

## MODULE 1

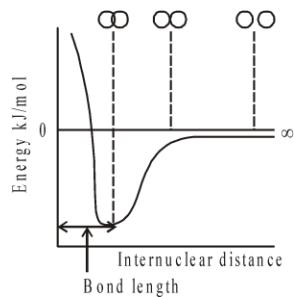
### **1. CHEMICAL BOND**

Chemical bonding, any of the interactions that account for the association of atoms into molecules, ions, crystals, and other stable species that make up the familiar substances of the everyday world. When atoms approach one another, their nuclei and electrons interact and tend to distribute them in space in such a way that the total energy is lower than it would be in any alternative arrangement. If the total energy of a group of atoms is lower than the sum of the energies of the component atoms, they then bond together and the energy lowering is the bonding energy.

A chemical bond is a sort of attraction which keeps the two atoms together. These chemical bonds are what keep the atoms together in the resulting from the loss, gain, or sharing of electrons between two atoms/molecules. Thus depending upon the variety of force, there may be variety of chemical bonds.

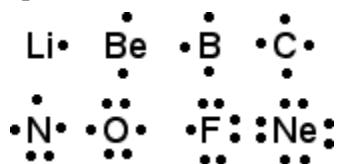
#### **1.1 REASONS FOR THE FORMATION OF A CHEMICAL BOND**

**1.1.1 Energy concept:** When two atoms approach each other, the attractive and repulsive forces operate between them. The distance at which the attractive forces outweigh the repulsive forces is known as the bond distance, the potential energy of the system is minimum and the bond is said to be formed.



**1.1.2 Lewis and Langmuir (Octet Rule) :** Concept of stable electronic configuration. Atoms enter into chemical bonding to acquire the stable inert gas electronic configuration. They can do so by losing, gaining or sharing of electrons.

**1.1.3 Lewis symbols :** The electrons present in the outermost energy level of an atom are known as valence electrons. Only valence electrons are involved in the combination of two atoms. The representation of valence electrons on an atom called Lewis Symbol eg-



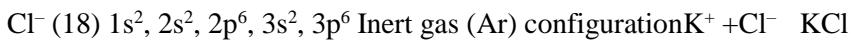
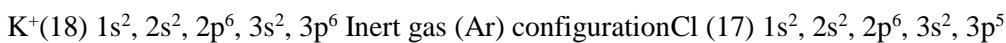
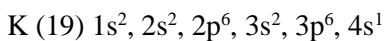
## 1.2 TYPES OF CHEMICAL BOND:

**Primary bond**- Primary bonds are formed when the bonding process involves a transfer or sharing of electrons. Primary bonds are those which are strong in nature. They have electronic attractions and repulsions just like secondary bonds but in equilibrium they are stronger than the later. They are broadly classified into four types:

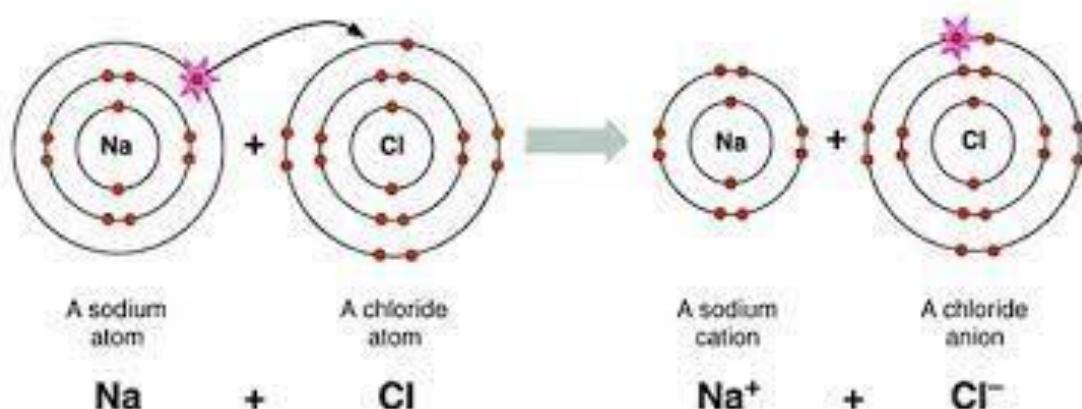
- Ionic bonds
- Covalent bonds
- Metallic bonds.
- Coordinate bond

### 1.2.1 IONIC BOND

Ionic bond is formed by the complete transference of one or more valence electrons of one atom to the valence shell of the other atom. Both atoms are converted into ions and have the electronic configuration of nearest noble gases. The electrostatic attraction between these oppositely charged ions, which always tends to decrease the potential energy of the system is known as the ionic bond. Consider the formation of KCl. The electronic configuration of K, Cl and their ions ( $K^+$  and  $Cl^-$ ) are given below



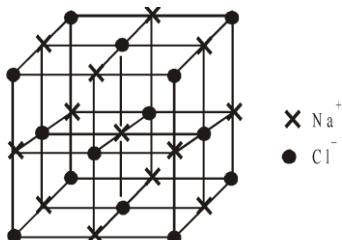
The number of electrons lost or gained by an atom represents the electrovalence of the atom.



## PROPERTIES OF IONIC COMPOUNDS

The important properties are as follows

1. **Crystal structure :** The crystalline ionic compounds have well defined crystal structure or crystal lattice eg in NaCl each  $\text{Na}^+$  is surrounded by six  $\text{Cl}^-$  ions and vice versa



Cubical structure of sodium chloride crystal

2. **Melting and boiling points:** Ionic compounds have high m.pt and b.pt due to powerful electrostatic force between ions.

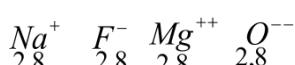
3. **Solubility:** They are generally soluble in polar solvents (having high value of dielectric constant). The solubility of ionic compounds decreases with increase in covalent character of ionic compounds. It is also governed by-

a. **Lattice energy:** More the lattice energy, lesser is the solubility, Eg. sulphates and phosphates of Ba and Sr are insoluble in water due to high lattice energy.

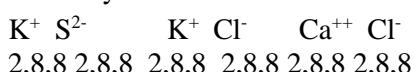
b. **Heat of hydration:** More the heat of hydration, more is the solubility. Eg.  $\text{AlCl}_3$  though covalent in nature is soluble in water due to high value of heat of hydration.

4. **Electrical conductivity:** In solid state they do not conduct electricity since there is no free movement of electrons but in molten state and in solution they conduct electricity.

5. **Isomorphism:**  $\text{NaF}$  and  $\text{MgO}$  are isomorphous due to similar electronic structure



Similarly  $\text{K}_2\text{S}$  and  $\text{CaCl}_2$  are isomorphous

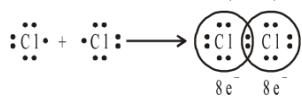


### 1.2.2 COVALENT BOND :

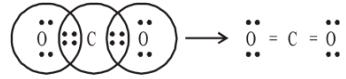
According to G. N. Lewis atoms may also combine by sharing of electrons present in their outermost shells and attain noble gas electronic configuration. One shared pair of electrons constitute a single bond, two electron pairs constitute a double bond and so on. The bonds thus formed are known as covalent bonds.

### EXAMPLES OF COVALENT COMPOUNDS

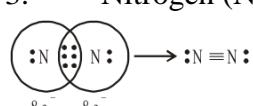
1. Chlorine ( $\text{Cl}_2$ )



2. Carbon dioxide ( $\text{CO}_2$ )



3. Nitrogen ( $\text{N}_2$ )



## PROPERTIES OF COVALENT COMPOUNDS

1. **Physical state** - They may be gases, liquids or solids.
2. **Crystal structure** - They may exist as simple molecules held together by weak forces, giant molecules united by covalent link Eg. diamond, silicon carbide, alumina, aluminum nitride etc. and can have layer structure. Eg. graphite.
3. **Solubility** - Generally soluble in non-polar solvents.
4. **Melting/ boiling points** - Low as compared to ionic compounds.
5. **Electrical conductivity** - Being non-electrolytes they do not conduct electricity, graphite does due to presence of free electrons.
6. **Stereo-isomerism** - They exhibit structural and stereo-isomerism both.

## HYBRIDISATION

Hybridisation is the redistribution of energy levels at the time of formation of molecules. It may also be defined as intermixing of atomic orbitals of nearly the same energy and resulting in the formation of new atomic orbitals same in number and identical in all respects (shape, energy and size). The new atomic orbitals are known as hybrid atomic orbitals.

The completely filled or half-filled atomic orbitals can take part in hybridization and hybrid atomic orbitals form stronger bonds.

### METHOD FOR FINDING THE TYPE OF HYBRIDISATION

Apply the following formula to find the hybridization of central atom.

$$\frac{1}{2} \left( \begin{array}{l} \text{Number of valence electrons of central atom} \\ + \text{number of monovalent atoms attached to it} \\ + \text{negative charge if any} - \text{positive charge if any} \end{array} \right) = z$$

**Value of z** 2 3 4 5 6 7

**Hybridization** sp sp<sup>2</sup> sp<sup>3</sup> sp<sup>3</sup>d sp<sup>3</sup>d<sup>2</sup> sp<sup>3</sup>d<sup>3</sup>

*Examples:*

1. hybridization of NH<sub>3</sub> = [5 + 3 + 0 - 0] = 4; sp<sup>3</sup>
2. hybridization of H<sub>2</sub>O = [6 + 2 + 0 - 0] = 4; sp<sup>3</sup>
3. hybridization of SO<sub>3</sub> = [6 + 0 + 0 - 0] = 3; sp<sup>2</sup>
4. hybridization of SO<sup>2-</sup> = [6 + 0 + 2 - 0] = 4; sp<sup>3</sup>
5. hybridization of CO<sup>3-</sup> = [4 + 0 + 2 - 0] = 3; sp<sup>2</sup>
6. hybridizations of PCl<sub>5</sub> = [5 + 5 + 0 - 0] = 5; sp<sup>3</sup>d
7. hybridization of SF<sub>6</sub> = [6 + 6 + 0 - 0] = 6; sp<sup>3</sup>d

**Note:** Species having same hybridization are isostructural in nature.

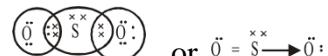
### 1.2.3 COORDINATE COVALENT BOND OR DATIVE BOND

When both the electrons for sharing between two atoms are contributed by one atom only the bond formed is known as coordinate bond or dative bond.

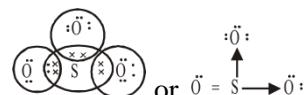
The atom donating the pair of electrons is called donor and the atom which accepts the pair of electrons is called acceptor. The compounds containing coordinate bonds are known as coordination compounds. The bond is represented by an arrow (→) pointing head towards the acceptor.

Some examples are:

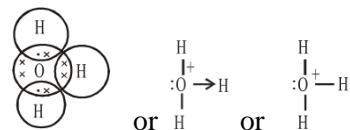
1. Formation of  $\text{SO}_2$



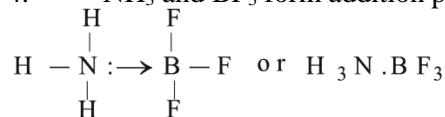
2. Formation of  $\text{SO}_3$



3. Formation of Hydroxonium ion



4.  $\text{NH}_3$  and  $\text{BF}_3$  form addition product by Coordinate covalent bond



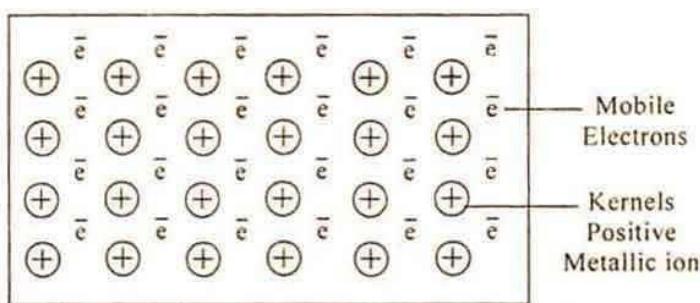
## PROPERTIES OF COORDINATE COMPOUNDS

Coordinate compounds have volatile character in between ionic and covalent compounds. Other properties like solubility, electrical conductivity and stereo-isomerism are similar to covalent compounds.

### 1.2.4 METALLIC BOND

'Metallic bond' is a term used to describe the collective sharing of a sea of valence electrons between several positively charged metal ions. Metallic bonding is a type of chemical bonding and is responsible for several characteristic properties of metals such as their shiny lustre, their malleability, and their conductivities for heat and electricity.

Both metallic and covalent bonding can be observed in some metal samples. For example, covalently bonded gallium atoms tend to form crystal structures that are held together via metallic bonds. The mercurous ion also exhibits metallic and covalent bonding.



Structure of a Metallic Crystal

The factors that affect the strength of a metallic bond include:

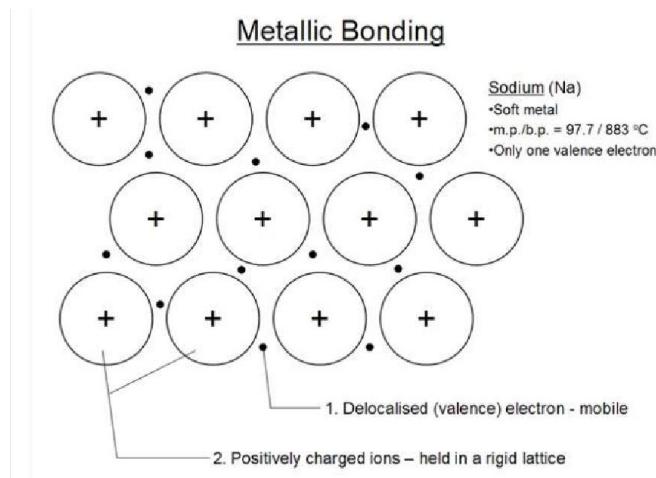
- Total number of delocalized electrons.
- Magnitude of positive charge held by the metal cation.
- Ionic radius of the cation
- Metallic bonds are not broken when the metal is heated into the melt state. Instead, these bonds are weakened, causing the ordered array of metal ions to lose their definite, rigid structure and become liquid. However, these bonds are completely broken when the metal is heated to its boiling point.

#### Example – Metallic Bonding in Sodium

The electron configuration of sodium is  $1s^2 2s^2 2p^6 3s^1$ ; it contains one electron in its valence

shell. In the solid-state, metallic sodium features an array of  $\text{Na}^+$  ions that are surrounded by a sea of 3s electrons. However, it would be incorrect to think of metallic sodium as an ion since the sea of electrons is shared by all the sodium cations, quenching the positive charge.

An illustration describing the metallic bonding in sodium is provided below.



The softness and low melting point of sodium can be explained by the relatively low number of electrons in the electron sea and the relatively small charge on the sodium cation. For example, metallic magnesium consists of an array of  $\text{Mg}^{2+}$  ions. The electron sea here contains twice the number of electrons than the one in sodium (since two 3s electrons are delocalized into the sea). Due to the greater magnitude of charge and the greater electron density in the sea, the melting point of magnesium (~650°C) is significantly higher than that of sodium.

## CONSEQUENCES OF METALLIC BOND

1. **Electrical conductivity** - It is due to presence of mobile valence electrons.
2. **Thermal conductivity** - On heating one part of metal, the K.E. of electrons is increased and they conduct heat to the other parts of the metal.
3. **Metallic lustre** - The mobile electrons are promoted to excited states by absorption of light and on coming back from the excited state light of all wavelengths in the visible region are emitted. The surface therefore emits metallic lustre.
4. **Malleability** - Metals can be made thin sheets
5. **Ductility** - Metals can be drawn into wires since metal kernels can easily be shifted.
6. **Electrical conductivity decreases with temperature** - It is due to random motion of mobile electrons which increases with increase of temperature.

**SECONDARY BOND-** Secondary bonds are formed from the subtle attraction forces between positive and negative charges. Secondary bonds are bonds of a different kind to the primary ones. They are weaker in nature and are broadly classified as:

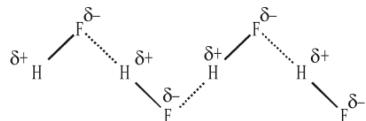
- Van der Waal's forces
- Hydrogen bonds.

## 1.2.5 HYDROGEN BOND

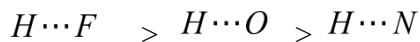
It may be defined as the force of attraction existing between hydrogen atom covalently bonded to highly electronegative atom (N, O or F) and the electronegative atom belonging to another molecule of the same or different substance. It is represented by dotted lines



The chains possess a **Zig-Zag** structure



Hydrogen bond is purely electrostatic in nature. It is a weak bond, the strength of the strongest being about 5 - 10 kcal per mole. The more the electronegativity of atom involved in H - bonding, the more is the bond strength eg.

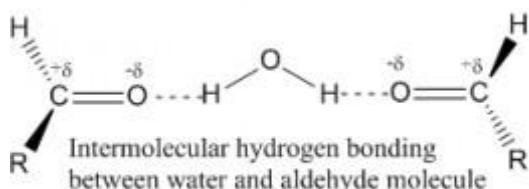


10 kcal/mole > 7 kcal/mole > 2.0 kcal/mole

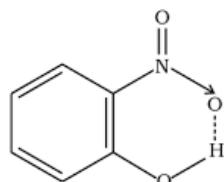
## TYPES OF HYDROGEN BONDS

Hydrogen bond is of two types

1. Intermolecular H-bonding (Association) -. When hydrogen bonding occurs between atoms of different molecule then it is called intermolecular hydrogen bonding. For such bonding one molecule should have a partially positive hydrogen as acceptor atom and another should have a partially negative or donor atom. As for example, hydrogen bonding between aldehyde and water molecule has given below: H-bonding involving two or more molecules.



2. Intramolecular H-bonding (Chelation)-. When hydrogen bonding occurs between two partially charged atoms of same molecule that is called intramolecular hydrogen bonding. This occurs when two functional groups are present in same molecule and they are in such way that can attract each other to form hydrogen bond. For example salicylic acid has two functional groups alcohol and carboxylic acid. Here intramolecular hydrogen bonding occurs between the hydrogen atom of alcohol group and the oxygen atom of carboxylic acid group. H-bonding taking place within



Intramolecular hydrogen bonding in  
single molecule. o-nitrophenol molecule

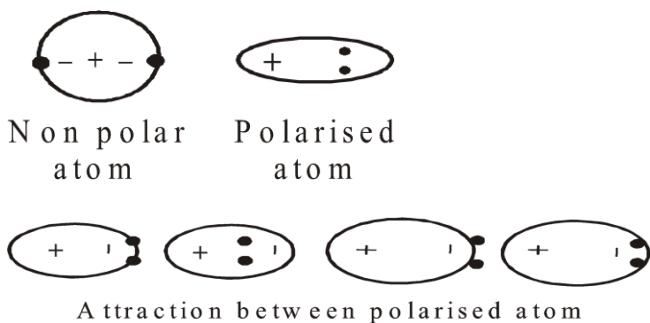
### 1.2.6 VAN DER WAAL'S FORCES

Attractive forces between uncharged molecules are known as van der Waals forces. These forces may be divided into three groups

1. Dispersion or London forces. These are due to transient polarization.
2. Dipole-dipole attraction. These are due to permanent polarization.
3. Dipole-induced dipole forces

### LONDON FORCES

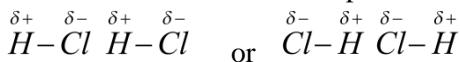
The negative electrons in a neutral molecule are balanced by the positive charges on the nucleus. Since the electrons are in motion the center of density of the electrons does not coincide continuously with the center of density of positively charged nuclei, the molecules acquire an electric dipole. Polarized molecules exert an attraction for other molecules having a dipole. Consider the case of helium.



- The greater the polarizability of a molecule, the stronger are the London forces.
- The polarizability increases with number of electrons and their distance from the nucleus.
- These forces are operative over a very short range.
- The inert gases have weak van der Waals forces of attraction
- The straight chain hydrocarbons boil at higher temperature than isomeric branched chain hydrocarbons due to greater magnitude of van der Waal's forces of attraction.

### DIPOLE-DIPOLE ATTRACTION

It is the attraction between the positive end of the one molecule and negative end of another molecule.



This type of interaction is called dipole - dipole interaction. The force of dipole - dipole attraction is

$$F = \frac{1}{r^4}$$

inversely proportional to fourth power of their separation of distance  $r$ . The dipole-dipole attractions in gaseous molecules are particularly small since the gas molecules are in continuous motion. This attraction increases the m.pt. and b.pt. of substances and makes their liquefaction easy.

### DIPOLE-INDUCED DIPOLE ATTRACTION

The attractive forces operate between polar molecules having permanent dipole and non-polar molecules. The polarity in the non-polar molecules is induced by the polar molecule



## **Advanced Materials**

Advanced materials are materials with mechanical and physical properties that are superior to those of commonly used materials like steel, aluminum, and magnesium. They have many applications, including in aerospace, automobiles, trains, oil and gas exploration, and medical devices.

Here are some properties of advanced materials:

- Strength and ductility: Advanced materials can absorb and redistribute high stress concentrations without failing suddenly.
- Stiffness and modulus: Advanced materials can maintain their shape and dimensions under external action.
- Temperature: Advanced materials can perform well at higher temperatures.
- Forgiveness: Advanced materials have good fracture toughness and fatigue-crack growth rate.
- Reduced density: Advanced materials can be less dense than other materials.

Some examples of advanced materials include:

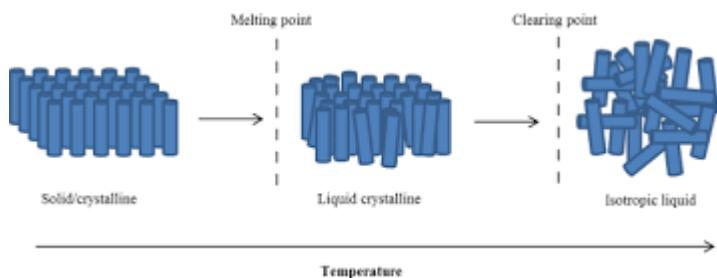
- **Chromo active materials (Liquid crystals)**
- **Nanomaterials**
- **Polymeric Materials- Conducting polymers**
- **Composite concepts: Materials made up of two or more components with different properties**
- **Monolithic metals: Materials like titanium**
- **Nickel-based alloys: Materials with high-temperature strength, low-temperature ductility, and oxidation resistance**

Advanced materials can be used to improve the performance of lightweight structures in a variety of engineering problems. They can also help to mitigate the shortcomings of traditional materials, such as brittleness and high cost.

### **CHROMO ACTIVE MATERIALS (LIQUID CRYSTALS)**

Liquid crystals form a state of matter intermediate between the solid and the liquid. For this reason, they are referred to as intermediate phases or mesophases.

When molecular crystals are heated to their melting point, they usually change directly into the liquid state. The periodic structure of die lattice as well as the orientational ordering of the molecules is destroyed simultaneously. However, if the constituent molecules have a pronounced anisotropy of shape, such as rod or disc, the melting of the lattice may precede the disappearance of the orientational ordering leading an intermediate phase composed of molecules which are more or less parallel to each other but at the same time exhibiting a certain degree of fluidity. The molecules can slide over one another while still preserving their parallelism. The fluid is therefore anisotropic; it is turbid and, like a crystal, shows optical birefringence and dielectric anisotropy. At a higher temperature, there is orientational melting and the anisotropic fluid transforms into the ordinary isotropic clear liquid. Such intermediate (or meso) phases are referred to as liquid crystals (LCs). They combine both, order and mobility.



## Classification of liquid crystals

Liquid crystals can be roughly divided into two areas:

1. Thermotropic, whose mesophase formation is temperature dependent,
2. Lyotropic, whose mesophase formation is solvent and concentration dependent.

The Lyotropic liquid crystal can be classified as:

- (a) Nematic liquid crystal
- (b) Smectic liquid crystal
- (c) Cholesteric liquid crystal

### **(a) Nematic liquid crystal:**

The nematic phase of calamitic liquid crystals is the simplest liquid crystal phase. The name "nematic" comes from the Greek word, nema means thread-like which can be observed under polarizing microscope. This name was given due to the thread-like discontinuities produced by variations in the molecular organization. The nematic phase is essentially a one dimensionally ordered elastic fluid in which the molecules have a high degree of long range orientational order, but there is no long-range translational order (positional order). It is the least viscous and least ordered mesophase with a high degree of fluidity. The phase is usually very easy to identify by optical polarizing microscope. In the nematic phase, the constituent molecules are completely disordered with respect to each other but the long molecular axes statistically point in a preferred direction known as the director ( $\mathbf{q}$ ). The most common texture adopted by the nematic phase is schlieren.

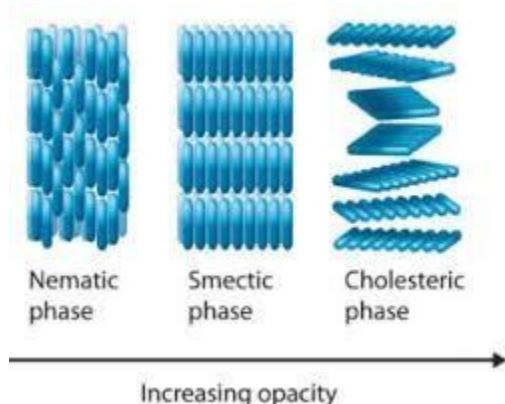
### **(b) Smectic liquid crystal:**

Smectic liquid crystals differ from nematics as smectics have two degrees of order namely orientational and positional. In smectic mesophase, the molecules form layers and translation of molecules from one layer to another is limited. Within these layered systems, a variety of molecular arrangements is possible leading to different sub phases. The term smectic comes from the word smectos-soap like, as the basic layered structure in the smectic phase gives them a soapy feel. The smectic phase is characterized by a long range orientational order and positional order which gives layered structure. The inter layer attractions are weak when compared with the lateral forces between the molecules and the layers are able to slide freely over one another. As a result, the smectic phase has fluidity and is more viscous than nematic phase. The smectic phase is more ordered than the nematic phase. The smectic phase exhibits polymorphism and the lamellar nature of smectic phase allows various combinations of molecular correlations both within the 'layers' and between the 'layers' each of which consists of different type of smectic phase. The smectic phases are found at lower temperatures than nematics which can be identified under optical polarizing microscope.

### (c) Cholesteric liquid crystal

The cholesteric phase is also called chiral nematic phase or twisted nematic phase. Cholesteric phase was first discovered in cholesterol. The chiral nematic phase exhibits chirality and is associated with the presence of an asymmetric carbon atom, so that left- and right-hand versions of molecules cannot be commuted by simple reorientation. The molecules forming this phase are always optically active, i.e. they have distinct right- and left-handed forms. Only chiral molecules (i.e., those that lack of inversion symmetry) can give rise to such a phase. This phase exhibits a twisting of the molecules perpendicular to the director, with the molecular axis parallel to the director.

### APPLICATIONS



- The most important use of liquid crystals is in displays because the molecules of a liquid crystal can control the amount, color, and direction of vibration of the light that passes through them.
- They are used in the LCDs and in digital watches.
- Also used in handheld calculators; flat-screen monitors; and car, ship, and aircraft instrumentation.
- They are used in all kinds of display devices including computer monitors and laptop screens, TVs, clocks, visors, and navigation systems.

## NANOMATERIALS

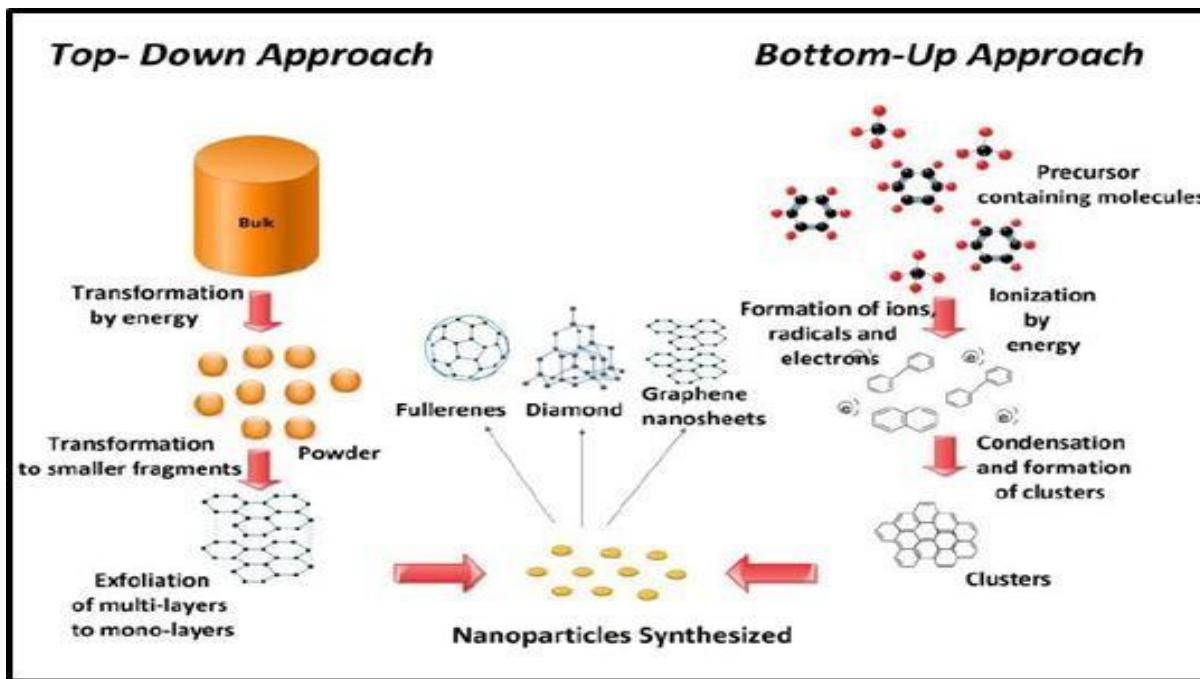
Nanomaterials are 'material with any external dimension in the nanoscale (size range from approximately 1 – 100 nm) or having internal structure or surface structure in the nanoscale'.

Nanomaterials are of interest because at this scale unique optical, magnetic, electrical, and other properties emerge. These emergent properties have the potential for great impacts in electronics, medicine, and other fields. These emergent properties have the potential for great impacts in electronics, medicine, and other fields. Some nanomaterials occur naturally, but of particular interest are engineered nanomaterials (EN), which are designed for, and already being used in many commercial products and processes. They can be found in such things as sunscreens, cosmetics, sporting goods, stain-resistant clothing, tires, electronics, as well as many other everyday items, and are used in medicine for purposes of diagnosis, imaging and drug delivery.

The two main reasons why materials at the nano scale can have different properties are increased relative surface area and new quantum effects. Nanomaterials have a much greater surface area to volume ratio than their conventional forms, which can lead to greater chemical reactivity and affect their strength. Also at the nano scale, quantum effects can become much more important in determining the materials.

### 1.7.1 PREPARATION OF NANOMATERIALS:

When it comes to the synthesis of metallic Nanoparticles, two distinct approaches are utilized. The first is the top-down strategy and the second approach is referred to as the bottom-up strategy. While the former deals with the reduction in size of current technological devices, the latter performs an



opposite role, which is building of even more complex molecular devices on an atomic arrangement.

#### TOP-DOWN APPROACH

The top-down approach usually involves the following processes:

1. Cutting
2. Grinding
3. Itching
4. Ionic/electronic irradiation

#### BOTTOM-UP APPROACH

The bottom-up approach utilizes physical and chemical processes that function at the nanoscale to integrate main components into bigger structures. A reduction in unit size, the approach yields a relevant consummation to the top-down approach. Biological systems provide a motivation for this approach in which natural forces of life harness their chemical counterparts to produce the structures.

Gold-palladium alloy nanoparticles which were based on carbon treated with acid and breaking down hydrogen peroxide are formed from the combination of white hydrogen and red oxygen when disallowing unwanted decay.

This approach has been used in the production of nanoparticles from condensation to coalescence of atomic vapors and liquids, respectively.

#### 1. Sol-gel techniques

This allows the production of nanomaterials from alkoxides or colloidal based solution. They take the

form of monoliths, crystallized nano pigments, and thin layers. They are centered on reactions in polymerization. Lithography in which growth of thin film is done.

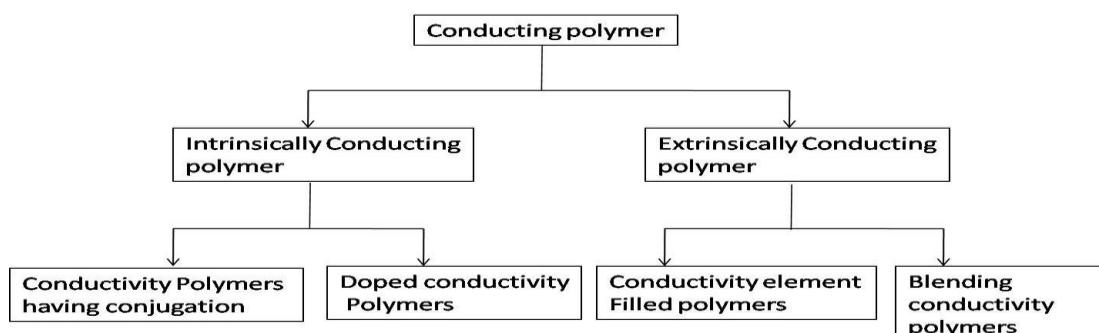
## APPLICATIONS

- Nanoscale additives to or surface treatments of fabrics can provide lightweight ballistic energy deflection in personal body armor, or can help them resist wrinkling, staining, and bacterial growth.
- Clear nanoscale films on eyeglasses, computer and camera displays, windows, and other surfaces can make them water- and residue-repellent, antireflective, self-cleaning, resistant to ultraviolet or infrared light, antifog, antimicrobial, scratch-resistant, or electrically conductive.
- Nanoscale materials are beginning to enable washable, durable “smart fabrics” equipped with flexible nanoscale sensors and electronics with capabilities for health monitoring, solar energy capture, and energy harvesting through movement.
- Nanoparticles are used increasingly in catalysis to boost chemical reactions. This reduces the quantity of catalytic materials necessary to produce desired results, saving money and reducing pollutants. Two big applications are in petroleum refining and in automotive catalytic converters.
- Nano-engineered materials make superior household products such as degreasers and stain removers; environmental sensors, air purifiers, and filters; antibacterial cleansers; and specialized paints and sealing products, such as self-cleaning house paints that resist dirt and marks.
- Nanoscale materials are also being incorporated into a variety of personal care products to improve performance. Nanoscale titanium dioxide and zinc oxide have been used for years in sunscreen to provide protection from the sun while appearing invisible on the skin.

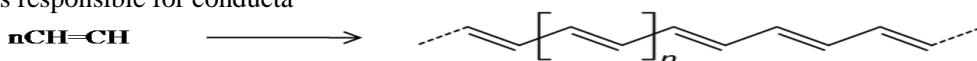
## POLYMERIC MATERIALS- CONDUCTING POLYMERS

A polymer which can conduct electricity is termed as conductivity polymer.

### Classification of conducting polymer



- A) Intrinsically Conductivity polymer.** These polymers have extensive conjugation in the backbone which is responsible for conductivity.



**Acetylene**

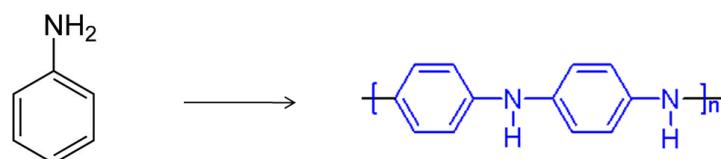
**Polyacetylene**

(a) **Conducting polymers having conjugated  $\pi$ -electrons in the backbone.** Such polymers contain conjugated  $\pi$ -electrons in the backbone which increases their conductivity to a large extent. This is because, overlapping of conjugated  $\pi$ -electrons over the entire backbone results in the formation of valence bands as well as conduction band, which extends over the entire polymer molecule. The valence band and conduction bands are separated by a significant band gap. Thus, electrical conduction could occur only after thermal or photolytic activation of electrons to give them sufficient energy to jump the gap and reach into the lower levels of the conduction band. Examples:

(i) **Polyacetylene**

(ii) **Polypyrrole**

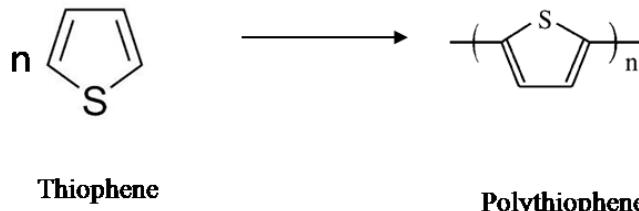
(iii) **Polyaniline**



Aniline

Polyaniline

(iv) **Polythiophene**

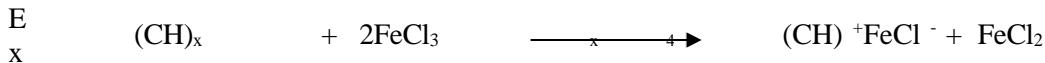


Thiophene

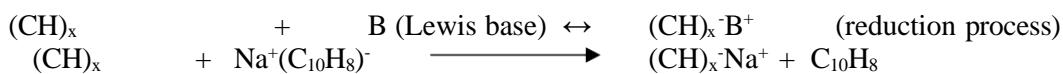
Polythiophene

(b) **Doped conducting polymer.** The conducting polymers of type (a) can be easily oxidized or reduced as they have low ionization potentials and high electron affinities. Their conductivity can be increased by creating positive or negative charge on polymer backbone by oxidation or reduction.

**p-doping** It is done by oxidation process. Conducting polymer of type (a) is treated with Lewis acid or with iodine vapour or iodine in  $\text{CCl}_4$ .



**n-doping** It is done by reduction process. For this, conducting polymer of type (a) is treated with lewis bases like sodium naphthalide.



Conducting polymer	Polyaniline	Polypyrrole	Polythiophene
Dopants	HCl	BF <sub>4</sub> <sup>-</sup>	Tosylate
Conductivity (Scm <sup>-1</sup> )	1000	500-7500	1000

**B) Extrinsically conducting polymer.** In this, the polymer owe their conductivity due to the presence of externally added ingredients in them. These are of following two types

- (a) **Conductivity element filled polymer.** In this, the polymer acts as the binder to hold the conducting element (such as carbon black, metallic fibre, metallic oxides) together in the solid entity. Minimum concentration of conductive filler which should be added so that polymer starts conducting is known as percolation threshold. Because at this concentration of filler a conducting path is formed in polymeric material. Generally Carbon black is used as filler which has very high surface area, more porosity.
- (b) **Blended conducting polymer.** These polymers are obtained by blending a conventional polymer with a conducting polymer. Such polymer possess better physical, chemical, electrical and mechanical properties. For example, up to 40% of polypyrrole will have little effect on tensile strength and also give a much impact strength than obtained with a carbon black filled compound at only 10% loading.

### Applications of Conducting Polymer

- a) In Rechargeable lithium ion batteries
- b) In analytical sensors: For making sensors for pH, O<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub>, NH<sub>3</sub> and glucose
- c) For making ion exchangers
- d) In electrochromic displays ad optical filters: conducting polymers can be used as electrochromic material (i.e. the materials which change color reversibly during the electrochemical charge and discharge)
- e) In electronics: In LED's and Data storage
- f) In photovoltaic devices: ex Al/conducting polymer/Au photovoltaic cell
- g) Polypyrrole is used in smart windows: smart windows can change their color in response to change in temperature or amount of sunlight.

## PANI AND PEDOT IN SENSORS

**Polyaniline (PANI)** is a conductive polymer that is used in a variety of sensors, including electrochemical sensors, chemi-resistive sensors, and transistor-based sensors:

- **Electrochemical sensors:** PANI is often used with nanomaterials to improve the sensitivity of electrochemical nanosensors. PANI and its nanocomposites have excellent electrocatalytic properties, which can lead to enhanced detection sensitivity, high conductivity, and reduced fouling.
- **Chemi-resistive sensors:** Polyaniline nanowires can be used as an active layer in chemi-resistive sensors. The conductivity change of the nanowires can be used to detect chemical or biological species.
- **Transistor-based sensors:** PANI-based materials can be used in transistor-based sensors.

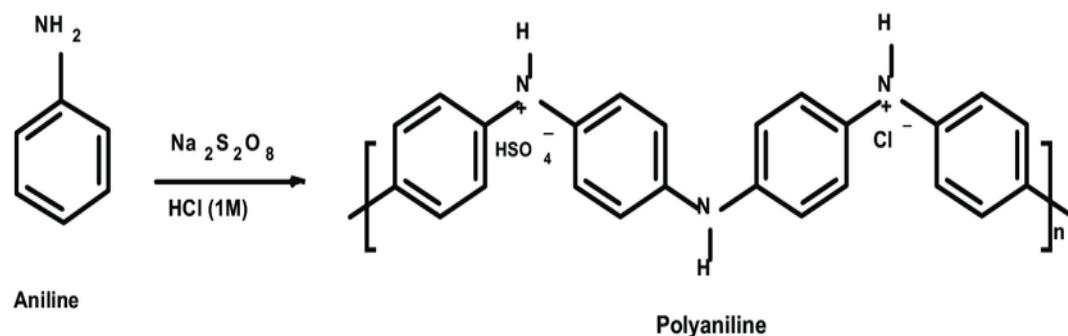
PANI is a popular choice for sensors because of its unique properties, including:

- Easy synthesis: PANI is easy to synthesize and dope with different acids and dopants.
- Environmental stability: PANI is highly environmentally stable.
- Biocompatibility: PANI is highly biocompatible.
- Tunable electrical conductivity: PANI's electrical conductivity can be tuned.

Polyaniline (PANI) is a conductive polymer that can be prepared in a variety of ways:

### PREPARATION

PANI can be prepared by chemical or physical methods, such as anodic oxidation of aniline monomers using an inert electrode. PANI can also be prepared by dissolving aniline in HCl, adding ammonium per sulfate (APS), and stirring for at least an hour. The resulting solution is then filtered to obtain a green, conducting polymer deposit.



### Oxidative polymerization of aniline monomer by sodium persulfate in HCl solution.

Polyaniline (PANI) is used in sensors in a variety of ways, including:

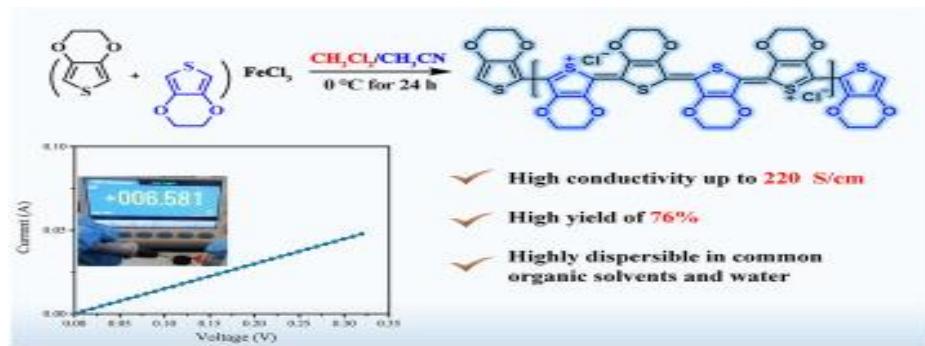
1. **Chemical vapor sensors:** PANI is used as a selective layer in chemical vapor sensors, such as resistance type detectors, because of its electrical properties.
2. **Electrochemical sensors:** PANI is used in electrochemical sensors, along with nanomaterials, to increase sensitivity.
3. **Biological sensors:** PANI is used as a matrix to immobilize enzymes, which then transduce chemical signals into electrical signals.
4. **Colorimetric sensors:** PANI nanoparticles are used in colorimetric sensors to detect bacterial growth in food and water. PANI is sensitive to protons in its microenvironment, and

a change in color indicates the presence of protons.

**5. Ammonia sensors:** PANI is known for its affinity with ammonia, and its deprotonation rate upon exposure to ammonia is related to the ammonia concentration.

## PEDOT polymer and its synthesis

PEDOT (Poly(3,4-ethylenedioxythiophene)) is a conjugated polymer which is formed of 3,4-ethylenedioxythiophene (EDOT) monomers. These monomers are joined at 2,5-positions of each five-membered thiophene ring to create linear polymer chains. Poly(3,4-ethylenedioxythiophene) (PEDOT) is the conductive component of PEDOT.



PEDOT (Poly(3,4-ethylenedioxythiophene)) is widely used in sensor applications due to its excellent electrical conductivity, stability, and ease of processing. Here are some key ways PEDOT is utilized in sensors:

### 1. Chemical Sensors

- **Conductometric Sensors:** PEDOT can be used as the sensing element in conductometric sensors, where the conductivity changes in response to the presence of specific chemicals (e.g., gases or volatile organic compounds). The change in conductivity is measured and correlated to the concentration of the analyte.
- **Electrochemical Sensors:** PEDOT serves as a working electrode material in electrochemical sensors, allowing for the detection of biomolecules, toxins, or pollutants through redox reactions.

### 2. Biosensors

- **Biomolecule Detection:** PEDOT can be functionalized with specific biomolecules (like enzymes or antibodies) to create biosensors that detect biological analytes, such as glucose, proteins, or pathogens. The interaction between the target analyte and the functionalized PEDOT leads to changes in conductivity or electrochemical response.

### 3. Pressure and Strain Sensors

- **Flexible Sensors:** Due to its flexibility, PEDOT can be used in pressure and strain sensors that conform to various surfaces. When mechanical stress is applied, the conductivity of the PEDOT changes, which can be monitored to measure strain or pressure.
- **Wearable Sensors:** PEDOT's flexibility and biocompatibility make it ideal for wearable sensors that monitor physiological parameters, such as heart rate or muscle activity.

### 4. Temperature Sensors

- PEDOT can be employed in temperature sensors, where changes in temperature affect its conductivity. This property can be utilized for temperature monitoring in various applications, from healthcare to environmental monitoring.

### 5. Optical Sensors

- **Electrochromic Sensors:** PEDOT exhibits electrochromic properties, allowing it to change color based on the applied voltage. This can be used in optical sensors to detect changes in chemical environments or to indicate the presence of specific analytes.

#### Advantages of Using PEDOT in Sensors

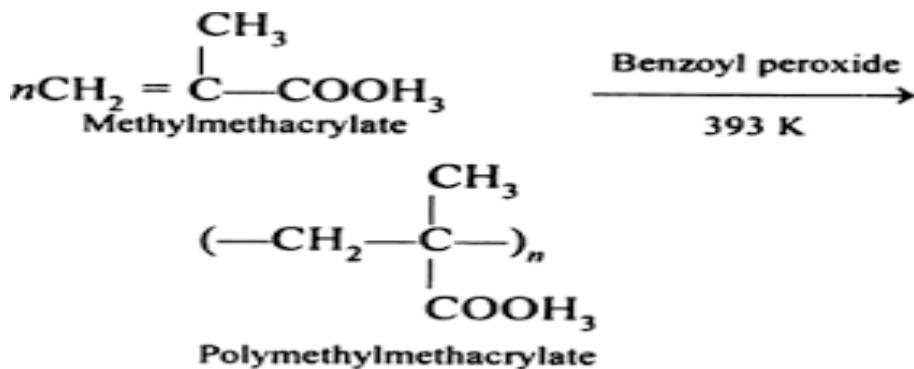
- **High Conductivity:** Provides rapid response times and enhances sensitivity.

- **Stability:** Maintains performance over time, even under varying environmental conditions.
- **Flexibility:** Suitable for a wide range of applications, especially in flexible and wearable technologies.
- **Ease of Functionalization:** Allows for the incorporation of various recognition elements, enhancing selectivity for specific analytes.

## PMMA IN SMART DEVICES,

Polymethyl methacrylate (PMMA), also known as acrylic or plexiglass, is a versatile polymer widely used in smart devices due to its unique properties.

**PREPARATION:** It is prepared by the polymerization of methyl methacrylate in presence of benzoyl peroxide as catalyst.



**PMMA contributes to the functionality and design of various smart devices:**

### 1. Display Technology

- **Transparent Substrates:** PMMA is often used as a lightweight and shatter-resistant alternative to glass in screens and displays. Its optical clarity makes it ideal for smartphones, tablets, and smart TVs.
- **Optical Coatings:** PMMA can be coated with various materials to enhance its optical properties, such as anti-reflective coatings or anti-scratch treatments.

### 2. Light Guide Applications

- **LED Lighting:** PMMA is used in light guides for LED applications. Its excellent light transmission properties allow for efficient illumination in smart lighting solutions, including smart bulbs and decorative lighting fixtures.

### 3. Sensors and Touch Panels

- **Touchscreens:** PMMA can serve as a protective layer for touch-sensitive displays. Its durability and ability to be easily shaped make it suitable for creating curved or custom-shaped interfaces.
- **Sensor Housing:** PMMA is often used to encapsulate sensors, protecting them while allowing light or signals to pass through.

### 4. Protective Casings

- **Device Enclosures:** PMMA is commonly used in the casings of smart devices, providing both protection and aesthetic appeal. It's resistant to UV light, making it suitable for outdoor devices and wearables.

### **5. 3D Printing and Prototyping**

- **Rapid Prototyping:** PMMA is popular in 3D printing for creating prototypes of smart devices. Its ease of processing allows designers to quickly iterate on designs.

### **6. Smart Home Applications**

- **Smart Appliances:** PMMA can be used in the housings and interfaces of smart appliances, contributing to their modern aesthetic and user-friendly designs.

#### **Advantages of PMMA in Smart Devices**

- **Lightweight:** Easier to handle and transport compared to glass.
- **Shatter Resistance:** Safer for consumer products, especially in portable devices.
- **Chemical Resistance:** Durable against various environmental factors, enhancing longevity.
- **Optical Clarity:** Provides excellent visibility and brightness for displays.

## **UNIT 1**

**(Advanced Materials for Smart Devices)**

### **Sustainable polymers ( PLA, PGA, PHBV)**

Sustainable polymers are materials designed to minimize environmental impact throughout their lifecycle, from production to disposal. These polymers are materials derived from renewable, recycled and waste carbon resources and their combinations, which at the end of life can be recycled, biodegraded or composted.

#### **Types of Sustainable Polymers:**

1. **Biodegradable Polymers:** Polymers like Polylactic acid (PLA), polyhydroxyalkanoates (PHA).
2. **Bio-based Polymers:** Bio-polyethylene (bio-PE), bio-polyethylene terephthalate (bio-PET).
3. **Recycled Polymers:** Recycled high-density polyethylene (HDPE).

#### **Synthesis and Application of Polylactic Acid (PLA)**

PLA is a biodegradable and bio-based polymer primarily derived from renewable resources like corn starch, sugarcane, and other plant materials. It is widely used as an environmentally friendly alternative to petroleum-based plastics, particularly in packaging, 3D printing, and medical applications.

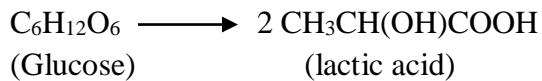
#### **Synthesis of PLA**

The synthesis of PLA generally occurs in two main steps: the production of lactic acid (or lactide) and its polymerization into PLA.

The synthesis of **Polylactic Acid (PLA)** involves the polymerization of lactic acid or its dimer, lactide, through different processes. The most common method is the **ring-opening polymerization (ROP)** of lactide. Here's a breakdown of the chemical reactions involved in the synthesis of PLA.

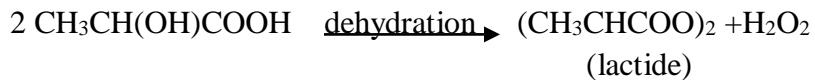
## 1. Fermentation: Production of Lactic Acid

The first step in the PLA synthesis process is the production of lactic acid. This is typically done through the microbial fermentation of carbohydrates (like glucose from corn starch) using bacteria such as *Lactobacillus*. The fermentation reaction is:



## 2. Formation of Lactide (Cyclic Dimer of Lactic Acid)

The lactic acid monomer undergoes a **condensation reaction** to remove water and form a dimer called **lactide**. The reaction typically occurs under heat:



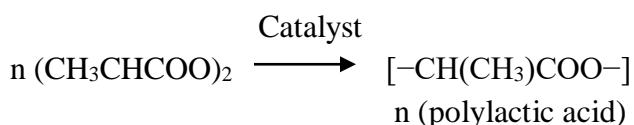
In this step, lactic acid molecules are heated to drive off water and convert the monomer into lactide, a cyclic dimer that is easier to polymerize.

There are three possible forms of lactide:

- **L-lactide** (two L-lactic acid units)
- **D-lactide** (two D-lactic acid units)
- **meso-lactide** (one L- and one D-lactic acid unit)

## 3. Ring-Opening Polymerization (ROP)

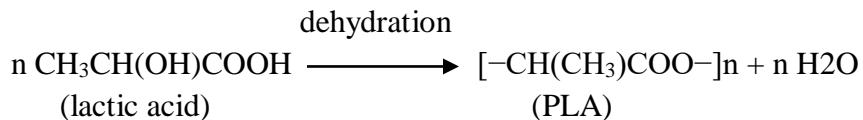
The polymerization of PLA from lactide occurs via **ring-opening polymerization**, which is the most common industrial method. This reaction uses a catalyst, such as **tin(II) octoate** and an initiator like an alcohol, to open the lactide ring and form long PLA chains. The general reaction is:



Here, the cyclic lactide molecule opens up and links with others to form a long polymer chain (PLA). This reaction can be controlled to produce either **low molecular weight** or **high molecular weight** PLA, depending on the conditions and catalysts used.

#### 4. Direct Polycondensation (Alternative Method)

In an alternative process, **direct polycondensation** of lactic acid is used, though this method is less common for industrial PLA due to lower molecular weight products. This process involves the dehydration of lactic acid monomers:



In this case, lactic acid molecules join to form PLA, with water being a byproduct of the reaction. However, this method can result in incomplete polymerization and lower-quality PLA, requiring further processing.

### Properties of PLA

#### 1. Biodegradability:

- PLA is fully biodegradable under industrial composting conditions (high temperature and humidity), breaking down into water, carbon dioxide, and biomass.
- In home compost or natural environments, PLA may take longer to degrade compared to commercial settings.

#### 2. Renewability:

- PLA is derived from renewable plant resources, making it a more sustainable alternative to conventional plastics derived from petroleum.

#### 3. Mechanical Properties:

- **Tensile strength:** PLA has a relatively high tensile strength and stiffness, making it suitable for packaging, fibers, and 3D printing.
- **Brittleness:** While PLA has good strength, it can be brittle and prone to cracking under stress. To improve flexibility, additives or copolymers like polycaprolactone (PCL) are sometimes mixed with PLA.

#### 4. Thermal Properties:

- **Glass transition temperature ( $T_g$ ):** Around 55–60°C, meaning PLA starts to soften at this temperature, limiting its use in high-temperature applications.
- **Melting point:** Around 150–180°C, allowing it to be processed in various applications like injection molding and 3D printing.

#### 5. Transparency:

- PLA can be produced as a clear, glass-like material, making it suitable for use in transparent packaging and films.

## 6. Barrier Properties:

- PLA has decent oxygen barrier properties, which is useful in food packaging, although it is not as good as petroleum-based plastics like PET.

## 7. Biocompatibility:

- PLA is non-toxic and biocompatible, making it ideal for medical applications such as sutures, drug delivery systems, and biodegradable implants.

## Applications of PLA

- **Packaging:** PLA is commonly used in food containers, bottles, and packaging films.
- **3D Printing:** PLA is one of the most popular filaments for 3D printing due to its ease of use and low toxicity.
- **Medical Devices:** PLA is used in biodegradable sutures, stents, and scaffolds for tissue engineering.
- **Textiles:** PLA can be used to make fibers for clothing and biodegradable bags.

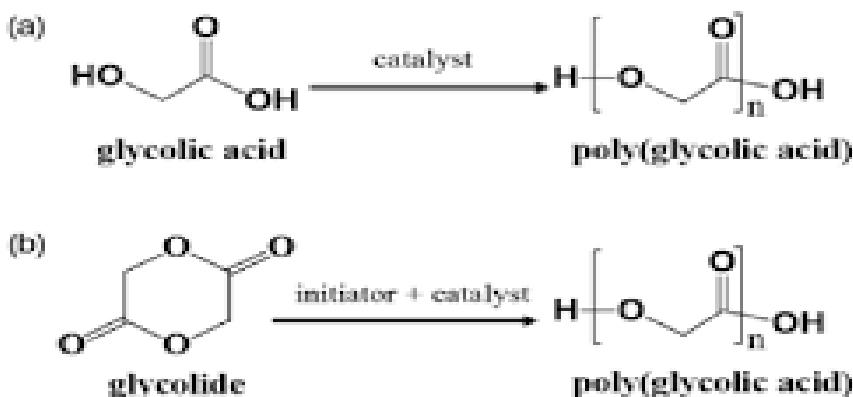
## Synthesis and Application of Polyglycolic Acid (PGA)

Polyglycolic acid (PGA) is a biodegradable polymer that is part of the polyesters family. It is synthesized from glycolic acid and has significant applications in medical and environmental fields.

### Synthesis:

Polyglycolic acid is a versatile biodegradable polymer synthesized primarily through the polymerization of glycolic acid. Its unique properties and applications in the medical and environmental sectors make it a key material in the pursuit of sustainable solutions. As research continues, its uses are likely to expand, further enhancing its role in biocompatible and eco-friendly technologies.

The polymerization of polyglycolic acid (PGA) typically involves the ring-opening polymerization (ROP) of glycolic acid, particularly in its cyclic dimer form. Here's a detailed overview of the polymerization reaction:



## Properties:

- **Biodegradability:** PGA degrades in the body through hydrolysis, making it suitable for medical applications.
- **Mechanical Properties:** High tensile strength and modulus, suitable for sutures and implants.
- **Thermal Properties:** Melting temperature around 225°C, making it stable for various applications.

## Applications:

### 1. Medical Applications:

- **Sutures:** PGA is widely used in absorbable sutures due to its biocompatibility and biodegradability.
- **Drug Delivery Systems:** PGA can be formulated into microspheres for controlled drug release.
- **Tissue Engineering:** Used as scaffolding materials for cell growth and tissue regeneration.

### 2. Environmental Applications:

- **Biodegradable Packaging:** PGA can be used in packaging materials that decompose naturally, reducing plastic waste.
- **Agricultural Films:** Used for mulch films that can biodegrade, minimizing environmental impact.

### 3. Biomedical Devices:

- **Implants:** Used in various biodegradable implants for tissue repair and regeneration.

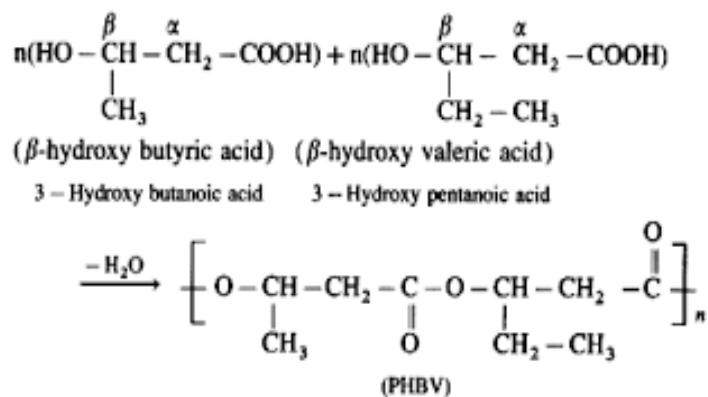
- **Wound Dressings:** PGA can be incorporated into dressings that promote healing while degrading over time.

### Synthesis and Application of Poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV)

PHBV (poly(3-hydroxybutyrate-co-3-hydroxyvalerate)) is a biopolymer belonging to the family of polyhydroxyalkanoates (PHAs). It's synthesized by various microorganisms, particularly bacteria, through the fermentation of carbon sources. It is a thermoplastic linear aliphatic polyester.

#### Synthesis of PHBV

It is obtained by the copolymerization of 3-hydroxybutanoic acid and 3-hydroxypentanoic acid.



#### Properties of PHBV

- Biodegradability:** PHBV is biodegradable, breaking down into harmless byproducts through microbial action, which makes it an environmentally friendly alternative to conventional plastics.
- Mechanical Properties:**
  - It exhibits good tensile strength and elasticity, although these properties can vary based on the ratio of 3-hydroxybutyrate (3HB) to 3-hydroxyvalerate (3HV) in the copolymer.
  - PHBV can have a glass transition temperature ( $T_g$ ) around 5°C and a melting temperature ( $T_m$ ) around 170°C.
- Thermal Properties:** PHBV shows thermal stability, which is advantageous for processing. However, it can be more sensitive to heat compared to conventional plastics.
- Barrier Properties:** It has good gas barrier properties, making it suitable for packaging applications.

## **Applications of PHBV**

1. **Packaging:** Due to its biodegradability and good mechanical properties, PHBV is used in biodegradable packaging materials, such as films, containers, and bags.
2. **Medical Applications:**
  - o **Sutures and Scaffolds:** PHBV is biocompatible, making it suitable for use in medical sutures and tissue engineering scaffolds.
  - o **Drug Delivery Systems:** Its ability to degrade in the body allows for controlled drug release applications.
3. **Agriculture:** PHBV can be used to create biodegradable mulch films, which help reduce plastic waste in farming.
4. **3D Printing:** Its thermoplastic nature makes it suitable for 3D printing applications, allowing for the creation of biodegradable products and components.
5. **Textiles:** PHBV fibers can be used in the textile industry for creating eco-friendly fabrics.

## **Leaching of Micro-plastics**

**Leaching of microplastics** refers to the process by which chemicals contained within microplastics are released into the environment, particularly water bodies, as the plastics break down or degrade. Microplastics are tiny plastic particles less than 5 mm in size, and they can originate from a variety of sources, such as larger plastic debris breaking down, synthetic fibers from clothing, or microbeads in personal care products.

When microplastics enter ecosystems, especially water, they can leach harmful chemicals. This happens in two primary ways:

1. **Additives in plastics:** Many plastics contain chemical additives like plasticizers (e.g., phthalates), stabilizers, and flame retardants. These chemicals can leach out of the plastic particles over time and potentially contaminate soil and water, posing risks to wildlife and humans.
2. **Adsorption of pollutants:** Microplastics can also absorb and carry external pollutants (such as heavy metals or persistent organic pollutants like PCBs) from the surrounding environment. Once ingested by marine organisms or other animals, these toxic substances can enter food chains.

Leaching of microplastics is a growing environmental concern, as it can affect water quality, ecosystems, and human health, particularly through bioaccumulation in food webs.

Preventing the **leaching of microplastics** requires efforts to reduce both the production of microplastics and their release into the environment. Here are some strategies to minimize leaching:

## 1. Reduce Plastic Use

- **Minimize single-use plastics:** Avoid products with excessive plastic packaging and choose alternatives like reusable bags, glass, or metal containers.
- **Choose natural fibers:** Opt for clothing made from natural materials like cotton, wool, or hemp, as synthetic fibers (like polyester) shed microplastics during washing.

## 2. Proper Waste Management

- **Recycling:** Ensure plastic waste is properly sorted and recycled to prevent it from entering ecosystems where it can break down into microplastics.
- **Improved waste disposal:** Encourage proper disposal of plastics and promote systems that prevent littering or leakage of plastic into the environment.

## 3. Use of Advanced Filtration Systems

- **Washing machine filters:** Install filters in washing machines to capture microfibers from synthetic clothes during washing, preventing them from entering water systems.
- **Water treatment upgrades:** Municipal wastewater treatment plants can be upgraded to better capture microplastics before they are discharged into rivers and oceans.

## 4. Designing Eco-friendly Products

- **Biodegradable plastics:** Promote the development of biodegradable plastics that break down into non-toxic components.
- **Safer plastic additives:** Manufacturers can design plastics with fewer harmful additives, reducing the risk of leaching toxic chemicals.

## 5. Legislation and Policy

- **Banning microbeads:** Support or implement bans on microbeads (tiny plastic particles) in personal care products, which directly contribute to microplastic pollution.
- **Plastic regulations:** Advocate for regulations that restrict the production and use of certain harmful plastic additives that can leach into the environment.

## **6. Public Awareness**

- **Education and outreach:** Increase public awareness about the dangers of microplastic pollution and how everyday actions contribute to it. This can help drive behavior change and support for policy measures.

By taking these steps, society can reduce the release of microplastics and prevent the harmful chemicals in plastics from leaching into ecosystems.

Microplastic pollution in the environment is a major concern for governments and companies worldwide attempting to understand and reduce the damage they cause. As well as the direct damage these plastic pellets can also act as chemical reservoirs that leach chemical contaminants into the environment and further damage ecosystems. The Column spoke to Manuel Miró from the University of the Balearic Islands, Spain, about his research into the pollution caused by chemical leaching from microplastics.

### **Factors that affect leaching**

The leaching of chemicals from microplastics is affected by a variety of factors, including:

Sunlight: Sunlight can cause photochemical degradation, which can lead to the release of chemicals.

Water flow: Microplastics in flowing water may release plasticisers at a faster rate.

pH levels: Acidic and basic pH levels are more aggressive to plastic materials than neutral pH levels.

Plasticizer content: The concentration of plasticizers in microplastics can affect the rate of leaching

### **Effects on organisms**

When aquatic organisms consume microplastics, they can be harmed by the physical ingestion of the microplastics, as well as by the toxic chemicals that leach out during digestion.

### **Effects on the environment**

Microplastics can contribute to a buildup of plasticisers in the environment. They can also release dissolved organic carbon (DOC), which can stimulate the growth of marine microbial communities.

### **Microplastic sources**

Microplastics can come from a variety of sources, including washing machines and synthetic clothing.

## UNIT 2

### (Eco-friendly Portable Energy Convertible Devices)

#### **1. Electrochemistry**

Electrochemistry is a branch of chemistry which deals with interconversion of electrical energy to chemical energy and vice versa. For ex: i) In a battery, chemical energy is converted to electrical energy ii) In electroplating / electrolysis electrical energy is converted to chemical energy. Substances that allow electric current to pass through them are known as conductors. For ex: the metals, graphite, fused salts, aqueous solution of acids, bases & salts. While insulator or non-conductor is a substance which does not allow electric current to pass through it. For ex: wood, plastic.

**1.1. Electrode Potential:** When a metal is kept in a solution of its own ions, the metal acquires either negative or positive charge with respect to the solution. So, a definite potential difference is developed between the metal and the solution. This potential difference is known as electrode potential. For example, when a plate of zinc is placed in a solution having zinc ions ( $Zn^{2+}$ ), it becomes negatively charged with respect to solution and thus a potential difference is set up between zinc plate and the solution. This potential difference is termed the electrode potential of zinc. Similarly, when copper is placed in a solution having copper ions ( $Cu^{2+}$ ), it becomes positively charged with respect to solution. A potential difference is set up between the copper plate and the solution. The potential difference thus developed is termed as electrode potential of copper. The potential difference is established due to the formation of electrical double layer known as Helmholtz double layer.

Osmosis is the diffusion solvent molecule through a semipermeable membrane, when a semipermeable membrane separates a solution from a solvent, then only solvent molecules can flow through the semipermeable membrane. During osmosis a pressure is developed on SPM which is known as osmotic pressure.

Solution pressure is a measure of the tendency of molecules or atoms to cross a bounding surface between phases and to enter into a **solution**.

The osmotic pressure of a solution is the pressure difference needed to stop the flow of solvent across a semipermeable membrane. The osmotic pressure of a solution is proportional to the molar concentration of the solute particles in solution. If the solution pressure is greater than the osmotic pressure, the tendency of the metal to lose ions predominates. A potential difference is therefore set up with the metal left with negative charge with respect to the solution. So the positive ions will enter the liquid and the metal negatively charged with respect to solution. The







## **1.5.Cell Potential**

The cell potential is the measure of the potential difference between the two half cells in an electrochemical cell. The potential difference is caused by the ability of electrons to flow from one half cell to the other.

- It is not possible to measure the absolute value of the single electrode potential directly. Only the difference in potential between two electrodes can be measured experimentally. So it is necessary to join the electrode with other electrode whose potential is known. This electrode is termed as reference electrode. The EMF of the resulting cell is measured experimentally.
- The EMF of the cell is equal to the sum of potentials on the two electrodes.
- E.M.F. of the cell = **EAnode + ECathode** = Oxidation potential of anode + Reduction potential of cathode
- It is not possible to measure the absolute value of the single electrode potential directly. Only the difference in potential between two electrodes can be measured experimentally. It is, therefore, necessary to couple the electrode with another electrode whose potential is known. This electrode is termed as reference electrode. The EMF of the resulting cell is measured experimentally.

**1.6.Electrochemical cell:** The devices which convert chemical energy to electrical energy & electrical energy into chemical energy are known as electrochemical cells they contain two electrodes in contact with an electrolyte, they are mainly of two types.

**1.6.1.Galvanic cells:** It is an electrochemical cell in which the free energy of chemical reaction is converted into electrical energy i.e. electricity is produced from a spontaneous chemical reaction. Example: voltaic cell or Daniel cell

**1.6.2.Electrolytic cell:** It is an electrochemical cell in which external electrical energy is used to carry out a non- spontaneous chemical reaction. Examples of electrolysis are the decomposition of water into hydrogen and oxygen, and bauxite into aluminium and other chemicals.

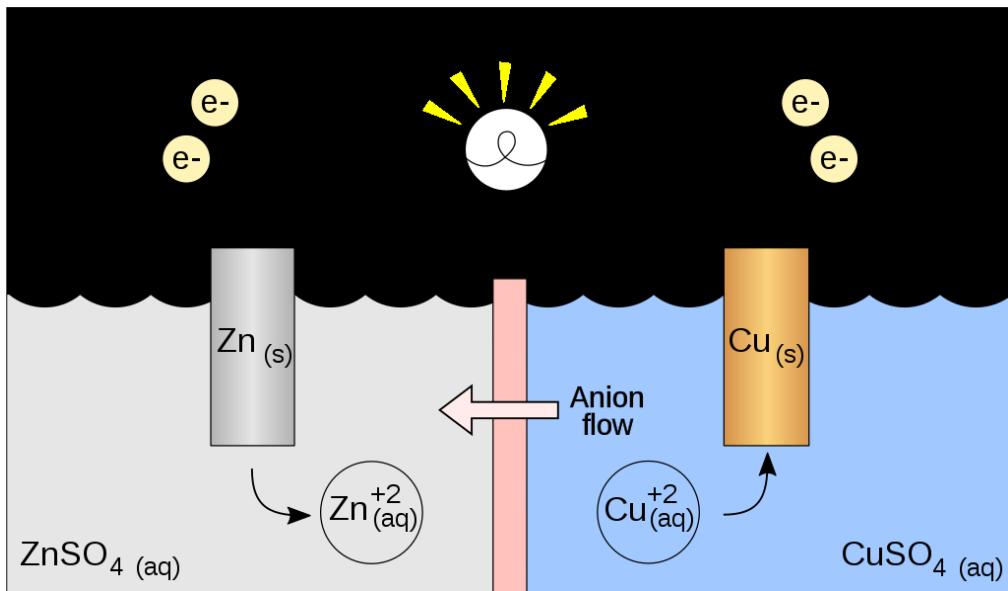
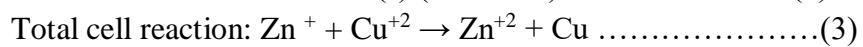
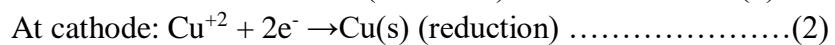
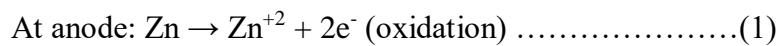
**1.7. Galvanic cell :** Daniel cell is an example of galvanic cell. It consists of Zn rod and Cu rod; Zn rod is dipped in  $ZnSO_4$  solution and Cu rod dipped in  $CuSO_4$  solution. Each electrode in its electrolytic solution is known as half-cell. The two solutions are connected by U shaped tube known as salt bridge. Thus two electrolytic solutions are in contact with each other. A salt bridge is a U- shaped tube containing concentrated solution of an inert electrolyte like  $KCl$ ,  $KNO_3$ ,  $K_2SO_4$  in order to complete the circuit.

### **Application of salt bridge:**

- Salt bridge prevents the mechanical flow of solution from one-half cell to another.
- It minimizes the liquid-liquid junction potential (Potential arises between two solutions when they are in contact).
- To maintain the electron neutrality.

Cell reactions:

The electrode reactions of Daniel Cell are :



## **Green Batteries and their applications**

Green batteries refer to environmentally friendly energy storage solutions designed to reduce environmental impact. They typically use sustainable materials and processes, aiming for lower toxicity and better recyclability compared to traditional batteries.

A green battery is first a battery that stores “green” electrons, those generated by renewable sources such as wind or solar. Batteries contain minerals that are mined from Earth's crust, which, like fossil fuels, are not naturally replenished.

### **Types of Green Batteries**

#### **1. Lithium-Ion Batteries (with Sustainable Practices)**

- **Description:** While traditional lithium-ion batteries have environmental concerns, improvements in mining practices and recycling technologies are making them greener.
- **Applications:** Electric vehicles (EVs), renewable energy storage, consumer electronics, and grid stabilization.

#### **2. Sodium-Ion Batteries**

- **Description:** Made from abundant sodium, these batteries are being developed as a cost-effective and sustainable alternative to lithium-ion batteries.
- **Applications:** Similar to lithium-ion batteries, including grid storage and EVs, particularly in regions with abundant sodium resources.

#### **3. Solid-State Batteries**

- **Description:** Use a solid electrolyte instead of liquid, potentially improving safety and energy density.
- **Applications:** Electric vehicles, consumer electronics, and portable devices, offering longer lifespans and quicker charging times.

#### **4. Flow Batteries**

- **Description:** Store energy in liquid electrolytes housed in external tanks, allowing for scalability and long discharge times.
- **Applications:** Large-scale renewable energy storage (e.g., solar and wind), grid energy management, and off-grid energy systems.

## 5. Organic Batteries

- **Description:** Utilize organic materials for electrodes, which can be derived from renewable sources.
- **Applications:** Energy storage for renewable energy systems and potentially consumer electronics, promoting a circular economy.

## 6. Biodegradable Batteries

- **Description:** Made from biodegradable materials that minimize environmental impact when disposed of.
- **Applications:** Consumer electronics, medical devices, and IoT devices where short-term use is required.

# Applications of Green Batteries

## 1. Electric Vehicles (EVs)

- Green batteries power EVs, reducing reliance on fossil fuels and lowering greenhouse gas emissions. Advances in sodium-ion and solid-state technologies are paving the way for more sustainable options in this sector.

## 2. Renewable Energy Storage

- Green batteries, particularly flow batteries and lithium-ion batteries, store excess energy generated from renewable sources like solar and wind, helping to balance supply and demand on the grid.

## 3. Consumer Electronics

- Laptops, smartphones, and other devices benefit from advances in lithium-ion and organic batteries, with a focus on improved recyclability and sustainable sourcing of materials.

## 4. Grid Stabilization

- Large-scale battery systems (like flow batteries) help maintain grid stability by storing energy during low demand and releasing it during peak demand periods, facilitating the integration of renewable energy.

## 5. Off-Grid Systems

- Green batteries are ideal for remote or off-grid applications, providing reliable energy storage for homes and businesses powered by renewable sources.

## 6. Medical Devices

- Biodegradable and organic batteries offer safe and sustainable options for medical devices that require short-term energy solutions.

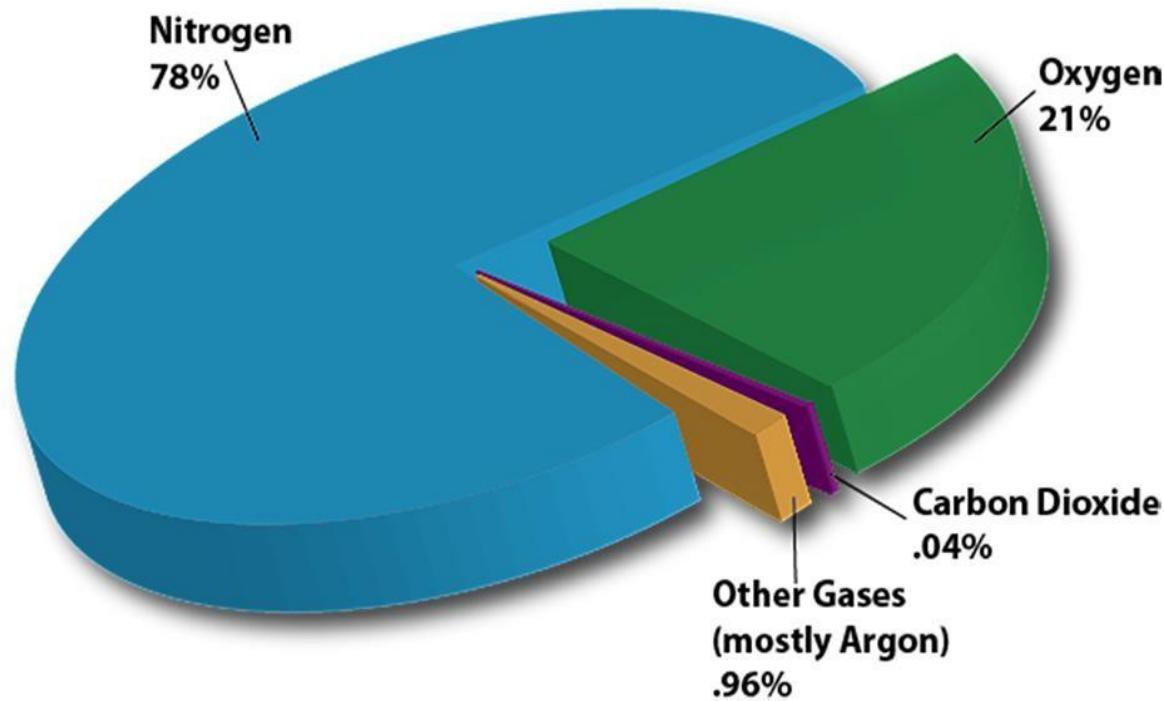
## 7. Wearable Technology

- Lightweight and efficient green batteries can enhance the performance and sustainability of wearable tech, such as fitness trackers and smartwatches.

# Environmental Chemistry

## Composition and Segments of Atmosphere

Earth's atmosphere is made up of layers of gases and is composed of the following composition:



The atmosphere of earth is composed of about 78% nitrogen, 21% oxygen, 0.04% carbon dioxide, 0.96% argon and trace amounts of neon, helium, methane, krypton and hydrogen, as well as water vapour.

**Nitrogen :** It is the most plentiful gas in the air. It is one of the primary nutrients critical for the survival of all living organisms.

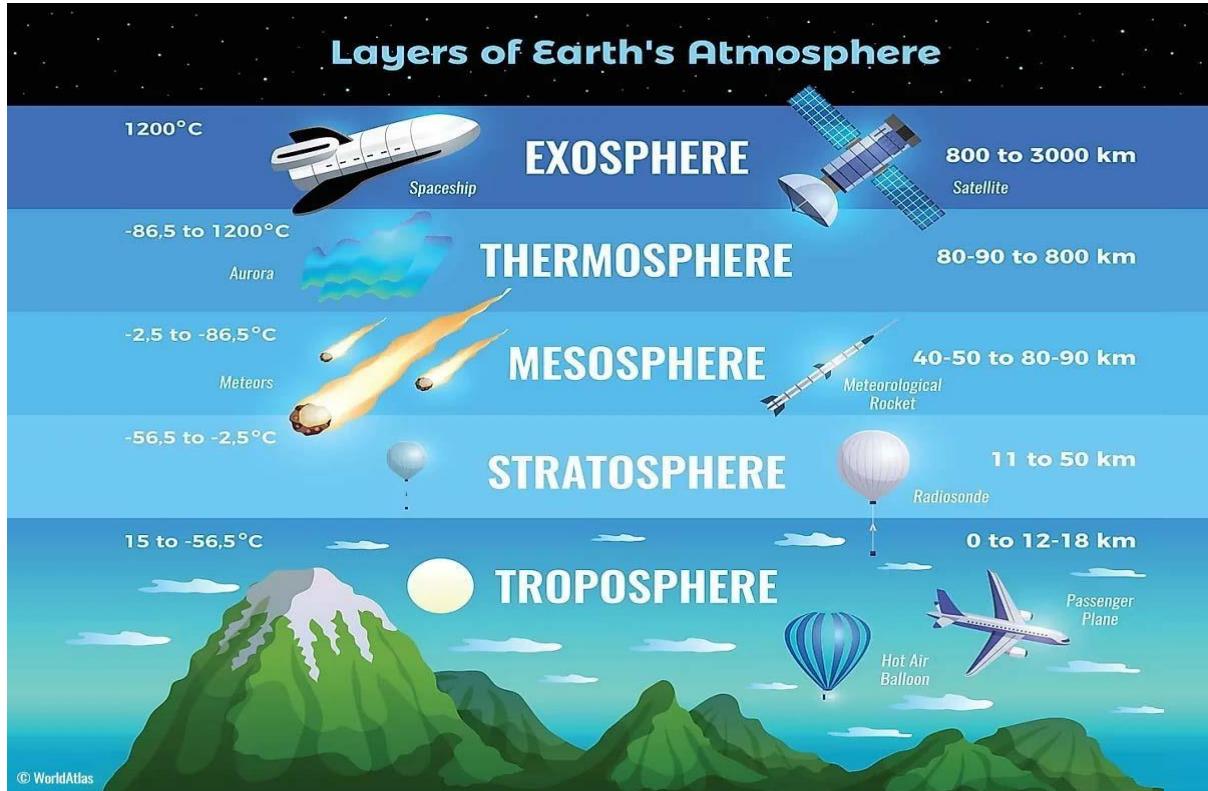
**Oxygen:** Oxygen is required for the survival of life. Green plants produce oxygen during photosynthesis. In this way oxygen content in the air remains constant.

**Carbon dioxide :** It is an important heat-trapping gas, or greenhouse gas, that comes from the extraction and burning of fossil fuels.

**It is the most important raw material which plant utilized during photosynthesis process**

## Segments of Atmosphere:

The vertical structure of atmosphere consists of several layers which are separated from one another by change in slope of the graph of temperature vs altitude.



## 1. Troposphere:

1. The lowest layer of atmosphere in which living organisms operate is called troposphere.
2. **It extends up to 10km**
3. It is the region of strong air movements and cloud formation
4. Water vapour and dust occurred in troposphere in extremely variable concentration **5. All the climatic and weather changes take place in this layer of the atmosphere.**
6. The temperature ranges from **14°C to -56°C** in troposphere
7. **Tropopause** is a zone that separates the troposphere from the stratosphere.
8. The changes in temperature with height is known as **lapse rate**
9. The decrease of temperature with increasing altitude in troposphere is called **Positive lapse rate**

## 2. Stratosphere:

1. The region above the tropopause is known as stratosphere about 50 km above the surface of earth.
2. Temperature ranges from **-56°C to -2°C**
3. In this zone the temperature-altitude curve shows warming trend with increasing altitude
4. The increase of temperature with increasing altitude in this layer shows **Negative lapse rate**.
5. Heat is produced in the process of the formation of Ozone, and this heat is responsible for **temperature increase**.

6. **Ozone** in atmosphere acts as a protective shield (Umbrella) for life on earth from injurious effects of sun's ultraviolet rays.
7. The region above the stratosphere is known as **stratopause**
8. Weather-related phenomena are absent in this layer of the atmosphere, that is why aeroplanes fly in the stratosphere for a smooth ride.

### **3. Mesosphere:**

1. Located between about 50 and 80 kilometres above Earth's surface
2. **It is known as a coolest layer of atmosphere**
3. Temperature ranges from  $-2^{\circ}\text{C}$  to  $-92^{\circ}\text{C}$
4. The decrease of temperature with increasing altitude in this layer shows **Positive Lapse rate**
5. **Most meteors burn up in this atmospheric layer. Sounding rockets and rocketpowered aircraft can reach the mesosphere.**
6. The region above the mesosphere is known as menopause

### **4. Thermosphere/Ionosphere**

1. It is located between about 80 and 700 kilometres above Earth's surface, whose lowest part contains the **ionosphere**.
2. **Temperature ranges from  $-92^{\circ}\text{C}$  to  $1200^{\circ}\text{C}$  as it is much closer to the sun.**
4. It shows Negative lapse rate as temperature increases with height.
5. The gases present in this layer absorb solar radiation and undergo ionization
6. The ionosphere is the atmospheric layer, which is mostly used for communication purpose. due to electrical conductivity.
8. **Ionosphere helps in radio communication.**
9. **The International Space Station (ISS) orbits in the thermosphere.**

### **5. Exosphere:**

1. It is located between about 700 and 10,000 kilometres above Earth's surface,
2. The exosphere is the highest layer of Earth's atmosphere and, at its top, merges with the solar wind.
3. **Molecules found here are of extremely low density, so this layer doesn't behave like a gas, and particles here escape into space.**
4. While there's no weather in the exosphere.
5. **Most Earth satellites orbit in this layer.**

**Note:** Atmosphere absorbs most of the cosmic rays from outer space and protects living things from their harmful effects. It also maintains the heat balance of the earth. It serves as insulation from heat loss at the earth's surface and stabilises weather and climate owing to the heat capacity of the air

## Unit-III

# Air pollution

### **1. Introduction:**

Air is one of the five essentials for almost all the life forms on biosphere. Even though the air is abundantly available over the surface of earth, but it contains a lot of impurities due to natural and manmade activities.

**Air pollution is broad term applied to any chemical, physical or biological agent that modifies the natural characteristics of atmosphere**

**OR**

**Exposure of pollutants affects the actual quality of Air is known as Air pollution**

### **2. Sources of Air pollutants:**

Stationary Sources	Point Sources	These are large stationary sources such as industries, power plants, Municipal incinerations etc.
	Area Sources	These are small stationary sources and mobile sources with indefinite routes such as residential heating, commercial and institutional heating, open burning, city traffic etc..
Mobile Sources	Line Sources	These are highways, railway tracks, navigation routes, etc.

	Area Sources	These are ports, Aircrafts, mobile vehicles etc
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### **3.Major Air Pollutants of Air Pollution:**

Pollutant	Common sources	Maximum acceptable concentration in the atmosphere	Environmental risks	Human health risks
<b>Carbon monoxide</b>	Automobile emissions, fires, industrial processes	35 ppm (1-hour period); 9 ppm (8-hour period)	contributes to smog formation	exacerbates symptoms of heart disease, such as chest pain; may cause vision problems and reduce physical and mental capabilities in healthy people
<b>Nitrogen oxides (NO and NO<sub>2</sub>)</b>	Automobile emissions, electricity generation, industrial processes	0.053 ppm (1-year period)	damage to foliage; contributes to smog formation	inflammation and irritation of breathing passages
<b>Sulfur dioxide (SO<sub>2</sub>)</b>	Electricity generation, fossil-fuel combustion, industrial processes, automobile emissions	0.03 ppm (1-year period); 0.14 ppm (24-hour period)	major cause of haze; contributes to acid rain formation, which subsequently damages foliage, buildings, and monuments; reacts to form particulate matter	breathing difficulties, particularly for people with asthma and heart disease
<b>Ozone(O<sub>3</sub>)</b>	Nitrogen oxides (NO <sub>x</sub> ) and	0.075 ppm (8-hour)	interferes with the	reduced lung

	volatile organic compounds (VOCs) from industrial and automobile emissions, gasoline vapours, chemical solvents, and electrical utilities	period)	ability of certain plants to respire, leading to increased susceptibility to other environmental stressors (e.g., disease, harsh weather)	function; irritation and inflammation of breathing passages
<b>Particulate matter</b>	Sources of primary particles include fires, smokestacks, construction sites, and unpaved roads; sources of secondary particles include reactions between gaseous chemicals emitted by power plants and automobiles	150 µg/m <sup>3</sup> (24-hour period for particles <10 µm); 35 µg/m <sup>3</sup> (24-hour period for particles <2.5 µm)	contributes to formation of haze as well as acid rain, which changes the pH balance of waterways and damages foliage, buildings, and monuments	Irritation of breathing passages, aggravation of asthma, irregular heartbeat
Lead (Pb)	Metal processing, waste incineration, fossil-fuel combustion	0.15 µg/m <sup>3</sup> (rolling three-month average); 1.5 µg/m <sup>3</sup> (quarterly average)	Loss of biodiversity, decreased reproduction, neurological problems in vertebrates	Adverse effects upon multiple bodily systems; may contribute to learning disabilities when young children are exposed; cardiovascular effects in adults

## **Carbon monoxide:**

Carbon monoxide is an odorless, invisible gas formed as a result of incomplete combustion. Nearly 50 percent of all CO emission originates from automobiles. It is also present in cigarette smoke.**it is highly poisonous and reduce the oxygen carrying capacity in blood**

## **Sulfur dioxide:**

A colorless gas with a sharp, choking odour, sulfur dioxide is formed during the combustion of coal or oil that contains sulfur as an impurity. Most sulfur dioxide emissions come from power-generating plants; very little comes from mobile sources. This pungent gas can cause eye and throat irritation and harm lung tissue when inhaled.**Sulfur dioxide also reacts with oxygen and water vapor in the air, forming a mist of sulfuric acid that reaches the ground as a component of acid rain. Acid rain is believed to have harmed or destroyed fish and plant life in many thousands of lakes and streams it also causes corrosion of metals and deterioration of the exposed surfaces of buildings and public monuments.**

**eg:Tajmahal**

## **Nitrogen dioxide:**

Of the several forms of nitrogen oxides, nitrogen dioxide—a pungent, irritating gas—is of most concern. It is known to cause pulmonary edema, an accumulation of excessive fluid in the lungs. Nitrogen dioxide also reacts in the **atmosphere** to form **nitric acid,contributing to the problem of acid rain**. In addition, nitrogen dioxide plays a role in the formation of photochemical **smog**, a reddish brown **haze** that often is seen in many urban areas and that is created by sunlight-promoted reactions in the lower atmosphere.

## **Ozone:**

A key component of photochemical **smog, ozone** is formed by a complex reaction between **nitrogen dioxide** and hydrocarbons in the presence of **sunlight**.it is considered as pollutant in lower atmosphere as and contribute in global warming and green house effect.

## **Lead:**

Inhaled **lead particulates** in the form of fumes and dusts are particularly harmful to children, in whom even slightly elevated levels of lead in the blood can cause **learning disabilities**, seizures, or even death

(see **lead poisoning**). Sources of **airborne** lead particulates include **oil refining, smelting**, and other industrial activities.

## **4.Effects of Air Pollution on Human Health:**

The air we breathe has not only life sustaining properties but also life damaging properties. The impurities in the inhaled air can affect human health in a number of ways depending upon the nature and concentration of pollutants, duration of exposure and age group of receptor. The various health effects are as under:

- Eye irritation can be caused by many air pollutants such as NO<sub>x</sub>, O<sub>3</sub>, smog and particulates
- Estimated 0.62 million mortalities occur annually in India that could be attributed to PM2.5 pollution in 2010. **TERI projected the mortalities to increase to 1.1 million in 2031 and 1.8 million in 2051, in a business-as-usual scenario.**
- Hydrogen fluoride can cause fluorosis and mottling of teeth
- Exposure of radioactive isotopes like iodine 131, phosphorous 32 etc can cause **anemia, leukaemia, cancer and genetic defects**
- Other than outdoor pollution, biomass used in rural regions and urban slums for cooking and kerosene for lighting is associated indoor air pollution and with a variety of health diseases such as Chronic Obstructive Pulmonary Disease, tuberculosis, cataract and adverse pregnancy outcomes

## **Effects of Air Pollution on Materials:**

Direct damage to structural metals, surface coating fabrics and other materials of commerce is a frequent and widespread effects of air pollution. This destruction is related to many types of pollutants but chiefly attributed to acid acid mists, oxidants of various kinds, H<sub>2</sub>S and particulate matters of combustion and industrial processing.

**Effect on Metals:** Corrosion of surface with eventual loss of materials from the surface and alteration in electrical properties of metals eg: Zinc is often used a protective coating on iron to form galvanized iron.

**Effect on Stones:** Soiling and deterioration of limestone, marble stone etc.eg: Carbon dioxide in presence of moisture forms carbonic acid. which is responsible for deterioration

**Effects on Paints:**  $\text{H}_2\text{S}$  reacts with lead base pigments to blackened it.

## **Effects of Air Pollution on Vegetation:**

The primary factor that governs the gas absorption by the plant leaves is the degree of opening of stomata. There are many effects of air pollution vegetation is listed below:

### **1) Reduced Photosynthesis and Growth**

Photosynthesis, the very cornerstone of plant life, ensures growth and nourishment. This process is imperilled by particulate matter, ozone, **sulphur dioxide**, and nitrogen oxides. **These agents often hamper the chlorophyll's absorption capability**, derailing the natural process of converting light to chemical energy.

**2) Damage to Leaf Structure and Function:** Air pollutants' insidious nature means they can settle onto the leaf surfaces, initiating a sequence of deleterious effects. **The visible symptoms are manifold, from necrotic spots and premature leaf drop to yellowing and stippling.** These damages disrupt essential functions like transpiration, making plants vulnerable to heat stress, nutrient deficiencies, and subsequent illnesses.

### **3) Changes in Reproductive Success**

From the larger perspective of an ecosystem's vitality, air pollution's effect on plant reproduction is severely unsettling. **Pollutants can distort the structural integrity of pollens, debilitating their function. With compromised pollen health, plants face daunting challenges in reproduction**

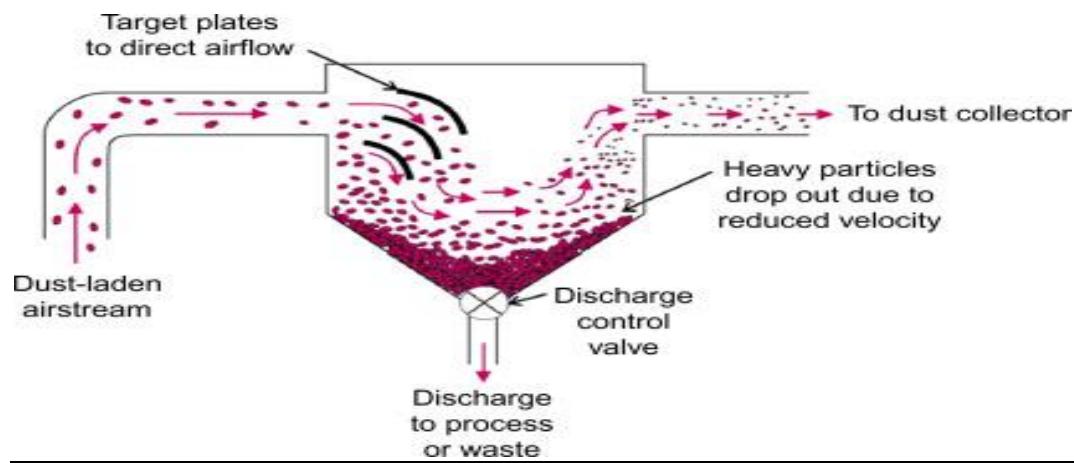
## **5.Strategies for Control of Air Pollution:**

- Drive less: Drive fewer miles by walking, biking, carpooling, or using public transportation.
- Use less energy: Use less electricity and reduce your energy consumption.
- Recycle and reuse: Reduce waste by recycling and reusing items.
- Avoid plastic bags: Plastic bags take a long time to decompose and are harmful to the environment.
- Use fans instead of air conditioners: Air conditioners use a lot of energy and emit a lot of heat.
- Avoid burning garbage: Don't burn your garbage or have backyard fires.

- Plant trees: Plant and care for trees.
- Use electric or hand-powered lawn equipment: Switch to electric or hand-powered lawn equipment.
- Keep your car in good repair: Keep your car serviced on time.

## **6.Air Pollution Control Devices/Equipments**

### **(a)Gravity Settling Tank:**



Gravitational settling chambers are generally used to remove large, abrasive particles (usually  $>50 \mu\text{m}$ ) from gas stream using a combination of gravitational and inertial forces.

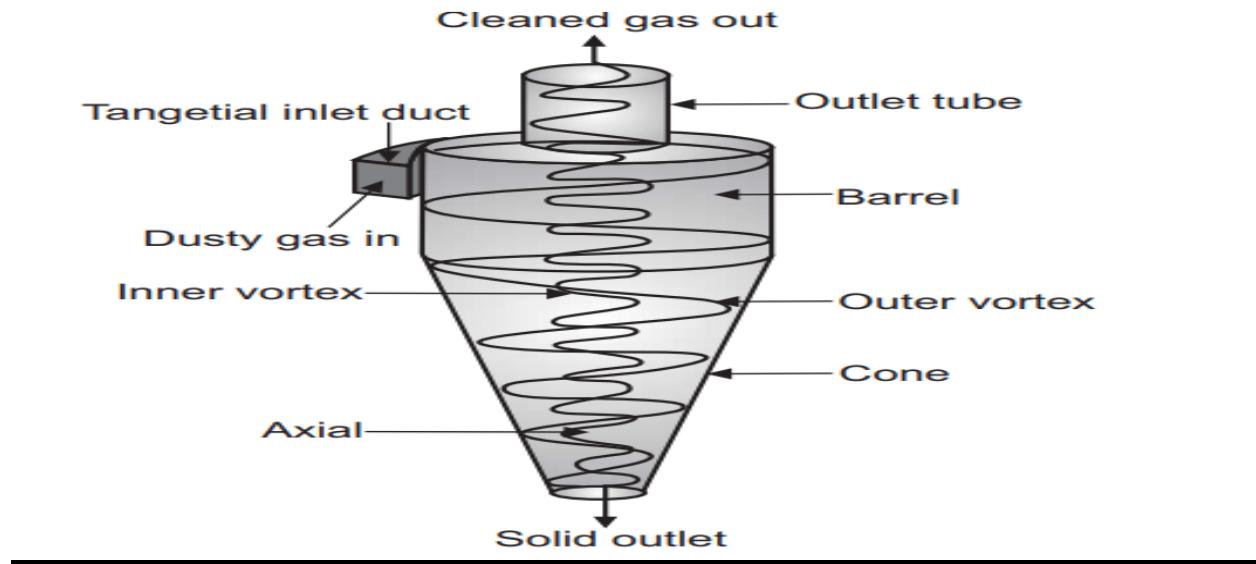
These forces move the dust to an area where the forces exerted by the gas stream are minimal which allow the dust to settle into a hopper under the effect of gravity.

Settling chambers are generally built in the form of long, horizontal, rectangular chambers with an inlet at one end and an exit at the side or top of the opposite end.

There are two primary types of settling chambers: the expansion chamber and the multiple-tray chamber. In the expansion chamber, the velocity of the gas stream is significantly reduced as the gas expands in a large chamber. The reduction in velocity allows larger particles to settle out of the gas stream.

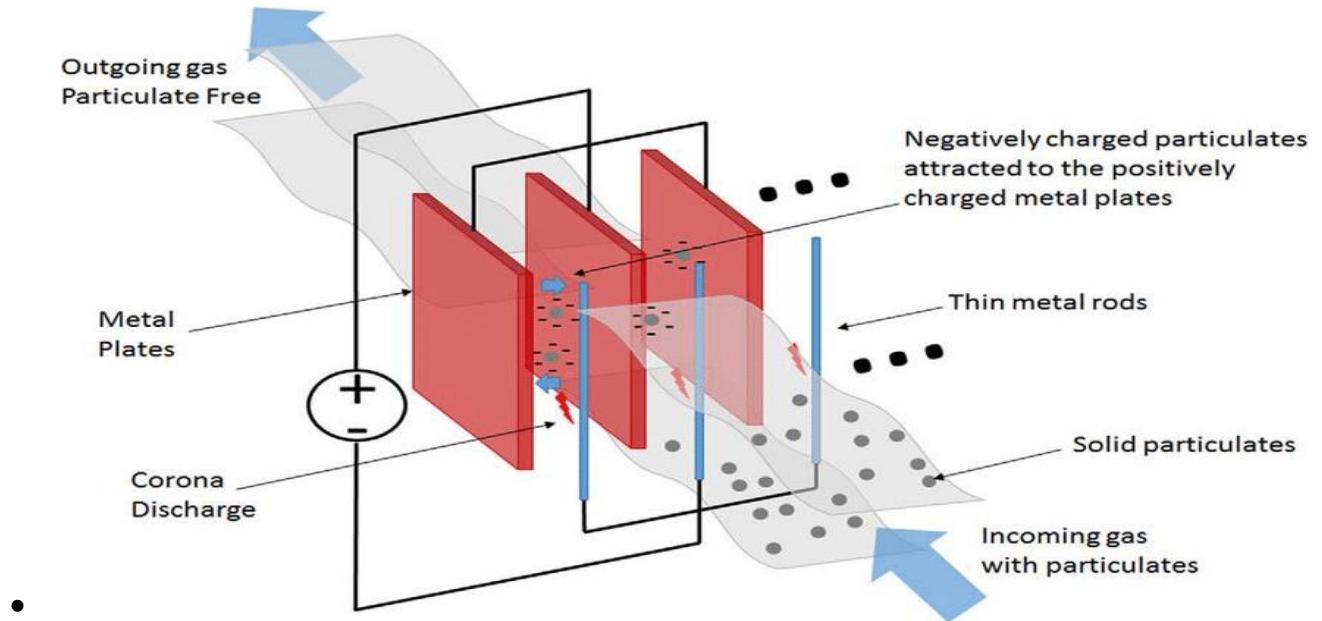
A multiple-tray settling chamber is an expansion chamber with a number of thin trays closely spaced within the chamber, which causes the gas to flow horizontally between them.

## **(b)Cyclone Separator**



- A cyclone separator consists of a cylindrical shell, conical base, dust hopper and an inlet where the dust-laden gas enters tangentially.
- Under the influence of the centrifugal force generated by the spinning gas, the solid particles are thrown to the wall of the cyclone as the gas spirals upward at the inside of the cone. The particles slide down the walls of the cone and into the hopper. The operating efficiency of a cyclone depends on the magnitude of the centrifugal force exerted on the particles.
- The greater the centrifugal force, the greater the spreading efficiency. The magnitude of the centrifugal force generated depends on particle mass, gas velocity within the cyclone, and cyclone diameter.

## (d) Electrostatic Precipitator:



- SP uses an electric field on electrically charged particles to separate liquid or solid aerosols from gas stream.
- The aerosol is deliberately charged and passed through an electric field causing the particles to migrate towards an appositively charged electrode which act. The precipitator system consists of a positively charged collecting surface and a high voltage discharge electrode wire suspended from an insulator at the top and held in passion by weight the bottom.
- At a very high DC voltage, of the order of 50kV, a corona discharge occurs close to the negative electrode, setting up an electric field between the emitted and the grounded surface.
- The particle laden gas enters near the bottom and flows upward. The gas close to the negative electrode is, thus, ionized upon passing through the corona.
- As the negative ions and electrons migrate toward the grounded surface, they in turn charge the passing particles.

- The electrostatic field then draws the particles to the collector surface where they are deposited. Periodically, the collected particles must be removed from the collecting surface. This is done by rapping or vibrating the collector to dislodge the particles. The dislodged particles drop below the electrical treatment zone and are collected for ultimate disposal.

## **7.History Overview:**

**Bhopal Gas Tragedy:** On December 3, 1984, about 45 tons of the dangerous gas methyl isocyanate escaped from an [insecticide](#) plant that was owned by the Indian [subsidiary](#) of the American firm [Union Carbide Corporation](#). The gas drifted over the densely populated neighborhoods around the plant, killing thousands of people immediately and creating a panic as tens of thousands of others attempted to flee Bhopal. The final death [toll](#) was estimated to be between 15,000 and 20,000. Some half a million survivors suffered respiratory problems, eye irritation or blindness, and other maladies resulting from exposure to the toxic gas; many were awarded compensation of a few hundred dollars. Investigations later established that substandard operating and safety procedures at the understaffed plant had led to the [disaster](#). In 1998 the former factory site was turned over to the state of [Madhya Pradesh](#)

## **London Smog:**

The Great London Smog of 1952 (also just called the Great Smog) was an environmental disaster of unprecedented severity as a result of critical air pollution. Its impact ultimately served as a turning point in enacting the first air quality legislation in the United Kingdom and paved the way for future environmentalism. [On December 5, 1952](#), fog descended upon the city of London. This was not unusual, as it was winter, and the capital was known for its misty weather. However, the fog later turned into [smog](#) as a result of mixing with smoke from coal-burning factories and chimneys, and diesel-fueled automobiles and buses. London had experienced these types of smog before. They were called “pea-soupers” due to their [yellowish-brown appearance](#). Today, pea-soupers are known as sulphurous smog or “London smog”. These result from a high concentration of sulphur oxides ( $\text{SO}_x$ ) in the atmosphere from fossil fuels high in sulphur, such as coal. They are exacerbated by dampness and particulate matter (PM): water vapour would stick to the released particulates and produce thick and dark clouds that impaired visibility.

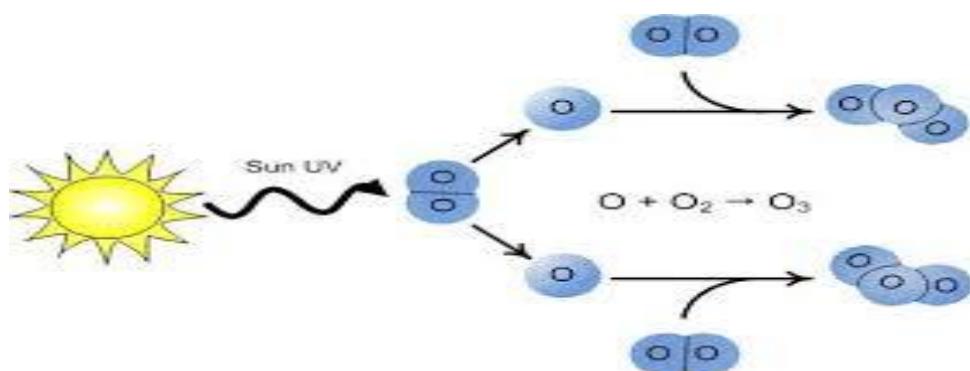
## UNIT-III

### Ozone layer

**Ozone layer**, region of the upper atmosphere, between roughly 15 and 35 km (9 and 22 miles) above Earth's surface, containing relatively high concentrations of ozone molecules ( $O_3$ ). Approximately 90 percent of the atmosphere's ozone occurs in the stratosphere, the region extending from 10–18 km (6–11 miles) to approximately 50 km (about 30 miles) above Earth's surface. In the stratosphere the temperature of the atmosphere rises with increasing height, **a phenomenon created by the absorption of solar radiation by the ozone layer**. The ozone layer effectively blocks almost all solar radiation of wavelengths less than 290 nm from reaching Earth's surface, including certain types of ultraviolet (UV) and other forms of radiation that could injure or kill most living things.

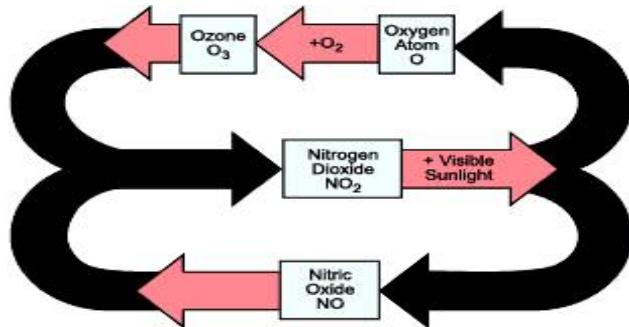
### Ozone creation :

The production of ozone in the stratosphere results primarily from the breaking of the chemical bonds within oxygen molecules ( $O_2$ ) by high-energy solar photons. This process, called **photo dissociation**, results in the release of single oxygen atoms, which later join with intact oxygen molecules to form ozone.





Thus ozone is constantly created by solar radiation on earth's atmosphere and eliminated by reaction with atomic oxygen, reactive hydroxyl radicals and nitric oxide.



#### Ozone production from NO<sub>x</sub>

Oxygen atoms freed from nitrogen dioxide by the action of sunlight attack oxygen molecules to make ozone. Nitrogen oxide can combine with ozone to reform nitrogen dioxide, and the cycle repeats.

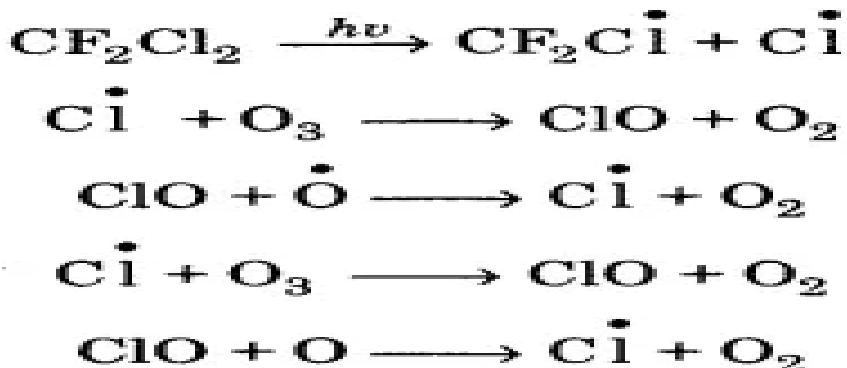
### Mechanism of depletion:

Over the course of several decades, however, human activities substantially altered the ozone layer. Ozone depletion, the global decrease in stratospheric ozone observed since the 1970s, is most pronounced in Polar Regions, and it is well correlated with the increase of chlorine and bromine in the stratosphere. Those chemicals, once freed by UV radiation from the chlorofluorocarbons (CFCs) and other halocarbons (carbon-halogen compounds) that contain them, destroy ozone by stripping away single oxygen atoms from ozone molecules. Depletion is so extensive that so-called ozone holes (regions of severely reduced ozone coverage) form over the poles during the onset of their respective spring seasons. The largest such hole—which has spanned more than 20.7 million square km (8 million square miles) on a consistent basis since 1992—appears annually over Antarctica between September and November.

## **Causes of depletion:**

The main cause of ozone depletion and ozone hole formation is called ozone depleting substances (ODS) due to industrial chemicals, especially manufactured halocarbon refrigerants, solvents, propellants and blowing agents (chlorofluorocarbons (CFCs), HCFCs, halons). These compounds are ejected from the surface and transported into the stratosphere by turbulent mixing, where the molecules mix much faster than they can settle. Upon reaching the stratosphere, they release atoms of halogen groups through photodissociation, which catalyses the breakdown of ozone ( $O_3$ ) into oxygen ( $O_2$ ).

## **Reaction involved in ozone layer depletion:**



..... and so on

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The ozone layer depletion came to the public eye after the creation of a chemical compound known as chlorofluorocarbons or CFCs (formerly used in refrigerators, aerosols, and air conditioners). It was discovered in the 1970s. These were used as refrigerants, aerosol spray propellants etc. CFCs are light and can move up in the air and reach the stratosphere. Here the chlorofluorocarbons react with the ozone layer in the presence of ultraviolet radiation and cause it to break down into oxygen molecules. The result is the depletion of the Ozone Layer. After an International Treaty was signed in 1973, the use of CFCs was lowered and subsequently banned. In the 1980s, it was observed that the ozone layer in an area of the Antarctic stratosphere had hit low levels coming at around as low as 33 percent of pre-1975 levels. This area became known as **the Ozone hole.**

## **Appearance of hole over Antarctica:**

This is an annual phenomenon that takes place from September to early December when the westerly winds circulate all over the continent. The frigid temperature during this time, in combination with the Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) contained in the manufactured chemicals that are emitted from the surface of the Earth, trigger ozone depletion. High altitude clouds are formed as the temperature goes down. Chlorine and bromine react within these clouds in a photochemical process and destroy the surrounding ozone layer. The following entry of ultraviolet rays increases the chances of skin cancer and blindness in humans and sun damage in animals.

The appearance of ozone hole over the Antarctic mobilized international community into signing the Montreal Protocol in 1987. Good news is that the year 2019 recorded the smallest ozone hole in Antarctic since 1984; however, the detection of a rare ozone hole in the Arctic in the late March of 2020 has called for a re-evaluation of the progress made by Montreal Protocol.

**In the Montreal Protocol, it was decided to phase out all the substances that cause damage to the ozone layer. It came into force in 1989 and considered the most successful model of international cooperation, especially when other important environmental treaties like Kyoto Protocol have failed to everybody's disappointment. While all the chlorine and bromine containing substances are controlled by the Montreal Protocol, other ozone depleting substances like nitrous oxide are yet to be regulated under the treaty.**

## **Effects of Ozone layer Depletion**

A small dose of UV-B radiation is useful as it promotes vitamin D synthesis in living organisms. UV radiation also acts as a germicide that controls microorganisms. However, with the depletion of the ozone layer, the atmospheric shield from the UV rays weakens as it allows harmful rays to reach the earth's surface. Some of the effects of ozone layer depletion are as follows:

- **On Human Beings**
  - Increased risk for developing several skin cancers, skin rashes and skin ageing. Malignant melanoma and basal and squamous cell carcinoma are the most common cancers.
  - Leads to difficulty in breathing, chest pain, and throat irritation.
  - A suppressed immune system may lead to severe infectious diseases.
  - UV rays are harmful to our eyes. Direct exposure to UV rays can lead to Cataract problems, Photokeratitis or snow blindness.
    - Prolonged exposure may permanently damage the cornea.
- It can lead to DNA mutation.

- **On Plants**

- It affects plant growth by altering the physiological and developmental processes of the plants as it inhibits photosynthesis.
- Causes mutation.
- Alters the Biodiversity in different ecosystems.
- Affects plant competitive balance, plant pathogens and biogeochemical cycles.

- **On Aquatic Ecosystem**

- Affects the productivity of marine/freshwater organisms.
- Affects the distribution of phytoplankton, which forms the foundation of aquatic food webs.
- Damages the early development stages of fish, shrimp, crabs, amphibians and other animals.
- Affects reproductive capacity and impairs larval development.

- **On Bio-Geochemical Cycles**

- Affects terrestrial and aquatic bio-geo-chemical cycles, thus altering sources and sinks of greenhouse gases.
- Alters the delicate balance among different ecosystems.
- Changes in the production and decomposition of plant matter.
- Reduction of primary production changes in the uptake and release of important atmospheric gases.
- Reduction of plankton growth in the upper ocean.
- Increased degradation of aquatic dissolved organic matter.

- **On Non-Living Materials**

- Accelerates the photodegradation rates of synthetic polymers, naturally occurring biopolymers and some other materials of commercial interest, thus limiting their lifetime.
- Affects the quality of these materials, ranging from discolouration to loss of mechanical integrity.

## **Control Measures:**

Control measures for ozone layer depletion primarily focus on reducing the emissions of ozone-depleting substances (ODS). Here are key strategies:

### **1. International Agreements**

- **Montreal Protocol:** This landmark treaty, signed in 1987, aims to phase out the production and consumption of ODS, including chlorofluorocarbons (CFCs) and halons.

## **2. Regulations and Policies**

- **National Legislation:** Countries implement laws to regulate the use of ODS and promote alternatives.
- **Import/Export Controls:** Monitoring and restricting the trade of ODS.

## **3. Alternatives and Substitutes**

- **Adoption of Safer Chemicals:** Encouraging the use of non-ozone-depleting substances in refrigeration, air conditioning, and aerosol products.

## **4. Public Awareness and Education**

- **Outreach Campaigns:** Informing the public about the importance of protecting the ozone layer and encouraging responsible consumption.

## **5. Research and Monitoring**

- **Ongoing Research:** Investing in scientific studies to monitor ozone levels and understand the effects of ODS.
- **Satellite Monitoring:** Utilizing technology to track ozone layer changes and assess recovery.

## **6. Support for Developing Countries**

- **Financial and Technical Assistance:** Providing support to help developing nations comply with ozone protection measures.

## **2. Smog: Sulphurous and photochemical smog,**

Smog = **smoke + fog (smoky fog)** caused by the burning of large amounts of **coal, vehicular emission and industrial fumes** (Primary pollutants).

Smog contains soot particulates like **smoke, sulphur dioxide, nitrogen dioxide** and other components.

At least two distinct types of smog are recognized: **sulfurous smog** and **photochemical smog**.

### **Sulfurous smog:**

Sulfurous smog is also called “London smog,” (first formed in London).

Sulfurous smog results from a high concentration of **SULFUR OXIDES** in the air and is caused by the use of sulfur-bearing fossil fuels, particularly coal (Coal was the mains source of power in London during nineteenth century).

The effects of coal burning were observed in early twentieth century). This type of smog is aggravated by dampness and a high concentration of suspended particulate matter in the air.

### **Photochemical smog:**

**Photochemical smog is also known as “Los Angeles smog”.**

Photochemical smog occurs most prominently in urban areas that have large numbers of automobiles (Nitrogen oxides are the primary emissions).

Photochemical (summer smog) forms when pollutants such as nitrogen oxides (primary pollutant) and organic compounds (primary pollutants) react together in the presence of SUNLIGHT. A gas called OZONE (Secondary pollutant) is formed.

Nitrogen Dioxide + Sunlight + Hydrocarbons = Ozone (Ozone in stratosphere it is beneficial, but near the earth's surface it results in global warming as it is a greenhouse gas)

The resulting smog causes a light brownish coloration of the atmosphere, reduced visibility, plant damage, irritation of the eyes, and respiratory distress.

### **Effects of Smog:**

- The **atmospheric pollution** levels of Los Angeles, Beijing, Delhi, Mexico City and other cities are increased by **inversion** that traps pollution close to the ground.

#### **Temperature Inversion – Types – Effects on Weather**

- It is usually highly toxic to humans and can cause severe sickness, shortened life or death.
- Smog is a combination of airborne particulate matter, like soot, and invisible toxic gases including **ozone (O<sub>3</sub>)**, **carbon monoxide (CO)**, **sulfur dioxide (SO<sub>2</sub>)**, which are **carcinogens (cancer causing agents)**.
- Temperature inversions are accentuated and **precipitation is reduced**.
- Smog related Haze lowers visibility.

## **Control Measures of Smog:**

**Avoid exercising outdoors:** When the air is toxic, prefer exercising indoors in a gym or use an exercise machine at home. Also, I would suggest you to avoid intense exercises or heavy weight lifting as they require deep inhaling and exhaling, which could affect your health due to excess smog in the air. Smog can cause cold, pneumonia and even deadly pulmonary diseases such as lung cancer. To keep your children away from the devastating effects of smog, ask your kids to play outdoors only for a limited time if the pollution levels are high. However, engaging them in indoor games would be best during air pollution.

**Stay away from high-traffic areas:** High traffic areas or busy highways have high pollution levels that are likely to spread up to 1/3rd of a mile. Therefore, you should avoid activities around such areas. If at all you don't have an option to avoid such routes to your office or home, then you can wear Masks N95 and Masks N99 as these are effective in protecting you from some pollutant particles.

**Tobacco-free indoors:** Say 'NO' to smoking indoors and equally support the initiatives for tobacco-free public places. Smoke not only adds to smog but also worsens the air quality around you. Besides that, passive smoking can be harmful to children causing them bronchial diseases.

**Green Home:** Keep small plants such as aloe vera, bamboo palm, snake plant, peace lilies and the likes of them in your home to purify the air indoors. Some of them like snake plant are effective enough to remove

trichloroethylene, formaldehyde, toluene, xylene, and benzene pollutants from the air, which are common in homes and offices.

**Stop burning wood or trash:** Burning of wood and trash releases pollutants in the air. It is one of the major causes of air pollution in our country and must be stopped with immediate effect.

## Water pollution

Water pollution is the contamination of water bodies (like oceans, seas, lakes, rivers, aquifers, and groundwater) usually caused due to human activities. Water pollution is any change in the physical, chemical or biological properties of water that will have a detrimental consequence to any living organism.

### Properties of water

Water is a simple molecule consisting of one oxygen atom bonded to two hydrogen atoms. Because of the higher electronegativity of the oxygen atom, the bonds are polar covalent (polar bonds). Water is amphoteric: it has the ability to act as either an acid or a base in chemical reactions. Due to hydrogen bonding, water exhibits the following unique properties:

1. Water is the universal solvent
2. Exists in nature as a solid, liquid, and gas
3. The density of ice is less than liquid water
4. Water exists as a liquid at room temperature

Earth's oceans contain 97% of the planet's water, so just 3% is fresh water, water with low concentrations of salts. The majority of the Earth's water can be classified as being saline (or salt containing). Most freshwater is trapped as ice in the vast glaciers and ice sheets of Greenland. A storage location for water such as an ocean, glacier, pond, or even the atmosphere is known as a reservoir.

Drinking water, also called Potable Water, is the water that is considered safe enough for human and animal consumption. This is water that is generally used for drinking, cooking, washing, crop irrigation, etc. These days chemicals, bacteria, and other pollutants are even affecting our drinking water.

### Water Pollution Sources

Water can be contaminated by various human activities or by existing natural features, like mineral-rich geologic formations, Agricultural activities, industrial operations, landfills, animal operations, and small and large scale sewage treatment processes etc. All can potentially contribute to contamination. As water runs over the land or infiltrates into the ground, it dissolves material left behind by these potential contaminant sources. The risks and type of remediation for a contaminant depend on the type of chemicals present.

**Point source pollution** can be attributed to a single, definable origin.

For example, animal factory farms raise a large number and high density of livestock such as cows, pigs, and chickens. Combined sewer systems that have a single set of underground pipes to collect both sewage and storm water runoff from streets for wastewater treatment can also be major point sources of pollutants.

**Nonpoint source pollution** is from multiple dispersed sources. The whole of the contribution of pollutants is harmful, but the individual components may not reach harmful concentrations. Nonpoint sources of pollution include agricultural fields, cities, and abandoned mines. Rainfall runs over the land and through the ground, picking up pollutants from throughout

the watershed (including areas of land and smaller streams that drain into a particular body of water). These pollutants might include herbicides, pesticides, and fertilizer from agricultural fields and lawns; oil, antifreeze, animal waste, and road salt from urban areas; and acid and toxic elements from abandoned mines.

**Water pollutants are categorized according to whether they arise from chemical, biological, or physical processes.**

### **Chemical Pollutants**

Chemical pollution from agriculture, industry, cities, and mining threatens global water quality. Air pollutants from these activities can also enter bodies of water (and become water pollutants) through dry deposition, precipitation, and runoff. Some chemical pollutants have serious and well-known health effects, whereas many others have poorly known long-term health effects.

- **Organic Pollutants**

Organic pollutants include herbicides and pesticides, pharmaceuticals, fuel (such as oil spills), industrial solvents and cleansers, and synthetic hormones associated with pharmaceuticals. These synthetic hormones can act as endocrine disruptors. Many are persistent organic pollutants (POPs), which are long-lived in the environment, biomagnify through the food chain, and can be toxic.

- **Inorganic Pollutants**

Inorganic pollutants include nutrients like nitrate ( $\text{NO}_3^-$ ) and phosphate ( $\text{PO}_4^{3-}$ ), heavy metals, chloride ( $\text{Cl}^-$ ), and radioactive isotopes released from mining or nuclear accidents (such as cesium, iodine, uranium, and radon gas).

### **Biological Pollutants**

Pathogens (infectious microorganisms or viruses) enter water primarily from human and animal fecal waste due to inadequate sewage treatment. In many underdeveloped countries, sewage is discharged into local waters either untreated or after only rudimentary treatment. In developed countries untreated sewage discharge can occur from overflows of combined sewer systems, poorly managed livestock factory farms, and leaky or broken sewage collection systems.

### **Physical Sources of Pollution**

Trash, sediments, and thermal pollution arise from physical sources of pollution. Excess sediments enter bodies of water when various land uses, such as mining, deforestation, and agriculture increases erosion. Sediments can carry toxins or excess nutrients with them, and they cloud the water (resulting in **turbidity**). High temperature disrupt aquatic organisms for several reasons; one is that warmer waters cannot hold as much dissolved oxygen

## **Water treatment and purification technologies**

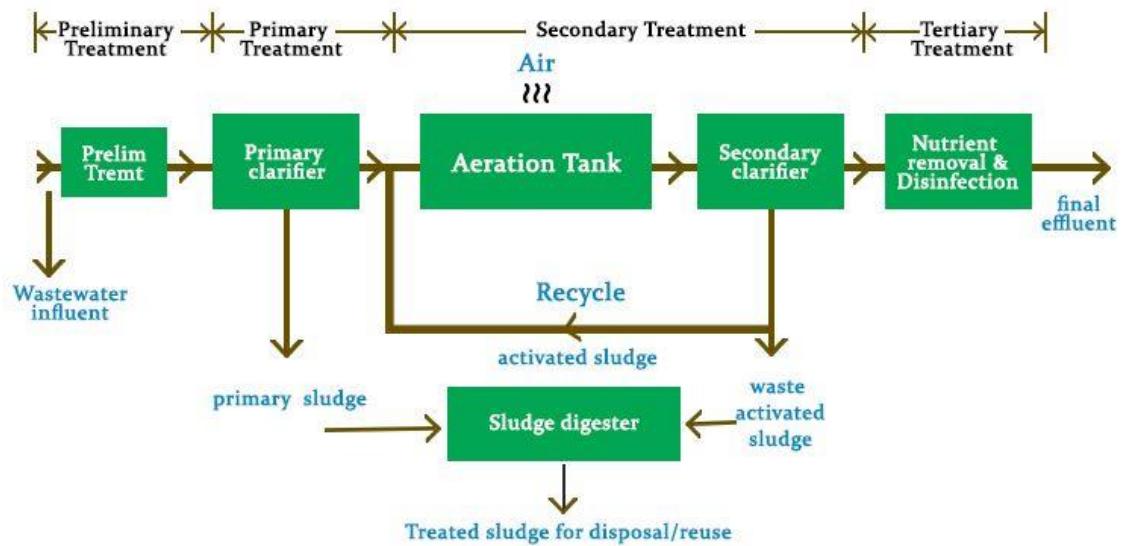
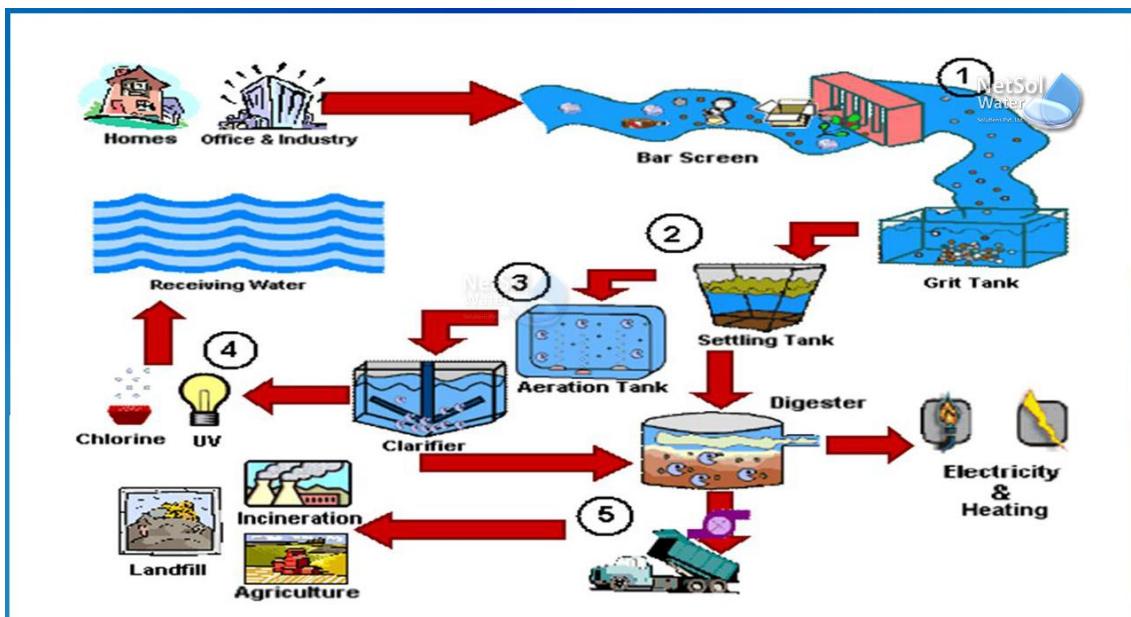
Wastewater treatment involves the following processes:

1. Preliminary treatment—The velocity of the wastewater from the sewer lines is reduced as it enters the treatment plant. This allows sand, gravel and other heavy materials to settle out into grit tanks. Mechanical cleaning bar screens then remove rags, sticks, plastic and other foreign objects from the Wastewater.
2. Primary treatment—The screened wastewater flows into a primary settling tank where it is held for several hours allowing solid particles to settle to the bottom of the tank. Fats, oil and grease (FOG) are skimmed from the tanks, dried and sent to the landfill.
3. Secondary treatment—Secondary treatment is a biological treatment process. The principal requirement of a biological treatment process are an adequate amount of bacteria that feed on the organic material present in wastewater, oxygen and some means of achieving contact between the bacteria and organics. The organic matter is metabolized to more stable inorganic forms.

Several methods are used:

the activated sludge system, biological film system, Rotating biological contactor,

4. Tertiary or Advanced Wastewater Treatment  
If Water produced is required to be of higher water quality Standards (in case the water to be put to some direct reuse) then advanced wastewater treatment is carried out. A wide variety of methods are used in advanced waste treatment, which include the removal of
  - (a) Suspended solids.
  - (b) BOD).
  - (c) Plant nutrients, (d) Dissolved solids and (e) toxic substances.
5. Final treatment—The wastewater that remains can be disinfected to kill harmful micro-organisms before being released into receiving waters. Although there are many methods available to kill these micro-organisms, ultraviolet disinfection, ozonation and chlorination are few of them.
6. Solids processing—Primary solids from the primary settling tank and secondary solids from the clarifier are sent to digesters for solids processing. During this process, micro-organisms use the organic material present in the solids as a food source and convert it to by-products, such as methane gas and water. Digestion results in a 90% reduction of pathogens and the production of a wet soil-like material called "biosolids" that contain 95-97% water. In order to remove some of this water, mechanical equipment such as a belt filter press or centrifuge are used to squeeze water from biosolids, reducing its volume prior to being used in soil amendment or composting.



**Treatment with Chlorine and/or Chloramine** Most communities use either chlorine or chloramines. Some communities switch back and forth between chlorine and chloramines at different times of the year or for other operational reasons.

**Ozone Disinfection** Ozone disinfection, or ozonation, is an unstable molecule which readily gives up one atom of oxygen providing a powerful oxidizing agent which is toxic to most waterborne organisms. It is an effective method to inactivate harmful protozoa that form cysts. It also works well against almost all other pathogens..

**Ultraviolet Disinfection** Ultraviolet disinfection of water is a purely physical, chemical-free process. Even parasites such as Cryptosporidium or Giardia, which are extremely resistant to

chemical disinfectants, are efficiently reduced. UV disinfection does not remove dissolved organics, inorganic compounds or particles in the water.

**Fluoridation** The mineral fluoride occurs naturally on earth and is released from rocks into the soil, water, and air. All water contains some fluoride. Usually, the fluoride level in water is not enough to prevent tooth decay; however, some groundwater and natural springs can have naturally high levels of fluoride. Fluoride has been proven to protect teeth from decay. Water fluoridation prevents tooth decay by providing frequent and consistent contact with low levels of fluoride.

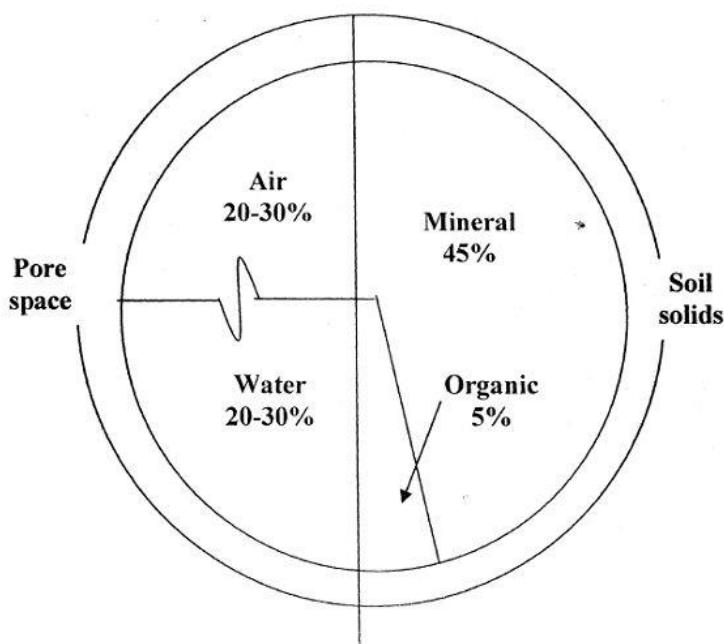
## **Soil pollution**

### **Origin and nature of soil**

Soil is defined as a dynamic natural body on the surface of the earth in which plants grow, composed of mineral and organic materials and living forms. The soil is made-up of broken-down rock material of varying degree of fineness and changed in varying degrees from the parent rocks by the action of different agencies such that the growth of vegetation is made possible.

### **COMPONENT OF SOIL (VOLUME BASIS):**

The soil consists of four major components (Fig.1.1) i.e. mineral matter (45%), organic matter (5%), soil air (20-30%) and soil water (20-30%).



Weathering is a natural process of breakdown and transformation of rocks and minerals into unconsolidated residues, called **regolith**. In other words, the process of transformation of solid rocks into soils is known as weathering.

Weathering processes are two types:

- (1) physical weathering brought about by the mechanical action of the various weathering agents, is designated as **disintegration**, and
- (2) chemical weathering is designated as **decomposition**.

### **Sources of Soil Pollution:-**

- “Any change in the physical, chemical & biological properties of soil due to natural or man-made activities is known as soil-pollution.
- The main cause of this degradation is overgrazing deforestation & agricultural activities.

## **Various Sources**

A) **Natural Sources:-** Some of the natural sources are -

- Landslides, earthquakes, landslides, hurricanes & floods.
- Such natural disasters cause severe damage to the composition of soil.

- **Man – Made Sources:-**

1) **Industrial Wastes:-**

- Contain different kind of toxic, flammable and non-biodegradable substances that may persist in the soil for a long time and destroy the composition of soil such as Mercury, Zinc , Iron and Cd etc.

2) **Mining:-**

- Mining activities leave behind heap of mining wastes containing several toxic substances and contaminate the soil.

3) **Agricultural Wastes :-**

- Non judicious use of chemical fertilizers, pesticides, insecticides and fumigants remain in the soil for long percale of without degradation causes soil pollution.

4) **Domestic Wastes:-**

- Kitchen and food wastes, paper etc are biodegradable but glass, plastic materials, metal cans etc are non-biodegradable. Improper disposal of hazardous domestic wastes such as batteries, paints, medicines, glass bulbs, spray cans etc contribute greatly to soil pollution.

5) **Radioactive Waste:-**

- Radioactive substances from nuclear power plants are released in to the soil.
- **Strontium** gets deposited in the bones and tissues instead of calcium.

6) **Biological agents:-**

- Soil gets large quantities of human and animal excreta which constitute the major part of land pollution.
- In addition to these excreta faulty sanitation, municipal garbage, waste water and wrong methods of agricultural practices also induce heavy soil pollution.
- Pathogens exerted by human and animals such as bacteria and parasitic worms contaminate the soil.
- Pathogenic soil bacteria like salmonella typhus causes infections of intestinal tract.

## Soil pollution and plant growth

Soil pollution, a significant environmental concern, poses a direct threat to plant growth and agricultural productivity. It occurs when harmful substances such as heavy metals, pesticides, and industrial waste accumulate in the soil, disrupting its natural properties and hindering the growth and development of plants.

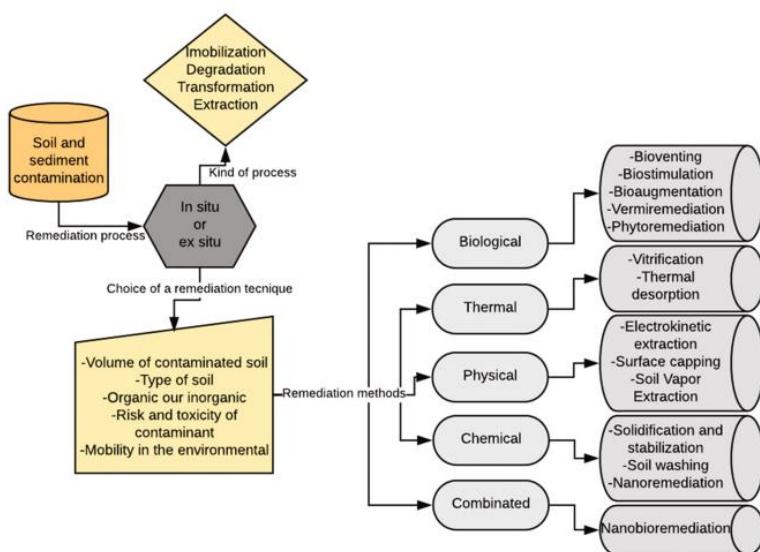
Soil pollutants disrupt the delicate ecological balance of crop systems. Each plant requires a specific soil type for optimal growth. However, most plants struggle to adapt to alterations in soil chemistry, resulting in stunted growth or diminished crop yields. Moreover, essential soil microorganisms like bacteria and fungi, crucial for soil cohesion, decline in the presence of toxic elements, exacerbating soil erosion and reducing fertility, rendering land unsuitable for agriculture.

Some effects on plant growth

- The balance of ecological system is affected due to contamination of the soil.
- Plants are mostly unable to adapt to the change in the chemistry of the soil in short time period.
- The microorganisms found in the soil decline and create additional problems of soil erosion.
- Fertility of the soil decreases due to soil pollution, making it unsuitable for agriculture and local vegetation to survive.
- Soil pollution is hazardous to health.
- Polluted lands cannot support most forms of life.

The chemicals present in the soil due to pollution are toxic and can decrease the fertility of the soil, thereby decreasing the soil yield. Agriculture on contaminated soil produces fruits and vegetable that lack quality nutrients. Consumption of these may be poisonous and cause serious health problems to people consuming them.

## Soil Remediation techniques



**Fig. 1.** Technologies that are used for the remediation of contaminated soils and sediments

**Physical Processes:** Physical processes refers to the immobilization or withdrawal of contaminants from the soil or sediment by some physical means. The main technologies used include:

- Surface Capping: This technique simply covers the contaminated site with a low permeability material.
- Vapor Extraction: This technology is applied in-situ to remove volatile and subvolatile organic contaminants from the soil, usually in unsaturated soils.
- Electrokinetic Remediation: A low-density electrical current is applied in the soil through electrodes and this induces the migration of the cations from the soil to the cathode and the anions to the anode through the established electrical field.

**Chemical Processes** Chemical processes are the main methods used to remove contaminants, and their mechanisms include adsorption, retalcation, load exchange, oxidation, reduction, or a combination

- Solidification and Stabilization: This technique, also known as chemical immobilization, captures or immobilizes contaminants in-situ or ex-situ by introducing chemical agents to convert mobile pollutants into hasty forms or strongly adsorbed. This technology does not remove contaminants from the soil; it only prevents them from moving.
- Soil Washing: This ex-situ technology uses aqueous solutions to extract contaminants from the environment. The excavated soil is mixed with the solution that will make the extraction and is then agitated. After washing, the clean soil can be reseated at the place of origin and should be made the treatment of the extraction solution.

**Biological Processes** Biological processes involve environmental decontamination by living things, such as plants, animals or micro-organisms These methods include adsorption processes, transformation, or degradation of contaminants.

**Thermal Processes** Thermal processes involve the heating of the subsurface, leading to the mobilization, volatilization, or destruction of contaminants in the soil or sediment. Heating methods include conductive heating, electric resistance heating, steam heating, and radio frequency heating

## Toxicants

Any toxic material or substance is termed as a toxicant. They are hazardous and poisonous. Toxicants are generally man-made and artificial products introduced into the environment due to human activity. They include bisphenol, insecticides and a number of industrial chemicals.

### Types and sources of Environmental Toxicants

Toxic agents can be chemical, physical, or biological in nature and produce toxic effects on the body. The different toxic agents include: chemical (cyanide), physical (radiation) and biological (snake venom). There exist a number of toxicants and they can be classified by various means. Classification may be by exposure classes and by user classes. The different toxicants include the following:

- 1) **Natural Pollutants:** Toxic pollutants can also be released through natural processes. For example, volcanoes emit particulate matter, sulfur dioxide, hydrogen sulfide, and methane. Forest fires release smoke, unburned hydrocarbons, carbon monoxide, nitrogen oxides, and ash. These can be harmful to human health when inhaled. Dust storms release particulate matter and oceans release aerosols in the form of salt particles. Plants produce pollen and spores, which cause respiratory problems and allergic reactions.
- 2) **Anthropogenic Pollutants:** These are pollutants introduced due to human activity/ man-made activities. These substances come primarily from three sources: (1) combustion; (2) industrial; (3) mining and drilling processes.

Some important man-made sources of toxicants are as follows:

- 1) **Air pollutants:** Humans have been polluting the air and there are also significant natural pollutants such as terpenes from plants, smoke from forest fires, and fumes and smoke from volcanoes. Among air pollutants there are gaseous pollutants like carbon dioxide, carbon monoxide, hydrocarbons, hydrogen sulfide, nitrogen oxides, ozone and other oxidants, sulfur oxides. There are also fine particulates in the air. The particulates include dust (coal, ash, sawdust, cement) that come from chemical processes, mist droplets, smoke resulting from incomplete combustion of fossil fuels and aerosols.
- 2) **Indoor Pollutants:** These are produced from heating, cooking, pesticides, tobacco smoking, radon, gases, microbes from people and animals. Materials used for construction of buildings can give out gaseous indoor chemicals that have serious health concerns. Carbon monoxide and polycyclic aromatic hydrocarbons released from wood, crop residues, animal dung used for cooking cause acute respiratory infections in poorly ventilated areas.
- 3) **Water pollutants:** Surface waters may be polluted from point and nonpoint sources. Industrial wastes discharged into waters contain organic and inorganic wastes including hazardous chemicals. Toxic effects are seen in humans when they consume this contaminated water.
- 4) **Soil pollutants:** When wastes are not properly disposed off then soil also gets polluted. Soil contaminants include: domestic waste, solid wastes, electronic wastes, municipal wastes, agricultural wastes that contain a number of chemicals harmful to life. Further agricultural toxicants like persistent pesticides that do not biodegrade remain in the soil of many years and

move into the food chain causing greater health impacts. The most toxic hazardous pesticides are the organochlorine compounds such as DDT, aldrin, dieldrin, and chlordane.

**5) Heavy metals:** Metals released from industrial activities cause toxicity. For example, the heavy metals lead and arsenic are highly toxic and is found in potable water in certain areas. Lead induces neurological damage and can penetrate the placental barrier and induce birth defects among children. Arsenic toxicity is also a serious cause of concern especially in West Bengal in India. It can leach into water from pesticide sprays, arsenic-containing fossil fuels, and leaching of mine tailings and smelter runoff. Cadmium enters the food chain through industrial activities. It can accumulate in the tissues of aquatic organisms. Cadmium contaminated rice in Japan caused the disease ItaiItai. The disease was characterized by severe kidney damage, painful bone and joint problems.

**6) Nitrates and phosphate:** These arise from contamination due to fertilizers, discharge from sewage treatment plants, leachate from septic tanks, manure and detergents which are hazardous. They leach into the soil and drinking water. Nitrates in drinking water cause adverse health effects. It occurs due to the formation of: (1) nitrosamine and (2) methemoglobinemia. The nitrates are converted to nitrites by bacteria in the intestine. Thereafter nitrite ions combine with hemoglobin to form methemoglobin. This reduces the oxygen-carrying capacity of the blood and leads to the blue-baby syndrome. This is seen in young or new born children who have ingested nitrate containing water or milk foods.

**7) Petroleum and oil pollutants:** Shore animals, such as crabs, shrimp, mussels, and barnacles, are also affected by the toxic hydrocarbons (oil and petroleum compounds) ingested by them.

**8) Volatile organic compounds (VOCs):** They include halogenated solvents and petroleum products. They are used in industries involving degreasing, dry cleaning, paint, and in the military.

**9) Therapeutic drugs:** Generally, all therapeutic drugs are toxic and produce hazardous effects at some dose. This depends on many factors like: dose, nature of the drug, individual (genetic) variation, diet, age, etc. The side effect of chloroquinol, an antidiarrhea drug used in Japan in 1960 caused stiffness of the joints accompanied by damage to the optic nerve.

**10) Biological toxicants:** Some naturally occurring substances that cause toxicity include plant, animal, algal, fungal and microbial toxins. They include many phytotoxins and mycotoxins. For example, Aflatoxins are products of *Aspergillus flavus*. It is fungus that contaminates grain, maize, peanuts, and so on. Aflatoxin B1 is the most toxic and is reported to have carcinogenic effects.

**11) Cosmetics:** Cosmetics induce allergies and contact dermatitis. Lipsticks contain lead at varying concentrations. Hair dyes contain resorcinol which is toxic. Paraffin wax is used in some lotions which hinders skin breathing.

## **Physiological response to toxicants: Mutagenesis**

Many agents (physical, chemical and environmental) have the mutagenic properties to cause mutations. They are known as mutagens. Mutagenic agents induce mutation in either of the following ways:

- a. They may replace in the DNA.
- b. They may alter the base in such a way that it specifically mispairs with another base.
- c. They may damage the base so much that it can no longer pair with any base.
- d. They may intercalate themselves in the DNA paving way for addition or deletion of bases.

**Physical Mutagens** These consist of high energy radiations which could penetrate living cells and affect the genetic material. The effect of radiations on living cells and tissues is directly proportional to the degree of penetration of the radiation. Radiations are of two types viz. electro-magnetic radiations and particulate radiations. X-rays, gamma-rays and UV rays are short wavelength electromagnetic radiations which penetrate cells and tissues strongly.

The physical mutagens are also divided as high energy ionizing radiations which include cosmic rays, X-rays, gamma-rays and particulate radiations and low energy non-ionizing radiations which include ultraviolet light. The high energy radiations create ionization in the living cells. Non-ionizing radiations such as UV rays have major effect in the formation of dimers whereby adjacent pyrimidine bases become linked to one another by carbon to carbon bonds.

## **Chemical Mutagens**

Chemical mutagens are classified into four major groups on the basis of their specific reaction with DNA.

1. **Base Analogs:** Base analogues are the chemicals that have molecular structure that are extremely similar to bases of DNA. These chemicals act as mutagens and during DNA replication get incorporated so as to form base pairs with usual bases. One such chemical is 5-bromouracil.

2. **Deaminating Agents:** Many chemicals [e.g. nitrous acid, hydroxylamine] are known to change the base sequence in DNA. Nitrous acid (-HNO<sub>2</sub>) and hydroxylamine replace amino group (-NH<sub>2</sub>) by hydroxyl group (-OH) which leads to deamination of nitrogenous bases.

For example, deamination of cytosine produces uracil.

3. **Alkylating Agents:** Such as ethyl methane sulfonate (EMS), ethyl ethane sulfonate (EES) and diethyl sulphate (DES) act on DNA by adding alkyl group (ethyl or methyl) to all four bases. However, these agents show a strong preference for base guanine. This results either in mispairing of affected base or its loss entirely, creating a gap thus causing mutations.

4. **Intercalating Agents:** This type of mutagen includes ethidium bromide and Acridine dyes (proflavin and acridine orange). Intercalating agents can mimic base pairs and slip between the base pairs in double helix and open the helix which leads to increase in distance between base pairs. This results in deletion or addition of base pairs during DNA replication.

## Environmental Mutagens

These mutagens include air and water pollutants, agricultural chemicals, pesticides, cigarette and industrial smoke which includes chemicals like Benzidine, Vinyl Chloride etc.

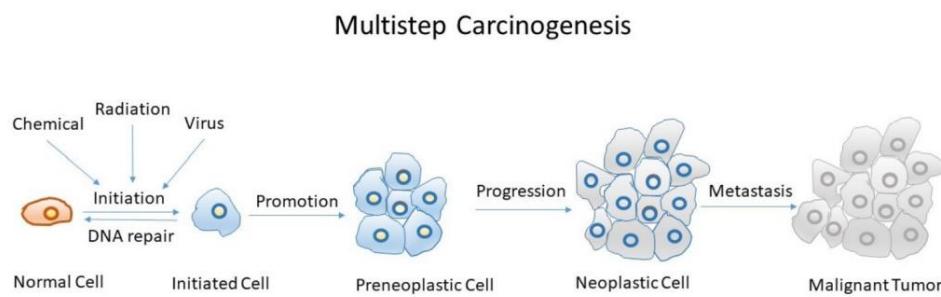
Some environmental mutagens are carcinogenic. Some of the biological agents may also act as mutagens which are listed below:

- a. Transposons.
- b. Virus – Inserted virus DNA into genome may change genetic function.
- c. Bacteria – Some bacteria like Helicobacter pylori cause inflammation and DNA damage which may lead to mutation.
- d. Parasitic Fungi of Field Crops.

## Physiological response to toxicants: Carcinogenesis

A carcinogen is any agent that directly increases the incidence of cancer. Most, but not all carcinogens are mutagens. Carcinogens that do not directly damage DNA include substances that accelerate cell division, thereby leaving less opportunity for cell to repair induced mutations, or errors in replication. Carcinogens that act as mutagens may be biological, physical, or chemical in nature, although the term is most often used in relation to chemical substances.

Carcinogenesis, also called oncogenesis or tumorigenesis, is the formation of a cancer, whereby normal cells are transformed into cancer cells. The transformation of a normal cell into a cancer cell is a multi-step process that involves initiation, promotion, progression and finally malignancy. This process takes years and starts with a single cell in which the right genes are mutated so the cell does not appropriately die and begins to proliferate abnormally. Then, additional mutations occur that select for more rapidly growing cells within this population leading to a tumor with rapid growth and malignancy. By the time the cells are cancerous, proto-oncogenes have been activated and tumor suppressor genes inactivated. Even within the same tumor type, like colon cancer, the specific genes mutated can vary from person to person making cancer a unique disease for each individual.



Multistep process involved in carcinogenesis that transforms a normal cell into a malignant tumor.

**Chemical Carcinogens** Chemical carcinogens can be either natural or synthetic compounds that, based on animal feeding trials or epidemiological (i.e. human population) studies, increase the incidence of cancer. The definition of a chemical as a carcinogen is problematic for several

reasons. Some chemicals become carcinogenic only after they are metabolized into another compound in the body; not all species or individuals may metabolize chemicals in the same way. Also, the carcinogenic properties of a compound are usually dependent on its dose.

#### Some Classes of Chemical Carcinogens.

Class	Examples and/or Sources
PAHs (polycyclic aromatic hydrocarbons)	benzo[a]pyrene and several other components of the smoke of cigarettes, wood, and fossil fuels
Aromatic amines	compounds formed in food when meat (including fish, poultry) are cooked at high temperature
Nitrosamines and nitrosamides	found in tobacco and in some smoked meat and fish
Azo dyes	various dyes and pigments used in textiles, leather, paints.
Carbamates	ethyl carbamate (urethane) found in some distilled beverages and fermented foods
Halogenated compounds	e.g. pentachlorophenol used in some wood preservatives and pesticides.
Inorganic compounds	asbestos; may induce chronic inflammation and reactive oxygen species
Miscellaneous compounds	e.g. alkylating agents, phenolics

### **Physiological response to toxicants: Teratogenesis**

#### **Birth Defects:**

**Teratogens:** A teratogen is a compound that permanently deforms the function or structure of a developing embryo or fetus in utero. In general, the degree of teratogenicity depends on:

- The potency of the drug as a mutagen.
- The susceptibility of the fetus to teratogenesis.
- The dose of the teratogen. The duration of teratogen exposure.
- The time of exposure.
- The degree of transfer from maternal to fetal circulation.

The global average of all live births complicated by malformation is 6% (Environmental Health Perspectives, (NIH), October 2009). The majority of these complications are due to unknown factors. The vast majority of recognized etiologies are genetic, with only 10% being attributed to environmental etiologies such as maternal health, infection, and toxicants. In general, the central nervous and skeletal systems are the most affected.

**Thalidomide** (a sedative previously marketed in Europe to prevent morning sickness) is a classic teratogen that caused limb defects in babies born to women who took this drug in the 1960s.

## **Case Studies of Toxic Events and Responses**

**Carcinogenesis:** An article concluded result from National Cancer Registry Programme, aims to provide an update on the cancer incidence estimates in India by sex, age groups and anatomical sites for the year 2022. It was found that, the cancer incidence burden is continuing to increase in India.

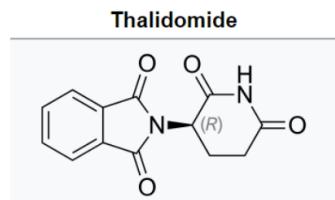
The estimated number of incident cases of cancer in India for the year 2022 was found to be 14,61,427 (crude rate:100.4 per 100,000). In India, one in nine people are likely to develop cancer in his/her lifetime. Lung and breast cancers were the leading sites of cancer in males and females, respectively. Among the childhood (0-14 yr) cancers, lymphoid leukaemia (boys: 29.2% and girls: 24.2%) was the leading site. The incidence of cancer cases is estimated to increase by 12.8 per cent in 2025 as compared to 2020.

Among the top five cancers in females, breast cancer was found to be the highest. Among males, three sites; lung, mouth and tongue were limited with tobacco-related cancers. A preventable measure needs to be taken for reducing the future burden of cancer. The new estimates are helpful for cancer prevention and control activities through the intervention of early detection, risk reduction and management in India.

**Teratogenesis:** Thalidomide was first marketed in 1957 in West Germany, where it was available over the counter. When first released, thalidomide was promoted for anxiety, trouble sleeping, "tension", and morning sickness. While initially deemed to be safe in pregnancy, concerns regarding birth defects were noted in 1961 and the medication was removed from the market in Europe that year. The total number of people affected by use during pregnancy is estimated at 10,000, of which about 40% died around the time of birth. Those who survived had limb, eye, urinary tract, and heart problems.

Its initial entry into the US market was prevented by Frances Kelsey at the FDA. The birth defects of thalidomide led to the development of greater drug regulation and monitoring in many countries. In 2006 the U.S. Food and Drug Administration granted accelerated approval for thalidomide in combination with dexamethasone for the treatment of newly diagnosed multiple myeloma patients.

Women may encounter a number of other teratogens. Smoking is most likely to cause growth retardation. Smoking may exert its effects through competitive binding of carbon monoxide with hemoglobin and/or through the various other components found in cigarettes that cause adverse biological effects.



Chemical structure of Thalidomide.



. *Thalidomide effects: A photograph of the limbs of baby born to a mother who took thalidomide while pregnant.*

### **Mutagenesis:**

In France in the 1890s, Bordeaux wine workers showed an unusually high incidence of skin cancer on the back of the neck. These workers spend their days bending over in the fields picking grapes, exposing the back of their necks to the sun. The ultraviolet (UV) radiation in natural sunlight was later identified as a mutagen.

## Waste management

Waste is any material that is not needed by the owner, producer, or processor. Humans, animals, other organisms and all processes of production and consumption produce waste.

All solid and semi-solid waste arising from human and animal activities, except human-excrete and sullage (liquid wastes from bathroom and kitchen, etc.) those are discarded as useless or unwanted, are included in the term solid wastes.

Gaseous waste, which is caused mainly by emissions from vehicles and other sources and carries fine particles of matter, leads to air pollution and smog. When gaseous waste is deposited on land as acid rain, it pollutes the soil and water. Most disposable wastes are in the form of solids, liquids or slurries.

### Types of Wastes

#### 1. Municipal Solid Waste

Municipal solid waste consists of household waste, construction and demolition debris, sanitation residue, and waste from streets. This garbage is generated mainly from residential and commercial complexes. They may be categorised as:

**Garbage:** Refers to the putrescible solid waste constituents produced during the preparation or storage of meat, fruit, vegetable etc. These wastes have a moisture content of about 70%.

**Rubbish:** Refers to non-putrescible solid waste constitute, either combustible or non-combustible waste. Combustible wastes would include paper, wood, scrap, rubber, leather etc., while non-combustible waste are metals, glass, ceramics etc. These wastes contain a moisture content of about 25%.

**2. Hazardous Waste:** USEPA defines Hazardous Waste as waste that is dangerous or potentially harmful to our health or environment. Hazardous wastes can be liquid, solid, gaseous or sludge. They can be discarded commercial products, byproducts from industries, or from households. Hazardous Waste includes many different toxic chemicals (organic compounds as well as metals). They require complex treatment processes. Some of the commonly known priority chemicals are polychlorinated biphenyls (PCBs), furans, polyaromatic hydrocarbons (PAHs); and toxic metals include lead, cadmium, chromium, mercury. These pose serious health hazards and their migration must be contained.

Wastes considered hazardous are those which are ignitable, corrosive, reactive, and toxic. Hazardous waste can be categorized into waste from non-specific sources and waste from specific sources.

Hazardous Waste from Non-Specific Sources
Solvent wastes
Electroplating wastes
Metal-treating wastes
Wood-preserving wastes
Petroleum refining wastes

Hazardous Waste from Specific Sources
Wood preservation
Inorganic pigment production
Organic chemical production
Pesticide production
Explosives manufacturing and production
Petroleum refining
Iron and steel production
Primary copper production
Ink formulation
Secondary lead smelting
Cooking products
...and so on.

*Classification of hazardous waste*

### **3. Industrial Waste**

They include chemicals, paints, sand, metal ore processing, fly ash, sewage treatment sludge etc. Manufacturing industries produce wastes which are solid or semi-solid. This waste can be self-igniting, explosive, toxic or radioactive. Chemical process industries generate a variety of waste, both organic and inorganic, which are mixtures with wide range of component concentration.

### **4. E-waste**

It is a term used to cover items of electrical and electronic equipment and their parts that have been discarded by the owner as waste without the intention of reuse.

E-waste includes almost any household or business item containing circuitry or electrical components with either power, or battery supply—items such as TV appliances, Computers, laptops, tablets, mobile phone, white goods (fridges, washing machines, dryers, etc.), home entertainment and stereo systems, toys, toasters and kettles

The industries that make such products thrive on obsolescence. New gadgets and new models appear almost daily, prices keep dropping and consumption is soaring. The older models are discarded as junk, even when they are in working condition, all this has resulted in becoming one of the fastest growing waste streams globally. From 19.5 m tonnes in 1990 global e-waste grew to 57.4 m tonnes in 2010 and is set to reach 75 m tonnes by 2030.

E-waste contains many hazardous materials like lead, copper, zinc, and aluminium, flame retardants, plastic casings, cables etc. If e-waste is disposed in landfills, burnt outdoors, or recycled in other appropriate ways, the toxic substances can contaminate the air, water, and soil, affecting all living creatures.

### **5. Bio-medical Wastes:**

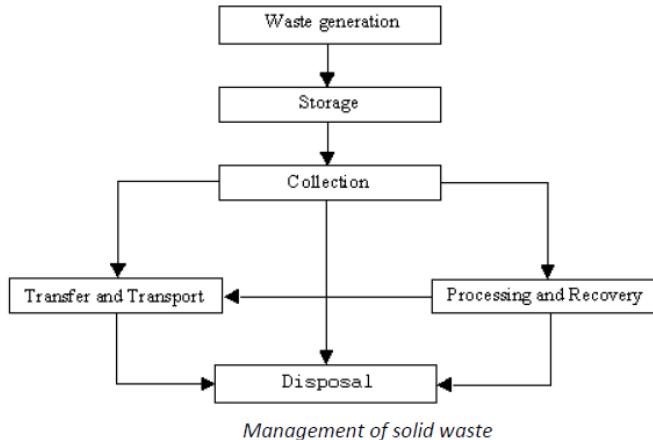
The wastes generated from hospitals, nursing homes, health centres, medical and dental colleges, veterinary institutes, laboratories and other associated areas constitute bio-medical wastes.

Examples of bio-medical wastes are - biological cultures; blood, cells and tissues; chemotherapy wastes; pathological wastes; waste from surgery and autopsy; used syringes, gloves, blades, instruments and empty gas containers; stocks (samples) of infectious agents; etc. These wastes are potentially dangerous and infectious.

is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities in these fields or in the production or testing of biologicals. They can pose serious environmental and health problems, if they are not properly handled.

## Waste Management Strategies (e.g., recycling, treatment, disposal)

The principle objectives of solid waste management include collection, processing and disposal of solid wastes in an economical manner consistent with the protection of public health:



**Reduce the generation of the waste:** The first principle for the solid waste management is- we should try our best to reduce waste.

**Collection:** It refers to the gathering of solid wastes from places such as residences, commercial, institutional and industrial establishments and other public places. Generally, there are two methods of collection- Hauled-container System and stationary-container system. In the hauled-container system, the container is hauled from the collection point to the final point of disposal, processing facility, or transfer station. In the stationary-container system, the container is emptied into collection vehicles at the point of collection.

### Handling and Separation

Waste handling and separation involves the activities associated with management of waste until they are placed in a storage container for collection. Handling includes the movement of loaded containers to the point of collection. Separation of waste components is an important step in the handling and storage of solid waste at the source.

### Transfer and Transport

- The transfer of wastes from the smaller collection vehicle to the larger transport equipment.
- The subsequent transport of the wastes, usually over long distances, to a processing or disposal site.

### Recycling

#### Treatment Facilities

The importance of increased interest in mechanized facilities for waste processing is that, as MSW disposal costs rise, recycling seems to come with incentives. Hence convenient and rapid methods of separation and processing should be developed.

**Shredding:** for size reduction; done using hammer mills, flail mills, shear shredder, glass crusher and wood grinder

**Screening:** for separation of over and under-sized material – using trammel

**Cyclone separator:** for separation of light combustible materials from air stream

**Air classification:** for separation of light combustible materials from air stream

Magnetic separation: for separation of ferrous metal from miscellaneous waste

Densification: for compaction and flattening; using balers and can crushers

Weighing and handling facilities

**Incineration:** Incineration means 'reduction to ashes'. It is a process of burning of the solid Waste at high temperature to form ash in properly constructed hearth of furnaces. Incineration is used to destroy combustible household waste, chemical waste and biological waste. The burning of solid wastes is carried out at a temperature of 1000°C or more so as to incinerate all the combustible organic matter and oxidize the foul smelling gases. In case the moisture content of the solid wastes is high, then auxiliary fuels (like wood, coal or oil) may be used along with the solid wastes for complete burning at high temperature. The ashes are disposed by dumping in low lying areas, while the clinkers can be used as aggregate for low grade concrete or as road material. The heat produced during incineration can also be used to produce electricity.

Advantages of Incineration:

- This method is hygienic. as all the pathogens and insects are destroyed.
- Incineration is free from odour and dust nuisance.
- Incineration substantially reduces the volume of waste to be disposed of in a landfill.
- Some revenue can be generated by raising steam/electricity and selling of the clinkers.
- Clinkers produced during incineration can be used as aggregate for low grade concrete or as road material.

Disadvantages of Incineration:

- High initial cost.
- Nuisance of smoke, odour and ash during the improper functioning of incinerators.
- Toxic substances like dioxin, mercury, ozone, etc. may be emitted during incineration.

**Composting:** Composting utilises natural degradation process in which biodegradable materials are decomposed by micro-organisms (bacteria, fungi and actinomycetes) and converted into humus and stable mineral compounds. It is a hygienic method which converts the solid wastes into manure. It not only reduces the volume of solid waste considerably but also makes it free from most of the pathogenic organisms.

Composting is a biological process. It can be either anaerobic (oxygen not required) or aerobic (oxygen required).

(i) **Anaerobic Composting:** Anaerobic composting is prevalent in Indian villages on a small scale, for combined disposal of solid waste and cattle dung. Anaerobic composting is characterized by slow degradation of biodegradable material extending over a period of 4 to 12 months, low temperature process, destruction of pathogens by their exposure to unfavourable environment for long period, and production of valuable biogas.

In anaerobic composting, trenches 4 to 10 m long, 2 to 3 m wide and 0.7 to 1.0 m deep are excavated. Biodegradable solid waste is disposed of into these trenches till the heaps

so formed rise about 30 cm above the original ground level. A layer of 5 to 7.5 cm of good earth is then spread on top of these heaps. Within 2-3 days, intensive biological action starts and the organic matter begins to decompose. After about 4 to 5 months, the decomposing mass gets fully stabilized and changes into brown odourless powdery humus (known as compost) having high fertilizing value. The compost is then removed from trenches, sieved to remove coarse inert materials (like brick bats, stones, bracken glass, etc.). The sieved compost is then used as manure.

(ii) Aerobic Composting: Aerobic composting is characterized by rapid degradation of biodegradable material, and speedy destruction of pathogens due to high temperature attained during the process. In aerobic composting (also called Open Window Composting), the coarse inert matter is first removed from solid wastes. Then it is dumped on the ground in the form of 5 to 10 m long, 1 to 2 m wide and 0.5 to 1.0 m high piles at about 60% moisture content. The pile is then covered with night soil/animal dung. Biological activity starts through aerobic bacteria and heat starts developing upto about 75°C in the piles. After few days, the pile is termed up for cooling and aeration to avoid anaerobic reactions. The pile temperature again rises and the process of turning, cooling and aeration is repeated. The complete process may take about 4 to 6 weeks. After this, the compost is ready for use as manure. Though aerobic composting is faster, its practical application is hindered due to following reasons—

- It requires mixing and/or aeration facilities.
- The process is dependent on availability of air as well as moisture. The moisture content should be maintained always above 40%.
- Offensive smells (odour) will start if aerobic system is not properly maintained.
- Aerobic composting is relatively expensive and thus not economical.

Benefits of Composting:

- Conversion of biodegradable solid waste into valuable organic fertilizer (manure) for crops.
- Considerable reduction of the quantity of waste to be disposed.
- Production of biogas that can be used directly for heating, cooking or electric power generation.
- It recycles organic materials and nutrients back into the soil.
- Less requirement of space for landfilling.

**Disposal:** It refers to the placing of solid waste in its ultimate resting place.

**Dumping or Land Filling:** Dumping is a method of controlled final disposal of solid waste into the low-lying land areas. The improved form of open dumping is termed as Land-filling.

In this method of disposal of waste, solid wastes are carried and dumped at landfall sites. The refuse is filled-up or dumped in layers of 1.5 m or so and each layer is covered by good earth of at least 20 cm thickness, so that refuse is not directly exposed. Each layer is left out for at least seven days and then compaction by trucks is carried out for its settlement before starting filling the next layer. Insecticides like DDT should be sprayed on top to prevent breeding of flies and mosquitoes.

Advantages of Land-filling:

- The method is simple and economical.

- NO costly plant and equipment is required.
- Skilled labour is not required.
- Separation of different kinds of solid-wastes is not required.
- No residue or by product; hence no further disposal.
- Low-lying areas can be reclaimed and put to better use.

Disadvantages of Land-filling:

- Larger land area requirement.
- Continuous evolution of foul smell near the site of disposal.
- Disposal landfill sites along the highways give an aesthetically unpleasant view
- Use of insecticides is required.
- These landfill sites may prove to be good breeding grounds for insects, rodents and birds.
- Liquid formed due to seepage Of rainy water in the landfill may dissolve the toxic compounds present in the refuse. When such polluted water contaminates the ground water. it may lead to diseases like cholera, typhoid, polio, etc.

**Disposal into Sea:** This method of solid waste disposal can be used in coastal areas having deep sea water ( $> 30m$ ) at reasonable distance ( $< 16$  to  $20$  km) and with strong forward currents- This is quite a simple and cheap method but it has following disadvantages:

- The bulky and tighter components of solid waste float, spread, and tend to return to the shores during high tides.
- During monsoons or stormy weather solid waste has to be either stored or disposed of by some other methods.
- Some portion of the solid waste may return and spoil the beaches, despite all the necessary precautions.

### **Three-Rs of Solid Waste Management**

In solid waste management, the stress should be on 3R's— Reduce, Reuse and Recycle.

**1. Reduce-** Reduction in the use of raw materials is one of the fundamental ways to decrease the production of Solid waste. This can be achieved by using fewer raw materials when making a product, reuse of products on site, designing of products or packaging to reduce their quantity.

**2. Reuse:** Reuse of the materials in their original form is the next fundamental way to minimize the generation of solid waste. The reuse of materials, instead of throwing them away, not only reduces waste but also save money. Some of the examples of reuse of materials are as under —

- Reuse the refillable containers after washing.
- Wash and reuse the disposable items like plastic bags, plastic utensils, etc. as most of them can last for a long time with many uses.
- Rubber rings made from discarded cycle tubes can be used by vendors instead of new rubber bands.

**3. Recycling:** is the reprocessing of discarded materials that may have some economic value into new useful products. Recycling will not only make materials available to

future generations but will also save energy and environment. It is important for the recovery of reusable products from waste before its final disposal. This can be done either at separation point or the waste can be brought to Material Recovery Facility (MRF). It is important to have the wastes homogeneous and free of contamination before going to MRF.

Some of the examples of recycling and waste utilization are as under:

- Recycling of metals, paper, glass and plastics- Mining of metals (like aluminium, iron, copper, tin, etc.) is expensive and hence recycling of metals is economically important, Recycling of paper helps in preserving forests, as it takes about 17 trees to make one ton of paper.

- Utilising fly ash (a waste material from coal fired thermal power plants)
- Conversion of agricultural wastes (like rice husk and groundnut shells) into cheap and efficient fuel.
- Paper from agricultural wastes
- Energy from urban wastes
- Utilisation of slaughter house waste- Blood is used in pharmaceutical industry; and hides and skins are used for leather production.

**Advantages of Recycling and Waste Utilization:** Recycling is an integral part of solid waste management. It also makes economic sense. By recycling and proper utilization of waste, particularly; in developing countries like India, many advantage can be availed.

These include—

- Directly or indirectly, recycling and waste utilization contributes to economic development.
- Recycling is helpful in conservation of natural resources.
- Recycling can reduce/control environmental pollution substantially
- Employment opportunities are also generated.

### **Bioremediation**

Bioremediation is the utilization of microorganisms to break down organic contaminants present in soil, groundwater, and sludge. To stimulate microbial activity, bioaugmentation or biostimulation is done.

**Bioaugmentation** is the introduction of microorganisms to the contaminated site, if the existing concentration of microorganisms is too low to be effective. **Biostimulation** is the addition of nutrient media or electron donors/ acceptors so as to favour microbial growth.

**Bioremediation may be performed ex-situ or in-situ.** In-situ processes treat the contaminants at the site where they are present, without removal to a different site. Ex-situ processes involve relocation of contaminated site to a designated treatment area. Biological processes are usually implemented at a lower cost as compared to physicochemical treatment processes. Contaminants are destroyed completely in most cases. Sometimes, more toxic by-products are generated (TCE to vinyl chloride). These contaminants may become mobilized, especially in ground water. To remediate such a site, bioremediation will be performed above a low permeability soil layer, and groundwater monitoring wells will be placed downgradient of the remediation area.

**Remediation with the help of microbes can be of two types: anabolic and catabolic.** Catabolism is the generation of energy from the degradation of organic contaminants. Bonds which are easily broken contribute to more energy being released. Anabolism is the synthesis of new microbial cells.

**In-situ bioremediation** is the remediation of soils and/or groundwater utilizing naturally occurring microorganisms in order to biologically break down contaminants present. The media is not removed from its location. The development of microbial culture within the site can be brought about with oxygen (aerobic) or without oxygen (anaerobic or anoxic).

The advantages of an in-situ treatment system are: ideal for small operational sites, minimal intrusion to above-ground structures. However, it is not suitable for sites with free phase contaminants.

In-situ bioremediation of soil involves supplying of oxygen and nutrients to the soil. Two such methods are bioventing and injection of hydrogen peroxide. Bioventing systems deliver air from the atmosphere to the soil above the water table through injection wells placed in the contaminated area. Injection of H<sub>2</sub>O<sub>2</sub> on the other hand, delivers H<sub>2</sub>O<sub>2</sub> which in turn stimulates microbial activity and helps speed up the biodegradation process. Injection of H<sub>2</sub>O<sub>2</sub> is done only in instances when the groundwater is already contaminated.

### **Aerobic bioremediation**

Aerobic bioremediation is the oxidation of waste using O<sub>2</sub> as the electron acceptor.

For example: HCHO + O<sub>2</sub> → CO<sub>2</sub> + H<sub>2</sub>O

It is effective for hydrocarbons (such as mid-weight petroleum products like diesel and jet fuel). Lighter products like gasoline volatilize readily, and it is more effective to remove them using soil vapour extraction or air sparging.

Oxygen is the most favoured electron acceptor, followed by nitrate, manganese, iron and so on. Most of the municipal waste components serve as electron donors.

Oxygen is usually a limiting factor in the progress of these reactions. At times, oxygen content in the media is enhanced by supplying oxygen externally. The process of supplying oxygen to the unsaturated zone is called bioventing. This method is used to treat contaminants such as benzene, toluene, acetone, phenol, chlorobenzene. It can take a long time (few years) for a contaminated site to be completely treated by bioventing. The process of supplying oxygen to the saturated zone is called biosparging. The success of biosparging depends on permeability of soil and the degree to which contaminants are biodegradable. This method is used to treat byproducts of petroleum refining which the soil layer has absorbed.

### **Anaerobic bioremediation**

Under anaerobic conditions, microorganisms will degrade organic contaminants to methane, limited amounts of carbon dioxide, and trace amounts of hydrogen gas. Some anaerobic processes which occur are: fermentation, methanogenesis, sulphate and iron reducing reactions, denitrification, and reductive dechlorination. Due to the absence of oxygen, other electron acceptors are used: nitrate, iron, manganese, sulphate.

Anaerobic bioremediation needs very little input compared to aerobic bioremediation.  
For example: HCHO → CO<sub>2</sub> (30%) + CH<sub>4</sub> (70%)

### **Ex-situ bioremediation**

Ex-situ bioremediation is a biological treatment process in which contaminated soil is excavated and placed in a lined above-ground treatment area. Usually, this setup is aerated, to enhance biological degradation of contaminants. Nutrients and/or microbial cultures are added depending on the availability of each and rate of degradation.

## **Unit-IV**

### **1. ENVIRONMENTAL PROTECTION ACT-1986**

#### **Introduction:**

- It empowers the Central Government to establish authorities charged with the mandate of preventing environmental pollution in all its forms and to tackle specific environmental problems that are peculiar to different parts of the country.
- The Act is one of the most comprehensive legislations with a pretext to protection and improvement of the environment.

#### **Objectives-**

- An Act to provide for the protection and improvement of environment and for matters connected therewith.
- It extends to the whole of India.

#### **Salient Features :**

- **Powers of the Central Government:** The Central Government shall have the power to take all such measures as it deems necessary or expedient for the purpose of protecting and improving the quality of the environment in coordination with the State Governments
- **Plan and Execute a nation-wide programme** for the prevention, control and abatement of environmental pollution.
- **Lay down standards for the quality of environment** in its various aspects.
- Lay down standards for emission or discharge of environmental pollutants from various sources.
- The restriction of areas in which any industries, operations or processes or class of industries, operations or processes shall/ shall not be carried out subject to certain safeguards.
- The Central Government may appoint officers under this Act for various purposes and entrust them with the corresponding powers and functions.

- The central government as per the Act has the power to direct: The closure, prohibition or regulation of any industry, operation or process. & the stoppage or regulation of the supply of electricity or water or any other service.
- No individual or organisation shall discharge/emit or permit to discharge/emit any environmental pollutant in excess of the prescribed standards.
- No individual shall handle or shall be caused to handle any hazardous substance except in accordance with the procedure and without complying with the safeguards, as prescribed.
- Any person empowered by the Central Government shall have a right to enter (with the assistance deemed necessary) at any place: For the inspection of compliance of any orders, notifications and directions given under the Act.
- For the purpose of examining (and if required seizing) any equipment, industrial plant, record, register, document or any other material object may furnish evidence of the commission of an offence punishable under this Act.
- The Central Government, as per the Act, is entitled to establish environmental laboratories.
- Recognise any laboratory or institute as environmental laboratories to carry out the functions entrusted to such a laboratory. The Central Government is also entitled to make rules specifying the functions of environmental laboratories.
- A Government Analyst is appointed by the Central Government for the analysing the samples of air, water, soil or other substance sent to a recognised environmental laboratory.
- Non-compliance or Contravention to any of the provisions of the Act is considered as an offence. Any offences under the EPA are punishable with the imprisonment of upto five years or a fine upto one lakh rupees or both.
- If an offence under this Act is committed by a company, every person directly in charge of the company, at the time of the commitment of offence, is deemed to be guilty unless proven otherwise.

- If an offence under this Act has been committed by any Department of Government, the Head of the Department (HoD) shall be deemed to be guilty of the offence unless proven otherwise.
- A person who has approached the Courts after a 60-day notice has been furnished to the Central Government or the authority on its behalf.<sup>3</sup>

### **3.Air Prevention and control of Pollution Act -1981:**

#### **Amendment:1987**

This is the Act that provide for the prevention, control and abatement of air pollution, for the establishment, with a view to carrying out this purposes, of Boards, for conferring on and assigning to such Boards powers and functions relating thereto and for matters connect therewith.

**Definition:** The following are the definitions under the Air (Prevention and Control of Pollution) Act.

Section 2(a) defines an ‘air pollutants’ as any solid liquid or gaseous substance which may cause harm or damage the environment, humans, plants, animals or even damage property. A 1987 amendment to the act also added ‘noise’ in the list of harmful substances.

The air act defines ‘air pollution’ as the presence of any dangerous pollutant that makes the air unbreathable

Section 2 (g) of the Act also set up the Central Pollution Control Board (CPCB) whose powers extended to the whole of India. To carry out the directives of the CPCB the act also called for the setting up of the State Pollution Control Board (SPCB) for the individual states of India

#### **Objectives:**

- To provide for the prevention, control and abatement of air pollution.
- To provide for the establishment of central and State Boards with a view to implement the Act.
- To confer on the Boards the powers to implement the provisions of the Act and assign to the Boards functions relating to pollution.
- The Air (Prevention and Control of Pollution) Act, 1981 extends to the whole of India.

## **Salient Features-**

- The Air Act consists of 54 sections that aims to define the terms associated with air pollution and related aspects.
- Person Whoever contravenes any of the provision of the Act or any order or direction issued is punishable with imprisonment for a term which may extend to three months or with a fine of Rs. 10,000 or with both, and in case of continuing offence with an additional fine which may extend to Rs 5,000 for every day during which such contravention continues after conviction for the first contravention.

**Functions of the Central Board-** The main functions of the Central Board shall be to improve the quality of air and to prevent, control or abate air pollution in the country. These are:

- To advise the Central Government on any matter concerning the improvement of the quality of air and the prevention, control or abatement of air pollution.
- To plan and cause to be executed a nation-wide programme for the prevention, control or abatement of air pollution.
- To co-ordinate the activities of the State and resolve disputes among them.
- To provide technical assistance and guidance to the State Boards, carry out and sponsor investigations and research relating to problems of air pollution and prevention, control or abatement of air pollution.

**Functions of the State Board-** The function of any State Board may be specified that are as follows-

- To plan a comprehensive programme for the prevention, control or abatement of air pollution and to secure the execution thereof.
- To advise the State Government on any matter concerning the prevention, control or abatement of air pollution.
- To collect and disseminate information relating to air pollution.

- To collaborate with the Central Board in organizing the training of persons engaged or to be engaged in programmes relating to prevention, control or abatement of air pollution and to organize mass-education programme relating thereto.

To inspect air pollution control areas at such intervals as it may think necessary, assess the quality of air therein and take steps for the prevention, control or abatement of air pollution

### **3.Water Prevention and Control of Pollution Act 1974**

#### **Amendment: 1988 and 2003,2024**

**Article 252-** It enables Parliament to legislate for 2 or more States by consent, as Water is a State list through this Article the Act is enacted by the Central government.

#### **Objectives-**

- To provide for prevention, control and abatement of water pollution
- For maintenance or restoration of the wholesomeness of water.
- For the establishment of pollution control water boards.
- To assess pollution levels and punish polluters.

#### **Powers and Functions of CPCB**

- Advise the Central Government on any matter relating to the prevention and control of water and air pollution and improving air quality.
- Plan and carry out a national programme to prevent, control, or reduce water and air pollution.
- Coordination of the State Board's activities and resolution of disputes among them.
- Organize a comprehensive mass awareness programme on the prevention, control, and abatement of water and air pollution through the media.
- Collect, compile, and publish technical and statistical data on water and air pollution and the measures developed to effectively prevent, control, or abate it.
- Prepare manuals, codes, and guidelines for sewage and trade effluent treatment and disposal, stack gas cleaning devices, stacks, and ducts.
- Disseminate information about water and air pollution and how to prevent and control it.

- Establish, modify, or repeal stream or well standards in consultation with the relevant state governments, and establish air quality standards.
- Provide technical assistance and guidance to state boards, conduct and sponsor investigations and research on water and air pollution problems, and for their prevention, control, or abatement.
- Plan and organise training for people involved in programmes to prevent, control, or mitigate water and air pollution.

### **Functions of State pollution control Board**

(1) Subject to the provisions of this Act, the functions of a State Board shall be -

1. to plan a comprehensive programme for the prevention, control or abatement of pollution of streams and wells in the State and to secure the execution thereof;
2. to advise the State Government on any matter concerning the prevention, control or abatement of water pollution;
3. to collect and disseminate information relating to water pollution and the prevention, control or abatement thereof;
4. to encourage, conduct and participate in investigations and research relating to problems of water pollution and prevention, control or abatement of water pollution;
5. to collaborate with the Central Board in organizing the training of persons engaged or to be engaged in programmes relating to prevention, control or abatement of water pollution and to organize mass education programmes relating thereto;
6. to inspect sewage or trade effluence, works and plants for the treatment of sewage and trade effluents and to review plans, specifications or other data relating to plants set up for the treatment of water, works for the purification thereof and the system for the disposal of sewage or trade effluents or in connection with the grant of any consent as required by this Act;
7. to lay down, modify or annual effluent standards for the sewage and trade effluents and for the quality of receiving waters (not being water, in an inter-State stream) resulting from the discharge of effluents and to classify waters of the State;
8. to evolve economical and reliable methods of treatment of sewage and trade effluents, having regard to the peculiar conditions of solids, climate and water resources of

- different regions and more especially the prevailing flow characteristics of water in streams and wells which render it impossible to attain even the minimum degree of dilution;
9. to evolve methods of utilization of sewage and suitable trade effluents in agriculture;
  10. to evolve efficient methods of disposal of sewage and trade effluents on land, as are necessary on account of the predominant conditions of scant stream flows that do not provide for major part of the year the minimum degree of dilution;
  11. to lay down standards of treatment of sewage and trade effluents to be discharged into any particular stream taking into account the minimum fair weather dilution available in that stream and the tolerance limits of pollution permissible in the water of the stream, after the discharge of such effluents;

## History of Sustainable Development Goals

The history of the Sustainable Development Goals dates back to 2000 when the UN adopted the Millennium Development Goals (MDGs) to address global poverty, hunger, and education. However, the MDGs had some limitations, leading to the development of a more comprehensive and universal set of goals. The 17 Sustainable Development Goals were introduced in 2015, with the aim of addressing a broader range of issues, including climate change, economic inequality, and sustainable consumption. The SDGs build on the success and lessons learned from the MDGs and serve as a global commitment toward achieving a better and more sustainable future for all.



## GOALS OF SUSTAINABLE DEVELOPMENT IN DETAIL

### GOAL 1: NO POVERTY

The first of the 17 Sustainable Development Goals aim to eradicate extreme poverty for all people everywhere by 2030. Poverty is a multidimensional issue, and this goal focuses on creating policies that address income generation, access to basic services, and social protection. Sustainable Development Goals India is committed to reducing poverty by promoting social and economic inclusion through various programs and schemes.

## **GOAL 2: ZERO HUNGER**

The second goal aims to end hunger, achieve food security, and promote sustainable agriculture. Zero Hunger involves increasing agricultural productivity, improving the resilience of food systems, and ensuring access to nutritious and sufficient food for all. India plays a significant role in achieving this goal by implementing policies and programs to improve food security and agricultural sustainability.

## **GOAL 3: GOOD HEALTH AND WELL-BEING**

The third goal seeks to ensure healthy lives and promote well-being for all, regardless of age. This involves reducing maternal and child mortality, fighting against communicable and non-communicable diseases, and promoting mental health. India has made significant strides in improving healthcare access and outcomes, contributing to the achievement of the Sustainable Development Goals 2030.

## **GOAL 4: QUALITY EDUCATION**

The fourth goal aims to provide inclusive and equitable quality education, as well as promote lifelong learning opportunities for all. Sustainable Development Goals Quality Education focuses on increasing access to education, improving learning outcomes, and reducing gender disparities in educational opportunities. India has made considerable progress in this area through various policies and initiatives.

## **GOAL 5: GENDER EQUALITY**

The fifth goal strives to achieve gender equality and empower all women and girls. This goal addresses various forms of discrimination, violence, and harmful practices against women, while also promoting women's participation in leadership roles and decision-making. India has been working towards gender equality through various policies, legislation, and awareness campaigns.

## **GOAL 6: CLEAN WATER AND SANITATION**

The sixth goal aims to ensure the availability and sustainable management of water and sanitation for all. This involves improving water quality, increasing water-use efficiency, and protecting water-related ecosystems. India has undertaken numerous initiatives to improve access to clean water and sanitation, contributing to the United Nations Sustainable Development Goals.

## **GOAL 7: AFFORDABLE AND CLEAN ENERGY**

The seventh goal seeks to ensure access to affordable, reliable, sustainable, and modern energy for all. This includes increasing the share of renewable energy, improving energy efficiency, and ensuring universal access to clean energy services. India has made significant progress in expanding its renewable energy capacity and promoting energy efficiency.

## **GOAL 8: DECENT WORK AND ECONOMIC GROWTH**

The eighth goal aims to promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. This involves improving labor market conditions, supporting entrepreneurship, and fostering innovation. India has implemented various policies and programs to boost economic growth, create jobs, and enhance workers' rights.

## **GOAL 9: INDUSTRY, INNOVATION, AND INFRASTRUCTURE**

The ninth goal focuses on building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation. This includes increasing access to information and communication technology, supporting research and development, and promoting sustainable industrial practices. India has been investing in infrastructure development and promoting a culture of innovation to achieve this goal.

## **GOAL 10: REDUCED INEQUALITY**

The tenth goal aims to reduce inequality within and among countries by promoting social, economic, and political inclusion. This involves ensuring equal opportunities, eliminating discriminatory policies, and fostering global partnerships for development. India has been working to reduce income inequality and promote social inclusion through various policies and programs.

## **GOAL 11: SUSTAINABLE CITIES AND COMMUNITIES**

The eleventh goal seeks to make cities and human settlements inclusive, safe, resilient, and sustainable. This involves ensuring access to affordable housing, improving urban planning, and enhancing the sustainability of cities. India has launched several initiatives to address urbanization challenges and promote sustainable urban development.

## **GOAL 12: RESPONSIBLE CONSUMPTION AND PRODUCTION**

The twelfth goal aims to ensure sustainable consumption and production patterns by promoting resource efficiency, reducing waste, and encouraging sustainable business practices. India has been working to implement sustainable production and consumption practices through various policies, regulations, and awareness campaigns.

## **GOAL 13: CLIMATE ACTION**

The thirteenth goal focuses on taking urgent action to combat climate change and its impacts by reducing greenhouse gas emissions, enhancing climate resilience and supporting climate adaptation efforts. India has been actively involved in international climate negotiations and has implemented various domestic initiatives to address climate change.

## **GOAL 14: LIFE BELOW WATER**

The fourteenth goal aims to conserve and sustainably use the oceans, seas, and marine resources for sustainable development. This includes preventing marine pollution, protecting marine ecosystems, and ensuring sustainable fisheries. India has been working to protect its marine resources and ecosystems through various conservation and sustainable management efforts.

## **GOAL 15: LIFE ON LAND**

The fifteenth goal focuses on protecting, restoring, and promoting sustainable use of terrestrial ecosystems, halting biodiversity loss, and combating desertification. India has made significant efforts in forest conservation, wildlife protection, and promoting sustainable land management practices.

## **GOAL 16: PEACE AND JUSTICE STRONG INSTITUTIONS**

The sixteenth goal seeks to promote peaceful and inclusive societies, provide access to justice for all, and build effective, accountable, and inclusive institutions. India has been working towards ensuring the rule of law, reducing corruption, and enhancing transparency and accountability in its institutions.

## **GOAL 17: PARTNERSHIPS TO ACHIEVE THE GOAL**

The seventeenth goal emphasizes the importance of global partnerships to support and achieve Sustainable Development Goals. This includes enhancing international cooperation, promoting sustainable development investments, and fostering multi-stakeholder partnerships. India has been actively engaged in international partnerships and collaborations to achieve the 17 Sustainable Development Goals.

The **Sustainable Development Goals (SDGs)**, set by the **United Nations (UN)** as part of the **2030 Agenda for Sustainable Development**, outline a shared global vision for a better, fairer, and more sustainable world by 2030. Each goal has its own specific targets and indicators, but they all work together to address key global challenges in an integrated manner.

Here's an overview of the **SDG Goals by 2030**, focusing on the **principles, challenges, and global initiatives and policies** supporting their achievement:

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### **Principles of the SDGs**

The SDGs are built on a set of guiding principles aimed at promoting inclusive and sustainable development worldwide. These principles are:

- Universality:** The SDGs apply to all countries, whether developed or developing. Every nation is expected to work towards achieving them.
- Leave No One Behind:** This is the central promise of the SDGs, ensuring that the benefits of sustainable development reach all people, especially the most marginalized.

3. **Integrated Approach:** The SDGs are interconnected, meaning that progress in one goal is often linked to progress in others. For example, improving education (SDG 4) can help reduce poverty (SDG 1).
  4. **Sustainability:** The SDGs focus on ensuring that development today meets the needs of the present without compromising the ability of future generations to meet their own needs.
  5. **Inclusive Participation:** The SDGs emphasize the importance of involving all stakeholders, including governments, businesses, civil society, and individuals, in the achievement of these goals.
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### **Challenges in Achieving the SDGs by 2030**

While the SDGs offer a framework for positive change, there are significant challenges to their achievement:

1. **Poverty and Inequality:** Despite progress in reducing global poverty, large disparities remain. Inequality—whether based on income, gender, geography, or other factors—remains a significant barrier.
  2. **Climate Change:** Global warming and environmental degradation threaten to undo decades of development progress. The urgency of SDG 13 (Climate Action) reflects this challenge.
  3. **Conflict and Political Instability:** Wars, civil unrest, and political instability undermine the achievement of SDGs, particularly those related to peace, justice, and institutions (SDG 16).
  4. **Lack of Financial Resources:** Achieving the SDGs requires substantial investment, and many countries, especially low-income ones, face challenges in mobilizing the necessary financial resources.
  5. **Global Health Crises:** The COVID-19 pandemic has shown how health emergencies can disrupt progress on multiple SDGs, especially SDG 3 (Good Health and Well-being).
  6. **Sustainable Consumption and Production:** Shifting towards sustainable production patterns and responsible consumption is a difficult challenge given global demand and waste.
  7. **Ineffective Governance and Corruption:** Poor governance, lack of accountability, and corruption hinder the ability of governments to implement policies that support the SDGs effectively.
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### **Global Initiatives and Policies Supporting the SDGs**

Achieving the SDGs requires coordinated global efforts, policy alignment, and innovative solutions. Some of the key global initiatives and policies supporting the SDGs include:

1. **The 2030 Agenda for Sustainable Development:**
  - This is the overarching framework for the SDGs, which was adopted by all UN member states in 2015. It provides a clear path

and set of principles for governments, businesses, and civil society organizations to work towards achieving the SDGs by 2030.

**2. The Paris Agreement (2015):**

- A landmark international treaty on climate change aimed at limiting global temperature rise to well below 2°C above pre-industrial levels, with efforts to limit the rise to 1.5°C. It aligns with SDG 13 (Climate Action) and supports other SDGs by mitigating the negative impacts of climate change.

**3. Financing for Development – Addis Ababa Action Agenda (AAAA):**

- Adopted in 2015, the AAAA outlines the financial commitments and policies to support the SDGs, focusing on public and private financing, trade, debt, and technology. It aims to increase the flow of resources to countries in need.

**4. The UN Global Compact:**

- A voluntary initiative for businesses that supports the SDGs by encouraging companies to adopt responsible business practices and align their operations with global sustainability principles, such as human rights, labor standards, and environmental protection.

**5. Global Partnership for Sustainable Development (SDG 17):**

- SDG 17 emphasizes the need for partnerships between governments, private sector, and civil society to support the achievement of the SDGs. The Global Partnership works to mobilize the financial resources, expertise, and technology necessary for implementation.

**6. The World Bank's Financing for Development:**

- The World Bank plays a key role in providing financial support and technical assistance to low- and middle-income countries, particularly in areas like infrastructure, education, and health, directly contributing to several SDGs.

**7. Regional and National Policies:**

- Many countries and regions have adopted their own SDG action plans, aligning national policies with the global goals. For example:
  - **Europe:** The European Union's **Green Deal** is closely aligned with SDG 13 (Climate Action) and SDG 12 (Responsible Consumption and Production).
  - **Africa:** The **African Union's Agenda 2063** is a framework for Africa's long-term development, closely linked to the SDGs.

**8. Corporate Social Responsibility (CSR):**

- Many private companies and corporations around the world have integrated the SDGs into their business models through CSR

programs that focus on environmental sustainability, social equity, and economic development.

## 9. Technology and Innovation:

- Technology and innovation play crucial roles in achieving the SDGs. Initiatives such as the **Global Innovation Index** and **Tech for Good** projects help promote technological solutions to challenges like education (SDG 4), health (SDG 3), and sustainability (SDG 12).
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## Policies and Actions by Governments

Governments around the world are adopting policies to promote SDG achievement, including:

- **National Sustainable Development Strategies (NSDS)**: These are country-specific plans that align national policies with the SDGs, integrating them into long-term development agendas.
  - **Climate and Environment Policies**: Governments are implementing policies to reduce emissions, promote clean energy, and protect ecosystems, particularly under SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land).
  - **Social Protection Programs**: To reduce poverty (SDG 1) and inequality (SDG 10), many governments are expanding social protection systems, including cash transfers and social safety nets.
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## Conclusion

The **SDGs by 2030** offer a blueprint for transforming the world through inclusive, sustainable, and integrated actions. However, achieving these goals by 2030 will require overcoming substantial challenges, including poverty, inequality, climate change, and global health crises. Governments, businesses, and individuals must work together through global initiatives, policies, and coordinated actions to make the SDGs a reality, ensuring a fair and sustainable future for all.