Acid Rain

- Unpolluted rain water is slightly acidic owing to the presence of carbon dioxie in the air. Its pH could be up to 5.7.

$$CO_2(g) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

- Acid rain" includes both wet and dry acidic deposits
  Precipitation with a pH **lower than 5.6** is considered acidic
- Acid rain originates from sulfur dioxide and nitrogen oxide particles
- Once these particles are emitted into the air they form sulfate and nitrate particles
- These particles can travel long distances on wind currents
- By combining with water vapor, these particles form acids which fall to the earth as acid rain.

Acid Rain

- The formation of sulphur compounds and Nitrogen compounds causing acid rain is influenced by the prevailing atmospheric conditions such as the following:
  - Sunlight
  - Temperature
  - Humidity
  - Presence of hydrocarbons
  - Particulates

Effects of Acid Rain

- Poor forest health due to acidification of soil: acid rain can kill nutrient-producing microorganisms
- Acidification of lakes and streams can lead to the death of aquatic life, such as trout and bass
- Acidity can leach mercury out of the soil, causing toxic levels to build up in the fish we eat
- Acid rain can erode buildings and monuments and destroy paint finishes

Vegetation: Acid rain can wash away essential plant nutrients from the soil. In addition, it makes the soil acidic and aids the release of aluminium and copper ions which are harmful to plants.

Aquatic life: When pH is less than 4.5, calcium metabolism in fresh water fish will be affected, leading to poor health. As a result, diversity and population of some fish species will be reduced.

Effects of Acid Rain

- **Building Material:** Acid rain will cause damage to common building materials (such as limestone and marble), in addition to damaging statues and monuments.

$$CaCO_3(S) + 2H^+(aq) \longrightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$$

- Many metals become oxidized. Iron corrodes with the presence of acid rain to form rust. The cost of maintenance of iron stuctures is high in highly polluted areas.

$$Fe(s) + 2H^+(aq) \longrightarrow Fe^{2+}(aq) + H_2(g)$$

Ozone Layer Formation

- Ozone (O3) occurs naturally in the atmosphere. The earth's atmosphere is composed of several layers.
- Ozone forms a layer in the stratosphere, thinnest in the tropics (around the equator) and denser towards the poles.
- Ozone is formed in the atmosphere when ultraviolet radiation from the sun strikes the stratosphere, splitting oxygen molecules (O2) into atomic oxygen (O).
- The atomic oxygen quickly combines with further oxygen molecules to form ozone.

$$O_2 + hv \rightarrow O + O$$

$$O + O_2 \rightarrow O_3$$

Need of Ozone Layer

- In the stratosphere we need ozone to absorb some of the potentially harmful ultraviolet (UV) radiation from the sun (at wavelengths between 240 and 320 nm) which can cause skin cancer and damage vegetation
- At ground level, ozone is a health hazard and is a major constituent of photochemical smog.

Ozone layer depletion- Measurement

- The most common stratospheric ozone measurement unit is the Dobson Unit (DU).
- The average amount of ozone in the stratosphere across the globe is about 300 DU.
- When stratospheric ozone **falls below 200 DU**, this is considered low enough to represent the beginnings of an ozone hole.
- Ozone holes commonly form during springtime above Antarctica, and to a lesser extent in the Arctic.
- The ozone is being destroyed because of the release of chlorofluorocarbons (CFCs), mostly in the **northern hemisphere**.
- These spread throughout the world and diffuse into the stratosphere, where they are broken down to release chlorine.
- The main long-lived inorganic carriers (reservoirs) of chlorine are hydrochloric acid (HCl) and chlorine nitrate (ClONO2). These form from the breakdown products of the CFCs.

Ozone layer depletion

- **CFCs (Chlorofluorocarbons) & halons (bromine containing gases) are identified as the major culprit in ozone destruction**.
- CFCs escape into the atmosphere, they reach the stratosphere intact as they are inert compounds.
- In the stratosphere, the CFCs are broken down by the sunlight releasing chlorine atoms.
- These chlorine atoms act as catalysts in the destruction of O3.
- Chlorofluorocarbons or CFCs (also known as Freon) are non-toxic, non-flammable and non-carcinogenic. They contain fluorine atoms.
- The following is a list of major uses of CFCs:
  - as coolants in refrigerators and air conditioners
  - as solvents in cleaners, particularly for electronic circuit boards
  - as a blowing agent in the production of foam (for example fire extinguishers)
  - as propellants in aerosols
- CFCs have a lifetime in the atmosphere of about 20 to 100 years, and as a result one free chlorine atom from a CFC molecule can do a lot of damage, destroying ozone molecules for a long time.

Ozone Layer Depletion- Impact

- UV radiation from the Sun can cause a variety of health problems in humans, including skin cancers, eye cataracts and a reduction in our natural immunity towards many diseases.
- Furthermore, UV radiation can be damaging to microscopic life in the oceans which forms the basis of the world's food chain, certain varieties of vegetation including rice and soya crops, and polymers used in paints, clothing and other materials.
- Health disorders, damage to plant and aquatic life, and degradation of materials will probably increase
- Ozone depletion may even affect the global climate.

Biological Carbon Sequestering

- Biological Carbon Sequestering refers to storage of atmospheric carbon in vegetation, soils, woody products, and aquatic environments. For example, by encouraging the growth of plants—particularly larger plants like trees

- **Photosynthesis**
  - Plants (esp. woody + grasslands) absorb CO_2 from the atmosphere.
  - CO_2 → Transformed into plant tissue.
- **Carbon Storage and cycling in Soil**
  - Plants transfer carbon into soil as **soil organic carbon**.
  - Soil stores large amounts of carbon, carbon retention in soil depends on type of soil and climatic condition
  - Some carbon is:
    - **Broken down** → returns to atmosphere as CO_2.
    - **Stabilized** → remains locked in soil long-term.
- **Ocean Storage**
  - CO_2 stored as:
    - **Dissolved gas**
    - **Carbonate sediments** on seafloor.

Geologic Carbon Sequestration

Geologic carbon sequestration is the process of storing carbon dioxide (CO_2) in underground geologic formations. The CO2 is usually pressurized until it becomes a liquid, and then it is injected into porous rock formations in geologic basins.

CO_2 Compression

- CO_2 compressed into **supercritical phase** (liquid-like).

Injection into Underground Rock

- Injected deep underground into **porous rock formations**.

Storage Mechanisms

- **Trapped** in rock pores.
- **Dissolves** in formation fluids.
- **Reacts** to form **stable minerals**.

Alternative Methods

- **CO_2 + Water (like soda)** → injected into **basaltic rocks** to **mineralize**.
- **Injection into oil-bearing formations**:
  - Stores CO_2.
  - Assists with oil extraction (economic benefit).

Thanks