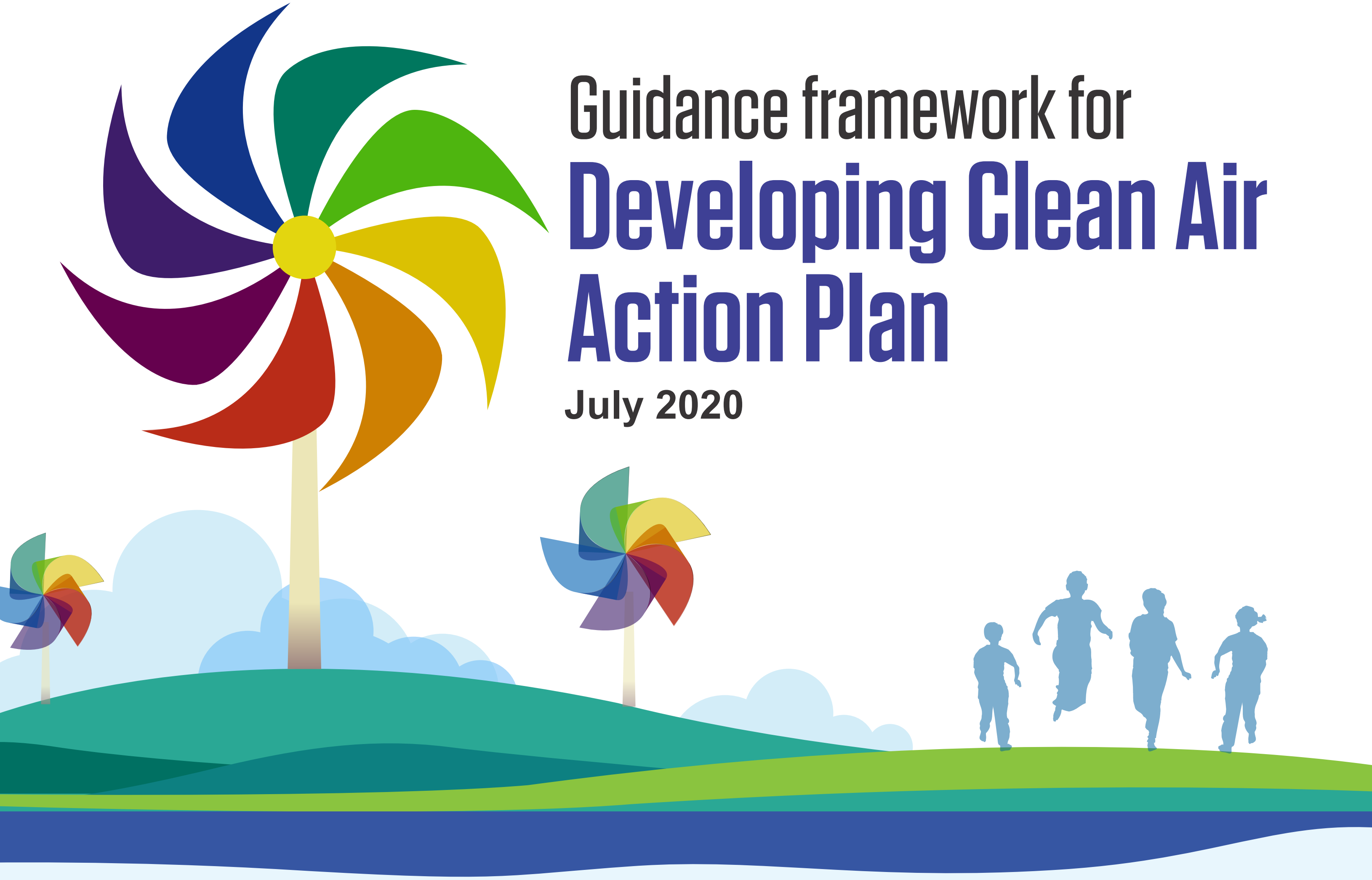

Guidance framework for

Developing Clean Air Action Plan

July 2020

Submitted to:

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Submitted by

ICF

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Shakti Sustainable Energy Foundation

Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation and clean energy finance.

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Abbreviations

AAQ	Ambient Air Quality
AOD	Aerosol Optical Depth
ARAI	Automotive Research Association of India
AQI	Air Quality Index
AQM	Air Quality Management
BS	Bharat Stage
CAAP	City Clean Air Action Plan
CAAQMS	Continuous Ambient Air Quality Monitoring Stations
C&D	Construction & Demolition
CEMS	Continuous Emission Monitoring System
CGD	City Gas Distribution
CNG	Compressed Natural Gas
CPCB	Central Pollution Control Board
DG	Diesel Generator
DPF	Diesel Particulate Filter
EI	Emission Inventory
EPCA	Environment Pollution (Prevention and Control) Authority
EV	Electric Vehicle
FGD	Flue Gas Desulfurization
GBD	Global Burden of disease
GIS	Global Information System
GRAP	Graded Response Action Plan
HEAL	Health and Environment Alliance (HEAL)
HEI	Health Effects Institute
HFCs	Hydrofluorocarbons
HIA	Health Impact Institute
IIT	Indian Institute of Technology
LPG	Liquefied Petroleum Gas
LULC	Land Use Land Cover
MoA	Ministry of Agriculture
MoEF&CC	Ministry of Environment forest and climate change
MoES	Ministry of Earth Sciences
MoHFW	Ministry of Health and Family Welfare
MoPNG	Ministry of Petroleum and Natural Gas
MoRTH	Ministry of Road Transport and Highways
MSME	Micro, Small and Medium Enterprises
MSW	Municipal Solid Waste
NAAQS	National Ambient Air Quality Standards
NAMP	National Air Quality Monitoring Programme
NAPCC	National Action Plan on Climate Change
NCAP	National Clean Air Programme
NCR	National Capital Region
NEERI	National Environmental Engineering Research Institute
NGT	National Green Tribunal
NMT	Non-Motorized Transport
OECD	Organisation for Economic Co-operation and Development
PHFI	Public Health Foundation of India (PHFI)
PM	Particulate Matter
PMUY	Pradhan Mantri Ujjwala Yojana
QA/QC	Quality Assurance/Quality Check
SA	Source Apportionment
SAPCC	State Action plan on Climate Change
SPCB	State Pollution Control Board
SLCP	Short-Lived Climate Pollutants
SWM	Solid Waste Management
UT	Union Territory
VOC	Volatile Organic Compounds
WHO	World Health Organization
WTE	Waste to Energy

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Introduction 1

Introduction

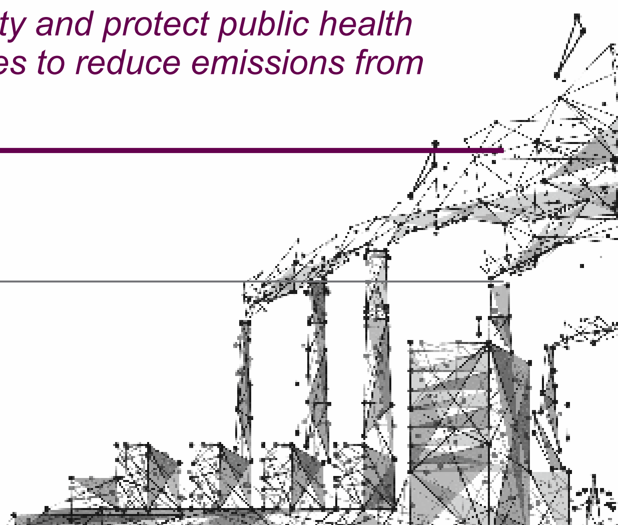
With rapid urbanization and industrial development, air pollution has become a serious environmental concern. As per estimates from the World Health Organization(WHO), 9 out of 10 people breathe air containing high level ($PM_{2.5}$ > 25 μg/m^3 24-hour mean) of pollutants. Long term exposure to air pollution causes diseases such as ischaemic heart disease, chronic obstructive pulmonary disease, lung cancer and acute low respiratory infections in smaller age groups. Further, air pollution also leads to economic losses on account of loss in working hours and healthcare costs. More than 80%[1] of people living in urban areas that monitor air pollution are exposed to air quality levels that exceed WHO guideline limits, with low- and middle-income countries suffering from the highest exposures, both indoors and outdoors.

With the Air (Prevention and Control of Pollution) Act in 1981, India took its first step towards regulating air pollution. Since then various initiatives have been undertaken by the Government, including up-gradation of NAAQS, launch of National Air Quality Index in 2015, and launch of the National Clean Air Programme (NCAP) in 2019.

There are about 4,000 cities and towns in India, and data collected by the World Health Organization (WHO) shows that only a few places in India are complying with the National Ambient Air Quality (NAAQ) standards.[2] To combat rising city air pollution levels, the Government of India launched the NCAP in January 2019 to reduce $PM_{2.5}$ and PM_{10} levels by 20-30% by 2024 with respect to 2017 levels. With the rollout of NCAP, the Central Pollution Control Board (CPCB) identified 102 non-attainment cities for achieving the above pollution targets. Later in August 2019, 20 more cities were added to the list, taking the number of non-attainment cities to 122 from 23 States and Union Territories (UTs).

The non-attainment cities were directed to come up with city-specific action plans, that included comprehensive mitigation actions for prevention, control, and abatement of air pollution besides augmenting the air quality monitoring network across their city and strengthening the awareness and capacity building activities. An Air Quality Action plan sets out the cost-effective measures to improve air quality towards compliance and identification of agencies with roles and responsibilities. them.

A clean air action plan intends to improve air quality and protect public health through the identification of cost-effective measures to reduce emissions from various sectors.



1 https://www.who.int/health-topics/air-pollution#tab=tab_1

2 Source: World Health Organization (WHO)

As the cities rolled out the action plans for their respective cities, every city followed a different structure. It was also observed that most cities submitted these action plans without clearly identifying the sources of regional air pollution i.e. emissions released outside the administrative boundaries of the cities. Many of these action plans were generic and focusing on the context and deficient with respect to implementation. Hence, it was felt that there is a need to standardize the process as well as the structure of the action plan to ensure that the actions proposed are context- specific, comprehensive, and robust towards effective implementation. **To address this objective, this report details guidelines for formulating a clean air action plan for Indian cities.**

Guidance Framework 2

Guidance Framework

The process of developing a city clean air action plan comprises of the steps below. Each step involves extensive stakeholder consultation:

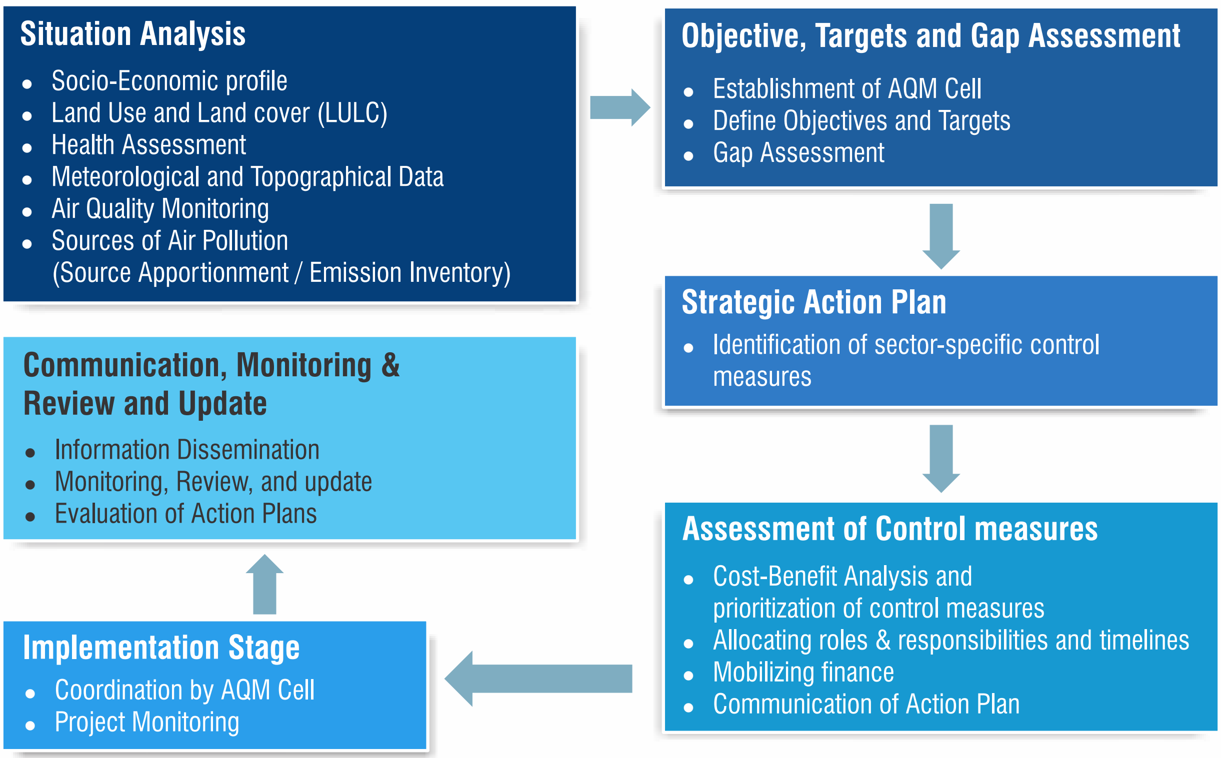
- **Situation Analysis:** This step includes an assessment of current and projected air emission and air quality scenarios within the city and the immediate surrounding region. It encompasses a review of the socio-economic profile of a city, meteorological and topographical data, land use pattern, health studies, sources of air pollution, air quality data and trends and capacity of responsible institutions, etc., to identify challenges, assess hot spots and effectiveness of the current air quality management related measures.
- **Objective, Target, and Gap Assessment:** This step includes setting air quality objectives and targets for the city. The targets set should be at par with the National Ambient Air Quality Standards (NAAQS) for various pollutants and based on current assessment, the gaps in controlling air emissions need to be determined.
- **Development of Strategic Actions (Prevention and Control Measures):** Strategic science-based cost-effective interventions need to be identified, prioritized, and detailed to achieve the targets that are set.
- **Assessment of prevention and control measures:** The prevention and control measures need to be prioritized through techno-economic assessment. Roles and responsibilities for each implementing agency/stakeholder must be clearly demarcated for implementing the interventions. It is also important to identify the source of financing for capital and operating costs. The action plan should also seek public consultation for their opinion and feedback.
- **Implementation Stage:** Once the plans are finalized, meticulous planning is required in the implementation of these action plans. There is a need to ensure coordination of all stakeholders, resource adequacy and Government/state/local authorities support for executing the plan to make sure that these are completed within the committed timelines.
- **Monitoring, Review, Communication, and Update:** To track the progress of implementation of interventions, monitoring and review are necessary. In case of any challenges being faced, the strategy needs to be revised and the action plan needs to be updated. An impact assessment of interventions is also necessary to gauge the effectiveness of the measures.

During the course of development of an action plan, all stakeholders should be communicated from time to time on the progress of various activities to ensure systematic and smooth implementation of the air quality management plan.

Key steps in the development of a city clean air action plans are outlined in Figure 1:

Checklist for city clean air action plans can be accessed here.

Figure 1: Key Steps in development of City level Clean Air Action Plan



2.1 Conduct Situation Analysis

Baseline information of emission sources and their relative contribution to the ambient air quality is a prerequisite for the development of any air quality strategy. Assessment of present and projected future scenarios form the starting point for the development of city clean air action plan. Whilst the Action Plan is intended to improve air quality within a city, it, however, necessitates to consider action over a wider area, as air being dynamic, is not restricted by local boundaries.

The baseline information should capture details of current and anticipated emission sources, meteorology and topography, population, and its growth and land use pattern, ambient air quality monitoring network, health status, epidemiological studies, etc. The baseline information helps assessing the existing situation, current efforts, and impacts, especially related to health resulting from exposure to air pollutants.

2.1.1 Socio-Economic Profile

It is essential to map the socio-economic profile of the city before formulating the air quality action plan. The socio-economic profile of the city provides information on cities projected growth, changes in land use, industrial growth etc. Critical data required includes information on:

- City population as per latest census
- Population density
- Projected population growth
- Employment pattern
- Projected economic growth
- Industrial profile
- Past and anticipated changes in land use especially related to zoning and public transport

Generally, the **city master plan document** encompasses the above information along with information on the planning guidelines, policies, development code and space requirements for various socio-economic activities for supporting cities growth during the projected plan period. For example, Delhi's master plan is prepared by the Delhi Development Authority (DDA) and is available on its website

City Master Plan

A master plan is a long-term planning document that provides a conceptual layout to guide future growth and development. A master plan includes analysis, recommendations, and proposals for a site's population, economy, housing, transportation, community facilities, and land use. It is based on public input, surveys, planning initiatives, existing development, physical characteristics, and social and economic conditions.

2.1.2 Land Use and Land Cover

Most of the Indian cities are seeing rapid industrialization and urbanization with sharp growth in infrastructure and vehicular density. The land use pattern and land cover (LULC) pattern govern the emission profile and pollutant dispersion and are important in formulating and evaluating strategies for abatement and control of air pollution. Land-use pattern i.e. residential, industrial, commercial or kerbside provides information on the air pollution hot spots or heat islands (e.g. the location of the cluster of industries or where brick kilns are located in). "Heat island" refers to areas that are hotter than nearby areas. Heat islands raise demand for electrical energy in summer, which in turn leads to an increase in air pollutant and greenhouse gas emissions. In addition to their impact on energy-related emissions, elevated temperatures can directly increase the rate of ground-level ozone formation[3], which is a harmful secondary pollutant.)

GIS and remote sensing techniques for land use mapping can be an effective tool to undertake an inventory of land use and also provide temporal information required to understand sustainable land management practices.

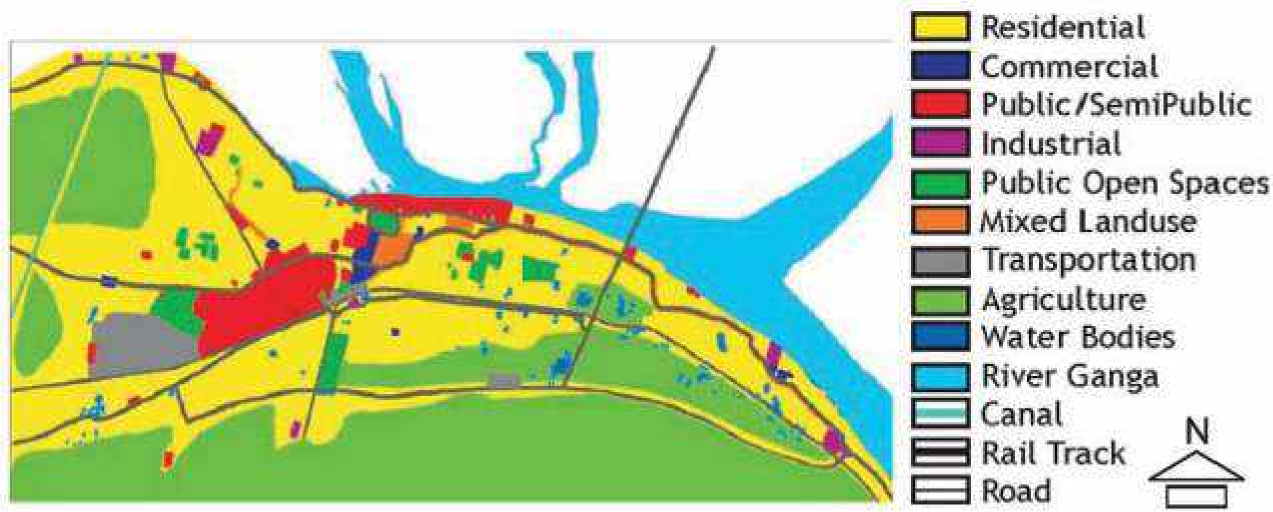
[3] *Ground-level ozone is formed when NOx and volatile organic compounds (VOCs) react in the presence of sunlight and hot weather*

Bhuvan Geoportal provides the actual digital map for further exploration through an online process. Weblink is given below:

https://bhuvan-app1.nrsc.gov.in/thematic/thematic/index.php

Land use and land cover (LULC) pattern is a crucial aspect in identifying the hot spots i.e. polluted areas and can help in identification of heat Islands, which deteriorate air quality.

Figure 2: Illustrative image of a land use pattern



2.1.3 Health Assessment

Health Impact Assessment (HIA) is a tool to improve decision-making, to weigh the policy options in different sectors so that possible impacts on health and the contribution of improved health to development are explicitly taken into consideration.

HIA provides information to decision makers for framing policies, develop strategies and plan programs and projects for achieving clean air.

All available data from earlier studies on the health impact of air quality (epidemiological studies) should be retrieved and reviewed to understand the health impacts of air pollution including the rate for mortality and morbidity. Following data to be retrieved from the studies:

Table 1: Data to be collected from Epidemiological studies

Endpoints	Dose Response Function Effects per (µg/m³) per capita	Heath Cost per Effect
Premature Mortality		
Morbidity Health Endpoints		
Adult Chronic Bronchitis		
Child Acute Bronchitis		
Respiratory Hospital Admission		
Cardiac Hospital Admission		
Emergency Room Visit		
Asthma Attacks		
Restricted Activity Days		
Respiratory Symptom Days		

ILLUSTRATIVE

"Health Impact Assessment (HIA) is a combination of procedures, methods and tools by which a policy, program or plan may be judged as to its potential effects on the health of the population and the distribution of those effects within the population" (WHO).

Fundamental equation to estimating the health impacts is as follows:

$\delta E = \beta * \delta C * \delta P$

Where,
δE = number of estimated health effects (various end points for mortality and morbidity);
β = the dose response function (DRF) for particular health endpoint. This is defined the change in number cases per unit change in concentrations.

δC = the change in concentrations;
δP = the population exposed to the incremental concentrations above;

AirQ+ is a tool developed by the WHO for HIA details of which are given below:

Table 2: Description of AirQ+ tool

Name of Tool	Description	Weblinks
AirQ+ (by WHO)	The tool is meant for any stakeholder that wants to carry out HIA and is developed in the form of software. To carry out an impact evaluation with this tool, pollutant concentration, and population data must be inserted. Also, an incidence rate (Mortality rate per lakh population) should be inserted for the chosen health indicator. Relative Risks (RRs) and counterfactual levels are set on default values but are adjustable. This makes the tool usable in any population where relative risks have been derived from epidemiological studies. The AirQ+ tool also allows the user to do life table calculations to calculate the decline in life expectancy, on a condition that population and mortality hazard rates are known for age groups of at least five years.	• **Download Tool** • **Demo**

AirQ+: A user-friendly software to estimate the effects of air pollution in a given population. It can be used for calculating estimates that support decision-makers to develop appropriate actions to protect public health. It is designed to calculate:

- How much of a particular health effect is attributable to selected air pollutants?
- Compared to the current scenario, what would be the change in health effects of air pollution levels changed in future?
- Health burden from long term exposure to air pollution at current levels.
- Health impacts associated with changes in air pollution levels (both decreases and increases)
- Health impacts attributable to changes in short-term exposure to air pollution
- Year of Life Lost (YLLs) due to air pollution exposure

2.1.4 Meteorological and Topographical data

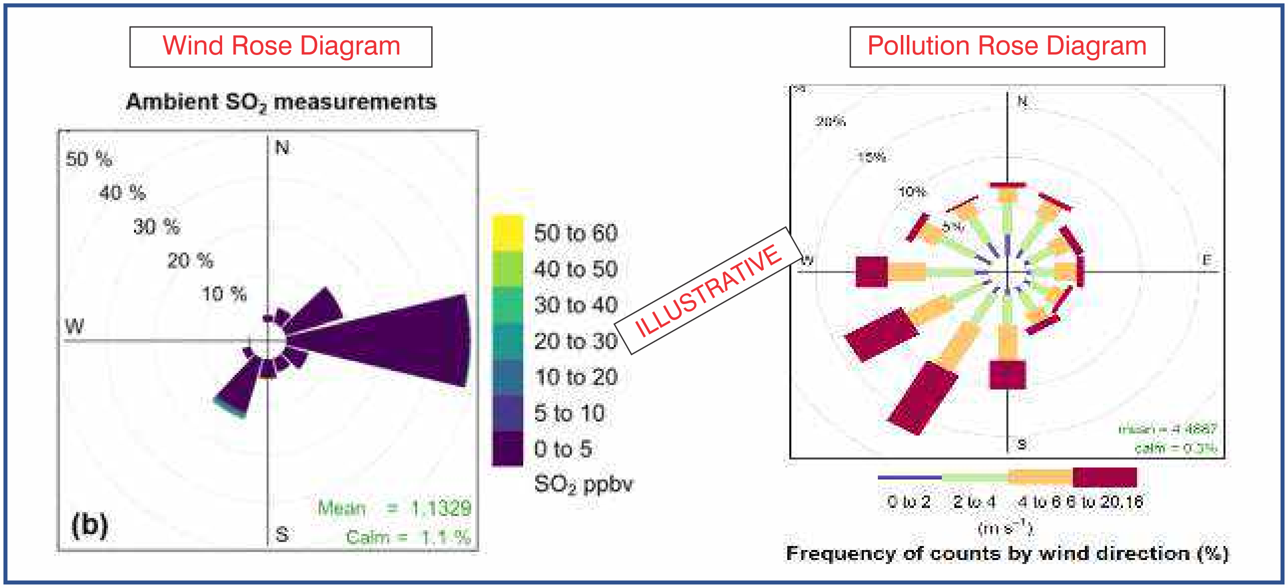
The dispersion of pollutants in an area is guided by the meteorological conditions and topography of the area. Calm conditions adversely affect the dispersion of pollutants, thereby leading to a higher concentration of pollutants in the environment. Whereas unstable environment (such as high wind speed) provides for adequate dispersion of air pollutants and therefore an improved air quality. **Meteorological data helps to identify the**

source of pollutants, predict air pollution levels such as inversions and high-pollutant concentration days and simulate and predict air quality using modelling. The topography of the area also impacts the airflow and dispersion pattern. A flat terrain will have a different flow pattern as compared to a hilly terrain. Both meteorology and topography have a significant impact on the modelling for predicting pollutant dispersion.

To develop a meteorological data set for air dispersion modelling the following parameters need to be monitored:

- **Ambient Temperature**
- **Atmospheric pressure**
- **Relative humidity**
- **Wind speed**
- **Wind direction:** A wind rose is a graphic tool used for a concise view of how wind speed and direction are typically distributed at a particular location. The wind rose summarizes the occurrence of winds at a location, showing their strength, direction, and frequency. The pollution rose is another means of illustrating the frequency distribution of wind direction temporally correlated with the concentration of a chosen pollutant. The pollution rose model lies on the simple idea of classifying the concentration measurements obtained in each site for a given period according to the direction in which the wind blows at the moment of the measure. This allows the determination of the geographical origin and the importance of steady state pollution sources affecting each site. An illustration of wind rose, and pollution rose diagram is given in the figure below .

Figure 3: Illustration of Wind Rose and Pollution Rose Diagram



Open Air tool from Natural Environment Research Council (NERC) can be used for making wind rose and pollution rose diagram.

Table 3: Description of openair tool

Name of Tool	Description	Weblinks
openair	openair is an R package developed for the purpose of analyzing air quality data or more generally atmospheric composition data. openair can plot basic wind roses very easily provided the variables ws (wind speed) and wd (wind direction) are available.	• **Download Tool** • **Demo**

- **Mixing height:** One of the most important parameters to characterize the dispersion potential of the Atmospheric Boundary Layer (ABL) is the mixing height (MH). Mixing height is the height to which the lower atmosphere will undergo mechanical or turbulent mixing. In dispersion models, the MH is a key parameter needed to determine the turbulent domain in which dispersion takes place or as a scaling parameter to describe the vertical profiles of ABL variables.

Below table indicates various sources from which meteorological data can be obtained.

Table 4: Sources for collecting meteorological data

Parameters	Weblinks
Meteorological data	Link
Mixing Height	Link
Cloud Cover	Link
Windrose Diagrams for Indian Cities	Link
Procedure for Plotting wind rose diagrams	Link
Rainfall data	Link

2.1.5 Air Quality monitoring

To assess ambient air quality, it is important to have a robust air quality monitoring network representative of the city air pollution. Knowledge of existing air pollutants levels and their spatial pattern within the area are essential for deciding the number and distribution of stations. The number of monitoring stations in a city can be selected using available information on emission sources, their geographic distribution and emission characteristics, topography of the area and wind pattern.

The number of sampling sites depends on:

- Size of the area to be covered
- The variability of pollutant concentration over the covered area
- The objectives of monitoring
- Pollutants to be monitored

Population related data can be used as indicators of criticality both from the view of likely air quality deterioration and also health implications. A general guide to the number of minimum stations and its distribution needed for monitoring trends of the common pollutants in urban areas is often based on population

The criteria followed in India requires that class I cities (cities with 100,000 population or more) should have a minimum of three stations each; megacities nine each; industrial areas should have about six, and capital cities six each.[4]

CPCB in its recent report filed with the Hon'ble' National Green Tribunal has revised the criteria for the establishment of monitoring stations.

Tool for calculating the number of monitoring stations can be accessed here.

2.1.5.1 Site Selection

The selection of site for locating the monitoring station is very important, as any data not representative of the area and not reliable, if used for framing policies will not give the desired results. The criteria for selection of the site for ambient air quality monitoring stations as specified in CPCB's guidelines is as given below.

- The site should be away from major sources of pollution i.e. chimney, industrial stacks, parking area etc. it should be at least 15 m distance from the source.
- The site should be away from absorbing material or surfaces.
- Site selected for monitoring should be available for a long period i.e. in years, as any relocation of the monitoring station will lead a disconnect the earlier data and mislead in the estimation of the trends.

[4] *Source: CPCB*

- The sampling site should be free from obstacles at least in 03 quadrants to have free airflow and preferably from the predominant wind direction.
- While sampling traffic emissions the sampling instrument should be at least 3 m above ground, so that particles not of interest are not sampled.
- Sampling instrument on unpaved roads should be at least 200 m away from roads to prevent the resuspended dust from entering into the instrument from the movement of vehicles.
- Site should have a sheltering, uninterrupted power supply, water etc.
- Sampler must be at least 20 m away from tall trees, especially exceeding the height of the sampler.
- Distance of sampler from any building should be double the height of the building.

Detailed CPCB guideline for site selection of the monitoring station is given in **Annexure 1**

2.1.6 Sources of Air Pollution

Development of Clean Air Action Plans and the related environmental policies require an accurate and reliable Emission Inventory (EI) and its application in dispersion modelling and Source Apportionment (SA) techniques to ensure a better understanding of air-pollution sources, their characterizations and contribution. There are currently two fundamental approaches to determine and quantify the impacts of air pollution sources - top-down or receptor-based source apportionment and bottom-up or source-based modeling.

The bottom-up approach begins by identifying pollution sources and their emission strengths, which are converted to emissions (via emission factors by category) and then by utilizing meteorological patterns predicting pollution dispersion over various averaging times and space.

The top-down approach begins by sampling air in each area and inferring the likely pollution sources by correlating key chemical and physical characteristics between source and air pollution samples.

Table 5: Comparison of Source based Dispersion and Receptor Modeling

Dispersion Modelling	Receptor Modelling
It follows bottom-up approach	It follows top-down approach
Predictions of future air quality is possible	Possible to assess relative emission influence. Future predictions not possible.
Assessment of alternative control strategies	Analysis of actual and worst-case impacts
It is not possible to identify unknown sources of emissions	It is possible to identify unknown sources of emissions

2.1.6.1 Emission Inventory

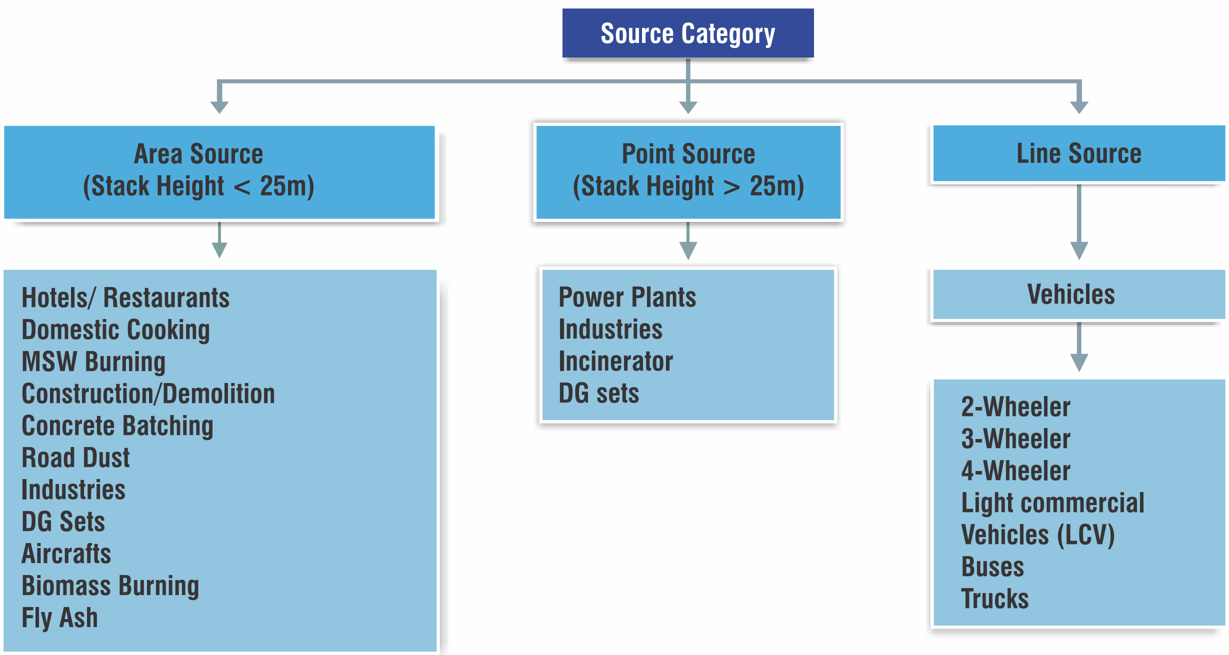
The Emission Inventory (EI) is a tool to estimate the total emission load from various emission sources in the city. EI accounts for the total emission load from various emission sources in a given geographical area or airshed, within a particular time frame e.g. over a year. EI helps to not only identify various sources of emissions in a city/state/region and their relative contribution to the emission load. The data available from the EI can also be used to project future emissions, considering various emission reduction/control scenarios.

EI for air pollutants should be systematically compiled based on secondary data from the emission generating activities and available emission factors. In some cases, few actual site inventories with emission measurements are used where secondary data is not readily available and/or is not reliable in the EI, all relevant sources (major and emerging) should be covered. EIs needs to be updated at a specified frequency (e.g. 3 years) and validated regularly. QA/QC procedures must be followed in compilation of EI.

Steps involved in compiling emission inventory include:

1. Define the study area, i.e., area for which the emission inventory shall be defined
2. The area shall be divided into grids, e.g. 2 km x 2 km.
3. Identify emission sources in grids under broad categories of **point, area, and line sources** to inventories various pollutants.

Figure 4: Classification of emission sources for EI



- **Inventory of Point Sources**

  A point source of pollution is a single identifiable source of air pollution such as industries. A comprehensive list of potential air polluting industries in the region can be obtained from State Pollution Control Boards/ Pollution Control Committees, Office of commissioner for Industries, District Industrial Center (DIC), MSME-Development Institute (MSME-DI) and other organizations in the city. Industry - specific information on production capacities, the requirement of raw materials, manufacturing process details, fuel consumption type, electricity consumption etc, should be collected from the available secondary records. In addition, sample collection may be carried out of major emission sources conduct of surveys through questionnaires for cross-checking and validation of the secondary data.

- **Inventory of Area Sources**

  Area sources are sources of pollution that are released over an area, e.g. emissions arising from domestic consumption of cooking fuel, open waste burning or dust entrainment in large construction projects etc. In order to assess the emission load from domestic sources, information needs to be collected includes the number of houses and family members in each house, type and quantify of fuel used for cooking as well as DG sets etc. Based on the information collected, daily per capita consumption of different fuels will be estimated. The questionnaire should also envisage seasonal variation in the fuel used. In addition, information on refuse and biomass burning, fuel consumption in commercial establishments, hotels and restaurants, bakeries, crematoria need to be obtained from the municipal or other concerned departments of the city.

- **Inventory of Line Sources**

  A line source is a source of air emissions that emanates from a linear activity. The most prominent linear sources are roadways carrying traffic. To assess emissions from such line sources, various transport related project reports should be examined to understand the profile of vehicular traffic emissions within the city and projected scenarios.

  In order to arrive at a realistic assessment of vehicular emissions, vehicle counts on major traffic corridors within the city should be undertaken. The vehicles can be categorized under various groups depending upon the vehicle type, age, engine technology, fuel used and their size viz. heavy-duty vehicles, light-duty vehicles, passenger cars, taxis, two/three-wheelers, etc. as far as possible. Hourly variation in the vehicles count to be recorded (manually/ videotapes) and vehicle speeds during periods of day/night, weekdays, and weekends

  The data needs to be collected for area, point and line sources and following methods can be used:

Table 6: Data collection method for different point sources

S. No	Source	Activity Data Collection Method
1	Hotels & Restaurants	All hotels having sitting capacity of more than 10 person to be surveyed.
2	Domestic	Domestic fuel consumption to be estimated through census of India and different government schemes
3	Burning of Municipal Solid Waste	• Mass balance of solid waste generation and treatment and disposal to estimate the MSW burning emission. • Physical survey in low, medium, and upper-class area to obtain the burning pattern.
4	Brick Kiln	• SPCB data for emission estimation. Validation through physical survey. • Fuel usage data will to be collected during survey.
5	Concrete Batching Plant	Secondary data from concrete supplier.
6	Incinerators	Data from respective State Pollution Control Boards
7	Industries	• Data from respective State Pollution Control Boards
8	Road Dust	• Primary Sampling in at least 10 points. Number may be increased depending upon city size. • Silt load identification • Mean Weight of fleet • Methodologies detailed in USEPA (2006) can be utilized to build a base on-road dust resuspension inventory.
9	Vehicle	• On-road traffic density to be video recorded on major traffic intersections to cover the entire city. • Parking lane survey to be conducted (2W,3W,4W, LCVs, Buses, Trucks) for obtaining on-ground traffic composition. • Toll entry and Exit data
10	Construction and Demolition activities	Secondary Data of PWD, Development Authority related to construction area.
11	Aircraft	Data can be collected from Airport Authority of India. Flight landing and takeoff (LTO) statistics are obtained from DGCA and http://flightstats.com

S. No	Source	Activity Data Collection Method
12	Locomotive	Data from Railways
13	DG Sets	Data from respective State Pollution Control Boards
14	Mining	Data from respective State Pollution Control Boards
15	Crusher	Data from respective State Pollution Control Boards
16	Agricultural Soil dust	Estimated with GIS and secondary data

4. Once the data on point, area and line sources is collected emission calculations are carried out using emission factors. Refer to **Annexure 7 and Annexure 8 for details.**

   A simple and practicable tool for preparation of emission inventory is SIM-air, which is described **here**.

   Development of accurate emission inventory poses a challenge to air quality engineers, as it requires systematic in situ surveys to collect activity data and proper management system for handling these data. **Therefore, it is important to develop emission inventories based on geographic information system (GIS), which could also help the policymakers for the implementation of legislation.** Besides representation and presentation of geo-referenced data, a variety of models now utilize GIS technology of air pollution analysis. The integration of GIS and air pollution modelling is of advantage for progress in environmental research since both methods are synergistic. The data collected over 2x2 km can be depicted using a Geographical Information System (GIS) for visualization and processing. GIS is a computer-based system for capturing, storing, checking, and manipulating data that are spatially referenced, which can be of immense utility in developing, displaying, and querying an information related to emission inventory.

A spatial grid-wise map is to be generated for all major pollutants ($PM_{2.5}$, PM_{10}, So_2, NO_x, CO, VOC, PAH, etc.) for each sector (Industrial, transport, domestic, solid waste management, construction, resuspended road dust, etc.)

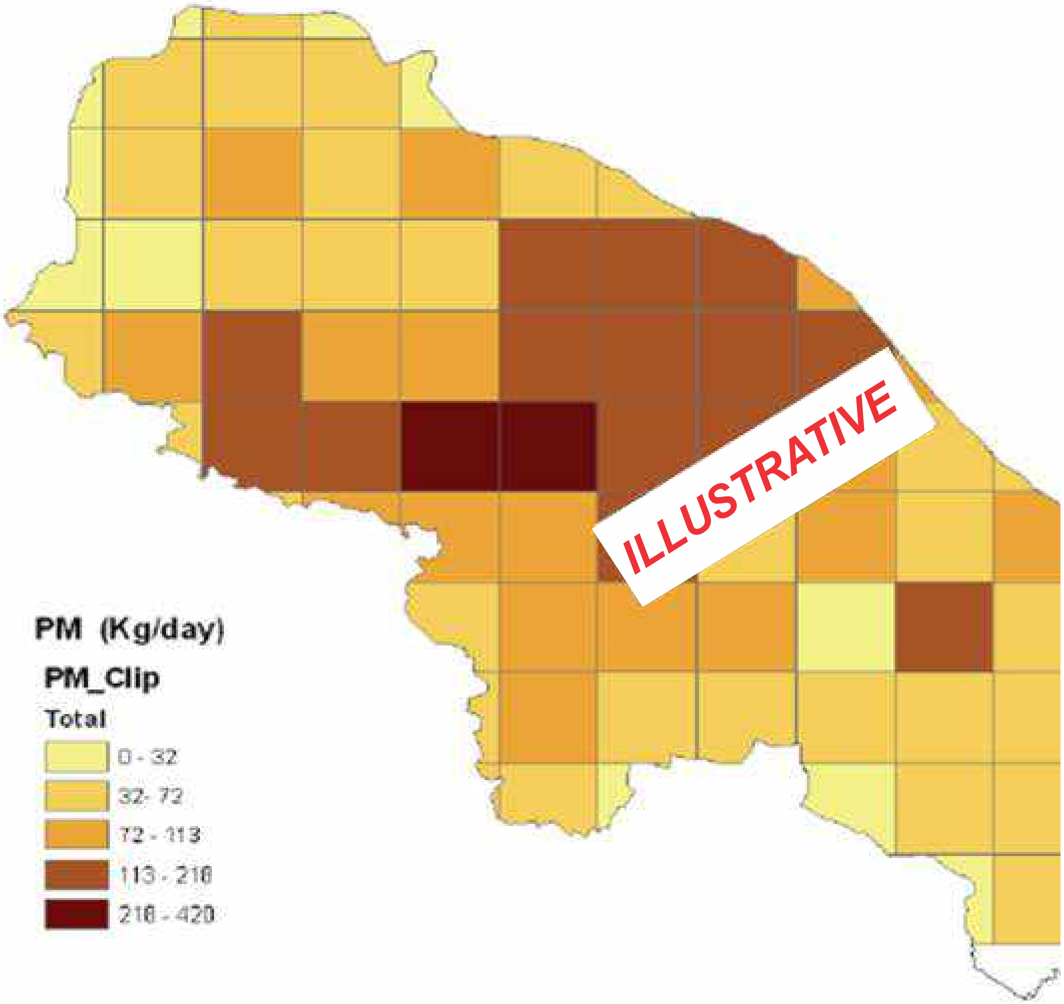
There are many tools available for representing emission inventory spatially grid wise for different sources and pollutants using GIS tools, prominent ones are indicated in below table:

Table 7: GIS Tools

Tool	Description	Weblinks
QGIS	QGIS is a user-friendly Open Source Geographic Information System (GIS) application that can produce maps and files with spatially allocated emissions in a grid format. QGIS can be used to explore, edit, analyze data, and compose and publish maps.	• Download • Tutorial
ArcGIS	The digitized map of the city can be generated using ArcGIS tool. After collecting data spatially resolved map of emission loads over the study area is generated and the contributions of identified sources towards pollution are assessed. It allows handling and analyzing geographic information by visualizing geographical statistic. ArcGIS is used to view, edit, create, and analyze geospatial data, and it allows the user to explore data within a data set. Imagery is offered in high-resolution, obtained from both the recent and historic sources worldwide, allowing for the building of historical maps as well as recent demographic data and information observations. Surface phenomena, like elevation, temperature, rainfall and so on, can also be fully integrated into such visual maps and models with amazing tools for surface analysis.	• Download Tool • Tutorial

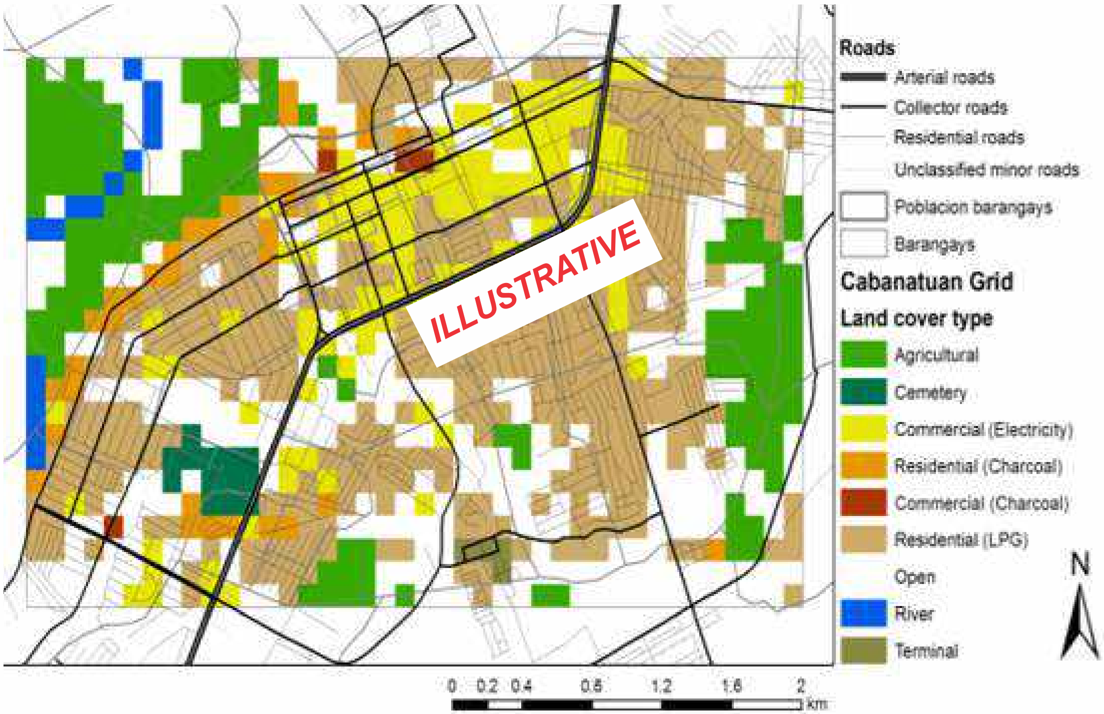
An illustrative of spatial grid-wise emission inventory for Particulate Matter(PM) is given in below figure:

Figure 5: Illustrative for Spatial Grid-wise emission inventory for Particulate Matter (PM)



The GIS tools can also be used for Land use and Land cover (LULC) satellite imageries to represent emissions spatially over a particular area. One such illustration is depicted below:

Figure 6: Use of land cover satellite imageries to represent emission spatially



5. Emission inventory should be periodically reviewed at least once in three years.

Once the emission inventory and spatial map emissions of each pollutant are prepared, then dispersion modelling could be carried out to estimate concentration of each pollutant and forecast future scenarios. For dispersion modelling, meteorological information will also be used as an input to the model.

The most commonly used modeling software's are **CALPUFF** and **AERMOD**, to determine concentration of pollutants. Dispersion modelling is performed to understand the physical and chemical transformation of air pollutants over a geographical area. A brief description of the tool is given below:

Table 8: Air Quality Modelling Tools

Name of Model	Description	Weblinks
AERMOD	The AERMOD atmospheric dispersion modeling system is an integrated system that includes three modules: • A steady-state dispersion model designed for short-range (up to 50 kilometers) dispersion of air pollutant emissions from stationary industrial sources. • A meteorological data preprocessor (AERMET) that accepts surface meteorological data, upper air soundings, and optionally, data from on-site instrument towers. It then calculates atmospheric parameters needed by the dispersion model, such as atmospheric turbulence characteristics, mixing heights, friction velocity • A terrain preprocessor (AERMAP) whose main purpose is to provide a physical relationship between terrain features and the behavior of air pollution plumes. It generates location and height data for each receptor location. It also provides information that allows the dispersion model to simulate the effects of air flowing over hills or splitting to flow around hills.	• Download instructions
CALPUFF	CALPUFF is a puff model that accounts for the effects of varying temporal or spatial conditions on pollution transport, transformation, and removal. From 2003-2017 CALPUFF was the US EPA-promulgated model for long-range transport modeling, however, with the 2017 revisions it was reclassified as an alternative model that can be used in a screening approach for long-range transport assessments.	• Download • User Guide

A comparison of AERMOD and CALPUFF models are indicated in below table:

Table 9: Comparison between AERMOD and CALPUFF models

AERMOD	CALPUFF
Predicts pollutant concentration up to 50 km	Predicts pollutant concentration up to 200 km
AERMOD typically uses representative observational meteorological data	CALPUFF requires detailed meteorological models. CALPUFF utilizes meteorological data both from multiple observation sites and from meteorological grid models (such as **Weather, Research and Forecasting (WRF) models**)
A USEPA approved model	This is an alternate Model-Best for Specialized situation
Has shorter run times	Has longer run times
Plume Model. Plume models are look at continuous flow of pollutants.	Puff Model. Puff models look at quasi-instantaneous or short-term releases

AERMOD is the more commonly used modelling tool. Key steps for carrying out dispersion modelling through AERMOD are summarized below:

1. Dispersion Modelling can be carried out through AERMOD. It is a steady-state dispersion model designed for short-range (up to 50 kilometers) dispersion of air pollutant emissions from stationary industrial sources.
2. Incorporation of detailed emission inventory for better prediction of pollutant concentration in the ambient air. Source locations and receptors are marked on GIS based map of 02 x 02 sq. km grids. Grid wise emission rate for different source groups for specific pollutants such as PM_{10}, NO_x , etc. can be worked out from baseline emission inventory data.
3. In-situ micrometeorological data to be collected at all sampling locations during the monitoring period as the site-specific data helps improve the reliability of predictions. Meteorological data needs to be captured on wind direction, wind velocity, ambient temperature, and percent relative humidity. The collected data for the monitoring period is to be converted into daily mean hourly parameters and used for prediction at respective sites as per the modelling requirement. Predominant meteorological data/IMD data can be used at a city level, as sources from far locations are unaffected by the local meteorology and their impact can best be evaluated by broad meteorology for the city. Regarding mixing height and diurnal stability pattern, the secondary data sources and/or established calculation procedure is to be adopted uniformly for all cities. For the model calibration exercise, the correlation curves for observed and predicted concentrations for ambient PM_{10} is to be analyzed for different seasons.

4. Model runs to be made at grid (02 x 02 sq. km around each monitoring location) as well as city levels. Receptors to be selected in Cartesian coordinate system wherein multiple receptor networks are defined.
5. Predictions to be made for three seasons viz. summer, post/pre-monsoon, and winter. For each season, observed and predicted concentrations to be plotted (iso-concentration) and R-square values to be determined for each of the locations.
6. With city-level EI (baseline) and future projections of emission growths, the Isopleths to be developed to generate air quality profiles. Dispersion modeling can also be carried out to determine the efficacy of control/management options. This can lead to long- and short-term city-specific action plans.

A tool called **Weather Research and Forecasting (WRF)** can be utilized to construct meteorological fields.

Table 10: Weather, Research and Forecasting (WRF) models

Name of Model	Description	Weblinks
Weather Research and Forecasting Model (WRF)	The Weather Research and Forecasting (WRF) Model is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications. WRF can produce simulations based on actual atmospheric conditions (i.e., from observations and analyses) or idealized conditions. WRF offers operational forecasting a flexible and computationally efficient platform	• **Download Tool**

Practicable tools for Air Quality Management

There have been some simpler tools being used recently for air quality analysis for Indian cities. The **SIM-air, "Simple Interactive Models for better AIR quality**", a family of tools is one such tool that has been developed to use available information to support integrated urban air quality management. The modules are designed to estimate emissions and to simulate the interactions between emissions, pollution dispersion, impacts, and management options. An integrated air pollution analysis tool to go from estimating emissions to pollution to impacts for a set scenario and perform optimization among options for better air quality. The average emission factors are included in the SIM-air program and available as an open-source information database. **All the databases, calculations, and interfaces are maintained in spreadsheets for easy access. For the analysis of emissions inventory and health impacts, a database of emission factors and concentration-response functions are included in the tools, which can be adjusted with specific data from cities.**

Table 11: Details of Sim-Air tools

Tool	Description	Weblinks
Sim-air	The SIM-air family of tools include the following: • **The SIM-air Model–** An integrated air pollution analysis tool to go from estimating emissions to pollution to impacts for a set scenario and also perform optimization among options for better air quality. • **VAPIS –** Vehicular Air Pollution Information System – A vehicular emissions calculator to estimate and compare emissions inventory, including a repository of emission factor databases. • **Atmos Dispersion Model –** The Atmospheric Transport Modeling System – A (Fortran language based) simplified lagrangian dispersion model to generate transfer matrices for multiple source and multiple pollutant types; for direct input to the SIM-air model.	The SIM-air Model VAPIS ATMoS Dispersion Model

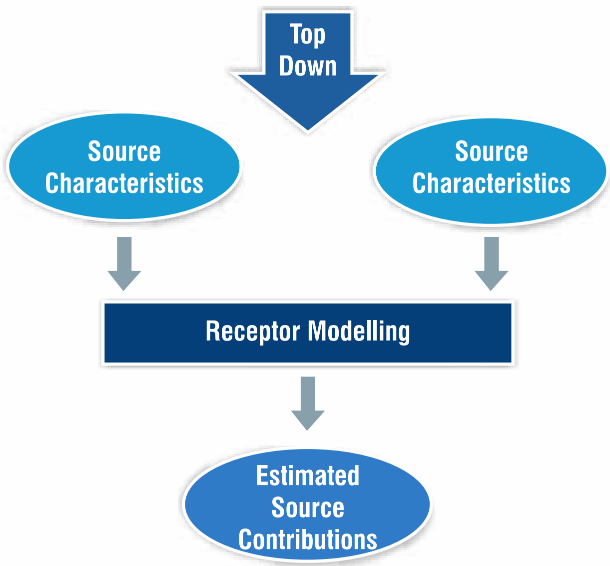
2.1.6.2 Source Apportionment Analysis

While dispersion models described in the earlier section, predict pollutant concentrations using emission and meteorological data, source apportionment (SA) technique uses monitored pollutant concentration and some information (signature) about the chemical composition of local air pollution sources to estimate the relative influence of the emissions at a monitoring location. This analysis also called as Receptor modelling are retrospective in the sense that they can only assess the impact of air pollution source categories on pollutant

Impact forecast for future, as anticipated in the chemical mass balance (CMB) based prediction, is based on rollback models. But these are highly qualitative. CMB is intended to complement rather than replace other modelling methods. Hence, use of dispersion modelling is generally practised for air quality planning concentrations that have already been monitored. Thus, SA cannot be used for prediction of pollutants in the future emission scenarios but only helps in the diagnostic of the existing emissions and their influence. Chemical Mass Balance (CMB) model is one of the popular techniques used for SA.

Receptor modelling is based on the top-down approach that begins by sampling air in a given area and inferring the likely pollution sources by matching common chemical and physical characteristics between source and air pollution samples. Top-down methods offer the promise of quantifying the relative contributions of the different sources to ambient air pollution, where rather little may be currently known. Additionally, top-down methods may require few atmospheric measurements and relatively simple analysis; simple of course is a relative term, as demonstrated in the coming sections.

Figure 7: Top Down Methodology-Receptor Modelling



The CMB procedure has following four steps:

1. **Ambient Sampling:** Identify and collect samples from receptors (Receptor is a place of interest where we want to maintain a certain air quality)
2. **Source Profiling:** For quantitative purposes, source profiles must contain chemical abundances for a range of components that can be identified appreciably between source and receptor, and that are reasonably constant among different emitters of the same type and operating conditions. Minor chemical components, constituting less than one percent of particle mass, are needed for quantitative apportionment as they are more likely to occur with patterns that allow differentiation among sources.

Table 12: Marker Elements Associated with Various Emission Sources

Emission Source	Marker Elements*
Soil	Al, Si, Sc, Ti, Fe, Sm, Ca
Road dust	Ca, Al, Sc, Si, Ti, Fe, Sm
Sea salt	Na, Cl, Na^+, Cl^-, Br, I, Mg, Mg^{2+}
Oil burning	V, Ni, Mn, Fe, Cr, As, S, SO_4^{2-}
Coal burning	Al, Sc, Se, Co, As, Ti, Th, S
Iron and steel industries	Mn, Cr, Fe, Zn, W, Rb
Non-Ferrous metal industries	Zn, Cu, As, Sb, Pb, Al
Glass industry	Sb, As, Pb
Cement industry	Ca
Refuse incineration	K, Zn, Pb, Sb
Biomass burning	K, C_{ele}, C_{org}, Br
Automobile gasoline	C_{ele}, Br, Ce, La, Pt, SO_4^{2-}, NO_3^-
Automobile diesel	C_{org}, C_{ele}, S, SO_4^{2-}, NO_3^-
Secondary aerosols	SO_4^{2-}, NO_3^-, NH_4^+
*** Marker elements are arranged by priority order**	

1. **Chemical Analysis:** The filters (Quartz and Teflon for analyzing a mix of pollutants) from ambient sampling are analyzed for mass, elements, ions, and carbon. Elements, ions (SO_4^{2-}, NO_3^-, Cl, NH_4^+, Na, K), organic carbon (OC), and black carbon (BC) are sufficient to account for most of the particle mass, with reasonable assumptions about unmeasured oxides and hydrogen contents.

2. **Receptor Modeling:** This step involves **quantitative assessment of source contributions to the measured ambient samples** based on the degree to which source profiles can be combined to reproduce ambient concentrations. The receptor model attributes primary particles to their source types and determines the chemical form of secondary aerosol when the appropriate chemical components are measured.

$$C_i = \sum F_{ij} * S_j$$

Where,

C = Concentration of the species measured at the receptor site

F = Fraction of species in emissions from sources

S = Estimate of the contribution of sources

i = Number of chemical species

j = Number of source types

The receptor modelling can be supported through chemical transport models such as CAMx (Comprehensive Air Quality Model with Extensions) described below:

Table 13: Details of CAMx Model

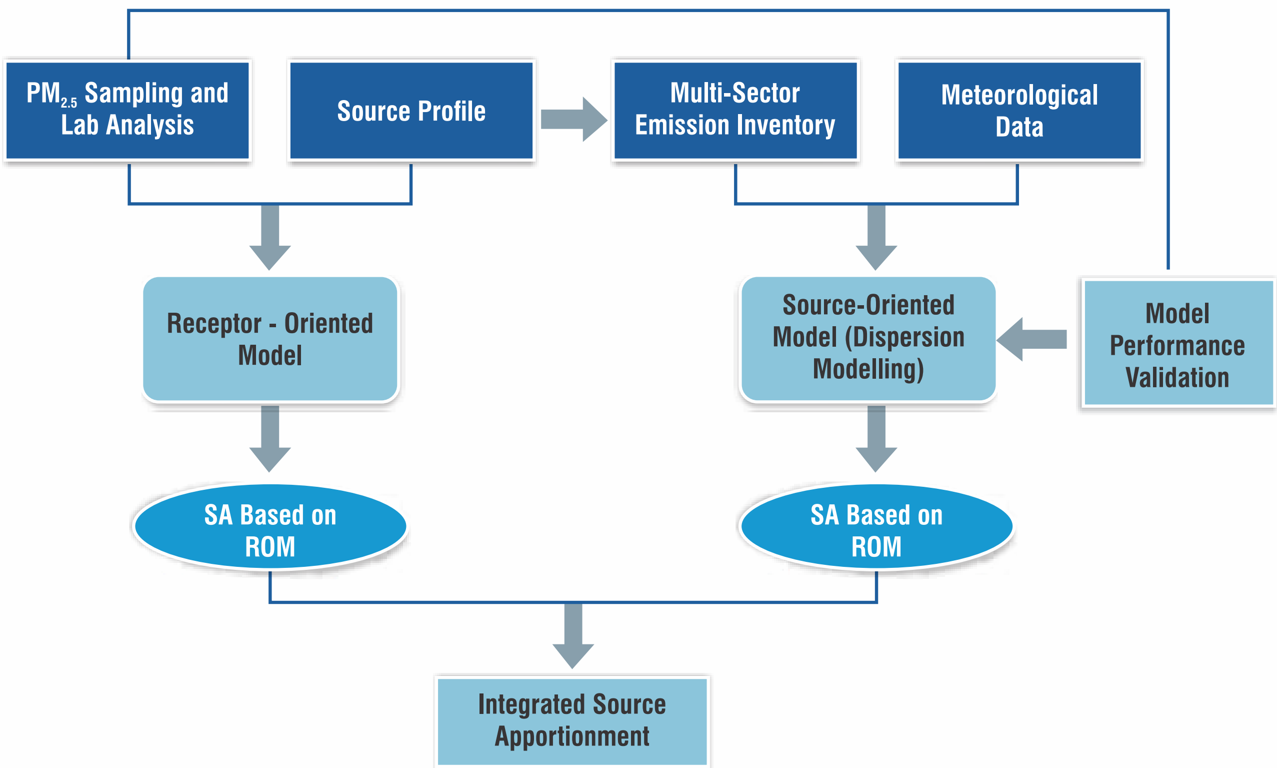
Tool	Description	Weblinks
Comprehensive Air Quality Model with Extensions (CAMx)	The model is used to estimate particulate concentrations for any airshed. CAMx is an open-source Eulerian photochemical dispersion model that supports: (a) 3-dimensional advection linked to 3-dimensional meteorological data at the grid level, including plume rise calculations for point sources (b) Scavenging schematics in the form of dry and wet deposition. (c) Multiple chemical mechanisms to characterize photochemistry. (d) Gas to aerosol conversions (from SO2 to sulfates, NOx to nitrates, and VOCs to secondary organic aerosols). (e) Links to online emission calculations for certain sources like sea salt. (f) Modular processing of area and point sources to estimate contributions by pre-defined region and source.	• Download

The source apportionment study results from dispersion modelling and receptor modelling should be validated to arrive at the final source apportionment results. It is possible to use both the approaches to achieve a more comprehensive understanding of the emission profiles, relative contribution as well as dispersion of pollutants through integrated source apportionment.

2.1.6.3 An Integrated Source Apportionment Methodology

An integrated source apportionment methodology is developed by amalgamating the receptor-oriented model (ROM) and source-oriented numerical simulations (SOM) or dispersion modelling, together to eliminate the weaknesses of individual source apportionment (SA) methods. The two pieces of information from both ROM and SOM are then stitched together to give comprehensive information on the polluting $PM_{2.5}$ sources over the region. With the integrated approach, the detailed contributing sources of the ambient $PM_{2.5}$ at different receptors including rural and urban, coastal and in-land, northern and southern receptors are analyzed. **This integrative approach is more comprehensive and can produce a more profound and detailed understanding between the sources and receptors, compared with single models.**

Figure 8: Methodology of integrated source apportionment



Once the SA studies are completed, the results need to be populated, covering the different sources of air pollution. Template for tabulating summary results (**for both $PM_{2.5}$ and PM_{10}**) from source apportionment studies (**Dispersion and Receptor Modelling**) is given below:

Table 14: Template for summarizing results from SA studies

Source Contribution (%)	Summers	Winters	Pre-Monsoon/ Post Monsson
Vehicles (Transport)			
Biomass burning			
Secondary Pollutants	ILLUSTRATIVE		
Solid Waste Burning (MSW)			
Coal & Fly Ash (Industries)			
Road Dust			
Construction			
Others			

2.2 Defining Objectives, Targets and Gap Assessment

2.2.1 Creation of Air Quality Management (AQM) Cell

An AQM cell needs to be set up with a Chairman or CEO (under Municipal Commissioner) for each non-attainment city with an allocated budget for its functioning. AQM cell should consist of a working group comprising of representatives from the following line departments:

- City level health department
- Municipal corporations
- Municipalities

- Town planning
- Civil department
- Land and Revenue department
- Finance officer
- Academic and Research Institutes (Like IIT's, civil society organizations, think-tanks)
- Meteorological departments
- Industries; constructions & building associations
- Traffic Police Department

Role of AQM Cell:

- Responsible for overall air quality management within the city for mitigating pollution levels within the city.
- Coordinate discussions and meetings to help understand the existing institutional arrangements, as well as the availability of resources.
- Assessment of existing air quality set up (Situation Analysis) within the city.
- Data collection from line departments to build up a central repository that can be used for the formulation of action plans.
- Ensure updating and review of Emission Inventory periodically.
- Facilitate preparation and implementation of city air quality action plan.
- Continuous monitoring and analysis of ambient air quality data within the city.
- Coordinate monthly review meetings. Monitor and track progress of air quality action plans.
- Reporting progress to state higher authorities such as chief secretary, CPCB, etc., highlighting the current air quality scenario and support needed.
- Create public awareness and build up institutional capacity in the city.
- Issue necessary guidelines and communication (or forecasted warnings) related to air quality.

2.2.2 Define Objectives and Targets

The objectives for improving air quality should be defined from the long-term vision and goals. It should align with the National Clean air Action Plan (NCAP) and National Ambient Air Quality Standards aiming for emissions reduction that contributes to improving public health and reducing environmental and climate change impacts. Any objective should have a target, action plans and timelines for achieving it.

For instance, as per the NCAP, non-attainment cities in India need to achieve 20-30% reduction in $PM_{2.5}$ & PM_{10} concentration levels by 2024, keeping 2017 as baseline year. For cities not classified as non-attainment should always meet ambient air quality corresponding to National Air Quality Standards (NAAQS). The targets for Indian non-attainment cities can be checked here.

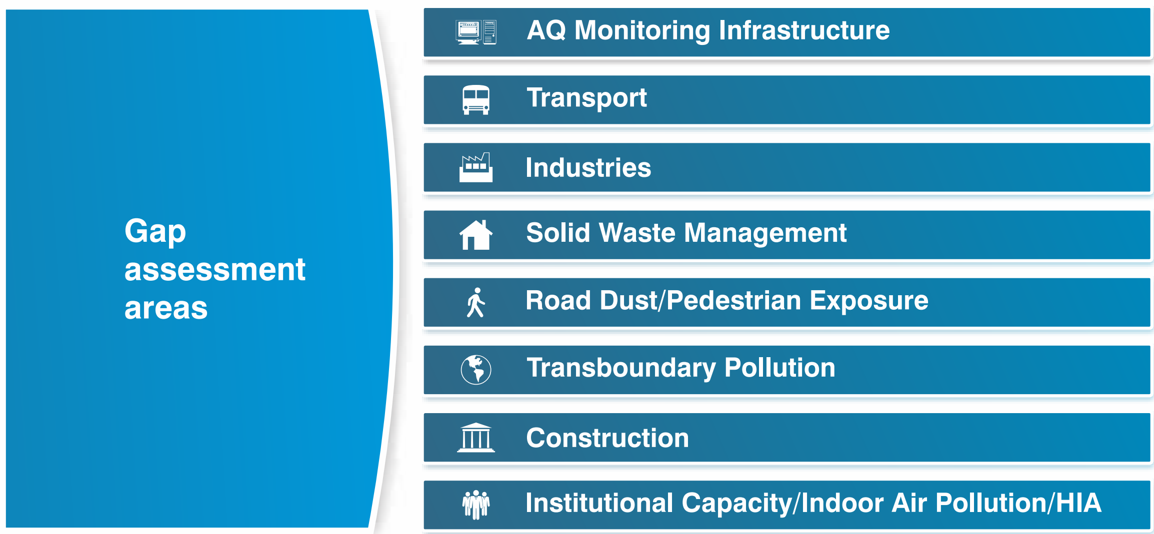
2.2.3 Gap Assessment

Based on Situation analysis and Targets, gap assessment needs to be done for different sectors to identify and finalize air pollution monitoring and control measures.

The AQM cell shall conduct the gap assessment. All existing policies and regulations related to air pollution and air quality for different sectors must be reviewed. The gaps should be identified in sections like monitoring infrastructure, public transport, power infrastructure, availability of cleaner fuels, institutional capacities on monitoring and enforcement which would need to be filled up to overcome the previously assigned targets. Along with identifying gaps, issues regarding indoor air quality, pedestrian exposure, and emissions transported from outside boundaries should be assessed.

The outcome required is an assessment of the relative contribution of different source types (typically traffic, industrial, construction, indoor air pollution, etc.) to air pollution. This can then be used to help assess the effectiveness of different control options and which of one or more source types should be addressed.

Figure 9: Gap Assessment Areas



Estimating the Improvement Required to meet Air Quality targets

Before identifying the options, it has available for improving air quality, there is a need to determine the overall level of improvement required. The percentage improvement can be calculated as the difference between the total predicted concentration and the relevant air quality objective. It can be expressed in terms of concentration units or as a percentage.

Example: An urban area is identified where the highest annual average SPM value is 50mg/Nm^3, against an objective value of 40 mg/Nm^3. The required improvement (mg/Nm^3) to meet the objective can therefore be calculated as:

Required Improvement = Predicted Concentration - Objective

= 50 mg/Nm^3 - 40 mg/Nm^3

= 10 mg/Nm^3

and as a percentage:

$$\text{Percentage Improvement} = \frac{\text{Required Improvement}}{\text{Predicted Concentration}} \times 100 = 20\%$$

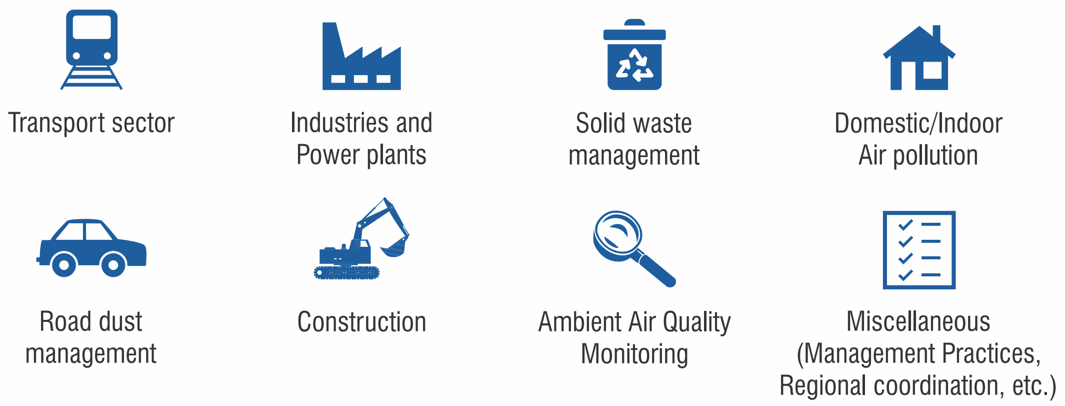
It is critical to identify points of maximum concentration (hot spots), where exposure is high and calculate the required improvement. There should be a provision to consider the need to allow for some space for future development or uncertainty in the overall assessment process. It may be appropriate therefore to seek a greater percentage improvement than would otherwise be required just to meet the objective. However, any additional requirement of this type will need to be properly justified as it will almost inevitably have implications on the costs of compliance.

The next stage in the selection and development of options is to identify the sources where controls might be effective in reducing concentrations and which makes a significant contribution to the exceedance of a particular objective. It would, for example, exclude most background sources, following which control options can be identified for the "relevant" sources.

2.3 Development of Strategic Actions (Control Measures)

Based on the gap assessment, emission inventory and source apportionment studies, science-based control measures should be identified. A comprehensive list of sector specific control measures (CMs) should be prepared for different sectors.

Figure 10: Sectors to be covered for control measures



A comprehensive list of control measures should be provided based on polluting sectors and their contributions with implementation timelines classified into short, medium, and long term based on availability of infrastructure and existing policy framework of various line departments. Cost benefit analysis of control measures should be undertaken for helping line departments prioritize their implementation strategies.

Sector wise compendium of best practices can be accessed in **Annexure 5** & **Annexure 6**

2.3.1 Emergency Response Action Plan

Despite interventions, there is a possibility that air quality gets deteriorated in a city due to a number of reasons and therefore it is essential to have an emergency response plan, the actions from which will ensure that air contaminants do not increase in concentration to a degree that would be detrimental to health, welfare and safety of the population.

The emergency plan should have different stages/levels, i.e., it should be Grades Response Action Plan (GRAP). The emergency action plan should be based on the forecast and not on actually recorded pollutant concentrations. This will ensure actions are implemented earlier rather than when pollutant concentrations are already high and peaking. Most international cities such as Beijing have their emergency action plans in service based on forecasted Air Quality Index (AQI). Whenever such emergency plans are pressed in service, these should also be communicated to all stakeholders and public.

Example for emergency response action plan for Beijing is given in **Annexure 4**

2.4 Assessment of Control Measures

Each control measure should be assessed in consultation with different stakeholders and specify:

Impact Reduction: Each control measure should specify its impact on air quality and its associated benefits (health). Refer section on **Cost Benefit Analysis.**

Feasibility: Each control measure should be assessed if it is technically feasible or not. It is important to characterize the potential positive and negative impacts of the control measure with sufficient evidence or confidence to decide to implement the measure.

Finance requirement: The capacity to successfully implement an Air Quality Action Plan is heavily dependent upon obtaining adequate funding and resources to deliver the proposed measures. Control measures must mention the total cost associated with implementing the measure including a source of funding.

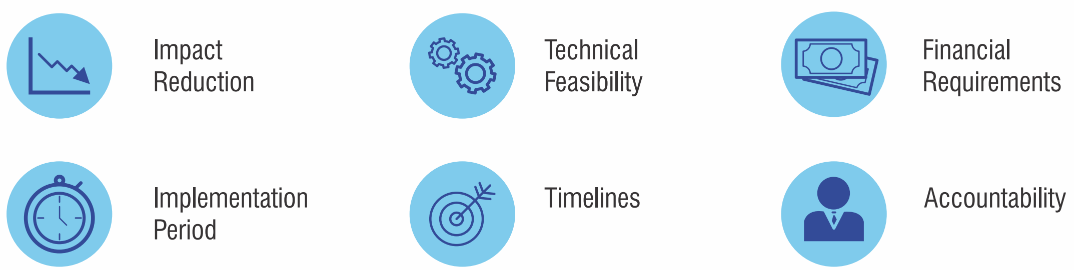
Implementation: The control measure should have an implementation plan including start date, milestones, and completion dates. Further, based on total implementation time, it may be termed as short term (<1 year), medium term (1-3 years) and long term (>3 years) measures.

Agency accountable: Clearly specify agencies accountable for implementing the control measure. In case of multiple agency involvement, the responsibilities should be clearly demarcated. Refer section on **Roles & Responsibilities.**

Once assessed, the control measures then need to be prioritized based on their impact and their cost (Benefit-cost ratio).

Figure 11: Assessment of Control Measures

Template for recording control measures can be accessed in **Annexure 3**

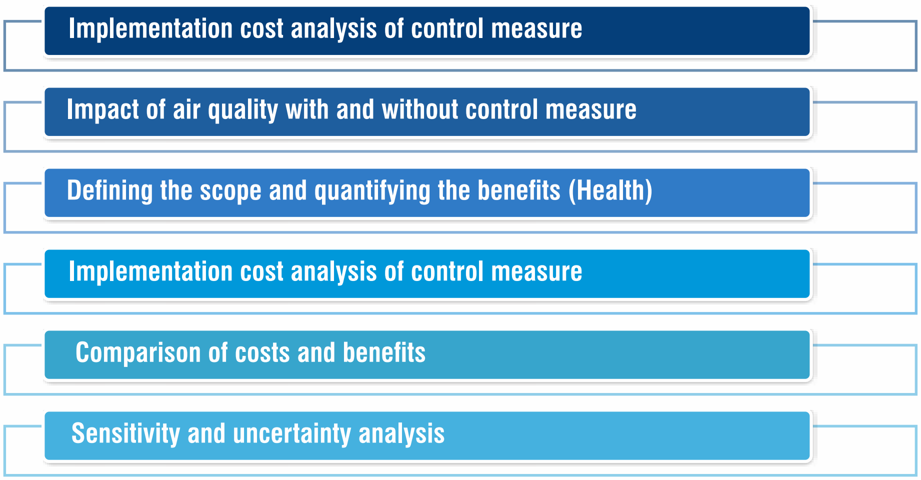


2.4.1 Cost Benefit Analysis (CBA) and Cost Effectiveness Analysis (CEA)

The goal of cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) is to investigate and identify the best set of measures. In CBA, the costs of a set of measures are compared to the benefits; for example, reduced environmental damage would be calculated in monetary terms. Because the monetary estimation of reduced environmental damage (a benefit) is usually not accurate enough to compare to costs of achieving such an outcome, CEA is often used as an alternative. In CEA, benefits like reduced environmental damage are not monetized. The measures meeting the targets with the least cost are the most lucrative to implement.

The following steps need to be done for conducting CBA or CEA:

Figure 12: Steps for Cost Benefit Analysis and Cost-Effective Analysis



1. **Implementation cost analysis of control measure: Cost identification needs to include:**

- Present and future costs of investments.
- Operation and maintenance costs.
- Estimated cost for technical innovations and development and indirect costs arising during implementation of the regulation

Cost analysis should also take into account annualization (comparing costs and benefits per year), discounting (adjusting the future value of money to the current value), salvage value and correcting for inflation.

2. **Impact of air quality with and without control measures:** Air quality assessment must provide information about expected air quality both with and without the implementation of control measures. Typically, this assessment will be based on a combination of air quality monitoring data and dispersion modelling.

3. **Defining the scope and quantifying the benefits (Health):** After assessing the local situation health-and ecosystem-related benefit categories should be considered for the analysis. The health status is measured at various endpoints (e.g. acute mortality, chronic pulmonary disease, hospital visits, and emergency room visits).

Health Endpoint	
Mortality	% change through control measure
Hospital Visit	
Emergency Room Visits	
Hospital Admissions	
Chronic Bronchitis	

ILLUSTRATIVE

The benefits must be assigned a monetary value, and the size of an effect must be determined.

Morbidity: For the acute morbidity endpoints, the opportunity costs of illness (COI) approach is used to reveal avoided medical care expenses, reduced time spent in hospital visits, regained productivity from bed confinement, and reduced work-day losses of family members taking care of the sick persons.

Mortality: The willingness-to-pay (WTP) approach is used to estimate the benefits associated with avoided mortality risk from improved air quality.

The following method can be adopted to estimate the mortality avoided annually due to implementation of a control measure (Pope et al., 2014)

$$M = \Delta PM_{2.5} \times E_p \times \Delta ER \times B_d$$

Where,

M - Mortality avoided annually

$\Delta PM_{2.5}$ - Change in $PM_{2.5}$ concentration levels before and after implementation of control

measure E_p - Exposed population of city

B_d - Baseline death rate (mortality rate)

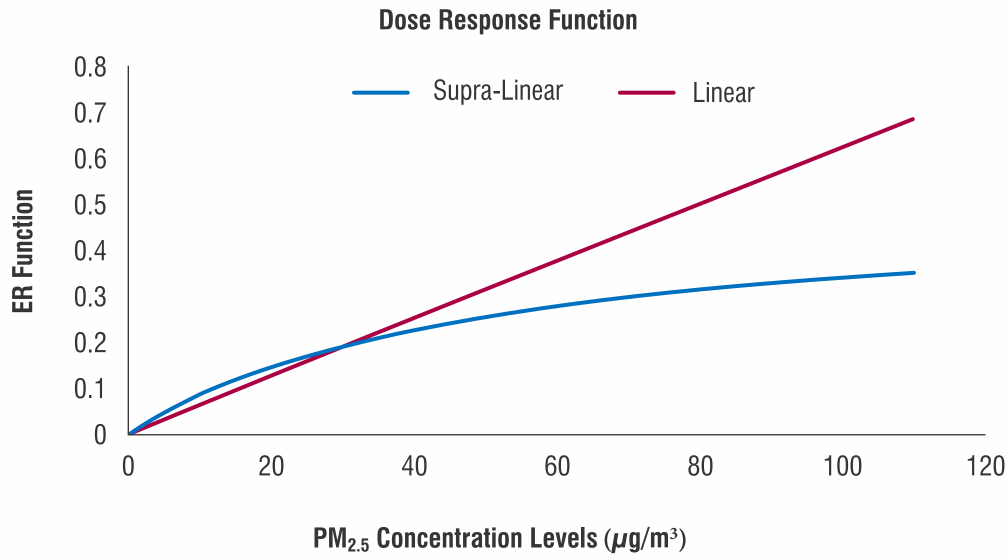
Δ ER (excess risk) - Supra-linear Concentration Response Function (CRF) considered

based on GBD assessments.

ER (excess risk) $= 0.4 \times \{1 - \exp[-0.03\,(PM_{2.5})^{0.9}]\}$

The excess risk function can follow either a supra-linear form (rate of change of risk decreases with higher pollution concentration levels) or a linear form (risk increases at the same rate irrespective of pollution levels). As per studies (Pope et al., 2014) ER or the CRF is more likely to be supra-linear at higher levels of exposure. This implies that the marginal benefits of pollution reduction at lower concertation levels are higher than the benefits in highly polluted areas. Below figure indicates difference between the supra-linear curve and the linear curve.

Figure 13:Difference between the supra-linear



USEPA's tool Benefits Mapping and Analysis Program - Community Edition (BenMAP-CE) calculates the number and economic value of air pollution-related deaths and illnesses.

Table 15: Description of BenMAP-CE tool

Name of Tool	Description	Weblinks
BenMAP-CE (by USEPA)	It is a software that estimates the health impacts and economic value of changes in air quality. It shows health benefits of improved air quality. **The program calculates the economic value of air quality change using both "Cost of Illness" and "Willingness to Pay" metrics.** The Cost of Illness metric summarizes the expenses that an individual must bear for air pollution-related hospital admissions, visits to the emergency department and other outcomes; this metric includes the value of medical expenses and lost work, but not the value that individuals place on pain and suffering associated with the event. By contrast, Willingness to Pay metrics are understood to account for the direct costs noted above as well as the value that individuals place on pain and suffering, loss of satisfaction and leisure time. The special features of BenMAP are as under: • It spatially interpolates air quality data • Estimates health effect incidences based on concentration-response functions. • Estimates economic value of avoided incidences. • Generates uncertainty distributions around incidence changes	• **Download Tool** • **User Manual**
BenMAP	BenMAP-CE tool provides country specific regional datasets for population, baseline death, air quality and grids for each country assessed in the Global Burden of Disease outdoor air pollution assessment. It includes baseline death rates for four mortality endpoints (COPD, cerebrovascular disease, ischemic heart disease, and lung cancer).	**Regional data set for India**

4. **Comparison of benefits with and without control actions:** This step involves combining the information on exposure–response relationships with air quality assessment and applying the combined information to the population at risk. Additional data needed in this step includes a specification of the population at risk and the prevalence of the different effects on health in that population.

2. **Comparison of costs and benefits:** CBA should provide a benefit–cost ratio based on monetized costs and benefits, accompanied by a description of the non-monetized items identified as relevant to the analysis.

3. **Sensitivity and uncertainty analysis:** Many uncertainties relate to the steps of CBA/CEA, e.g. exposure, exposure–response, control costs estimate, benefits valuation. The results of sensitivity and uncertainty analyses should be presented to characterize the impact of major uncertainties on the result of the CBA/CEA. The BenMAP-CE tool can be utilized to perform sensitivity analyses of health or valuation functions, or other inputs.

Illustrative Example of Cost Benefit Analysis

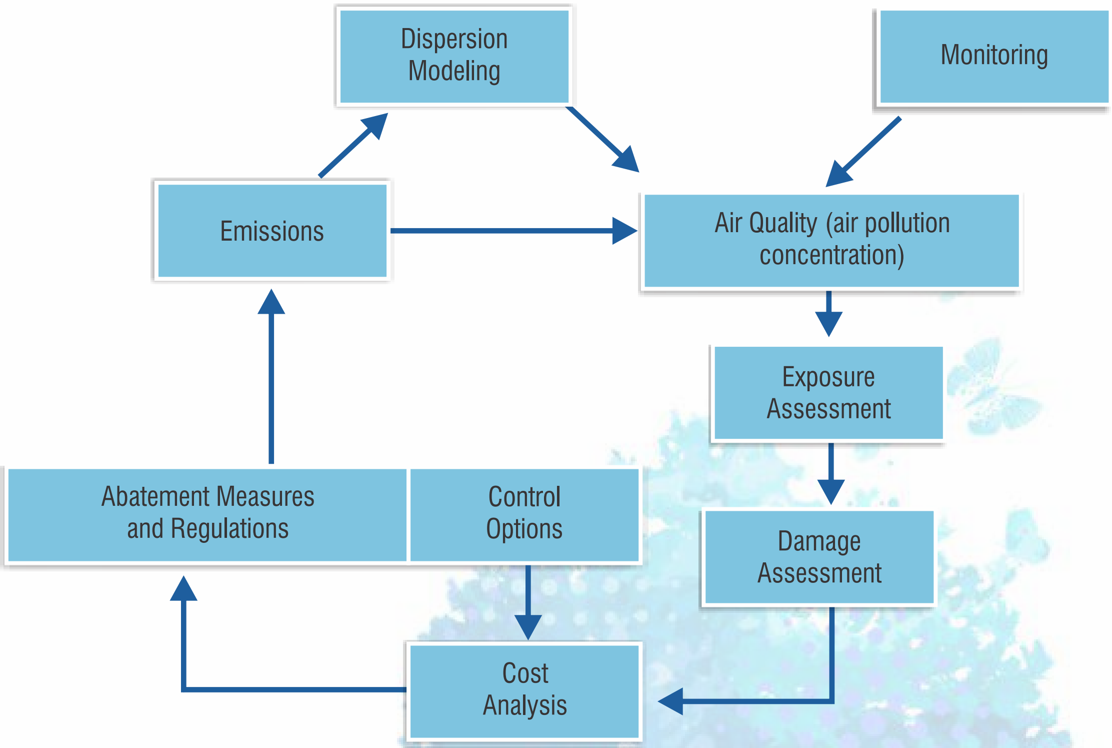
Control Measure: Conversion of Fixed Chimney Brick Kilns (FCBK) to Zigzag Kilns

Table 16: Example of cost benefit analysis

Description	UOM	Values
Capital Investment per kiln	INR lakh	25
Operational Cost per kiln	INR Lakh	2.5
Annual savings per mill	(INR lakhs)	41
Total number of kilns	Number	122
Total investment required (A)	INR Crores	30.5
Total Operational cost (B)	INR Crores	3.05
Total cost (A+B)	INR Crores	33.55
Total annual savings	INR Crores	50
Emission reduction	mg/m^3 per 1000 bricks	350
Emission (PM) reduction potential	%	35%
Mortality Saved	Number	1242

A typical project cycle in AQM capturing elements of CBA and CEA are shown in in Figure 14:

Figure 14: Typical Project Cycle in Urban Air Quality Management. Source: WHO



2.4.2 Roles and Responsibilities

An action plan should clearly define roles and responsibilities for all concerned stakeholders for effective implementation various activities

Table 17: Activity wise roles and responsibilities

What	Who
Establishment of Implementation committee	State Chief Secretary
Establishment of Air Quality Cell	Municipal Commissioner
Air Quality Monitoring	SPCB/ Air Quality Management Cell
Conduct of health-related studies and assessing economic impact	Medical Research Institution/Hospital
Objective and Targets for Action Plan	Steering Committee Air Quality Management cell
Emission inventory / Source Apportionment Study	Research & Academic Institutions
Situation analysis	All departments coordinated by AQM Cell
Formulate prevention and control measures	Respective departments coordinated by AQM Cell
Cost benefit Analysis of the strategies	Respective departments coordinated by AQM Cell
Prioritization of Action Plans	Steering Committee and Air Quality Management Cell
Public Consultation of Action Plans	Air Quality Management Cell
Implementation of Action Plans	Respective departments coordinated by AQM Cell
Monitoring, Review and Evaluation	Air Quality Management Cell
Communication	CBOs and Air Quality Management Cell

An **institutional framework** for implementation of city clean air action plan is given in below figure:

Figure 15: Institutional framework for implementation of city clean air action plan

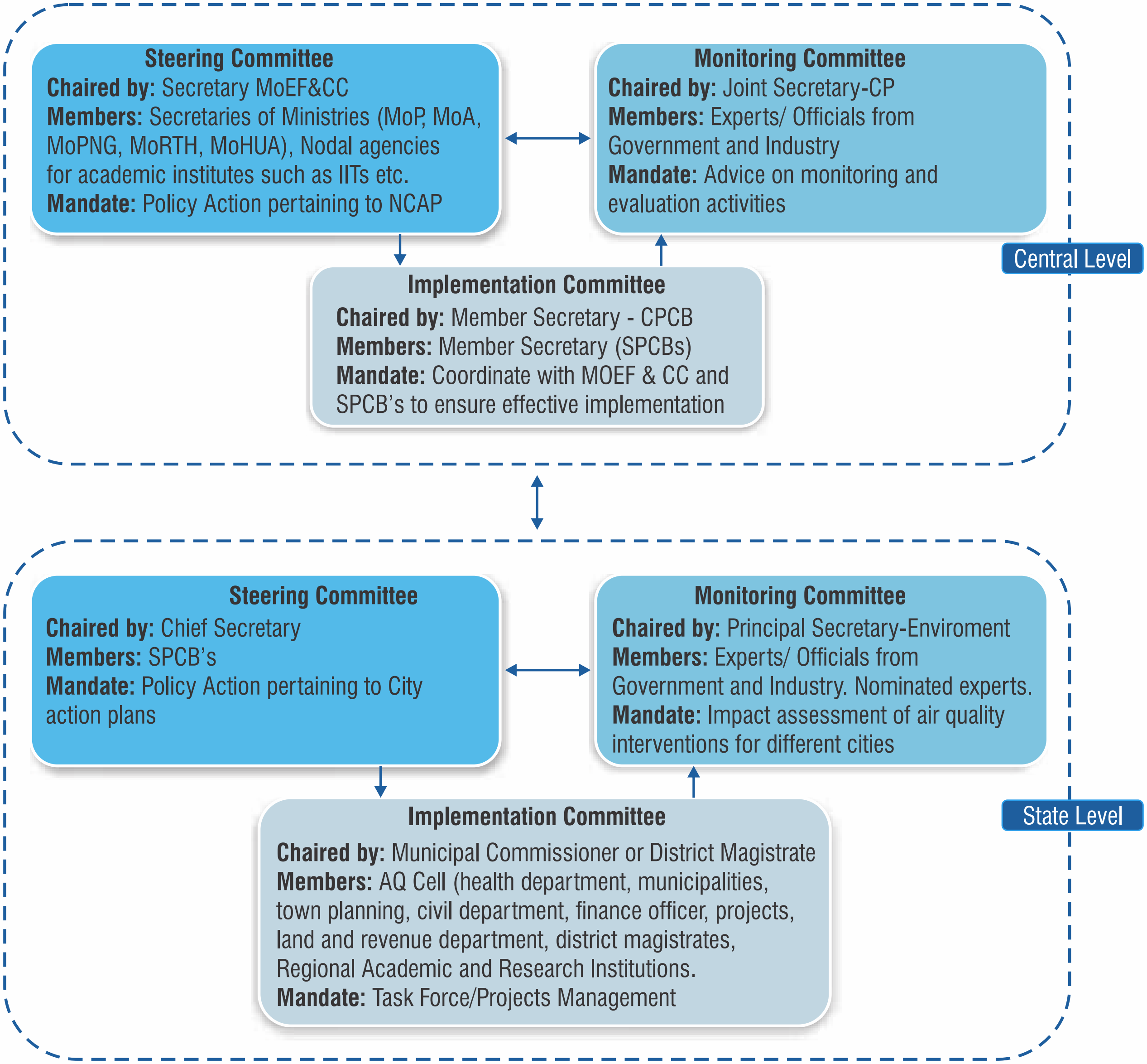


Table 18: Institutional Roles and Responsibilities

Agency	Responsibilities
Air Quality Management Cell (at city level)	• Responsible for overall air quality management within the city for mitigating pollution levels within the city. • Coordinate discussions and meetings to help understand the existing institutional arrangements, as well as the availability of resources. • Assessment of existing air quality set up () within the city. • Data collection from line departments to build up a central repository that can be used for the formulation of action plans. • Work as a project management unit • Ensure updating and review of Emission Inventory periodically. • Facilitate the preparation and implementation of city air quality action plan. • Continuous monitoring and analysis of ambient air quality data within the city. • Coordinate monthly review meetings. Monitor and track progress of air quality action plans. • Reporting progress to state higher authorities such as chief secretary, SPCB, etc., highlighting the current air quality scenario and support needed. • Create public awareness and build up institutional capacity in the city. • Issue necessary guidelines and communication (or forecasted warnings) related to air quality.
Steering, monitoring and implementation committee	• Steering Committee: Policy action pertaining to NCAP, tracking progress at state and city level • Monitoring Committee: Advising on monitoring and evaluation activities • Implementation Committee: Project management, a task force at ground level
MoEF&CC	• Constitute steering, monitoring & implementation Committees under NCAP at the central level. • Direct chief secretaries of state to set up steering, monitoring and implementation committee at state level. • Allocate funding to different cities for the implementation of action plans. • Plantation initiatives under the NCAP at pollution hot spots in the cities/towns. Execution of city specific plantation plans. • Develop a market mechanism to support clean technologies. • Develop a comprehensive national emissions inventory.

Agency	Responsibilities
MoEF&CC	• Monitor and track progress of city clean air action plans through a structured monitoring and evaluation framework. • Building specific guidelines and protocols on monitoring and management of indoor air pollution. • Strengthening of CPCB and SPCB by providing technical staff exclusively for the purpose of implementation of NCAP control measures. This staff will coordinate with Air Quality management cells formed in cities for all air quality related activities. • Collaboration with academic institutions such as IIT's, including strengthening of National Knowledge Network (NKN) and thinktanks to support monitoring, source identification and prioritization of source mitigation, in addition to capacity building. • Increase public awareness through different capacity building programs. • Establish international scientific and technical cooperation in air pollution with different agencies. • Coordination with other departments to ensure smooth implementation of action plans.
Ministry of Health	• Studies on health and economic impact of air pollution • Provide strategic direction for health delivery services with respect to air quality • Strengthen institutional capacity in India by strengthening research, training, and policy development in Public Health. • Conduct Epidemiological Studies to assess the health impacts of air pollution • Framework for a monthly analysis of data w.r.t health to be created. The data from mapping of the industry, i.e., tabulation of a daily AQI, $PM_{2.5}$ and PM_{10} measurements; Metrological parameters; deaths due to heart attack, strokes, respiratory arrest following the existing respiratory ailments, trends in lung cancer if available w.r.t all cities to be fed in to a central computer and to be analyzed every month by people trained in environmental health for correct interpretation.
Ministry of Petroleum and Natural Gas (MoPNG)	• Enhanced LPG penetration through PMUY. • Expand City Gas Distribution (CGD) network distribution on priority within the country, emphasizing on 122 non-attainment cities. • Explore feasibility of converting coal-based industries to gas-based industries.
Ministry of Agriculture (MoA)	• Evolve a plan for the management of agricultural emissions from fertilizers and livestock waste based on strong R&D • Initiatives for addressing the issue of crop residue burning

Agency	Responsibilities
Ministry of Road, Transport and Highways (MoRTH)	• Planning, development, and maintenance of National Highways in the country to reduce congestion. • Extends technical and financial support to state governments for the development of state roads and the roads of inter-state connectivity and economic importance. • Setting up of infrastructure for moving towards cleaner transport-CNG, EVs, etc. and increased testing facilities. • Auto fuel policy for stringent norms for fuel and vehicles, road to rail/ waterways, fleet modernization, electric vehicle (EV) policies, clean fuels, bypasses, taxation policies, etc. • Stringent implementation of BS VI norms all over India by April 2020. • Regulating Taxation of motor vehicles.
CPCB	• Ensure compliance to emission/effluent standards, specially by industries. • Coordination with State Pollution Control Board (SPCBs) and assist them in implementation of NCAP framework. • Periodic review National Ambient Air Quality Standards (NAAQS). • Setting up of infrastructure such as testing laboratories, air quality monitoring network etc. • Develop market mechanism for revenue generation, which can be utilized for air quality interventions. • Public awareness and capacity building.
SPCB	• Coordination with cities and assist them in implementation of NCAP framework. • Expand air quality monitoring network within the state. • Stricter enforcement of standards in large industries through continuous monitoring. • Constitute and deploy mobile enforcement unit. • Formulate transboundary plan to mitigate air pollution.
Municipalities	• Municipalities have the most critical role to play in ensuring enforcement of control measures at the local level: ✓ Enforcement of Construction & Demolition (C&D) waste management rules to reduce pollution from construction activities ✓ Enforcement of solid waste management rules to ensure proper segregation and utilization of solid waste ✓ Build infrastructure for parking to reduce congestion

Agency	Responsibilities
	✓ Prevention of garbage burning in open ✓ Mechanized street sweeping and water sprinkling ✓ Wall to wall pavement of roads ✓ Proper maintenance of road ✓ Greening the road corridors
Meteorological department	• Ensure meteorological information for all non-attainment cities to be made readily available. • Develop forecasting mechanisms such as SAFAR (System for Air quality Forecasting and Research) to forecast air quality for cities so that proactive action can be taken.
Academic & Research Institutions (IIT's, NEERI, etc.)	• Act as knowledge partners to provide research expertise in air quality and public health. (e.g. IIT Delhi set up Center of Excellence for Research on Clean Air (CERCA) to take up research to study air pollution issues in Delhi and NCR region. • Providing help to the state government for implementing clean air Programme in those states. • Assist cities in carrying out source apportionment studies to identify sources of air pollution and prioritization of action plans. • R&D to explore new avenues to mitigate air pollution. • Providing scientific information to policy makers. • Providing feedback on the effectiveness of various pollution management Programme.
Industries	• Ensure compliance under: ✓ Effluent Standards ✓ Emissions Standards ✓ Waste utilization • Installation of energy and resource efficient technologies to improve performance. • Ensure healthiness of CEMS. • Capacity building of personnel
Science Based NGOs	• Technology assessment • Work upon innovative technologies to mitigate pollution • Capacity Building • Running awareness campaign

Regional Coordination mechanism

About a quarter of the pollution in cities comes from sources outside the city boundary and so it becomes imperative that an action plans defines strong regional coordination mechanisms to prevent overlapping of responsibilities. Hence, for each control measure, agencies should be assigned specific duties. China in recent past has adopted a strong regional coordination mechanism to counter this issue. As an example, the average annual $PM_{2.5}$ concentrations in the Beijing-Tianjin-Hebei region decreased by nearly 25 per cent during 2013-17 through strong institutional framework within the region as depicted in below box. Similar, mechanism needs to be adopted by Indian cities.

Box 1: Illustration for regional coordination mechanism

Regional Coordination Mechanism (Beijing-Tianjin-Hebei) Example

- The Coordination Group Was established Leb by the Beijing Municipal Government.
- The Coordination Group encompasses the municipalities of the identified regions and eight ministries:
  - The National Development and Reform Commission (NDRC)
  - Ministry of Finance
  - Former Ministry of Environmental Protection (MEP)
  - Ministry of Industry and Information Technology
  - Ministry of Housing and Urban-Rural Development
  - Ministry of Transport
  - China Meteorology Administration
  - National Energy Administration
- The Coordination Group rolled out 22 supporting policies and measures, which include 3 aspects like energy restructuring, economic incentives and responsibility.

2.4.3 Communication of Plan

Public consultation of the action Plan

Air quality action plans will work best when they enjoy public support and where they strike a balance between environmental and social and economic benefits. Action plan once finalized should be presented and published to public through various mediums for consultation and feedback. The feedback recorded and collated must be discussed in stakeholder consultation and necessary amendments should be incorporated in the final plan.

Final Approval

Once finalized all concerned stakeholders should approve and sign-off the plan. The plan can then be published.

2.5 Implementation Stage

Implementation and enforcement are key to reducing air pollutant emissions and achieving air quality objectives. Once the plans are finalized, meticulous planning is required in the implementation of these action plans. This is a key step that requires clear institutional framework and **responsibilities** (refer section 2.4.2), stakeholder coordination and **communication** (refer section 2.6), political support, allocation of financial resources, technical capabilities, and **review** (refer section 2.6.2) and improvement. Need to ensure coordination of all stakeholders, resource adequacy and political support for executing the plan to make sure that these are completed within the committed timelines.

2.6 Monitoring, Review, Update and Communication

2.6.1 Communication

Communication is essential for 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. Increased communication also ensures that the public is more responsible and concerned regarding the air they breathe in.

2.6.1.1 Strategies for communication

The action plan should encompass strategies for effective communication for air quality. Some key strategies are listed below:

- **Use of air quality indicators:** Promote use of indicators such as Air Quality Index (AQI) to communicate the status of air quality to public can a go a long way in creating awareness among the people. For ease of understanding these indicators should be colour coded form Red (Severe) to Green (Good Quality) under different bands/ stages. These bands should further correlate health conditions corresponding to each band.

Figure 16: Illustrative indicators for air quality

AQI Category (Range)	PM_{10} (24hr)	$PM_{2.5}$ (24hr)	Associated Impact
Good (0-50)	0-50	0-30	Minimal Impact
Satisfactory (51-100)	51-100	31-60	May cause minor breathing discomfort to sensitive people.
Moderately polluted (101-200)	101-250	61-90	May cause breathing discomfort to people with lung disease such as ast[illegible]ma, and discomfort to people with heart disea[illegible]ren and older adults.
Poor (201-300)	251-350	91-120	May caus[illegible]g discomfort to people on prolon[illegible]sure, and discomfort to people with he[illegible]. ILLUSTRATIVE
Very poor (301-400)	351-430	121-250	[illegible]ause respiratory illness to the people on [illegible]longed exposure. Effect may be more pronounced in people with lung and heart diseases.
Severe (401-500)	430+	250+	May cause respiratory impact even on healthy people, and serous health impacts on people with lung/heart disease. The health impacts may be experienced even during light physical activity.

- **Communicating Environmental and Health Impacts of air pollution:** Communication of environmental and health impact of air pollution including benefits for air quality can motivate the stakeholders to take actions at their respective level. These can also be related to health.

- Issue advance warnings/forecasts and public health hazards of air pollution impacts.

  Up to date air quality information on a real-time basis through online modes (including data trends, health impacts); ensure accessibility to the public and all stakeholders.

  The **System of Air Quality and Weather Forecasting and Research (SAFAR)** is one such national initiative introduced by the Ministry of Earth Sciences (MoES) to measure the air quality of a metropolitan city, by measuring the overall pollution level and the location-specific air quality of the city. It gives real-time air quality index along with a 72-hour advance forecast.

- Strengthen capacity to issue routine press releases regarding air quality. Develop capacity to use one or two media channels to communicate AQ Information. The Indian Institute of Technology (IIT) Tirupati, has developed an Android application "AiR: Pollution visualizer" to visualize air pollutants using augmented reality i.e. it will help the user "see" air pollution levels in their surroundings. Similar apps can be made by cities to create awareness around air pollution.

2.6.2 Monitoring and Review

The progress of the action plans should be assessed fortnightly and any foreseen challenges shall be discussed and addressed. Strategies must be made to ensure effective implementation of action plans.

Further a monitoring and evaluation (M&E) plan to assess effectiveness of implemented action plans should be formulated. The purpose of M&E strategy is to:

- Track progress and impact of action plans.
- Steering committee and monitoring committee review meetings should be held quarterly. Similarly, the implementation committees should meet once every month to assess the implementation progress
- Assess more effectively how far the objectives are being achieved.
- To determine if the outputs, deliveries, and schedules planned have been reached so that action can be taken to correct the deficiencies as quickly as possible.
- Outline specific steps and tools for informed decision making.
- Develop plans for data collection, analysis, use, and data quality.
- Carry out oversight activities and program evaluation.
- Outline various roles and responsibilities regarding M&E with a view to tracking progress and demonstrating results.

An M&E plan should be developed when the interventions are being designed. This will ensure there is a system in place to monitor the program and evaluate success. Steps involved in preparation of M&E plan are outlined in **Box 2**

Box 2: Steps involved in M&E plan

Steps for preparing a Monitoring & Evaluation (M&E) plan

Step 1: Identify Program Goals & Objectives
Clearly define measurable goals/objectives and their targets

Step 2: Define Indicators
Once the goals and objectives are defined, it is time to identify indicators for tracking progress towards achieving those goals.

Step 3: Define Data Collection Methods and Timelines
After identifying monitoring indicators, decide on methods for gathering data and how frequently the data will be recorded to track these indicators. These methods will have important implications to decide the data collection methods which will be used and how the results will be reported.

The source of monitoring data depends largely on what each indicator is trying to measure. The program will likely need multiple data sources to answer all of the programming questions.

Step 4: Identify M&E Roles and Responsibilities
The next element of the M&E plan is a section on roles and responsibilities. It is important to decide from the early planning stages who is responsible for collecting the data for each indicator. To make the program effective, timely collection of data is essential

Step 5: Create an Analysis Plan and Reporting Templates
Once all of the data have been collected, it needs to be analyzed and tabulated for external reporting. Reasons for deviations need to be analyzed and

Step 6: Plan for Dissemination and Reporting
The last element of the M&E plan describes how and to whom data will be disseminated.

Annexures

Annexure 1: CPCB guidelines for Selection of Monitoring Location

Principal factors governing the locations of the sampling stations are the objectives, the particular method of instrument used for sampling, resources available, physical access and security against loss and tampering. Air quality monitoring should be done in areas where pollution problem exists or is expected, i.e., mainly in industrial areas, urban areas, traffic intersections etc. One of the objectives of monitoring is to determine status and trends and the air quality monitoring should be done in metropolitan cities and other urban areas to compare their levels and determine trends. Following should be kept in mind while a selection of monitoring location.

(a) Representative Site

A site is representative of the data generated from the site reflect the concentrations of various pollutants and their variations in the area. It is not easy to specify whether the location of the station is satisfactory or not, however, it may be checked by making simultaneous measurements at some locations in the area concerned. **The station should be located at a place where interferences are not present or anticipated. In general, the following conditions should be met:**

- The site should be away from major pollution sources. The distance depends upon the source, its height, and its emissions. The station should be at least 25 m away from domestic chimneys, especially if the chimneys are lower than the sampling point; with larger sources the distance should be greater.
- The site should be away from absorbing surfaces such as absorbing building material. The clearance to be allowed will depend on the absorbing properties of the material for the pollutant in question, but it will normally be at least 1 m.
- The objective of monitoring is often to measure trends in air quality and measurements are to be conducted over a long time; thus the site should be selected such that it is expected to remain a representative site over a long time and no land use changes, rebuilding etc., are foreseen in near future. The instrument must be located in such a place where the free flow of air is available. The instrument should not be located in a confined place, corner, or a balcony.

(b) Comparability

For data from different stations to be compared, the details of each location should be standardized. The following is recommended:

- On all the sides it should be open, that is the intake should not be within a confined space, in a corner, under or above a balcony.
- For traffic pollution monitoring the sampling intake should be 3 m above the street level. The height of 3m is recommended to prevent re-entrainment of particulates from the street and also to ensure free passage of pedestrians. This will also protect the sampling intake point from vandalism from public.

- Sampling in the vicinity of unpaved roads and streets results in entrainment of dust into the samplers from the movement of vehicles. Samplers are therefore to be kept at 200 m from unpaved roads and streets.

(c) Physical requirement of the monitoring site

Following physical aspects of the site must be met:

- The site should be available for a long period of time
- Easy access to the site should be available throughout the year.
- Site sheltering and facilities such as electricity of sufficient rating, water supply, communication etc. should be available.
- It should be vandal proof and protected from extreme weather conditions.

Table 19: CPCB guidelines for selection of monitoring stations

Station Type	Description
Type A	**Downtown pedestrian exposure stations** Locate station in the central urban area in a congested, downtown street surrounded by building where there is considerable pedestrian movement. Average daily travel on the street should exceed 10000 vehicles with an average speed of less than 6.7 m/s. Monitoring probe is to be located 0.5 m from the curb at a height of 3 ± 0.5 m
Type B	**Downtown neighborhood exposure station** Locate station in the central urban area but not close to any major street. Specifically, streets with average daily travel exceeding 500 vehicles should be located at least 100 m away from the monitoring station. Typical locations are parks, malls or landscaped areas having no traffic. Probe height is to be 3 ± 0.5 m above the ground.
Type C	**Residential Station** Locate station amid a residential area or sub-urban area. Station should be more than 100 m away from any street having a traffic volume more than 500 vehicles/day. Station probe height must be 3 ± 0.5 m.
Type D	**Mesoscale Station** Locate station in the urban area at an appropriate height to collect meteorological and air quality data at upper elevations. The purpose of this station is not to monitor human exposure but to gather trend data and meteorological data at a different height. Typical locations are tall buildings and broadcast towers. The height of the probe, along with the nature of the station location must be carefully documented in each case.
Type E	**Non – urban station** Locate station in a remote non- urban area having no traffic and no industrial activity. The purpose of this station is to monitor for trend analysis for non – degradation assessments and large scale geographical surveys, the location or height must not be changed during the period over which trend is examined. The height of the probe must be documented in each case. A suitable height is 3 ± 0.5 m.
Type F	**Specialized source survey station** Locate station very near to a particular air pollution source. The purpose of this station is to determine the impact on air quality, at specified locations, of a particular emission source of interest. Station probe height should be 3 ± 0.5 m unless special considerations of the survey require non – uniform height.

Annexure 2: Checklist for Air Quality action plan

Checklist for development of Air Quality Action Plan				
Below checklist assesses whether an action plan includes all necessary components of not (To be filled by Air Quality cell)				
S. No	**Activity**	**Yes**	**No**	**Remarks/Notes**
1	**Formation of Implementation Committee**			
1.1	Project Management Unit or Air Quality cell formation at city level done? (Yes/No)			
1.2	Do the action plans include institutional framework along with roles/responsibilities of all stakeholders? (Yes/No)			
2	**Situation Assessment**			
2.1	Evaluation of Socio-economic profile of city done? (Yes/No)			
2.2	Identified land use and land cover pattern of city? (Yes/No)			
2.3	Meteorological and Topographic analysis being done? (Yes/No)			
2.4	Regular measurement, monitoring and analysis of air quality data from CAAQMS and manual monitoring stations being done? (Yes/No)			
2.5	Estimation done for number of monitoring stations required by city? (Yes/No)			
2.6	Identified emission sources? (Yes/No)			
2.6.1	Whether emission inventory made for city? (Yes/No)			
2.6.2	Conducted source apportionment study (Dispersion and Receptor Modelling)? (Yes/No)			
2.6.3	Forecasting of future scenarios with respect to Air quality done? (Yes/No)			
2.6.4	Validation of dispersion Modelling and Receptor Modelling results done? (Yes/No)			
2.7	Assessment of health impacts due to Air Quality from past studies/reports done? (Yes/No)			
3	**Objective, Targets and Gap Assessment**			
3.1	Are Objectives clearly defined? (Yes/No)			

S. No	Activity	Yes	No	Remarks/Notes
3.2	Are targets set for air quality action plan? (Yes/No)			
3.3	Gap assessment done based on target air quality and existing air quality? (Yes/No)			
4	**Control Measures**			
	Have the control measures been formulated to ensure coverage of all below sectors ? (Yes/No)			
4.1	Industries			
4.2	Transport (Vehicular)			
4.3	Road dust			
4.4	Construction			
4.5	Municipal Solid waste			
4.6	Air Quality Monitoring			
4.7	Transboundary air pollution			
4.8	Biomass Burning			
4.9	Domestic (Household)			
4.10	DG sets			
4.11	Public Awareness/Capacity Building			
4.12	Indoor Air Pollution			
4.13	SLCP			
5	**Assessment of Control Measures**			
	Do all control measures include information on:			
5.1	Timelines: Expected start date and completion date (Yes/No)			
5.2	Financial Requirements (Yes/No)			

S. No	Activity	Yes	No	Remarks/Notes
5.3	Technical Feasibility of control measure (Yes/No)			
5.4	Responsibility for each agency involved (Yes/No)			
5.5.	Cost-benefit analysis (Yes/No)			
6	**Prioritization of control measures**			
6.1	Prioritization of control measures done? (Yes/No)			
7	**Budget**			
7.1	Has the action plan estimated total finance requirement for meeting the targets?			
8	**Communication**			
8.1	Has the action plan been communicated to public for feedback? (Yes/No)			
9	**Implementation**			
9.1	Implementation plan prepared for control measure? (Yes/No)			
10	**Monitoring and Review**			
10.1	Does the action plan include mechanism to review the progress of control measures? (Yes/No)			
10.2	Does the action plan include mechanism to assess impact of implemented control measures? (Yes/No)			
10.3	Are the action plans being updated based on feedback from implementation stage? (Yes/No)			
11	**Approval**			
11.1	Has the action planned been signed and acknowledged by all stakeholders? (Yes/No)			

Annexure 3: Template for recording control measures

S. No.	Control Measure	Benefit-Cost Ratio	Technical Feasibility	Requirement of Financial Resources	Implementation Period (Short /Medium/Long term)	Timelines	Responsibility	Remarks
1								
2								
3								
4								
5								
6								
7								

ILLUSTRATIVE

Annexure 4: Example of Emergency Response Action Plan (Beijing)

Air Warning Standards		
Level	Standard (24-hour average AQI level)	Mandatory Measures
Blue	AQI forecast > 200 for 1 or more days	None
Yellow	AQI forecast > 200 for 2 or m**Air** ore days	a. Additional Road Cleaning b. Construction Limitations
Orange	AQI forecast > 200 for 3 or more days AND AQI forecast > 300 for 2 consecutive days	a. Additional Road Cleaning b. Construction Limitations c. Nat I & II cars restricted from rush hours d. Construction vehicles prohibited e. Designated pollution industries shut f. Fireworks, outdoor barbecues banned
Red	AQI forecast > 200 for 4 or more days AND AQI forecast > 300 for 2 consecutive days OR AQI forecast > 500 for any 1 24-Hour period	a. Additional Road Cleaning b. Construction Limitations c. Nat I & II cars vehicles prohibited; Others restricted on odds/ evens basis; City vehicles to additionally reduce overall usage by 30% d. Construction vehicles prohibited e. Designated pollution industries shut f. Fireworks and outdoor barbecues banned

Annexure 5: Management practices for Air Quality Management

S. No	Name of Practice	Description
1	Strengthened governance structure	The success of efforts to clean the air is determined by governance structures and policies unique to each country. To achieve cleaner air, policies and strategies need to be developed within the limits of existing governance structures. They should be undertaken in partnership with key stakeholders such as government agencies, private sector businesses and civil society, which all have a role to play in implementing strategies to achieve better air quality. There must be a consensus among key stakeholders on suitable institutional arrangements including the institutional responsibilities, coordination and planning, political support, financial resources, technical capabilities. Collaboration and coordination of structures and responsibilities are essential for the implementation of actions, budgets, and a time frame for each action plan. Institutional arrangements, laws and regulations are important parts of an AQM. It is important to ensure that stakeholders expected to implement key AQM strategies have the legitimacy and powers to effectively implement them. A range of local, regional, and national government agencies may have overlapping responsibilities in areas of AQM including local government, environment, energy, transport, industry, planning, finance, health, and other institutions including meteorological departments and research institutes. These overlapping responsibilities need to be clearly defined.
2	Emission Inventories and Management	An Emission inventory(EI) is a listing, by source, of the amounts of air pollutants and this information from EIs can be used to establish emission trends and determine hotspots and exposure areas. Complementary to information provided by EIs and dispersion models, Source Apportionment (SA) of pollutant contribution is likewise necessary for the development of sector-specific city clean air action plans. Results from EI and SA can be integrated into mathematical models to estimate probable changes in observable pollutant concentrations that are expected to occur if recommended control measures are implemented. Hence, cities must get Emission Inventory and Source Apportionment study done.
3	Use of economic instruments	Economic or market-based instruments rely on market forces and changes in relative prices to modify the behaviour of public and private polluters in a way that supports environmental protection or improvement. In contrast to regulatory instruments, economic instruments have the potential to make pollution control economically advantageous to commercial organizations and lower pollution abatement costs. The principal types of economic instruments used for controlling pollution are: • **Pollution charges**: A pollution charge or tax can be defined as a "price" to be paid on the use of the environment.

S. No	Name of Practice	Description
		• **Marketable permits**: Under this approach, a governing authority sets maximum limits on the total allowable emissions of a pollutant. It then allocates this total amount among the sources of the pollutant by issuing permits that authorize industrial plants or other sources to emit a stipulated amount of pollutant over a specified period . • **Subsidies**: These include tax incentives, grants and low interest loans designed to induce polluters to reduce the quantity of their discharges by investing in various types of pollution control measures. • **Deposit-refund systems**: Under this approach, consumers pay a surcharge when purchasing a potentially polluting product. When the consumers or users of the product return it to an approved center for recycling or proper disposal, their deposit is refunded. • **Enforcement incentives**: These instruments are penalties designed to induce polluters to comply with environmental standards and regulations.
4	Private sector involvement	Air quality management should not only be left to the government officials and role of private sector should be encouraged in areas such as source apportionment, health impact studies, etc. The private sector, particularly financial institutions, can complement government efforts by supporting investment that reduces air pollutants. The private sector can also support innovation in clean technologies, sustainable products, and clean air solutions. Increasing health problems and decreasing employee productivity must be of great concern to all businesses. They must recognize the problems associated with air pollution and act in ways to ensure cleaner air quality for all.
5	Citizen engagement	Public participation is viewed as integral to effective air quality management. Citizens have greater access to information and are demanding to be more involved at early stages of the policy development process. In many countries, data are available via the internet and people can determine for themselves the sources of local pollution. Citizens can use that information to influence decisions of governmental entities or the industry directly. Before finalizing any policy, draft needs to be made available for citizens to get their views. The comment period provides an opportunity for citizens to participate in the decision-making process. This will also ensure high level commitment from them during the enforcement stage.

S. No	Name of Practice	Description
6	Health impact studies	If there were no impacts of air pollution, there would also be no need for action plan. 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. Strengthening the capacity for health and environmental impact assessment helps shape and define policies for improving air quality. Hence it is important to conduct Health Impact Assessment (HIA) vis-a-vis air pollution for each city.
7	Embedding AQM in smart cities and linking it to SAPCC	For non-attainment cities, air quality management programme can be embedded within the smart city framework for better implementation. Smart city mission includes features like reduce congestion, air pollution and resource depletion, boost local economy, promote interactions, and ensure security. The road network is to be created or refurbished not only for vehicles and public transport, but also for pedestrians and cyclists, Promoting a variety of transport options – Transit Oriented Development (TOD), public transport and last mile para-transport connectivity. Since the Smart Cities Mission has air pollution abatement measures as its key components, it will be easier to implement action plans and enhance pollution reduction target after the mid-term review. State governments should ensure that for their non-attainment cities, clean air action plans should also be integrated with State Action Plan for Climate Change (SAPCC). As five out of the eight missions under NAPCC have direct link with mitigation of air pollution, so this can be one of the co benefit of these ongoing missions.

Annexure 6: Compendium of control measures for different sectors

Transport Sector

S. No	Name of Practice	Description
1	Switch over to cleaner fuels	Use of cleaner fuels like LPG/CNG (particularly for heavy-duty diesel buses and trucks or two-stroke three-wheelers, which are considered as most polluting source) and Electric Vehicles can go a long way in curbing vehicular pollution. Gaseous fuels lower particulate emissions significantly compared with conventional diesel. For successful fuel switching, however, it is necessary to consider fuel availability and distribution networks; refueling infrastructure; and costs related to vehicle modification, maintenance, and operation.
2	Improve fuel quality	In order to support increasingly tighter emission standards, fuel specifications need to be made stringent with time. The European emission standards have gradually transitioned from Euro 1(1992) to Euro 7 (2020-21) and have gone a long way in reducing air pollution in European countries. Transition to the new standards can become an uphill task for original equipment manufacturers (OEMs) for making new cars compliant as this needs high investment for technology upgrade. India also is on track to about to adopt BS VI norms (Equivalent to Euro 6) from April 2020. Biofuels such as ethanol and biodiesel should also be actively promoted
3	Installation of catalytic converters in vehicles	A catalytic converter is an exhaust emission control device that reduces toxic gases and pollutants in exhaust gas from an internal combustion engine into less-toxic pollutants by catalyzing a redox reaction. As part of an air pollution abatement program, the use of catalytic converters has been mandatory in Mexico City since 1991. Every car that is exported from India has a catalytic convertor in Mexico, but the same car in India does not have it.
4	Install vapour recovery systems in fuel refueling outlets to reduce benzene emissions	Petrol refueling stations are a major source of benzene emission which is a carcinogenic compound and people in its vicinity can be at risk of its exposure. Vapour recovery device is an instrument to capture displaced vapours that emerge from inside a vehicle's fuel tank when petrol or diesel is dispensed into it.
5	Installation of Diesel Particulate Filter(DPF)	A diesel particulate filter (DPF) is a device designed to remove diesel particulate matter or soot from the exhaust gas of a diesel engine. DPF remove 99.9% of particles coming from the engine, including ultrafine particles. The installation of DPF filters will help reduce emissions from these vehicles by at least 70%. DPFs have been made mandatory in European countries since 2011, when the Euro 5b exhaust emission legislation was introduced.

S. No	Name of Practice	Description
6	Restricted use of vehicles on road (No-drive days)	Instead of implementing odd-even scheme, which is not possible to implement throughout the year, Mexico adopted a system where a car would remain off-road for only one day per week. Under this scheme, the movement of vehicles depended on the last number of the registration plate. This helped Mexico in keeping nearly 2.3 million vehicles off the road on a given day. But additional measures to supplement this program are required as after a certain duration, better-off households can invest and buy extra cars, as it happened in Mexico.
7	Labelling of vehicles and phase out policy for older vehicles	To counter vehicular emissions, cities like Beijing issues yellow labels to vehicles (YLV) whose emission levels fail to meet a set criteria and green labels to those that do. These criteria can be revised with time to ensure effectiveness of the system. Through this policy, also known as an accelerated vehicle retirement (AVR) program, the government accelerates the scrappage of YLVs by giving subsidies to owners.
8	Intelligent Traffic Management system	Intelligent Transportation Systems (ITS) has emerged as an important element for both improving air quality and economy with the main objective of optimizing road traffic by managing the capacity of the roads, improving driver safety, reducing energy consumption and improving the quality of the environment. Real time information can influence drivers to take alternative routes around congested areas, alleviating air pollution hotspots.
9	Promote use of public Transport	Use of public transport such as Bus Rapid Transit (BRT) and Mass Rapid Transit (MRT) is an effective way to reduce vehicular pollution. BReno htiw selcihev llams evfi ro ruof ecalper ot elbissop ti ekam smetsys T larger vehicle, which can then operate more rapidly and smoothly with shorter dwell times. When trunk lines are integrated, physically and in ticketing arrangements, with a system of feeder services they have proved capable of maintaining or increasing the public transport share of trips even when incomes are increasing. Results from countries like Mexico show that that BRT constitutes an effective environmental policy, reducing emissions of CO, NOX, $PM_{2.5}$ and PM_{10}. A strong MRT network can reduce congestion even in big cities as it encourages masses to shift from private vehicles to using public transportation sercfifart ,noitullop ria edulcni stfieneb-oc htlaeh ehT .seciv injuries and physical activity.

S. No	Name of Practice	Description
10	Encouraging Nonmotorized Transport (NMT)	In many developing country cities, walking or using other nonmotorized forms of transport is so inconvenient and dangerous that even very short motorized trips are uncommon. Eliminating impediments to NMT by providing adequate sidewalks and bicycle lanes and ensuring the safety of pedestrians and cyclists can deter the use of the most polluting motorized vehicles for short trips. Segregated lanes for bicyclists and pedestrians enhance public safety and encourage people to adopt NMT. Strong NMT network will also reduce physical injuries.
11	Link Pollution Under Control (PUC) certificate with insurance	Making PUC mandatory before renewing insurance for vehicles can put a check and improve compliance of vehicle emissions.
12	Tighten pollution control norms for newer vehicles.	With the advancement of technology, stricter emission limits to be gradually placed on carbon monoxide, total hydrocarbons, nitrogen oxides and particulate matter produced by new motor vehicles. Countries like China have been gradually tightening the vehicular emission norms with time along with systematic planning to bring for smooth transition.
13	Incentives & Taxation	• Introduction of subsidies and incentives can encourage masses to shift to environment friendly transport system: ✓ Subsidies for phasing out old vehicles ✓ Subsidies/Incentives for adoption of cleaner fuel vehicles such as CNG and Electric Vehicles ✓ Subsidizing public transport fares to encourage modal transport shift. • **Road Pricing or Taxation for Congestion:** Direct road pricing includes charges for entering or traveling within a designated part of the city experiencing congestion, for use of selected road links, or for parking. In the few cases in OECD countries where direct cordon or area congestion prices are charged, part or all of the revenues have been earmarked for public transport improvements. For cities in developing countries that lack resources to finance urban transport, the introduction of direct charges might be expected to have a double attractiveness: that is, as a source of finance as well as an instrument of restraint. Congestion charging, introduced in 2003 in London, appears to have been successful in shifting motorists to public transport and reducing journey times. The major focus of the charge was to reduce traffic congestion in the designated charging zone. • Imposition of charges on non-destined trucks. • Check overloading of heavy vehicles through weigh-in-motion (WIM) bridges at entry points in a city.

S. No	Name of Practice	Description
14	Check Fuel adulteration	Strict enforcement mechanisms to prevent adulteration of petrol and diesel with kerosene. Deploy teams to carry out random checks at fuel outlets.
15	Parking Policies	Non-availability of adequate parking space leads to congestion and traffic jams and ultimately polluting the air. Urban land is valuable. **Graded parking fee should recover the cost of the land.** This should be used as a means to make use of public transport and make it more attractive. Studies have indicated that parking charges does influence commuting choice. Public transport vehicles and non-motorized modes of transport should be given preference in parking space allocation. Use of **multilevel parking** can also reduce decongestion.
16	Using of Taxibots to tow aircrafts	Aviation industry also contributes to air pollution. Taxibot is a robot-used aircraft tractor for taxiing an aircraft from parking bay to runway and vice versa. With Taxibot, it is possible to tow an aircraft from the parking bay to the runway with its engines switched off. It is basically a pilot controlled semi-robotic towbar-less aircraft tractor, used as an alternate taxiing equipment. Taxibots will also help in decongesting boarding gates. The TaxiBots can bring down fuel consumption used during taxiing by 85%. At present the cost of a taxibot is on higher side (INR 118 crores), but with technology advancement this is expected to come down.
17	Improved infrastructure for high fuel efficiency	Adequate infrastructure for maintenance (service centers) and testing (CNG hydro testing, PUC centers, laboratories) of vehicles and fuels is necessary to improve fuel efficiency. **Installation of Onboard diagnostics (OBD):** OBD systems monitor emission control components for any malfunction or deterioration that cause emission limits to be exceeded and alert the driver of the need for repair via a dashboard light when the diagnostic system has detected a problem. BS6 complaint vehicles come fitted with these systems.
18	Construction of highways to reduce traffic congestion	Building of expressways and highways as well as alternative routes/bypass roads can reduce congestion and improve air quality.

Industrial Sector

S. No	Name of Practice	Description
1	Switching to cleaner fuels (Natural Gas)	Promotion of use of cleaner fuels such as natural gas to curb air pollution. Ban the use of fuels with high Sulphur content such as heavy furnace oil and pet coke and move towards cleaner fuels like PNG. Cities like Delhi-NCR have already implemented this initiative.
2	Flue Gas Desulphurization and Denitration technologies in industries.	Sox and NOx emitted from industrial combustion contribute to air pollution. Moreover, these also form secondary sources of particulate matter and these must be controlled. China has made it mandatory to have desulphurization units installed in all coal fired boilers greater than 20 TPH.
3	Emission reductions from coal combustion sources (small boilers)	In India there are several small-scale units(MSME) manufacturing units using coal-fired boilers which contribute significantly in air pollution. Countries like China accelerated the construction of **centralized heating, "coal-to-gas" and "coal-to-electricity"** for small boilers and by 2017, except for the necessary reservations, coal-fired boilers of 10 steam tons per hour or less were eliminated in built-up areas at prefecture level and above. It is forbidden to build new coal-fired boilers below 20 steam tons per hour; in other regions, in principle, no new coal-fired boilers below 10 steam tons are built. In areas where the heating and gas supply network cannot be covered, use electricity, new energy, or clean coal, and promote the application of energy-efficient and environmentally friendly boilers. In the chemical, paper, printing and dyeing, tanning, pharmaceutical and other industrial agglomeration areas, dispersed coal-fired boilers have been planned to be phased out through the centralized construction of **combined heat and power units (CHP)**. Based on the above, following measures can be practiced in India: • **Explore possibility of developing common infrastructure in new industrial clusters on the pattern of the CETP (Combined Effluent Treatment Plant):** In MSME clusters instead of every unit having an individual boiler, centralized boilers can be installed which can make operation & maintenance simpler and more efficient. Similarly, a common DG for power back up can also be installed for efficient operation. • **Examine feasibility of restricting size of industrial units for their enviro-economic sustainability:** Explore possibilities to restrict installation of small coal fired boilers (E.g. below 10 tph). Also, installation of higher capacity units leads to higher efficiency. • **Feasibility to permit new industries in the polluted areas with stringent norms can be explored:** For clusters which already are dirty (polluted), setting up of more similar industries can be restricted. "Let's clean the polluted areas and not make the clean areas polluted."

S. No	Name of Practice	Description
		• Emission norms should be more stringent for newer units being set up, as they would have access to more advanced technology. • Certain energy intensive sectors should only be allowed to operate as large-scale industries instead of large number of small-scale industries to reduce pollution. • Development of emission standards by SPCBs for state specific industries
4	Upgradation of brick kiln manufacturing technology	Brick kilns are recognized as one of the largest stationary sources of black carbon. Among the brick kiln zigzag kiln have higher efficiency and lower emissions as compared to Fixed Chimney Bull Trench Kiln (FCBTK) and down-draught kiln. India needs to ensure that all kilns are converted to zig-zag technology. Conversion to Zig-Zag technology needs smaller investment, offer easy integration with the existing production process of FCBTKs and has shorter paybacks.
5	Installation of CEMS	Continuous emission monitoring system (CEMS) is real-time air pollution monitoring systems and important tools for pollution monitoring, control, and reporting. The systems ensure data accuracy, higher monitoring frequency, minimal manual intervention, firm regulatory monitoring, and better transparency to strengthen the pollution control regime. Continuous emission monitoring of stationary sources has been made mandatory in many industrialized and developing countries like the US, EU, China, and Brazil. In India, CEMS is mandated by the Indian government for power plants & only 17 other grossly polluted industries. CEMS can be brought in regulatory framework for all industries and used as a tool beyond compliance.
6	Implementation of fiscal measures	**Emission Charge:** An emission charge is a fee or tax per unit of pollutant emission and is based on the polluters' pay system. The charge is levied on the level of pollutant emitted. The charge is intended to provide an incentive to encourage use of lower emission technology. Revenues collected can be used to finance emission reduction measures. Emission charge scheme has been applied in aviation in countries such as Switzerland, Sweden, France, UK and Germany. **So2 and NOx charges** In many European countries, these are introduced in conjunction with permit system. A base charge is applied to all pollution within the permitted level and a penalty rate is added above that level. Large point sources are subjected to these charges. The fines, non-compliance fees, are intended to provide incentive to reduce pollution to permitted levels and play a compliance function.

S. No	Name of Practice	Description
		Refund based tax system for NOx Practiced in Sweden, this approach is designed to provide an incentive to the participants to reduce emissions. The system imposes tax on the emitting sources based on their emission and then redistributes the revenue so collected to the sources in proportion to their energy production. While the tax is collected on the basis of emissions, it is rebated(redistributed) to them in proportion of energy production. That is, the plants, which produce more energy with less emissions, would benefit more from the system. **Sulphur tax:** In 1991, Sweden had also imposed Sulphur tax which was applicable to fuel oils and coal having Sulphur content more than 0.1% . It was observed that a remarkable reduction in the Sulphur content of oil products was achieved due to Sulphur tax. **Fuel and Environmental taxes:** Fuel taxes are indirect taxes charged on the polluting fuel so as to increase the price of fuel and the product and services using the polluting fuel. On the other hand, environmental taxes are either charged to the goods used as input in polluting activity. Germany in 1999, had levied eco-tax which is similar to environmental tax. It was designed to energy and resource consumption more expensive, while lowering the cost of labour. This system increased the prices of electricity, oil and as considerably. A considerable portion form the eco-tax revenue was used to promote renewable energy. **Emission trading system:** If a source or a firm reduces emission below the level required, the extra reduction is credited to the source. The credit so earned by the firm can or another firm to comply with the emission allowance. As the cost of pollutant abatement will be different for different firms, some firms may opt for buying the credits from other firms if the formers cost of abatement is higher than that of the latter. This mechanism is called emission trading.

Solid Waste Management

S. No	Name of Practice	Description
1	Source Segregation and collection of waste	Burning of waste/garbage in in open at public places and landfills causes air pollution. Hence it is important that at both household level as well as at commercial level, segregation of waste at source is done so that waste can be recycled and reused. The practice of waste segregation is even more important for cities which do not have landfill sites. This does not require any additional investment but awareness. Cities like Panaji (Goa) requires households to segregate wastes into five fractions-wet waste, plastic, paper and cardboard, metal and glass, and non-recyclables. A proper waste-collection mechanism is needed to ensure safe transportation and treatment of the generated waste.
2	Composting Plants	The composting process utilizes wet waste. Through composting, the amount of garbage sent to the landfill is reduced, the organic matter is reused rather than dumped, and it is recycled into a useful soil amendment. Hence it is important to have composting plants in each city. Several composting technologies like vermicomposting, aerated stack-pile composting, and in vessel are currently available, but windrow method is suited to producing large volumes of compost. In India, as per MSW Rules 2016, it is mandatory for fertilizer companies to use city compost as raw material. Hence tie-ups to be done with the national fertilizer companies for long term sale of compost.
3	Bio-Methanation plants	About half of the solid waste generated in Indian cities is biodegradable. If this waste is segregated at source, it can be collected and delivered to a local bio methanation plant for anaerobic processing. Unlike composting in which biogas is released into the environment, bio methanation allows the capture of biogas which can be used for cooking or for electricity generation; it also produces liquid fertilizer.
4	Waste to Energy (W2E) Plants/Incinerators	When operated properly W2E plants are a good option for disposable of non-recyclable waste. For effective operation W2E plants requires a continuous supply of segregated waste with a sufficiently high calorific value and low moisture content. Even though it is often claimed that incineration can take unsegregated waste, segregating biodegradable waste and inert waste also helps improve the calorific value of dry waste.
5	Reused Derived Fuel (RDF) Plants	Refuse-derived fuel (RDF) is a fuel produced from various types of waste such as municipal solid waste (MSW), industrial waste or commercial waste. RDF consists largely of combustible components of such waste, as non-recyclable plastics (not including PVC), paper cardboard, labels, and other corrugated materials. RDF can be used in a variety of ways to produce electricity. It can be used alongside traditional sources of fuel in coal power plants. In Europe RDF has been used in the cement kiln industry. RDF pellets can have CVs up to 4000 kCal/kg.

S. No	Name of Practice	Description
6	Recycling	Recycling waste material like paper, cardboard, glass, bottles, e-waste, etc., is essential. Kamikatsu (Japan) and Canberra (Australia) have recycle rate greater than 80%.
7	Policies/ Strong enforcement mechanisms	Incentives for segregation and penalty for non-segregation must be the first action point of any agenda on municipal solid waste management. Enforcement of ban on open burning of garbage/solid waste. In US and UK, deposit-refund scheme for drinking bottles and cans has reduced littering and increased recycling. Japan has a Home Appliance Recycling Law where in Consumers are asked to pay a collection and transport fee and a recycling fee when disposing of End-of-Life(EoL) home appliances.
8	Community based waste management	Introduce solid waste management systems that are decentralized and community-based and at the same time reduce the extreme poverty of informal sector waste pickers. Community-based composting has been practiced in China, Indonesia, and Philippines.
9	Prevention of stubble burning	Farmers resort to burning the stubble as it is an easy option and the costs are low. Since the problem of stubble burning pertains to lower income grade, so the local governments should adopt fiscal incentives to control this menace. Some good practices include: • **Happy Seeders**: Machines that cut and lift the crop stubble, sow the wheat, and deposit the straw over the sown area as mulch. Need to ensure through affordability of happy seeder through government subsidies. • **Waste Decomposer:** The use of waste decomposer in fields can convert crop residue into compost. The method involves a 'waste decomposer', a solution concocted with effective microorganisms that propel in-situ composting of the crop residue. This is done by spraying the preparation on the post-harvest stalks of crop plants and leaving it for a month. In India, the waste decomposer comes in a small bottle that is distributed to farmers at a measly price of ₹20. • **Incentivizing farmers to grow crops that are not water intensive:** In areas like Punjab (India), where there is underground water crisis and since paddy is a water-intensive crop, farmers can be made to shift towards millets, which are suitable for the land available in Punjab and are highly nutritious. Crop rotation should also be encouraged. • **Turn unwanted straw into bio-energy pellets:** The paddy straw can be used to make briquettes/pellets and used as blended fuel in industries. India produces more than 550 million tonnes of crop residue every year, so there is a considerable potential for conversion. This will need setting up of the infrastructure for collection, transportation, and conversion of crop residue into pellets. • Besides making farmers aware of the consequences of crop burning, need to ensure strict enforcement by deploying additional teams to prevent crop burning.

C&D Waste Management

S. No	Name of Practice	Description
1	Preparation of environmental management plan	A site-specific environmental plan a must before start of construction & demolition activities. The plan should include site-specific design elements, operating practices, specific technologies, products, and equipment that will be applied to prevent or control emissions from all sources and also include management of solid and liquid waste.
2	Use of water and dust suppressants at construction sites	Water and dust suppressants can be applied to mitigate fugitive dust from site preparation, storage piles, materials handling, and transfer. Water is the most common of the two as it is cheap. The chemical suppressants though are expensive than water but are very effective. The two most frequently used dust suppressant options are calcium chloride and magnesium chloride, which are hygroscopic (moisture attracting) materials that draw moisture from the air to provide extended dust suppression. It is important that these suppressants are utilized keeping in mind any environmental consequences their usage can have.
3	Mitigate Traffic Congestion	Wherever possible, traffic should be re-routed and diverted from major construction sites. In case not possible, rapid on-site construction can also reduce the duration of traffic interference and therefore reduce emissions. U.S. Transportation Research Board adopted practices such as **off-site fabrication of structures such as bridges to reduce the duration of on-site road construction.**
4	Efficient management of storage piles of construction materials	• Storage pile activity (i.e. loading and unloading) should be confined to the downwind side of the storage pile. This practice applies to areas around the storage pile as well as the pile itself. Storage piles should also be located away from downwind site boundaries. • Covering or enclosures (three sided bunkers, silos) of inactive piles is an effective way of reducing fugitive dust emissions. For small scale construction, Tarpaulins can also be used as a temporary covering, but they should be properly anchored to prevent the wind from removing them. • Use of wind fences or screens for storage piles can reduce wind velocity and thereby reduce emissions. • The shape of the storage pile should be maintained so that they do not have steep sides. • Construction material inventory should be made strategically. Material should not be ordered unless it is to be used shortly after delivery. • Restriction on storage of construction materials along the road.

S. No	Name of Practice	Description
5	Transfer and handling of construction materials	• Minimum drop heights to be maintained during transfer of materials onto vehicles and conveyor belts. When feasible, the transfer points should be enclosed from top and sides. Conveyor belts should be equipped with belt wiper and hoppers of proper size to prevent excessive spills. • Elimination of dirt track out/carryout can thus significantly reduce paved road emissions. Need to take control measures such as wheel washing to ensure removal of material from truck underbodies and tires prior to leaving the site as well as techniques to periodically remove dirt track out/carryout from paved streets at the access point(s). The accumulated dirt or similar debris deposited on paved roads should be removed and cleaned at the end of each day. In urban areas, this cleaning should be undertaken immediately if the track out/carryout extends more than 10 meters (33 feet) onto the paved public road. • Use of **foam system** on material transfer systems. They provide adequate control at lower moisture addition rates than water spray systems. • Deployment of closed tankers/trucks with enclosures for transfer of transportation of material to a construction site. • During very windy conditions, where feasible, specific material handling/transfer activities that generate greater levels of dust may be avoided or reduced. Instead, these activities can be conducted at a fast pace when more favourable weather conditions occur. • Limiting the speed of vehicles transferring construction materials can also mitigate fugitive dust emissions.
6	Demolition/destruction techniques	Most often deconstruction and demolition activities lead to heavy pollution, which can be reduced by following few good practices: • Buildings should to the extent be deconstructed rather than demolished so that materials can be reused in other buildings. Deconstruction generally results in lower fugitive dust emissions compared to demolition. • Blasting must be avoided wherever possible. • Debris materials should be dropped from minimum height and in sequential stages for large distances. • Use of enclosures to cover chutes dropping demolished materials. • Fogging system can be used to inject fog into fugitive dust area to increase moisture in dust and thereby settling it down. • While loading debris in trucks, if possible, fine debris should be placed into the truck bin first, followed by larger debris on top. Alternatively, if possible, dry debris should be placed into the truck bin first, followed by wet debris on top. • Avoid prolonged storage of debris on site and its exposure to wind.

S. No	Name of Practice	Description
7	Waste segregation	Segregation (concrete, soil, steel, wood and plastics, bricks, and mortar) of C&D waste and depositing it to the collection centers for processing is important to ensure effective utilization. To ensure this there is a need to have strong collection, processing, and disposal system for waste.
8	Recycling of construction wastes	Recycling of the waste matter is a vital aspect of the management process. The recycled aggregate can be used as general bulk fill, sub-base material in road construction, canal lining, fills in drainage projects or for making new concrete. Other products such as metals or wood can be subjected to suitable recycling methods for reuse. **Due to strictly enforced waste disposal laws and disposal fees that encourage recycling, over 90% of C&D waste produced in Germany is utilized for a wide range of applications.** In developing countries like India there is a need to develop C&D waste recycling facilities to increase utilization of construction waste.
9	Maintain good road conditions within the construction site	To mandate facility of tar road inside the construction site for movement of vehicles carrying construction material can help in controlling construction dust.
10	Restriction of construction activities during high pollution levels	Enforce restrictions on construction activities within urban airshed zones during high pollution period. Construction should be allowed with control measures in certain areas like airports, railway station, etc., to ensure economic development is not getting hampered.

Road Dust Management

S. No	Name of Practice	Description
1	Pavement of roads/Road Maintenance	Unpaved roads are the primary reason for road dust and needs to be followed. Need to ensure that no road patch remains unpaved. Paving the roads carpet to carpet is essential. Maintain pot-hole free roads for free flow of traffic to reduce emissions and dust. Local bodies need to chalk out plans to improve conditions of all roads.
2	Mechanized road cleaning	Manual sweeping by brooms release the dust otherwise settled on road back into the air, polluting it further. This proves to be counterproductive. High speed mechanized sweeping machines should be deployed. Some key points for this practice include: • Focus on removing the smallest particles and not only large debris • Use street sweepers that collect data. Newer street sweeper models have the capability to collect data while they sweep. If sweepers collect this data, it can be examined closely to further refine street sweeping routes and practices.
3	Soil stabilization	The stabilization of soil and aggregate is being used worldwide towards optimal usage of scarce resources. Though soil stabilization exists in Indian codes since last several decades, the concept is yet to be utilized on ground in any significance. The concept of "Cold in Place Recycling ("CIPR)" and Cement treated base ("CTB") have been approved by NHAI and provide a comprehensive solution for restoration of existing road network. The incorporation of stabilization technique will ensure more durable, longer lasting roads and hence lead to lower dust pollution.
4	Reducing volume of traffic on unpaved roads	Vehicles traveling on unpaved roads stir up dust. Reducing the number of vehicles can reduce dust. Traffic can be reduced voluntarily; encouraging walking is one way. Traffic can be reduced by restricting vehicle weight or type, or by limiting motor vehicle access to dirt roads.
5	Reduce traffic speed	Fast moving vehicles stir up dust. PM_{10}, or dust, goes up with vehicle speed. Reducing speed from 40 miles per hour (mph) to 20 mph reduces dust emissions by 65%. Speed limit signs and enforcement can reduce speeds. This is a must specially in case of unpaved roads.
6	Periodic watering of roads	Cities like Delhi which do not have the advantage of high humidity struggle to combat dust pollution. The moisture content of dirt roads can be increased by watering the road surface. Moisture in the surface of dirt roads causes particles to stick together. Treated STP water should be used for sprinkling

S. No	Name of Practice	Description
7	Increasing moisture content of the road surface through deliquescent salts	Moisture in the surface of dirt roads causes particles to stick together. The moisture content of dirt roads can be increased either through spreading water or by application of deliquescent salts which attract water. Deliquescent salts like calcium chloride and magnesium chloride are a kind of dust palliative. Calcium chloride is both hygroscopic (draws moisture from the air) and deliquescent (resists evaporation and stays in solution).
8	Binding dust particles together through use of chemicals	Dust particles are very fine and so float easily in air. Use of Chemicals which bind fine particles together or onto larger particles can help in reducing the dust pollution. These chemicals fall into several groups, such as petroleum-based, organic nonpetroleum, electrochemical stabilizers, and synthetic polymers. • Petroleum-based Binders include emulsified asphalts, cutback asphalt, and Bunker C. • Organic Nonpetroleum Dust Suppressants include lignosulfonates, and resins. • Electrochemical Stabilizers include sulphonated petroleum, ionic stabilizers, and bentonite. • Synthetic Polymer Products include polyvinyl acrylics and acetates.
9	Increasing green cover of traffic corridor and public places	Covered ground does not blow away and create dust. Each dirt parking area, footpath, shortcut, or eroding bluff can produce dust. Maintaining the native vegetation; replanting barren areas; planting gardens; and just driving only on designated roads or trails can all be dust control measures. Living plants not only cover the ground, but their roots hold soil together as well. Introduce water fountain at major traffic intersection wherever feasible with the use of tertiary treated water
10	Use of wind breaks	Windbreaks are barriers designed to slow the speed and redirect the flow of wind. These can be useful in areas where speed of wind is on higher side. Effective windbreaks do not stop the wind but break its forward movement, to slow it down. Windbreaks can take form of hedge, hedgerow, shelter belt or vegetative barrier. Factors effecting efficiency of windbreaks include height, length, vegetation density, number of rows, continuity, orientation, and species composition.

Domestic Sector

S. No	Name of Practice	Description
1	Use of cleaner fuels in domestic and commercial areas	Cooking simple stoves fueled by kerosene, biomass (wood, animal dung and crop waste) and coal in household and commercial areas (hotels, eateries, etc.) needs to be replaced with cleaner fuels like LPG, electricity, PNG, etc. Hence, there is a need to have policies to facilitate access to these cleaner fuels to all masses.
2	Establish Indoor Air Quality Guidelines	Countries need to have indoor air quality standards for different pollutants which should be legally binding. Countries like Japan and South Korea already have indoor air quality standards. Many countries have also adopted WHO guidelines for indoor air quality. There are no guidelines or standards with respect to indoor air quality in India. The city level clean action plans may start with indoor air quality certifications as earlier described. Indoor air quality in enclosed public places could be the priority. Such a certification scheme will require a good coordination with all the key stakeholders. The certification schemes will have to established at the national level under NCAP. Each city in their air quality action plans could then come up with its adoption, a roll out plan, listing the “hot spots” and explain how the certification scheme will operate. For example, if a movie theatre for instance obtains a certificate on Indoor Air Quality, then it may proudly display on its signage and even print at the backside of the ticket as “Here you can breathe safe”. Surely, this communication will make it as the preferred theatre by the patrons and people will not mind even paying extra amount for that assured safety.
3	Proper ventilation of kitchens	Use of chimney, exhaust fans and windows in kitchens to ensure proper ventilation of smoke from cooking activities. Periodic cleaning of chimney to prevent it is clogging is also needed.
4	Install filtration system/purifiers	Purifiers and filtration system can be installed to ensure clean indoor air. Smoking to be allowed only at designated places.
5	Use of vacuum cleaners	Use of vacuum cleaner to avoid resuspension of dust while performing cleaning activities in domestic and commercial areas.

Ambient Air Quality Monitoring

S. No	Name of Practice	Description
1	Use of low-cost sensors	Real time monitoring of air quality has become indispensable for timely intervention to check pollution levels. The number of monitoring stations should be a representative of population distribution. As per the WHO guidelines, every city needs to have one monitoring station for every 1 million population. So, there is a need to build up infrastructure in the remaining cities. Till the time the monitoring network is strengthened to cover all the non-monitored cities and cities with sparse monitoring stations, the use of quality low cost sensors for collecting base data for trend analysis can be explored. Beijing deployed over 1000 $PM_{2.5}$ monitoring sensor stations, and built a low-cost, high-density grid monitoring system. The system can accurately identify the areas and time periods with high $PM_{2.5}$ emissions and provide support for evaluating the air quality
2	Satellite based monitoring for tracking air pollution.	Satellite remote sensing provides complete and synoptic views of large areas in one image on a systematic basis due to the good temporal resolution of various satellite sensors. Satellite remote sensing technology can monitor many pollutants simultaneously. It has the capability to monitor in near real-time and provides continuously rapid monitoring. Satellite remote sensing method has many advantages of monitoring air quality at micro-scale level. Satellite observations can provide a complete survey of the city; show the major sources of pollution and the distribution pattern; assist in determining where the effort should be focused to decrease the level of pollution and determine any relationship between the city features and the air pollution distribution. **Satellite-based observations should be corelated with ground-based measurements to get a better picture of air quality. Satellites generate data used to calculate Aerosol Optical Depth (AOD), capturing how much sunlight is blocked by aerosol particles from reaching the earth's surface. China and the US already use satellite imagery to estimate levels of fine particulate matter.**
3	Geographic information system	A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions. GIS technology allows us to locate where pollutants are coming from and monitor those areas for change to conserve the quality of our air. Geographical Information System (GIS) are increasingly being used for inventory, analysis, understanding, modelling, and management of the natural environment

Miscellaneous

S. No	Name of Practice	Description
1	Emission control from DG Sets	DG sets are a source of power back up and can cause substantial air pollution in urban areas. Following practices are recommended to reduce the pollution emitted by DG sets: • Ensure continuous supply of Electricity. Solar rooftops (SRTs) are a clean and cheaper alternative to highly polluting DG sets and can ensure uninterrupted power supply. • Strict enforcement to ensure running DG sets are meeting emission standards.
2	Emission reductions from SLCP	The short-lived climate pollutants such as black carbon, methane, tropospheric ozone, and hydrofluorocarbons are the most important contributors to the man-made global greenhouse effect after carbon dioxide. • **Black Carbon:** Solutions like use of clean cooking fuel, BS VI/EURO VI fuel upgradation, installation of diesel particulate filter, ban on burning of agricultural and municipal waste can reduce black carbon emissions. • **Hydrofluorocarbons (HFCs):** Replace high-global warming potential hydrofluorocarbons with low- or zero-global warming potential alternatives, combined with improvements in lifecycle energy efficiency can reduce HFC emissions. Implementation of ECBC code can improve building efficiency and reduce the need for air-conditioners, thereby reducing HFC emission • **Methane:** Methane emissions can be categorized into their source: ✓ **Agricultural Activities:** • Improve manure management and animal feed quality • Apply intermittent aeration of continuously flooded rice paddies • Promote farm-scale anaerobic digestion to control methane emissions from livestock ✓ **Fossil Fuels:** • Carry out pre-mining degasification and recovery and oxidation of methane from ventilation air from coal mines • Reduce leakage from long-distance gas transmission and distribution pipelines • Extend recovery and utilization from gas and oil production • Recover and use gas and fugitive emissions during oil and natural gas production

S. No	Name of Practice	Description
2	Emission reductions from SLCP	✓ **Waste Management** • Separate and treat biodegradable municipal waste and turn it into compost or bioenergy. • Divert organic waste from landfills. • Improve anaerobic digestion of solid and liquid waste by food industry. • Wherever use of landfills is done it is recommended to collect, capture, and use landfill gas.
3	Restriction on use of firecrackers	Restricted use of firecrackers during episodic events like Diwali, weddings celebrations, etc. Also, eco-friendly green crackers should be preferred.
4	Public Awareness & Capacity building	• Issue of advisory to public for prevention and control of air pollution. • Launch public awareness programme campaign to control air pollution. • Help line to oversee non compliances of air pollution rules. • Build Mobile app & websites displaying current and forecasted air quality levels. Countries like China have a forecasting system wherein they intimate the masses regarding poor air quality in coming days so that people can take appropriate actions. • Past source apportionment studies in India (Delhi) have concluded with different results on contribution of various pollutants to air quality. Hence there is a need to have uniformity in source apportionment studies, which is possible by develop standard guidelines for carrying these studies. • Need to build capacity and awareness on air quality issues and work on grey areas of limited manpower and infrastructure at ULBs and regulators i.e. CPCB and SPCBs.

Annexure 7: Emission Inventory Calculations

Vehicles: Emission from the vehicles can be calculated using the following expression:

$$E_v = \Sigma\,(Veh_i \times D_i) \times EF_i$$

Where,
E_v is PM_{10} mass emission from vehicles per day,
i is the vehicle category,
Veh is number of vehicles,
D is distance traveled in km in one day by the vehicle i
EF is the mass emission factor per km travel per vehicle

Industries: Emission from industries can be calculated using the following expression:

$$Ei = \sum_{i}\sum_{j} (Ai,j \times EF\, i,,j) \times (1 - ER_{i,j}/100)$$

Where,
E_i is mass emission from industries per day,
i is the industry type,
j is fuel type,
A is quantity of fuel use
EF is emission factor
ER is emission reduction efficiency (%) of devices installed

Household: Emissions from fuel consumed in households, hotels and restaurant can be calculated using the following expression:

$$Eh = \Sigma\,(Fuelj \times EFj)$$

Where,
E_h is mass emission per day from households,
j is the fuel type,
Fuel is the mass consumption of fuel per day,
EF is mass emission factor

Other sources: The emission from other area sources can be estimated as:

$$E_{co} = \Sigma\ (Activity\ data_{source\_cat}) \times (Emission\ factor_{source\_cat})$$

Where,
E_o is the emission from all other source categories,
Source category is the other area sources (i.e. diesel generator, open burning, construction and demolition, medical waste incinerator),
Activity data is the amount of individual source category,
Emission factor is the emission factor individual source category.

Annexure 8: Emission Factors[5]

Emission Factors for Vehicular Exhaust

Vehicle Type	Model Year	PM	CO	HC	NO2
		g/km	g/km	g/km	g/km
Scooters-2s	1991-1995	0.073	6	3.68	0.02
Scooters-2s	1996-2000	0.073	5.1	2.46	0.01
Scooters-2s	2001-2005	0.049	2.37	2.05	0.03
Scooters-4s	2001-2005	0.015	0.93	0.65	0.35
Scooters-4s	2006-2010	0.015	0.4	0.15	0.25
(4 Stroke) Motorcycles	1991-1995	0.01	3.12	0.78	0.23
(4 Stroke) Motorcycles	1996-2000	0.015	1.58	0.74	0.3
(4 Stroke) Motorcycles	2001-2005	0.035	1.65	0.61	0.27
(4 Stroke) Motorcycles	2006-2010	0.013	0.72	0.52	0.15
3-Wheeler - CNG- 4S OEM	2006-2010	0.015	1	0.26	0.5
3-Wheeler - Auto Rickshaw-Petrol 2S	Post 2000	0.045	1.37	2.53	0.2
3-Wheeler - Auto rickshaw-LPG 2S	Ret-pre 2000	0.721	4.39	3.6	0.08
	Ret-post-2000	0.13	1.7	1.03	0.04
3-Wheeler - Auto rickshaw-D	Post 2000	0.347	2.09	0.16	0.69
	Post 2005	0.091	0.41	0.14	0.51
4-Wheeler - Petrol	1991-1995	0.008	4.75	0.84	0.95
4-Wheeler - Petrol	1996-2000	0.008	4.53	0.66	0.75
4-Wheeler - Petrol	2001-2005	0.004	1.3	0.24	0.2
4-Wheeler - Petrol	2006-2010	0.002	0.84	0.12	0.09
4-Wheeler - Diesel	1996-2000	0.145	0.87	0.22	0.45
4-Wheeler - Diesel	2001-2003	0.19	0.72	0.14	0.84
4-Wheeler - Diesel	2003-05	0.06	0.3	0.26	0.49
4-Wheeler - Diesel	2006-2010	0.015	0.06	0.08	0.28
4-Wheeler - LPG	1996-2000	0.001	6.46	1.78	0.44
	2001-2005	0.002	2.72	0.23	0.2
	2006-2010	0.002	2.72	0.23	0.2

Vehicle Type	Model Year	PM	CO	HC	NO2
4-Wheeler - CNG	2006-2010	0.006	0.06	0.46	0.74
LCVs	1991-1995	0.998	3.07	2.28	3.03
		g/km	g/km	g/km	g/km
(Light Commercial Vehicles) 4-Wheeler GC	1996-2000	0.655	3	1.28	2.48
	2001-2005	0.475	3.66	1.35	2.12
	2006-2010	0.475	3.66	1.35	2.12
Large Trucks + MAV	1991-1995	1.965	19.3	2.63	13.84
	1996-2000	1.965	19.3	2.63	13.84
	2001-2005	1.24	6	0.37	9.3
	2006-2010	0.42	4.13	0.28	8.63
Buses-Diesel	1991-1995	2.013	13.06	2.4	11.24
	1996-2000	1.213	4.48	1.46	15.25
	2001-2005	1.075	3.97	0.26	6.77
	2006-2010	0.3	3.92	0.16	6.53
Buses - CNG	2001-2005	N A	3.72	3.75	6.21
	2006-2010	-	3.72	3.75	6.21

[5] *Source: CPCB, 2011, Air quality monitoring, emission inventory and source apportionment study for Indian cities- National Summary Report, Central Pollution Control Board.*
https://cpcb.nic.in/displaypdf.php?id=RmluYWxOYXRpb25hbFN1bW1hcnkucGRm

Emission Factors for Vehicle Exhaust Future Scenario Generation

For Emission factors for BS IV and BS VI grade fuel vehicles please click here

Vehicle Type	Model Year	PM (g/km)	% red.	Remarks	NO^{2} (g/km)	% red.	Remarks
2 Wheelers - 2S	2006 – 2010	0.057		20% reduction assumed with technology changes (Direct Injection etc.)	0.02		BS-II to BSIII: HC+ NOx limit
	2011 – 2015	0.0456	20%		0.0134	33.0%	0.333
	2015 – 2017	0.0365	20%		0.0107	20.0%	In absence of road map, 20% reduction assumed
2 Wheelers (4-Stroke) Scooters	2006 – 2010	0.015		20% reduction assumed with technology changes (Fuel Injection etc.)	0.25		BS-II to BSIII: HC+ NOx limit
	2011 – 2015	0.012	20%		0.1675	33.0%	0.333
	2015 – 2017	0.0096	20%		0.134	20.0%	In absence of road map, 20% reduction assumed
2 Wheelers (4 Stroke) Motorcycles	2006 – 2010	0.013		20% reduction assumed with technology changes (Fuel Injection etc.)	0.15		BS-II to BSIII: HC+ NOx limit
	2011 – 2015	0.0104	20%		0.1005	33.0%	0.333
	2015 - 2017	0.0083	20%		0.0804	20.0%	In absence of road map, 20% reduction assumed
3-Wheeler- OE - 4S CNG/ LPG/ Petrol	2006 – 2010	0.015		20% reduction assumed with technology changes (Injection etc.)	0.5		BS-II to BSIII: HC+ NOx limit
	2011 – 2015	0.012	20%		0.3125	37.5%	0.375
	2015 - 2017	0.0096	20%		0.25	20.0%	In absence of road map, 20% reduction assumed
3-Wheeler - Diesel	2006 – 2010	0.091		BS-II to BSIII	0.51		BS-II to BSIII: HC+ NOx limit
	2011 – 2015	0.0455	50%	0.5	0.4202	17.6%	0.176
	2015 – 2017	0.0364	20%	In absence of road map, 20% reduction assumed	0.3362	20.0%	In absence of road map, 20% reduction assumed

Vehicle Type	Model Year	PM (g/km)	% red.	Remarks	NO^2 (g/km)	% red.	Remarks
3-Wheeler- OE - 2S CNG/ LPG/ Petrol	2006 – 2010	0.045		20% reduction assumed with technology changes (Injection etc.)	0.2		BS-II HC+ to BSIII: NOx limit
	2011 – 2015	0.036	20%		0.125	37.5%	0.375
	2015 – 2017	0.0288	20%		0.1	20.0%	In absence of road map, 20% reduction assumed
3-Wheeler - LPG 2S- retro	2006 – 2010	0.13		20% reduction assumed with technology changes (Injection etc.)	0.04		BS-II HC+ to BSIII: NOx limit
	2011 – 2015	0.104	20%		0.025	37.5%	0.375
	2015 – 2017	0.0832	20%		0.02	20.0%	In absence of road map, 20% reduction assumed
3-Wheeler – CNG 2S – retro	2006 - 2010	0.118		20% reduction assumed with technology changes (Injection etc.)	0.19		BS-II HC+ to BSIII: NOx limit
	2011 - 2015	0.0944	20%		0.1188	37.5%	0.375
	2015 – 2017	0.0755	20%		0.095	20.0%	In absence of road map, 20% reduction assumed
4-Wheeler - Petrol	2006 – 2010	0.002			0.09		
	2011 – 2015	0.0016	20%		0.0477	47.0%	
	2015 – 2017	0.0013	20%	EURO-V, PM norm instruction in line with diesel values	0.0358	25.0%	EURO-V
	2015 – 2017	0.0013	0%	EURO-VI, no change in norms from EURO-V to VI	0.0358	0.0%	EURO-VI, no change in norms from EURO-V to VI
4-Wheeler - Diesel	2006 – 2010	0.015			0.28		
	2011 – 2015	0.0083	45%		0.14	50.0%	
	2015 – 2017	0.0008	90%	EURO-V	0.1008	28.0%	EURO-V
	2015 – 2017	0.0008	0%	EURO-VI	0.0454	55.0%	EURO-VI

Vehicle Type	Model Year	PM (g/km)	% red.	Remarks	NO^{2} (g/km)	% red.	Remarks
4-Wheeler - CNG	2006 – 2010	0.006			0.74		
	2011 – 2015	0.0048	20%		0.3922	47.0%	In line with petrol
	2015 – 2017	0.0038	20%		0.2942	25.0%	
	2015 – 2017	0.0038	0%		0.2942	0.0%	
4-Wheeler - LPG	2006 – 2010	0.002			0.2		In line with petrol
	2011 – 2015	0.0016	20%		0.106	47.0%	
	2015 – 2017	0.0013	20%		0.0795	25.0%	
	2015 – 2017	0.0013	0%		0.0795	0.0%	
LCVs (Light Commercial Vehicles) – diesel	2006 – 2010	0.475			2.12		
	2011 – 2015	0.0808	83%		1.484	30.0%	
	2015 – 2017	0.0808	0%	EURO-V	0.8459	43.0%	EURO-V
	2015 – 2017	0.0339	58%	EURO-VI	0.1692	80.0%	EURO-VI
LCVs (Light Commercial Vehicles) – CNG	2006 – 2010	0.058		data taken from vehicle emissions source profile	5.7		data taken from vehicle emissions source profile
	2011 – 2015	0.0464	20%		3.99	30.0%	In line with diesel
	2015 – 2017	0.0371	20%		2.2743	43.0%	
	2015 – 2017	0.0297	20%		0.4549	80.0%	
Large Trucks + MAV	2006 – 2010	0.42		data taken from vehicle emission source profile	8.63		
	2011 – 2015	0.0714	83%		6.041	30.0%	
	2015 – 2017	0.0714	0%	EURO-V	3.4434	43.0%	EURO-V
	2015 – 2017	0.03	58%	EURO-VI	0.6887	80.0%	EURO-VI
Large Trucks + MAV CNG	2006 – 2010	0.032		data taken from vehicle emission source profile	3.92		
	2011 – 2015	0.0256	20%		2.744	30.0%	In line with diesel
	2015 – 2017	0.0205	20%		1.5641	43.0%	
	2015 – 2017	0.0164	20%		0.3128	80.0%	

Vehicle Type	Model Year	PM (g/km)	% red.	Remarks	NO^2 (g/km)	% red.	Remarks
Buses-Diesel	2006 – 2010	0.3			6.53		
	2011 – 2015	0.051	83%		4.571	30.0%	
	2015 – 2017	0.051	0%	EURO-V	2.6055	43.0%	EURO-V
	2015 – 2017	0.0214	58%	EURO-VI	0.5211	80.0%	EURO-VI
Buses - CNG- OE	2006 – 2010	0.044		taken from TERI-ARAI report	6.21		
	2011 – 2015	0.0352	20%		4.347	30.0%	In line with diesel
	2015 – 2017	0.0282	20%		2.4778	43.0%	
	2015 – 2017	0.0225	20%		0.4956	80.0%	
Buses - CNG-Retro	2006 – 2010	0.032		data taken from vehicle emissions source profile	3.92		
	2011 – 2015	0.0256	20%		2.744	30.0%	In line with diesel
	2015 – 2017	0.0205	20%		1.5641	43.0%	

Non-Vehicular Emission Factors (CPCB)[6]

USEPA AP-42 Emission Factors can also be accessed by clicking here

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
1	Fuel Combustion Oil	TSP = {9.19(S) + 3.22} * 0.120 SO2 = 18.84S NO_x = 6.6 CO = 0.6 CH_4 = 0.0336 TOC = 0.1248 NMTOC = 0.091 **(Unit: kg/10^3 L)**	TSP may be considered PM10 TOC is Total Organic Compound including VOC. EPA-42: Table 1.3 – 1 And Table 1.3 – 3; S – Sulphur Content in Fuel (For 1% Sulphur S=1); Gm/Lit Oil, Fuel Oil Combustion, Normal Firing.
2	Natural Combustion Gas	TSP = 121.6 SO_2 = 9.6 NO_x = 1600 CO = 1344 CO_2 =1,920,000 CH_4 = 36.8 VOC =88 TOC = 176 NMTOC = 0.091 **(Unit: kg/10^6 M^3)**	TSP may be considered PM10
3	Liquefied Petroleum Combustion Gas	PM= 2.1 SO2 = 0.4 **(Unit: Gm/kg)** NO_x = 1.8 CO = 0.252 CO_2 =1716 CH_4 = 0.024 VOC =88 TOC = 0.072 NMTOC = 0.091 (Unit: kg/106 M_3)	Reddy And Venkatraman (Commercial Boilers)

[6] Source: CPCB, 2011, Air quality monitoring, emission inventory and source apportionment study for Indian cities- National Summary Report, Central Pollution Control Board. https://cpcb.nic.in/displaypdf.php?id=RmluYWxOYXRpb25hbFN1bW1hcnkucGRm

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
4	Bagasse Combustion	TSP = 7.8 NO_x = 0.6 CO_2 = 780 **(Unit: kg/Ton)**	EPA-AP42: Table 1.8-1, Uncontrolled Emission Factors
5	Residential Wood Stoves/Restaurants	PM10 =15.3 CO=115.4 NO_x=1.4 So_x= 0.2 TOC=41.5 CH_4 =15 TNMOC=26.5 **(Unit: kg/Mg)**	Table 1.10-1 Conventional AP-42
6	Kerosene Combustion Domestic	PM=1.95 SO_2 =4 **(Unit: G/Lit)** TSP=0.61 CO=62 NOx=2.5 CH4 =1 TNMOC=19 **(Unit: G/kg)**	PM & SO2 – Reddy And Venkatraman TSP May Be Considered as PM10. USEPA 2000
7	Coal Combustion -Tandoor/ Domestic	TSP=20 CO=24.92 NO_x=3.99 SO_2 = 13.3 **(Unit: kg/Mg)**	TERI Report Uncontrolled wherever controlled use efficiency.
8	Coal Combustion Boilers	**Stoker Fired Boilers** CO=0.3 CO_2 =2840 SO_x=19.5 NO_x=4.5 PM=0.04A **FBC Boilers** CO=0.3 CO_2 =ND	S= Weight Percent Sulphur A= Ash content (weight %) AP-42 1.2-1,2,3 Use suitable EF pertinent to the city & 2x2 grid

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
8	Coal Combustion Boilers	SO_x=1.45 NO_x=0.9 **Pulverized Coal Boilers** SO_x=19.5S NO_x=9.0 **(Unit: kg/Mg)**	
9	Chulha (Dung, Wood)	PM=6.3 PM10 =5.04 SO_2 = 0.48 **(Unit: G/kg)** TSP=1.9 CO=31 NO_x=1.4 TNMOC=29.8 CH_4 =3 **(Unit: G/kg)**	Reddy And Venkatraman - (PM10, SO2, PM) TSP may be Considered as PM10. USEPA 2000 Use suitable EF pertinent to the city & 2x2 grid
10	Agricultural Waste (From Pune And Kanpur)	PM=11 PM10 =11 CO=58 CO_2 =207 SO_2 =0.12 NO_x=0.49 **(Unit: kg/Ton)**	EPA-AP42: Table 2.5-5 Emission Factors for Open Burning of Agricultural Materials, kg/Ton; Unspecified Field Crop Burning Emission Factor Is Considered. Particulate Matter from Most Agricultural Refuse Burning Has Been Found to Be in The Sub micrometer Size Range. For SO2 And NO2 : M. S. Reddy And C. Venkatraman (2002), Inventory of Aerosol and Sulphur Dioxide Emissions from India. Part II - Biomass Combustion, Atm. Envt., Vol 36, Issue 4, Pp 699-712 Manish Shrivastava, Gazala Habib, Venkatraman C, Jeffery W. Sterh, Russell R. Dickerson (Sept. 8 2003) Emissions from Biomass Burning in India : II - Sulfur Dioxide and Nitrogen Dioxide, Global Biogeochemical Cycles, Pp15
11	Garden Waste Combustion	(Same as under 10)	

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
12	Medical Waste Incineration	PM=2.33 SO_2 =1.09 CO=2.95 NO_x=1.78 **(Unit: kg/Ton)**	EPA-AP42: Table 2.3.2. Apply Emission Factors for uncontrolled Emission
13	Solid Waste Burning (Landfill Sites)	PM10 = 8 PM2.5 = 5.44 CO= 42 SO_x=0.5000 NO_x=3 VOC= 21.5 **(Unit: kg/MT)**	A Guide to Rapid Source Inventory Techniques and Their Use in Formulating Environmental Control Strategies – Part One – Rapid Inventory Techniques in Environmental Pollution by A.P. Economopoulos, WHO, Geneva, 1993
14	Kerosene Generators Domestic	Apply same EF as for item no. 6: domestic Kerosene combustions	
15	Diesel Industrial Generators Large Stationary Diesel and All Stationary Dual - Fuel Engines (Film Shooting	PM10 = 1.33 10^{-3} CO_2 = 0.69 CO=4.06 10^{-3} SO_x= 1.24 10-3 NO_x=0.0188 Aldehydes= 2.81 10^{-4} TOC Exhaust = 1.50 10^{-3} Evaporative =0 Crankcase = 2.68 10^{-3} Refueling =0 **(Unit: kg/Kw-Hr)**	AP-42 (Table 3.3-1) EF For Uncontrolled Gasoline & Diesel Industrial Engines.
16	Petroleum Refining	**Boilers & Process Heaters** Fuel Oil – EF Used for Fuel Oil Combustion (Sec 1.3 AP-42)	

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
16	Petroleum Refining	Natural Gas - EF Used for Natural Gas Combustion (Sec 1.4 AP-42) **Fluid Catalytic Cracking Units Uncontrolled** PM=0.695 SO_2 =1.413 CO=39.2 Total Hydrocarbons=0.630 NO_2 =0.204 Aldehydes=0.054 Ammonia=0.155 **Electrostatic Precipitator and CO Boiler** PM=0.128 SO_2 =1.413 CO=Negligible Total Hydrocarbons= Negligible NO_2 = 0.204 Aldehydes= Negligible Ammonia= Negligible **Moving Bed Catalytic Cracking Units** PM=0.049 SO_2 =0.171 CO=10.8 Total Hydrocarbons=0.250 NO_2 =0.014 Aldehydes=0.034 Ammonia=0.017	

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
16	Petroleum Refining	**Fluid Coking Units Uncontrolled** PM=1.50 SO2 =ND CO= ND Total Hydrocarbons= ND NO2 = ND Aldehydes= ND Ammonia= ND **Electrostatic Precipitator and CO Boiler** PM=0.0196 SO_2 =ND CO= Negligible Total Hydrocarbons= Negligible NO_2 =ND Aldehydes= Negligible Ammonia= Negligible **(Unit: kg/103 L Fresh Feed)** **Vapor Recovery System and Flaring** PM= Negligible SO_2 =0.077 CO=0.012 Total Hydrocarbons=0.002 NO_2 =0.054 Aldehydes= Negligible Ammonia= Negligible **(Unit: kg/103 L Refinery Feed)**	

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
16	Petroleum Refining	**Vacuum Distillation Column Condensers** Uncontrolled PM=Negligible SO2 =Negligible CO=Negligible Total Hydrocarbons=0.14 NO2 =Negligible Aldehydes=Negligible Ammonia=Negligible Controlled (Vented to Heater or Incinerator) PM=Negligible SO2 =Negligible CO=Negligible Total Hydrocarbons=Negligible NO2 =Negligible Aldehydes=Negligible Ammonia=Negligible **(Unit: kg/103 L Refinery Feed)** Claus Plant and Tail Gas Treatment (See Sec 8.13- “Sulphur Recovery” AP-42) **Cooling Towers (Uncontrolled Emissions)** PM=0.7 (Unit: kg/106 L Cooling Water) **Oil Water Separators (Uncontrolled Emissions)**	

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
16	Petroleum Refining	PM=0.6 **(Unit: kg/103 L Wastewater)** Storage (Uncontrolled Emissions) (See Chapter 7-Liquid Storage Tanks AP-42) Loading (Uncontrolled Emissions) (See Section 5.2 – Transportation and Marketing of Petroleum Liquids AP-42) **Fugitive VOC Emissions (Uncontrolled Oil Refinery Of 52,500 M3/Day)** Total =20,500 **(Unit: kg/Day)**	
17	Electric Arc Welding	TSP=6.3 SO2 =ND NOx=0.16 CO=9.75 VOC=0.09 **(Unit: kg/Day)**	WHO 1993, Rapid Techniques in Environmental Pollution Part 1 By Alexander P. Economopoulos EF Are Cited Without Control Equipment
18	Secondary Metal Smelting	PM=16-35 Pb=4-8 SO_2 =ND	

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
	(Lead) And Other Operations (Foundries)	**Reverberatory Smelting** PM=162 Pb=32 SO_2 =40 **Blast Smelting Cupola** PM=153 Pb=52 SO_2 =27 **Kettle Refining** PM=0.02 Pb=0.006 SO_2 =ND **Kettle Oxidation** PM=< 20 Pb=ND SO_2 =ND Casting PM=0.02 Pb=0.007 SO_2 =ND (Unit: kg/Mg) **Steel Foundries** Melting 3 Electric Arc TSP=6.5 (2 To 20) NOx=0.1 PM10 =ND **Open Hearth** TSP =5.5 (1 To 10)	

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
		NO_x=0.005 PM10 =ND **Open Hearth Oxygen Lanced** TSP =5.5 (1 To 10) NOx=0.005 PM10 =ND **Electric Induction** TSP =0.05 NOx=ND PM10 =0.045 **Sand Grinding / Handling in Mold and Core Making** TSP =ND NOx=NA PM10 =0.27 3.0 **Core Ovens** TSP =ND NO_x=ND PM10 =1.11 0.45 **Pouring and Casting** TSP =ND NOx=NA PM10 =1.4 **Casting Cleaning** TSP =ND NOx=NA PM10 =0.85 **Charge Handling**	

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
		TSP =ND NOx=NA PM10 =0.18 **Casting Cooling** TSP =ND NO_x=NA PM10 =0.7 **(Unit: kg/Mg)** **Zinc** Reverberatory Sweating Clean Metallic Scrap PM= Negligible **General Metallic Scrap** PM=6.5 Residual Scrap PM=16 **(Unit: Mg/Mg of Feed)** **Rotary Sweating** PM=5.5-12.5 **Muffle Seating** PM=5.4-16 **Kettle Sweating Clean Metallic** Scrap PM= Negligible **General Metallic Scrap** PM=5.5 **Residual Scrap** PM=12.5	

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
		Electric Resistance Sweating PM=<5 **Sodium Carbonate Leaching Calcining** PM=44.5 **(Unit: kg/Mg of Zinc Used)** **Kettle Pot** PM=0.05 **(Unit: Mg/Mg)** **Crucible Melting** PM=ND **Reverberatory Melting** PM=ND **Electric Induction Melting** PM=ND **Alloying** PM=ND Retort and Muffle Distillation Pouring PM=0.2 – 0.4 **Casting** PM=0.1-0.2 **Muffle Distillation** PM=22.5 **(Unit: kg/Mg of Product)**	

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
		Graphite Rod Distillation PM-Negligible **Retort Distillation/Oxidation** PM=10-20 **Muffle Distillation/Oxidation** PM=10-20 **Retort Reduction** PM=23.5 **Galvanizing** PM=2.5 **(Unit: kg/Mg of Zinc Used)**	
19	Cast Iron Furnace	Cupola Uncontrolled PM=6.9 Electric Arc Furnace Uncontrolled PM=6.3 **(Unit: kg Of Pollutant/Mg of Grey Iron Produced)**	AP-42 (Table 12.10-2) Use suitable EF pertinent to the city & 2x2 grid
20	Power Plant - Natural Gas	CO2 =1920000 Pb=0.008 PM(Total)=121.6 NOx=4480 CO=1344 SO2 =9.6 TOC=176 CH4 = 36.8 VOC=88 **(Unit: kg /106 M3)**	AP-42 Table (1.4-1-2) Use suitable EF pertinent to the city & 2x2 grid
21	Wood Residue Combustion in Boilers / Bakeries	SOx=0.2 NOx=1.3 CO2 =1700 Total VOC=114.5 **(Unit: kg /Mg)**	AP42 (Sec. 1.9, Pp. 1.10.4, Table 1.9.1) Use suitable EF pertinent to the city & 2x2 grid

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
22	Coal Combustion - Power Plant	PC, Dry Bottom, Wall-Fired, Sub-Bituminous Pre-NSPS SOx=19S NOx=11 (5.5 With Low NOx Burners) CO=0.25 Filterable PM=5A Filterable PM10 =1.15 **(Unit: kg /Mg)**	AP-42 (Table 1.1-3-4) Use suitable EF pertinent to the city & 2x2 grid Particulate Is Expressed in Terms of Coal Ash Content, A, Factor Is Determined by Multiplying Weight % Ash Content of Coal (as Fired) By the Numerical Value Preceding the A.
23	Plastic And Leather Waste Burning	SO2 =0.5 NOx=3 CO=42 CH4 =6.5 TSP=8 **(Unit: kg /Mg of Waste)**	AP 42/(Table 2.4-7)
24	Bricks and Related Clay Products (Earthen Pot Kiln)	TSP=0.9 PM10 =0.7 SO2 =0.6 NOx=0.255 CO=0.4 CO2 =150 **(Unit: kg /Tons of Bricks)**	EPA-AP42 (Table: 11.3-2) Apply for uncontrolled Emissions for Coal Fired Kiln unless a different fuel is used.
25	Cupola Cast Iron	TSP=6.9 SO2 =0.6S NOx=ND CO=73 VOC=ND Pb=0.32 **(Unit: kg /Tons)**	WHO 1993, Rapid Techniques in Environmental Pollution Part 1 By Alexander P. Economopoulos

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
27	Municipal Solid Waste Landfills	PM10 = 8 PM2.5 =5.44 CO=42 SOx=0.5000 NOx=3 VOC= 21.5 **(Unit: kg/MT)**	A Guide to Rapid Source Inventory Techniques and Their Use in Formulating Environmental Control Strategies – Part One – Rapid Inventory Techniques in Environmental Pollution by A.P. Economopoulos, WHO, Geneva, 1993 Divide under different types of emissions such as vehicular movement on unpaved roads, combustion of organic content, loading and unloading etc. Determine the activity levels for each category and apply suitable factors
28	Fertilizer and Inorganic Chemical Industry	**Solution Formation and Concentration** PM=0.0105 NH4 =9.23 Non-Fluidized Bed Prilling Agricultural Grade PM=1.9 NH4 =0.43 **Feed Grade** PM=1.8 NH4 =ND Fluidized Bed Prilling **Agricultural Grade** PM=3.1 NH4 =1.46 **Feed Grade** PM=1.8 NH4 =2.07 **Drum Granulation** PM=120 NH4 =1.07 **Rotary Drum Cooler** PM=3.89	AP-42 8.2-1 – Chapter – 8 Use suitable EF pertinent to the city & 2x2 grid

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
		NH_4 =0.0256 **Bagging** PM=0.095 NH_4 =NA **(Unit: kg /Mg of Product)**	
29	Hot Mix Asphalt Plants	Batch HMP PM=16 PM10 =2.25 CO=0.2(Natural Gas-Fired Dryer, Hot Screens and Mixer) CO=0.2 (Fuel Oil-Fired Dryer, Hot Screens and Mixer) CO=0.2 (Waste Oil-Fired Dryer, Hot Screens and Mixer) CO_2 =18.5(For All Type O Process) NO_x=0.0125(Natural Gas-Fired Dryer, Hot Screens and Mixer) NO_x=0.06 (Fuel Oil-Fired Dryer and Waste Oil- Fired Dryer, Hot Screens and Mixer) SO_2=0.0023(Natural Gas- Fired Dryer ,Hot Screens and Mixer)	AP-42 11.1-1, 5 & 6 Use suitable EF pertinent to the city & 2x2 grid

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
		SO2=0.044(Fuel Oil-Fired Dryer, And Waste Oil Fired Dryer Hot Screens and Mixer) SO2=0.0215 (Coal-Fired Dryer, Hot Screens and Mixer) TOC =0.0075 (Natural Gas- Fired Dryer, Hot Screens and Mixer) TOC=0.0075 (No.2 Fuel Oil- Fired Dryer, Hot Screens and Mixer) TOC=0.0215(No.6 Fuel Oil- Fired Dryer, Hot Screens and Mixer) CH4 = 0.0037 (For All Type O Process) VOC=0.0041(Natural Gas- Fired Dryer, Hot Screens and Mixer) VOC=0.0041(No.2 Fuel Oil- Fired Dryer, Hot Screens and Mixer) VOC=0.018(No.6 Fuel Oil- Fired Dryer, Hot Screens and Mixer) **(Unit: kg /Mg)** Drum Mix HMP	

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
		PM=14 PM10 =3.25 CO=0.065 (For All Process Type) CO2 = 16.5(For All Process Type) NOx=0.013 (Natural Gas Fired Dryer) NOx=0.0275(No.2 Fuel Oil and Waste Oil Fired Boiler) TOC=0.022 (For All Process Type) CH4 =0.006(For All Process Type) VOC=0.016(For All Process Type) **(Unit: kg /Mg)**	
30	Glass Manufacturin g	TSP=0.7 SO2 =1.7 NOX =3.1 CO=0.1 VOC=0.1 **(Unit: kg /Ton)**	WHO 1993, Rapid Techniques in Environmental Pollution Part 1 By Alexander P. Economopoulos
31	Lead Oxide and Pigment Production	TSP=7 SO2 =NA NOX= NA CO= NA	WHO 1993, Rapid Techniques in Environmental Pollution Part 1 By Alexander P. Economopoulos

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
		VOC= NA Pb=7 **(Unit: kg /Ton)**	
32	Construction (Building)	TSP=1.2 **(Unit: Tons/Acre/ Month of Activity)**	For Details Refer AP-42 Section 13.2.3.3 Use suitable EF pertinent to the city & 2x2 grid depending upon construction activity
33	Construction Roads (A) Aggregate Laying And (B) Asphalt	TSP=1.2 **(Unit: Tons/Acre/ Month of Activity)**	For Details Refer AP-42 Section 13.2.3.3 Use suitable EF pertinent to the city & 2x2 grid depending upon construction activity)
34	Construction of Flyovers	TSP=1.2 **(Unit: Tons/Acre/ Month of Activity)**	For Details Refer AP-42 Section 13.2.3.3 Use suitable EF pertinent to the city & 2x2 grid depending upon construction activity
35	Carbon Black	**Oil Furnace Process Main Process Vent** PM=3.27 CO=1400 NO=0.28 SO=0 CH4 =25 Non CH4 VOC=50 **Flare** PM=1.35 CO=122 NO=ND SO=25 Non CH4 VOC=1.85 **CO Boiler and Incinerator** PM=1.04 CO=0.88	AP 42 Table 6.1-3 Use suitable EF pertinent to the city & 2x2 grid

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
		NO=4.65 SO=17.5 Non CH4 VOC=0.99 **Oil Storage Tank Vent** Non CH4 VOC=0.72 **Fugitive Emissions** PM=0.10 **(Unit: Weight of Emissions /Weight of Carbon Black Produced)**	
36	Paint Applications (Auto)	Prime Coat (Solventborne Spray) 6.61 Guide Coat (Solventborne Spray) 1.89 Topcoat (Enamel) 7.08 **(Unit: Automobile kg Of VOC / Vehicle)**	AP 42 Table 4.2.2.8-1 Based on the number of vehicles being painted in each location
37	Paved Roads	Refer Section 13.2.1.3 Of AP-42	AP 42 (13.2.1.3) Given equation has to be used and respective parameters shall vary for each city and/or grid
38	Unpaved Roads	Refer Section 13.2.2 Of AP- 42	AP 42 (13.2.2) Given equation has to be used and respective parameters shall vary for each city and/or grid
39	Soil Dust (Wind Erosion)	PM=0.263 PM10 =0.1315 **(Unit: kg/Acre/Year)**	Pune EI Study Conducted By ARB, In kg/Acre/Year, 1. Emission Factor for TSP Is 0.001052 Tons Per Acre Per Year, Which Is the Default Emission Factor for Default San Joaquin Valley, California, Averaged Over All the Counties. Multiplication Factor Of 0.5 For Deriving PM10 Is Used. 2. Assumed A Longer Vegetative Coverage in India After the Harvest, Hence Multiply the Above Emission Factor by A Factor Of 1/4.

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
40	Stone Pulverization Industry, Quarries	Primary and Secondary Crushing Total PM=ND Total PM10 = ND Total PM2.5 = ND Tertiary Cushing Total PM=0.0027 Total PM10 = 0.0012 Total PM2.5 = ND Fines Crushing Total PM=0.0195 Total PM10 = 0.0075 Total PM2.5 = ND Screening Total PM=0.0125 Total PM10 = 0.0043 Total PM2.5 = ND Fines Screening Total PM=0.15 Total PM10 = 0.036 Total PM2.5 = ND Conveyor or Transfer Point Total PM=0.0015 Total PM10 = 0.00055 Total PM2.5 = ND Wet Drilling Unfragmented Stone Total PM=ND Total PM10 = 4.0 * 10-5 Total PM2.5 = ND Truck Unloading – Fragmented Stone	AP 42 Table (11.19.2-1) Use EF of uncontrolled Emission

S. No	Source / Activity	Common Emission Factor	Reference/Remarks
		Total PM=ND Total PM10 = 8.0 * 10-6 Total PM2.5 = ND Truck Unloading – Conveyor Crushed Stone **Total PM=ND** **Total PM10 = 5.0 * 10^{-5}** **Total PM2.5 = ND** (Unit: kg/Mg)	

Source: *CPCB, 2011, Air quality monitoring, emission inventory and source apportionment study for Indian cities- National Summary Report, Central Pollution Control Board, New Delhi*

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ICF | 2nd Floor, Novotel – Pullman Caddie Commercial Tower, Aerocity, Delhi - 110037 | India
+91.11.4354.3000(Main) | www.icf.com