Climate Centre for Cities

सत्यमेव जयते
Ministry of Housing and Urban Affairs
Government of India

CLEAN AIR ASIA

Level of Air Pollution (Monitoring)

TRAINING MANUAL

ClimateSmart Cities Assessment Framework

Mobility and Air Quality

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NIUA | C3
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Level of Air Pollution (Monitoring)
Training manual

Developed by:
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Executive Summary

On one hand, cities are a significant contributor of carbon emissions aggravating climate change and on the other, cities are considerably impacted by climate disasters. The recently released Global Climate Risk Index 2021 ranks India as the 7th most affected country from climate related extreme weather events (*storms, floods, heatwaves etc.*). Further, studies indicate that poor planning and urban management are expected to cost Indian cities somewhere between $2.6 and $13 billion annually.[1] Cities are increasingly at the forefront of addressing both urbanization and climate change and to strengthen climate-sensitive urban development, a holistic understanding of the urban development from a climate lens is crucial. The ClimateSmart Cities Assessment Framework (CSCAF) launched in 2019 by the Ministry of Housing and Urban Affairs (MoHUA), Government of India aimed to address this gap. This first-of-its-kind assessment with 28 progressive indicators across 5 thematic areas helps cities to benchmark their development, understand the gaps and further prioritize climate relevant development.

With a focus on building local capacities to develop and adopt climate measures, the Climate Centre for Cities (C-Cube) at the National Institute of Urban Affairs (NIUA) initiated a series of training aligned to the thematic areas of CSCAF - Energy and Green Buildings, Urban Planning, Green Cover & Biodiversity, Mobility and Air Quality, Water Management, Waste Management. The focus of the training is to provide a step-by-step approach of conducting studies, assessments and stakeholder consultations, establishing committees, developing action plans and implementing relevant measures that not only makes the cities climate resilient but also helps them progress across the assessment of CSCAF. The training on the 'Level of Air Pollution (*Air Pollution Monitoring (understanding level of air pollution)*) under the thematic areas of Mobility and Air Quality in the CSCAF is developed in association with Clean Air Asia.

Level of Air Pollution is an indicator identified under the Mobility and Air Sector. The rationale of the indicator is to develop an approach which complements the Central Pollution Control Board's existing monitoring system to provide data on localised areas, hot spots and help generate real-time information. Air pollution data will not only help the

[1] *Mani, M. et al., 2018. South Asia's Hotspots: The Impact of Temperature and Precipitation Changes on Living Standards, Washington D.C, World Bank Group.*

government in framing policies and measures but allow citizens to make informed decisions that can improve the quality of their lives. The smart cities present a unique opportunity to adapt to advanced air quality-monitoring technologies. Cities are encouraged to adopt affordable technologies by introducing low-cost air-quality sensors and linking the latter to the Integrated Command and Control Centres.

A city level air-quality monitoring grid is important to generate holistic data, helps to assess the risks, implements control measures and assesses other climate smart strategies adopted by the city. The city is encouraged to assess to what extent it has achieved National Ambient Air Quality Standards (NAAQS),2009. The National Clean Air Programme sets a target of 20 -30 percent reduction of air pollution levels with 2017 as the base year.

A city level air quality monitoring grid is important to generate holistic data, that helps to assess the risks, implements control measures, and integrate the issues of air pollution in a climate framework to ensure a co-benefits approach. However, to understand this need for data it is also essential to understand overall air quality management issues. The manual focuses on basic areas of understanding Air Quality Management with a focus on data and data generation (and use).

The main objective of the module is to help the participants understand the importance of data in the context of Air Quality Management. Specifically, to prepare informed policies for air pollution mitigation and for improving livability in cities.

The key concepts that are covered in this training manual are:

i. Pollutant Categories, Emission Sources, Health and Welfare Effects
ii. Air Quality Standards
iii. Importance of Air Quality Monitoring
iv. Designing Ambient Air Monitoring Network
v. Methods of Measurement

Who is the training manual designed for?

What is the focus of the training manual?

How to make use of this manual?

What are the Learning outcomes of the training?

Scope and limitations of the training

The training manual has been designed for

- Senior and Mid - level Smart City Officials
- Mid- level Officials involved in Air Pollution Mitigation Work at City Level
- Urban Planners, Architects, Designers involved in City Planning

The focus of the manual is to highlight key areas of Air Quality Management in order to provide working knowledge on air pollution monitoring and data use for developing and mapping out policies and measures for mitigating air pollution at city level.

The manual is designed to guide readers to achieve a basic understanding of air quality management with an emphasis on air quality monitoring. In addition to detailed information provided in the manual, a set of reference materials are indicated for additional reading. Case studies to demonstrate the theoretical concepts are also covered to demonstrate the practical application of concepts.

- Overview of the impact of air pollution
- Provide overview of regulatory framework for Air Pollution Monitoring in India.
- Convey broad information on the process of identifying key pollution sources and measures to address them.
- Improved understanding of air pollution monitoring and air quality management

The manual is designed to guide readers to achieve basic understanding of air quality management. Scientific methods like sampling in air quality monitoring and the science of emissions inventory and other assessments have not been included. However, additional reference materials indicated can support further understanding the scientific methods.

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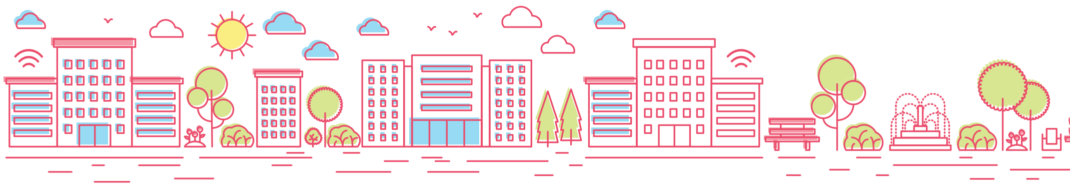

Abbreviations

AQ	Air Quality
AQG	Air Quality Guidelines
AQI	Air Quality Index
AQM	Air Quality Monitoring
AQMS	Air Quality Monitoring System
CCAC	Climate and Clean Air Coalition
CFC	Chlorofluorocarbons
CH4	Methane
CO	Carbon Monoxide
CO2	Carbon Dioxide
CPCB	Central Pollution Control Board
EU	European Union
GHGs	Greenhouse Gases
GWP	Global Warming Potential
HAP	Hazardous Air Pollutant
HC	Hydrocarbons
HFC	Hydrofluorocarbons
LPG	Liquid Petroleum Gas
MIT	Massachusetts Institute of Technology
MOEF&CC	Ministry of Environment, Forest, and Climate Change
N2O	Nitrous Oxide
NAAMP/ NAMP	National Ambient Air Monitoring Programme
NAAQS	National Ambient Air Quality Standards
NAPCC	National Action Plan on Climate Change
NCAP	National Clean Air Programme
NOx	Nitrogen Oxide
O3	Ozone
Pb	Lead
PCC	Pollution Control Committee
PM	Particulate Matter
RH	Relative Humidity
RSPM	Respirable Suspended Particulate Matter
SAFAR	System of Air Quality and Weather Forecasting and Research
SF6	Sulphur Hexafluoride
SIP	State Implementation Plan
SLCPs	Short – Lived Climate Pollutants
SOx	Sulphur Oxide
SPCB	State Pollution Control Board
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Compound
WHO	World Health Organisation

1

Air Pollution – Definitions and Key Concepts

This chapter introduces key air pollutants and emissions sources, along with providing an overview of air pollution and highlighting its impact.

The Earth's atmosphere is made up of mixture of dynamic natural gaseous system which is essential to support life on the planet.[1] If we damage/disturb the composition, it would mean damaging the giant safety blanket of Earth that keeps the temperature on the surface from dipping to extreme icy cold that would freeze everything solid, or from soaring to blazing heat that would burn up all life.[2]

The atmosphere is made up of many layers of air namely: troposphere, stratosphere, mesosphere, thermosphere, and exosphere. In the study of air pollution, the layers of the air that are most important are the troposphere and the stratosphere.[3]

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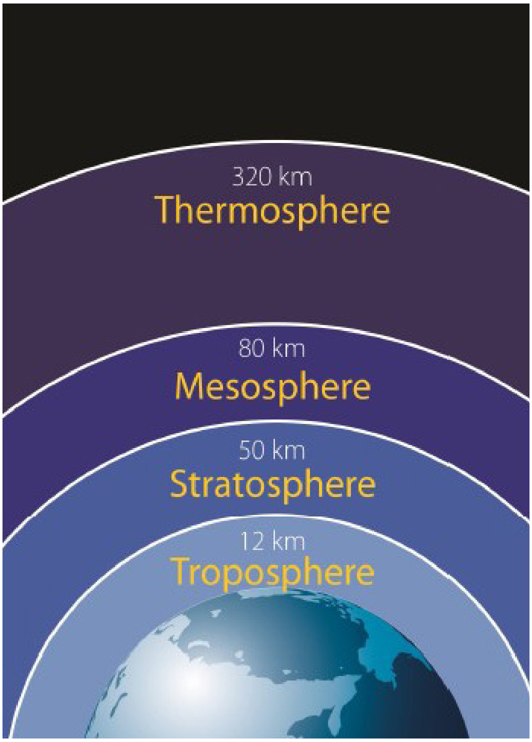
[1] *Science Direct, Air Pollution, ScienceDaily, https://www.sciencedaily.com/terms/air_pollution.htm, Accessed on 5th November 2021*

[2] *National Geography, Atmosphere, Resource Library, https://www.nationalgeographic.org/encyclopedia/atmosphere/, Accessed on November 2021*

[3] *Maduna, K. & Tomašić, V., 2017. "Air Pollution Engineering" Physical Sciences Reviews, 2(12)*

Figure 1: Layers of Atmosphere



Source: Layers of Earth's Atmosphere (2020), Windows to the Universe

1.1 What is Air Pollution?

In the simplest of terms, “air pollution” refers to air that contains substances like gases, dust, fumes, or odour in harmful amounts.[1] There are various sources of these air pollutants, namely – anthropogenic (*i.e., human activity*), biogenic (*e.g., volatile organic compound (VOC) emissions from forests and methane* (CH_4) *emissions from swamps*), or geogenic (*sources that are not part of the natural atmosphere or are in higher concentrations than the natural atmosphere*).[2] These pollutants have been known to cause short-term and long-term adverse effects on the environment and human health.

Industrial activities and use of fossil fuels (*oil, coal, and gas*), and even changes in land use are all responsible for producing polluting air emissions. When emissions of these air pollutants exceed the capacity of natural processes to convert or disperse them, they can cause damage to human health and the environment.[3]

In theory, air has always been polluted to some degree. Natural phenomena such as volcanic eruptions, windstorms, decomposition of plants and animals, and even the aerosols emitted by the ocean ‘pollute’ the air.[4] However, air quality is largely affected due to the pollutants usually generated as a result of human activity, such as driving motor vehicles, burning of coal, oil and other fossil fuels, and manufacturing chemicals.

Air pollution can be divided into 2 main categories – outdoor air pollution and indoor air pollution. Outdoor or ambient air pollution is a result of emissions released into the atmosphere due to human activities such as use of motor vehicles, waste burning, construction activities and occurrence of natural phenomena like dust storms. Whereas, indoor air pollution occurs due to use of solid fuels such as wood, dung, agricultural residue, and charcoal that is used for cooking and heating.

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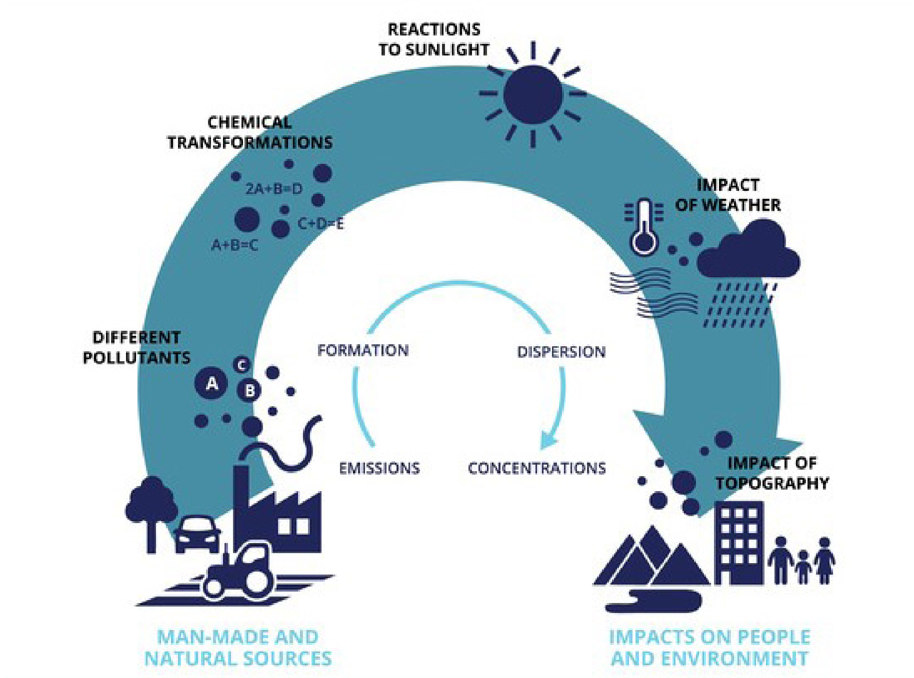
[1] *Australian Academy of Science, Where does Air pollution come from?, https://www.science.org.au/curious/people-medicine/where-does-air-pollution-come, Accessed on 19th May 2021*

[2] *Maduna, K. & Tomašić, V., 2017. “Air Pollution Engineering” Physical Sciences Reviews, 2(12)*

[3] *United States Environmental Protection Agency, Air Pollution: Current and Future Challenges, www.epa.gov, https://www.epa.gov/clean-air-act-overview/air-pollution-current-and-future-challenges. Accessed October 2021.*

[4] *Frank R. Spellman (2015) Economics of Clean Air, Economics For Environmental Professionals, Page 214*

Figure 2: Air Pollution from emissions to exposure



Source: European Environment Agency, 2020, Air Pollution: From emissions to exposure

1.2 Categories of Pollutants

Any unconfined portion of the atmosphere is known as **Ambient air**. Everyone has access to this air. There are hundreds of **air pollutants** present in ambient air that cause harm to humans and the environment.

Air pollutants are classified into primary or secondary pollutants and are in the form of solid particles, liquid gases, or gases.

Pollutants such as ash from a volcanic eruption, carbon monoxide gas from a motor vehicle exhaust or sulphur dioxide released from factories are known as **Primary Pollutants** as they have been directly emitted from the source.

Pollutants which are formed in the air due to interactions between primary pollutants are called **Secondary Pollutants**. These are not emitted directly from the source but form pollutants due to reactions.

Examples of major primary air pollutants produced by human activity include Particulate Matter, Sulphur Oxides (SOx) Nitrogen Oxides (NOx), Carbon monoxide (CO), and Volatile organic compounds (VOCs). Secondary air pollutants on the other hand include ground level ozone (O_3), and smog.

Air pollutants are further classified into Criteria pollutants and Hazardous Air Pollutants (HAP's) keeping in mind regulations and ease of identification.

Criteria pollutants are pollutants that are both common and detrimental to human welfare. **(PM, SO_2, NO_2, O_3, Lead (Pb) and CO)**.

Air pollutants known or suspected to cause diseases like cancer, birth defects, reproductive complications, and other serious health effects are classified as **Hazardous Air pollutants or Air Toxics**. They consist of different types of chemical, physical and biological agents such as hydrocarbons (HC) **(***e.g., benzene, toluene and xylenes and other toxic organic pollutants***)**.

Table 1: Six (6) Common Criteria Pollutants

Ozone (O3)	Created by chemical reactions between nitrogen oxides (NOx) and volatile organic compounds (VOCs) in sunlight. It is the main component of the photochemical smog formed in the atmosphere. Major sources of NOx and VOC include: emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapours, and chemical solvents. Ground level ozone is a toxic air pollutant, different from stratospheric ozone, which protects the Earth from harmful ultraviolet radiation.
Particulate Matter (PM)	Also known as particle pollution, it is made up of a mixture of solid particles and liquid droplets found in the air. Common examples are: dust, dirt, soot, or smoke that are large or dark enough to be seen with the naked eye. Others, however, can only be detected through an electron microscope. It is generated from a wide variety of natural processes, such as dust storms, oceans/seas (sea salt), fugitive dust erosion by the wind, forest fires, volcanic eruptions, release of biogenic PM (e.g., plant wax) and anthropogenic sources: traffic, non-combustion and combustion industrial processes, power plants, construction activities, agricultural activities (including agricultural waste burning).
Carbon Monoxide (CO)	A colourless, odourless gas emitted from combustion processes. Mobile sources are the main source of CO emissions in the urban areas; open fires are another source that may be more significant in local areas.
Nitrogen Dioxide (NO_2)	One of a group of highly reactive gases known as nitrogen oxides (NOx), which include nitrous acid and nitric acid. Forms rapidly from emissions from cars, trucks and buses, power plants, and off-road equipment.
Sulphur Dioxide (SO_2)	It is an acidic gaseous pollutant that can affect human health, associated with increased daily mortality and hospital admissions from respiratory and cardiovascular disease. Fossil fuel combustion in power plants and other industrial facilities are the main sources of SO_2 emissions; other sources include: industrial processes such as extracting metal from ore, burning of high sulphur fuels by locomotives, large ships, and non-road equipment.
Lead (Pb)	Motor vehicles have been known to be the major contributor of lead emissions in the air. A multi-stakeholder initiative, the Partnership for Clean Fuels and Vehicles (PCFV) at the global level was established 10 years ago to phase-out the use of lead-based additives in gasoline and to address its adverse health impacts. Afghanistan, Myanmar, and North Korea are the three remaining countries that have yet to ban lead in gasoline (Rona and Fabian, 2014).

Source: US Environmental Protection Agency (2015)

1.3 Air Pollution and Climate Change

Not only does air pollution have adverse effects on our health, it also impacts the environment, ecosystems and climate. There is a clear association between air pollution and climate change and any measures undertaken to improve air quality will result in the co-benefits of climate change. Similarly, any implementation of climate change mitigation measures will also result in improvement of air quality.

This underscores the importance of curbing greenhouse gases (GHGs), such as carbon dioxide (CO_2) and methane (CH_4), and common air pollutants, ozone, and particle pollution. These pollutants, directly and indirectly, contribute to global warming, the impacts of which are palpable and urgent in urban areas and other vulnerable regions.

In 2012, the United Nations Environment Programme (UNEP), together with six countries (Bangladesh, Ghana, Canada, Mexico, Sweden, and the United States), established the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) to harness collective resources and maximize co-benefits of mitigation measures. While the coalition is at the global level, initiatives undertaken help raise awareness on short-lived climate pollutants (SLCPs) and enhance and develop national and regional actions.[5]

Global and regional Initiatives, such as the ones cited above and policies at the national level are by no means exhaustive. However, it is to be understood that seeing the relationship between air quality and climate change, addressing either one of these issues requires a collective effort and involvement of multiple stakeholders in order to achieve effective and sustainable results.

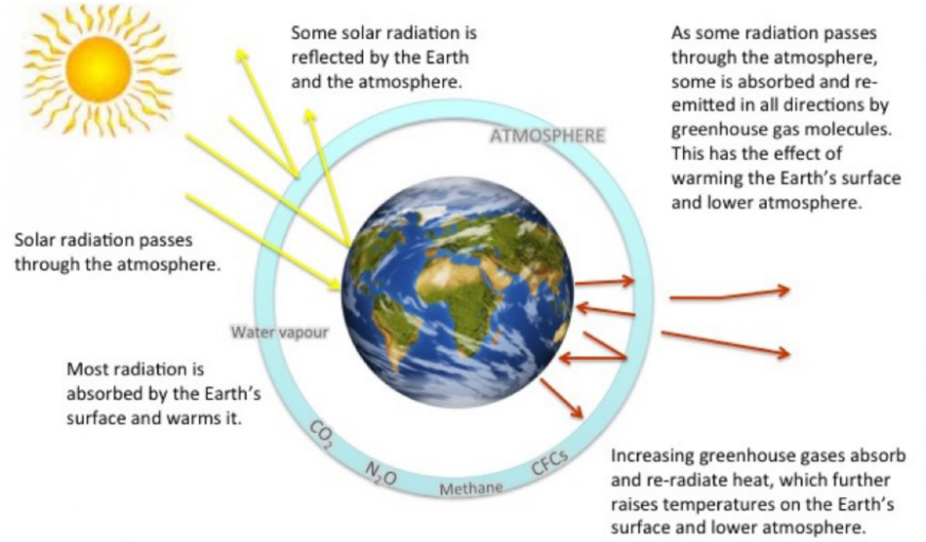
1.3.1. Greenhouse Gases

The earth's climate is fuelled by the sun. Most of the sun's energy, called solar radiation, is absorbed by the earth, but some is reflected into space. Clouds and a natural layer of atmospheric gases absorb a portion of earth's heat and prevent it from escaping into space. This keeps our planet warm enough for life and is known as the natural **'greenhouse effect'**[6]. Without the natural greenhouse effect, the planet would be uninhabitable due to the cold temperature of Earth.

[5] *United States Environmental Protection Agency, National Air Quality: Status and Trends of Key Air Pollutants, https://www.epa.gov/air-trends, accessed on 21st May 2021*

[6] *ISRIC World Soil Museum, 2013, What is greenhouse effect?, https://museum.isric.org/content/themestation/what-greenhouse-effect/climatechangeb2, accessed on May 2021*

Figure 3: Greenhouse Effect



Source: ISRIC World Soil Museum, 2013

The high levels of Carbon dioxide, methane, particulate matter (*especially black carbon or soot*), nitrous oxide, fluorinated compounds, and ozone being released into the earth's atmosphere, thereby causing the earth's temperature to rise and consequently an increased greenhouse effect[7]. This consistent rise in temperatures is called **Global Warming.**[8],[9]

Carbon dioxide (CO_2) is a natural gas present in the atmosphere. It is a greenhouse gas emitted from combustion but at the same time, is also vital to living organisms. Carbon dioxide accounts for the major share of greenhouse gases released in the world. CO_2 emissions largely occur due to the combustion of fossil fuels in electric power generation, motor vehicles, and industries. Although plants convert carbon dioxide back to oxygen, the rate of release of carbon dioxide from human activities is higher than what the world's plants can process. This situation is made worse by vast deforestation and damage to plant life due to acid rain.

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[7]*United States Environmental Protection Agency (2021), Climate Change Indicators: Atmospheric Concentrations of Greenhouse Gases, https://www.epa.gov/climate-indicators/climate-change-indicators-atmospheric-concentrations-greenhouse-gases, Accessed on November 2021*

[8]*Holi Riebeek (2010), Global Warming, Earth Observatory, National Aeronautics and Space Administration*

[9]*Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M. Wairiu, and K. Zickfeld, 2018: Framing and Context. In: Global Warming of 1.5°C.*

Methane (CH_4) emissions, which result from agricultural activities, landfills, and other sources, are the next largest contributors to greenhouse gas emissions in the world. Methane is not toxic; however, it is extremely flammable and may form explosive mixtures with air. CH_4 is estimated to have a GWP of 28–36[10] over a period of 100 years. CH_4 emitted today lasts for about a decade on average, which is much less time than CO_2. But CH4 also absorbs much more energy than CO2. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The CH4 GWP also accounts for some indirect effects, such as the fact that CH4 is a precursor to ozone, and ozone is itself a GHG.

Nitrous oxide (N_2O) is a greenhouse gas released from biomass burning, nitrogen fertilizers, and sewage. The major use of this gas is as an anaesthetic in dentistry and it is also a propellant in the food industry. N2O has a much higher GWP of 265–298[11] times that of CO_2 for a 100-year timescale. N_2O emitted today remains in the atmosphere for more than 100 years, on average.

Greenhouse gases like sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) are also subject to the Kyoto Protocol. SF6 is used as a gas medium in the electrical industry and medical applications. HFCs are used in refrigeration and air conditioning, solvents, degreasing agents, and cleaning agents. Use of PFCs is found in medical and non-medical applications such as in insulation, refrigerating unit, and fire extinguisher.

The Global Warming Potential[12] (GWP) was developed to allow comparisons of the global warming impacts of different gases. To put it in more specific terms – it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period, relative to the emissions of 1 ton of CO_2. The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over that time period. The time period usually used for calculating GWPs is 100 years. GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases (*e.g., to compile a national GHG inventory*), and allows policymakers to compare emissions reduction opportunities across sectors and gases.[13]

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[10]Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M. Wairiu, and K. Zickfeld, 2018: Framing and Context. In: Global Warming of 1.5°C.

[11]Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M. Wairiu, and K. Zickfeld, 2018: Framing and Context. In: Global Warming of 1.5°C.

[12, 13] United States Environmental Protection Agency, Understanding Global Warming Potentials, https://www.epa.gov/ghgemissions/understanding-global-warming-potentials, Accessed on 21st May 2021

1. CO_2, by definition, has a GWP of 1 regardless of the time period used, because it is the gas being used as the reference. CO_2 remains in the climate system for a very long time: CO_2 emissions cause increased atmospheric concentrations of CO_2 that will last thousands of years.[14]
2. CH_4 is estimated to have a GWP of 28–36[15] over a period of 100 years. CH_4 emitted today lasts for about a decade on average, which is much less time than CO_2. But CH_4 also absorbs much more energy than CO_2. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The CH_4 GWP also accounts for some indirect effects, such as the fact that CH4 is a precursor to ozone, and ozone is itself a GHG.
3. N_2O has a much higher GWP of 265–298[16] times that of CO_2 for a 100-year timescale. N_2O emitted today remains in the atmosphere for more than 100 years, on average.
4. Chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6) are sometimes called high-GWP gases because, for a given amount of mass, they trap substantially more heat than CO_2. (*The GWPs for these gases can be in the thousands or tens of thousands.*)[17]

The Kyoto Protocol is a protocol to the United Nations Framework Convention on Climate Change (UNFCCC) aimed at fighting global warming. The UNFCCC is an international environmental treaty with the goal of achieving stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Continuous emissions of **greenhouse gases** are causing a rise in temperatures and resulting in global warming. Extreme weather events such as droughts and floods, rising sea levels due to an increased rate of polar ice cap melting, which in turn are threatening the coastal resources and wetlands are some of the effects of global warming that are already visible today. Added to this, there is an increase in certain diseases due to the production of new breeding sites for pests and pathogens. Woodlands and agricultural areas are also vulnerable to changes in climate, which could result in an increased insect population and plant diseases. This degradation of natural ecosystems could lead to reduced biological diversity.

[14,15, 16, 17, 18] *United States Environmental Protection Agency, Understanding Global Warming Potentials, https://www.epa.gov/ghgemissions/understanding-global-warming-potentials, Accessed on 21st May 2021*

1.3.2. Ozone Depletion

The ozone layer in the stratosphere protects the Earth from harmful ultraviolet radiation from the sun. The stratosphere is affected by the chemicals released by human activities.[18] Harmful CFCs are released from use of aerosol cans, cooling systems like the air conditioners, and refrigerator equipment. These CFCs initially accumulate in the lower atmosphere before being transported to the stratosphere. Here, they interact with other gases and form reactive gases that in turn destroy the ozone layer.[19] The depletion of stratospheric ozone due to the release of gases containing chlorine and bromine allows additional ultraviolet radiation to pass through the atmosphere and reach the Earth's surface.[20] Exposure to these harmful radiations causes a rise in ultraviolet related health effects such as skin cancer, skin ailments, and harmful effects on our eyes like formation of cataracts.[21] In addition, it has a damaging effect on plants and wildlife on earth.

1.3.3. Short-Lived Climate Pollutants

These are powerful climate pollutants that tend to stay in the atmosphere for a much shorter duration than carbon dioxide (CO_2). Yet, their potential to warm the atmosphere can be many times greater. Some of them have also been identified as dangerous air pollutants that have harmful effects on people, ecosystems, and agricultural productivity.

Pollutants such as black carbon, methane, tropospheric ozone, and hydrofluorocarbons are categorised as short – lived climate pollutants and are significant contributors to the man-made global greenhouse effect after carbon dioxide, which is responsible for up to 45% of current global warming. These are expected to be the cause of as much as half of the global warming crisis in the coming years if no effective action is taken to reduce the emissions of these pollutants soon.

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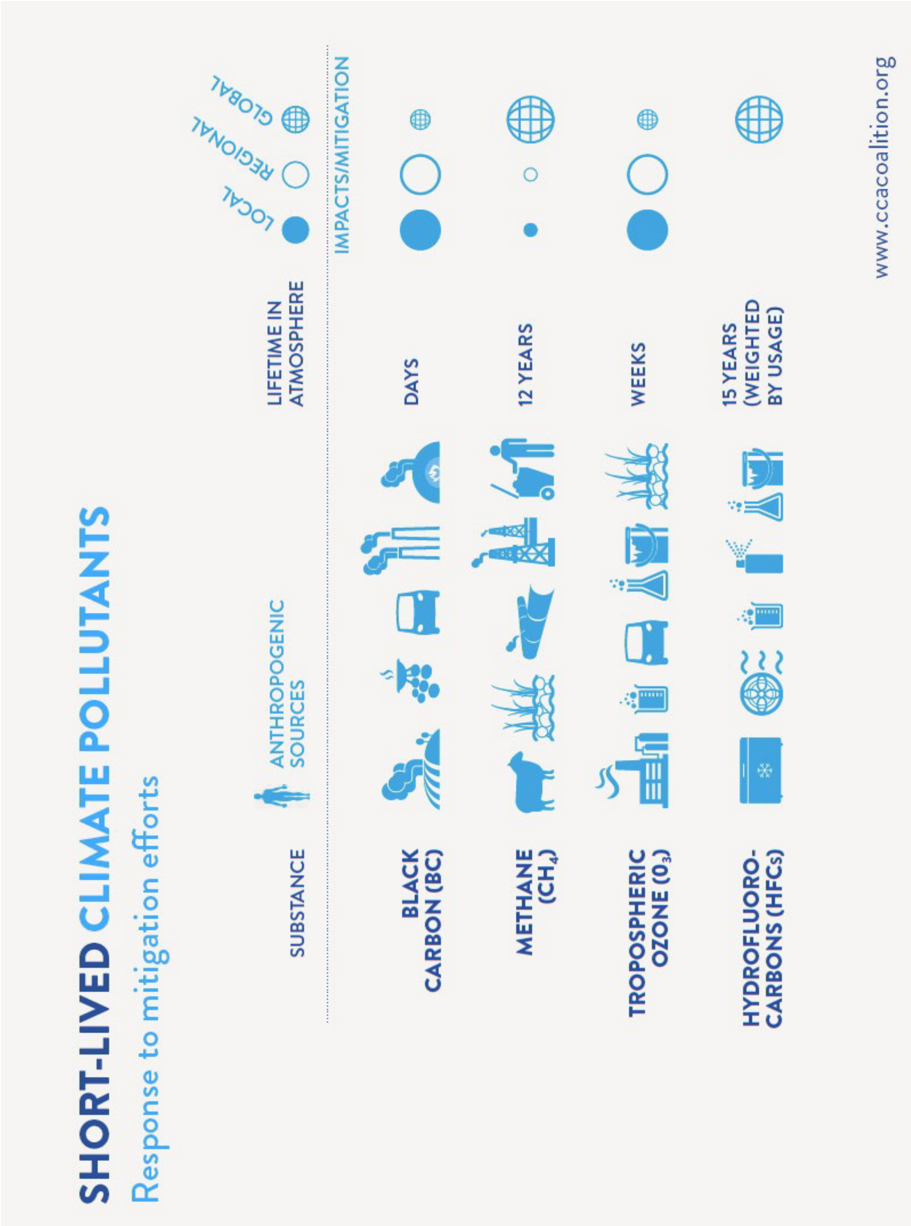
[19] *Union of Concerned Scientists (2017), Is there a connection between the Ozone Hole and Global Warming?, https://www.ucsusa.org/resources/ozone-hole-and-global-warming, Accessed on May 2021*

[20] *National Oceanic & Atmospheric Administration, Scientific Assessment of Ozone Depletion 2010, https://csl.noaa.gov/assessments/ozone/2010/, Accessed on May 2021*

[21] *United States Environmental Protection Agency, Ozone Layer Protection, https://www.epa.gov/ozone-layer-protection, Accessed on 21st May 2021*

Figure 4: Short-Lived Climate Pollutants



Source: www.ccacoalition.org

1.3.4. Black Carbon

It is a proven fact that combustion of any fuel is never a 100% and the process of combustion produces emissions of CO_2, carbon monoxide, volatile organic compounds, and organic carbon and black carbon particles. Black carbon is formed by the incomplete combustion of fossil fuels, wood, and other fuels. Black carbon or "Soot" as it is more commonly known is a complex mixture of particulate matter resulting from incomplete combustion.

Though Black carbon is categorized as a short-lived climate pollutant with a lifetime of only days to weeks after release in the atmosphere, it can have significant direct and indirect impacts on the climate, the cryosphere (*snow and ice*), agriculture and human health.

1.3.5. Methane

A powerful GHG, CH_4 is produced through human activities such as agriculture production, (*like rice cultivation*), ruminant livestock, coal mining, gas production and distribution, biomass burning, municipal waste land filling, animal activities and even stagnant water. According to the Inventory the U.S. Greenhouse Gas Emissions and Sinks 1990-2015, cows produce 150 billion gallons of methane per day. Wetland is also the largest natural source of anthropogenic methane in the world, contributing approximately 167 Tg of methane to the atmosphere per year.

It not only directly influences climate patterns, but also effects human health, crop yields and the quality and productivity of vegetation indirectly through its role as an important precursor to the formation of ground-level O_3.

CH_4 is a short-lived climate pollutant with an atmospheric lifetime of around 12 years. While its lifetime in the atmosphere is much shorter than CO_2, it is much more efficient at trapping radiation. Per unit of mass, the impact of methane on climate change over 20 years is 84 times greater than CO_2 over a 100-year period it is 28 times greater.

While CH_4 does not cause direct harm to human health or crop production, O_3 is responsible for about 1 million respiratory deaths globally. In India, there are an estimated 400,000 O_3 attributable respiratory deaths.[22]

The relatively short atmospheric lifetime of methane, combined with its strong warming potential, means that targeted strategies to reduce emissions can provide climate and health benefits within a few decades.

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[22] *Malley, C. S. et al. (2017) Updated Global Estimates of Respiratory Mortality in Adults ≥30Years of Age Attributable to Long-Term Ozone Exposure. Environmental Health Perspectives.*

1.3.6. Hydrofluorocarbons (HCFs)

Hydrofluorocarbons are man-made greenhouse gases. Although HFC's represent a small fraction of current greenhouse gas emissions, their potential to warm the atmosphere is thousand times greater than that of a similar mass of carbon dioxide. HFC's are most commonly used in air conditioning, refrigeration, solvents, fire extinguishing systems, and aerosols. The increasing use of these household items means an increased rate of emission of HFC's into the atmosphere, thus accelerating the global warming problem.

1.3.7. Tropospheric Ozone

Tropospheric or ground-level O_3 is the toxic pollutant which we breathe in contrast to stratospheric O_3, which protects the earth from harmful ultraviolet radiation.[23]

Ground-level O_3 is formed from the photochemical reactions of VOC and NOx in the presence of sunlight. This results in higher ambient O_3 concentrations in summer months. CH_4 is the dominant anthropogenic VOC contributing to O_3 formation in the global troposphere (See Figure 6). In the lowest part of the atmosphere, in regions where NOX concentrations are sufficiently high, reactions of OH radicals with CH_4 and other substances leads to the production of O_3.[24]

Tropospheric ozone is a major air pollutant. This greenhouse gas is formed by the interaction of sunlight with hydrocarbons and nitrogen oxides, which are emitted by vehicles, fossil fuel power plants, refineries, and other industries. It is especially harmful to vegetation and human health.

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[23] *United States Environmental Protection Agency, Ground Level Ozone Basics, https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics, accessed on 26th May, 2021*

[24] *Van Dingenen R. et al. (2018) Global trends of methane emissions and their impacts on ozone concentrations. JRC Science for Policy Report, EC Joint Research Centre, Ispra, Italy*

1.4 Emission Sources

Major sources of air pollution in India include coal fired power stations, industry, construction activity, and brick kilns, transport vehicles, road dust, residential and commercial biomass burning, waste burning, agricultural stubble burning, and diesel generators.[25]

Polluting air emissions can be identified based on their source:

1. Stationary (point) sources such as major industrial sites
2. Area (nonpoint) sources such as domestic emissions and emissions from light industry and commercial areas
3. Mobile (line) sources such as motor vehicles
4. Natural (biogenic) sources such as dust storms, forest fires, and volcanic eruptions.

1.4.1. Stationary sources

A stationary source refers to a fixed-site emitter of pollution which usually involves industrial combustion processes. Emissions could be generated from several single sources over a small area (*e.g., several smokestacks in a copper smelter*) or may be from various large or small sources. Emissions may also be released from material transfers, equipment leaks, stacks, or vents. Point source emissions can further be divided into various sub-categories, depending on the industrial process such as fugitive emissions, process emissions, combustion emissions, various solvent usage emissions, and storage tank emissions.

In India, the use of coal as a fuel accounts for two thirds of the share in electricity generation and a quarter of a share in various industries. It is a key component of the energy system. The efficiency and environmental performance of the coal sector is critical to reducing stationary emissions polluting air emissions such as SOx, PM and NOx.[26]

1.4.2. Area sources

Area sources refer to any source of air pollution emitted over an area, which cannot be classified as a point source. Area sources can be many similar small stack point sources (*e.g., household emissions*) which can be difficult to estimate individually.[27]

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[25] *The Lancet Planetary Health (2018), The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: The Global Burden of Disease Study 2017, Volume 3, Issue 1, E-26-E39*

[26] *IEA (2020) India's Energy Policy: key findings of the IEA in-depth Review 2020. International Energy Agency, Paris, France*

[27] *Nicole Davis, Kebin He, Jim Lents, Huan Liu et.al., Estimating Emission from Sources of Air Pollution, Accessed on 12th June 2021*

Household activities such as cooking, space- and water- heating, and kerosene used for lighting, all contribute to emissions generated from an Area Source.

> Since the inception of the Ujjwala LPG distribution programme, an initiative taken by the Government of India, the use of fuels like coal and kerosine has significantly decreased in households.

Other area sources include small business activities, agricultural residue burning, waste combustion fugitive dust from deposits and roads, forest fires, small activities from gasoline service stations, small paint shops, consumer use of solvents and biogenic (natural) sources. Waste deposits can also be a large area source of emissions.

Large urban cities in India are often surrounded by agricultural lands. This proximity to agricultural land makes the urban areas vulnerable to pollutants produced due to agricultural practices like open agricultural waste burning.

Urban areas are also prone to emissions produced from backyard burning of refuse (*garbage and biomass*) as well as open street cooking (*a result of poor urban planning which results in temporary settlements of migrants mushrooming in all parts of cities*). In the absence of properly monitored urban waste management facilities, open garbage burning has become another contributor of rapidly increasing air pollution. It is recognised that the combined impact of area sources could be significant but given the challenge of collecting data for each individual source, it is a difficult endeavour to calculate the level of emissions.

Diffuse sources are sources that are not clearly delimited such as open windows, gates, doors, tube connections and flanges in a plant. Emissions from diffuse sources include evaporative emissions from motor vehicles and non-road mobile sources (*e.g., hot soak emissions, running and diurnal losses*) and emissions from areas with light industry, domestic and wood burning as well as emissions from natural sources.

Area sources can be difficult and time-intensive to inventory and various screening techniques are often used to estimate their emissions.

1.4.3. Mobile sources

Mobile sources refer to the road and non-road vehicles, ships, and aircraft. Emissions from vehicles are usually generated near and in areas populated with people and can be distributed over a large urban area in addition, the tail-pipe emissions are close to the breathing level of the individual (*e.g.*, *breathing zone of children*); therefore, exposure and impact of vehicle source emissions on human health may be higher than that of stationary sources with elevated emission outlets.

Mobile road sources include all vehicles which move on roads. On-road sources include passenger cars; light duty vehicles; heavy duty vehicles; urban buses and coaches; and two- and three-wheelers.

Non-road sources include emission sources such as construction machines and equipment, tractors, lawn mowers, oil field equipment, boats, ships, aircraft, etc. Emissions from these sources are like those from road vehicles but difficult to estimate due to the fact that for most of the categories, no registration and activity rates are available.

Ships and aircraft Emissions from ships can be seen in harbours and on shipping routes close to ports. Similarly, aircraft emissions are at their highest during activities of take-off, landing and taxiing on the runway.

HCs are the main pollutant categories associated with motorised vehicles. They contain several different hydrocarbon species including carcinogenic substances such as benzene and PAH. Other pollutants emitted from motor vehicles include PM, NOx, CO, and NH_3. PM includes black carbon, metal oxides, sulphates, nitrates, and other chemicals.

1.4.4. Natural sources

Natural sources of air pollution include sand and dust storms, volcanic activity, and forest fires (*e.g.*, *those caused by lightning*). However, human activity like deforestation, can act as contributors to these natural sources.

Pollutants like SO_2 are emitted into the atmosphere from naturally occurring phenomena like volcanic eruptions. Volcanic eruptions generate gaseous, liquid, or solid products that deteriorate air quality.

Sand and dust storms usually occur during dry periods. They are a meteorological hazard, which is related to the process of wind erosion of surface soil and the mineral dust aerosol emission to the atmosphere.[28]

A large variety of natural VOC and inorganic gases (*NOx*, *NH_3 and sulphur compounds*) are emitted in the troposphere from terrestrial and water sources. It is now recognised that these volatile emissions affect the quality of the atmosphere at local, continental, and global scales, by producing secondary volatile pollutants (*O_3, carbonyl and carboxyl compounds*, *peroxyacylnitrates*, *peroxylakil nitrates*, *nitric and nitrous acids*) and aerosols (*sulphuric acid*, *sulphate and nitrate salts and organic particles*) through photochemical processes.

It is widely recognised that natural sources also contribute to air pollution. However, due to uncertainties like emission, reactivity, transport, and deposition of biogenic compounds in the atmosphere and the inability of mathematical models to describe these processes, it is difficult to do a precise assessment of the share of emissions from natural sources.

1.5 Impacts of Air Pollution

Air pollution can have detrimental effect on human health, ecosystems, vegetation, plant life and material assets both directly and indirectly. The severity of impact is dependent upon the concentration and mixture of the pollutants, the duration of exposure and the susceptibility of the sensitive receptor (i.e., human, flora, etc.).

Humans can suffer acute (short-term) and chronic (long-term) effects as a result of exposure to air pollution. Acute effects like eye irritation, headaches, nausea, and upper respiratory infections such as bronchitis and pneumonia are usually immediate and often reversible when exposure to the pollutants ends. Chronic effects on the other hand, surface only at later stages, when the damage has been substantial and therefore tend not to be reversible even after the exposure to the pollutants ends. According to WHO, some chronic health effects include stroke, heart disease, lung cancer and respiratory diseases resulting from long-term exposure to toxic air pollutants.

[28] *WMO (2019) WMO Airborne dust bulletin. World Meteorological Organization, Geneva, Switzerland, https://library.wmo.int/doc_num.php?explnum_id=6268, Accessed on June 2021*

1.67 million deaths were attributable to air pollution in India in 2019, accounting for 17.8% of the total deaths in the country.[29] The burden of disease linked to air pollution is substantial — air pollution contributes to a large percentage of deaths globally from each of these major types of disease.[30]

Table 2: Sources, Health and Welfare effects of Criteria Pollutants

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches, reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, death.	Contribute to the formation of smog.
Sulfur Dioxide (SO_2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO_2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O_3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

Source- no-air.rors.weebly.com (crop background

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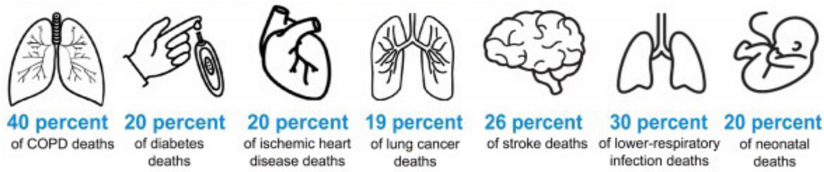
[29] *The Lancet Planetary Health (2020), India State-Level Disease Burden Initiative Air Pollution Collaborators. The health and economic impact of air pollution in the states of India: The Global Burden of Disease Study 2019, http://www.healthdata.org/research-article/health-and-economic-impact-air-pollution-states-india-global-burden-disease-study, Accessed on 21st May 2020*

[30] *State of Global Air 2020, Health Effects of Air Pollution, The latest data on air quality and health where you live and around the globe, https://www.stateofglobalair.org/, Accessed on 21st May 2020*

Figure 5: Percentage of Global Deaths attributed to Air Pollution in 2019



Source: State of Global Air 2020, Health Effects of Air Pollution

1.5.1. Environment

Air Pollutants are not just harmful to human health, but also cause great harm to the environment, architectural structures and all kinds of building and manufacturing materials. Urban cities are often plagued with haze resulting in reduced visibility and the main component of this is particulate matter present in the air. Particles can also make lakes and streams acidic, deplete the soil of nutrients, damage forests and farm crops, and affect diversity of ecosystems.[31] Similarly, ozone, which is the main component of the photochemical smog, affects materials and plants and can result in forest damage and reduced agricultural productivity. High SO_2 concentrations also damage vegetation by reducing chlorophyll in leaves.

Even man-made synthetic materials are not spared of the eroding effects of ozone. It can cause rubbers to crack, accelerate fading of dyes and deterioration of some paints and coatings. Ozone is also harmful to natural as well as synthetic textiles like cotton, acetate, nylon, polyester, and many others.

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[31] *United States Environmental Protection Agency, Particulate Matter Pollution, https://www.epa.gov/pm-pollution, Accessed on 21st May 2020*

1.5.2. Economic Costs

Adverse health impacts of air pollution affect a country's economy through a decline in productive days, revenues, and increased medical expenses. This is confirmed by a 2012 study done by the Massachusetts Institute of Technology (MIT), which shows that despite overall improvements in air quality, cost of illnesses resulting from ozone and PM exposure in China is estimated at USD112 billion.[32]

Another study conducted by the Hong Kong University's Faculty of Medicine illustrated that for every 6.5-kilometre reduction in visibility resulting from increased air pollution levels, there is a marked 1.13% increase in death by natural causes. For the period 2007-2010, around 1,200 annual deaths are associated with heightened exposure to air pollution.[33]

Moreover, cities such as Singapore, Hong Kong, and Baguio[34], which rely heavily on tourism for their income, are predicted to experience revenue losses during severe air pollution episodes.

1.6. Aligning with ClimateSmart Cities Assessment Framework 2.0

This training manual will focus on the Level of Air Pollution (Monitoring) indicator under the Mobility and Air Quality thematic area, which is aligned with CSCAF 2.0 aims to support adoption, implementation, and dissemination of global best practices towards green, sustainable, and urban resilient habitats.

The indicator of Clean Air Action Plan assesses cities in fostering key actions in monitoring air quality. It also accesses cities based on PM10 PM2.5, NOx, Sox pollutants monitoring, measures taken to comply with the National Air Quality Standards and the extent of air quality data made available to the public.

[32]Kira Matus et al. (2012), Health damages from air pollution in China, Global Environmental Change, 55-66.
[33]The University of Hong Kong (2011) HKU Study on Impact of Loss of Visibility on Mortality Risks: A Report of Regional and Global Importance, https://www.hku.hk/press/news_detail_6353.html, Accessed 21st May 2021.
[34]Joel Locsin (2014), Baguio air is among the dirtiest in the country, https://ph.news.yahoo.com/baguio-air-among-dirtiest-country-110541891.html, Accessed 21st May 2021.

Figure 5.1: Climate Smart City Assessment Framework 2.0, including five themes and 28 indicators, indicating Level of Air Pollution (Monitoring)

Table 3: Performance Levels of CSCAF

	1	2	3	4	5
Progression Levels	**No Consideration**	**Basic Monitoring**	**Availability of Data in Public Domain**	**Air Pollution Reduction Trend**	**Achievement of National Air Quality Standards**
Evidence/ Data sources		• Capture levels of PM_{10}, $PM_{2.5}$, NO_x, SO_x (as per CPCB Guidelines) • Additional Pollutants Monitored (like CO, NH_3, Pb and O_3 etc. as per NAAQS)	• Daily AQI levels are published and available to public through display boards/ SAFAR/ Sameer App/ any other app	• Reduction Air Pollution level based on previous year reading if available • Reduction trend / incremental improvement in compliance to National Clean Air Programme, • NCAP target (base year 2017)	• National ambient air quality standard for PM10, PM2.5, NOx and SOx has been met.
Responsible Department/ Agency	Central Pollution Control Board, State Pollution Control Board, Pollution Control Committee				
Reference Document	• National Ambient Air Quality Standards (NAAQS) (CPCB; 2009) https://cpcb.nic.in/uploads/National_Ambient_Air_Quality_Standards.pdf • Central Control Room for Air Quality Management, Delhi NCR https://app.cpcbccr.com/ccr/#/caaqm-dashboard-all/caaqm-landing				
Score	0	25	50	75	100

Photo Credits: India TVNews

2

Air Quality Standards

2.1 What are Air Quality Standards?

On the one hand, human health and the environment need to be protected from the harmful effects of air pollutants. On the other hand, industrialisation, urbanisation and use of technology is imperative for the development of any society. This in turn gives rise to emissions which further result in air pollution.

Air quality standards[1] are intended to provide the basis for protecting human health and the environment from the harmful effects of air pollutants. These are guidelines, collectively laid down by the governments and other global pollution control as well as health control agencies (like WHO) which define the permissible levels of emissions as well as acceptable levels of exposure to these emissions in a given area. Although these standards are protective towards human health, the endeavour has to be to reduce the emissions, rather than letting the pollutants reach the allowable limits. Attempts should be made to keep air pollution levels as low as practically achievable. Following are some factors to be considered while setting legally binding standards:

1. **Sensitive receptor** – human population such as children, the elderly and disabled persons, and people with asthma or other pulmonary and cardiac afflictions, vulnerable to air pollution
2. **Pollutant behavior** – the reactions the pollutant undergoes, its residence time in the atmosphere and its ability to accumulate or decompose

[1]*Clean Air Asia (2016), Guidance Framework for Better Air Quality in Asian Cities, Pasig City, Philippines https://cleanairasia.org/wp-content/uploads/2017/03/Ambient-Air-Quality-Standards-and-Monitor.pdf/*

3. **Natural levels** – concentration levels and fluctuations of pollutants that occur naturally or enter the atmosphere from uncontrollable sources such as volcanoes
4. **Technical feasibility** – the cost and availability of technology to control or avoid emissions

The authorities of a state decide on the air quality standards. The setting and application of air quality standards is an example of the authorities' right and obligation to define the standards and implement them.

2.2 WHO Air Quality Guidelines

First produced in 1987 and updated in 1997, the WHO AQGs are based on expert evaluation of existing scientific evidence. They offer guidance to reduce the health impacts of air pollution. The WHO AQG are intended to inform policy-makers and to provide appropriate targets for a broad range of policy options for AQM in different parts of the world.

In 2021, the WHO updated the AQGs which offer recommended exposure levels for PM10 and PM2.5, O_3, NO_2 and SO_2. The 2021 update lowered the recommended limits of many pollutants, making them much more stringent than the national standards currently applicable in many parts of the world (see Table 3).[2]

[2] *WHO (2021) Global Air Quality Guidelines. World Health Organization, Geneva, Switzerland. [Online] https://www.who.int/news-room/questions-and-answers/item/who-global-air-quality-guidelines (Accessed 30 Nov, 2021)*

Table 4 WHO Air Quality Guidelines

Pollutant	Averaging time	2005 AQGs	2021 AQG level
$PM_{2.5}$, µg/m³	Annual	10	5
	24-hour[a]	25	15
PM_{10}, µg/m³	Annual	20	15
	24-hour[a]	50	45
O_3, µg/m³	Peak season[b]	–	60
	8-hour[a]	100	100
NO_2, µg/m³	Annual	40	10
	24-hour[a]	–	25
SO_2, µg/m³	24-hour[a]	20	40
CO, mg/m³	24-hour[a]	–	4

Source: isgloble.org

Table no. 3 outlines the interim targets for each pollutant. These are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. These targets promote a shift from high air pollutant concentrations (*which have acute and serious health consequences*) to lower air pollutant concentrations. Successful achievement of these targets will pave the way for significant reductions in risks for acute and chronic health effects arising from air pollution. Progress towards the guideline values should be the ultimate objective of AQM and health risk reduction in all areas.

The basis of the WHO AQG values is presented keeping in mind the threshold limits for various air pollutants. These are derived from the concepts of lowest–observed- effect level, lowest–observed-adverse-effect level, or no-observed-adverse-effect level, by application of uncertainty factors (*e.g., threshold of carcinogens*).

If thresholds for the onset of health effects do not appear to exist, air quality guidelines are derived in the form of percentage-change-of-effect/concentration relationships (*risk–concentration relationships*).

WHO AQG are intended to provide background information and guidance to local authorities in making decisions for AQM in their respective regions. In the practical sense, populations are exposed to a complex mixture of chemicals. However, the guidelines have been designed to address the permissible levels of single pollutants. There are no guidelines to suggest acceptable levels of emissions or exposure for a mix of chemical air pollutants. The effect of exposure from a mixture of pollutants can have additive, synergistic or antagonistic effects.

However, WHO AQG are not standards that need to be applied to all countries. Rather, they have been adopted by various countries as guidelines and used for setting their own standards after considering various factors such as prevailing exposure levels, natural background concentration, meteorological conditions, and socio-economic considerations. The policy options in setting standards include questions on which proportion of the general population and which susceptible groups should be protected.

2.3 National Ambient Air Quality Standards

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

The CPCB, working together with the SPCBs, provides technical advice to MoEF&CC to fulfil the objectives outlined in the Air (Prevention and Control) Act, 1981.

NAAQS are set taking into consideration geographical conditions, pollutant background concentrations, available air pollution control technologies and the cost of treatment, international standards (*WHO, USEPA, EU and Chinese*) and the sensitivity/tolerance of the receptor. The SPCBs/PCCs can set more stringent standards than the existing national standards in their respective states but do not have the powers to relax these standards. Such a process is similar to the local divisions used within the USEPA with the goal of providing for the prevention, control, and abatement of air pollution.

Based on existing air quality in the region, number of complaints received, directions from the courts, the carrying capacity of the specific area, the cost of control strategies and many more such factors, regulatory authorities need to undertake concrete measures to ensure that the standards are successfully implemented. The process takes years or even decades, especially for pollutants where the level of standards is not easily available. The air pollution areas can be identified and designated as attainment and non-attainment areas. Two types of State Implementation Plans (SIP) can then be developed— an attainment-maintenance SIP if the area is designated as attainment, and an attainment-demonstration.

Table 5: Different Air Quality Standards

Sr. No.	Pollutant	Time weighted average	Indian AQS		Chinese AQS		USEPA AQS	EU AQS	WHO AQS
			Industrial, Residential, Rural area	Ecological sensitive area	Natural Protection Area	Residential, Commercial, Industrial and Rural Area			
1	Particulate Matter Pm10 (μg/m3)	Annual	60	60	40	70	-	40	20
		24 hours	100	100	50	150	150	50	50
2	Particulate Matter PM2.5 (μg/m3)	Annual	40	40	15	35	12	-	10
		24 hours	60	60	35	75	35	25	25
3	Sulphur Dioxide So2 (μg/m3)	Annual	50	20	20	60	75ppb (1 hour)	125	-
		24 hours	80	80	50	150	-	350	20
4	Nitrogen Dioxide No2 (μg/m3)	Annual	40	30	40	40	53 ppb	200	40
		24 hours	80	80	80	80	100ppb (1 hour)	-	-
5	Ozone O3 (μg/m3)	8 hours	100	100	100	160	0.070 ppm	-	100
		1 hour	180	180	160	200	-	-	-
6	Lead Pb (μg/m3)	Annual	0.5	0.5	-	-	-	-	-
		24 hours	1.0	1.0	-	-	0.15 (Rolling 3 month average)	-	-
7	Carbon Monoxide CO (mg/m3)	8 hours	2.0	2.0	-	-	9.0	10	-
		1 hour	4.0	4.0	10	10	35.0	-	30
8	Ammonia Nh3 (μg/m3)	Annual	100	100	-	-	-	-	-
		24 hours	400	400	-	-	-	-	-
9	Benzene C6H6 (μg/m3)	Annual	5	5	-	-	-	5	-
10	Benzo(a)pyrene BaP (μg/m3)	Annual	1	1	-	-	-	-	-
11	Arsenic As (ng/m3)	Annual	6	6	-	-	-	-	-
12	Nickel Ni (g/m3)	Annual	20	20	-	-	-	-	-
13	Poly Aromatic Hydrocarbon PAH (1 ng/m3)	Annual	-	-	-	-	-	1	-

Source: Clean Air Asia, WHO Air Quality Standards, EU Air Quality Standards, USEPA Air Quality Standards, China Air Quality Standards and NAAQS

2.4 National Air Quality Index

Citizens should be able to understand their location – specific vulnerabilities so that they can take precautions to reduce their exposure. AQ communication related to city hotspots (*using spatial maps or innovative graphics*) can enhance people's understanding of health risks and air pollution sources. Though citizens are potential casualties of air pollution due to their exposure to poor air quality, they are also the contributors to the problem through their actions (*e.g., travelling by car or open burning waste*). Effective communication is vital to increase awareness amongst the public to make pro-environment choices and become active participants. There is a need to promote active public engagement as part of the communication strategy to achieve air quality improvement actions and to foster behavioural change.

The Indian government launched the National Air Quality Index (AQI) in the year 2015. This is an alert system that aims to protect citizens from air pollution by notifying the public about the air quality status and associated health risks. AQI is described as 'One Number-One Colour-One Description' and allows the general public to judge the air quality within their vicinity. It transforms complex air quality data of various pollutants into a single number (index value), category and colour.[3] Many Indian cities have now established AQI to display air pollution levels.

There are six AQI categories: Good, Satisfactory, Moderately Polluted, Poor, Very Poor and Severe. Each category is based on the ambient concentration values of air pollutants and their likely health impacts (*known as health breakpoints*). The lower value of the range is known as a health breakpoint (*e.g., 51 is the minimum for the category 'satisfactory'*). AQ sub-index and health breakpoints have been developed for eight pollutants (*PM10, PM2.5, NO_2, SO_2, CO, O_3, NH_3 and Pb*) for which short term (up to 24 hours) NAAQS exist[4].

[3] *National Ambient Air Quality Standards, National Air Quality Index, Arthapedia, http://www.arthapedia.in/index.php?title=National_Air_Quality_Index, Accessed on 2nd June 2021*

[4] *Central Pollution Control Board, About National Air Quality Index, https://app.cpcbccr.com/ccr_docs/About_AQI.pdf, Accessed on 2nd June 2021*

Figure 6: Air Quality Index

AQI	Associated Health Impacts
Good (0-50)	Minimal Impact
Satisfactory (51-100)	May cause minor breathing discomfort to sensitive people
Moderate (101-200)	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor (201-300)	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease with short exposure.
Very Poor	(301-400)May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
Severe (401-500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

Source: MoEF&CC (2019) Government launches National Clean Air Programme (NCAP)

Communication of Air quality information during emergency situations needs a different approach for successful outcomes as compared to a long-term strategy to enable individual/community action. In the case of air pollution alerts, test procedures should be followed to ensure effective action.

The AQI provides an alert system to protect citizens from air pollution (see Figure 7). A health alert should be issued when the AQI is forecasted to be Very Poor and a health warning when the AQI is forecasted to be Severe. For the vulnerable category of people however, a health advisory is issued when the AQI is forecasted to be Poor.

Figure 7: AQI and associated health advisory and effects

Air Quality Index (AQI)	PM 2.5 Health Advisory	PM 2.5 Health Effect Statement	Overall Associated Health Impact with AQI Level
Good (0 – 100)	No cautionary action required	Air pollution poses little or no risk	Minimal impact
Moderate (101 – 200)	Unusually sensitive people should consider reducing prolonged or heavy exertion and heavy outdoor work	Air quality acceptable for general public but moderate health concern for sensitive people	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor (201 – 300)	Children and adult with heart or lung disease, should reduce prolonged or heavy exertion and limit outdoor activity	Children and adult people at risk. More chances of precipitating respiratory symptoms in sensitive individuals.	May precipitate severe attack on short term exposure in high risk individuals and respiratory symptoms (breathing discomfort) in normal individual on long term exposure.
Very Poor (301 – 400) Triggers **"Health Alert"**	Everyone should reduce prolonged or heavy exertion. More caution for children or adult with heart or lung disease.	Triggers health alert. Everyone may experience more health effects. Significant increase in respiratory effects in general population	May cause mild respiratory problems in normal individual/ more pronounced in people with lung and heart disease.
Severe (401 – 500) Triggers **"Health Warning"**	Everyone should avoid all outdoor physical activity. Sensitive individual should remain indoor with minimal activity.	Should be declared as emergency condition. Serious risk of respiratory effect in general population as high risk.	May cause respiratory effects even on healthy people and serious health impacts on people with lung and heart diseases. The health impacts may be experienced even during light physical activity

Source: Ahmedabad Municipal Corporation (2018) Ahmedabad Air Information and Response Plan

2.4.1. Health Advisory

When the pollution levels are between 201 – 300, the AQI is forecasted as Poor. People under the vulnerable categories can be severely affected by even these levels of pollution, and therefore, a health advisory is issued for them to take precautions. Information about alerts is shared with the Pollution Control Board. Actions to be carried out under health advisory include informing relevant departments, medical facilities and schools about the air quality conditions.

2.4.2. Health Alert

An air health alert is issued when AQI levels are forecasted to be Very Poor at 301 or greater within the next 24 hours. Actions to be carried out under health alert include informing urban health centres as well as private medical practitioners, pulmonologists, paediatricians to alert them to expect and be prepared for more cases of respiratory health effects.

2.4.3. Health Warning

A health warning is called when AQI levels are forecasted to be Severe and equal to or greater than 401 within the next 24 hours. Actions to be carried out for a health warning include informing urban health centres as well as private medical practitioners, pulmonologists, paediatricians to alert them to expect and be prepared for more cases of respiratory health effects. Inform 108 emergency ambulance service that air pollution is forecasted to be severe. City departments include transport, traffic police, estate department, schools and colleges and environmental management should also be informed. Finally, an Air Health Warning should be published in the print and broadcast media, including newspapers, radio, and television.

2.5 National Clean Air Programme

In 2019, the Ministry of Environment, Forest and Climate Change launched the National Clean Air Programme (NCAP), as a long – term, time-bound, national level strategy to tackle air pollution across the country in a comprehensive manner.

The target of NCAP is to achieve a 20% - 30% reduction in Particulate Matter (PM) concentration by 2024 keeping 2017 as the base year for comparison concentration.[5]

There are several initiatives which are being taken under the NCAP:

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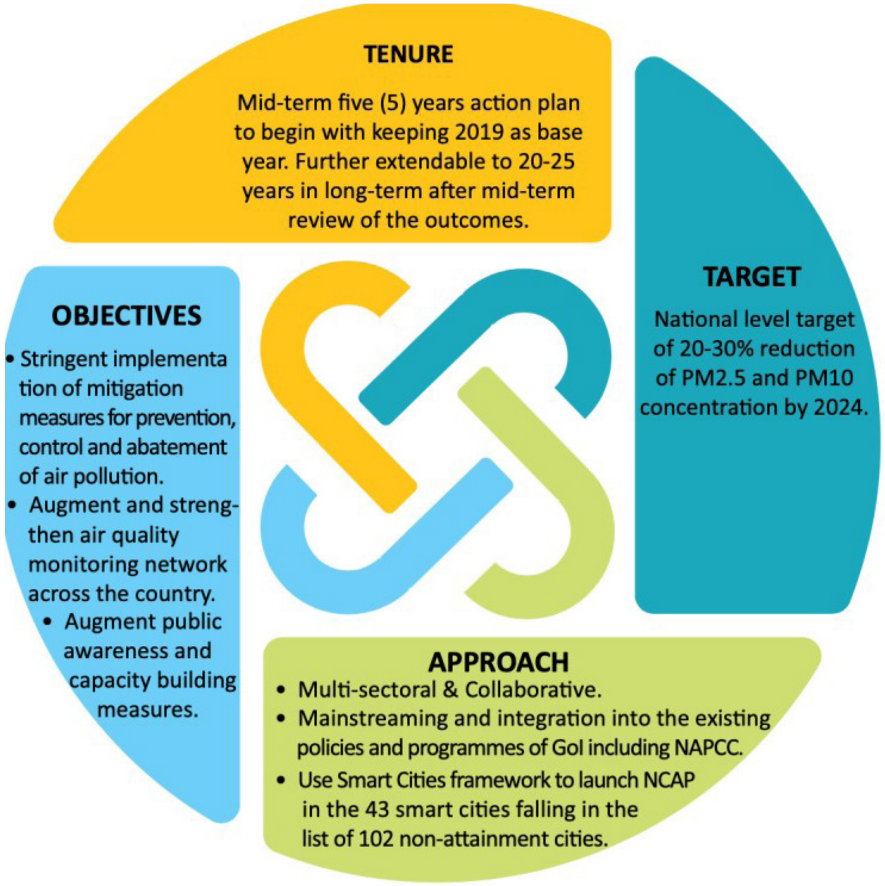
[5] *Press Information Bureau, (Sept, 2020), National Clean Air Programme, Long-Term, Time-Bound, National Level Strategy to Tackle Air Pollution-National Clean Air Programme (NCAP) To Achieve 20% to 30% Reduction in Particulate Matter Concentrations by 2024, Accessed on September 2021*

1. Augmenting Air Quality Monitoring Network.
2. Air Quality Management Plans for Non-Attainment Cities
3. Indoor Air Pollution Monitoring and Management
4. National Emission Inventory
5. Network of Technical Institutions
6. Technology Assessment Cell
7. Institution Framework.

Figure 8: Overview of National Clean Air Programme



Source: National Clean Air Programme

The NCAP proposed to formulate time bound clean air action plans for the identified 102 Non – Attainment cities. The idea behind the city action plans (under the NCAP) was to prepare the cities to control specific air pollution sources through multidimensional actions. This was to be done by bringing several implementation agencies to work together. Other important goals of this plan are expansion of the ambient air quality network, source apportionment studies, public awareness, grievance redressal mechanism and sector specific action points for the respective cities.

These Action plans need to be guided by a comprehensive science-based approach involving:

1. Identification of emission sources
2. Assessment of extent of contribution of these sources
3. Prioritising the sources that need to be tackled.
4. Evaluation of various options for controlling sources regarding feasibility and economic viability.
5. Formulation of action plans

NCAP's approach includes collaborative, multi-scale and cross-sectoral coordination between the relevant central ministries, state governments and local bodies. This includes coordination with existing policies and programmes, such as the National Action Plan on Climate Change (NAPCC) and the Climate Smart Cities Assessment Framework. Under NCAP, the 132 non-attainment cities[6] must develop city specific action to implement mitigation actions.

Box 1. National Action Plan on Climate Change

Launched in 2008, NAPCC included eight core "national missions" which represents a multi-pronged, long-term, and integrated approach for achieving key goals in the context of climate change. These include: National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a Green India, National Mission for Sustainable Agriculture, and National Mission on Strategic Knowledge for Climate Change. In 2016, India ratified the UN Paris Agreement to combat climate change. The Paris Agreement requires all Parties to put forward their best efforts through "nationally determined contributions" (NDCs). NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change. The Paris Agreement (Article 4, paragraph 2) requires each Party to prepare, communicate and maintain successive NDCs that it intends to achieve.[7]

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[6] *Central Pollution Control Board, List of Non-Attainment Cities, List of 132 Non-attainment/ Million plus cities in India under NCAP, cpcb.nic.in, accessed on 21st May 2021*

[7] *UNFCCC, What is the Paris Agreement? United Nations Framework Convention on Climate Change, Berlin, Germany.*

Photo Credits: real-time-aqi-air-quality-index

3

Air Quality Monitoring

3.1 Why Monitor Air Quality?

Air quality monitoring is a key element of air quality management (AQM) and provides data to:

1. assess compliance with current ambient air quality guidelines and standards
2. help development and evaluation of existing and proposed control policies and strategies.
3. determine if an area is attaining or not attaining the air quality standards.

Only through effective monitoring systems can we obtain robust and credible AQ data that can contribute to effective decision-making in AQM. But this is not enough. In order for the monitoring systems/programs to be successful, factors like cost-effectiveness; have stable financial, operational and personnel resources; and adaptability to local needs and conditions should be considered while designing them.

Air quality monitoring data is also used to:

1. generate or validate computer models of air pollution dispersion
2. inform the public about air quality and raise awareness
3. enable comparison of air quality data from different areas and countries
4. collect data for traffic and land-use planning purposes
5. determine exposure and assess effects of air pollution on health, vegetation or building materials and develop warning systems for prediction of air pollution episodes.

Table 6 Common Objectives of Air Quality Monitoring

Basic Objectives	Specific Objectives
Timely public reporting	Assess short-term pollution levels
	Develop an air quality index (or other tools for data communication)
	Forecasting
Compliance	Determine compliance levels with standards
	Observe pollution trends
	Formulate pollution control strategies
	Examine the extent and causes of elevated concentrations
	Enhance understanding of chemical and physical properties of atmospheric pollution and pollution sources
	Evaluate the effectiveness of pollution control strategies
	Support national and international agreements and initiatives
Research	Identify pollutant generation and behavioral characteristics
	Assess impacts to different groups of populations
	Assess impacts to visibility impairment, climate change and ecosystems
	Validate models
	Discover new contaminants

Source: United Nations Framework Convention on Climate Change (2016)

Box 2: Current Status of Air Monitoring

Air Pollution data can be collected through two methods.

- Manual Methods – Specific techniques that must be followed when collecting and analysing an air pollutant sample.
- Automated Methods – They are primarily used to collect and analyse ambient air on a continuous basis.

The Central Pollution Control Board initiated the National Ambient Air Quality Monitoring Programme (NAMP) in 1984. Under N.A.M.P., four air pollutants viz., SO_2, NO_2, Respirable Suspended Particulate Matter (RSPM / PM10) and Fine Particulate Matter (PM2.5) have been identified for regular monitoring at all the locations. The monitoring of meteorological parameters such as wind speed and wind direction, relative humidity (RH) and temperature were also integrated with the monitoring of air quality. (*Source: About National Air Monitoring Programme https://cpcb.nic.in/about-namp/*)

In 2010, Continuous Ambient Air Monitoring was launched. A continuous monitoring system is comprised of sampling, conditioning, and analytical components and software designed to provide direct, real-time, continuous measurements of pollution by analyzing representative sample(s) of air.

- Total Number of Continuous Ambient Air Monitoring Stations Installed:**166**
- Total Number of Manual Ambient Air Quality Monitoring Stations Installed:**793**

Source: Central Pollution Control Board

Photo Credits: ***Ivan Bogdanov on Unsplash***

4

Mechanism of Monitoring Air Quality

4.1 Designing Ambient Air Monitoring Network

Air quality monitoring program will depend upon the monitoring objectives, the measuring strategy, and the pollutants to be assessed. For the air quality parameters or selected indicators to be relevant, the concentration of an air pollutant and associated averaging time needs to be specified. Some review of information and a screening study would have to estimate the following:

1. magnitude and variation of pollutant concentrations in space and time;
2. availability of supplementary information, such as topographical data, population density and spatial distribution, background concentrations, air quality standards or guidelines, sources, emission estimates, wind speed and direction distribution, dispersion modelling capacity and others;
3. required accuracy of the estimated concentrations.

One can get information about expected air pollution levels, highly impacted areas, and general air pollution background levels through these estimates.

4.2 Steps to Design Air Quality Monitoring Network

An operational sequence is to be followed once the objective of air sampling is well-defined and results of the screening study are available. In general, there are ten individual items that need to be addressed in designing an ambient air-monitoring network.[1]

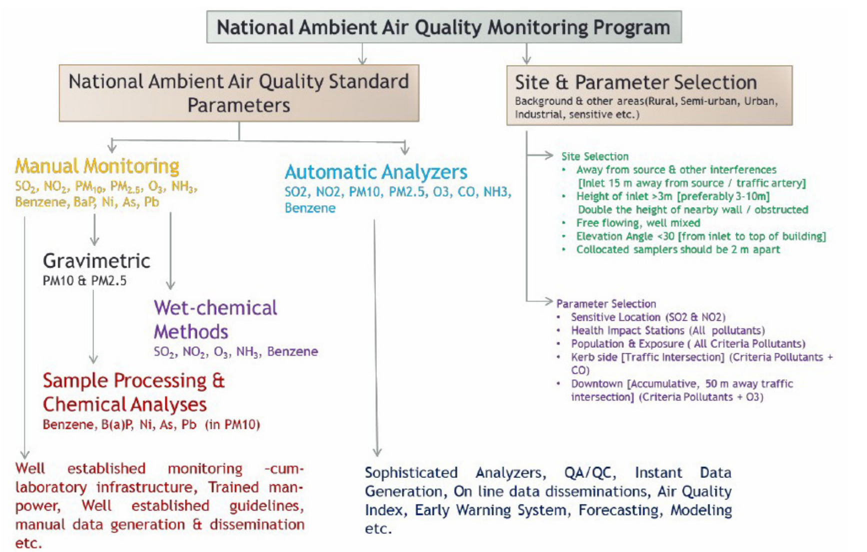
[1]*Haq, G & Schwela, D. (2008). Air Quality Monitoring, Climate and Clean Air in Developing Countries, https://www.researchgate.net/publication/263970505_Air_Quality_Monitoring, Accessed on 21st May 2021.*

4. Set objectives—these refer to the quality of data needed, what air pollutants should be measured, sampling times and seasons of the year sampling will be performed.
5. Choosing the parameters to be measured, in addition to specific pollutants, meteorological parameters (*i.e., speed, wind direction, temperature and mixing depth*) and topographical features may need to be included.
6. Selecting sampling sites—this is with reference to the number and placement based on money and manpower constraints and confidence in the desired results.
7. Scheduling sampling and duration—to ascertain whether the sampling is to be conducted over long term or short term.
8. Selecting air sampling methods—this step requires selecting the most suitable sampling method namely, continuous, integrated, grab sampling, intermittent sequential sampling, or a combination of these.
9. Equipment selection—identification of suitable instruments, calibration instruments and shelter design and fabrication is very important to ensure accuracy of readings.
10. Setting calibration procedures—this step refers to the preparation of gas mixtures of known air pollutant concentrations along with instrument flow calibrations.
11. Choosing data recording methods—choosing the most suitable data recording method out of the available ones (*i.e., strip chart, analog or digital electronic data loggers*).
12. Data analysis—useful types of analysis include spatial distribution of pollutants, concentration frequency distribution, averaging time analysis and regression analysis.
13. Reporting results—presented results can be in the form of graphs, histograms, pollution roses and isopleth maps.

Several documents have been published by the CPCB describing air quality monitoring, largely for regulatory purposes. The relevant publications in the context of air quality monitoring and summary, protocols, and guidelines described in the CPCB are presented here.[2]

It is explained in these documents, that under the National Ambient Air Quality Monitoring Programme (NAAMP), air quality monitoring can be done in two ways - manually and through automatic analysers. Monitoring of the some of the pollutants could be done manually as well as through automatic analysers (e.g., SO_2, NO_2, PM10, PM2.5, CO, NH_3, O_3, C_6H_6) but for all metals and benzo(a)pyrene (BaP), the monitoring has to be done manually on filter paper. However, CO can be monitored only through an automatic analyser. A summary sheet developed by CPCB for air quality monitoring under NAAMP, site and parameter section and methods to be employed is presented in this image.

Figure 9: National Ambient Air Quality Monitoring Program Site and Parameters



Source: Central Pollution Control Board (2003), Guidelines for Ambient Air Quality Monitoring

[2] *Central Pollution Control Board (2003), Guidelines for Ambient Air Quality Monitoring, Delhi, India: Central Pollution Control Board.*

4.2.1. Guidelines for Monitoring

For setting up of any ambient air quality monitoring station, the most important thing to be considered prior to commencement of actual monitoring is to collect its background information.

Details of sources and emissions, health status, demography, population growth, land use pattern, epidemiological studies are all part of the background information that needs to be collected. Such prior information will provide immense help to identify the likely effects and in particular health impacts resulting from population exposure to air pollutants.

1. **Sources and Emissions**
    i. Emission sources in a city can be vehicular, industrial, or domestic. Usually, it is a combination of emissions from all three sources that causes air pollution in cities.
    ii. Information about number and distribution of sources needs to be collected from industrial areas for better calculation of level of emissions. Information should also be obtained on the type of industries including their number, fuel used, composition of fuel, pollutants emitted etc. This information will help in identifying which pollutants can be expected in an area and thus should be measured. In case of industrial stacks, locations of maximum ground level concentrations should be determined by modelling. The stations should be located at locations where maximum ground level concentrations are expected. Information on type and number of vehicles should be obtained. Information on domestic fuel that is used in households should also be obtained. Pollution load emanating from these sources should be estimated so as to identify sources that are generating a significant amount of pollution.

2. Health and Demographic
    i. Information Investigations shall be carried out based on the public complaints received from an area related to air pollution. In case the investigations reveal that the pollution levels are high in an area, then it can be considered for ambient air quality monitoring. Areas where population density is high (*more than one million*) can be considered for locating monitoring stations. Factors like socio – economic status and age are also important for making a decision on initiation of ambient air quality monitoring. Location of monitoring stations in such areas will help in finding exposure levels to the population which can be used further in epidemiological studies to evaluate health effects of air pollutants.

3. Meteorological Information
    i. Meteorological data such as temperature, relative humidity, wind speed and direction should be collected. Predominant wind direction plays an important role in determining location of monitoring stations. It is important to keep in mind specific meteorological factors such as land and sea breezes, valley effects etc. while collecting local meteorological data specific to the site as these will affect the readings for that region. The monitoring stations should be located in areas that are downwind from the sources. Mixing height data should also be collected from the Indian Meteorological Department. Information on the duration of various seasons in a year is also important. Measurement frequency should be such that monitoring is done in all the seasons so that all seasonal variations are included in computing the annual average.

4. Topographical Information
    i. Local winds and stability conditions are affected by topography. In river valleys there is an increased tendency of developing inversions. More number of monitoring stations should be located in areas where spatial variations in concentrations are large. Presence of mountains, hills, water bodies in a region also affect dispersion of pollutants.

5. Previous Air Quality Information
    i. Any previous information collected on ambient air quality can serve as a basis for selecting areas where monitoring should be conducted and previous studies may include data collected for any health studies etc. Previous studies are helpful in estimating the magnitude of the problem. Once the background information is collected, the ambient air quality monitoring is to be initiated and selection of type of pollutant to be measured, number and distribution of monitoring stations etc. should be made.

4.3 Methods of Measurement

The above-mentioned publications of CPCB provide the guidelines for sampling and analysis of the pollutants under NAAMP (*both for manual and automatic sampling*).

Some important points from the above publication of CPCB regarding air quality monitoring are reproduced below[3]

Manual Sampling

2. Sulphur dioxide in ambient air (*Improved Westand Gaeke Method*)
3. Nitrogen dioxide in ambient air (*Modified Jacob and Hochheiser Method*)
4. Particulate Matter (*(PM10) in ambient air Gravimetric Method*)
5. PM2.5 in ambient air (*Gravimetric Method*)
6. Ozone in ambient air (*Chemical Method*)
7. Ammonia in ambient air (*Indophenol Method*)
8. Benzo(a)pyrene & other PAHs in Ambient Air (*Solvent Extraction & GC Analysis*)
9. Lead, Nickel and Arsenic in ambient air (*Atomic Absorption Spectrophotometer Method*)
10. Data sheets

Automatic Analysers

1. Sulphur Dioxide in ambient air (*UV Fluorescence Method*)
2. Particulate Matter (PM10 and PM2.5) in ambient air (*Beta Attenuation Method*)
3. Carbon Monoxide (CO) in ambient air (*Non-Dispersive Infrared Method*)
4. Oxides of Nitrogen (NO – NO_2 - NOx) and Ammonia (NH_3) (*Chemiluminescence Method*)
5. Ozone (O_3) in ambient air (*UV Photometric Method*)
6. Benzene Toluene and xylene (BTX) in ambient air (*Gas Chromatography Methods*)
7. Data Formats

The following publication of CPCB describes some important aspects of air quality monitoring objectives, NAAMP, monitoring locations, number of monitoring locations, sampling duration and frequency, measurement methods laboratory requirement quality assurance and operation of air quality monitoring equipment.

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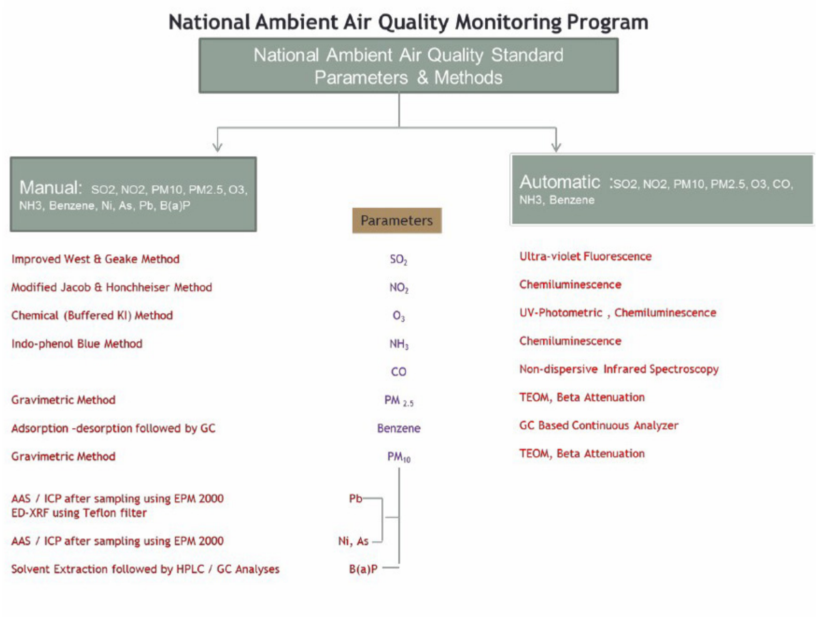
[3]*Central Pollution Control Board (2003), Guidelines for Ambient Air Quality Monitoring, Delhi, India: Central Pollution Control Board.*

Figure 10: National Ambient Air Quality Monitoring Program Parameters and Methods



Source: Central Pollution Control Board (2003), Guidelines for Ambient Air Quality Monitoring

4.3.1. Components of Monitoring

The following parameters need to be decided for carrying out ambient air quality monitoring.

8. Number and Distribution of Monitoring Locations
    i. The number of air stations required as well as their distribution depends upon the knowledge of existing air pollutant levels and patterns of emissions within the area. Isopleths distribution of an ambient concentration determined from modelling or previous air quality information can be used to determine number and distribution of stations. In case of absence of isopleths maps, information of emission densities and land use pattern may be used with windrose data to determine areas of expected higher concentrations. The number of monitoring stations in a city can be selected based on background information collected on sources and emissions, Population figures which can be used as indicators of region variability of the pollutant's concentration

The no. of sampling sites depends on:

a. Size of the area to be covered
b. The variability of pollutant concentration over the area to be covered
c. The data requirements, which are related to the monitoring.
d. Pollutant to be monitored and
e. Population figures which can be used as indicators of criticality both from view of likely air quality deterioration as also health implications.

Figure 11: Recommended Minimum Number of Stations (Population wise)

Pollutant	Population of Evaluation Area	Minimum No. of AAQ Monitoring Station
SPM (Hi-Vol.)	<100 000	4
	100 000- 1000 000	4+0.6 per 100 000 population
	1000 000 – 5000 000	7.5 + 0.25 per 100 000 population
	>5000 000	12 + 0.16 per 100 000 population
SO_2 (Bubbler)	<100 000	3
	100 000- 1 000 000	2.5+0.5 per 100 000 population
	1000 000 - 10 000 000	6+0.15 per 100 000 population
	>10 000 000	20
NO_2 (Bubbler)	<100 000	4
	100 000- 1000 000	4+0.6 per 100 000 population
	>1000 000	10
CO	<100 000	1
	100 000- 5 000 000	1+0.15 per 100 000 population
	>5 000 000	6+0.05 per 100 000 population
Oxidants	-do-	-do-

Source: Central Pollution Control Board (2003), Guidelines for Ambient Air Quality Monitoring

4.4 Air Quality Monitoring Site Selection

Principal factors like the objectives of the sampling, the methods and instruments[4] used for sampling, the available resources, physical accessibility, and security against loss and tampering of data need to be kept in mind while deciding on an air quality monitoring site. Air quality monitoring should be prioritised for areas where the pollution problem exists or is expected to be high. For example, industrial areas, densely populated urban areas, busy traffic intersections etc. To avoid getting results that do not meet the objectives of monitoring or limited value data collection, it is important not to choose incorrect sites for air quality monitoring. In general, the following requirements should be satisfied for site selection.

4.4.1. Site

A site is selected if the data generated from the site reflects the concentrations of various pollutants and their variations in the area. To understand the level of satisfaction for the chosen area for monitoring, an activity of taking simultaneous measurements at some locations in the area concerned can be undertaken. The station should be located at a place where interferences are not present or anticipated. In general, the following conditions should be met:

1. 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.
2. The site should be away from absorbing surfaces such as absorbing building material. The acceptable clearance should be atleast 1*m* but the actual distance will depend on the absorbing properties of the material for the pollutant in question.
3. As the monitoring activity tends to be conducted over long periods of time, the site selection should be such that no land use changes (*like rebuilding, expansion, construction etc.*) should be expected on the site for the duration of the monitoring activity. The objective of monitoring is often to measure air quality trends.

The instrument must be placed in areas where free flow of air is available. The instrument should not be in a confined place, corner, or a balcony.

[4]*Central Pollution Control Board (2003), Guidelines for Ambient Air Quality Monitoring, Delhi, India: Central Pollution Control Board.*

4.4.2. Comparability

For data of different stations to be comparable, the details of each location should be standardised. The following is recommended in IS 5182 (Part 14) 2000

1. 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.
2. For traffic pollution monitoring the sampling intake should be 3*m* above the street level. The height of 3*m* is recommended to prevent re-entrainment of particulates from the street, to prevent free passage of pedestrians and to protect the sampling intake from vandalism.
3. 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.

4.4.3. Physical requirement of the monitoring site

The following physical aspects of the site must be met:

1. The site should be available for a long period of time
2. Easy access to the site should be there anytime throughout the year.
3. Site sheltering and facilities such as electricity of sufficient rating, water, telephone connection etc. should be available.
4. It should be vandal proof and protected from extreme weather

Highest concentrations and concentration gradients of carbon monoxide are likely to be in the vicinity of roads, highways. The gradients vary in both time and space on the micro and on the neighbourhood scale. The recommended criteria for siting monitoring stations for CO is given IS 5182 (Part 14): 2000.

Topographical factors like the presence of mountains, lakes, valleys, oceans, and rivers should be considered while selecting a monitoring site. The topographical factors can give rise to meteorological phenomena that may affect air pollutants distribution.

5

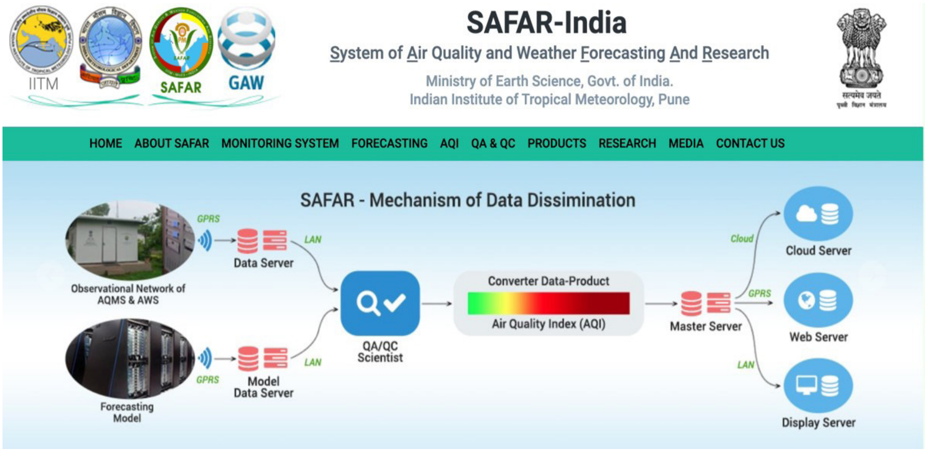
Case Study

5.1 SAFAR

SAFAR or the System for Air Quality Weather Forecasting and Research was set up under The Ministry of Earth Sciences (*Government of India*), which leads this project, implemented by Indian Institute of Tropical Meteorology. SAFAR is applicable in 4 Indian cities, namely Ahmedabad, Delhi, Mumbai, and Pune. It is an observational network of Air Quality Monitoring Stations (AQMS) and Automatic Weather Stations (AWS).

The objective of SAFAR is to ensure a true representation of the city's environment. It does so by operating within the city limits and collecting data for selected urban microenvironments. These microenvironments could be industrial, residential, background/cleaner, urban complexes, and agricultural zones.

Figure 12: SAFAR - India



Through SAFAR, the city can see location specific information on current air quality and even an advanced air quality forecast of up to three days. Some of the pollutants covered under this monitoring system are particulate matter, nitrogen dioxide, nitrogen oxides, carbon monoxide, black carbon, and ground-level ozone. SAFAR also enables data for specific weather forecasting, harmful radiation, and emission scenarios over the city area. Air Quality is monitored at about three metre height from the ground with online sophisticated instruments.

SAFAR has incorporated an easy-to-understand format for to disseminate[1,2] information. Health advisories are also displayed along with the pollution levels, thus leading to self-mitigation and policy help, sequentially benefiting the society. There are plans for SAFAR to be expanded in Bengaluru, Chennai, and Kolkata.

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[1] *SAFAR website - http://safar.tropmet.res.in/index.php?menu_id*

[2] *SAFAR Application - https://play.google.com/store/apps/details?id=com.cloud.mobile.android.airqualityindex&hl=en (or) https://apps.apple.com/us/app/safar/id982823016?ls=1*

5.2 Ahmedabad Heat Action Plan: Communication During Emergency

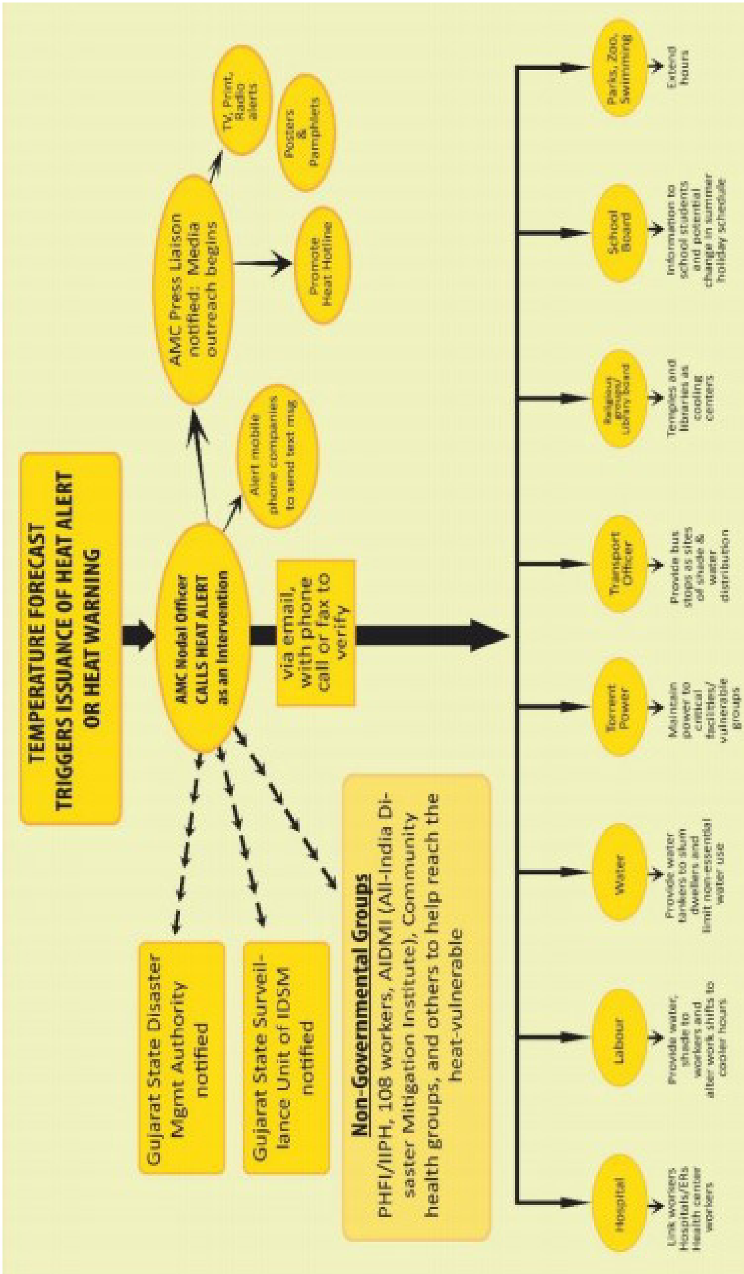
The Ahmedabad's Heat Action Plan is a comprehensive early warning system and preparedness plan for extreme heat events in Ahmedabad.

The main objective of this plan is to spread awareness amongst the public about how they can take immediate and long-term actions as precautionary measures against the extreme heat of Ahmedabad. The objectives also include increased preparedness, information-sharing, and response coordination to reduce the health impacts of extreme heat on vulnerable populations.

The communication is affected through the dissemination of public messages on how to protect people against extreme heat. This is done by making using of numerous media channels, like distribution of informational materials such as pamphlets, print advertisements as well as television commercials addressing heat stress prevention and the use of social media. Platforms like Facebook, Instagram, Twitter, Televisions and Radio are used to reach people with information about prevention from extreme heat. Efforts also include sending text messages, e-mails and WhatsApp messages for communication of alerts.

Special efforts are made to reach vulnerable people through inter-personal communication as well as other outreach methods. The Ahmedabad Municipal Corporation has created formal communication channels to relay news about the forecasted extreme temperatures and alert governmental agencies, the Met Centre, health officials and hospitals, emergency responders, local community groups, and media outlets.

Figure 13: Ahmedabad Heat Action Plan



6

Exercise – Understanding Air Pollution

The objective of this exercise is to know the understanding of participants on Air Pollution and how they can made themselves updated on the same.

1. What is the key difference between air quality and climate change?
   i. **One is short-term the other is long-term**
   ii. One involves emissions from transport the other does not.
   iii. One involves people the other involves animals.
   iv. One can improve with a reduction in the emissions the other cannot.

2. Which of the following fuels contribute significantly to air pollution?
   i. Electric fuels
   ii. Organic fuels
   iii. Renewable fuels
   iv. **Fossil fuels**

3. Why should we focus on air and climate change co-benefits?
   i. Because co-benefits require double the effort.
   ii. Because it is fun to focus on air and climate co-benefits
   iii. Because co-benefits can be dangerous for human health.
   iv. **Because air and climate co-benefits means improving air quality and mitigating against climate change**

Understanding Air Quality Monitoring

1. What are the physical requirements that are to be met for placing a Monitoring location? (Multiple Choice)
    - **i. The site available for a long period of time**
    - **ii. Easy access to the site.**
    - **iii. Site sheltering and facilities**
    - **iv. Vandal proof and protected from extreme weather**

2. As per the general requirements for siting monitoring station, what should be the height of the inlet of the sampler?
    - i. 10 – 15 metres above the ground level
    - ii. 7 – 12 metres above the ground level
    - **iii. 3 – 10 metres above the ground level**
    - iv. 2 – 5 metres above the ground level

3. How far should the sampler be placed from trees?
    - i. 30 metres
    - ii. 10 metres
    - iii. 15 metres
    - **iv. 20 metres**

4. What background information can be collected before one proceeds with Air Monitoring? (Multiple Choice)
    i. **Sources and Emissions**
    ii. **Health Status and Demography and Previous Air Quality Information.**
    iii. **Meteorological Information and Previous Air Quality Information**
    iv. None of the above

5. What could be the reason for Inadequate Data
    i. Calibration - 5
    ii. Locations & Type of Monitoring Station - 3
    iii. Non-availability of Continuous Power Supply - 4
    iv. Number of Stations - 1
    v. Human Resources - 2

    Prioritize on a scale to 1 to 5

6. What is the need of air quality management?
    i. To ensure that air pollution concentrations exceed defined targets that are needed to harm human health and the environment.
    ii. To ensure that air pollution concentrations are higher defined target levels to harm human health and the environment.
    iii. **To ensure that air pollution concentrations do not exceed defined target levels that are needed to protect human health and the environment.**
    iv. To ensure that air pollution concentrations can harm human health and the environment.

7. Do you regularly check AQI?
    i. Yes
    ii. No

8. If Yes, which platform do you prefer to check that AQI?
    i. TV
    ii. Newspaper
    iii. Website
    iv. Mobile App

9. Which statements best describes the Air Quality Index?
    i. It indicates the colour of the air.
    ii. It predicts particulate matter levels in your area.
    iii. It determines the intensity of sound and sound pollution.
    iv. It estimates air pollution mainly sulphur content in the air.

10. Statement best describes the potential health impacts when the air quality index category is 'Moderate'?
    i. Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
    ii. May cause respiratory effects even on healthy people and serious effects health impacts on people with lung/heart disease
    iii. May cause discomfort to people with lung disease
    iv. May cause minor breathing discomfort to sensitive (vulnerable) people

11. When is a 'health warning' called using an air quality index?
    Please select the best answer
    i. When the air quality index is forecast to be good
    ii. When the air quality index is forecast to be poor
    iii. When there is the air quality index is not in use
    iv. When the air quality index is forecast to be severe

7

List of Reading Material

1. Amdavad Municipal Corporation, Indian Institute of Public Health and Natural Resources Defence Council, (2018) Ahmedabad Air Information and Response Plan, *https://www.nrdc.org/sites/default/files/air_plan_2018_dec3_v2.pdf*
2. Clean Air Asia, Guidance Framework for Better Air Quality in Asian Cities, Pasig City, Philippines
3. The Guidance Framework serves as a cornerstone document of Clean Air Asia's Integrated Programme for Better Air Quality in Asia (IBAQ Programme), which supports countries and cities in implementing the Guidance Framework through a range of targeted interventions, including knowledge-sharing platforms to strengthen regional collaboration, capacity building activities such as trainings, study tours and city twinning, and technical assistance at both the national and subnational levels
4. *https://cleanairasia.org/wp-content/uploads/2017/03/Ambient-Air-Quality-Standards-and-Monitor.pdf/*
5. Guidelines for continuous sampling and real time analyses (CPCB, 2013- National Ambient Air Quality Series: NAAQMS/37/2012-13 Volume-II
6. The Central Pollution Control Board Manual lays out the outline for continuous air quality monitoring and placement of monitors.
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Notes:

सत्यमेव जयते

Ministry of Housing and Urban Affairs
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