Environmental Pollution – Part 1

Air Pollution, Major Air Pollutants and Their Impact

Air pollution refers to the presence of harmful substances in the atmosphere, which can be in the form of gases, particulates, or biological molecules. These pollutants cause adverse effects on human health, the environment, and the climate.

Key Points:

- **Sources of Air Pollution:** Can be natural or anthropogenic (human-made).
  - **Natural Sources:** Include volcanic eruptions, forest fires, dust storms, and sea spray.
  - **Anthropogenic Sources:** Include industrial emissions, vehicle exhaust, agricultural activities, and residential heating and cooking.
- **Types of Pollutants:**
  - **Primary Pollutants:** Emitted directly from a source, such as carbon monoxide (CO), sulphur dioxide (SO2), nitrogen oxides (NOx), particulate matter (PM), and volatile organic compounds (VOCs).
  - **Secondary Pollutants:** Formed in the atmosphere through chemical reactions involving primary pollutants, such as ground-level ozone (O3) and secondary particulate matter.
- **Health Impacts:** Can cause respiratory and cardiovascular diseases, aggravate pre-existing health conditions, and lead to premature death. Vulnerable populations include children, the elderly, and those with pre-existing health conditions.
- **Environmental Impacts:** Can lead to acid rain, eutrophication of water bodies, damage to vegetation, and reduction of biodiversity.
- **Climate Impacts:** Some pollutants, such as carbon dioxide (CO2) and methane (CH4), are greenhouse gases that contribute to global warming. Particulate matter can also influence climate by affecting the Earth's radiative balance.

Table of Major Air Pollutants and Their Impacts

Pollutant	Source	Health Impacts	Environmental Impacts
Particulate Matter (PM)	Combustion processes, industrial activities, construction, and	Respiratory issues, cardiovascular diseases, lung cancer, aggravation of asthma and bronchitis	Reduces visibility, soil and water acidification,

Pollutant	Source	Health Impacts	Environmental Impacts
	natural sources (dust storms, wildfires)		damages vegetation
Sulphur Dioxide (SO2)	Fossil fuel combustion (power plants, industrial facilities), natural sources (volcanoes)	Respiratory problems, aggravation of cardiovascular diseases, eye irritation	Formation of acid rain, which damages ecosystems and buildings
Nitrogen Oxides (NOx)	Vehicle emissions, power plants, industrial processes	Respiratory issues, increased susceptibility to respiratory infections, aggravation of asthma	Contributes to smog and acid rain, eutrophication of water bodies
Carbon Monoxide (CO)	Incomplete combustion of fossil fuels (vehicles, industrial processes, residential heating)	Reduces oxygen delivery to organs and tissues, causes cardiovascular and neurological effects	Indirect contributor to greenhouse gas formation (CO2)
Ozone (O3)	Secondary pollutant formed by reactions of NOx and VOCs in sunlight	Respiratory problems, aggravation of asthma, decreased lung function	Damages crops, forests, and man-made materials, contributes to climate change
Volatile Organic Compounds (VOCs)	Emitted from vehicles, industrial processes, solvents, and natural sources (plants)	Eye, nose, and throat irritation, headaches, liver and kidney damage, some VOCs are carcinogenic	Contributes to the formation of ground-level ozone and smog
Lead (Pb)	Industrial processes, leaded gasoline, paint, batteries	Neurological damage, developmental issues in children, cardiovascular problems	Contaminates soil and water, affects wildlife and ecosystems
Ammonia (NH3)	Agricultural activities (fertiliser application, livestock waste)	Respiratory irritation, eye irritation	Contributes to the formation of secondary particulate matter, eutrophication of water bodies

Reasons for Severe Air Pollution in India

1. Residential Sector

- **Solid Fuel Burning**:
  - Major source of PM2.5 due to burning firewood, cow dung, and crop residues.
  - Household air pollution is 60% higher than coal burning and 4-6 times higher than open burning and transportation.
- **Indoor Air Pollution**:
  - Reliance on biomass for cooking in rural areas exacerbates indoor air pollution and impacts overall ambient air quality.

2. Industrial Sector

- **Unregulated Emissions**:
  - Small-scale industries using biomass, plastic, and crude oil emit various toxic pollutants.
  - Industrial emissions account for approximately 51% of total air pollution.
- **Brick Kilns and Factories**:
  - Often operate without adequate pollution control measures, leading to high emissions of particulate matter and other pollutants.

3. Power Generation

- **Coal Burning**:
  - Significant source of SO2 and NOx emissions.
  - Power generation contributes 44%-62% of SO2 emissions and 24%-43% of NOx emissions.
- **Thermal Power Plants**:
  - Older and inefficient plants contribute disproportionately to air pollution.
  - Example: Badarpur Thermal Power Station in Delhi, a major source of particulate matter before its closure in 2018.

4. Transportation

- **Vehicle Emissions**:
  - Significant contributor to air pollution in urban areas.
  - Emissions from diesel and petrol engines release NOx, CO, and particulate matter.
  - In Delhi, vehicle exhaust contributes up to 30% of PM2.5 pollution.
- **Resuspended Road Dust**:
  - Movement of vehicles resuspends road dust, a major source of particulate matter in cities.

5. Agricultural Activities

- **Crop Residue Burning**:

- Significant emissions of particulate matter and other pollutants from burning crop residues in northern India, particularly in Punjab and Haryana.
- Major contributor to seasonal spikes in air pollution.

- **Open Waste Burning**:
  - Burning of agricultural waste and other refuse in open fields adds to the pollution load.

6. Other Sources

- **Construction Activities**:
  - Dust from construction sites contributes to particulate pollution, especially in rapidly urbanising areas.
- **Diesel Generators**:
  - Use of diesel generators for power backup in urban areas adds to NOx and particulate emissions.
- **Natural Factors**:
  - Seasonal dust storms, forest fires, and sea salt (in coastal areas) also contribute to air pollution.

Why North India is Particularly Badly Impacted

1. Geographical and Meteorological Factors

- **Topography**:
  - Northern India, including the Indo-Gangetic Plain, is landlocked and surrounded by the Himalayas to the north, trapping pollutants and preventing dispersion.
- **Weather Conditions**:
  - During winter, temperature inversions trap pollutants close to the ground.
  - Calm winds and lower mixing heights prevent the dispersion of pollutants.

2. High Population Density

- **Urbanisation**:
  - Cities like Delhi have high population densities, leading to higher concentrations of vehicles, industries, and construction activities, contributing to poor air quality.
- **Residential Emissions**:
  - High population density means more households burning solid fuels for cooking and heating, especially in rural areas.

3. Agricultural Practices

- **Stubble Burning**:
  - Burning of crop residues in Punjab and Haryana significantly impacts air quality in northern India during the post-harvest season in autumn.
  - Can account for up to 45% of Delhi's pollution during peak burning periods.

4. Industrial and Power Plant Emissions

- **Concentration of Industries**:
    - High concentration of industries and power plants in northern India contributes significantly to the region's air pollution.

Air Quality Index (AQI) System in India

Introduction and Implementation

- **Launch Date**: October 2014, as part of the Swachh Bharat Mission.
- **Development**: Developed by the Ministry of Environment, Forests, and Climate Change (MOEF-CC) and the Central Pollution Control Board (CPCB) in collaboration with researchers from IIT-Kanpur.

Objectives

- **Public Awareness**: Inform the public about air quality in a simple and comprehensible manner.
- **Health Advisories**: Provide health advisories, especially for sensitive populations (e.g., asthma, lung ailments, heart disease).
- **Resource Allocation**: Assist administrators in allocating funds and determining priorities for air pollution control strategies.
- **Trend Analysis**: Analyse air quality trends over time and identify areas with potential hazards.

How It Works

- **Pollutants Monitored**: PM10, PM2.5, SO2, NO2, CO, O3, NH3, Pb.
- **Categories**: Six categories - Good, Satisfactory, Moderately Polluted, Poor, Very Poor, Severe. Each category has a specific colour and health advisory.
- **Calculation**: Transform the weighted values of individual pollutants into a single number. The worst sub-index among the pollutants reflects the overall AQI.
- **Real-Time Data**: Provided through continuous monitoring stations, display boards, and the SAFAR-AIR mobile app.

Implementation

- **Cities Covered**: Initially implemented in ten cities (Delhi, Agra, Kanpur, Lucknow, Varanasi, Faridabad, Ahmedabad, Chennai, Bangalore, Hyderabad). Expanded to more cities over time.
- **Monitoring Stations**: Plans to install approximately six continuous monitoring stations and display boards in each city. Aim to expand to all Indian cities with a population larger than one million.

Current Status

- **Air Quality Levels**: As of May 21, 2024, cities like New Delhi have an AQI of 182 ("Unhealthy"), causing breathing discomfort for sensitive groups.
- **Most Polluted Cities**: Several cities have AQI levels in the "Harmful" category.

Number of Cities with Air Quality Monitoring

- **Overall Deployment**: Out of India's 4,041 census cities and towns, only 476 (around 12%) have air quality monitoring stations as of January 1, 2023.
    - **Manual Stations**: 267 cities
    - **Real-Time Stations**: 98 cities
    - **Both Manual and Real-Time Stations**: 111 cities
- **Monitoring Capacity**: Current capacity is 6-8% of the minimum recommended by Indian Standard 5182 guidelines.
- **Continuous Ambient Air Quality Monitoring Stations (CAAQMS)**:
    - **January 2024**: 539 CAAQMS across 271 cities.
    - **March 2024**: 257 cities had CAAQMS data for more than 80% of the days.
    - **Non-Attainment Cities**: Out of 131 identified under the National Clean Air Programme (NCAP), only 101 had a CAAQMS as of January 2024.

Summary

India's AQI system is a vital tool for monitoring and communicating air quality, aimed at protecting public health and guiding policy and resource allocation for air pollution control. Despite significant progress, the monitoring network remains limited compared to recommended guidelines based on population size and pollution levels.

SAFAR (System of Air Quality and Weather Forecasting and Research)

SAFAR is an initiative by the Ministry of Earth Sciences (MoES) in India, aimed at monitoring and forecasting air quality in major metropolitan cities.

Objectives

- **Real-Time Air Quality Monitoring:**
    - Provides location-specific information on air quality in real-time.
    - Aims to raise public awareness about air pollution and its health impacts.
- **Air Quality Forecasting:**
    - Forecasts air quality up to 2-3 days in advance.
    - Crucial for planning and mitigating the effects of poor air quality.
- **Weather Forecasting:**
    - Provides weather forecasts, including parameters like temperature, humidity, wind speed, and UV radiation.

Development and Implementation

- **Development:**
    - Developed indigenously by the Indian Institute of Tropical Meteorology (IITM), Pune, and the Ministry of Earth Sciences.

- Initially implemented during the Commonwealth Games in New Delhi in 2010.

- **Operational Cities:**
  - Currently operational in Delhi, Pune, Mumbai, and Ahmedabad.
  - Plans to expand to other cities like Chennai and Kolkata.
- **Data Processing:**
  - Data is processed using a supercomputer housed at IITM, Pune.
  - Processed data is disseminated in a user-friendly, colour-coded format.

Features

- **Pollutants Monitored:**
  - **Particulate Matter:** PM1, PM2.5, PM10
  - **Gaseous Pollutants:** Ozone (O3), Carbon Monoxide (CO), Nitrogen Oxides (NOx), Sulphur Dioxide (SO2)
  - **Others:** Black Carbon (BC), Methane (CH4), Non-methane Hydrocarbons (NMHC), Volatile Organic Compounds (VOCs), Benzene, Mercury
- **Meteorological Parameters:**
  - Monitors temperature, humidity, wind speed, and UV radiation.
- **Public Dissemination:**
  - Information is available through digital display boards, a web portal, IVRS, and mobile applications.
  - Aims to spread awareness and enable people to take necessary precautions.

Impact and Recognition

- **Public Health:**
  - Provides critical information to improve public health by informing people about air quality and enabling them to take preventive measures.
- **Scientific Research:**
  - Data is used by hospitals, research agencies, and other institutions for various studies, including the impact of air pollution on health and agriculture.
- **International Recognition:**
  - Recognised by the World Meteorological Organization as a prototype activity due to its high-quality control and standards.

Table: Pollutants Monitored by SAFAR and Their Health Impacts

Pollutant	Health Impacts
PM1, PM2.5, PM10	Respiratory issues, cardiovascular diseases, lung cancer
Ozone (O3)	Respiratory problems, decreased lung function

Carbon Monoxide (CO)	Reduces oxygen delivery to organs, cardiovascular and neurological effects
Nitrogen Oxides (NOx)	Respiratory issues, increased susceptibility to respiratory infections
Sulphur Dioxide (SO2)	Respiratory problems, eye irritation
Black Carbon (BC)	Respiratory and cardiovascular diseases, climate change contributor
Methane (CH4)	Contributes to climate change
Non-methane Hydrocarbons (NMHC)	Respiratory irritation, some NMHCs are carcinogenic
Volatile Organic Compounds (VOCs)	Eye, nose, and throat irritation, some VOCs are carcinogenic
Benzene	Carcinogenic, affects bone marrow and blood
Mercury	Neurological and developmental damage

GRAP

The Graded Response Action Plan (GRAP) is a set of measures implemented in Delhi and the National Capital Region (NCR) to combat air pollution. It is a comprehensive framework designed to address various levels of air quality, with specific actions prescribed for different levels of pollution.

Objectives

- **To Mitigate Air Pollution:** GRAP aims to reduce the levels of air pollution by implementing targeted actions based on real-time air quality data.
- **To Protect Public Health:** The plan is designed to protect public health by reducing exposure to harmful pollutants, particularly during episodes of severe pollution.

Implementation

- **Authority:** The Environment Pollution (Prevention & Control) Authority (EPCA), a statutory body under the Ministry of Environment, Forest and Climate Change, oversees the implementation of GRAP.
- **Activation:** GRAP is activated based on the Air Quality Index (AQI) levels, with different measures triggered as pollution levels escalate.

Action Levels and Measures

- **Moderate to Poor AQI (101-300):**
    - Mechanised sweeping of roads.
    - Water sprinkling to reduce dust.

- Enforcement of pollution control regulations in industries.

- **Very Poor AQI (301-400):**
  - Ban on diesel generator sets, except for essential services.
  - Increase in frequency of public transport.
  - Increase in parking fees to discourage the use of personal vehicles.
- **Severe AQI (401-450):**
  - Closure of brick kilns, hot mix plants, and stone crushers.
  - Increase in bus and metro services to encourage public transport use.
  - Restrictions on the use of coal and firewood in hotels and open eateries.
- **Severe+ or Emergency AQI (above 450):**
  - Ban on entry of trucks into Delhi, except those carrying essential commodities.
  - Closure of schools, colleges, and educational institutions.
  - Ban on construction activities.
  - Odd-even scheme for private vehicles, allowing vehicles to run based on their registration numbers on alternate days.

Table: GRAP Action Levels and Measures

AQI Level	Actions
Moderate to Poor (101-300)	Mechanised sweeping of roads, water sprinkling, enforcement of pollution control regulations in industries
Very Poor (301-400)	Ban on diesel generator sets (except for essential services), increased public transport frequency, increased parking fees
Severe (401-450)	Closure of brick kilns, hot mix plants, and stone crushers; increased bus and metro services; restrictions on the use of coal and firewood
Severe+ or Emergency (above 450)	Ban on entry of trucks (except essential commodities), closure of schools and colleges, ban on construction activities, odd-even scheme for private vehicles

Impact and Effectiveness

- **Improved Air Quality:** GRAP has led to temporary improvements in air quality during severe pollution episodes by implementing immediate and targeted actions.
- **Public Awareness:** The plan has increased public awareness of air pollution issues and the need for collective action to combat it.
- **Challenges:** Despite its effectiveness in reducing pollution during high AQI levels, long-term and sustainable improvements require addressing the underlying sources of pollution comprehensively.

Smog Towers in New Delhi

Overview:

- **Purpose:** Smog towers are designed to combat severe air pollution in urban areas by filtering and purifying the air. They are equipped with large fans and multiple filters to capture pollutants and release clean air.
- **Inauguration:** The first smog tower in Delhi was inaugurated in Connaught Place in 2021. Another smog tower is located in Anand Vihar, a known pollution hotspot in the city.

Working Mechanism:

- **Downdraft Air Cleaning System:** The smog tower in Connaught Place uses a downdraft system where polluted air is sucked in from the top, passed through filters, and clean air is released from the bottom.
- **Components:** The tower is 24 meters tall, equipped with 40 fans and 5,000 filters. It can filter 1,000 cubic meters of air per second within a one-kilometre radius.

Effectiveness and Challenges:

- **Limited Impact:** Studies and reports have shown that the smog towers have a limited impact on reducing air pollution. The Delhi Pollution Control Committee (DPCC) found that the reduction in particulate matter (PM) was only around 12-13% within a 100-meter radius.
- **Operational Issues:** The smog tower in Connaught Place has faced operational challenges and was found to be locked and non-operational during periods of severe pollution.
- **High Costs:** The installation and maintenance of smog towers are expensive. Each tower costs around ₹20-25 crore to build and approximately ₹15 lakh per month to operate.

Criticisms and Recommendations:

- **Ineffectiveness:** Experts and studies have criticised the smog towers for their ineffectiveness in significantly improving air quality over larger areas. The DPCC and IIT-Bombay studies suggest that the towers are not a viable long-term solution for Delhi's air pollution problem.
- **Alternative Measures:** Recommendations include focusing on reducing pollution at the source, such as controlling vehicle emissions, banning stubble burning, and implementing stricter regulations on industrial emissions.

National Clean Air Programme

Overview:

- **Launch:** The NCAP was launched in 2019 by the Ministry of Environment, Forest and Climate Change.
- **Objective:** To address the severe air pollution crisis across India.

Objectives:

- **Reduction Targets:**

- Initially aimed to reduce **particulate matter (PM10 and PM2.5)** pollution by **20-30%** by 2024 from 2017 levels in **122 non-attainment cities**.
- In 2022, the target was revised to a **40% reduction** by 2026 compared to 2017 levels.

Implementation Strategy:

- **City-Specific Plans:** Non-attainment cities are required to develop city-specific air pollution mitigation action plans with time-bound targets and budgets.
- **Air Quality Monitoring Network:**
  - Increase the number of **continuous ambient air quality monitoring stations (CAAQMS)** from **703 to 1,500** by 2024.
  - Establish **air information centres** for data management, public outreach, and pollution forecasting in non-attainment cities.
- **Committees:** Establishment of committees at central, state, and local levels for effective implementation and coordination.

Funding and Progress:

- **Funding Allocation:**
  - The central government allocated **₹600 crore** (approx. $75 million) for NCAP in 2018-19 and 2019-20.
  - By November 2023, out of **₹1,253 crore** allocated to 82 non-attainment cities, only **₹498 crore (40%)** was utilised.
- **Monitoring Stations:**
  - Target for **150 CAAQMS** exceeded with **531 stations** operational by December 2023.
  - Goal of augmenting manual monitoring stations to **1,500** fell short, with only **931 stations** operational.
- **Source Apportionment Studies:**
  - Only **44 out of 131 non-attainment cities** conducted source apportionment studies by December 2023.

Challenges and Criticisms:

- **Uneven Progress:** NCAP is not on track to achieve its original 2024 targets, prompting a revision to 2026.
- **Stakeholder Involvement:** Limited involvement of health stakeholders and lack of transparency.
- **Public Information:** Inadequate public availability of information.
- **Comprehensive Approach:** Experts argue for stricter regulations, better enforcement, and addressing pollution sources beyond identified non-attainment cities.

Summary:

- **NCAP** is India's flagship programme aimed at reducing air pollution levels through a multi-pronged strategy involving monitoring, source identification, mitigation action plans, and public awareness.

- Despite progress, the programme faces significant challenges in achieving its ambitious targets and requires stronger implementation and coordination across various stakeholders.

Table: NCAP Implementation and Progress

Aspect	Target	Achievement (by Dec 2023)
CAAQMS	1,500	531 operational
Manual Monitoring Stations	1,500	931 operational
Source Apportionment Studies	Conducted in 131 cities	44 cities
Funding Utilisation (₹1,253 crore)	Full utilisation expected	₹498 crore (40%) utilised

In conclusion, while NCAP has made some progress, achieving the revised targets requires enhanced efforts and more robust implementation mechanisms.

WHO Highlights on Air Pollution in India

Health Impacts:

- **Premature Deaths:** Air pollution causes over **1.2 million premature deaths** in India annually (IQAir World Air Quality Report 2022, cited by Greenpeace India).
- **Children's Exposure:** Around **93% of children** globally breathe outdoor air exceeding WHO air quality guidelines, with India being heavily impacted.

Pollution Levels:

- **Most Polluted Cities:** A 2018 WHO report found that **14 of the world's 15 most polluted cities** (in terms of PM2.5 levels) were in India, with Delhi ranked as the most polluted.
- **PM2.5 Levels:** In 2019, India's annual average **PM2.5 levels** were over **10 times higher** than the WHO's recommended safe limit of 5 µg/m³.

WHO Recommendations:

- **Stricter Standards:** The WHO's Global Air Quality Guidelines (updated in 2021) provide stricter targets for key air pollutants, including **PM2.5** and **nitrogen dioxide (NO2)**, underscoring the need for stringent air quality standards in India.
- **Policy Implementation:** The WHO urges India to implement stronger policies and measures to address the sources of air pollution, such as **emissions from industries**, **vehicles**, and **burning of solid fuels for domestic use**.

Socioeconomic Disparities:

- A 2023 study published in **Scientific Reports** used WHO air quality guidelines to analyse the disproportionate exposure of certain socioeconomic groups in India to high PM2.5 levels.

Summary of Key Facts:

Aspect	Detail
Annual Premature Deaths	Over **1.2 million** due to air pollution in India
Children's Exposure	**93%** of children breathe air exceeding WHO guidelines
Most Polluted Cities	**14 of the world's 15** most polluted cities in India
PM2.5 Levels in 2019	Over **10 times** higher than WHO's safe limit of 5 μg/m³
WHO's 2021 Guidelines	Stricter targets for **PM2.5** and **NO2**
Policy Recommendations	Stronger measures to address emissions from **industries**, **vehicles**, and **solid fuels**

In