenges

2.6.1 Air Quality Standard (AQS)

We have had standards in place for years and even decades, but challenges persist in ensuring that the implementation and revision of standards, which translate into safe AQ levels that protect the health of the public and that of susceptible populations.

2.6.1.1 Institutional

- There is no global target/roadmap/framework on air pollution
- Alignment between AQS and other sectoral standards (e.g. vehicle and fuel quality standards) at the country or city level is also missing.

2.6.1.2 Management and technical

- Air pollution competes with other environment and development issues
- Environmental enforcement and implementation of standards is also generally weak
- Alignment of AQ Monitoring policies with other sector policies and plans are limited
- Have not updated/revised the standards for more than five years.

2.6.1.3 Financial

The financial constraints for AQS is not so much related to the establishment of the standards but more on the implementation of the standards, especially in the lack of funds for AQ monitoring systems to check compliance with the standards. There is also limited funding for local research and studies on exposure risks, policy reviews and relevant pollutant control strategies which are necessary inputs to the establishment or review of AQS.

2.6.2 Air Quality Monitoring

Non-availability of trained and experienced persons, lack of awareness about air quality data and its utilization in enforcing agencies, and lack of regular training and skill up-gradation for fresh staff are the major challenges.

2.6.2.1 Institutional

- Awareness of AQ monitoring data and results in all levels of government, stakeholders and the general public is lacking
- Collaboration with other relevant stakeholders is weak.

2.6.2.2 Management and technical

- There is often a lack of staff dedicated to AQ monitoring in Asian cities
- There is limited training for new staff and skills upgradation for existing staff
- Technical capability relevant for AQ monitoring is lacking or missing

2.6.2.3 Financial

Funding for AQ monitoring is often inadequate and not sustainable. Some countries in Asia have benefited from foreign grants or technical assistance to fund the establishment of their AQ monitoring system. Several of these networks' operations ended as soon as the project funds were depleted. Some countries and cities started to make significant investments from local funds but the monitoring activities are not maintained due to lack of sustainability plans. There should be a strong commitment from authorities to continue monitoring efforts. The city and industrial authorities shall make provisions for funds in this respect while preparing the budget every year.

2.6.3 General

- The number of monitoring stations in the area under the monitoring programme
- Type of the monitoring method i.e. continuous or manual
- Calibration of instruments & their temper proofness
- Selection of parameters to be analyzed
- The accuracy of the method of analysis and the chemicals (GR/LR grade) used for the analysis
- The experience and the expertise of the persons doing the analysis work
- The accuracy of the instrument used for the analysis
- Availability of reliable meteorological data

2.7 Roadmap for ambient air quality standards

2.7.1 Management Process

- Regular awareness campaigns to sustain public interest on air pollution and demand for more stringent AAQS for all criteria pollutants.
- Strengthen implementation of AAQS through development of clean air action plans, reporting and review of the progress.
- Strengthen coordination and integration of AQ Monitoring policies with other sector policies and plans (e.g. transport, energy, industry, among others).
- Regular review and fixation of standards at a predefined interval, say, five years.

2.7.2 Technical Process

- Develop standard / uniform methodologies for AQ monitoring at the national level to guide cities.
- Build capacity for AQ monitoring system to cover selected pollutants of concern and hotspots, monitor compliance to AAQS and ensure that major cities have at least one monitoring station per area to help designate and assess attainment and non-attainment areas.
- Build capacity for ad hoc review of AAQS
- Periodic review of installed air quality monitoring stations in all respects to ascertain its objective relevance in the rapidly growing city as well as its brownfield and Greenfield developments.

2.8 Road map for Air quality monitoring

2.8.1 Management Process

- Create project opportunities with other sectors (e.g. health, transport) to link AQ monitoring activities.
- Refine AQ monitoring objectives and data quality objectives.
- Identify capacities, skills and training to strengthen staff resources.
- Start reporting AQ data to the public.
- Collaborate with local or international academic organizations for AQ monitoring studies.
- Identify funding sources for AQ monitoring activities.
- Prepare AQ monitoring plans and guidelines.
- Provide sustainable training to address staff movements and technological developments.

2.8.2 Technical Process

- Expand the AQ monitoring network by adding more continuous stations or pollutants monitored, or improving the frequency according to monitoring objectives, supporting compliance monitoring to AAQS and gradually phasing out the dominance of manual stations.
- Develop QA/QC plan, SOPs, and guidelines at the national level for AQ monitoring to guide cities.
- Develop and implement QA/QC measures.
- Improve data management and use of AQ monitoring data for health assessments.

2.8.3 Other recommendations

- Check the reliability of data received from the stations after monitoring and random cross checking of some crucial parameters regularly.
- Wherever possible, insist on using the reliable, tamper proof and handy instruments for monitoring and analysis of different parameters which gives on the spot results (print outs) to avoid the possibility of manipulation and error at the laboratory.
- Collect the samples as per the CPCB guidelines for the measurement of ambient air pollutants (manual and real time) and maintain evidence of the same by proper upkeep of records.
- Strictly follow 'standards methods for analysis-USEPA' while carrying out the analysis.
- Strengthen CPCB/SPCBs for regular monitoring and attending to complaints on air pollution.
- Reduce sulfur content in lignite/coal/oil before it is used as a fuel.
- Petcoke shall not be used as a fuel in individual industries but can be used as a fuel in cement plants and petcoke-based power plants with adequate APCD to achieve prescribed norms.
- As per NCAP, increase: the number of monitoring stations in the country including rural monitoring stations, technology support, emphasis on awareness and capacity building initiatives, setting up of certification agencies for monitoring equipment, source apportionment studies and emphasis on enforcement.
- Source Apportionment Studies for all cities which are polluting and rapidly developing.
- Imposition of immediate exemplary fine/punishment for the habituated and gross violators (industries and all other sources of generation) and erring officials in the enforcing agencies.
- Determine the carrying capacity of the areas before and after the commercial/ residential/industrial development.
- Devise standard methods for monitoring. Identify reliable technical/research/ engineering institutes to impart trainings for monitoring and analysis. The trainings for all the technical and scientific officers of the enforcing agencies must be compulsory.
- Identify critically polluted areas as well as areas at the boundary line of critical pollution level and prepare action plans to reduce/control air pollution.
- Enhance the capacities of common people and other stakeholders in understanding the air quality data, its interpretation and action thereafter.
- Use local language for information/communication of data to the common people.
- Encourage common infrastructure development in industrial clusters like common boiler, common spray dryer, etc.

- Ensure stringent implementation of the national biofuel policy with respect to the ethanol and biodiesel blending target of 20% and 5% respectively by 2030.
- Utilize the Gujarat case study as a compelling case for other states to adopt third-party audits. The environment audit scheme, introduced by Hon'ble Gujarat High court for polluting industries in order to enhance implementation.
- Ensure stringent implementation of C&D Rules, 2016, and Dust Mitigation notification, 2018, of Government of India.
- Evaluate the status of the implementation of the Ministry of Agriculture funded scheme in the states and the impact on the reduction of air pollution in the country.
- Evaluate the socioeconomic feasibility for the implementation of ex-situ options, such as production of Prali-Char, bio char, pellets, briquettes, bio-CNG, bioethanol, etc., as ex-situ solutions for the management of crop residue burning, especially with the NPB in place.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Module 2: Emission Inventories and Modeling

Emission Inventories and Modeling

3.1 About the module

India is committed to create a clean environment and pollution free air and water. In fact, it is mandated in our constitution. India's commitments and obligations to environmental conservation and protection within the ambit of the targeted goals on environmental sustainability under the SDGs is manifested in the fact that several administrative and regulatory measures, including a separate statute on air and water pollution, are under implementation since long. The factors affecting air pollution are not limited to local sources but regional and trans-boundary sources. This widespread violation of air quality norms is validated by several modelling based studies and satellite based air quality data.

This module addresses the issues of developing an accurate and reliable Emissions Inventory (EI) which can be used as input to dispersion models in order to estimate the exposure of human populations and the environment. Information from EIs are also important for understanding air pollution sources, so as to draw up control measures to mitigate industrial, transport and residential emissions and achieve compliance with emission standards by taking adequate air pollution control measures.

Source Apportionment (SA) is a scientific approach to assess the contribution of emissions of specific source types to air pollutant concentrations at receptor sites. The module discusses the issues and challenges in cities and regions and develops a roadmap and recommendations on how to implement effective approaches to resolve the challenges.

The module through Clean Air Action Plans (CAAPs) and related environmental policies aims to strengthen AQM and the basis for subsequent evaluation of the effectiveness of measures to protect human health and the environment.

Atmospheric dispersion modeling is the prediction of the dispersion of pollutants in the ambient air, using computer programmes based on algorithms. This tool is useful to identify the future ground level concentration of pollutants from different sources like industrial plants, vehicular movement or mining activities. It has been proposed that air quality management needs to evolve from a single pollutant perspective to regulating emissions through more integrated multi-pollutant approaches.

3.2 Objectives

To develop EI and apply SA and dispersion modeling techniques to guide CAAPs and related environmental policies; strengthen AQM and the basis for subsequent evaluation of the effectiveness of measures to protect human health and the environment.

3.3 Emission inventories, source apportionment and Modeling

In an area of concern (i.e. area of non-attainment of air quality standards), it has to be assessed which sources are the most relevant ones for which the reduction of emissions will lead to a significant decrease of pollutant concentrations. Two approaches used to resolve this task are EI and SA.

3.3.1 Emission inventory

An EI is a list of the amount of pollutants from all sources entering the air in a given time period. The air pollutants include criteria pollutants, Green House Gases (GHGs) and VOCs among others, which are actually or potentially discharged into the atmosphere of a community. EI is a valuable tool

- To help define priorities and set specific objectives for AQM policies and guidance mechanisms,
- To help assess the potential health and environmental impacts, and consequently,
- To estimate the costs of control and benefits of health and environmental impacts.

Inventory - includes comprehensive, accurate and current information of actual emissions from all sources of the relevant pollutant or pollutants in a specific area, including such periodic revisions as the administrator may determine necessary to assure that the requirements of this area are met. There are two approaches in establishing EI, top-down and bottom-up.

The top-down approach uses national or regional-level emission estimates allocated to a city, area or grid according to surrogate parameters (i.e. population, employment, energy consumption, resource use, vehicle number, etc.), typically used when local data are not available and resources are limited.

The bottom-up approach gathers information from individual sources, processes, activity rates and their levels, and subsequently estimates Emission Factors (EFs).

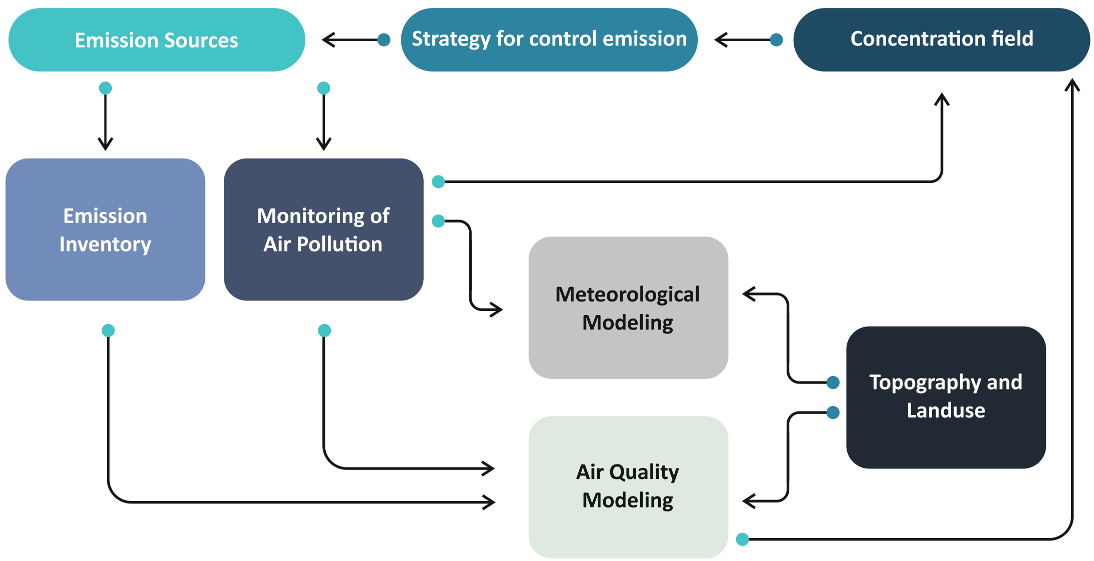


Figure 3.1 Air quality monitoring and modeling

3.3.2 Source Apportionment

This is the practice of deriving information about pollution sources and the amount they emit. When the results of air pollution measurements are interpreted, one of the first questions asked by scientists, engineers, and policy makers is: where did it come from? Sorting out the various sources of pollution is known as source apportionment. A number of tools are used to try to locate the sources of pollutants. A widely used approach is the "source–receptor model" or as it is more commonly known, the receptor model.

Three SA approaches or techniques are in use: (1) source emission shares of pollution load in an area based on EI, (2) SA based on dispersion modeling, and (3) SA based on receptor modeling. SA based on EI provides information on the contribution of different source categories (e.g. power plants, vehicles) and sub-categories (e.g. diesel-powered vehicles, two-wheelers, passenger cars within vehicle category) to total emission loads of identified pollutant(s).

The receptor models are based on measurements taken in the ambient environment and from these observations, determining pollution sources by making use of algorithms and functions. One common approach is the mathematical "back trajectory" model. Often, chemical co-occurrences are applied. It may be that a certain fuel is contaminated with a unique element. Some fuel oils, for example, contain trace amounts of the element vanadium.

The methodology for emission inventories and source apportionment mainly requires:

- Identification of all major sources like point source, volume source, area sources and movable sources along with its quantities and significant pollutants like PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, etc.
- Various factors influencing the emission sources like land use, atmospheric condition and habitation
- Estimation of frequency and time weighted emission for each source.

3.3.3 Modeling

3.3.3.1 Receptor-based modeling

Receptor-based models are mathematical or statistical procedures that use source profiles as well as physical and chemical characteristics of pollutant gases and particles at sources and receptor sites in a given area to estimate the presence and fraction of source contributions at receptor locations.

Unlike dispersion models, receptor-based models do not require pollutant emissions, meteorological data, chemical transformation and deposition mechanisms to estimate the contribution of sources to receptor concentrations.

- Receptor based modeling is an analysis to identify the source, types, origin and contribution to the ambient air.
- Receptor based model are extensively used for source contribution quantification at local and regional scales.

- Receptor based models have demonstrated that receptor models provide quantitative estimations of contributions by source category with, at the most, 50% uncertainty.

Limitations

Receptor-based models cannot identify the contribution of individual sources if several sources of the same type and emission characteristics (e.g. two or more power plants, two or more cement plants) are located in the area considered. Receptor-based models complement dispersion models instead by apportioning concentrations at receptor sites to distinct source types.

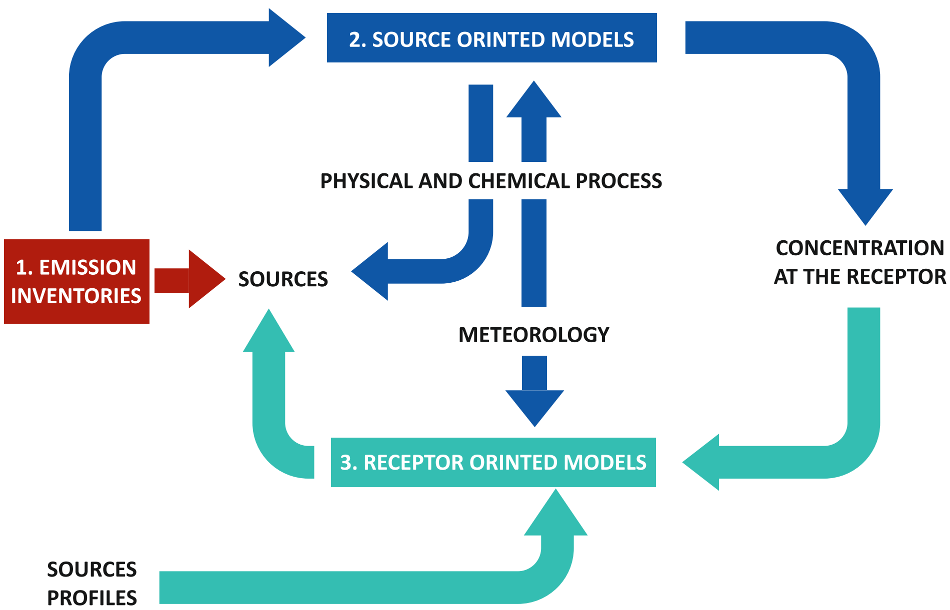


Fig 3.3 Components of source based modeling

3.3.3.2 Dispersion or Source-based modeling

The dispersion model, also known as Air Quality Simulation Model (AQSM) or source-based model, is a numerical technique or methodology for estimating air pollutant concentrations in space and time. Data inputs to dispersion models consist mainly of emissions, meteorological and topographical data. The parameters that constitute a dispersion model include (SEI, 2008): a) emissions sources, including their locations and emissions rates; b) receptor locations; c) meteorological specifications; d) deposition rates (if these will be considered); and e) output specifications or what kind of values are required (e.g. average concentrations).

- Source based modeling is based on the source from where pollution comes, which could be anything like a point source, volume source or vehicle exhausts.
- For source based model emission load, meteorological condition and terrain data are required.
- Source based modeling can also be useful in evaluating the impact and in identifying the cumulative impact, considering the background impact.
- Dispersion models can contribute in designing ambient air monitoring networks.
- They can also be useful in evaluating the impact and efficiency of policy and mitigation strategies

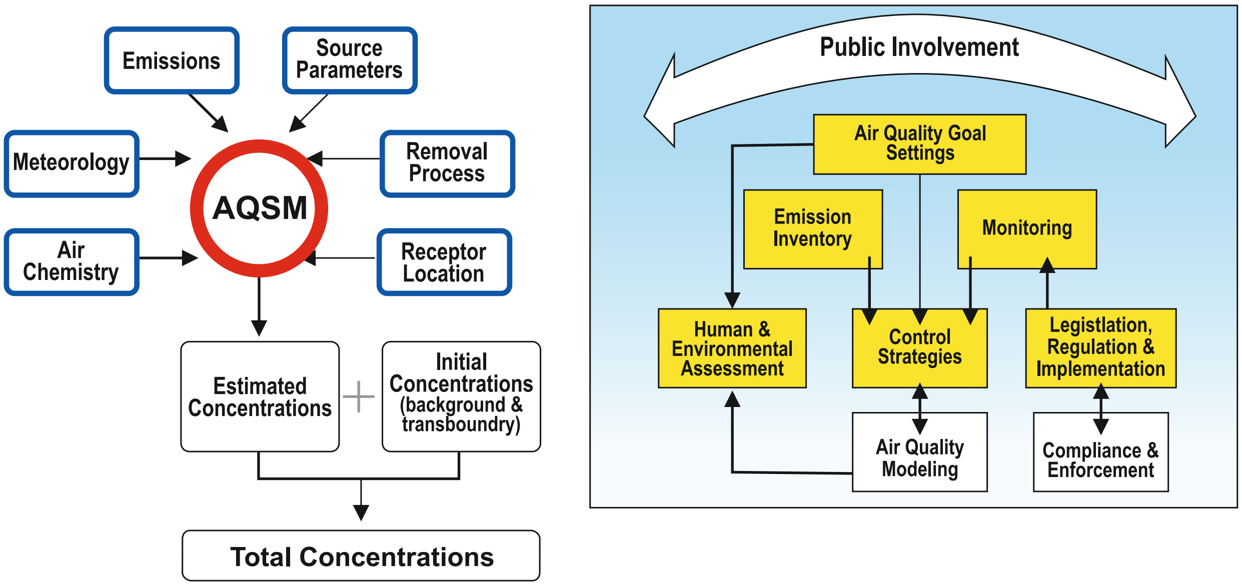


Fig 3.3 Components of source based modeling

3.4 Action points/Suggestions

3.4.1 Source Apportionment

- Unified guidelines for SA study to be formulated and updated.
- SA studies to be extended to all 102 nonattainment cities and adequate fund allotment to be done by central and state governments.
- Qualification and tools required for EI and SA should be briefed during the training so that local capacity building on city basis can be made, and EI and SA can be conducted locally to ensure the representativeness of data on a cost-effective basis.
- A bottom-up approach type of methodology should be adopted so that the local circumstances can be listed out.
- Adopt the quality assurance and quality control practices adopted by key institutions throughout the world (at least India, US, European Union and China).

3.4.2 Emission Inventory

- Objective and scope of EI to be clearly spelt out.
- Identification of local stakeholders to participate in EI estimation exercises and the scope of developing a common platform where different stakeholders can integrate their information for the completeness of EI.
- A list of activities to be suggested for preparing a guideline for the selection of sectors and sectoral EI.
- All cities should be encouraged to develop local emission factors based on the activity data available.

- A geographic information system tool should also be included to aid capacity building for the computation of high resolution EI and for smaller grids of a city.
- There are numerous models available for EI. Hence the model selected should be sector specific (both point and non-point), requiring large variation/ segregation in data, etc. to ensure that none of the activity level default data should be used by the models to compute EI. In case of non-availability of data, either country level research data should be used or data should be generated.

3.5 Significance of EI, SA and modeling AQM framework

3.5.1 Emission Inventories

- The role of EI is to identify and quantify the various pollutants being released into the ambient air.
- EI contains the total emission from all the pollutants with source categories based on the geographical location at a particular time.
- EI is also useful to establish emission trends for the particular regions.
- EI is very useful to pollution control agencies as well as planning and zoning agencies.
- It can point out the major sources whose control can lead to a considerable reduction of pollution in the area.
- It can be used with appropriate mathematical models to determine the degree of overall control necessary to meet ambient air quality standards.
- It can be used to indicate the type of sampling network and the location of individual sampling stations if the areas chosen are small enough. For example, if an area uses very small amounts of sulfur-bearing fuels, establishing an extensive SO_2 monitoring network in the area would not be an optimum use of public funds.
- EI can be used for publicity and political purposes.

3.5.2 Source Apportionment

- SA provides major information for the air quality management framework in terms of the quality of ambient air.
- SA is a tool to derive the information on pollution sources and their contribution to air pollution, and helps to validate the data of EI.
- Identification along with quantification with the time and location of EI and SA can be effectively used for dispersion modeling purposes.

3.5.3 Modeling

- Modeling is a useful tool to monitor and predict the ambient air quality and helpful to determine the compliance of any existing or proposed activities/facilities with the stipulated standards.

- The models are also useful for the design of control strategies for emission reduction and preparing the action plan for the control of air pollution.

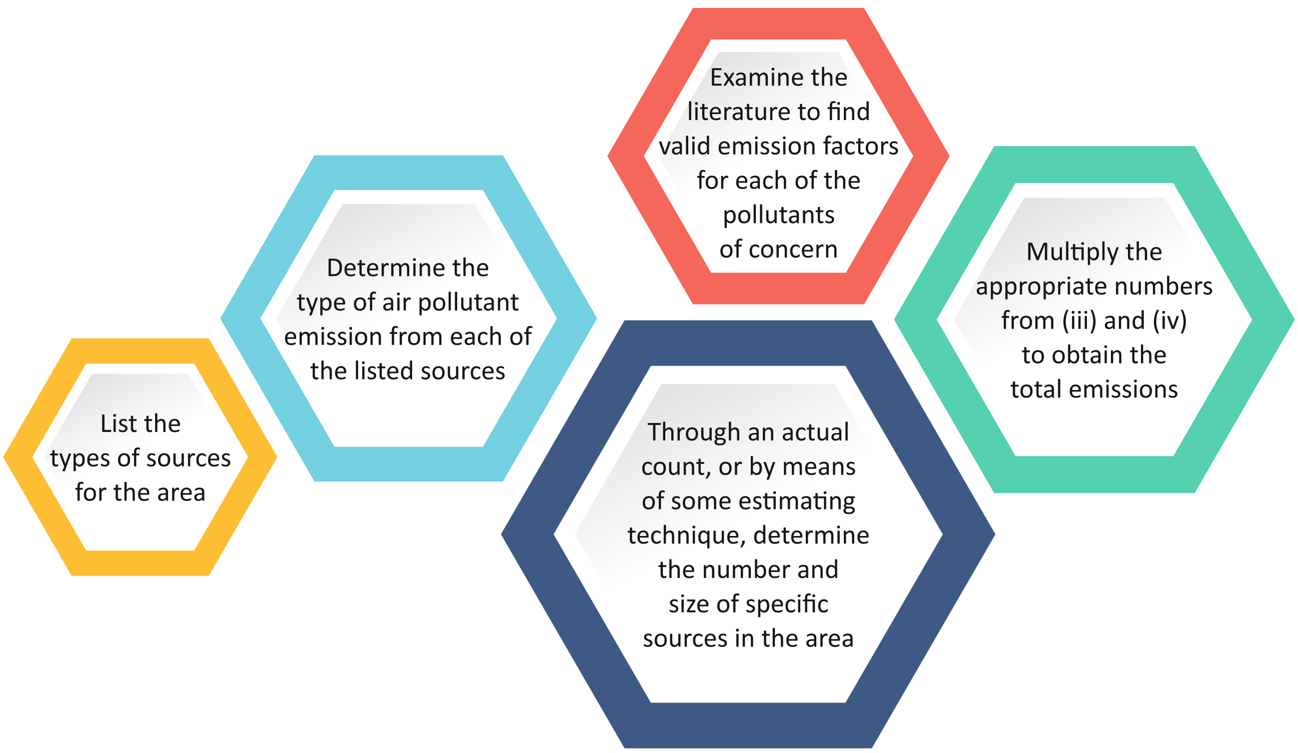
3.6 Stages of EI, SA and receptor and dispersion modeling

3.6.1 Emissions Inventory

EI is one of the techniques used for the SA. EI is a compilation of all predicted sources, quantity and geographical locations. EI depends on the sources emission factors. Emission Factors requires revising the emission inventory factors every three years. Valid emission factors for each source of pollution are the key to the EI. By keeping the EI current and updating it at least yearly as fuel uses change, industrial and population changes occur, and control equipment is added, a realistic record for the area is obtained. It must also be realized that an uncontrolled source will emit at least 10 times the amount of pollutants released from one operating properly with air pollution control equipment installed. Actual emission data are available from many handbooks, government publications and literature searches of appropriate research papers and journals. In addition, online support is available, especially from the technology transfer network/clearinghouse for inventories and emissions factors. This site provides information on emission factors, inventory and modeling, along with a knowledge base for emissions monitoring.

3.6.1.1 Inventory techniques

To develop an emission inventory for an area, one must



3.6.1.2 Data Gathering

Compilation of the EI requires a determination of the number and types of units of interest in the study area. Data regarding emissions are available from many sources. Sometimes the same item may be checked by asking two or more agencies for the same information.

3.6.1.3 Data Reduction and Compilation

The final EI should be prepared preferably on a computer so that it can be updated rapidly and economically as new data or new sources appear. The updated EI of the change in fuel uses, industrial and population changes, and control equipment added will help in obtaining the realistic record for the area.

3.6.1.4 Action points

A comprehensive national EI, which is still lacking in the country, will be formalized under the NCAP.

3.6.2 Source Apportionment

Different approaches and techniques are used for SA. Some of the commonly used techniques are

- Explorative methods (based on mathematical equations)
- Inverse modeling
- Lagrangian models
- Gaussian models (based on Gaussian distribution profile)
- Eulerian models (based on chemical and physical composition)
- Receptor models

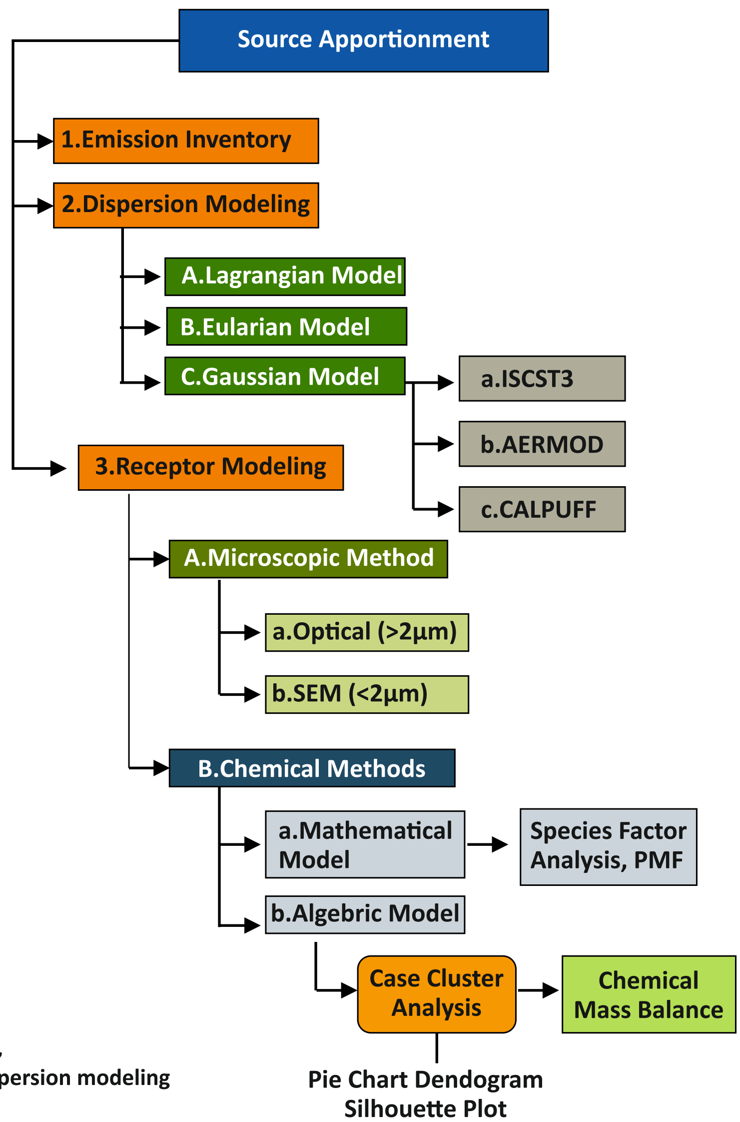


Figure 3.4 Stages of emissions inventory, source apportionment, receptor and dispersion modeling

3.6.3 Dispersion Modeling

The different stages for dispersion modeling are as under:

- Identification of the modeling domain to define the other details like terrain data, rural-urban classification and land use
- Identification of all emission sources and calculation for the emission load based on the emission factor for each of the identified pollutants
- Details of SA along with their geographical location
- Identification of the receptor network, such as sensitive receptors or uniform receptors.
- Surface characteristics of the model domain like meteorological parameters.

3.7 Issues and Challenges

Air pollution models are advanced computer based programmes developed over a long period. Some of the challenges in relation to the different input parameters are as mentioned below:

· An institutional framework with specific focus on the development and application of EI and SA techniques is not available.

- Policy and decision making processes are limited.
- Only a limited number of reliable EI and SA studies are extant.
- Studies concerning the linkage of air pollution EI to climate change are limited.
- Poor data/information availability and transparency on EI and SA.
- Availability of meteorological data related to specific sites for surface as well as upper air data are poor.
- Some EIs do not include future projections or, if they do, projections are inaccurate due to a lack of understanding of the dynamic changes of economy and the development process in a certain area.
- Analytical uncertainty
- Lack of local source profiles
- Uncertainties in EI and SA and difficulties in their estimation because of the behaviour of pollutants in respect to various influencing factors
- Model performance uncertainty
- Complexity of more sophisticated EI calculations
- Lack of quality assured data for developing and updating EI
- Necessity of model validation
- Identification of each source with their emission load

- Boundary conditions - the dispersion of pollutants in complex urban areas is dominated by the actual physical and geometric boundary conditions.
- Identification, availability and consideration of background concentration to the output of ground level concentration.
- Estimating short term and long-term concentration at sensitive receptors based on their sensitivity.
- Quantitative assessment for long-term exposure is more complex.
- Limitation in respect of low wind speed
- Consideration of uniform meteorological conditions in respect of big domain areas
- Due to the high number of variables to be considered, the source apportionment study is complex.
- Sometimes SA creates a problem in dispersion modeling due to lack of information like their chemical composition, location, history and duration of activity.
- Receptor modeling requires skill for good knowledge about atmospheric processes, the chemical nature of the source emissions, and competence in the use of computational tools.

3.8 Roadmap for EI, SA, Receptor and Dispersion modeling

3.8.1 Management Process

- Adequate budget allocation by the central/state government to the respective departments for EI and SA
- Fixing the accountability of government departments for carrying out EI and SA
- Involve more stakeholders
- Establish a cooperation framework by the local or national government among the working group (i.e. technical team, data providers), advisory group and experts to set up a stable EI system.
- Develop a sustainable data collection plan with relevant organizations producing data inputs for EI.
- Develop a review process involving experts and stakeholders for continual improvement in EI for use in AQM policies.
- Enhance technical capacity for EI through sustainable training.

3.8.2 Technical Process

- Build the capacity for compiling mixed top-down and bottom-up EI for criteria and other pollutants.
- Evaluate the applicability of default EFs and EFs obtained from academic and/or other countries' research.
- Assess capacity to use more sophisticated EI approaches (i.e. USEPA, EEA).
- Adapt applicable methods used in regional EI networks and disseminate results.
- Develop a review process and conduct regular validation of EI to ensure good data quality.
- Prepare and implement the monitoring plan (sampling locations and schedule, among others) for the collection of ambient samples, and arrange for necessary monitoring and analytical instruments. Refer to available literature (e.g. CPCB, 2006; 2007a)
- Identify laboratories within the region capable of doing the analysis for major PM components, e.g. ions, elements, Organic Carbon (OC) and elemental carbon.
- Collect ambient samples and send them to laboratories (in-country or abroad) with the appropriate technical capacity, for analysis for key chemical constituents.
- Build capacity for initial SA for PM and VOCs/semi-VOCs on an ad hoc basis or by research/academic institutions.
- Evaluate applicability of any PM source profiles available (external or from local studies) for major local sources.
- Initialize characterization of local source profiles and apply in Chemical Mass Balance (CMB) runs.
- Use CMB model to determine SA, and compare results with similar reported studies.
- Develop QA/QC procedures for SA.
- Secure appropriate receptor model software and source profiles (e.g., SPECIATE [USEPA, 2014b], CPCB, 2010).
- Initialize the use of dispersion models for exposure (concentration) simulation.
- Analyze the correlation of SA results from dispersion and receptor-based models, and provide recommendations to improve their alignment.
- Develop and propose control measures on the basis of the findings from the modeling.
- Calculation for emission load for each source
- Modeling domain boundary
- Terrain data for modeling domain
- Selection of receptor network

3.9 Case-studies

3.9.1 Emissions inventory for major cities in India

Emissions inventories were developed for six cities in 2007 for SO_2, PM, NO_x, CO, and Hydro Carbons (HCs), with future projections for the years 2012 and 2017. It involved the estimation of emissions from various activities (vehicular, industrial, residential, commercial, etc.). A combination of top-down and bottom-up approaches was used for the identification of all major emission sources, reliable estimates, and adequate representation of various factors influencing emissions (land use, socio-economic structure, and spatial and temporal distribution of source activities vis-à-vis pollutants). In addition to the data obtained from secondary sources of information, activity rates were collected through primary surveys including questionnaire surveys, personal interviews, house-to-house surveys, actual traffic counts, among others. While this approach provides a reasonable quality of data on emission estimates, resolutions with respect to time and space are limited in view of the available resources and timeframe. The important features of the methodology are summarized below:

- Detailed in-situ primary surveys within 2x2 km zone of influence around each monitoring location to identify all significant pollution sources (e.g., construction activities, industries' fuel use, domestic fuel consumptions, size and activities of diesel generator sets, etc.) and also to collect the activity rate through personal interviews.

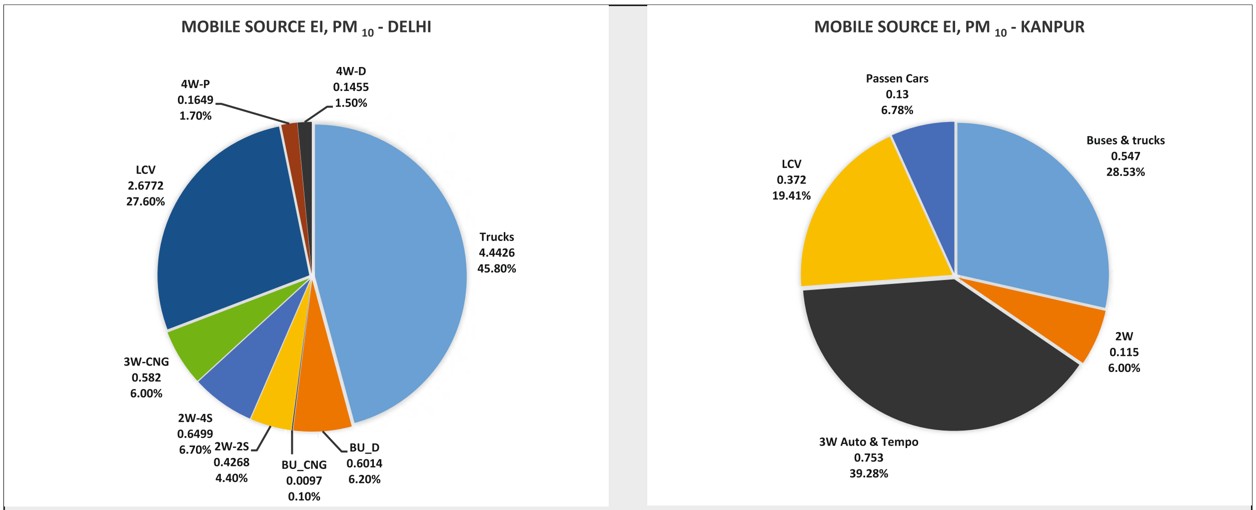
- Diurnal traffic count surveys on different categories of roads along with personal interviews at parking lots/petrol pumps with vehicle owners for obtaining data on age, fuel use, Vehicle Kilometers Travelled (VKT) per day, etc.

- Use of local EF for vehicular exhaust emissions and selection of appropriate EF for stationary sources (i.e. roadside dust, domestic fuel consumptions, industries, construction activities, etc.);

- Extrapolation of city level EI based on detailed inventories prepared in 2x2 km grids, and city land use plans.

- Future projections of emission scenarios considering developmental plans, changes in the land use and activities and/or activity levels, (with or without the implementation of given pollution control plans), etc.

Results



Bu_D : Bus (diesel); Bu_CNG: Bus(Compressed natural gas); 2W-2S: Two-wheeler (two stroke); 2W-4S: Two-wheeler (Four Stroke); 3W-CNG: Three- wheeler (Compressed natural gas); LCV: Light Commercial vehicle; 4W-P:Four wheeler (petrol); 4W-D: Four-wheeler (diesel)

Fig 3.5 Emissions inventory of Delhi and Kanpur

Source: CPCB-2011

3.9.2 Source apportionment studies in Indian Cities

AAQM data generated in Indian cities over the last decade reveal that PM concentrations are exceeding the air PM standards at many locations. The air pollution problem becomes complex due to the multiplicity and complexity of air polluting sources (e.g. industries, automobiles, generator sets, domestic fuel burning, road side dusts, construction activities, etc.). The CPCB considers a cost-effective approach for improving air quality in polluted areas to involve (i) identification of emission sources; (ii) assessment of the extent of contribution of these sources to ambient environment; (iii) prioritizing the sources that need to be tackled; (iv) evaluation of various options for controlling the sources based on feasibility and economic viability; and (v) formulation and implementation of the most appropriate action plans. Source apportionment studies help in identifying the sources and the extent of their contribution.

Accordingly, SA studies have been initiated in six major cities, viz.,

1. Bangalore
2. Chennai
3. Delhi
4. Kanpur
5. Mumbai

6. Pune.

The studies focus on apportionment of PM_{10}, one of the most critical pollutants. Conceptual guidelines for a common methodology and Standard Operating Procedures (SOPs) for sampling and analysis were developed to guide the investigators for each city. In addition, separate projects on the development of EFs for vehicles and emission profiles for vehicular as well as non-vehicular sources have been executed, which would provide necessary inputs to the SA studies.

The scope for SA studies includes the concentrations for various constituents of PM_{10}, such as Elemental Carbon (EC), Organic Carbon (OC), Total Carbon (TC), the sum of ions of Sulfate (SO_4^{2-}), Nitrate (NO_3^-), Ammonium (NH_4^+) or Secondary Inorganic Aerosols (SIA), and the sum of elements Aluminum, Calcium, Silicon, Iron, Sodium, Palladium and ions Calcium (Ca^{++}), Sodium (Na^+), Chlorine (Cl^-), representative of Crustal, Alluvial, Marine constituents (CAM) at selected locations (7–10 locations covering different land use, viz., residential, industrial and kerbside) and application of receptor (CMB8) and receptor-based models to assess the contribution from various sources, future projections and evaluation of various control options to develop cost-effective action plans.

Results

Results obtained in these studies are numerous. The most relevant are those for PM_{10}, EC, OC, TC, SIA, and CAM concentrations and source apportionment - see table 3.1-3.3 below (explanation of acronyms in the text). Industrial and kerbside carbon contents are major contributors to PM_{10}.

Table 3.1 Major components (µg/m^3) of PM_{10}, EC, TC, SIA and CAM at residential sites in six Indian cites

City	PM_{10}*	EC	OC	TC	SIA	CAM
Bangalore	98	5.6	14.0	19.6	15.5	26.8
Chennai	123	4.7	14.4	19.1	10.7	17.5
Delhi	419	18.5	100.4	118.8	21.2	27.2
Kanpur	213	19.4	53.7	73.1	29.9	16.1
Mumbai	207	9.2	41.1	50.3	9.8	28.2
Pune	132	4.4	29.6	34.0	14.1	40.6

Source: Gargava & Rajagopalan, 2015

Table 3.2 Major components (µg/m^3) of PM_{10}, EC, TC, SIA and CAM at industrial sites in six Indian cites

City	PM_{10}*	EC	OC	TC	SIA	CAM
Bangalore	137	8.1	21.4	29.5	9.5	23.6
Chennai	142	8.3	27.8	36.1	15.5	14.6
Delhi	519	13.7	73.3	87.1	18.7	33.5
Kanpur	385	38.0	105.3	143.4	30.2	15.2
Mumbai	196	9.1	36.5	45.6	11.4	24.5
Pune	136	4.0	27.8	31.9	9.4	32.6

Source: Gargava & Rajagopalan, 2015)

Table 3.3 Major components (µg/m^3) of PM_{10}, EC, TC, SIA and CAM at Kerbside sites in six Indian cites

City	PM_{10}*	EC	OC	TC	SIA	CAM
Bangalore	164	14.3	34.3	48.6	10.9	25.6
Chennai	170	10.9	27.1	38.0	12.9	10.9
Delhi	576	13.7	64.2	77.9	13.5	25.0
Kanpur	275	24.3	61.6	85.5	27.6	18.3
Mumbai	205	10.3	41.6	51.9	8.9	27.1
Pune	195	10.4	37.1	47.5	8.9	33.9

*** Average of 20-day monitoring in each of the seasons (winter, summer, post-monsoon)**

Source: Gargava & Rajagopalan, 2015

Module 3: Health and Other Impacts

Health and Other Impacts

"The exposure to ambient air pollution, particularly fine particulate matter is estimated by WHO to have caused 6.73 lakh premature deaths in India, in 2017."

4.1 About the Module

Appropriate and localized health impact assessments are the key to reduce impacts and are required to build the knowledge base in India. The module describes the significance of studies on air pollution and its health impacts.

The module highly recommends the setting up of a system of health impact assessment and air surveillance, and also also suggests measures to establish linkages with the existing city level surveillance mechanisms.

4.2 Objective

To establish and strengthen national and city level programmes that monitor the health impact of air pollution consistently.

4.3 Air pollution and its Health Impacts

Air quality in Indian cities is emerging as a serious concern because of its health impacts. Ambient air pollution is a much more significant public health risk than previously assumed. Research around cities worldwide shows that when air pollution levels increase, so do the number of people dying. Studies of long-term exposure to air pollution demonstrate that

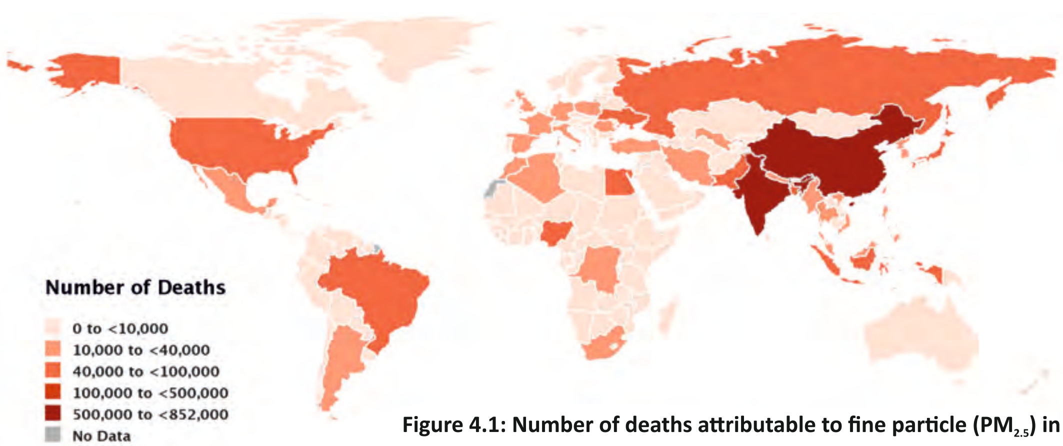


Figure 4.1: Number of deaths attributable to fine particle ($PM_{2.5}$) in 2017

Source: www.stateofglobalair.org/data/#/health people living in more polluted locations die prematurely, compared with those living in areas with lower levels of pollution. Research also provides details on how air pollution affects human health, with evidence clearly showing impacts on the rates of cardiovascular disease, stroke, and type II diabetes, in addition to the more easily appreciated effects on respiratory diseases. While these impacts on health are large, there are also documented examples from locations where AQM approaches have reduced pollution, and show that when air quality improves, so does population health.

The exposure to ambient air pollution, particularly fine particle or particulate matter ($PM_{2.5}$) is estimated by WHO to have caused 6.73 lakh premature deaths countrywide in 2017. In India over 38 million years[2] of healthy life are lost due to air pollution in 2017 according to the GBD's finding (Lim et al.). The GBD ranks air pollution as the fifth most important risk of premature death worldwide. In India, Chronic Obstructive Pulmonary Diseases (COPD) is estimated to rank second with 9.58 lakh deaths for all ages and sexes in 2017.
(https:// vizhub.healthdata.org/gbd-compare/#)

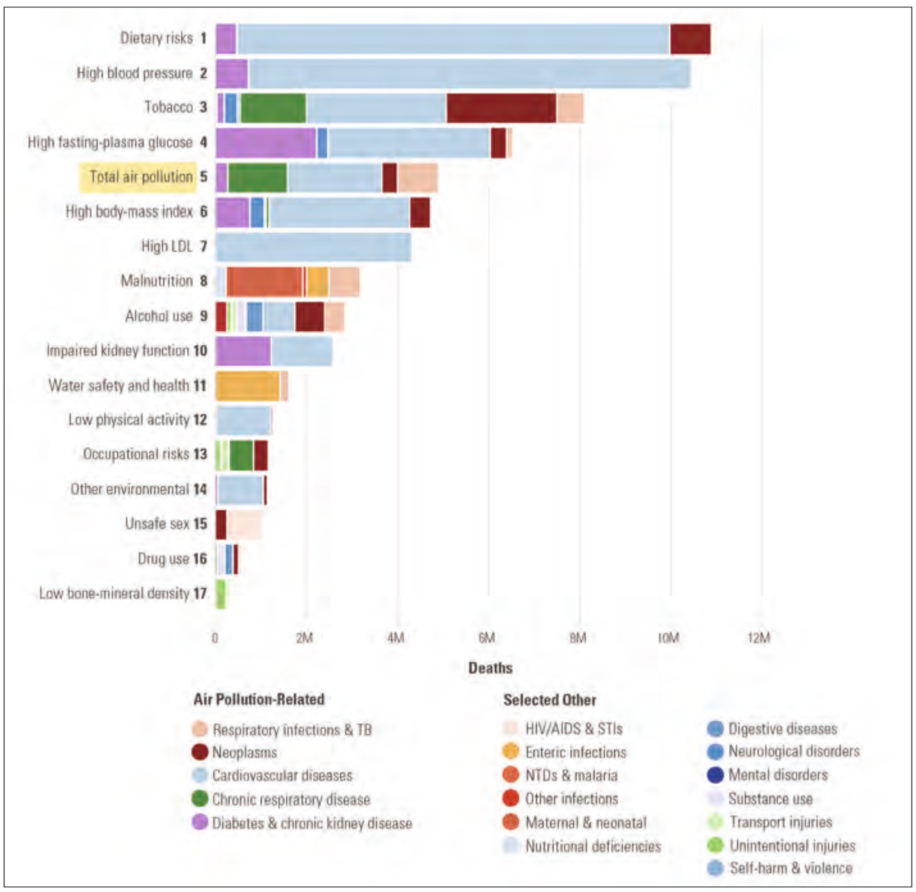


Figure 4.2: Global ranking of risk factors by total number of deaths from all causes for all ages and both sexes for 2017.
Source: State of Global Air/2019. (www.healthdata.org/data-visualization/gbd-compare)

[2] The disability-adjusted life year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. It was developed in the 1990s as a way of comparing the overall health and life expectancy of different countries.

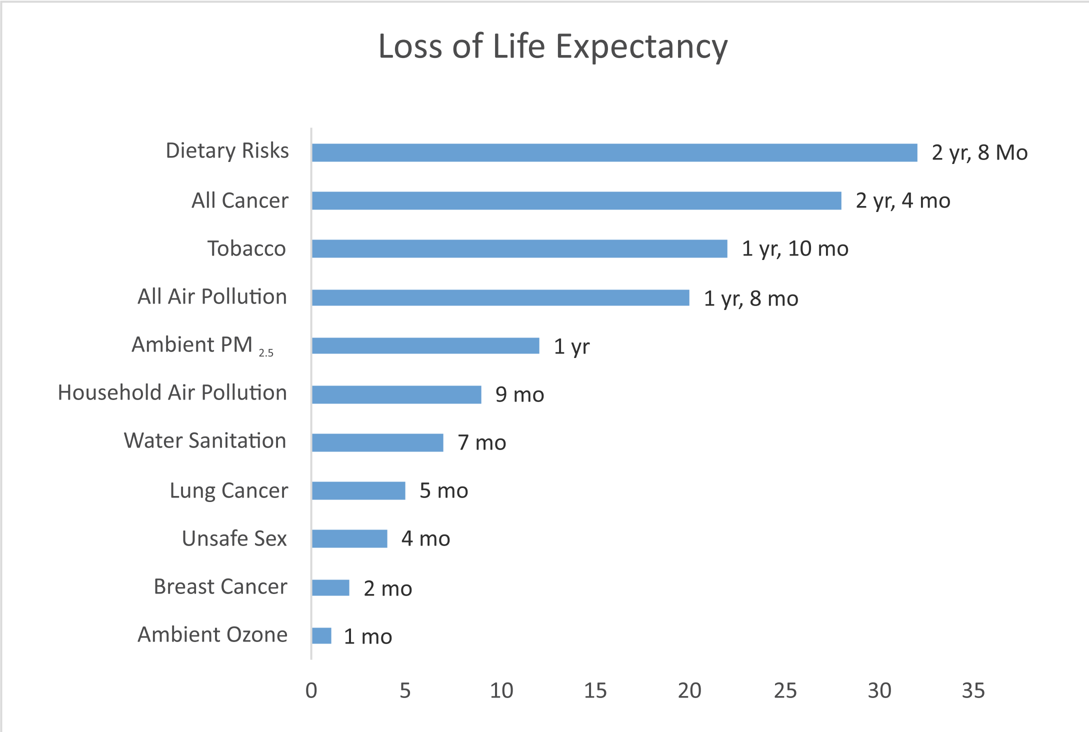


Figure 4.3: Contribution of major risk factors to loss of life expectancy

Source: State of Global Air/2019. (stateofglobalair.org/health/life-expectancy)

	India
Ischemic heart disease	1
COPD	2
Stroke	3
Diarrheal diseases	4
Lower respiratory infect	5
Tuberculosis	6
Neonatal disorders	7
Astham	8
Diabetes	0
Chronic kidney disease	10

Figure 4.4: Burden of diseases as deaths due to air pollution in India by both sexes and all ages, in 2017

Source: https://vizhub.healthdata.org/gbd-compare/#

The GBD study shows that India gets the second largest share of the ambient $PM_{2.5}$ related deaths worldwide with an estimated 6.73 lakh deaths in 2017. Approximately 23% of these cases are in India. This is also the case with premature deaths worldwide due to ground-level ozone (O_3) exposure, with India accounting for approximately 31% of such deaths or 1.45 lakh cases in 2017.

In 2013, a group of experts working on behalf of WHO's International Agency for Research on Cancer (IARC) classified ambient air pollution in general and $PM_{2.5}$ in particular as carcinogenic (IARC Group 1) to humans (WHO/IARC, 2013a,b,c). This classification is based on sufficient evidence of carcinogenicity in humans and experimental animals and strong evidence on the mechanisms (Brauer et al., 2012; Loomis et al., 2013; 2014). As a carcinogen, particulate matter (PM) has no threshold for the onset of effects.

The long-term exposure to ambient $PM_{2.5}$ is linked to deaths from COPD, ischemic heart disease, stroke, lung can¬cer and Lower Respiratory Infections (LRIs). Of these deaths attributable to $PM_{2.5}$, most were caused by ischemic heart dis¬ease and stroke (State of Global Air/2018).

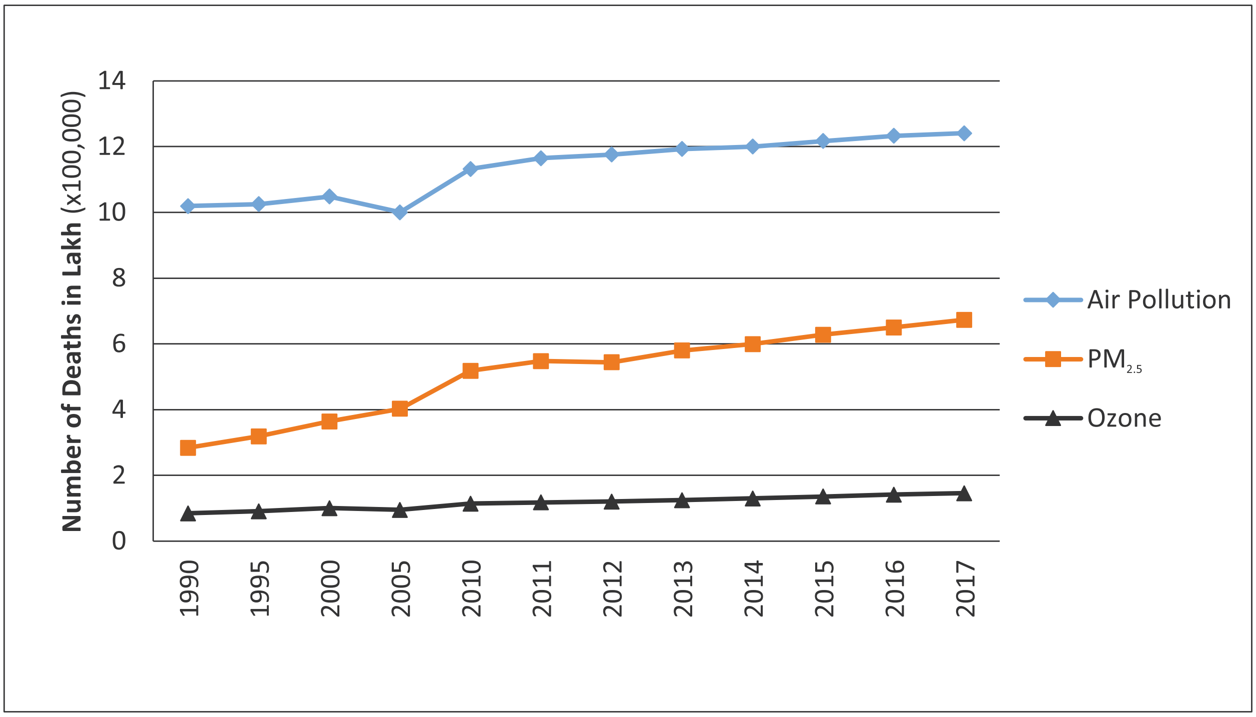


Figure 4.5: Number of deaths attributable to Air Pollution, $PM_{2.5}$ and Ozone in India

Source: www.stateofglobalair.org/data/#/health/plot

Table 4.1: Number of Deaths Attributable to Air Pollution, $PM_{2.5}$ and Ozone in India

Year	Number of Deaths Attributable to Air Pollution	Number of Deaths Attributable to $PM_{2.5}$	Number of Deaths Attributable to Ozone
1990	1019000	283900	84600
1995	1025000	318700	91100
2000	1048000	364200	100400
2005	1000000	402700	95200
2010	1132000	518100	114100
2011	1165000	547500	117600
2012	1176000	544100	120700
2013	1193000	580100	124800
2014	1200000	599600	130100
2015	1217000	627800	135600
2016	1233000	649800	141300
2017	1241000	673100	145700

Source: www.stateofglobalair.org/data/#/health/plot

"To establish and strengthen national and city level programmes that monitor the health, environmental and economic impact of air pollution consistently."

4.4 Importance of considering health and environmental impacts

A healthy adult human breathes about 16 kg of air every day. Ambient air pollution has many significant impacts on human health and the environment. Many air pollutants have been classified as carcinogenic, in addition to causing a variety of respiratory, cardiovascular diseases and physiological disorders in humans. Air pollution also impacts animals and plants including agricultural crops.

As an emerging economy accelerating its growth rate to reduce its widespread poverty, the country faces the challenge of air pollution. Ironically, air pollution affects health, employability and coping capabilities of those living in poverty the most.

Understanding and estimating the impacts of air pollution as well as its economic costs to society are integral in the overall Air Quality Management (AQM) framework. Any AQM

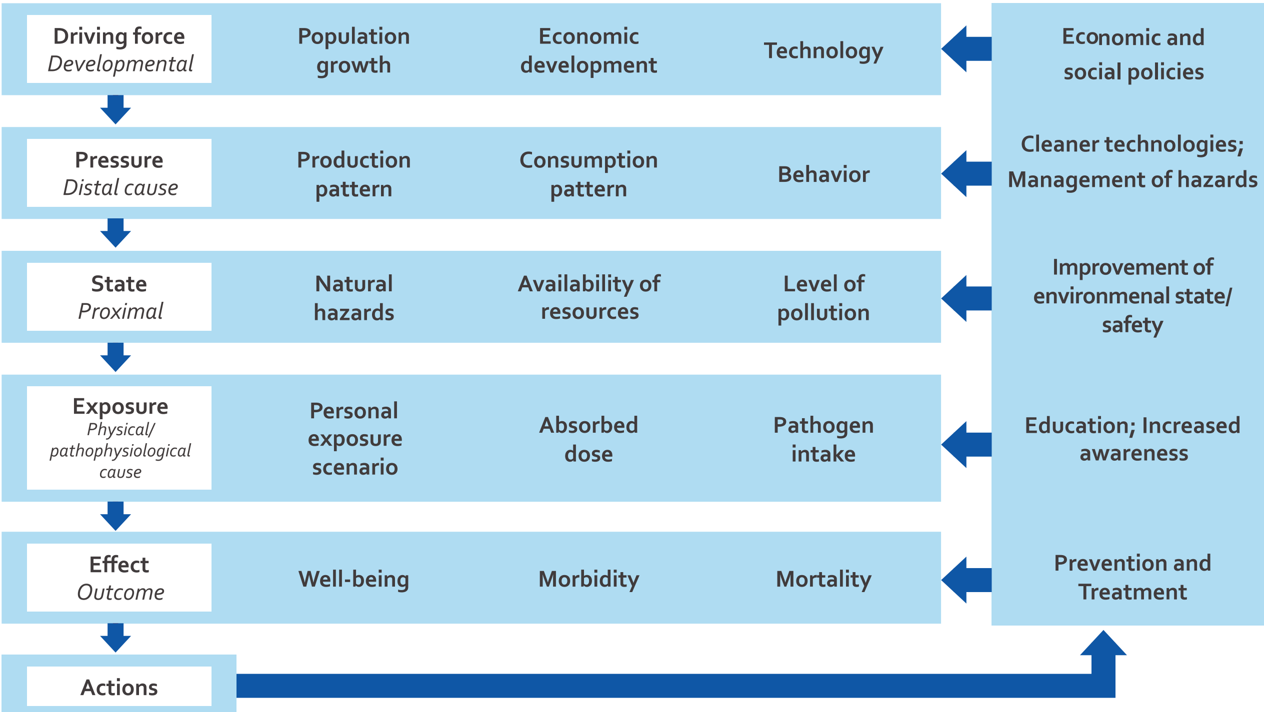


Figure 4.6: The DPSEEA framework,

Source: Adapted from WHO, 1995a

framework is based on the Driving Force-Pressure-State-Exposure-Effect-Action (DPSEEA) framework depicted in Figure below.

Analyzing the cost of air pollutant control measures *vis a vis* the benefits of avoided health and environmental impacts as a result of these measures is critical in improving the effectiveness of air quality management. Without estimates on pollution damage costs, it is impossible to determine the cost effectiveness of air pollution prevention, mitigation and control strategies. Identifying efficient and effective technologies and policy tools, needed for target setting and management strategy, also becomes unworkable.

"Understanding and estimating the impact of air pollution as well as its economic costs to society are integral in the overall air quality management framework."

4.4.1 Health impacts of air pollution

The greatest impacts on human health tend to be focused on the effects of these common pollutants – $PM_{2.5}$, O_3, NO_2 and SO_2 – as well as toxic air pollutants, secondary pollutants, VOCs and heavy metals.

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[3] Absorbed dose: The amount of air pollution absorbed and therefore available to undergo metabolism, transport, storage or elimination in the human body (WHO, 2000b).

[4] Pathogen intake: The taking in of substances which can cause harm or disease (WHO, 2000a; Cyclopedic Medical Dictionary, 1997).

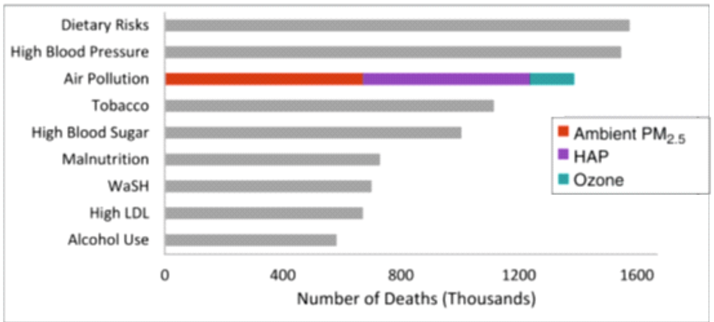

Figure 4.7: Leading risk factors for death and disability in India in 2017

Source: www.stateofglobalair.org

4.4.1.1 Particulate matter

Evidence suggests that there is a close correlation between exposure to high concentrations of small particles and increased mortality or morbidity, both in the short and long term (Hirota & Martin, 2013; United States Environmental Protection Agency [USEPA], 2009; Hogg et al., 2004; WHO, 2013a,b; Brook et al., 2010; Chuang et al., 2007; Rückerl et al., 2006). Fine particulate matter, after it is inhaled, penetrates deep into the lungs and the air sacs. The particles damage cells in the airways and affect the lung; this is associated with the exacerbation of asthma and COPD (Riva et al., 2011; USEPA, 2009; Risom et al., 2005). The fine particulates cause further damage as they impact the heart and circulatory system.

$PM_{2.5}$ related deaths occur due to:

- ischemic heart disease
- cerebrovascular disease (ischemic stroke and hemorrhagic stroke) (WHO, 2013a,b),
- type II diabetes
- chronic obstructive pulmonary disease (COPD) (WHO, 2013a,b,c) and
- acute lower respiratory infection (LRIs) (WHO, 2013a, b; Roth et al., 2008; Lanata et al., 2004).

Non-fatal health impacts of exposure to $PM_{2.5}$ include:

- non-fatal heart attacks,
- irregular heartbeat,
- aggravated asthma,
- decreased lung function, acute bronchitis and
- increased respiratory symptoms.

These can lead to absence from work and reduced school attendance as well as increased hospital admissions and doctor's visits.

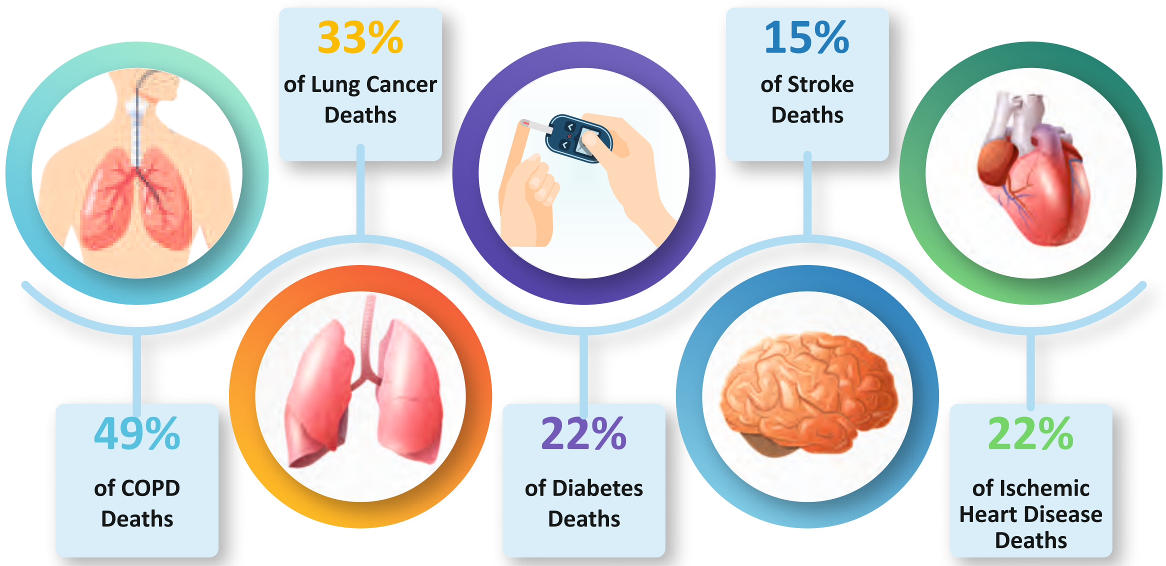

Figure 4.8: Percentage of deaths by cause attributable to air pollution in India

Source: State of Global Air, Health Effects Institute, www.stateofglobalair.org

A component of $PM_{2.5}$ that should also be mentioned is Black Carbon (BC) which refers to elemental carbon containing particles that are emitted from incomplete combustion of fossil fuels and biomass (Long et al., 2013). According to WHO, there is sufficient evidence for an association between short and long term BC exposure and all-cause and cardiovascular mortality as well as cardiopulmonary hospital admissions (Janssen et al., 2012) and mortality.

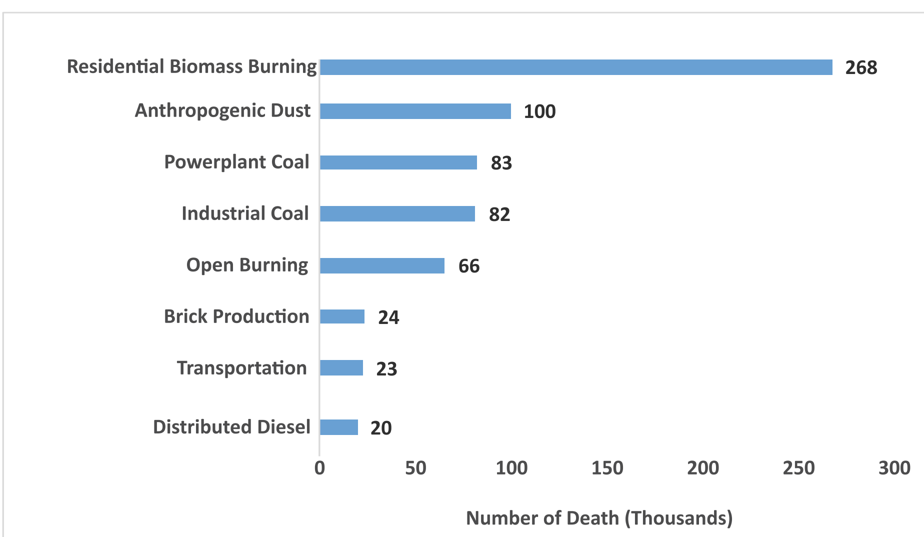

Figure 4.9: Source contribution to deaths attributable to $PM_{2.5}$ in India in 2015.

Source: State of Global Air/2019 www.stateofglobalair.org

A wide range of industrial, residential and transportation air pollution sources contribute to PM exposure; all these sources need to be controlled to reduce the health burden. The study reported that if no further action is taken, population exposures to $PM_{2.5}$ are likely to increase by over 40% by 2050. More aggressive actions with all major sectors achieving reductions in air pollution could avoid up to 1.2 million deaths in 2050 compared with just instituting currently planned policies.

4.4.1.2 Ground-level ozone

Ground-level ozone is less soluble in water. It is thus not scrubbed in the upper respiratory tract and reaches the lower respiratory tract where it dissolves in the fluid of the thin surface layer of lung cells. Free radicals and other oxidants in the fluid are assumed to react rapidly with the cell molecules and mediate the effects of O_3 exposure of the human lung. Ozone exposure is a major factor in asthma morbidity and mortality. Even short-term exposure can aggravate existing lung diseases and make the lungs more susceptible to infection.

Health effects of short-term exposure to O_3 include (USEPA, 2014a, 2013a; WHO 2013a, b):

- Increased all-cause mortality
- Increased cardiovascular mortality in adults younger than 75 years
- Increased hospital admission for heart diseases in adults older than 65 years
- Increased hospital admissions for respiratory diseases in adults older than 65 years
- Increased hospital admissions for chronic obstructive pulmonary disease
- Potentially increased hospital admissions for asthma
- Increased school absences

4.4.1.3 Nitrogen dioxide

Upon inhalation of NO_2, the human respiratory tract can absorb between 70-90% of the gas, and even greater levels when breathing from the mouth, e.g., during exercise. Nitrogen dioxide is increasingly deposited in the lower respiratory tract and can remain in the lung for prolonged periods (WHO, 2006). Short-term exposure to NO_2 is enough to cause aggravations in people with asthma and other lung diseases. Above safe levels, NO_2 exposure can cause inflammation of the airways. Some studies have shown associations between NO_2 long-term exposure and mortality. However, present evidence is not sufficient to conclude that effects on mortality can be attributed to exposure to NO_2 itself (Institute of Occupational Medicine, 2004).

Health effects of long-term exposure to No_2:

- Exacerbation of symptoms of bronchitis in asthmatic children (WHO, 2013b)
- Reduced lung function in children (WHO, 2013a; b)

4.4.1.4 Sulfur dioxide

The main anthropogenic source of SO_2 is the burning of sulfur containing fossil fuels for motor vehicles, power generation and domestic heating. Being highly soluble in water, inhaled SO_2 is readily absorbed in the human respiratory tract, in particular, while breathing from the mouth. Inhaled SO_2 can cause inflammation of the respiratory tract (WHO, 2013a).

Epidemiological studies have linked SO_2 long-term exposure to:

- Causation of changes in lung function
- Exacerbation of existing heart diseases
- Increased number of asthma attacks

WHO, in its most recent factsheet (WHO, 2014), believes that present evidence is sufficient to conclude that effects on mortality can be attributed to exposure to SO_2.

4.4.1.5 Toxic air pollutants and heavy metals

Toxic air pollutants include hydrocarbons, VOCs, heavy metals and secondary pollutants. Examples are benzene (in petrol/gasoline), benzo-α-pyrene (in tar and asphalt fumes and diesel engine emissions), perchloroethlyene (in drycleaning chemicals), methylene chloride (in solvents and paint strippers), asbestos, toluene, polycyclic aromatic hydrocarbons (PAH), arsenic and metals such as lead, cadmium, mercury, chromium, nickel and zinc compounds. Primary pollutants and air constituents undergo photochemical changes and form secondary pollutants like ozone, peroxyacetyl nitrate (PAN) and smog. The level of O_3 and NO_2 increases due to the increase of unburnt hydrocarbon.

Smog has many injurious effects on man, animals, plants and materials (Sharma & Kaur). People exposed to toxic air pollutants due to poisonous smog at ample concentrations and durations may have increased chances of cancers, reproductive and birth defects, immunological damages, physiological disorders and retarded neurological developments. Some persistent toxic air pollutants accumulate in body tissues because unlike organic pollutants, toxic metals do not decay.

Toxic air pollutants such as benzene, benzo-α-pyrene, nickel and arsenic, in particular, are classified as carcinogenic; no safe level of exposure has been derived by WHO for these metals. While ammonia (NH_3) in itself is not classified as carcinogenic, it converts gaseous acids, especially sulfuric and nitric acids, to $PM_{2.5}$, which is carcinogenic (Martin, 2008). In a recent publication, Paulot & Jacob (2014) suggested that elimination of NH_3 emissions would achieve a greater health benefit than the reduction of the $PM_{2.5}$ national standard from 15 to 12 $\mu g/m^3$.

More detailed information about health impacts due to exposure to toxic air pollutants can be accessed at WHO (1995b) and USEPA (2007).

Table 4.2: Common air pollutants and their pathological effects on human

	Pollutant	Source	Pathological Effect on Human
1.	Aldehydes	Thermal decomposition of oils, fats and glycerol	Irritate nasal and respiratory tracks
2.	Ammonia	Explosives, dye making, fertilizer plants and liquors, sewage treatment	Inflames upper respiratory passages
3.	Arsines	Process involving metal or acids containing arsenic soldering	Damage RBC in blood and kidneys, and cause jaundice
4.	Carbon monoxide	Burning of coal, petrol, motor exhausts	Reduces oxygen carrying capacity of blood, headache, dizziness, fatigue, vomiting
5.	Chlorine and chlorinated compounds – dioxins, DDT, PCB	Industries, bleaching agent, burning of plastics, garbage, biomass, agricultural residues	Carcinogenic, mining immune and reproductive systems, masquerade hormones, cancer, birth defect, learning disabilities, attack entire respiratory tract, pulmonary edema
6.	Ground-level Ozone	Formed in atmosphere by photochemical reaction of NO_2 or hydrocarbons	Nose and throat irritation, cough, headache, breathing difficulty, chest pain, death due to pulmonary edema, narrowing of airways deep in the lung, aging of lung tissues, lung cancer, loss of immune system, emphysema, affect lung phagocytes, chronic bronchitis, chronic obstructive lung and heart diseases, changes in nucleic acid, RNA and DNA
7.	Hydrocarbons – benzene, toluene, benzo-α-pyrene, PAH, PAN	Petroleum products use, industrial activities, automobiles	Highly carcinogenic to multiple organs, irritation of eyes, nose and throat, respiratory distress, weakness, fatigue, cough, blockage of respiratory tract, affect nervous system

8.	Hydrogen cyanides	Blast furnace, fumigation, chemical manufacturing, metal plating	Interfere with nerve cells, produce dry throat, indistinct vision, headache
9.	Hydrogen fluorides	Glass etching, aluminum and fertilizer manufacturing, petroleum refining	Irritate and corrode all body passages
10.	Hydrogen sulfide	Refineries, chemical industries and bituminous fuels, sewage and waste treatment	Causes nausea, irritates eyes and throat
11.	Metallic contaminants – Cd, Cr, Hg, Ni, Pb, Zn, etc.	Industrial processes, incineration, automobile, e-waste	Chronic bronchitis, pulmonary, emphysema, asthma, eye, nose, throat irritation, headache, dizziness, coma, cancer, nerve impairment
12.	Nitrogen oxides	Soft coal, automobile exhausts	Inhibit cilia action so that soot and dust penetrate deep into lungs, irritation, bronchitis
13.	Particulate matter	Combustion of petroleum, natural gas, coal and wood, burning of garbage and vegetation, industrial activities, power plant, mining, automobile, air-borne, construction	Damage lung tissues, absorbed to blood, alveoli and lymphatic streams, crosses blood-brain barrier and affects child's brain, bronchio-constriction, asthmas, affect maturation of RBC, acute and chronic cancer, hypertension and cardiovascular diseases
14.	Phosgene or carbonyl chloride	Chemical and dye making	Induces coughing, irritation and fatal pulmonary edema
15.	Soot, ash, smokes, etc.	Incinerators and almost every manufacturing process, thermal power plant	Cause emphysema, eye irritation and possibly cancer
16.	Sulfur dioxide	Coal and petroleum oil combustion	Causes chest constriction, cough, eye and throat irritation, headache, vomiting, asthma, allergenic infections and death from respiratory ailments, lung diseases, bronchitis, emphysema

Source : Sharma & Kaur

4.4.2 Environmental impacts of air pollution

Air pollutants are causing changes in the ecosystem and are indirectly affecting wildlife, in addition to directly affecting animal populations that are exposed to harmful air pollutants (United Kingdom Website (UK), 2014b). The impact of air pollution is not limited to health but extends to agriculture and the general well-being of humans, floral and faunal population. Extensive experimental studies to assess the potential threat from O_3 to agriculture conducted in Europe and North America have demonstrated crop losses due to O_3 impacts amounting to billions of dollars (Avnery et al., 2011a). The impact of air pollution on cultural heritage materials is also a serious concern because it can lead to the loss of important parts of a county's history and culture. The Taj Mahal has been affected due to air pollution as the marble of which it is constructed is getting corroded and turning yellow due to reaction and deposition of pollutants like SO_2.

4.4.2.1 Acid rain

Acid rain containing nitric and sulfuric acids, washes away nutrients, causes damage to forests and the acidification of soils and water bodies, potentially disrupting the food chain. Acid deposition may have various effects on crops, including significant yield loss in many species. Acid rain also accelerates the erosion of buildings, statues and sculptures. [USEPA (2012b), Phinney et al. (2004), and UK (2014a)]

4.4.2.2 Haze

Haze is caused by the scattering and absorption of sunlight by airborne fine PM (USEPA, 2012c). Haze degrades visual range, obscuring the clarity, colour, texture and forms of objects in cities and scenic areas. Haze has potential impacts on air quality, climate and the hydrological cycle (Ramanathan et al., 2001).

4.4.2.3 Ozone layer depletion

Stratospheric ozone, particularly in the polar zones, is being gradually destroyed by chlorine and bromine containing substances referred to as ozone depleting substances (ODS). The Montreal Protocol on Substances that Deplete the Ozone Layer entered into force in 1989 to protect stratospheric ozone and consequently, protect life from increased ultraviolet radiation on the Earth's surface (United Nations Environment Programme [UNEP], 2011). These controls under the Protocol have proven effective for safeguarding public health. Ultraviolet radiation can damage sensitive crops and reduce crop yields. Most ozone-depleting substances are also potent greenhouse gases (GHGs), contributing to global

[5] Controls implemented under the Montreal Protocol have enabled the global community to avoid millions of cases of fatal skin cancer and tens of millions of cases of non-fatal skin cancer and eye cataracts. The U.S. estimates that, by the year 2065, more than 6.3 million skin cancer deaths will have been avoided in that country alone and that efforts to protect the ozone layer will have saved it an estimated US$4.2 trillion in healthcare costs over the period 1990–2065 (United Nations Development Programme, 2012). Moreover, in 2011, the United States Environmental Protection Agency estimated that more than 22 million Americans born between 1985 and 2100 would avoid suffering from cataracts as a result of the Montreal Protocol (UNEP, 2012).

warming. There is strong evidence available on the effect of stratospheric ozone changes on Earth's surface climate (UNEP, 2010; USEPA, 2011a).

4.4.2.4 Crop and forest damage

Ground-level Ozone can reduce agricultural crop and commercial forest yields, diminish growth and influence survival of tree seedlings and increase plant susceptibility to disease, pests and other stresses. Wang & Mauzerall (2004) estimated a total US$5 billion loss per year for wheat, rice, maize and soybean for Asian countries. Ghude et al. (2014) estimated India's crop loss for cotton, soybean, rice and wheat amounting to 6 million tons with a value of US$1.3 billion for 2005 as base year. These studies, however, may have substantially underestimated the effect O_3 has on crop productivity in India due to more sensitivity to O_3 of India-grown wheat and rice cultivars (Emberson et al., 2009).

4.5 Air pollution and climate change, similar sources

Many air pollutants such as PM, SO_2, NO_2 and CO have the same sources as GHGs. Major GHGs are CO_2, CH_4 and O_3. Ozone formation follows from various chemical transformations such as photochemical oxidation of organic vapours by organic peroxyl free radicals in the presence of NO_x and CH_4 photo-oxidation via various sequences (Johnston & Kinnison, 1998). Greenhouse gases have to be reduced to mitigate climate change, while air pollutants have to be controlled to avoid direct effects on human and environmental health. Measures to mitigate climate change can reduce air pollution, while actions taken to reduce local and regional air pollution can reduce GHG emissions. There is a need to jointly assess these interrelated policies. The co-control of air pollution and GHG emissions will be cost-effective and create co-benefits (Intergovernmental Panel on Climate Change [IPCC], 2007; Anenberg et al., 2012; Climate and Health Alliance (CAHA), 2012; HEAL, 2012; West et al., 2013; GCEC, 2014).

"Measures to mitigate climate change can reduce air pollution and actions reducing local and regional air pollution can reduce greenhouse gas emissions. There is a need to jointly assess these interrelated policies."

4.6 Health and Economic Impact Studies

The statistics presented in international studies correlating air pollution with health impacts which are not based on indigenous studies of dose response functions complicates the understanding and possibly creates an ambiguous perception among the public as well as policymakers. Attributing one to one correlation and the number of deaths and ailments due to air pollution needs to be investigated and supported by local studies and strong evidences. More authentic local data and studies may strengthen the efforts, public demand and confidence of policymakers in improving the air quality.

With a focus on environmental health issues, MoEF&CC constituted an Apex Committee and a Working Group under the joint chairmanship of the Indian Council of Medical Research (ICMR) and the Ministry to identify thrust areas in environment health and to evaluate the related projects. In line with the recommendation of the Working Group, the ministry has initiated action towards a study on the National Environmental Health Profile for 20 cities, with an emphasis on the impact of air pollution on health.

There are numerous effects of air pollution on the ecosystem which in turn have various economic implications. It primarily causes respiratory and other health hazards in people who are being directly exposed to poor air quality. The secondary and long-run impact would be that following the health problems, the productivity of workers might be adversely affected, which in turn hampers output. The economic burden of health limits the discretionary household expenses. This is how air pollution exerts an indirect effect on the overall economy. The recognition of anthropogenic sources of pollutants and their biological and economic effects on managed ecosystems such as agricultural crops and forests, provides the impetus for air pollution control programmes.

The link between economics and natural science economic analysis can be an effective tool for comparing the costs and benefits of alternative resources or environment management policy actions. When rationally formulated, such economic analyses can be useful in estimating the monetary values of vegetation and other receptor losses from air pollution or the welfare consequences of air pollution reductions.

Box 4.1

The NCAP suggests the following strategies and approaches for AQM pathways:

- Indigenous/local studies to investigate serious health implications of air pollution with correlation to deaths/ailments due to air pollution
- Studies on authentic Indian data to strengthen the efforts, public demand and policymaking for improving local air quality
- Collaborated study projects on identified thrust areas of environment and health
- Studies on direct and indirect effects of air pollution on overall economy through health hazards to people, and long run impacts of productivity loss, effect on ecosystem, biological and economic effects on managed ecosystems
- Analysis of linkages between economics and natural sciences for comparing costs and benefits of alternative resources or environment management policy actions
- Studies on estimating losses on monetary values of vegetation and other receptors due to air pollution
- Studies on welfare consequences of air pollution reductions
- Support studies on health and economic impact of air pollution

"Action point 2.3.7 of the NCAP suggests for supporting studies on health and economic impact of air pollution. Cities can recommend and propose to undertake local specific air pollution and health studies."

The NCAP enlists some of the air pollution and health impact studies to be undertaken. It also recommends the agencies that can be entrusted to conduct and support these studies along with timelines. Action point 2.3.7 of the NCAP suggests for supporting studies on health and economic impact of air pollution. Cities can recommend and propose to undertake local specific air pollution and health studies. NCAP further recommends for international cooperation in capacity enhancement. Air quality and health impact studies are potential areas for such collaborations.

Table 4.3: Action Points on Health and Economic Impact Studies (NCAP)

Sl No	Component / Activities	Level of funding	Level of Implementation	Agencies	Timeline
2.3.1	Study on the national environmental health profile	Centre	Centre	MoEF&CC	2019
2.3.2	Response study and cohort study programme	Centre	Centre	MoH&FW	2019
2.3.3	Ministry of Health to actively take up environmental health for ensuring a regular health profile or database for assisting decision making	Centre	Centre	MoH&FW	2019
2.3.4	Framework for monthly analysis of data wrt health to be created. Data from mapping of industry, tabulation of daily AQI, $PM_{2.5}$ and PM_{10} measurements, metrological parameters, deaths due to heart attack, strokes, respiratory arrest following existing respiratory ailments, trends in lung cancer if available wrt all cities to be fed in a central computer and to be analysed every month by people trained in environmental health for correct interpretation	Centre	Centre	MoH&FW	2024

2.3.5	Awareness and orientation workshops focused on target audience and media to be used for wider dissemination of information. However, precise information to be shared should be carefully worked out by a team of experts in air pollution and environmental health	Centre	Centre	MoH&FW, MoEF&CC, CPCB	2024
2.3.6	Train researchers in study design through workshops in epidemiology, toxicology and biostatistics	Centre	Centre	MoH&FW, MoEF&CC, CPCB	2024
2.3.7	Studies on health and economic impact of air pollution to be supported	Centre	Centre	MoH&FW, MoEF&CC	2024
2.3.8	Media to be used for wider dissemination of information, and the precise information to be shared to be carefully worked out by a team of experts in air pollution and environmental health	Centre	Centre	MoH&FW	2024

Source: NCAP

Table 4.5: Action Points on International Cooperation including Sharing of International Best Practices on Air Pollution and Health (NCAP)

Sl No	Component / Activities	Level of funding	Level of Implementation	Agencies	Timeline
2.4.1	International scientific and technical cooperation in the area of air pollution will be established in accordance with national priorities and socio-economic development strategies and goals	Centre	Centre	MoEF&CC	2019
2.4.2	Modalities of such cooperation may include joint research and technology development, field studies, pilot scale plants and field demonstration projects with an active involvement of academia, research institutions and industry on either side. Funding for co-financing purposes are to be indicated.	Centre	Centre	MoEF&CC	2019

Source: NCAP

"Health impact assessment in a clean air action plan is a means of assessing the positive and negative health impacts of existing air pollution abatement policies, strategies, plans and projects."

4.7 Health impact assessments in city-specific AQM plans

A city-specific air quality management (AQM) programme is a long-term plan of action intended to improve the air quality and public health of the city by identifying measures to reduce emissions from sectors such as transportation, industries, waste management and household burning, among others [See Module 5]. The health impact assessment (HIA) in a city AQM programme is a means of assessing the positive and negative health impacts of existing air pollution abatement policies, strategies, plans and projects. Many definitions of HIA exist (Birley, 1995; European Centre for Health Policy [ECHP], 1999; Lock, 2000; International Association for Impact Assessment, 2006), the main definition being that of the ECHP: "A combination of procedures, methods and tools by which a policy, programme or project may be judged as to its potential effects on the health of a population and the distribution of those effects within a population" (WHO, 2007).

The health impact assessment is a valuable tool within a city AQM programme to develop policies, strategies, programmes and projects for cleaner air by providing information for decision making and addressing policymaking requirements. One of the objectives of an HIA study is to assess whether or not air pollution has an effect on human health. This tool brings policies and people together and involves all stakeholders. It is a proactive process that can mitigate health impacts due to air pollution. The HIA procedure within an AQM programme is shown in Figure 4.10 .

Deciding whether to do an epidemiological study on air pollution- related impacts

Review the need for full-scale study on health effects

↓

Apply epidemiological principles

Selection of target population to estimate the effect of exposure	Estimation of the quantitative relationship between an air pollutant and the health outcome

↓

Exposure assessment

determination of air pollutant concentrations and their durations

↓

Health effects assessment

Usage of primary and secondary data

↓

Study design and methods

Comparison of health effects and exposure levels

Figure 4.10. A stepwise process for HIA development and implementation

PHASE	PROCESS	DESCRIPTION
Policy and programme development for prospective assessments	Screening	Quickly establishes the 'health relevance' of air polution. Is HIA required?
	Scoping	Identiies key air pollutants & public concerns, establishes Terms of Reference, sets boundaries
	Appraisal	Rapid or in-depth assessment of baseline health status, adverse health impacts of air pollution using available evidence – who will be afected, signiicance, projection, mitigation
Policy implementation	Recommendations	Identifies strategies and measures to manage adverse health impacts
	Reporting	Communicates to stakeholders conclusions & recommendations to mitigate adverse health impacts
	Monitoring	Action, where appropriate, to monitor actual adverse health impacts to enhance existing evidence base

Figure 4.11 Procedure for health impact assessment in AQM programme[6]

Source: Adapted from WHO, 2015

4.8 Health and environmental impact assessment

Strengthening the capacity for health and environmental impact assessment helps shape and define policies for improving air quality. Such capacity also helps in the assessment of the effectiveness of measures to protect human health and the environment.

The following serve as key considerations in progressing through the health and environmental impact assessments:

- Availability of information for estimating health and other impacts
- Processes for estimating health impacts of air pollution
- Capacity for estimating health and other impacts of air pollution
- Presentation of results of health impacts assessment for policy development purposes

[6] City Administration may be represented by the City-level Review Committee under the Municipal Commissioner; District Administration may be represented by the DM-level committee in the districts; SPCB may be represented by the State-level PMU at the SPCB, State Health, Environment and other concerned departments may be represented and coordinated by the State Monitoring Committee under the Chief Secretary in the states; Local NGOs, Civil Societies, Citizens Groups, Educational and Research Institutes, Health Care Establishments are key actors and stakeholders.

In India, cities are overall at the beginner's level *vis-à-vis* air quality and health impact assessments. Indian cities can be represented by the following indicators with respect to the assessment of health and other impacts due to air pollution:

- Health surveillance system for monitoring impacts due to air quality not available in majority of cities.
- Required air quality databases are unavailable for many non-attainment cities. However, meteorological and air quality databases are being developed for emission-exposure-impacts modeling for some cities.
- Initial observations on health impacts due to air pollution exposure exist.
- Lack of capacity for:
    - air pollution monitoring with low-cost sensors or sophisticated analyzers with respect to HIA
    - exposure assessment
    - health and environmental impact assessment
- Local specific studies on the socio-economic cost of pollution and benefits of pollution control are not available.
- Cost effectiveness/cost-benefit analysis not conducted.

A fully developed stage for assessment of health and other impacts due to air quality can be understood and achieved by the following indicators:

- Health surveillance system that makes reliable data available which is always taken as the basis of HIA due to air pollution
- Meteorological and air quality databases are regulated to be available and routinely used for emission-exposure-impacts predictions.
- Systematic epidemiological studies on health impacts due to air pollution exposure are performed, including exposure and health impact assessment studies of major facilities or areas (e.g., schools, hospitals) and of vulnerable populations (e.g., children and elderly), using sophisticated assessment techniques.
- Capacity sustainably enhanced for:
    - air pollution monitoring with low-cost sensors or sophisticated analyzers with respect to HIA
    - exposure assessment
    - health and environmental impact assessment
- Studies on the socioeconomic cost of pollution and benefits of pollution control are available, performed by academic/research institutions and government. A process is in place for estimating socioeconomic costs adapted to local conditions.
- Cost-effectiveness/cost-benefit analyses routinely performed by academic/research institutions and government following a localized system for estimating costs and benefits including social.
- Presentation of results of HIA, studies on socioeconomic cost of pollution and cost-effectiveness/cost-benefit analysis systematically considers its use in AQM policy development, implementation and evaluation.

4.9 Issues and Challenges

A number of cities in Asia have developed AQM programme over the last 15 years to address the challenge of air pollution; a considerable number of challenges remain to be resolved yet, especially in urban areas. This relates particularly to conducting health impact assessments (HIA) *vis-à-vis* air pollution. Moreover, the valuation of the benefits of avoiding health impacts within the AQM programme is often not performed.

4.9.1 Institutional

- **Insufficient human resources and institutional capability within government agencies possessing knowledge on the health and environmental impacts of air pollution,** and understanding the linkages between air pollution reduction and minimizing the burden of health and environmental impacts.
- **Limited understanding of government institutions of the importance of studies on health and environmental impacts caused by air pollution.** This understanding needs to get the support of all agencies and other stakeholders in providing the data necessary for epidemiological studies.
- **Lack of collaboration, communication and coordination between environmental authorities and health authorities** – preventing agencies from sharing of demographic, monitoring, mortality and morbidity data needed for epidemiological studies.
- **Lack of understanding among government agencies of the linkage between source and emissions inventory, air quality monitoring, meteorological situation and health and environmental impacts due to air pollutant exposure.** All these issues are important components of an AQM programme, with health and environmental impacts as the most relevant, as these could help bring about desired behaviour change.
- **Lack of media information and awareness** on health and environmental impacts of air pollution and of the health and economic benefits of actions to avoid or minimize the impacts due to air pollution.
- **Lack of public awareness** that would enable civil society groups, NGOs with interest in combating air pollution and pushing the government to act. These organizations can be interested to launch citizen science projects on air pollution exposure and effect assessment.

4.9.2 Management and Technical

- **Limited information on health impacts due to air pollution.** Policy and decision making processes are limited and constrained by poor information on health effects/impacts, and social and economic burden of health risks. Limited connection with planning and policy development.
- **Limited health impact modeling** and/or short-term and long-term impact estimation by means of epidemiological health impact studies.
- **Poor "public health surveillance programmes**[7]—i.e. poor collection of mortality and morbidity information or even patient admission data for air pollution specific health impacts, lack of cohort and time-series studies.

- **Poor early warning systems to protect the public against air pollution episodes**. These are needed in case of trans-boundary air pollution (haze episodes), emergency situations due to industrial malfunction and meteorological events (such as strong inversions).

- **Lack of awareness and studies** on the following:
  - Short-term and long-term health and environmental impacts: Awareness is important to protect the public and the environment against the impacts of air pollution. Local specific studies are needed to assess the severity of health and environmental impacts.
  - Valuation of health and environmental impacts: Such studies are critical to get information about the benefits of avoiding health and environmental impacts as trade-offs to costs of abatement measures.
  - Risk communication and effective guidance to protect the population from the impacts of heavy pollution.
  - Valuation of co-benefits of air pollution health impacts and GHG mitigation measures: The co-benefits of simultaneous air pollution reduction and GHG mitigation in terms of health and environmental impacts are usually higher than those of reducing air pollutant emissions and mitigating GHG emissions separately.

4.9.3 Financial

The lack of sufficient government funding prevents the development and implementation of a health surveillance system and the conduct of epidemiological studies to assess relationships between the exposure to air pollutants and health. Funding is especially needed for studies on long-term exposure to air pollutants. Poor communities are constrained financially to introduce and apply protective and adaptation approaches.

In addition, the valuation of the benefits of avoiding health impacts as a consequence of AQM programmes is often not performed. Funds should be allocated in municipal, state and national budgets for conducting studies, implementing HIA *vis-à-vis* air pollution, city AQM programmes and preparing policy guidelines. The opportunities of tapping into other sources of funding such as public-private-partnerships, grants, CSR funds or loans from national/international funding agencies and citizen science or crowd sourcing approaches are often not known or if known, not explored (Oxford English Dictionary, 2014)[8].

Despite these challenges, some Asian countries have assessed the local health consequences of air pollution and estimated their economic impact. Health studies in Bangkok and Hong Kong have provided some rationale to take air pollution abatement actions (Lee et al., 2013; Vichit-Vadakan & Vajanpoom, 2011; Hedley, 2009; Vassanadumrongdee & Matsuoka, 2005). The estimated premature deaths, hospital

[7] Public health surveillance is defined as the ongoing, systematic collection, analysis and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to the appropriate individuals or institutions"(WHO, 1999)

[8] Citizen science is also known as crowd science, crowd-sourced science, civic science, volunteer monitoring or networked science.

admissions, outpatient visits and economic loss from air pollution in the Hedley Environmental Index system give such a strong incentive (Box 4.2). The USEPA has collaborated with national experts in several Asian cities to conduct systematic studies on the health and economic impacts of air pollution control policies (e.g. USEPA, 2014h).

Box 4.2

Hedley Environmental Index: measuring Hong Kong's air pollution cost

Hedley Environmental Index (Hedley Index) closes the gap between generating scientific evidence and communicating the risks in terms of the number of deaths, number of hospital bed-days, number of doctor visits, total economic loss, loss of tangible cost – hospital admissions, outpatient visits (including travel cost) and work absence and loss of healthy life value (Hedley Index, 2014a). Using internationally established exposure-response relationships between air pollutants and health impacts of current levels of pollution, Hedley Index is acting as a tool to assess potential public health benefits for strengthened air quality standards in Hong Kong.

"On December 30, 2013, Hong Kong EPD launched the Air Quality Health Index to replace the Air Pollution Index which reports the short term health risk of air pollution and helps public take precautionary measures to protect health."

On the Hedley Index website, data on five key air pollutant indicators $PM_{2.5}$, PM_{10}, NO_2, SO_2 and O_3 are reported from three roadside stations and 10 general monitoring stations run by the Hong Kong Environmental Protection Department (EPD). Data is then plotted real-time against WHO's short and long term Air Quality Guidelines. To delve deeper into the issue, a historical series within a programme called "Air Quality Tracker" adds a different function, allowing to review the data beginning in 1998 and track the history of each pollutant (Hedley Index, 2014b).

Actual figures in the Hedley Index provide a rather conservative estimate, which does not yet account for air pollution's effects on vulnerable groups such as pregnant women and young children, monetary losses of long term health burden or economic costs of Hong Kong's lost tourism.

According to the Hedley Index, each year, air pollution kills more than 3,000 people in Hong Kong (Kwong, 2012). Hedley Index is frequently cited and used as a teaching tool by policy researchers, media and NGOs and has become a key reference for Hong Kong EPD officials (Ng, 2012; Cheng & Luo, 2009).

Hedley Index promoted communication on air quality and its health impacts as well as raised awareness in Hong Kong. On December 30, 2013, Hong Kong EPD launched the Air Quality Health Index to replace the Air Pollution Index which reports the short term health risk of air pollution and helps public take precautionary measures to protect health.

4.10 Roadmap for health and environmental impact assessment

Reliable information on health and environmental impacts is essential for AQM. In order to implement a roadmap for health and environmental impact assessment within AQM, cities can start with the steps recommended here.

4.10.1 Management Process

- Start to prepare an air quality monitoring system, for cities lacking it (NCAP). It can be done using low-cost sensors or sophisticated analyzers for HIA.
- Start to conduct health and environmental impact assessment (WHO, 2004b; USEPA, 2011b).
- Ensure that health risk estimations are used to inform policy development and are being considered and integrated in the policies, strategies and plan development.
- Prioritize identification of air pollution control plans and policies that consider impacts on health.
- Establish a robust localized health statistics database based on local specific health surveillance system to enable and facilitate health studies (NCAP).
- Develop and implement communication strategies targeted at policy makers, media and the public (NCAP).
- Ensure that scenarios for future needs of AQM are developed (USEPA, 2012f).

4.10.2 Technical Process

- Learn from international experiences and studies on health impacts and consider health factors in the policy, plan and strategy development processes (NCAP)
- Enhance capacities for:
  - o estimating exposure (Global Atmospheric Pollution Forum (GAPF), 2011)
  - o initial estimates of health risks and/or other impacts (WHO, 2004b)
  - o an initial health surveillance approach (WHO, 2014d; Nsubuga et al., 2006)
  - o estimates of economic impacts (NCAP), based on international studies and experience (Organisation for Economic Co-operation and Development (OECD), 2014)
- Ensure:
  - o improved understanding of technical and economic feasibility of major pollution control measures (USEPA, 2011d; 2008b; Reis, 2005)
  - o exposure and HIA studies of major facilities or areas (e.g., schools, hospitals) and of vulnerable populations (e.g., children, elderly, pregnant women) are conducted (Makri & Stilianakis, 2008)
- Further develop emissions inventories and dispersion modeling (European Environment Agency, 2013; NCAP).
- Report results to influence policies. Develop air quality simulation models to support policymaking.

- Link health and environmental impacts projections based on scenarios with policy changes in emissions-related sectors (e.g., transport).
- Conduct cost-effectiveness/cost-benefit analysis (USEPA, 2010b; Clean Air for Europe, 2012).

Box 4.3

Responding to the health effects of air pollution in Indian Cities

Outdoor air concentrations of various air pollutants in Indian cities are continuing to be a major health concern in India because of their persistent high levels. The impact of long-term exposure to urban air pollution on the respiratory and other organs of the body was studied in Kolkata and Delhi, two highly polluted megacities in the country (Ray & Lahiri, 2010). Moreover, the health impacts of vehicular pollution during 2007 to 2010 have been investigated (Ray & Lahiri, 2012). Compared to their rural counterpart, the urban population had a significantly higher prevalence of upper and lower respiratory symptoms, bronchial asthma and lung function deficits. The adverse health consequences in urban population were directly associated with PM_{10} levels in ambient air and with personal exposures to benzene. Long term exposures to high levels of urban air pollution in these cities are adversely affecting the physical and mental health of citizens, especially of the children and elderly. In Kolkata and also in most other cities, long term exposure to air pollution arises mostly from vehicular exhausts.

Another study estimated the number of premature deaths in 14 Indian cities (Nema & Goyal, 2010). Based on the PM_{10} concentration levels of 2001, among the metro cities, the highest number of mortality cases is observed in Delhi (4889), followed by Kolkata (4303), Mumbai (1959) and Chennai (1272). India has set up institutions to respond to the air pollution and its health impacts. The Ministry of Environment, Forest and Climate Change (MoEF&CC) is the nodal agency in the Central Government for overseeing the implementation of India's environmental policies and programmes. The MoEF&CC initiated environmental epidemiological studies in different areas of indoor and outdoor pollution to identify and develop programmes that will create a database and suggest environmental mitigation measures.

The Central Pollution Control Board (CPCB) is responsible for planning and executing comprehensive nationwide programmes for the prevention and control of air pollution. CPCB is executing a nationwide National Air Quality Monitoring Program (NAMP). The NAMP is covering 545 operating stations spread over 225 cities/towns in 26 States and five Union Territories. A system for collecting real-time online data has been established and publishes air quality data from 35 continuously monitoring stations operated by various agencies (MoEF&CC, 2014). CPCB under the Air (Prevention and Control of Pollution) Act, 1982 has stipulated National Ambient Air Quality Standards (NAAQS) since 1982. The NAAQS are based on health criteria and follow a land-use based approach. The NAAQS have been revised in November 2009 in consultation with the civil society and experts, for 12 pollutants including SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3, Pb, As, Ni, CO, NH_3, benzene and B-α-P. These standards/limits provide a legal framework for the control of air pollution and the protection of public health.

In January 2014, a Steering Committee on health related issues on Air Pollution was formed, with a view towards framing an action plan for mitigating the adverse health impacts of indoor and outdoor air pollution.

In June 2015, the Government of India launched the air quality index in New Delhi and urged the people to change their lifestyle in order to help protect the environment (Hindustan Times, 2015).

As: Arsenic; B-α-P: Benzo-α-pyrene; NH_3: Ammonia; Ni: Nickel; Pb: Lead

Source: CPCB, 1998; MOEF, 2014

Municipal, state and national governments should recognize the need to consider health and environmental impacts as an important ingredient of AQM. In fact, if there were no impacts of air pollution, there would also be no need for action. It is important to strengthen the political will and understanding of the social and economic costs of air pollution, which often surpass the costs of control measures [See Module 5]. A strong governmental response is needed to mitigate the health and environmental effects of air pollution (Box 4.3). It is also important to strengthen the linkages among source inventory, emission, air quality monitoring, meteorological situation and health and environmental impacts due to air pollutant exposure. To better understand these linkages, it is necessary to involve all relevant stakeholders in the development of action plans for health and environmental impact assessment as an integral part of city specific AQM programmes [See Module 5]. Similarly, the collaboration, communication and coordination between environmental authorities and health authorities on the municipal, state and national levels should be strengthened. Enhancing the institutional capability with respect to AQM issues through sustainable education and training and provision of sufficient human resources is also significant [See Module 5].

Sufficient financial resources should be allocated for the following health and environmental impact studies. If reliable emissions and meteorological data exist, models can be used to estimate exposure [See Module 2] and – with the application of established exposure-response relationships – corresponding health environmental impacts. This would be the low-cost option because appropriate models can be downloaded free of charge e.g. the USEPA website. If a health surveillance system is in place, epidemiological studies can be performed but the cost of such studies can be high to very high depending on the type of study, the number of cases and the planned duration of the study.

Financial resources should be made available for:

- emission-exposure-impact studies
- a health surveillance system (if it does not exist)
- short-term and long-term health and environmental studies
- studies on the valuation of health and environmental impacts
- studies on the linkage between air pollution health impacts and GHG mitigation measures
- studies on the valuation of co-benefits of air pollution health impacts and GHG mitigation measures

"Municipal, state and national governments should recognize the need to consider health and environmental impacts as an important ingredient of AQM. In fact, if there were no impacts of air pollution, there would also be no need for action. It is important to strengthen the political will and understanding of the social and economic costs of air pollution, which often surpass the costs of control measures."


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Module 4:
Air Quality Communication

Air Quality Communication

"Communication is an essential part of air quality management because the adoption of air pollution control measures will only be effective if its relevance and impact are conveyed to policymakers and to interested parties likely to be affected by the intervention"

5.1 About the Module

Communication is important to raise awareness, change public attitudes, and promote environmentally friendly behaviour for improved air quality. Communication is also important in engage the public in city-level planning and air quality management processes.

This module explains strategies for effective public communication that could be taken up by cities to address the current issues and challenges. The module also charts out how cities could use communication proactively to create demand for better air quality among the citizens.

5.2 Objective

To develop an effective communication strategy to inform, educate and strengthen stakeholders' participation in all aspects of AQM, in order to prevent and reduce air pollution impacts.

5.3 Significance of Communication

Improving air quality requires understanding and action by not only governments, but also the public and many different stakeholders. AQ communication in India will require interventions at four levels as depicted in Figure 5.1.

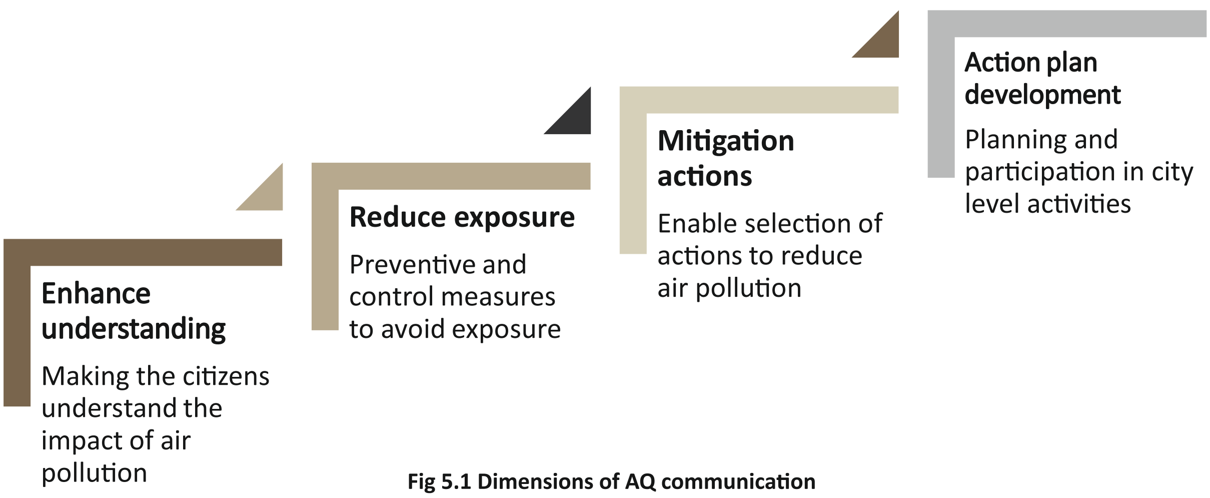


Fig 5.1 Dimensions of AQ communication

Through communication, a city can achieve improved understanding on the issues of air pollution and its impacts which may help its citizens to take relevant actions and measures in reducing exposure. Proper communication channels would increase success of individual, community and city-level mitigation actions. AQM communication will also enhance participation in city-level action plan development at various stages.

One of the three main objectives of India's National Clean Air Programme (NCAP), in the context of Indian cities, mentions about augmenting 'public awareness and capacity building measures encompassing data dissemination and public outreach programmes for inclusive public participation and for ensuring trained manpower and infrastructure on air pollution'.

The NCAP also recommends and suggests:

- Wide and precise dissemination of information on air quality through media
- Public involvement through the use of social media and mobile apps
- Creating platforms for people to monitor and report regarding sources of pollution and ensuring relevant control measures.

Communication is woven into each strategy of NCAP as depicted in Table 5.1.

Table 5.1 Focused communication activities in NCAP

Strategy	Communication as part of the Strategy	Level of implementation	Agency/ies
	Mitigation Action		
Stringent Enforcement through Three Tier Mechanism for Review Of Monitoring, Assessment And Inspection	Intensive training of all the stakeholders involved in implementation of this web based system	State/City	MoEF&CC & CPCB
Sectoral Interventions - Agricultural Emission	The capacity-building initiatives for Krishi Vigyan Kendra (KVK) shall be strengthened.	State	MoA
Sectoral Interventions - Emissions from Unsustainable Waste Management Practices	• Mandatory training and capacity building of municipalities and the RWA. • Focus on training municipalities and SPCBs to be on national and international technologies for integrated waste management options.	City/State	MoHUA, Municipal Corporation

Knowledge and Database Augmentation			
Air Pollution Health and Economic Impact Studies	• Awareness and orientation workshops to be undertaken focussing on a target audience • Media is to be used for wide dissemination of information and the precise information to be shared has to be carefully worked out by a team of experts in air pollution and environmental health. • Training researchers in study design through holding workshops in epidemiology, toxicology, and biostatistics	Centre	MoH&FW, MoEF&CC and CPCB
Institutional Strengthening			
Public Awareness and Education	• City-specific awareness programme targeting key stakeholders to be formulated and taken up for implementation. This could include awareness generation in the general public for prevention of adverse effects of air pollution. • Sensitization of the media for right interpretation of international reports and data as well as for disseminating information on measures being taken by the government for the abatement of air pollution to be undertaken.	State	CPCB, SPCB
Training and Capacity Building	• Extensive capacity-building programmes for both the CPCB and SPCBs with reference to both manpower and infrastructure augmentation. • Intensive training, comprising national and international best practices and technological options, of all the associated stakeholders.	Centre/State	MoEF&CC, CPCB and SPCB
Setting up Air Information Centre	Air information centres at the central level and regional level will be set up in some of the identified institutes.	Centre/State	MoEF&CC, CPCB and SPCB

Network of Technical Institutions, Knowledge Partners	System of a regular web-based online interaction mechanism will be evolved to ensure continuity of interactions.	Centre	MoEF&CC and CPCB

Source: NCAP

5.4 Current issues and challenges

Several key challenges currently exist in Indian Cities, which prevent the effective communication of AQ information. These can be identified under three broad headings:

5.4.1 Institutional

- **Limited capacity in processing AQ information.** Where AQ data is available, there may not be in-house capacity to use this data and develop awareness-raising programmes to target different stakeholder groups.

5.4.2 Management/Technical

- **Limited dissemination and coverage of AQ information**: The availability of AQ data may be limited. If data is available, its scope, type and frequency may be restricted to certain cities.
- **Limited understanding of AQIs by the public**: Use of AQI by the public to understand its implications on themselves and the gravity of the situation is absent. Awareness regarding behaviour changes required and relevant local individual actions to be taken to reduce air pollution is also lacking.
- **Limited public guidance on air pollution episodes**: Information on what the public should do to reduce exposure and emissions in a severe air pollution event may be unavailable.
- **Limited influence of AQ communication on attitudes and behaviour**: Where public information is available, it may not be developed to have an impact on influencing the attitudes and behaviours of different target audiences to reduce emissions and health impacts. This could be partly due to the poor understanding of influential groups – e.g., media and civil society – of air pollution issues.

5.4.3 Financial

- **Limited availability of financial resources for AQ communication**: Communication may be considered less important compared to identifying air pollution sources, determining the status of air quality, and assessing its impact on human health and wellbeing. However, in order to reduce pollution and protect public health, the communication of air pollution information should be seen as a key component of effective air quality management.

5.5 Components of effective communication

In order to reduce exposure, citizens need to understand their location-specific vulnerabilities in a simplified manner. Communication related to city hotspots (using spatial maps or innovative graphics) would enhance people's understanding of the risks in terms of locations that are more polluted and also explain to them the sources and related health impacts. Further, communication regarding methods/ways to reduce exposure would help them to select appropriate actions and reduce their vulnerabilities.

In India, National Air Quality Index (AQI), an alert system that notifies the public about air pollution levels and associated health risks, was launched in 2014 to protect citizens from air pollution. AQI is described as 'One Number-One Colour-One Description' for the common man to judge the air quality within his vicinity. The AQI is a tool for the effective communication of air quality status to people in terms which are easy to understand. It transforms complex air quality data of various pollutants into a single number (index value), nomenclature and colour. (For more details refer to module 1 - Air Quality Standards and Monitoring)

AQI in India has been established in many cities displaying air pollution levels and informing generic actions. AQI communication could be strengthened through systematic interventions, advance public warnings and forecast systems to advise subsequent action. This would help bridge the gap between translating AQI information and individual actions.

In case of air quality deterioration, individuals are victims as well as contributors, based on their lifestyle choices. Communication thus also requires public engagement for air quality improvement actions. The communication of AQ issues at various levels enables independent actions.

Communication forms an integral part of public participation in the formulation of City Specific AQM plan (as specified in module 5). Regular communication of various stages of development of city specific AQM plan and implementation status to the public would help in citizens' monitoring of the action plan. Communication will also enable community based action and evaluation of changing behaviours.

5.5.1 Platforms for communicating air quality

A wide range of channels, such as those listed below, is currently used to communicate the status of AQ in Indian cities to the general public and key stakeholders.

Table 5.2: Communication Platforms for AQ

Communication platforms	Enhance understanding/ Reduce exposure	Mitigation actions	Action plan development
Research paper	X		
Published (printed) reports – reports, brochures, papers	X	X	X
Print media – newspapers	X	X	X
Broadcast media – television and radio	X	X	X
Website – online databases	X	X	X
Public display screens or booths/ information boards	X	X	
Internal communications/ requests			X
Information upon-request	X	X	X
Print Media	X	X	X
Others: social networking sites, microblogs	X	X	X
Mobile Apps	X	X	X
Policy briefs		X	X
Written reports		X	X
Summary tables		X	X
Visual presentations	X	X	X
Interpretation of information	X	X	X
Pie chart and map	X	X	X
Satellite imagery	X	X	X
Email lists and e-groups	X	X	X
SMS alerts/WhatsApp alerts on request	X		X
Workshops and meetings	X	X	X
Multi-stakeholder Working Groups		X	X

Source: Guidance Framework for Better Air Quality in Asian Cities developed by Clean Air Asia (2016)

The effectiveness of these platforms depend on the coordination and facilitation from various departments, organizations and authorities. To be an effective strategy, this should be largely facilitated by the city authorities.

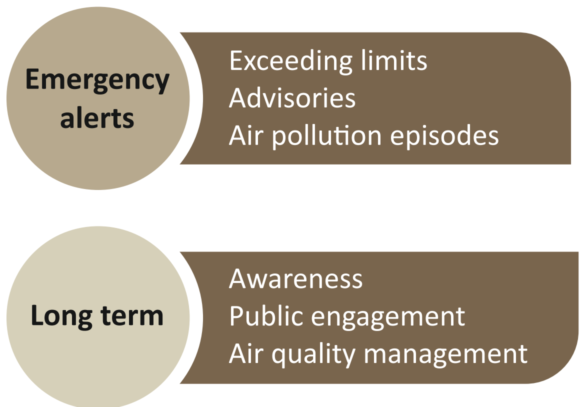
5.5.2. Types of information and target group

Table 5.3: Types of information and target group

Target Group	Sub Groups	Key messages
Urban citizens	Town occupants, Motorists and public transport, and non-motorized transport, Users, Pedestrians, cyclists, tourists, parents of babies and small children, Sports people (outside), Shop owners	• General city information • Real-time air quality levels • Daily AQI • Air quality forecast • Number of days where standard has exceeded air quality trends and tendency analysis • Air quality warnings • Health impacts, Costs of air pollution (health, economic, etc.), Other impacts (visibility, tourism, others) • Air quality legislation and regulations • Annual achievements on clean air management • Status of implementation on control measures • Planned air pollution control measures • Yearly budget for clean air management
People sensitive to air pollution	Older people, Parents of babies and small children, Asthmatics, patients' association Groups, People with allergies, Heart and lung patients	
Health professionals	General practitioners, Specialists (hospital), Public health service	
Managers	Industry, transport, power plants	
Non-governmental	Interest groups (in general), Consumer organizations, Environmental groups	
organizations	Research institutions, Universities	
Academia	Individual researchers	

Source: Guidance Framework for Better Air Quality in Asian Cities developed by Clean Air Asia (2016)

AQM related information needs to be communicated differently during an emergency and as a long term strategy to enable individual/community action. In case of alerts for air pollution, the set procedures for disaster management should be replicated to ensure effective action. Social media should be used for awareness campaigns and not just for alerts/threats.



5.6 Stakeholders for communication

A wide range of stakeholders in AQM are required for public outreach as well as engagement for involving them at various stages of AQM. Stakeholders include individuals, media, local governments, industries, non-governmental organizations, public health agencies and others affected by air pollution.

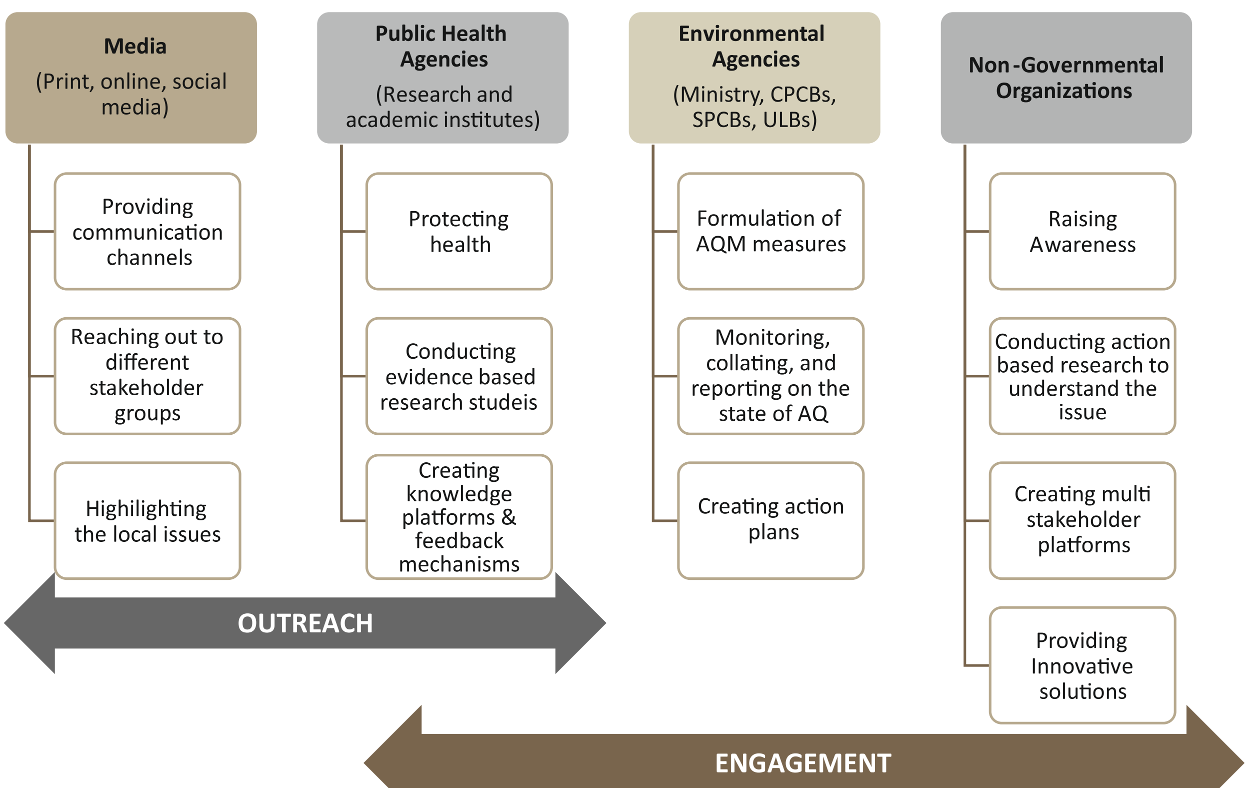


Figure 5.2: Stakeholder Communication

5.7 Potential communication strategy

5.7.1 Developing Communication Plan

Step 1. Determine communication goals

- Identify aim of communication

Step 2. Identify the target group

- Best communication channel for each group
- Identify kind of response required

Step 3. Determine types of information needed

- Select type of information
- Target audience and communication channel to be used

Step 4. Formulate key messages

- Guided by the city communication strategy
- Encourage individuals to take actions to limit exposure

Step 5. Choose the means of communication

- Transmit messages to the target group or audience
- Choose relevant channels of communication

Step 6. Engage Stakeholders

- Identify different tools and ways of engaging a wide range of stakeholders

Step 7. Planning and budget

- Outlining each step of the communication strategy
- Making a communication calendar
- Budget allocation

Step 8. Evaluation

- Develop performance indicators
- Determine the impact of the communication

Figure 5.3: Developing Communication Plan

5.7.2 Public engagement strategy for City Action Plan

Communication is an important tool for enabling public engagement in the city action plan as discussed in Module 4. Following are the stages of development of the city AQM plan where communication can be integrated:

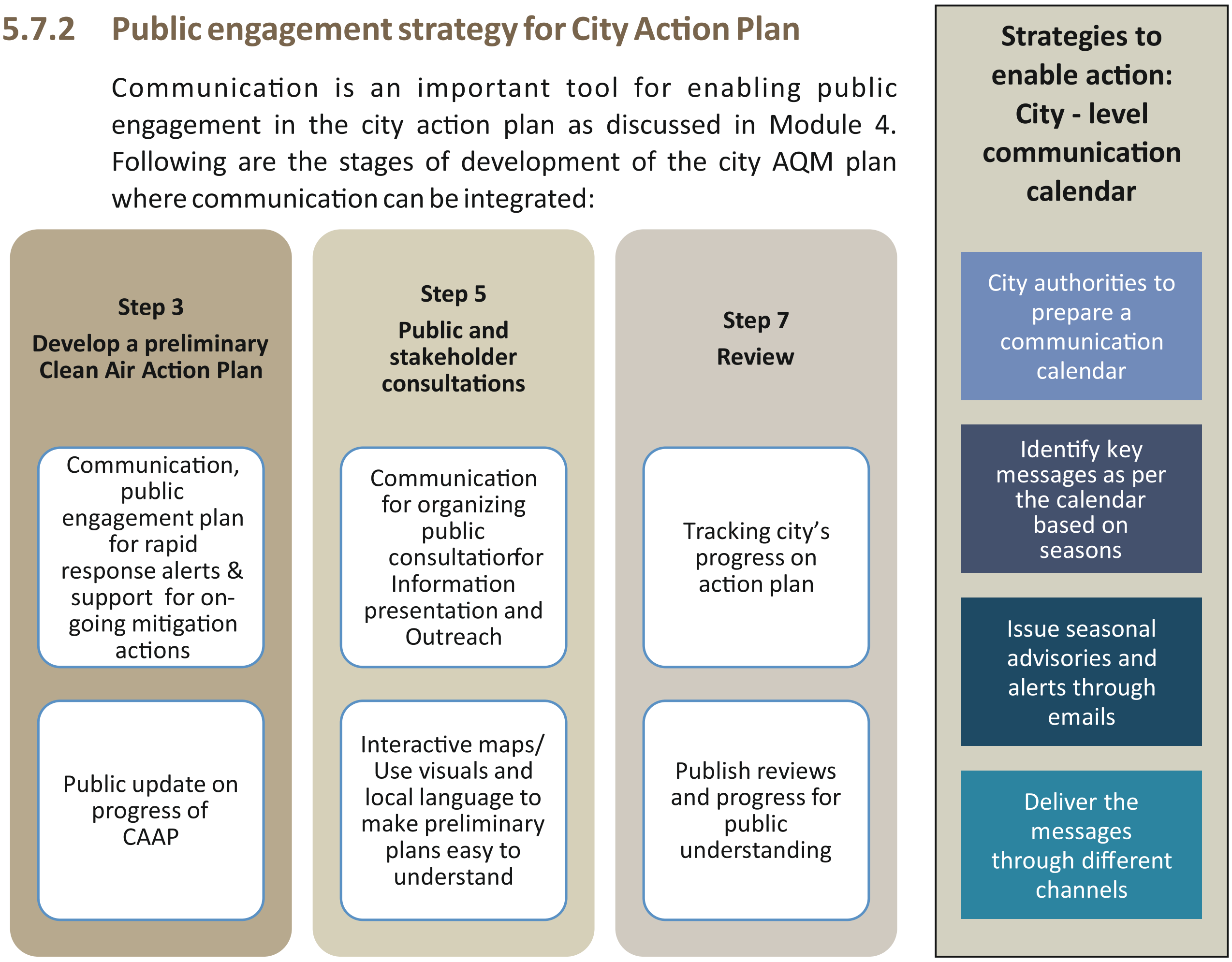


Figure 5.4: Stepwise Public Engagement Strategy for City Action Plan

In addition to the above mentioned strategies, communication is also required to strengthen systems, manage processes and build capacities of stakeholders. Following are the recommended strategies for the same:

- Build/enhance capacity for communicating AQM to policymakers and the public in a more systematic way
- Build capacity to issue ad hoc press releases on the state of AQ and advisories during pollution episodes
- Start building capacity for information technology to ensure online accessibility of general AQ information and relevant control measures to reduce exposure to the public
- Effective multiple communication channels for collaborative, multi-scale and cross-sectoral coordination between the relevant departments/ministries, state governments and local bodies.

- Set up systems for the display of AQ, advance public warnings and forecast systems to advise subsequent action
- Strengthen capacity to measure, collate, process and update AQ monitoring data from ad hoc or project-based monitoring activities, and gather general information on pollution sources for use in more regular communication activities

5.8 Case studies

5.8.1 System of Air Quality Weather Forecasting and Research (SAFAR), India

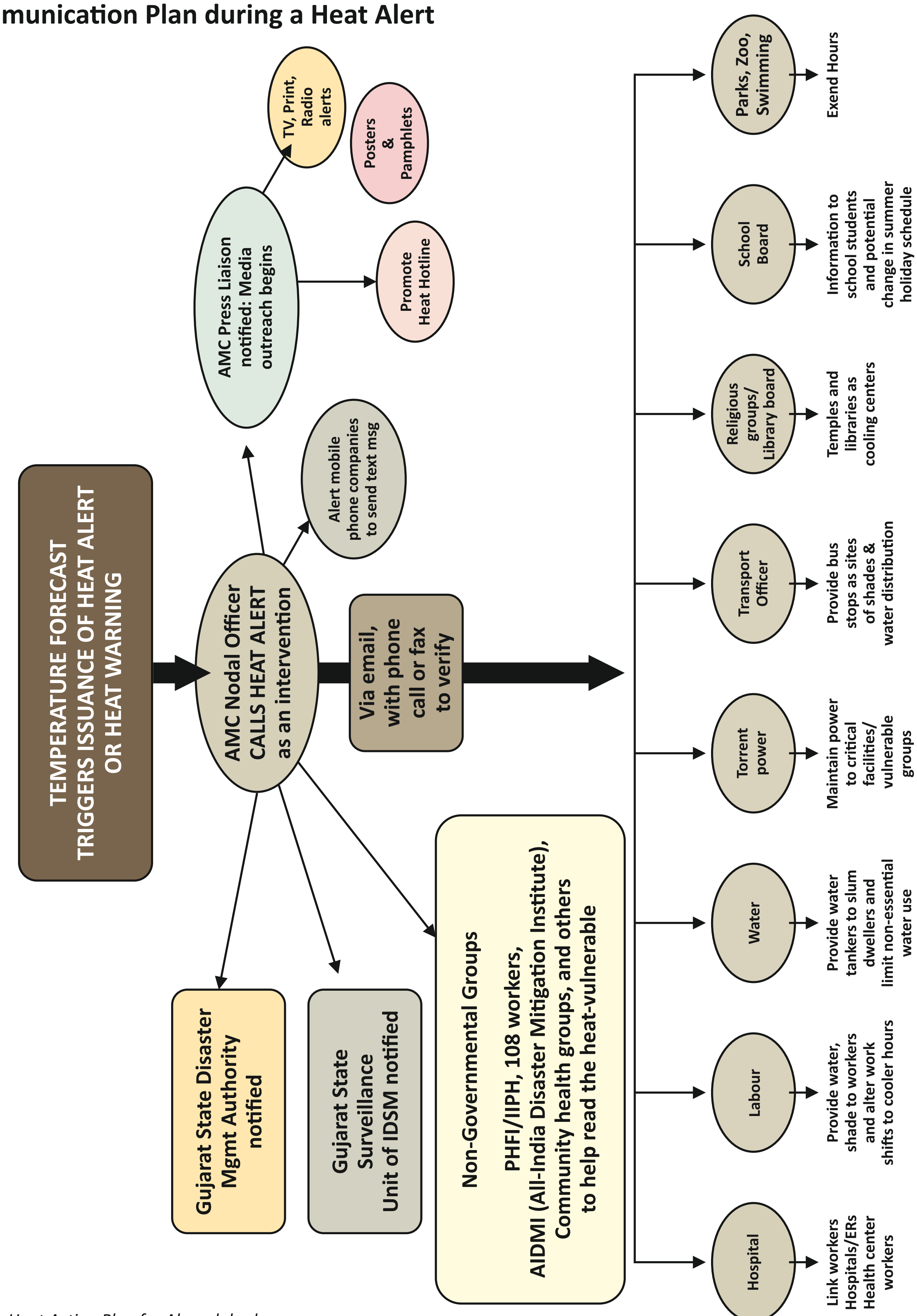
The SAFAR observational network of Air Quality Monitoring Stations (AQMS) and Automatic Weather Stations (AWS) has been established within city limits and represents selected microenvironments of the city including industrial, residential, background/ cleaner, urban complex, agricultural zones etc. as per international guidelines, which ensures the true representation of the city environment. SAFAR envisages a research based management system and the monitors provide location specific information on air quality in near real time at Delhi, Mumbai, Pune and Ahmedabad. The mission based project is led by the Ministry of Earth Sciences (Government of India) and is conceived, developed and implemented by Indian Institute of Tropical Meteorology. SAFAR in India provides location specific information on current and up to three days advance forecast for air quality and weather, along with the current ultraviolet index (skin related) and emission scenarios over the city area. Air Quality indicators are monitored at about 3 m height from the ground with online sophisticated instruments. The information is disseminated in an easy to understand format, and health advisories are displayed along with it, leading to self-mitigation and policy help, sequentially benefitting the society. SAFAR plans to be operational in Kolkata, Bengaluru and Chennai soon.

5.8.2 Communication during emergency - Ahmedabad's Heat Action Plan

The Ahmedabad's Heat Action Plan is a comprehensive early warning system and preparedness plan for extreme heat events in Ahmedabad. The Plan presents immediate and longer-term actions to increase preparedness, information-sharing, and response coordination to reduce the health impacts of extreme heat on vulnerable populations.

The communication is effected through the dissemination of public messages on how to protect people against extreme heat, through media outlets and informational materials such as pamphlets and advertisements on heat stress prevention. Efforts also include the use of social media such as SMS, text messages, email, radio and mobile applications such as WhatsApp especially to communicate alerts. Special efforts are made to reach vulnerable populations through inter-personal communication as well as other outreach methods. The Ahmedabad Municipal Corporation has created formal communication channels to alert governmental agencies, the Met Centre, health officials and hospitals, emergency responders, local community groups, and media outlets, of forecasted extreme temperatures.

Communication Plan during a Heat Alert



Source: Heat Action Plan for Ahmedabad

5.8.3 Ballon de Paris, Paris France

Since 2008, in Paris, the balloon, called Ballon de Paris, has been partnering with AIRPARIF (a licensed air-quality-measurement company in France). Not only does the balloon have the capacity to take air quality measurements, but it also changes colour depending on the quality of ambient air in Paris. Every two hours the balloon shows two air quality indices: ambient air quality provided by six urban stations and air quality measured at five traffic stations in Paris.

The indices illustrate in a simple and easily understandable manner the amount of the three most problematic pollutants in major European cities: NO_2, O_3 and PM. The balloon turns green for good air quality in Paris, orange for fair and red for poor. It can be seen for over 19 kilometres (12 miles).

5.8.4 School Flag Programme under the Ahmedabad Air Information & Response plan

Ahmedabad Air Information & Response (AIR) plan has been developed in collaboration with Ahmedabad Municipal Corporation (AMC), Gujarat State Pollution Control Board (GPCB), Indian Institute of Public Health, Gandhinagar (IIPHG), and Natural Resources Defense Council (NRDC) as well as Indian Institute of Tropical Meteorology (IITM) and Indian Meteorological Department's SAFAR project.

One of the key strategies of the Ahmedabad Air Information & Response plan is to focus on vulnerable groups, especially children. With this view, the AMC has developed a “school flags” programme with the objective of protecting children in Ahmedabad.

Under the programme, the AMC provides brightly coloured flags corresponding to the AQI colour codes to 50 identified schools across the city. The flags are hoisted daily, based on the AQI reading for that day and accompanied by informative posters that educate students on the AQI levels as well as preventive health guidance. The information includes advice on how to modify outdoor activities when the air quality in dangerously unhealthy.

Module 5: Developing City-specific Air Quality Management Plans

Developing city-specific Air Quality Management Plan

1. *Introduce the rationale for preparing a city-specific Air Quality Management Plan for an urban region*
2. *Describe the elements of such an Action Plan*
3. *Present approaches and methodologies, and clarify roles and responsibilities in preparing and implementing such a plan.*

6.1 About the Module

The purpose of this module is to introduce the rationale for preparing a city-specific Air Quality Management Plan, describe the elements of such an Action Plan, present approaches and methodologies, and clarify roles and responsibilities in preparing and implementing such a plan. Extracts from the National Clean Air Programme are also presented to provide the policy context for the preparation of city-specific Air Quality Management Plan.

The roadmap for city AQM Plans details steps that enable governments and other stakeholders to identify appropriate policies and regulations, building on an understanding of the sources of air pollution and the status of air quality. Recommended components of a city-specific Air Quality Management Plan and case studies from different sectors are provided.

6.2 Objectives

A city-specific Air Quality Management Plan enables the government as well as the wider stakeholder groups to recognize the vision and goals for air quality improvement, set objectives, mobilize resources and collaborate effectively and efficiently to achieve improved air quality.

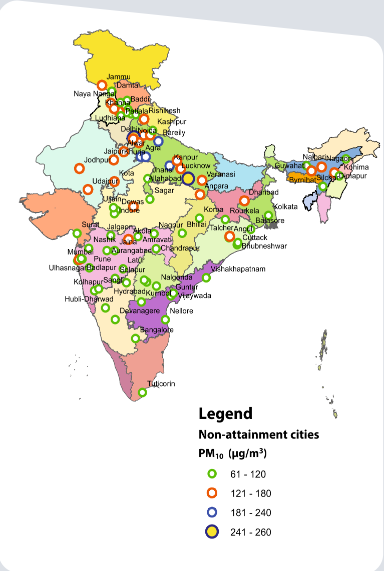
Under India's National Clean Air Programme, City Air Quality Management Plans, including Graded Response or Emergency Action Plans, are to be prepared for all non-attainment cities. (See Box 6.1)

A city-specific Air Quality Management Plan intends to improve air quality and public health by identifying cost-effective measures to reduce emissions from sectors such as transport, industries, waste deposits and residential burning among others, and bring it to the level of National Ambient Air Quality Standards. Plans should be city-specific because the background conditions, sources of air pollution, mitigation measures and other factors like population, density of population, geographical area, availability of pucca roads, common mass transport facilities, density of plantation and traffic sense among the people will differ city to city.

Box 6.1

City-specific Air Quality Management Plans for 102 Non-attainment Cities under NCAP

The National Clean Air Programme (NCAP) has identified 102 cities (see Appendix) that do not meet the air quality standards, based on data from the Central Pollution Control Board and the WHO. The NCAP recommends that city action plans and emergency action plans be prepared. The Actions suggested are:



1. Preliminary city-specific action plans to be formulated for 102 non-attainment cities.
2. City-specific action plans to be taken up for implementation by State Government and city administration.
3. City-based clean air action plans are to be dynamic and evolved based on the available scientific evidence, including the information available through source apportionment studies.
4. A separate emergency action plan in line with GRAP of Delhi to be formulated for each city for addressing the severe and emergency AQIs.

Under the NCAP, source apportionment studies are to be taken up in all the non-attainment cities and towns in a phased manner. Studies for ten cities are being commissioned on priority initially.

The air quality objectives are derived from the long-term vision and goals for improving air quality. An example of vision and goal statements and objectives of improving air quality in Palembang City, Indonesia is shown in Box 6.2. The Indonesian city of Palembang has recently completed its Clean Air Plan under the framework of ASEAN-GIZ CASC project (ASEAN-GIZ CASC, 2014; Clean Air Asia, 2012).

Box 6.2

Vision and goal statements and objectives of improving air quality in Palembang City, Indonesia

Vision: Clean and healthy air in Palembang

Goal: To improve air quality through implementation of science-based strategies for emissions reduction that contributes to public health and reduced environmental and climate change impacts

Objectives: To achieve and maintain air quality within the ambient air quality standards for which there is an accepted risk for human beings and the environment, with the indicator of performance at a minimum of 340 days in a year compliance with the National Ambient Air Quality Standards for criteria pollutants by 2018.

Source: ASEAN-GIZ Clean Air for Smaller Cities, 2015

The experience of developed countries demonstrates that developing clean air action plans has been an efficient instrument for air pollution control. With such plans, multi-year efforts to reduce emissions have been made through various control measures and clear frameworks for implementation and enforcement of the control strategies. As a result, emissions from anthropogenic sources have been substantially reduced, and most developed countries reported improvement in their nation's urban air quality (United States Environmental Protection Agency [USEPA], 2012; European Environment Agency [EEA], 2015).

On the other hand, efforts to reduce emissions are yet to be seen in most developing countries even as accelerating urban growth is likely to cause increased air pollution–generating activities. Clean air is most often a least-priority programme in developing countries. It is not generally known that, for developing cities and countries that do not have established procedures for AQM and have limited AQM capacity, a simplified air quality plan could be developed so as not to delay addressing the air pollution problem. A simplified AQM plan could include: a rapid assessment of the most important sources; monitoring results from a minimal set of air pollutant concentration monitors; comparison with air quality standards; impacts on public health and the environment; and identification of air quality objectives, control measures and key projects or sectors (Schwela & Haq, 2004; Clean Air Asia, 2011).

6.3 Elements of a City-specific AQM Plan

The key features of a City AQM Plan may include:

- Measures to set-up or strengthen the air quality monitoring and analysis system
- Measures to communicate air quality status to the public, vulnerable groups and relevant stakeholders for reducing exposure
- Adoption and implementation of control measures
- Instruments and strategies to comply with air quality and emission standards and fixing the time bound accountability of all responsible agencies/stakeholders.
- Regular review of the progress of the action plan at the level of the **Chief Secretary** of the state.
- Continuous improvement after compliance, including through public reporting
- A City AQM Plan is also a collection of regulations, policies and programmes for cleaner air.

It is essential to conduct a source apportionment study for a city in addition to taking measures for developing an effective air quality management plan. The study provides information about emission sources and its percentage contribution (as mentioned in Chapter 3: Module 2) which will help the city to concentrate its efforts based on the results.

6.4 Suggested Methodology for Preparing a City AQM Plan

The process of City AQM Plan development is led by the government and involves the stakeholders. In the NCAP, the preparation of city action plans is expected to be done by the CPCB and the MoEF&CC. However, the Municipal Corporation/district administration would have a key role to play in the implementation of the action plans. In line with the same, a city level environment management department under the aegis of the Municipal Corporation is suggested to look after the various environmental pollution issues, actionable measures as well as plans including air pollution.

In general, the process of developing an AQM Plan typically includes at least four aspects (Clean Air Asia, 2011), with stakeholder participation and communication being part of the whole process:

1. Assessment
2. Action plan development
3. Implementation and enforcement
4. Review and improvement

The approaches to prepare a City AQM Plan may vary depending on the contexts of the cities, districts and states, as well as the needs and capacities to develop and implement the plans.

Nevertheless, baseline assessment, goal setting, and evaluation are the essential steps for either a detailed AQM Plan or a basic one. As cities and countries progress to different stages of action plan development, the content and level of detail of the plan components could be expanded to respond to local needs and capacities.

Table 6.1 Extract from the National Clean Air Programme on City-Specific AQM Plans

1.12	CITY - SPECIFIC AIR QUALIT Y MANAGEMENT PLAN FOR 102 NON - ATTAINMENT CITIES				
Sl. No.	**Component/Activities**	**Level for Funding**	**Level For Implementation**	**Agencies**	**Timeline (Year)**
1.12.1	Preliminary city - specific action plans to be formulated for 102 non attainment cities.	Centre	City/State	CPCB, MoEF&CC	2019
1.12.2	City - specific action plans to be taken up for implementation by the state government and city administration.	State	City/State	D/o Environment, SPCB	2020
1.12.3	City - based clean air action plans should be dynamic and evolve based on the available scientific evidence, including the information available through source apportionment studies.	Centre	City/State	CPCB, MoEF&CC	2020
1.12.4	A separate emergency action plan in line with GRAP for Delhi to be formulated for each city for addressing the severe and emergency AQI.	Centre	City/State	CPCB, MoEF&CC	2020

6.5 Steps to Prepare a City AQM Plan

- **Step 1 -** Set up an Air Quality Actions Review Committee
- **Step 2 -** Conduct a status review
- **Step 3 -** Develop a preliminary Clean Air Action Plan
- **Step 4 -** Detailed institutional stakeholder consultations
- **Step 5 -** Public and stakeholder consultations
- **Step 6 -** Prepare draft plan for placement before decision-makers
- **Step 7 -** Implementation and Enforcement
- **Step 8 -** Review and Improvement

Figure 6.1: Steps to Prepare City AQM Plan

The generic steps to prepare a City AQM Plan are suggested here.

Step 1 - Set up an Air Quality Actions Review Committee

The NCAP recommends that a City-level review committee be set up with the Municipal Commissioner as the Chairperson, or at the District-level with the Collector as the Chairperson.

Though not defined by NCAP, this committee may play a role towards:

- Be the prime institutional anchor and driver for air quality improvements
- Facilitate the links between central and state government induced actions with local government actions and public/community efforts
- Inspire and facilitate the range of actions necessary for air quality improvements, including multi-actor, collaborative actions, that require convening of various government agencies and departments
- Provide continuity and stability for short, medium and long-term actions
- Provide the platform for reviewing plans and implemented actions
- Keep the initiatives focused on outcomes of air quality improvement

The review committee may include:

1. Guardian Minister/Mayor
2. Municipal Commissioner/District Collector
3. Representative of the State Pollution Control Board
4. Representatives from all relevant state and local government departments, related to the mitigation sectors
    a. RTO
    b. Traffic Police
    c. Public Works Department/Municipal Road Department
    d. Public transport utility
    e. Municipal Waste Management Department
    f. Factory Inspector
    g. Industry associations
    h. Builders/developers associations
    i. Garden Dept and Forest Department
    j. Civil Supplies Department (for fuel quality checks)
5. Representatives of state and municipal health department and Indian Medical Association/ associations of health care professionals (especially related to the health of infants and children, pregnant women, senior citizens, patients of respiratory ailments), public health professionals and researchers
6. Representatives of IMD/IITM
7. Technical staff from local universities/specialized institutions with expertise in air quality modeling
8. Representatives of NGOs/RWAs/NGOs working in slums

Step 2 - Conduct a status review

The status review may include preliminary inferences about air quality, based on:

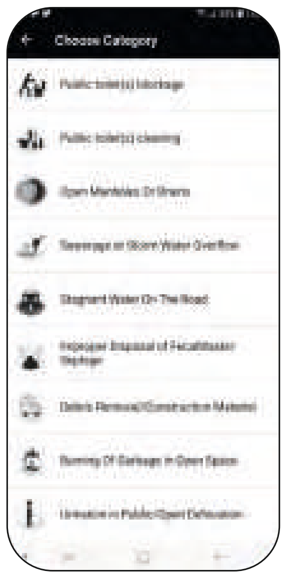
- Available data on air quality from the NAAQM and any other sources
- Data related to
    - o Trends of motor vehicle registration at the local RTO
    - o Mode share of trips if any mobility studies have been carried out, or from the 2011 Census work trips data
    - o Garbage burning incidences from waste management complaints data/ Swachata app
    - o Kilometres of roads with unpaved margins

- o Number of brick kilns
- o Proportion of households with biomass burning cook stoves/water heating stoves
- o No of air polluting industries, pollutants-APCM, number of industrial areas, ambient air quality monitoring stations.

- Any studies available in relation to the city/urban region, on the health impacts of air pollution
- Descriptions and observational analysis of the main sectors highlighted for mitigation actions - that is, nature and extent of public transport, intermediate public transport (share auto services), fuel used in public transport and share auto vehicles, construction practices, extent of vegetated versus open areas devoid of vegetation.

Step 3 – Develop a Preliminary City AQM Plan

The preliminary Clean Air Action Plan may include



1. Status and data sources
2. Suggested Goal, which as per the NCAP should be 'at least 30% reduction of air pollutants by 2024, with 2017 as the base year' (if data on pollutant loads is available)
3. Need to strengthen monitoring and modeling of air quality for urban region proposals
   a. Set up new monitors from the resources of the municipal corporation or CSR funds
   b. Utilize low cost sensors as an immediate measure to obtain AQ data, by also calibrating the margin of error compared to the standard CPCB-approved equipment
   c. Develop capability for modeling and forecasting
4. Need for locale-specific Health Studies
5. Mitigation Actions options for each relevant mitigation sector suggested in the NCAP and additional actions, as relevant in the local situation - Industry, road dust, construction dust, vehicles and mobility, waste burning, agricultural burning, biomass cook stoves, DG sets, restrictions on fire-crackers/Holi burning, installation of electric crematoria, etc. The co-benefits of Climate Change mitigation actions may also be considered when developing Air Quality improvement actions. (See Box 1 and Box 2)
6. **6.** Communication, public engagement plan
   a. Rapid response alerts
   b. Support for ongoing mitigation actions
   c. Public update on progress of CAAP
7. **7.** Periodic review mechanisms

Step 4 - Thematic discussions with Institutional and Other Key Stakeholders

Institutional stakeholders include the Municipal Corporation/Regional Development Authority/District Board. For each sector, the key government agencies, associations, service providers, etc. may need to jointly consider the status of the sector and its contribution to air pollutant loads, and discuss the range of actions that may be taken to mitigate emissions, feasibility, financing, social impacts, etc.

Discussions may focus on

1. Priority actions in each mitigation sector
2. Potential gains for air quality
3. Cost estimates, budget sources
4. Social impacts
5. Feasibility (high, medium, low) and implementation barriers
6. Duration (short, medium, long-term)
7. Responsibility for each action
8. Vision, goal and targets for air quality improvement

Some examples of stakeholders for different mitigation areas are:

- Roads – municipality, Smart City corporations, PWD, RWAs for neighbourhood streets
- Mobility – RTO, municipality, Traffic Police, public transit utility, Smart City, auto unions, electricity utility, Civil Supplies Dept (fuel quality checks)
- Waste – municipality, panchayats, plastic manufacturers, EPR mechanism, RWAs
- DG sets – Commercial users, RWAs, DG suppliers, maintenance contractors, solar inverter suppliers
- Renewables – Electricity utility, ESCOs
- Improved air pollution management by Industry units, audits, improved enforcement - State Pollution Control Board, Factories Inspectorate, Industries Associations

The stakeholder consultations should help in the evaluation of options and implementation barriers, such as institutional, policy, economic, human resource, and public awareness related, and suggest measures to address the barriers. The following tables may be useful to systematically structure the discussions and plan the development.

Table 6.2a Evaluation of emission control options

Source group	Control option	Expected reduction and impacts[1]	Technical feasibility[2]	Requirement of financial resources[3]	Implementation period (short / mid / long-term)	Time target for implementation[4]	Responsible agency(ies)	Any other information

1 Preferably, quantify each priority pollutant. Otherwise, a qualitative statement (low/medium/high) may be given.
2 Whether it is technically feasible (e.g., replacing coal with natural gas may not be feasible, if its sustained availability is not assured); whether any implementation issues exist (e.g., low-income group may not have finances to use liquefied petroleum gas for cooking) ; assess its control efficiency
3 Estimate the total costs (investment and maintenance costs) over the duration of implementation period, and provide sources of financing.
4 Define the expected start and completion year (e.g., 2015-2020).

Table 6.2b Evaluation of implementation barriers and required actions

		Identified barriers				Required actions			
No	Control option	Institutional, regulatory, and policy framework	Economic, investment, and market	Human resources and private sector support	Public awareness	Institutional, regulatory and policy framework	Economic, investment and market	Human resources and private sector support	Public awareness

Step 5 - Conduct public and stakeholder consultations

The preliminary action plan can be presented to the public for discussion and obtaining the inputs of different segments of the society.

Why conduct Public Consultations?

Public consultations can help to:

- Highlight the need for air quality improvement
- Help set a vision for air quality improvements in the city, and enhance the leadership and commitment of the city and the role of the public in addressing air quality issues
- Provide an occasion for outreach and enhance the understanding of the need for air quality improvements
- Make the actions being suggested more realistic
- Clarify the role that the government must play and actions that individuals and community groups may take

- Bring on board measures people themselves can take
- Improve collaborative actions
- Improve transparency and accountability of the planning and implementation process

A Strategy for Public Consultations

It is useful to think through and prepare a strategy for conducting public consultations. This may include, for example:

- Information presentation – what is to be said
- Outreach – how the public will be engaged, including face to face as well as through online media
- Inputs - what inputs will be taken and how will they be collated and integrated into the action plan
- Reporting - How action plan progress will be reported back to the public

Make the preliminary plan easy to understand

The preliminary status and action plan may be presented using visuals and in the local language, avoiding highly technical terms, so that it may be easily understood.

- Use visuals and local language
- Avoid highly technical terms

Type of consultations

Consultations may be conducted in different parts of the city (such as through wards), and with particular stakeholders, and may even include detailed workshops for developing solutions.

Consultations may include

- Ward level meetings
- Meetings with particular stakeholders
- Workshops/deliberations for particular issues

For example,

- Conversion of autorickshaws from diesel to CNG or LPG, or streamlining share-auto services may be discussed with autorickshaw owners, drivers' unions and community members.
- A meeting at a neighbourhood level may be held in a slum community to understand the requirements for helping people shift from wood or biomass burning to LPG, such as by devising community water heating solutions run on biogas from organic waste, or subsidizing solar water heating systems.
- Identification of pollution hot spots may also be done through community discussions and further triangulated through rapid surveys. Plantation initiatives around hotspots may be taken up by inviting voluntary support from the public, youth groups, corporate groups, etc.
- Multi-stakeholder workshops may be needed for issues like garbage burning, which requires

behaviour change by the community, a reporting system for incidents, rapid response system from the municipality and fire department, and longer term response for improving area-based waste management services from the municipality and waste service providers.

- Discussions are also necessary with all the relevant government authorities and departments, as several mitigation actions will require improved strategies, management interventions, infrastructure development, etc.

Step 6 - Finalize the draft plan for placement before the Municipal General Body or Regional Development Authority or District Board

The final Air Quality Management Plan may have sections on:

a. Current status of air quality (if available), and/or inferences on major sources of air pollutants, based on data and observations related to various mitigation sectors

b. Vision and Goal for air quality improvement, at least as mandated in the NCAP, based on the severity of the situation and aspirations for improvement

c. Need for strengthening monitoring and modeling, and information on actions to be taken for the development of proposals and identification of funding sources

d. Need for carrying out localized health studies, and information on actions to be taken for the development of proposals and identification of funding sources

e. Details of mitigation actions including priority, term/duration, funding sources, time-frame, responsibilities, plans for public engagement for implementation of actions, and expected gains in the reduction of pollutants

f. Periodic review mechanisms

g. Periodic public updates on status of implementation

The draft action plan shall be in line with the national and state (if prepared) environment policies.

Step 7 - Implementation and enforcement are key to reducing air pollutant emissions and achieving air quality objectives. A successful and implementable city AQM Plan needs clear institutional framework and responsibilities, stakeholder coordination and communication, political support, allocation of financial resources, technical capabilities, and review and improvement (Clean Air Asia, 2012). Three factors determine the success of a city or country in providing better air quality:

- the existence of policies and action plans, and their implementation details (mechanism, timeline, assignment of responsibility);
- provision of enough resources to implement the policies and action plans; and
- actual implementation of the policies and action plans.

Step 8 - Review and improvement refers to the process to track and report on the implementation of the measures and the overall changes in emissions (comparing the plan and change in monitored air quality). It is important to identify mechanisms and responsibilities for monitoring/tracking progress to enable a review of the effectiveness of available control measures; and to determine if changes are needed to achieve greater reductions, address excessive costs or amend measures, as appropriate.

While customized to the local needs, constraints, and air quality objectives, the process of AQM Plan development is also evolving. Several trends have emerged in AQM Plan development (Clean Air Asia, 2012): move from single pollutant to multiple pollutant action planning; expansion to regional AQM; involvement of multiple stakeholders in the development and implementation process; planning for long-term air quality improvement; and integration of AQM Plans and greenhouse gas (GHG) mitigation plan.

6.6 Policies and control measures to improve air quality

AQM Plans encompass short-term, medium-term, and long-term mitigation and control measures to reduce emissions from mobile (transport), stationary (industry), and area sources. Several different types of measures for improving air quality can be broadly identified and categorized as follows:

1. Conservation: reducing the use of resources through energy conservation
2. Efficiency: carrying out the same activity, but doing so more efficiently, thus reducing resource use and emissions of air pollutants
3. Abatement: applying a technological approach to reduce emissions
4. Fuel switching: substituting a lower emission fuel for a higher emission fuel
5. Demand management: implementation of policies or measures which serve to control or influence the demand for a product or service
6. Behavioural change: changing the habits of individuals or organizations in such a way as to reduce emissions – e.g. travelling by bus instead of by car

These measures can be brought about in many different ways through legislation, economic instruments, voluntary agreements and available technologies. Specifically, measures to reduce air pollution from mobile and stationary sources – i.e. transport sector, industrial, and area sources – can be summarized as follows:

6.6.1 Measures to reduce emissions from transport

Emissions from motor vehicles are determined by vehicle technology, fuel type and quality, land use, and use of vehicle. Hence, controlling emissions involves addressing each one of the following measures:

1. improved emissions standards and technologies;

2. cleaner fuels;
3. improved fuel efficiency;
4. improved inspection and maintenance;
5. improved transport planning and traffic demand management;
6. shift to public transport, promotion of non-motorized/active transport (i.e. cycling, walking)

Some of the measures can only be taken together with other specific interventions. For example, more stringent emissions standards cannot be achieved without imposing stricter fuel quality standards. Table 6.2 presents an overview of measures to control emissions from transport.

Table 6.2: Overview of measures to control emissions from transport

Measure	Regulation	Economic	Action Level
Emissions standards and technologies	• Maximum emission standards for conventional emissions -carbon monoxide (CO), hydrocarbons, nitrogen oxides (NO_x), particulate matter (PM) and for toxic air pollutants	• Tax differentials favouring abatement technology • Vehicle taxes for emission levels • Incentives/ disincentives • Fiscal incentives for scrapping old vehicles	
Cleaner Fuels	• Certification and assembly line testing • Fuel quality standards for gasoline (lead, volatility, benzene, aromatics) • Fuel quality standards for diesel fuel (volatility, sulfur, aromatics, cetane number, polyaromatic hydrocarbons) • Limitations on fuel additives	• Differentiated fuel pricing favouring cleaner fuels	
Fuel Efficiency	• Fuel efficiency for vehicle fleets • Maximum power/weight ratios • Speed limits • Various traffic management	• Broad based carbon tax on fuels/emission charges • Fuel-economy based vehicle taxes	

	measures to increase share of optimal anti-congestion measures, combined with measures controlling vehicle kilometres travelled	• Research and Development incentives (direct funding, tax credits, emissions test exemptions)	
Inspection and maintenance	• Mandatory inspection and maintenance, anti-tampering and enforcement programmes • Diesel smoke control programmes		
Transport planning and traffic demand management: to increase load of fleet, reduce travel demand times and reduce travel time	• Public transportation system • Parking control measures • Individual ownership limitations • Pedestrian-only zones in cities • Car use restrictions • Privileges (e.g. restricted highway lanes) for high-occupancy vehicles • Improvement of biking/walking conditions • "Park and ride" programmes • Limitations and restrictions on freight transport	• Road-based carbon tax on fuel • Emission-related vehicle taxes • Road pricing or distance charges • Parking charges • Fiscal incentives for carpool programmes • Insurance adjustment for distance • Land-use and physical planning instruments to reduce commuter travel and redistribute urban activities • Redistribute mechanisms for financing more efficient transport modes	

Source: Adapted from Stockholm Environmental Institute (SEI), 2008

6.6.2 Measures to reduce air pollution from industrial sources

Measures to reduce air pollution from industrial sources may include the following key areas:

6.6.2.1 Land use planning and zoning

- Use of planning regulations to restrict the location of new industries and to establish suitable industrial areas/zones;
- Compulsory environmental impact assessment for specified new major industries required for assessment of their potential for air pollution and to recommend improvement in location, processes, fuels, industry technology and emission limits; and
- Relocation of existing industries away from residential and other sensitive land uses.

6.6.2.2 Promotion of cleaner production

- Increase the efficiency of industrial processes;
- Energy and materials saving;
- Use of improved quality fuels (e.g. with lower sulfur content) or switch to cleaner fuels such as natural gas; and
- Adoption of new technologies.

6.6.2.3 Reduction of emissions in industry

- Setting priorities by focusing on emissions from the major emission sources;
- Requirements for use of cleaner fuels;
- Requiring the use of – and providing an action plan for implementation of – the best available technology for specific industrial processes;
- Compulsory notification of accidents;
- Licensing of specified polluting processes;
- Compulsory emission standards required, as well as an enforcement strategy for such; and
- Setting strict fines for exceeding emission standards.

6.6.3 Measures to reduce air pollution from area sources

- Burning of biomass, open burning of waste, forest fires, and dust from soil, roads and construction sites can be major area sources in a city. Measures to control these emissions may include:
- Enforcement of bans on burning of materials or waste;
- Promotion of alternatives to burning;
- Better waste management; and
- Paving roads, re-vegetation programmes in dust control areas and use of street sweeping equipment.

Actions requiring low cost with high effectiveness and shorter implementation period are better than those having high effectiveness but high costs or long implementation period. A few promising scenarios with a select combination of options may be evaluated using a source model. Model predictions should particularly focus on hotspots. Alternative plans may be discussed with stakeholders (e.g., fuel quality improvement programme with petroleum oil companies, stricter norms for vehicles with automobile manufacturers) and the most appropriate one may be adopted.

Choosing between technology-based options (cost-intensive) and management-based options (less costly but may be difficult to enforce) will always be a dilemma. As a guiding principle, impact of cleaner technology options is long-lasting.

For example, stricter fuel quality and emission standards such as EURO IV, V, and VI may provide better dividends in the long run. Similarly, use of natural gas in place of coal for industrial combustion and/or efficient control systems (Electrostatic Precipitator and/or bag filter) may offer better results. However, a few technology-based interventions (e.g., improving auto fuel quality) are decided at the national level and not at the local scale (nonetheless, they can influence such decisions).

Certain measures – such as cleaner transport and energy – may require substantial financial resources, and at times, delay implementation. Necessary funds may be organized through internal or external sources. Internal funds provide a sense of ownership, which may result in more efficient implementation of AQM plans. In addition to public funding, private partnership may be explored. The "polluter pays principle" may be applied and "pollution tax" (could also be 'congestion charge' and 'parking fee') may be levied for generating funds. External funding from international financial institutes or donor agencies may also be available.

Box 6.3

Menu of City-level Mitigation Actions in NCAP

Several mitigation actions are suggested in the NCAP, which may be included as relevant locally.

AQ Monitoring

- Increase stations, mobile station and explore the use of low-cost sensors
- Enhance local analysis capability by training local technical institutes

Road and Construction Dust

- Mechanical sweepers and SOP for managing the collected dust
- Implement C&D Rules 2016, Dust Mitigation Notification, 2018
- Paving road shoulders *(Street design, permeable pavers?)*
- Construction dust management using fogging machines, barriers and C&D Rules
- Maintain, repair roads and keep them pothole free
- Water sprinklers and fountains on roads using treated sewage water

Solid Waste Management

- Improve implementation of all 6 Rules related to waste management
- Ensure convergence of AQ plans with Swachh Bharat Mission

- Promote decentralized waste management, source segregation, zero waste and composting and address garbage burning on priority
- Strengthen training of municipality and RWAs in decentralized waste management
- Set up plants for conversion of MSW to drop-in fuel, co-processing of MSW in cement plants
- Set up Extended Producer Responsibility systems in e-waste and plastics
- Regular monitoring of ambient air quality in and around the TSDF/CHWIF/BMWTF/solid waste disposal/dump sites and taking remedial action.
- The plastic/hazardous waste shall be sent to nearby cement/iron and steel or power plants for co-processing.

Vehicles and Mobility

- Strengthen inspection of phased-out vehicles, vehicle maintenance, certification and PUC
- Prepare action plan to check fuel adulteration and random checks at petrol stations
- Support fleet modernization and retrofit to reduce tail pipe emissions
- Reduce emissions by congestion management
- Set up mass rapid transit systems, improve infrastructure for walking and cycling and establish measures for restricting or reducing growth of private motorized trips by congestion charging, parking restraints
- Develop E-mobility action plans at city level, including charging infrastructure and conversion of public buses, three wheelers to electric mode and/or CNG plan and conversion to CNG

Greening

- Greening of arterial roads and hotspots of pollution, for which CAMPA funds may be used
- Green Corridor' extension to all 102 cities

Biomass burning

Enhance coverage of Pradhan Mantri Ujjwala Yojana for cooking gas

Others

- Reduce DG sets, retrofit *(may be useful to leap-frog and incentivize conversion to solar back-ups)*
- Enhance setting up of renewable energy systems/roof top solar *(may require facilitation of net metering, business models)*
- Adopt randomized 3rd party audit of State Pollution Control Board to enhance enforcement
- Conduct city specific awareness programmes for key stakeholders

Box 6.4

Co-benefits of addressing air pollution and climate change

An aspect of air pollution control measures that has gained considerable traction is that these measures should capture synergies and minimize trade-offs in addressing climate change.

The application of the co-benefits approach of addressing air and climate pollutants helps identify and implement win-win strategies that help meet the economic and social development needs of developing countries. Opportunities for the reduction of CO_2 include energy efficiency, energy conservation, fuel switching, and carbon capture or sequestration (United States Environmental Protection Agency [USEPA], 2015). Nemet et al. (2010) surveyed peer-reviewed studies and found estimates (expressed in $/t$CO_2$ avoided) of USD$2 to 128/t$CO_2$ for developed countries and USD$27 to 196/t$CO_2$ for developing countries in the economic value of the air quality co-benefits of climate change mitigation. Technologies and strategies targeting SLCPs such as BC, O_3, CH_4 and some hydrofluorocarbons will likewise be able to reduce both near-term warming as well as air pollution levels.

The United Nations Environment Programme (UNEP) published a report in 2012 outlining a package of 16 measures that could, if fully implemented across the globe, save close to 2.5 million lives a year, avoid crop losses amounting to 32 million tons annually and deliver near-term climate protection of about half a degree Celsius by 2040 (UNEP, 2012). For Asia, the reduction of BC emissions from diesel vehicles and biomass cook stoves, and the reduction of CH_4 emissions from coal mining, oil and gas production and municipal waste are estimated to bring about the largest benefits (UNEP, 2011).

Measures to reduce emissions from transportation such as traffic decongestion or public campaigns encouraging non-motorized transport such as cycling and walking also yield benefits other than air quality improvement (European Environment Agency, 2012). For instance, a study by the British Medical Journal of Barcelona's public bicycle sharing scheme called "Bicing" programme was estimated to have avoided about 9,000 tons of CO_2 emissions and 12 lost lives based on the shift to non-motorized transport and an 11% increase in the level of physical activity of the city population (over 182,000 people) availing of the programme (Kelland, 2011).

Disregarding these co-benefits in the analysis of measures could misrepresent results, overstate costs, and prevent decision makers from being fully informed.

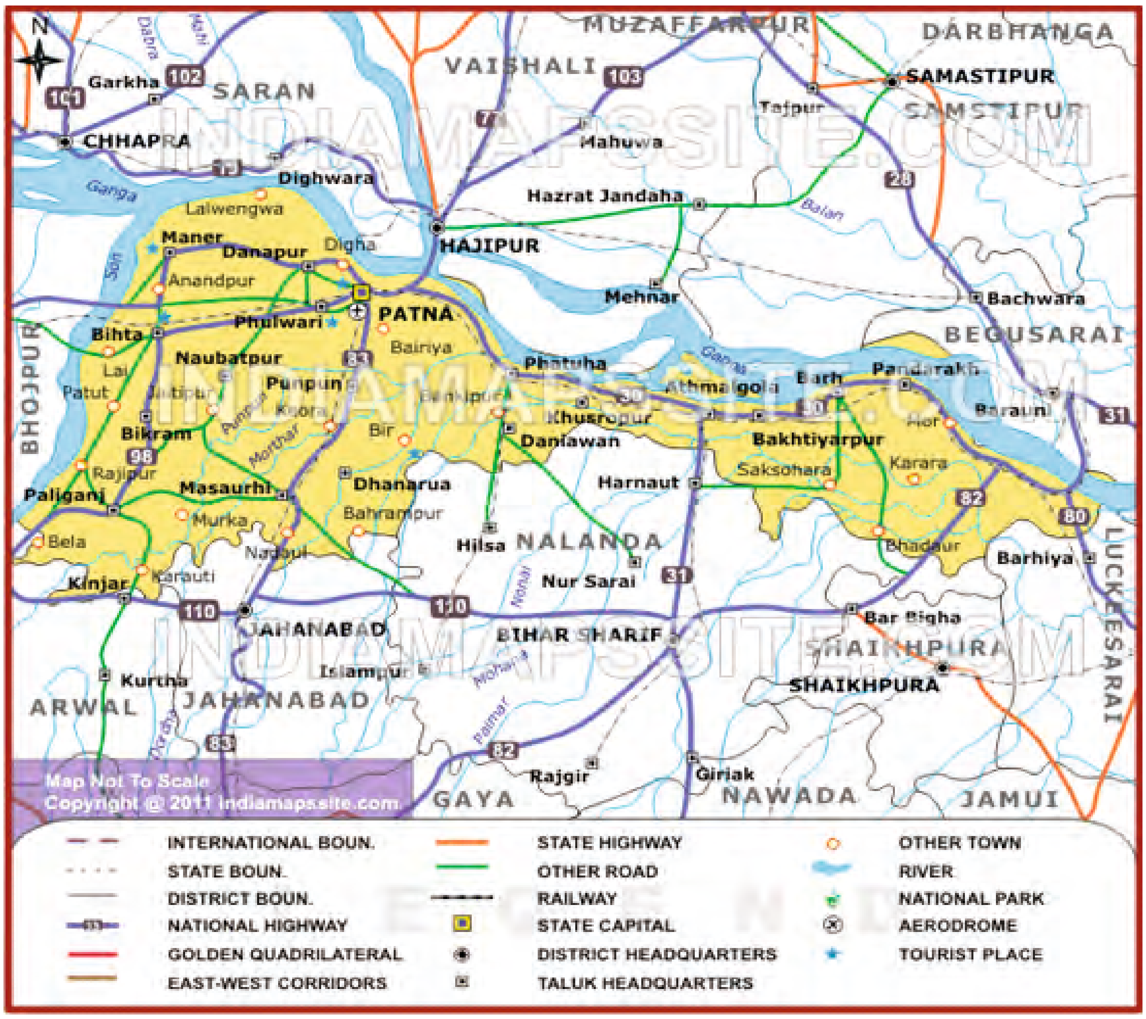
6.7 Case-studies

6.7.1 Patna Air Action Plan

Preamble

Action Plan for Control of Air Pollution in the Non-Attainment City of Bihar (Patna) by Bihar State Pollution Control Board

Patna, the capital of Bihar is situated on the southern bank of the holy river Ganga at $25^{0}30'$ - $25^{0}40'$N latitude & $85^{0}10'$ - $85^{0}20'$E longitude and about 53m above sea level. It is spread over an area of 110 sq km and has a population of 16.84 lakh (City)/20.49 lakh (Urban Agglomerations) as per Census 2011. The Patna agglomeration includes Patna Municipal Corporation Area, Patliputra Housing Colony, Phulwarisharif, Danapur Nizamat, Danapur Cantonment, Khagaul, etc. The total number of vehicles registered as on March 2016 in Patna District with the Transport Department is 11,36,075 (Truck: 42037, Bus: 7627, Car: 150078, Taxi: 15236, Jeep: 33630, Three Wheeler: 58647, Two Wheeler: 788069, Tractor: 23047, Taller: 13458 and others: 4246).



The major sources of air pollution in Patna are road dust, vehicular emission, domestic fuel burning, open waste burning, construction activities, industrial emissions, etc. Bihar State Pollution Control Board is regularly monitoring the ambient air quality in Patna through the Continuous Ambient Air Quality Monitoring Station (CAAQMS) installed at Indira Gandhi Science Complex; Planetarium premises and Beltron Bhawan, Shastrinagar; and Gandhi Maidan, Bankipur Bus Depot under NAMP.

Particulate Matter (PM_{10} & $PM_{2.5}$) has been identified as the main air pollutant as it is found above the prescribed national standards. This is mainly due to the re-suspension of road dust, emission from vehicles, DG sets, construction activities, burning of domestic fossil fuels, open burning of solid wastes, transportation of construction materials such as sand, soil, etc. without covering and emission from brick kilns located around Patna. No_2 also has been observed to be at an alarming level. This is mainly due to vehicular emissions. Plying of old vehicles and traffic congestion causes higher levels of NO_2. It has been observed that the air quality of Patna during winter season becomes very poor and severe due to the condensation of fine particulate matter in the lower portions of the atmosphere.

Table 6.3: Action Plan for Control of Air Pollution in the Non-Attainment City of Bihar

Name of the city	Patna
Air Pollution concerns	PM_{10}, $PM_{2.5}$, NO_2
Air pollution levels: (provide range of 24-houly average concentration values; Annual average for past five years; No. days in various AQI categories)	
Months with high air pollution levels	January, February, November & December

Source: Action Plan for Control of Air Pollution in Non-Attainment city of Bihar

Table 6.4: Action Plan

Source group	Action	Implementation period (Short/ Mid/Long- term)	Time target for Implementation	Responsible agency(ies)
Vehicles	1. Restriction on plying and phasing out of 15 years old commercial diesel driven vehicles.	Mid	December 2018	Transport Department
	2. Introduction of cleaner fuels (CNG/LPG) for vehicles.	Mid	June 2018	Transport Department & Oil companies
	3. Regular checking of vehicular emission and issue of Pollution under Control Certificate (PUC).	Short	March 2018	Transport Department & Traffic Police
	4. Good traffic management including re-direction of traffic movement to avoid congestion.	Mid	July 2018	Traffic Police
	5. Ban on registration of diesel driven auto-rickshaw/tempo.	Short	April 2018	Transport Department
	6. Promotion and operationalization of E-rickshaw.	Mid	June 2018	Transport Department
	7. Development of multi-layer parking.	Long	December 2019	PMC, UD&HD & District Admin
	8. Retrofitting of particulate filters in diesel driven vehicle.	Mid	December 2018	Transport Department
	9. Checking of fuel adulteration	Short	April 2018	District Admin & Oil company
	10. Monitoring of vehicle fitness.	Short	April 2018	Transport Department & Traffic Police
	11. Periodic calibration test of vehicular emission monitoring instrument.	Short	April 2018	BSPCB & Transport Department

Road Dust	1. Regular cleaning of road dust.	Short	April 2018	PMC
	2. Water spraying on road through tankers.	Short	April 2018	PMC
	3. Construction of pucca pavement along the roads.	Mid	December 2018	PMC and Road Construction Department
	4. Tree plantation along the roads.	Long	August 2019	Department of Environment and Forest
	5. Development of green belt in open areas, gardens, parks/ community places, schools & housing societies.	Long	August 2019	Department of Environment and Forest
	6. Introduction of water fountains at major traffic intersection/ Golambar/circle	Long	August 2019	PMC
Construction Activities	1. Covering of construction site.	Short	April 2018	Building Construction Department and PMC.
	2. Transportation of construction materials like sand, soil, stone chips, etc. in covered system.	Short	April 2018	Transport Department, District Adm. & Traffic Police.
	3. Restriction on storage of construction materials along the road.	Short	April 2018	PMC
Biomass and garbage burning monitoring	1. Restriction on open burning of municipal solid waste, biomass, plastic, horticulture waste, etc.	Short	March 2018	PMC
	2. Immediate lifting of solid wastes generated from de- silting and cleaning of municipal drains for its disposal.	Short	April 2018	PMC
	3. Transportation of municipal solid wastes, construction materials and debris in covered system.	Short	April 2018	PMC
	4. Ensuring promotion & use of cleaner fuel for commercial purposes like local Dhaba/eateries	Long	December 2019	District Admin & Oil company

Industries	1. Ensuring installation and operation of air pollution control devices in industries.	Short	April 2018	BSPCB
	2. Ensuring emission standards in industries.	Short	April 2018	BSPCB
	3. Adoption of cleaner technology in brick kilns at five blocks of Patna, viz. Patna Sadar, Danapur, Phulwarisharif, Maner and Fatuha, by 31.08.2018.	Mid	August 2018	BSPCB
	4. Shifting of polluting industries.	Long	December 2019	BSPCB & Industry Department
	5. Ban on polluting industries	Short	April 2018	BSPCB & Industry Department
Strengthening of AAQ	1. Installation of four CAAQMS at Patna			
	1. Two CAAQM stations under CSR funds of CPSU through CPCB at Eco-Park and IGIMS, Patna premises.	Mid	August 2018	BSPCB
	2. Two CAAQM stations under State Govt. financial assistance.	Mid	August 2018	BSPCB
	2. Source apportionment study	Mid	December 2018	BSPCB
Public Awareness	1. Issue of advisory to public for prevention and control of air pollution	Short	April 2018	BSPCB & BSDMA
	2. Involvement of school and other academic institutions in awareness programme.	Mid	August 2018	BSPCB
Others	1. Compliance of guidelines on D.G. sets and action against violation	Short	April 2018	BSPCB & PMC
	2. Helpline to oversee non compliances issues. on aforesaid	Short	April 2018	BSPCB & PMC

Monitoring mechanism for implementation

The aforesaid action plan shall be implemented by Bihar State Pollution Control Board in co-ordination with the Department of Environment and Forest, Government of Bihar; Urban Development & Housing Department, Government of Bihar; Transport Department, Patna Municipal Corporation, Traffic Police and District Administration. Bihar State Pollution Control Board shall regularly review the implementation of the aforesaid action plan.

Implementation status

The Chief Secretary, Government of Bihar, convened meetings with different concerned departments on 23.09.2015, 21.12.2015 and 11.07.2016, and directed that the directions for the improvement of the air quality of Patna should be complied with. The Principal Secretary, Environment and Forest, Government of Bihar, also convened meetings on 10.12.2017 and 11.01.2018 for following up on the aforesaid directions. The Hon'ble Deputy Chief Minister also reviewed the issues on 12.12.2017 for the improvement of the ambient air quality of Patna.

6.7.2 EPCA directed action plan in Pune

Extract from EPCA Report No: 13 - 2nd Final Report on Particulate Pollution Reduction Strategy in Seven Critically Polluted Cities in Response to the Hon'ble Supreme Court Order Dated August 14, 2003 (In the matter of W.P.(C) No.13029 of 1985; M.C. Mehta v/s UOI & others), February 2005

Pune city is not included in the original directions of the Hon'ble Supreme Court to EPCA, but finds mention in the order dated April 5, 2002 and so also in the order dated May 9, 2002, which asked for a preparation of a scheme with regard to the improvement of air quality with special reference to vehicular pollution in cities other than Delhi, which are equally or more polluted.

The pollution levels in Pune are extremely alarming and because of its proximity to Sholapur, a city EPCA is already monitoring, it decided to include the city in the list. Like any other city, Pune is also witnessing a spurt in the number of vehicles. For example, close to around 10,000 vehicles are added to the Pune roads every month. This not only adds to the congestion, but also deteriorates the air quality of the city. It is estimated that about 60% of the Pune Municipal Corporation (PMC) roads in the heart of the city are congested whereas the remaining 40% of the roads in the fringe area have relatively lower traffic volumes. The air pollution levels in the city shows an increasing trend for key pollutants. The levels of PM_{10} in the city show a consistent increase over the years.

PM_{10} exceeded the safe levels for residential areas by 2.4 times in 2003

Issues for discussions

Gaseous fuel programme

The Ministry of Petroleum and Natural Gas (MoPNG) in early January 2004 has allocated 0.4 MMSCMD of gas for Pune city. Pune city has been allocated an Administered Price Mechanism (APM) gas, which would be cheaper than the gas bought from the private players. Gas Athority

India Limited (GAIL) has already signed joint venture agreements with the BPCL for implementing the city gas project in Pune. For the city, GAIL's proposed Dahej-Uran Pipeline (DUPL) will be extended up to Pune and the project is to be implemented in 2006-07. Mahanagar Gas Limited (MGL), which is managing the city gas business in Mumbai shall also be a partner in the Joint Venture Company of Pune. The city government also LPG available as an alternative fuel. Already two auto LPG outlets are being operated on trial basis in Pune.

Public transport

The public transport situation in the city of Pune is appalling. The city bus undertaking is not meeting the travel demand of the commuters in any significant way. A look at the statistics of the Pune Municipal Transport (PMT) shows it all. Similarly the age profile of the city buses is also on the higher side. The government though has initiated a process of scrapping their older buses and introducing new buses.

The passenger load factor of the PMT has over the years shown a consistent decline. Compared to 1990-91 when the load factor was around 64%, it declined to around 45% in the year 2000-01, though in this year - 2003-04 - the load factor has improved to around 55%. What this effectively means is that even with 55% load factor, half of the PMT's buses are running empty. The mobility crisis in Pune is evident from the fact that the trip rate per capita by bus (it is a ratio of average passengers per day/population) is consistently falling, from 0.35 in 1990-91 to just 0.17 in 2000-01. This effectively means that Pune citizens are shifting from bus to other modes. This is the most discouraging factor preventing the resolution of the mobility crisis. The Pune city action plan actually shows how less and less commuters are using the PMT for commuting. Thus the city needs a total overhaul in its mobility patterns. The city government will have to intervene and improve the public transportation systems. Further policy interventions by the government should help in reversing the trip rate per capita by bus for Pune city.

The key deadlines are as follows:

1. Transition to LPG: The city to convert 20,000 autos, which are pre-1991, to LPG by June 31, 2005;
2. GAIL to ensure that it meets its deadline of December 2005 for supply of CNG to the city;
3. City government to submit a comprehensive plan for public transportation to EPCA by April 30, 2006;
4. City government to finalize and implement a parking policy by April 30, 2006;
5. City government to implement an upgraded PUC system, meeting new norms set by the Central government by April 30, 2006.
6. Pre-mixed 2-T oil to be made compulsory by April 2005.

6.7.3 Indore Waste Management

Indore has been top ranked in the Swachhata Sarvekshan for two years in a row. This case describes the solid waste management system adopted by Indore and the role of IEC in achieving the transformation.

The city has been divided into 85 Wards and 19 Zones as the operational area for Solid Waste Management (SWM).

Waste is collected in a segregated manner - i.e. the waste is segregated at source by the generators. The total waste generation in Indore is 1115 MTPD. Out of the total waste, 58.25% is wet or organic waste, 41.75% is dry waste and 0.5% is household hazardous and sanitary waste. The total wet waste generation is 650 MTPD (approximately) and dry waste generation is 465 MTPD (approximately).

The collected waste is transported by the tri-partitioned garbage tippers deployed in all the 85 wards to the designated Garbage Transfer Station (GTS). Previously, the waste was being transported to the centralized processing plant which is approximately 20-23 km from the city.

To strengthen and reduce the cost of the Secondary Collection and Transportation System, IMC has constructed eight ultra-modern transfer stations of three types of models, such as Ramp based static GTS, portable Compactors based GTS and semi portable Compactors based GTS, installed by Hyva and TPS at different locations in the city. All of the above vehicles have provision for segregated waste collection and transportation through Hook loaders to the disposal site. There are two hoppers - one for the collection of dry waste (blue colour) and the second for the collection of wet waste (green colour).

The MSW from door to door garbage tippers is collected in two steps. At first the dry waste is off loaded in the blue hopper and thereafter the wet waste is off loaded into the green hopper. These hoppers are connected to blue and green containers respectively. The segregated MSW is compressed into the respective containers. When the containers are filled to capacity, they are lifted by a dedicated hook loader and sent to the disposal site in a segregated manner. The Hook loader carrying wet waste off load their waste directly to the Centralized Composting Unit whereas dry waste is off loaded to the Material Recovery Facility.

The wet waste of the bulk generators is processed on-site by the respective generators.

The bucket for the sanitary waste and domestic hazardous waste is off loaded into dedicated drums and is transported to the Common Biomedical Waste Treatment Facility (CBWTF) as per the rules covered under Biomedical Waste Rules 2016 on a regular basis.

Central Processing Facility

Indore has central dry waste processing facilities at Deveguradiya.

A computerized Weighment Bridge facility is established at the central processing plant facility where all the wet waste that is being collected by the door to door collection and the bulk collection system is brought to be weighed before it can move to the processing plant.

At these facilities, the dry waste is segregated into different components such as metal, rubber, board, plastic, etc. This segregation is done by the 343 rag pickers employed at the two Material Recovery Facilities at the plant.

Information, Education and Communication

Information, Education and Communication (IEC) is the key to behaviour change which lies at the foundation of making a success of Swachh Bharat Mission.

IMC adopted and undertook a range of IEC activities, ranging from traditional to audiovisual to print and electronic media to social/digital media, to change the behaviour of different segments of the population and those who are associated with different sectors, viz. hotel and restaurants, hospitals, industry, transportation, commercial complex, parks and entertainment, etc.

Grassroots innovations street plays, wall paintings, FM radio were used with upgraded content through incorporating new thematic messages to be communicated and utilizing creative ways of undertaking the same. Cultural events such as Ganesh festival, Dusshera and Gandhi Jayanti were utilized as events to spread the swachhata message. An important aspect related to IEC was its integration into monitoring activities. These activities verified (monitored) the current status of service delivery.

The verification process took place through different means. These included a) 311 App for service delivery, b) surprise checks through online site visits, c) monitoring staff attendance through biometrics. The 311 App has emerged as an important means for registering complaints emerging from different residential areas. The complaints are addressed in a quick turnaround time. The status of complaints registered and addressed is monitored by the Municipal Commissioner.

IEC was aimed at educating citizens regarding who they could reach out to for availing services as well as articulating issues. The success of Swachh Indore depended on the nature of collaboration between service providers (community associations, citizen volunteers, NGOs) and IMC official machinery (CSI, Zonal officers and core IMC officials). While certain IEC media, such as nukkad nataks, rallies and swachhata samitis connected citizens with service providers, while on the other hand, technologies such as 311 App and walkie-talkies helped in directly connecting with the IMC official machinery.

Hence, IEC was designed in a manner to build the capability of the citizen to reach out to service providers and the official IMC machinery. For example, an aspect of solid waste management was recycling the waste to prepare compost. Linkages were created with the Department of Chemicals and Fertilizers for the preparation of compost. Linkages were strengthened with the Department of Agriculture for ensuring supply of the compost to the farmers in neighboring locations.

The NGOs, through IEC, not only communicated how waste can be recycled but also how to prepare compost and how these can be beneficial to other stakeholders. Hence a cross partnership was established where the waste turned into a value product serving the needs of others. Alignment was thus built between different stakeholders – the waste generators, waste collectors, waste processors and users of the value-added products of recycled waste. The IEC innovation ensured that the message as to how the current set of Swachh activities align with the policies and departmental efforts and has beneficial effects on other stakeholders, are communicated to the citizens: .

6.7.4 Vibrant Pune: City's Streets Transform into Vital Public Spaces[9]

"On our firm course towards sustainable transportation, we are also transforming Pune into a great city for the people, with numerous initiatives to encourage walking, cycling and the use of public transport", said Mr. Kunal Kumar, IAS, the Commissioner of Pune Municipal Corporation. Indian cities are gradually taking greater efforts to improve the quality of life for its citizens, especially in terms of transportation. Pune has come to be a pioneer in this regard.

Among the host of people-oriented initiatives being undertaken by the city, Pune has been working to improve its pedestrian and cycling environment by redesigning its arterial roads as Complete Streets. 27 km of streets have been identified for redesign, in the ABD (Area-Based Development) area as part of the Smart City proposal, and 100 km under the city's annual budget. The first phase of these street design projects has already transformed Aundh's DP Road and JM Road into more vibrant public spaces.

Complete Streets are those that cater to all user groups – designed with wide and continuous footpaths, safe pedestrian crossings, separate cycle tracks where applicable, conveniently placed bus stops, clearly designated on-street parking, organised street vending and properly-scaled carriageways. With the Smart Cities Mission encouraging the improvement of non-motorised and public transport infrastructure, cities across India are now developing networks of complete streets. Pune has gone over and beyond the Smart City proposal, by setting over twice that target with the Corporation's own budget.

As the first step towards redesigning the 100 km network, PMC has empanelled 4 nationally acclaimed architecture and urban design firms – IBI Group Inc., HCP Design, Planning and Management Pvt. Ltd., Oasis Designs Inc. and Design & Planning Counsel. The network has been equally divided and allocated to the designers. Each firm thus gets a 'package' of streets, ensuring uniformity in design language and better integration on ground.

Following PMC's footsteps, Pune Smart City Development Corporation Ltd. is also allotting the 27 km network in the ABD Area as 3 neighbourhoods to the empanelled designers. 9 km of streets in one neighbourhood, including DP Road in Aundh, has been contracted to the IBI Group in partnership with Prasanna Desai Architects.

The first phase of reconstruction under the Smart City Mission has commenced on DP Road.

[9] *Source: https://www.itdp.org/2017/08/31/vibrant-pune-transforming-streets/*

The 1.5 km stretch is being remodelled by the designers, kickstarting 520 m on the ground. The 3.5 m wide footpath on either side of the street has been streamlined to dedicate spaces for different users.

The numerous existing trees that line the stretch have been fundamentally incorporated in the design, with care taken to demarcate soft areas around them to allow for growth, and the perimeter forming seating. In addition, benches have also been provided along the footpath, complementing the shops and making the stretch more vibrant. Art installations, including the attractive casing that has been used to cover up the junction boxes, spruce up the space. Other features such as life-sized snake & ladder boards on the footpath further augment the character of DP Road.

Similarly, JM Road, being revamped by Oasis Designs Inc., has also been kicked off on a 300 m stretch as part of the first phase. Streamlining the haphazard parking has helped reclaim space for the people, enabling a wider footpath and cycle track. Green spaces serve as buffers to segregate the two speeds of walking and cycling. Bus stops have been located so as to allow for smooth flow of pedestrians and cyclists.

Vendors now have dedicated spaces, as do children – play areas with rubberised soft flooring have been designed at regular intervals between the green buffers. Frontage of the shops spillover to the wide footpath, adding life to the street. Better signage, street lighting and seating are other features that collectively make JM Road a stellar example of street design in the country.

Backing these design changes in the city, are institutional reforms that help enhance the capacity of the government. A dedicated Street Design Cell has been set up with professionals such as urban designers and urban planners to oversee general maintenance of streets and work done by design consultants and contractors, in addition to designing neighbourhood streets. The Corporation has also developed a unique set of Urban Street Design Guidelines (USDG) which give clear priority to walking and cycling.

Streets are vital public spaces which go beyond serving as mere channels for the movement of vehicles, but are crucial to the very identity of a city. Acknowledging this fact, Pune is remodeling its streets to respond to the multitude of activities and functions they host. The city thus continues firmly on its course towards becoming more people-friendly by the day.

6.7.5 Pune Cycle Plan[10]

The Comprehensive Bicycle Master Plan for Pune was prepared through an extensive study-based participatory process over 2016 and 2017. The preparation of the Plan was commissioned by the PMC with support from the Ministry of Housing and Urban Affairs. The plan was prepared by the consortium of iTrans, Prasanna Desai Architects and CEE. The Plan was approved by the PMC General Body in December 2017.

[10] *Source : https://punecycleplan.wordpress.com/*

Pune was once famous as a city of cyclists. Old timers recall their cycling days in the 1950s, 60s and 70s, when the cycle was the primary mode of commute for children and adults alike. However, 'transportation' is a major civic issue now. Facilities for walk, cycle, public transport have not kept pace with the growth of the city. The number of private motorized vehicles has increased very rapidly in the last 10-15 years. This is leading to health impacts from polluted air, accidents and wastage of time in congestion.

The PMC initiated the preparation of a Comprehensive Bicycle Plan for Pune through a project supported by the Ministry of Housing and Urban Affairs, Government of India. PMC engaged iTrans, Prasanna Desai Architects and CEE as the team of consultants to prepare the draft Pune Cycle Plan.

Work on the Pune Cycle Plan started in 2016, and extensive surveys were carried out in 2016 as part of the situation analysis. These included a stratified randomized household survey of 1500, stratified randomized street survey of 2300, online survey of 7000, traffic counts, street mapping and assessment of existing cycling infrastructure.

Extensive public engagement through ward level consultations, stakeholder consultations, including with bicycle shops, cyclists, non-cyclists, school representatives, youth/colleges, corporates and CSR, public bike share vendors, etc. Two rounds of public consultations were done as part of the process of preparing this plan.

The first round of consultations was held in mid-2016. The intent of the PMC to prepare a cycle plan in the context of the CMP was explained. For this, meetings were arranged at each Ward Office and presentations were made to Prabhag Samitis and citizens groups. Meetings were held with cyclists, representatives from cycle shops and various corporate groups promoting cycling. Inputs were also sought from non-cyclists. Inputs were sought on the current experience and expectations in relation to cycling, and conditions desired for non-cyclists to shift to cycling. The aim was to assess the current status and patterns of usage, attitudes towards cycling, willingness and potential for shifting certain types of private motorized or long walk trips to cycle and the conditions that would enable such shift.

A Preliminary Draft of the Pune Cycle Plan was published in August 2017, providing the results of the studies and detailed provisions for cycle improvement. Public inputs were sought on this preliminary draft through the second round of consultations, meetings and surveys done in August and September 2017. This time too, meetings were organized at ward offices for Prabhag Samitis and with citizens groups. Information about the preliminary provisions was also shared through newspaper articles, website and social media. Over 11000 individuals were directly engaged in different ways through these forums, in addition to the dissemination of information through newspapers, website and social media.

The Comprehensive Bicycle Plan for Pune was approved by the PMC General Body in December 2017. This plan has been prepared with financial support from the Ministry of Housing and Urban Affairs, Government of India. The Pune Cycle Plan envisages the creation of a Bicycle Department, creation of cycling infrastructure including over 800 km of city-wide cycle network, and parking locations, integration with transit, enforcement planning, promotion, monitoring and evaluation, including through user feedback, to facilitate sustainable mobility in an effort to create healthier lifestyles in the city.

The project cost at implementation stage is approximately Rs. 350 crore in phases.

The Vision of the Pune Cycle Plan is to 'Make Pune a cycling-friendly city where cycling is safe, comfortable, convenient, attractive and enjoyable'. **The Objective** is to increase the modal share of cycling from the current 3% to 25%, by the year 2031.

The Elements of the Pune Cycle Plan are

- Bicycle Department at PMC
- Cycling-inclusive Planning
- City-wide Cycle Network of over 800 km of segregated cycle track, cycle lanes and greenways
- Cycle Design Guidelines
- Public Bicycle Share System
- Cycle Parking locations identified across the city
- Integration with Transit, including trains, metro and public bus system
- Regulation and Enforcement to ensure cycle infrastructure is kept free of encroachments and is usable by cyclists
- Outreach and Promotion
- Monitoring and Evaluation including through user feedback to facilitate sustainable mobility in an effort to create healthier lifestyles in the city and regular reports on the implementation of the plan and achievement of desired outcomes

6.7.6 Towards a cleaner and more efficient brick sector[10]

Despite the availability of cleaner technologies, the majority of bricks in India are produced from polluting kilns using antiquated technology, which are a significant source of GHG and black carbon emissions. With the construction sector booming, the demand for bricks will increase significantly. This is why Shakti is working towards making brick kilns cleaner and resource efficient through better policy and technology solutions. In 2017, efforts enabled by Shakti contributed to the development of the draft emission standards for brick kilns prepared by the MoEF&CC. The standards will be applicable to brick kilns across the country. They are more stringent than the existing standards and require brick kilns to transition to cleaner technologies such as zig-zag technology.

In Bihar, Shakti has been engaging with stakeholders in the brick sector since 2012. Since then, our support has helped over 1,500 of the 7,000 brick kilns in the state upgrade to cleaner technologies. We have also contributed to the increase in the number of fly ash brick kilns in the state from 10 in 2012 to 150 today. But one of the most important outcomes of this engagement has been the announcement of an order by the Bihar State Pollution Control Board in 2016, which required brick kilns in Patna and the surrounding areas to upgrade to cleaner technologies. This is a key development — a first for any SPCB to ask brick-makers to move away from traditionally used technologies. Several initiatives supported by Shakti contributed to the technical evidence that shaped this order.

[11] *Source : https://shaktifoundation.in/wp-content/uploads/2019/02/Getting-to-a-breath-of-fresh-air_Web.pdf*

References

Action Plan for Control of air pollution. (2018). Retrieved from Bihar State Pollution Control Board: http://bspcb.bih.nic.in/DRAFT%20CLEAN%20AIR%20ACTION%20PLAN.pdf

Ahmedabad Air Information & Response Plan. (2018, December). Retrieved from National Resources Defense Councile: https://www.nrdc.org/sites/default/files/air_plan_2018_dec3_v2.pdf

Ahmedabad Heat Action plan. (2018). Retrieved from National Respurces Defense Council: https://www.nrdc.org/sites/default/files/ahmedabad-heat-action-plan-2018.pdf

Air Quality Trends in India. (2019). Retrieved from Centre for Science & Environment: https://cdn.cseindia.org/docs/aad2019/BEIG-ALWAR-CSE-Conclave.pdf

Airpoclypse - Not-just-Delhi Air in most Indian cities hazardous. (n.d.). Retrieved from Greenpeace: https://www.greenpeace.org/archive-india/Global/india/Airpoclypse--Not-just-Delhi--Air-in-most-Indian-cities-hazardous--Greenpeace-report.pdf

Anenberg, S., Schwartz, J., Shindell, D., Amann, A., Faluvegi, G., Klimont, Z., Janssens-Maenhout, G., Pozzoli, L., Van Dingenen, R., Vignati, E., Emberson, L., Muller, N.Z., West, J.J., Williams, M., Demkine, V., Hicks, W.K., Kuylenstierna, J., Raes, F.,. (2012). Global air quality and health co-benefits of mitigating near-term climate change through methane and black carbon emission controls. Environmental Health Perspectives,.

Association of Southeast Asian Nations-Deutsche Gesellschaft für Internationale Zusammenarbeit Clean Air for Smaller Cities in the ASEAN Region. (2014). Clean Air Plan. Palembang, Indonesia: Association of Southeast Asian Nations-Deutsche Gesellschaft für Internationale Zusammenarbeit Clean Air for Smaller Cities in the ASEAN Region.

Avnery, S., Mauzerall, D.L., Liu, J., & Horowitz, L.W. (2011). Global crop yield reductions due to surface ozone exposure: Year 2000 crop production losses and economic damage. Atmospheric Environment, 2284 - 2296.

Birley, M. (1995). The health impact assessment of development projects. London, U.K: Her Majesty's Stationery Office.

Brauer, M. A. (2012). Exposure assessment for estimation of the global burden of. Environmental Science and Technology disease attributable to outdoor air pollution, 652–660.

Brook, R.D., Rajagopalan, S., Pope III, C.A., Brook, JR, Mittleman, M.A., Peters, A., Siscovick, D., Smith, S.C., Whitsel, L., & Kaufman, J.D. (2010). Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. Statement from the American Heart Association, pp. 2331 - 2378.

Central Pollution Control Board, India. (1998). Ambient air quality standard for ammonia. New Delhi, India: Central Pollution Control Board, India.

Central Pollution Control Board. (2006). Model standard operating procedures (SOPs) for sampling and analysis - air quality monitoring, emission inventory & source apportionment studies for Indian cities. New Delhi, India: Central Pollution Control Board.

Central Pollution Control Board. (2007). Conceptual guidelines and common methodology for air quality monitoring, emission inventory & source apportionment studies for Indian cities. New Delhi, India: Central Pollution Control Board.

Central Pollution Control Board. (2010). Source apportionment studies. New Delhi: Central Pollution Control Board.

Central Pollution Control Board. (2011). Air quality monitoring, emission inventory and source apportionment study for Indian cities –National Summary Report. Central Pollution Control Board.

Central Pollution Control Board. (2013). Guidelines for the Measurement of Ambient Air Pollutants Volume I. Central Pollution Control Board.

Central Pollution Control Board. (2018). Guidelines for Continuous Emission Monitoring Systems. Delhi: Central Pollution Control Board.

Cheng, E. & Luo, R. (2009). Hedley's Environmental Index sheds new light on Hong Kong's air pollution. Washington, D.C: Wilson Center.

Chuang, K.J., Chan, C.C., Su, T.C., Lee, C.T., & Tang, C.S. (2007). The effect of urban air pollution on inflammation, oxidative stress, coagulation, and autonomic dysfunction in young adults. American Journal of Respiratory and Critical Care Medicine, 370 - 376.

Clean Air Asia. (2011). 7th China air quality management city workshop of MEP and Clean Air Asia: Clean air action planning and city clean air reporting (Workshop report). Pasig City, Philippines: Clean Air Asia.

Clean Air Asia. (2012). Clean air action planning on Chinese cities: Hangzhou and Jinan cases (Annex 5 report on Clean Air Action Plan preparation). Pasig City, Philippines: Clean Air Asia.

Clean Air Asia. (2016). Guidance Framework for Better Air Quality in Asian Cities. Pasig City, Philippines: Clean Air Asia.

Clean Air for Europe – Cost benefit analysis. (2012). Retrieved from Clean Air for Europe. (2012). : http://www.cafe-cba.org/

Clearinghouse for Inventories and Emissions Factors (CHIEF). (n.d.). Retrieved from United States Environmental Protection Agency: https://www.epa.gov/chief

Climate and Health Alliance and the Climate Institute. (2012). Our uncashed dividend. The health benefits of climate action. Climate and Health Alliance and the Climate Institute.

Constitution of India. (1951).

Control strategies. (2011). Retrieved from United States Environmental Protection Agency: http://www.epa.gov/airquality/aqmportal/management/control_strategies.htm

Cost analysis models/tools. (2008). Retrieved from United States Environmental Protection Agency: http://www.epa.gov/ttn/ecas/costmodels.html

Emberson, L.D., Büker, P., Ashmore, M.R., et al. (2009). A comparison of North American and Asian exposure-response data for ozone effects on crop yields. Atmospheric Environment, 1945–1953.

EMEP/EEA air pollutant emission inventory guidebook. (2013). Retrieved from European Environmental Agency: http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook

EPCA 2nd report on critically polluted cities. (2005, February). Retrieved from Environment Pollution (Prevention & Control) Authority: http://indiaenvironmentportal.org.in/files/2nd%20Final%20report.pdf

European Centre for Health Policy. (1999). Health impact assessment: main concepts and suggested approach (Gothenburg consensus paper). Copenhagen, Denmark: European Centre for Health Policy.

European Environment Agency. (2015). Emissions of the main air pollutants in Europe. European Environment Agency.

G. H. (2008) (eds.,). Foundation Course on Air Quality Management in in Asia: Emission. Stockholm Environment Institute.

Gargava, P. &. (2015). Source apportionment studies in six Indian cities – drawing broad inferences for urban PM10 reductions. Air Quality, Atmosphere and Health.

General information on Ballon de Paris. (2015). Retrieved from Ballon de Paris: https://www.ballondeparis.com/en/ballon-de-paris/presentation/

Ghude, S.D., Jena, C., Chate, D.M., Beig, G., Pfister, G.G., Kumar, R., & Ramanathan, V. (2014). Reductions in India's crop yield due to ozone. Geophysical Research Letters, 5685–5691.

Gurjar, B. R., Molina, L. T., & Ojha, C. S. P. (2010). Air pollution: health and environmental impacts. CRC press.

Health and Environmental Alliance. (2012). The health benefits of greenhouse gas reduction policies.. Health and Environmental Alliance.

Health and Environmental Alliance. (2012). The health benefits of greenhouse gas reduction policies.. Health and Environmental Alliance.

Health, P. H. (2017). Air Pollution and Health in India: A review of the current evidence and opportunities for the future.

Hedley Environmental Index. (2014). Cumulative loss due to air pollution. Hedley Environmental Index.

Hedley, A. (2009). Air pollution and public health - The current avoidable burden of health problems, community costs and harm to future generations. Hong Kong: University of Hong Kong: CB (1) 733/08-09(02).

Hirota, N. &. (2013). Mechanisms of airway remodeling. CHEST Publications, 1026-1032.

Hogg, J.C., Chu, F., Utokaparch, S., Woods, R., Elliott, W.R., Buzatu, L., Cherniack, R.M., Rogers, R.M., Sciurba, F.C., Harvey, O., & Pare, P.D. (2004). The nature of small-airway obstruction in chronic obstructive pulmonary disease. New England Journal of Medicine 350 (36), 2645-2653.

India Announces National Air Quality Index to Increase Public Awareness. (2015, April 30). Retrieved from National Resources Defense Council: https://www.nrdc.org/experts/anjali-jaiswal/india-announces-national-air-quality-index-increase-public-awareness

Institute for Health Metrics and Evaluation. (2017). Retrieved from GBD : https://vizhub.healthdata.org/gbd-compare/#

Institute of Occupational Medicine and Searl, A. (2004). A review of the acute and long-term impacts of exposure to nitrogen dioxide in the United Kingdom (Research Report TM/04/03). Edinburgh, UK: Institute of Occupational Medicine and Searl, A.

Intergovernmental Panel on Climate Change. (2007). Climate change 2007 (Contribution of working group III to the Fourth Assessment Report of the IPCC. Intergovernmental Panel on Climate Change.

International Association for Impact Assessment. (2006). Health impact assessment –international best practices. International Association for Impact Assessment.

International Energy Agency. (2013). World energy outlook 2013 factsheet. International Energy Agency.

Janssen, N.A.H., Gerlofs-Nijland, M.E., Lanki, T., Salonen, R.O., Cassee, F., Hoek, G., Fischer, P., Brunekreef, B., & Krzyzanowski, M. (2012). Health effects of Black carbon. Copenhagen, Denmark: WHO Regional Office for Europe.

Johnston, H. &. (1998). Methane photooxidation in the atmosphere: Contrast between two methods of analysis. Journal of Geophysical Research, 21967–21984.

Karagulian, F. and Belis, C.A.,. (2012). Enhancing source apportionment with receptor models to foster the air quality directive implementation. International Journal of Environment and Pollution - 50(1-4), 190-199.

Lanata, C.F., Rudan, I., Boschi-Pinto, C., Tomaskovic, L., Cherian, T., Weber, M., & Campbell, H. (2004). Methodology and quality issues in epidemiological studies of acute lower respiratory infections in children in developing countries. International Journal of Epidemiology 33(6), 1362 - 1372.

Lee, S.L., Tinsley, H., Chau, J., Lai, H.K., Thach, T.Q., Ip, P., Chow, C.B., & Hedley, A.J. (2013). Review of outdoor air pollution and child health in Hong Kong. Hong Kong Journal of Pediatrics (new series), 69-76.

Long Term Vision for Urban Air Quality in Asia . (2008). Retrieved from Clean Air Asia: https://cleanairasia.org/node2466/

Long, C.M., Nascarella, M.A., & Valberg, P.A. (2013). Carbon black vs. black carbon and other airborne materials containing elemental carbon. 271–286.

Makri, A. S. (2008). Vulnerability to air pollution effects. International Journal of Hygiene and Environmental Health, 211(3-4), 326–336.

Martin, R. (2008). Ambient ammonia – air quality and health impacts.

Ministry of Environment, F. a. (2019, January 10). Government launches National Clean Air Programme (NCAP). Delhi.

Ministry of Environment, Forest and Climate Change, India. (2014). Annual report of 2013-14 of Government of India. . Ministry of Environment, Forest and Climate Change, India.

Ministry of Environment, Forest and Climate Change. (2019). National Clean Air Programme. Ministry of Environment, Forest and Climate Change.

Ministry of Environment, Forest and Climate Change.(2008). National Action Plan on Climate Change. Ministry of Environment, Forest and Climate Change.

Nemet, G. F., Holloway, T., and Meier, P. (2010). Implications of incorporating air-quality co-benefits into climate change policymaking. Environmental Research Letters.

Ng, S. (2012). Hedley Environmental Index.

Nsubuga, P., White, M. E., Thacker, S. B., Anderson, M. A., Blount, S. B., Broome, C. V., ... & Stroup, D. F. (2006). Public health surveillance: A tool for targeting and monitoring. Washington, D.C: Disease control priorities in developing countries.

Organisation for Economic Co-operation and Development. (2014). The costs of air pollution: Health impacts of road transport. Organisation for Economic Co-operation and Development.

Ostro, B. (. (2004). Outdoor air pollution.Assessing the environmental burden of disease. World Health Organization.

Patel, A. (2019, March 26). Cost of rising air pollution. Ahmedabad Mirror. Ahmedabad: Ahmedabad Mirror.

Paulot, F. J. (2014). Hidden costs of U.S. agricultural export: Particulate matter from ammonia emissions. Environmental Science and Technology, 48(2), 903 - 908.

Pune Cycle Plan. (2018). Pune, Maharashtra, India. Retrieved from https://punecycleplan.wordpress.com/

Ramanathan V., Crutzen P.J., Kiehl J.T., & Rosenfeld D. (2001). Aerosols, climate, and the hydrological cycle. Science,, 2119–2124.

Ray, M.R., & Lahiri, T. In Gurjar, B.R., Molina, L.T., Ojha, C.S. P. (Eds.). (2010). Health Effects of Urban Air Pollution in India. Air Pollution: Health and Environmental Impacts.

Ray, M.R.,Lahiri, T. (2012). Air pollution and its effects on health – Case studies, India.

Reis, S. (2005). Costs of air pollution control. Analyses of emission control options for ozone abatement strategies. Springer Press.

Risom, L., Møller, P., Loft, S. (2005). Oxidative stress-induced DNA damage by particulate air pollution. Mutation Research, 592, 119–137.

Riva, D. R., Magalhaes, C.B., Lopes, A.A.,Lançiv, T., Mauad, T., Malm, O., Valen V, S.S., Saldiva, P.H., Faffe, D.S., & Zin, W.A. . (2011). Low dose of fine particulate matter (PM2.5) can induce acute oxidative stress, inflammation and pulmonary impairment in healthy mice. Inhalation Toxicology, 257 - 267.

Roth, D.E., Caulfield, L.E., Ezzati, M., & Black, R.E. (2008). Acute lower respiratory infections in childhood: Opportunities for reducing the global burden through nutritional interventions. 356-364.

Schwela, D. & Haq, G. (2004). A strategic framework for air quality management in Asia.

Shakti Foundation. (2019). Getting to a breath of fresh air. Shakti Foundation.

Smart City Indore. (2019). Retrieved from Smart City Indore: https://www.smartcityindore.org/solid-waste/

State of Global Air. (2017). Retrieved from www.stateofglobalair.org/data/#/health

State of Global Air. (2018). Retrieved from www.stateofglobalair.org/data/#/health/plot

State of Global Air. (2019). Retrieved from www.healthdata.org/data-visualization/gbd-compare

Sunil Dahiya, Lauri Myllyvirta and Nandikesh Sivalingam. (2017, January). Airpoclypse - Assessment of Air Pollution in Indian Cities. Greenpeace. Retrieved from Greenpeace.

Sustainable Development Goals. (2015). Retrieved from United Nations: https://sustainabledevelopment.un.org/?menu=1300

System of Air Quality and Weather Forecasting And Research. (n.d.). Retrieved from System of Air Quality and Weather Forecasting And Research: http://safar.tropmet.res.in/

The new climate economy. Chapter 4. Energy. Better energy, better climate. (2014). Retrieved from Global Commission on the Economy and Climate Website: http://newclimateeconomy.report/energy/

United Kingdom website. (2014). Retrieved from Impacts of Air Pollution & Acid Rain on Wildlife: http://www.air-quality.org.uk/17.php.

United Nations Environment Programme. (2011). The Montreal Protocol on Substances that Delete the Ozone Layer. United Nations Environment Programme.

United Nations Environment Programme.(2010). The 2010 assessment of the Scientific Assessment Panel. United Nations Environment Programme.

United States Environmental Protection Agency. (2010). The benefits and costs of the Clean Air Act: 1990 to 2020 (Revised draft report). United States Environmental Protection Agency.

United States Environmental Protection Agency. (2007). Lead: Human exposure and health risk assessments for selected case studies Volume I. Human exposure and health risk assessments –full scale. United States Environmental Protection Agency.

United States Environmental Protection Agency. (2009). Integrated science assessment for particulate matter. United States Environmental Protection Agency.

United States Environmental Protection Agency. (2010). Methane and Nitrous Oxide Emissions from Natural Sources. United States Environmental Protection Agency.

United States Environmental Protection Agency. (2011). Basic information on stratospheric ozone depletion. United States Environmental Protection Agency.

United States Environmental Protection Agency. (2011). Health and environmental assessment –resources: Organizations and agencies. United States Environmental Protection Agency.

United States Environmental Protection Agency. (2012). Scenarios for the future of air quality: Planning and analysis in an uncertain world. United States Environmental Protection Agency.

United States Environmental Protection Agency. (2013). Integrated science assessment for ozone and related photochemicaloxidants. United States Environmental Protection Agency.

United States Environmental Protection Agency. (2014). EPA Collaboration with India. Improving air quality . United States Environmental Protection Agency.

United States Environmental Protection Agency. (2014). Health effects in the general population. United States Environmental Protection Agency.

United States Environmental Protection Agency. (2014). USEPA Technology Transfer Network Clearing House for Emission Inventories & Emission Factors. Research Triangle Park, N.C: United States Environmental Protection Agency.

United States Environmental Protection Agency: Office of Air Quality Planning and Standards. (2012). Our Nation's Air: Status and Trends through 2010. Research Triangle Park, North Carolina: United States Environmental Protection Agency: Office of Air Quality Planning and Standards.

Vassanadumrongdee, S., & Matsuoka, S. . (2005). Risk perception and value of a statistical life for air pollution and traffic accidents: Evidence from Bangkok, Thailand . Journal of Risk and Uncertainty, 30(3), 261-287.

Vibrant Pune: City's Streets Transform into Vital Public Spaces. (2017, August 31). Retrieved from Institute for Transportation and Development Policy: https://www.itdp.org/2017/08/31/vibrant-pune-transforming-streets/

Vichit-Vadakan, N., & Vajanpoom, N. . (2011). Health impact from air pollution in Thailand: Current and future challenges . Environmental Health Perspectives, 119(5), A197-A198.

Wang, X., & Mauzerall, D. L. (. (2004). Characterizing distributions of surface ozone and its impact on grain production in China, Japan and South Korea: 1990 and 2020. Atmospheric Environment, 4383–4402.

West, J.J., Smith, S.J., Silva, R.A., Nak, V., Zhang, Y., Adelman, Z., Fry, M.M., Anenberg, S., & Horowitz, L.W. . (2013). Cobenefits of mitigating greenhouse gas emissions for future air quality and human health. Nature Climate Change, 885–889.

WHO Global Ambient Air Quality Database. (2018). Retrieved from World Health Organization: https://www.who.int/airpollution/data/cities/en/

Wismar, M., Blau, J., Ernst, K., & Figueras, J., (Eds.), . (2007). The effectiveness of health impact assessment: Scope and limitations of supporting decision-making in Europe. . World Health Organization.

World Health Organization. (1995). Inorganic lead. Environmental Health Criteria. Geneva, Switzerland: World Health Organization.

World Health Organization. (1995). Linkage methods for environment and health analysis. General guidelines. Geneva, Switzerland: World Health Organization.

World Health Organization. (2006). Air quality guidelines – global update 2005. World Health Organization.

World Health Organization. (2013). Chronic obstructive pulmonary disease (Factsheet No. 315). World Health Organization.

World Health Organization. (2013). Health risks of air pollution in Europe – HRAPIE project. Recommendations for concentration-response functions for cost-benefit analysis of particulate matter, ozone and nitrogen dioxide. World Health Organization.

World Health Organization. (2013). Review of evidence on health aspects of air pollution –REVIHAAP Project (Technical Report). Copenhagen, Denmark: WHO Regional Office for Europe: World Health Organization.

World Health Organization. (2014). Ambient (outdoor) air quality and health. World Health Organization.

World Health Organization. (2014). Burden of disease from ambient air pollution for 2012. World Health Organization.

World Health Organization. (2015). Health impact assessment (HIA) – tools and methods. World Health Organization.

World Health Organization. (2018). State of Global Air. World Health Organization.

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