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.

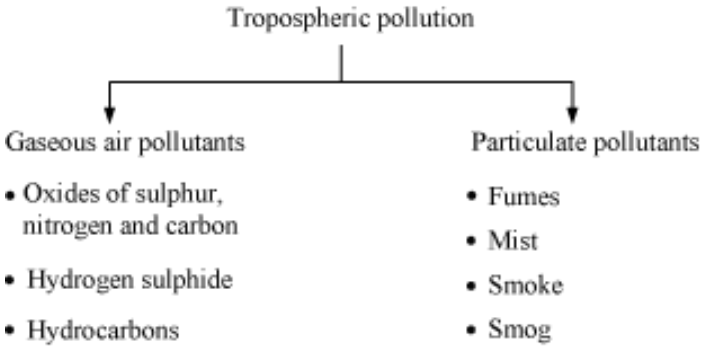
Atmospheric Pollution

- 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

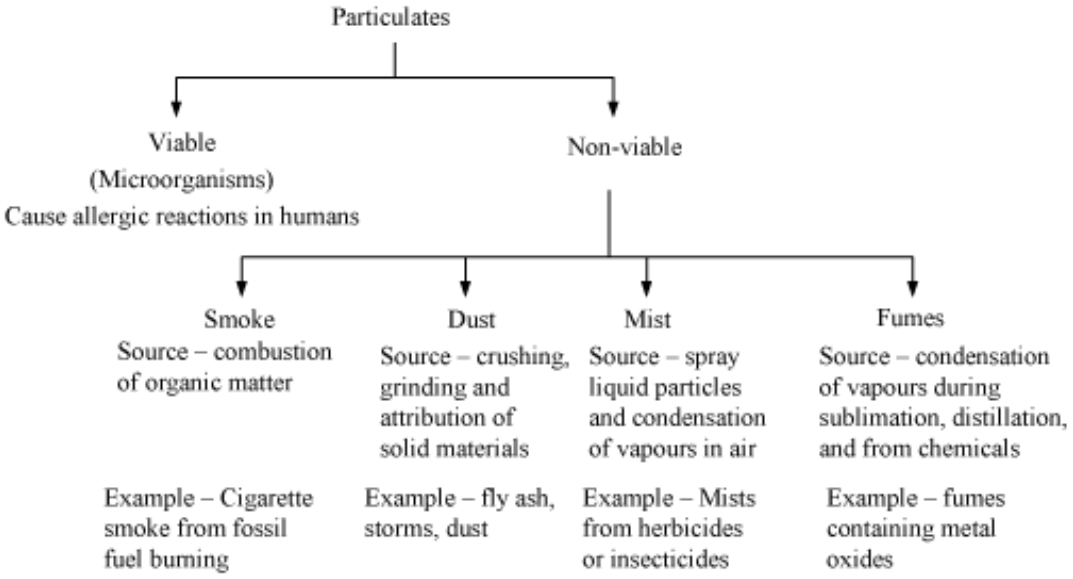
$$4NO_2 + O_2 + 2H_2O \longrightarrow 4HNO_3$$
$$2SO_2 + O_2 + 2H_2O \longrightarrow 2H_2SO_4$$

- 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

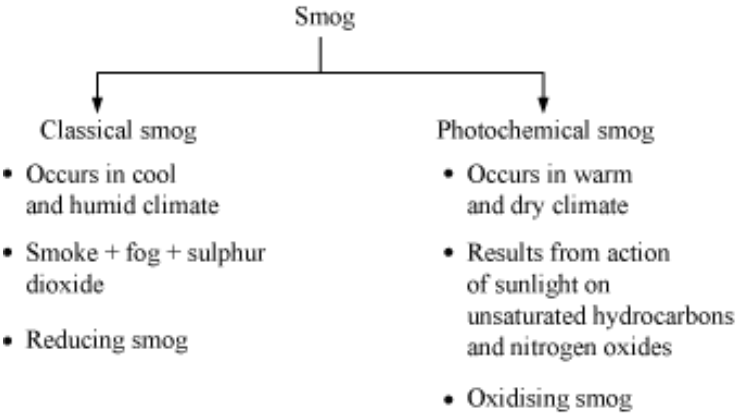
- Minute solid particles or liquid droplets in air
- Source − vehicle emission, smoke, dust particles, ash



- 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.

$$CF_2Cl_2 \xrightarrow{UV} \overset{\circ}{Cl} + \overset{\circ}{C}F_2Cl$$

- $\overset{\circ}{Cl}$ 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.

$$\overset{\circ}{Cl} + O_3 \longrightarrow Cl\overset{\circ}{O} + O_2$$
$$Cl\overset{\circ}{O} + O \longrightarrow \overset{\circ}{Cl} + O_2$$

- 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.

$$\overset{\circ}{Cl}O + NO_2 \longrightarrow ClONO_2$$
$$\overset{\circ}{Cl} + CH_4 \longrightarrow \overset{\circ}{C}H_3 + HCl$$

- 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.

- 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.

$$HOCl \xrightarrow{h\nu} \overset{\circ}{O}H + \overset{\circ}{Cl}$$
$$Cl_2 \xrightarrow{h\nu} 2\overset{\circ}{Cl}$$

- **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