Environmental Chemistry

Atmospheric Pollution

Environmental Pollution − What Does It Mean?

- Introduction of pollutants into the environment that cause undesirable changes and have harmful effects on plants, animals, and human beings
- Pollutants − Waste materials, which cause pollution
- Biodegradable waste/pollutant − Breaks down easily

  Examples: food and garden waste, human waste, etc.
- Non-biodegradable waste − Not easily degradable

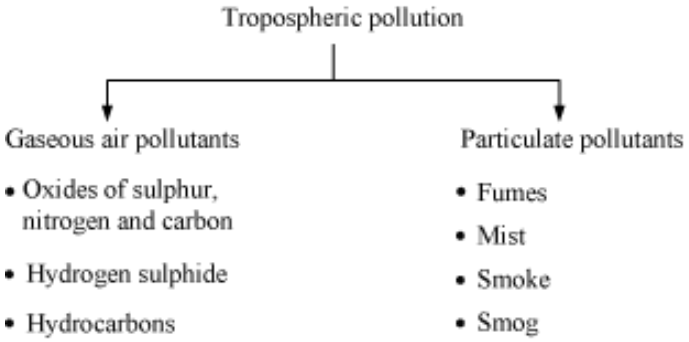
  Examples: plastic, glass, heavy metals, etc.

Atmospheric Pollution

- Natural sources of air pollution:
- Volcanoes: Releases pollutants like carbon monoxide, sulphur dioxide, hydrogen sulphide, chlorine, hydrogen chloride, hydrocarbons, particulates
- Decaying vegetation: Action of microbes on organic matter releases pollutants like nitrous oxide
- Forest fires: Release pollutants like carbon monoxide
- Winds and dust storms:Carries pollutants like particulate matter, sand, dust, etc.
- Man-made sources of air pollution:
- Automobiles: Release pollutants like carbon monoxide, sulphur dioxide, hydrocarbons, nitrogen oxides, particulates (lead)
- Factories: Release pollutants like carbon dioxide, sulphur dioxide, nitrogen monoxide, particulates
- Industries: Release pollutants like carbon monoxide, sulphur dioxide, ash, smoke, nitrogen oxides, ammonia

Air Pollution

- Degradation of the quality of air due to addition of harmful pollutants
- Affects plant, animal and human lives



Gaseous air pollutants

Compounds of Sulphur

- Sulphur dioxide
- It is produced when sulphur containing fossil fuels are burnt.
- Harmful effects of SO_2:
- Respiratory diseases such as bronchitis, emphysema, and asthma
- Irritation to eyes
- High concentration of SO_2 leads to stiffness of flower buds which ultimately causes them to fall from the plants
- Sulphur dioxide undergoes catalytic oxidation to form SO_3.

$$2SO_{2(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$$

  - Reaction of SO_2 with ozone and hydrogen peroxide

$$SO_{2(g)} + O_{3(g)} \longrightarrow SO_{3(g)} + O_{2(g)}$$
$$SO_{2(g)} + H_2O_{2(l)} \longrightarrow H_2SO_{4(aq)}$$

- Hydrogen sulphide
- It is produced when organic matter decays
- Harmful effects of H_2S:
- Nausea

- Irritation to eyes and throat
- Destruction of vegetable matter due to acidic nature

Oxides of Nitrogen

- Main constituents − NO and NO_2

- How are they produced?

  - Lightening results in the production of oxides of nitrogen.

  - Combustion of fossil fuels also produces NO and NO_2.

$$N_{2(g)} + O_{2(g)} \longrightarrow 2NO_{(g)}$$

  - NO_2 is formed instantly when NO reacts with oxygen.

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$$

- Harmful effects:

  - Causes respiratory diseases

  - Toxic to plants

  - Decreases oxygen transport efficiency in humans

Oxides of Carbon

Carbon Monoxide

- Colourless, odourless, and highly poisonous gas

- Sources − Major source of carbon monoxide is automobile exhaust. It is also formed by the incomplete combustion of coal, firewood, petrol, etc.

- Harmful Effects:

  - Binds with haemoglobin to form carboxyhaemoglobin. This reduces oxygen carrying capacity of blood.

  - Oxygen deficiency causes nervousness, headache, weak eyesight, etc.

Control of carbon monoxide pollution

- Switch over to electrically powered vehicles
- Installing pollution control devices in cars causing complete combustion of gasoline to carbon dioxide and water

  $2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$

- Using CNG and LNG instead of gasoline

- Using catalytic convertors to convert the oxides of nitrogen and carbon monoxide to nitrogen gas and carbon dioxide gas, respectively

$$2\ NO \xrightarrow{Pt} N_2 + O_2$$
$$2\ NO_2 \xrightarrow{Pt} N_2 + 2\ O_2$$
$$CO \xrightarrow[[O]]{Pt} CO_2 + H_2O$$

Carbon Dioxide

- Sources − Respiration, burning of fossil fuels, decomposition of limestone, volcanic eruptions

- Green plants maintain a balance of CO_2 in atmosphere.

Global Warming

- Earth's surface absorbs 75% of solar energy coming to the earth, 25% radiates back.

- A natural greenhouse effect is maintained by the blanket of atmosphere to trap the solar energy and keep the earth warm.

- Greenhouse gases (CO_2, CH_4, CFCs) trap the radiation and cause increase in temperature of earth resulting in global warming.

- Greenhouse gases:

- Carbon dioxide − Transparent to sunlight, but not to heat radiations

  If levels increase beyond 0.03%, then it results in global warming.

- Methane − Produced when vegetation is burnt, digested or rotten in absence of oxygen

- Chlorofluorocarbons − Industrial chemicals used in air conditioning, refrigeration, etc.

- Green house gases within optimum levels maintain life on earth.
- If their level increases the average temperature of earth's surface increases.
- This phenomenon is known as **Global Warming**.
- Advantages of Green House Effect:
- Contributed to evolution of life by trapping sun's heat.
- Helps maintaining water cycle.
- Expected results of global warming:
- Melting of polar ice caps, flooding of low lying areas
- Change in rain pattern
- Shift in crop zones
- Adverse effect on habitats of plants and animals
- Reducing Global Warming
- Minimal usage of automobiles
- Afforestation and reforestation
- Use of public transport
- Proper waste disposal
- Creating awareness

Acid Rain

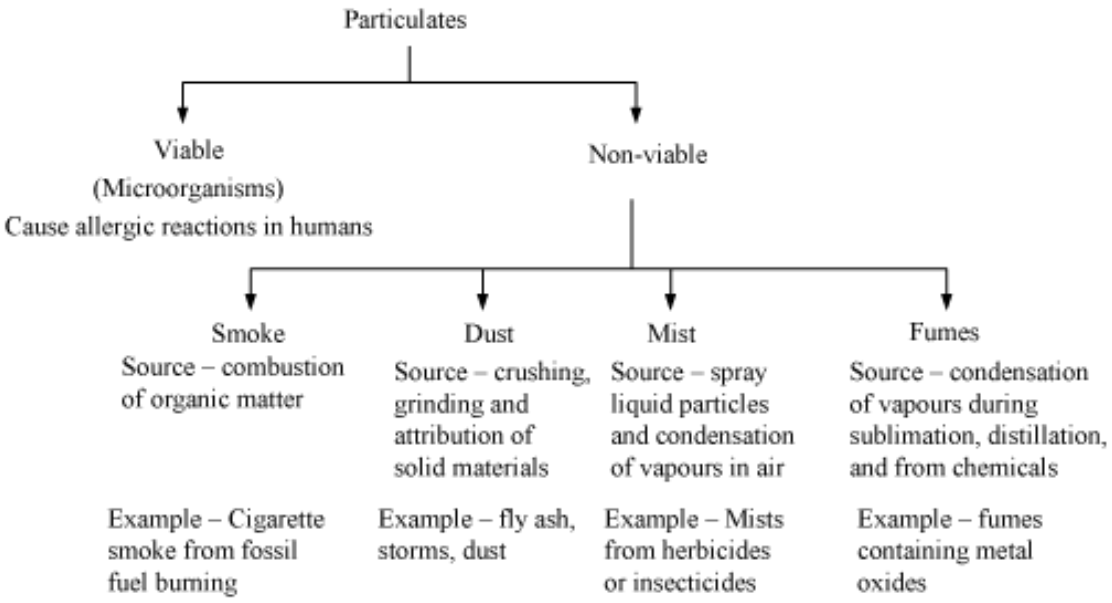
- Normal pH of rain water is 5.6 due to reactions of carbon dioxide with rain water to produce carbonic acid.
- Acid rain − When pH of rain water drops below 5.6
- Causes of acid rain − Reaction of SO_2 and NO_2 produced by burning of fossil fuels with rain water

$$4NO_2 + O_2 + 2H_2O \longrightarrow 4HNO_3$$
$$2SO_2 + O_2 + 2H_2O \longrightarrow 2H_2SO_4$$

- Other than HNO_3 and H_2SO_4, ammonium salts are also produced and occur as atmospheric haze (aerosol particles that settle with rain drops as wet deposition). On the other hand, SO_2 results in dry deposition.
- Harmful effects:
- Dissolves nutrients essential for plant growth
- Causes respiratory ailments in humans
- Affects aquatic ecosystem
- Corrodes water pipes resulting in leaching of heavy metals in drinking water
- Damages buildings made up of marble, limestone, slate, mortar etc.
- For example, the marble walls of **Taj Mahal** are deteriorating due to acid rain.
- Increases corrosion of metals
- Reducing effects of acid rain
- Reducing emission of sulphur and nitrogen oxides by using:
- Coal or oil low in sulphur content
- Scrubbers (a device that absorbs gaseous pollutants)

Particulate Pollutants

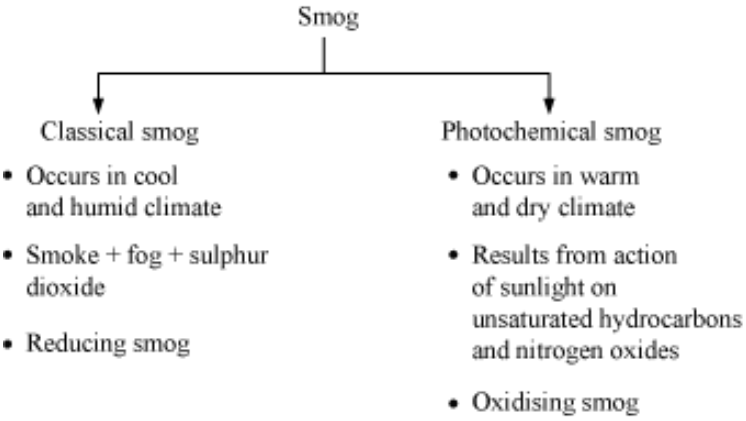
- Minute solid particles or liquid droplets in air
- Source − vehicle emission, smoke, dust particles, ash



- Harmful effects − Depend upon size

  If size > 5 μ, then it affects the nasal passage. If size ≈ 1 μ, then it enters the lungs.

  Smog (Smoke +Fog)



  Photochemical Smog

- Formation

- Chain reaction in which NO is converted to NO_2

  It then decomposes to form NO and free radical of oxygen that reacts with atmospheric oxygen to produce ozone. Ozone then reacts with NO to produce NO_2 that results in haze.

$$NO_2 \xrightarrow{h\nu} NO + O$$
$$O + O_2 \longleftrightarrow O_3$$
$$NO + O_3 \longrightarrow NO_2 + O_2$$

- Also, ozone reacts with unburnt hydrocarbons to form formaldehyde, acrolein and PAN (peroxyacyl nitrate).

$$3CH_4 + 2O_3 \longrightarrow \underset{\text{formaldehyde}}{3CH_2=O} + 3H_2O$$

- **Effects**
- PAN and ozone are eye irritants.
- Ozone and NO irritate throat and in high concentration, cause headache, chest pain, and difficulty in breathing.
- Photochemical smog also causes cracking of rubber, damage to plants, and corrosion of metals, painted surfaces etc.
- Control
- By reducing primary precursors such as NO_2 and hydrocarbons
- By using catalysis converters in automobiles; they prevent release of NO_2 and hydrocarbons
- By plantation of *Pinus*, *Pyrus, Vitis*, etc., which metabolise nitrogen oxide.

Stratospheric Pollution

Ozone

- **Formation**
- UV radiations act on O_2 to generate oxygen atom, which combines with O_2 to form ozone.

$$O_2 \xrightarrow{UV} O + O$$
- $$O + O_2 \longleftrightarrow O_3$$

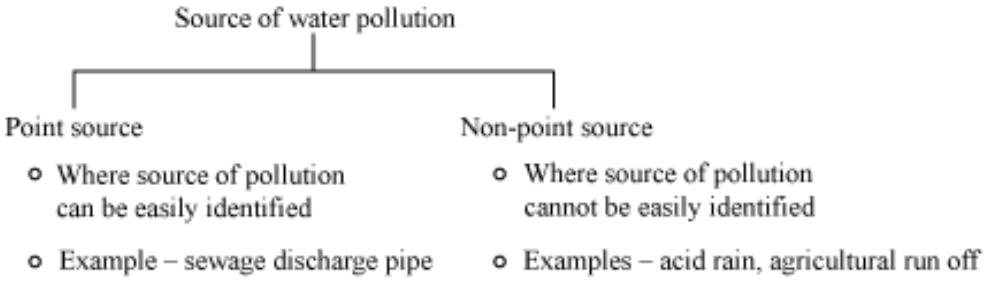
- Uses of ozone − Forms shield in atmosphere to protect us from harmful UV radiations that cause skin cancer
- Breakdown of ozone
- CFCs are broken down by UV rays to release chlorine radical.
- $CF_2Cl_2 \xrightarrow{UV} \dot{Cl} + \dot{C}F_2Cl$
- $\dot{Cl}$ reacts with O_3 to form chlorine monoxide radical and O_2. This chlorine monoxide radical reacts with atomic oxygen to produce more Cl radicals and O_2.
- $\dot{Cl} + O_3 \longrightarrow Cl\dot{O} + O_2$
  $Cl\dot{O} + O \longrightarrow \dot{Cl} + O_2$
- Chlorine radicals are continuously regenerated causing continuous breakdown of ozone.
- **Ozone hole**
- A unique set of conditions are responsible for depletion of ozone over South Pole resulting in ozone hole.
- In summers, NO_2 and CH_4 react with chlorine monoxide and chlorine radicals respectively and act as chlorine sinks.
- $\dot{Cl}O + NO_2 \longrightarrow ClONO_2$
  $\dot{Cl} + CH_4 \longrightarrow \dot{C}H_3 + HCl$
- In winters, polar stratospheric clouds are formed that provide surface for formation of chlorine nitrate (formed in summers) and get hydrolysed to form hypochlorous acids. Also, molecular chlorine is formed when chlorine nitrate reacts with HCl.
- $ClONO_2 + H_2O \longrightarrow HOCl + HNO_3$
  $ClONO_2 + HCl \longrightarrow Cl_2 + HNO_3$
- In springs, when sunlight returns to Antarctica, HOCl and Cl_2 so produced in winters get photolysed to form chlorine radical, which acts on ozone to produce oxygen.
- $HOCl \xrightarrow{h\nu} \dot{O}H + \dot{Cl}$
  $Cl_2 \xrightarrow{h\nu} 2\dot{Cl}$

- **Effects of ozone depletion:**
- Ageing of skin, cataract, skin cancer
- Killing of phytoplanktons, decrease in fish productivity
- Mutation in plant cells
- Decrease in moisture content in plants and excess loss of water through stomata of leaves
- Damage to paints and fibres by causing them to fade faster

Water Pollution

- Introduction of unwanted substances to the water bodies that affects the natural quality of water decreasing its usability
- Ways to identify polluted water:
- Foul smell
- Bad taste
- Oil or grease floating on the surface
- Excessive algal growth
- Growth of weeds

Sources of Water Pollution



- Household detergents
- Sewage
- Domestic and industrial waste
- Oil spills
- Thermal pollution

Causes of Water Pollution

- **Pathogens** − Enter water from sewage and animal excreta

  E.Coli and *S.faecalis* cause gastrointestinal diseases.

- **Organic wastes** − Leaves, grass trash, etc. reach water with run off.

- Oxygen dissolved in water is called dissolved oxygen (DO). DO in water (10 ppm) is very less as compared to air (200,000 ppm).

- For decomposition of organic matter, oxygen is required by bacteria. Therefore, presence of organic matter in water depletes the DO of water.

- If DO reaches less than 6 ppm, then the growth of fish gets inhibited.

- If there is deficiency of oxygen in water, then anaerobic bacteria start degrading the organic matter, resulting in foul small and harmful effects on human health.

- *Biochemical Oxygen Demand* (BOD) − Amount of oxygen required by bacteria to break down organic matter present in water.

- Therefore, BOD represents the amount of organic matter present in water.

- Less polluted water has lower BOD value and vice-versa.

- **Chemical pollutants**

- Heavy metals dissolved in water are harmful as our body cannot excrete them. These metals cause damage to kidneys, CNS, liver, when accumulated beyond tolerance limit in body.

- Acids and raw salts (used to melt ice) also act as water pollutants.

- Organic chemicals such as petroleum products (from oil spills), pesticides, industrial chemicals such as PCBs, detergents also fall under category of chemical water pollutants.

- Fertilizers also cause water pollution. These fertilizers contain phosphates, which enhance algae growth (algae bloom). Algae consume a major part of dissolved oxygen, thus depriving aquatic plants and animals of it, hence killing them. This condition is called *Eutrophication*.

Parameters Used to Determine Water Quality

- **pH value**
- Presence of pollutants alters the natural pH (7) of water.
- This causes harm to aquatic plants and animals
- pH value less than 7 indicates water is acidic.
- pH value greater than 7 indicates water is basic.

- **Bacteria**

- Presence of bacteria can be detected by observing samples of water from a source under microscope at regular intervals.
- Presence of bacteria in water indicates water is polluted.

- **Hardness**
- Hard water produces less or no lather with soap.
- It is unsuitable for washing, drinking etc.
- Presence of hardness in water indicates pollution.

- **Dissolved oxygen**
- It is responsible for support of aquatic life.
- Water present in streams, rivers contains high level of dissolved oxygen than that found in lakes, ponds etc.
- Water in a river or stream is considered polluted if the level of dissolved oxygen is less that what is found in normal water.
- It is measured using an instrument known as Oxygen Flow Meter.

- **Biological Oxygen Demand**
- It is the amount of dissolved oxygen utilised by micro-organisms when oxidising organic matter.
- Polluted water has high level of biological oxygen demand.
- It is determined by comparing the amount of oxygen present in pure water and polluted water.

- **Turbidity**
- It refers to the amount of suspended particulate matter in water.
- It measures the amount of light scattered by suspended solids in water.
- Greater the amount of suspended solids, greater is the scattering of light and hence water has high turbidity.
- Turbid water is incapable to support aquatic life.
- Solids that cause turbidity in water are:
- Clay
- Insoluble waste substances
- Microorganisms

Ways to Control Water Pollution

- Proper treatment of sewage before its discharge in water bodies.
- Neutralization of chemicals released from factories.
- Gravity settlement and screening processes helps in removal of heavy floating solids.
- Oxidation of organic matter for its removal.
- Destruction of pathogens by ultraviolet radiations.

International Standards for Drinking Water

- **Fluoride**

- Concentration upto 1 ppm − Useful and recommended as it makes enamel of teeth hard by converting hydroxyapatite into fluorapatite
- Concentration above 2 ppm − Causes brown mottling of teeth
- Concentration over 10 ppm − Harmful effects on bone and teeth

- **Lead**

- It is a water pollutant.
- Should not exceed beyond 50 ppb
- Can damage kidney, liver, and reproductive system

- **Sulphate**

- Moderate − Harmless
- Excessive − Laxative effect

- **Nitrate**

- Maximum limit − 50 ppm
- Excess nitrate causes ‘Blue Baby Syndrome’.

Soil Pollution and Industrial Waste

Soil Pollution

It is basically caused by insecticides, pesticides, herbicides, etc.

Pesticides

- DDT was the first chemical pesticide to be used after World War II.

- Persistent use of DDT made the pests resistant to it and then other toxins such as aldrin and dieldrin were introduced.

- Most pesticides used are water insoluble and non-biodegradable.

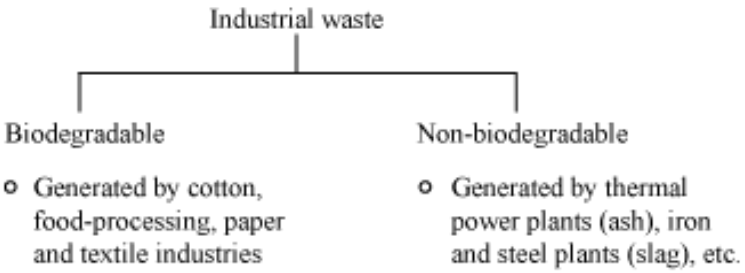
- Pesticides persist in the soil and act as pollutants. They travel along the trophic levels with their concentration increasing by 10 times at each level.

- New sense of less persistent and bio-degradable products such as organophosphates was also introduced, but they acted as nerve toxins. Insects became resistant to these too.

- Subsequently, herbicides were introduced (example, sodium chlorate, sodium arsenite, etc.), but these too acted as chemical pollutants. Though being lesser persistent, they act as toxins and are believed to cause birth defects in humans.

  Biomagnification

  Industrial Waste



- Hazardous waste such as metals, drugs, pharma, pesticides, dyes, etc. is produced by industries.

- Non-biodegradable solid waste is required to be disposed in a proper manner.

- Waste generated by one industry can be utilized as raw material in other. Example − Fly ash and slag which are waste from steel industry are utilized by cement industry.

- Solid waste disposal − Large quantities are destroyed by controlled incineration while small quantities are burnt in open bins.

Controlling Pollution and Green Chemistry

Controlling Pollution

Waste Management

- Waste includes household discards; medical, agricultural,and mining wastes.

- Waste is required to be disposed in a proper manner.

- Collection of waste − In small bins, from where they are carried to disposal site where it is sorted out and separated into biodegradable and non-biodegradable

- Non-biodegradable is sent for recycling and biodegradable is deposited into land fills to form compost.

- If not collected properly, then these wastes are introduced into sewer or eaten by animals. The waste may choke the sewer or may prove fatal for the animal. (For example, polythene −a non-biodegradable waste)

- Improper waste management leads to epidemics and contamination of ground water.

Green Chemistry

- Over-exploitation of soil and natural resources and excessive use of chemicals such as pesticides and fertilizers have adverse effect on environment.

- Green chemistry− Production process that would bring about minimum environmental deterioration and pollution; involves utilization of existing knowledge base of chemistry and other sciences to devise methods that are environmental friendly as well as cost effective

- A chemical reaction depends upon

- reactants

- attacking reagents

- reaction medium

- catalyst

- physical parameters (temperature, pH, etc.)

- If during a chemical reaction environment friendly reactants and medium are used to fully convert reactants into product which are environment friendly, then it will not result in pollution.