1. What are Pollutants?

- Pollutants are the **elements, molecules and particles** involved in pollution.
- They can be introduced into the environment in many ways, both **naturally and by humans** and can cause adverse effects on the natural quality of any component of the environment.
- Different types of pollutants include Particulate matter (PM), Nitrogen dioxide (NO2), Ground level ozone (O3), Carbon monoxide (CO), Arsenic, Mercury, Lead; and more.

1.1. Classification of Pollutants

(i) Depending upon their existence in nature:

(a) Quantitative Pollutants:

- **Naturally-occurring substances** that become pollutants of concern due to human activities, increasing concentration.
- For example, carbon dioxide, if present in the atmosphere in concentrations greater than normal due to automobiles and industries, causes measurable effects on humans, animals and plants.

(b) Qualitative Pollutants:

- Those substances which **do not normally occur in nature** but are added by humans. Examples: pesticides, insecticides, etc.

(ii) According to their nature of disposal:

(a) Bio-degradable Pollutants:

- Pollutants that are **quickly degraded by natural means.** Mainly comes from plant or animal sources. Examples: agriculture residues, domestic wastes, etc.

(b) Non-degradable Pollutants:

- These are the substances that either **do not degrade or degrade very slowly** in the natural environment. These include heavy metals, DDT, plastics, etc.

(iii) Depending upon the form in which they persist after being released into the environment:

(a) Primary Pollutants:

- Pollutants that are formed and emitted **directly from particular sources.**
- They can be emitted from many sources including coal-fired power plants, natural gas power plants, biomass burning, natural forest fires, etc.

(b) Secondary Pollutants:

- Pollutants that are formed from the primary pollutants **by chemical interaction** with some constituents present in the atmosphere.
- Examples are: Sulphur trioxide, nitrogen dioxide,secondary organic aerosol (haze), etc.

2. Air Pollution

- Air pollution is contamination of the indoor or outdoor environment by any **chemical, physical or biological agent** that modifies the natural characteristics of the atmosphere.
- **Nine out of ten** human beings currently breathe air that exceeds the WHO's guideline limits for pollutants, with those living in low- and middle-income countries suffering the most.

2.1. Air Pollutants, their Sources and Effects

Pollutants	Sources	Effects on Humans and Environment
Carbon monoxide (CO)	● Incomplete burning of carbon-based fuels including petrol, diesel, and wood. ● Combustion of natural and synthetic products such as cigarettes.	● Diffuses across the lung tissues and into the bloodstream, making it difficult for the body's cells to bind to oxygen. ● Exposure can cause difficulties breathing, exhaustion and dizziness. ● Can contribute to ground-level ozone.
Carbon dioxide (CO2)	● Burning of coal, oil, and natural gases. ● From natural processes like volcanic eruptions.	● Contributes to the rise in global temperatures and influences climate change. ● Cause respiratory complications.
Sulphur dioxide (SO2)	● Combustion and refining processes of coal, oil, and metal-containing ores. ● Thermal power plants	● Respiratory diseases in humans and animals. ● Forms acid rain when dissolved in water. ● Forms secondary particulate matter.
Nitrogen dioxide (NO2)	● Oxidation of nitric oxide (NO) from combustion processes such as diesel engines and coal, oil, gas, and wood. ● Paddy field	● Irritation and inflammation of lungs; impairs enzyme function in the respiratory system and causes bronchitis and asthma. ● Forms acid rain. ● Contributes to ground-level ozone (O3). ● Forms secondary particulate matter.
Ground-level ozone (O3)	● Formed through the photochemical reactions of other pollutants such as nitrogen oxides, carbon	● It leads to reduced lung function and respiratory diseases, with exposure linked to premature mortality. ● Damages vegetation, decrease in crop

	monoxide, and volatile organic compounds from strong sunlight and UV radiation.	productivity and forest decline. ● Accelerates the deterioration of rubbers, dyes, paints, coatings, and various textiles. ● Major component of smog.
Lead (Pb)	● Metal processing, waste incineration, fossil-fuel combustion.	● Damage to the central nervous system and kidneys. ● Learning disabilities in young children. ● Loss of biodiversity, decreased reproduction, and neurological problems.
Ammonia (NH3)	● Agricultural processes, particularly in fertilizer production and livestock waste management; cigarette smoke and cleaning solutions.	● Irritates the eyes, nose, throat, and respiratory tract. ● Pollutes and contributes to the eutrophication and acidification of terrestrial and aquatic ecosystems.
Methane (CH4)	● Fossil fuels, composting, livestock farming, animal waste, coal mining, rice fields (one of the most important sources of CH4), burning of wood fuel and biomass.	● Greenhouse effect and climate change. ● Can lead to headaches, vomiting, nausea and loss of consciousness.

2.2. What is Particulate Matter?

- Particulate matter, also called PM or soot, consists of microscopically **small solid particles or liquid droplets** suspended in the air.
- The smaller the particles, the deeper they can penetrate into the respiratory system and the more hazardous they are to breathe.

2.2.1. Types of Particulate Matter

1. PM 10

- Also known as coarse particles, PM10 is defined as all particles with an aerodynamic **diameter of 10 µm or smaller.**
- They are produced by the **mechanical break-up** of larger solid particles.
- Examples of PM10 are mold spores, bacteria, dust, smoke etc.
- These particles can penetrate into our lungs and can irritate the nose, throat, and eyes.

2. PM 2.5

- PM 2.5 is a grouping of particles with an aerodynamic **diameter of 2.5 µm or less.**
- PM 2.5 comes from **natural or human-made sources**, like vehicle exhaust, wildfires, power plant emissions and other combustion activities.

- It can penetrate into the lower respiratory tract or deeper in the respiratory tract, and the blood stream, causing cardiovascular problems.

3. PM 1

- PM1 are extremely fine particulates with a **diameter of fewer than 1 micron.**
- It can penetrate the cardiovascular stream even further, and **give rise to lasting conditions**, such as predisposing people to heart diseases.
- PM 1 can lead to premature births and affect foetal development.

2.3. What is Smog?

- It refers to a **combination of smoke and fog**, thus forming the word smog.
- It is a complex mixture that is **formed by various pollutants**, such as nitrogen oxides and dust particles, which interact with the sunlight to form ground-level ozone, leading to the build-up of haze that hangs in industrial cities.

2.3.1. Causes of Smog

- Smog is caused as a result of industrial activities, vehicular traffic, open burning, incinerators, higher temperature, and geography of a place, sunlight and calmer winds.
- These factors contribute to an all-encompassing smog, which can remain trapped in the atmosphere with higher temperature and sunlight.

2.3.2. Effects of smog

- **Chest infections/Irritation:** When ground-level ozone is inhaled, it can affect the respiratory system in an adverse way, leading to coughing and irritation.
- **Worsening of asthma/bronchitis/emphysema:** Patients of such respiratory problems have the worst of times when smog hits such high levels.
- **Cold and eye irritation:** Reduces one's immunity to cold and can cause irritation in the eyes.
- **Damage to crops:** Inhibit plant growth and can cause damage to forests and crops.

2.4. Air Pollution In India

- A Lancet study estimated that air pollution in India accounted for **1.7 million premature deaths** in 2019.
- The same study estimated that economic losses from premature deaths and morbidity amount to US$ 37 billion annually or **1.36 percent of India’s GDP.**
- All of India’s 1.4 billion people live in areas where the annual average particulate pollution level exceeds the WHO guideline. Ninety-four percent live in areas where it exceeds India’s own air quality standard.
- Industrial activities (36 percent) and residential combustion (39 percent) account for the bulk of PM2.5 emissions.

- Since 1998, average annual **particulate pollution has increased 22 percent,** cutting 1.3 years off the life of the average resident over those years.
- A quarter of India's population is exposed to pollution levels not seen in any other country, with 248 million residents of northern India on track to lose more than 8 years of life expectancy if pollution levels persist.

3. Air Quality Management

3.1. National Air Quality Index (AQI)

AQI	Remark	Color Code	Possible Health Impacts
0-50	Good		Minimal impact
51-100	Satisfactory		Minor breathing discomfort to sensitive people
101-200	Moderate		Breathing discomfort to the people with lungs, asthma and heart diseases
201-300	Poor		Breathing discomfort to most people on prolonged exposure
301-400	Very Poor		Respiratory illness on prolonged exposure
401-500	Severe		Affects healthy people and seriously impacts those with existing diseases

Figure.1. Air Quality Index

- The National Air Quality Index (AQI) was launched on **17 October 2014** to disseminate information on air quality in an easily understandable form for the general public.
- The measurement of air quality is based on **eight pollutants**, namely, PM10, PM2.5, Nitrogen Dioxide (NO2), Sulphur Dioxide (SO2), Carbon Monoxide (CO), Ozone (O3), Ammonia (NH3), and Lead (Pb), for which short-term (up to 24-hourly averaging period) National Ambient Air Quality Standards are prescribed.
- AQI has **six categories** of air quality. These are: Good, Satisfactory, Moderately Polluted, Poor, Very Poor and Severe.

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

- It is introduced by the **Ministry of Earth Sciences** to measure the air quality of a metropolitan city, by measuring the overall pollution level.
- The system is **developed by the Indian Institute of Tropical Meteorology** (IITM), Pune and is operationalized by the India Meteorological Department (IMD).
- The framework was first developed and implemented for Delhi in 2010, and in 2015 it was extended to Mumbai and in Ahmedabad (2017).

- SAFAR is an **integral part of India's first Air Quality Early Warning System** operational in Delhi.
- The ultimate objective of the project is to increase awareness among the general public regarding the air quality in their city in advance so that appropriate mitigation measures and systematic action can be taken up for betterment of air quality.

3.3. National Air Quality Monitoring Programme (NAMP)

- The Central Pollution Control Board is executing a **nation-wide** programme of ambient **air quality monitoring** known as National Air Quality Monitoring Programme (NAMP).
- The network consists of **804 operating stations** covering 344 cities/towns in 28 states and 6 Union Territories of the country.
- The NAMP monitors the **four major pollutants** as part of the AQI – sulphur dioxide, oxides of nitrogen, respirable particulate matter and fine particulate matter.
- Meteorological parameters such as wind speed and wind direction, relative humidity (RH) and temperature were also integrated with the monitoring of air quality.
- The monitoring of pollutants is carried out for 24 hours (4-hourly sampling for gaseous pollutants and 8-hourly sampling for particulate matter) with a frequency of twice a week.
- The objectives of the NAMP are:
    - to determine status and trends of ambient air quality;
    - to ascertain whether the prescribed ambient air quality standards are violated;
    - to Identify Non-attainment Cities;
    - to obtain the knowledge and understanding necessary for developing preventive and corrective measures; and
    - to understand the natural cleansing process undergoing in the environment through pollution dilution, dispersion, and chemical transformation of pollutants generated.

4. Water Pollution

- Water pollution is the contamination of water sources by substances which make the water unusable for drinking, cooking, cleaning, swimming, and other activities.
- **All forms of pollution eventually make their way to water**, such as, air pollution settles onto lakes and oceans, and land pollution can seep into an underground stream, then to a river, and finally to the ocean.

4.1. Categories of water pollution sources

Point source pollution

- Point source water pollution occurs where pollution comes from a **specific, identifiable source**, such as a sewage pipe or factory wastewater pipe.

- Point source pollution is generally readily prevented since it is possible to identify where it is coming from.

Diffuse pollution

- Diffuse water pollution is caused by **various sources**, which are often hard to identify. Individual sources may be relatively small, but the combined effect of numerous sources can be damaging.
- Examples of diffuse pollution include the leaching to surface water and groundwater of contaminants from roads, manures, nutrients and pesticides used in agriculture and forestry, and atmospheric deposition of contaminants arising from industry.

4.2. Sources of Water Pollution

Nutrients

- The main potentially-polluting nutrients in relation to water are nitrogen, ammonia, phosphorus and sulphur. They arise from the **natural breakdown** of crop residues and soil organic matter, fertilisers, wastewater and industrial effluents, etc.

Pesticides

- These include herbicides, insecticides and fungicides that are used in gardens and in agriculture.

Heavy metals

- Industrial contaminated land can be a source of heavy **metals leaching** into the environment. They also exist naturally in soils at low concentrations.

Suspended solids

- Suspended solids might be eroded soil or decayed leaves. Wastewater from sewage works and industry might also carry suspended solids into water bodies.

Pathogens

- These are present in faeces from human and animal sources, including wildlife.
- They can enter water **through poor wastewater management** or poor handling of manures, slurry and other farm wastes.

Hydrocarbons

- These include vegetable and mineral oils (including petrol, diesel, white spirit, heating and lubricating oil), and chlorinated solvents such as dry cleaning fluids.

Persistent organic pollutants (POPs)

- These are chemicals that are capable of long-range transport, and accumulate in human and animal tissue.
- They include substances such as dioxin and polychlorinated biphenyls (PCBs).

Contaminated land

- Water contamination from these sites occurs largely as a result of rainfall which flushes chemicals, contaminated sediment and dissolved compounds into nearby streams or into groundwater beneath a site.

Mining

- The principal source of water contamination from mining is **acid mine drainage.**

- When acid mine drainage enters streams and rivers, the change in pH causes the iron to precipitate as unsightly ferric hydroxide.

4.3. Harmful effects of water pollution

On human health

- According to a study published in The Lancet, water pollution was responsible for **1·4 million deaths in 2019** globally**.**
- **Waterborne pathogens,** in the form of disease-causing bacteria and viruses from human and animal waste, are a major cause of illness from contaminated drinking water.
- The WHO estimates that about **2 billion people have no option but to drink water contaminated** by excrement, exposing them to diseases such as cholera, hepatitis A and dysentery.

On the environment (Eutrophication)

- When water pollution causes an **algal bloom** in a lake or marine environment, the proliferation of newly introduced nutrients stimulates plant and algae growth, which in turn reduces oxygen levels in the water.
- This dearth of oxygen, known as **eutrophication**, suffocates plants and animals and can create **"dead zones,"** where waters are essentially devoid of life.
- In certain cases, these harmful algal blooms can also **produce neurotoxins** that affect wildlife, from whales to sea turtles.
- Chemicals and heavy metals from industrial and municipal wastewater contaminate waterways as well. These contaminants are toxic to aquatic life—most often reducing an organism's life span and ability to reproduce—and make their way up the food chain.

Arsenic contamination of water

- The greatest threat to public health from arsenic originates **from contaminated groundwater.**
- Drinking-water, crops irrigated with contaminated water and food prepared with contaminated water are the sources of exposure.
- According to WHO, drinking of arsenic-rich water over a long period results in various **health effects including skin cancer, cancers of the bladder, kidney and lung**, and possibly also diabetes, high blood pressure and reproductive disorders.
- In utero and early childhood exposure has been linked to **negative impacts on cognitive development** and increased deaths in young adults.

Mercury Contamination

- Mercury is a global pollutant that ultimately makes its way into every aquatic ecosystem through one of two routes:
    - Point-source discharges

    - Atmospheric deposition
- **Atmospheric deposition** (rain, snow, dry particles) **is the primary source** of mercury to most aquatic ecosystems.
- Nearly all of the mercury **found in fish tissue is methylmercury.**
- Minamata disease describes methylmercury poisoning, which results in irreversible damage to the nervous system.
- The inorganic salts of mercury are corrosive to the skin, eyes and gastrointestinal tract, and may induce kidney toxicity if ingested.

4.4. Measurement of Water Pollution

4.4.1. Biochemical Oxygen Demand (BOD)

- BOD is the most widely used parameter to measure the organic pollution in sewage as well as surface water.
- It involves the **measurement of dissolved oxygen** (DO) utilized by the microorganisms for the biochemical oxidation of organic matter.
- It indicates the amount of organic matter present in the sewage. Thus, the more organic the content is, the higher is the BOD.
- If the available oxygen is less than the BOD, the organic matter decomposes anaerobically, putrefies and produces foul smell.

4.4.2. Chemical Oxygen Demand (COD)

- It is the amount of dissolved oxygen that must be present in water to **oxidize chemical organic materials**, like petroleum.
- COD is used to gauge the short-term impact wastewater effluents will have on the oxygen levels of receiving waters.
- When compared with BOD, COD **oxidizes more organic compounds**; hence COD values are higher than BOD values.
- High levels of wastewater COD indicate concentrations of organics that can deplete dissolved oxygen in the water, leading to negative environmental and regulatory consequences.

5. Namami Gange

5.1. Introduction

- ‘Namami Gange Programme’, is an **Integrated Conservation Mission,** approved as ‘Flagship Programme’ by the Union Government **in June 2014** for a period up to 31 March, 2021, to accomplish the **twin objectives** of
    - effective abatement of pollution,

    - conservation and rejuvenation of National River Ganga.

5.2. Implementation

- It is being operated under the **Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti.**
- The program is being implemented **by the National Mission for Clean Ganga** (NMCG), and its state counterpart organizations i.e State Program Management Groups (SPMGs).
- NMCG is the implementation **wing of National Ganga Council.** It has a Rs. 20,000-crore, centrally-funded, non-lapsable corpus and consists of nearly 288 projects.

5.3. Main pillars of Namami Gange

- Sewerage Treatment Infrastructure
- River-Surface Cleaning
- River-Front Development
- Afforestation
- Biodiversity
- Industrial Effluent Monitoring
- Public Awareness
- Ganga Gram

5.4. Three-tier mechanism

The Namami Gange Programme is implemented by a three-tier mechanism for project monitoring comprising of:

- A high-level task force under Cabinet Secretary assisted by the NMCG at the national level.
- A state-level committee under Chief Secretary assisted by the SPMG at the state level.
- A district-level committee under the District Magistrate.

5.5. Namami Gange Mission-II

- The Government has approved Namami Gange Mission-II in February 2023 with a budgetary outlay of Rs 22,500 crore till 2026.
- Till 31st December 2022, a total of 409 projects have been taken up at an estimated cost of Rs. 32,912.40 Crore, out of which 232 projects have been completed and made operational.